An update on Condensed Matter Nuclear Science (cold fusion)

JEAN-PAUL BIBERIAN,[a] NICOLAS ARMAMET [b]

Faculté des Sciences de Luminy, Université d'Aix-Marseille
163 avenue de Luminy, 13288 Marseille cedex 9, France
jpbiberian@yahoo.fr, armanetnicolas@hotmail.com

ABSTRACT. The discovery of Cold Fusion was announced on March 23, 1989 at a press conference at the University of Utah in Salt Lake City. The two discoverers: Stan Pons and Martin Fleischmann described their electrochemical device that produces more heat than the electric energy used to run it. Since then lot of progress has been made, and it is more and more obvious that this phenomenon now named Condensed Matter Nuclear Science is a genuine scientific research field with many important potential applications. It is the purpose of this paper to present an update of the worldwide research.

1 Introduction

The achievements of Cold Fusion are now very well documented [1, 2]. However, since this review [2], more work has been produced world-wide and it is important to show that the field is very well alive and that progress is being made. In this paper we recall the various theoretical problems encountered when trying to understand "cold fusion". This is important since they bring fuel to critics of the field. We also detail some recent experimental discoveries that bring more weight to the credibility of Condensed Matter Nuclear Science. We also describe some of our own work in deuterium gas in palladium that has promising consequences.

2 Why cold fusion is not accepted?

When Pons and Fleischmann [3, 4, 5] revealed their extraordinary discovery in 1989 most critics used theoretical arguments to discredit their work. Some experimentalists tried to duplicate it, and many failed by lack of competence or effort put in order to succeed. However a small number of them succeeded and most are still active. Recently Storms [1] wrote a book that reviews both the experimental and the theoretical aspects of Low Energy Nuclear Reactions as it is sometimes named.

On the experimental side, even though the experiment looks very simple, it is not as easy as it looks. A current is passed in an electrolytic cell having a palladium cathode and a platinum anode. The electrolyte is heavy water (D_2O) with LiOD added to ensure electrical conductivity. Several obstacles are under way: first calorimetry must be well performed in order to measure small excess heat production [2]. Second, the palladium must be of "good quality". This characteristic is hard to define, because up till now we still wonder what makes a good palladium cathode. Certainly metallurgical structure is of prime importance, but also maybe the absence or presence of some impurities. Finally an important factor is time. These reactions take time to appear, one of the main reasons being the time it takes to load palladium with deuterium. Therefore many experimenters failed in their attempts to duplicate the Pons and Fleischmann experiment.

On the theoretical side, what was suggested by the discoverers [3] was that the reaction could not be chemical because the amount of excess heat generated was way too large to be chemical, and therefore had to be nuclear. If that was the case, it was proposed that a deuterium-deuterium fusion reaction would be the cause.

First of all, the reaction could not occur because between two deuterons there is a strong repulsive Coulomb force that prevents them to fuse. It would be necessary to have very large kinetic energies to overcome this barrier. Therefore the proposed model could not be correct.

Secondly, even if by some miracle this barrier could be crossed, from experimental high energy physics it is well known that the reactions between two deuterium ions are the following:

D + D → T + p	4.0 MeV	50%
D + D → He-3 + n	3.3 MeV	50%
D + D → He-4 + gamma	24 MeV	10-7

According to the above three reactions there would be in addition to heat, formation of tritium and neutrons in equal amounts. The excess heat produced during the experiments would generate so many neutrons that the experimentalists should be killed during the experiment. The only possibility as suggested by the authors [3] would be the third reaction, the less likely to occur.

Thirdly, if by some unknown mechanism helium-4 is produced there should be also generation of intense gamma rays that would also kill the experimentalists. These are the three miracles: Coulomb barrier, no neutrons, no gamma rays that prevented Cold Fusion to enter mainstream science.

Cold Fusion has been demonstrated experimentally without any doubt by many experimentalists using lots of different techniques that eliminate the idea of systematic errors. On the other hand, the theoretical aspect is still missing. Many (too many) theories have been developed, but none is capable of explaining all the aspects of Cold Fusion. Even though helium-4 has been measured along with excess heat by different experimentalists, it is not certain that the reaction responsible for the excess heat is the deuterium-deuterium reaction described above. There are other possibilities to produce alpha particles (helium-4 nuclei).

3 Duplication of Pons & Fleischmann experiment

Many people tried to replicate the Pons and Fleischmann experiment. However, very few performed exact replications. Figure 1 shows excess heat versus current density in a Pons and Fleischmann type experiment: Mc Kubre et al. (6). A comparison is given showing the difference between D_2O and H_2O. At high current density an excess heat of more than 500 mW is measured with D_2O, versus no excess energy with H_2O

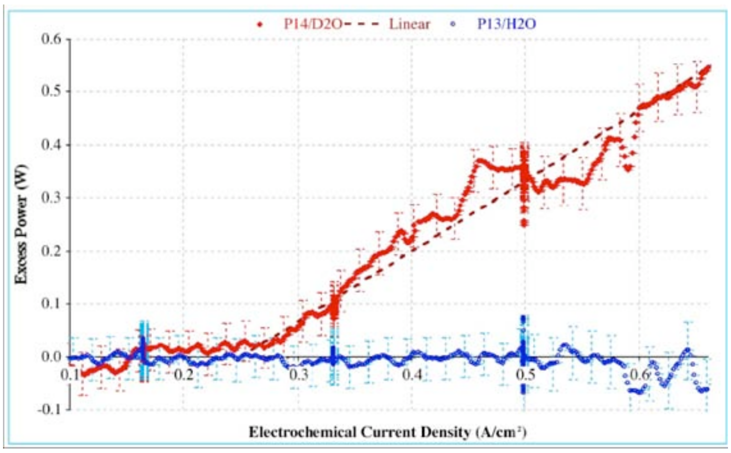

Figure 1: Graphs showing excess heat production versus current density in a cell similar to the Pons and Fleischmann one. In red a cell with D_2O, and in blue the same with H_2O

Similarly, Lonchampt et al. [7, 8] have replicated the boiling experiment of Pons and Fleischmann. They stopped adding water in the cell when it reached boiling temperature. By measuring the amount of water that evaporated and comparing the heat necessary to evaporate it to the input power they have shown that excess heat is produced.

4 Helium detection

In order to obtain better results, it is important to understand the mechanisms involved in “Cold Fusion” experiments. An important element in this endeavour is the production of helium. Effectively if the overall reaction is D+D → He-4 with production of 23 MeV energy, a correlation between excess heat and helium production is essential. Figure 2 shows results obtained by McKubre et al. (9). They performed a gas phase experiment using the procedure developed by Case (10), where a palladium catalyst is loaded with deuterium. Excess heat is observed and helium is measured. Their determination of 32 MeV per helium molecule produced is compatible with the D + D reaction, even though this value is larger than the expected 23 MeV. The discrepancy can be explained by the difficulty in extracting helium from palladium, and it is possible that some helium remains in the catalyst itself.

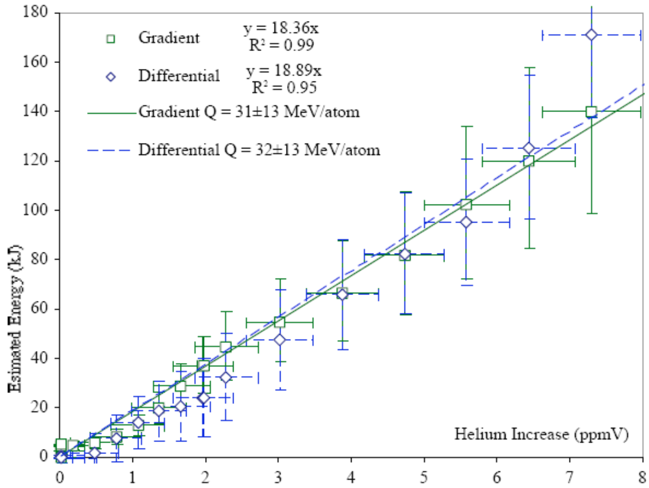

Figure 2: Heat production versus helium formation during an experiment.

5 Alpha particles

Helium molecules are actually alpha particles that attract an electron and form an atom. Experimentalists have tried to measure directly the production of alpha particles. In particular Oriani et al. [11] have used CR39, a plastic detector sensitive to alpha particles that leave tracks after etching. Figure 3 is a description of the electrolytic cell used by Oriani.

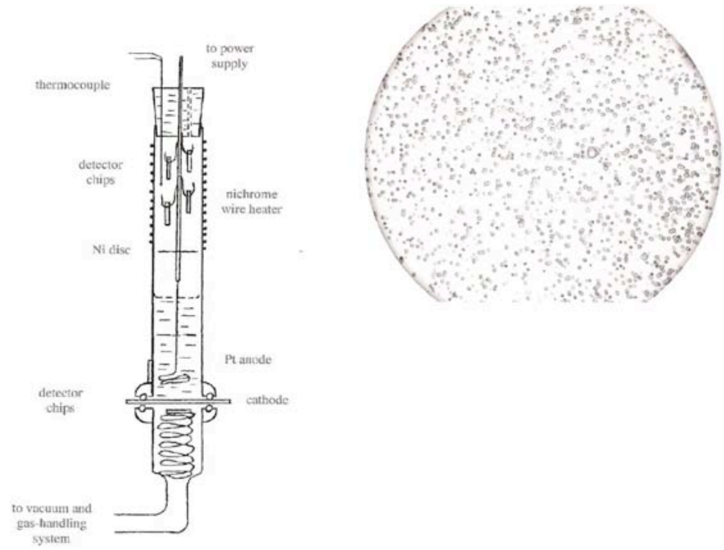

Figure 3:
Left: electrochemical cell used by Oriani et al. (11) to detect alpha particles.
Right: a micrograph showing large quantities of pits due to alpha particles.

6 Excess heat by deuterium diffusion

Most Cold Fusion experiments have been performed in electrolytic cells. However electrolysis in water has draw backs. One is the complexity of the technology for future applications, and the other one is the temperature limitation: water boils at 100°C at atmospheric pressure, and this limits the potential applications to hot water production. That is why scientists have tried gas phase experiments. Back in 1989, Fralick [12] at NASA showed excess heat when he de-loaded deuterium from palladium, and no such effect with hydrogen. Similarly Li [13] demonstrated similar effects with deuterium loaded in palladium wires.

Recently Biberian and Armanet [14] have shown production of excess heat when deuterium flows through the walls of a palladium tube. They have observed an excess heat of 3 Watts with an input power of 40 Watts.

7 Conclusion

After more than eighteen years of research, the field of Condensed Matter Nuclear Science is still looking for a major breakthrough that will bring this science back in the mainstream. We have more and more evidence of the reality of Cold Fusion: production of anomalous excess heat, detection of nuclear products showing that the phenomenon is probably of nuclear origin, but so far no experiment has been conclusive enough to trigger a new beginning to the field. Hopefully this will happen in the coming years.

References

[1] E. Storms, "*The Science of Low Energy Nuclear Reaction*", World Scientific Publishing Compagny, 2007.Curie P., J. de Phys., 3-ième série, **3**, 393-415, (1894).

[2] J.P. Biberian, Ann. Fond. L. de Broglie, 29, (2004), 1095.

[3] M. Fleischmann, S. Pons and M. Hawkins, *Electrochemically induced nuclear fusion of deuterium*, in *J. Electroanal. Chem.,* 1989, 261 : p. 301 and errata in Vol. 263 : p. 187.

[4] S. Pons and M. Fleischmann, *Calorimetry of the Palladium-Deuterium system*, in *The First Annual Conference on Cold Fusion*, F. Will, Editor, 1990, National Cold Fusion Institute : University of Utah Research Park, Salt Lake City, Utah. p. 1.

[5] M. Fleischmann, S. Pons, M. W. Anderson, L. J. Li and M. Hawkins, *Calorimetry of the Palladium-Deuterium-heavy water system*, in *J. Electroanal. Chem.,* 1990, 287 : p. 293.

[6] M.C. McKubre, F. Tanzella, P.L. Hagelstein, K. Mullican and M. Trevithick, *The need for triggering in cold fusion reactions*, in *Tenth International Conference on Cold Fusion*, Hagelstein, P. L. andChubb, S. R. World Scientific Publishing Co., Cambridge, MA, 2003, pp. 199.

[7] G. Lonchampt, L. Bonnetain and P. Hichter, *Reproduction of Fleischmann and Pons Experiments,* in *Sixth International Conference on Cold Fusion*, Progress in New Hydrogen Energy, 1996, Lake Toya, Hokkaido, Japan : New Energy and Industrial Technology Development Organization, Tokyo Institute of Technology, Tokyo, Japan.

[8] G. Lonchampt, J.-P. Biberian, L. Bonnetain and J. Delepine, *Excess heat measurement with Pons and Fleischmann Type cells*, in *The Seventh International Conference on Cold Fusion*, Jaeger, F. ENECO, Inc., Salt Lake City, UT, Vancouver, Canada, 1998, pp. 202.

[9] M.C.H. McKubre, et al. *The Emergence of a Coherent Explanation for Anomalies Observed in D/Pd and H/Pd System : Evidence for 4He and 3He Production*, in *8th International Conference on Cold Fusion,* 2000, Lerici (La Spezia), Italy : Italian Physical Society, Bologna, Italy.

[10] L. Case, *Catalytic Fusion of Deuterium into Helium-4*, Proc. ICCF7, Vancouver, Canada, April 19-24, 1998.

[11] L. Case, *Catalytic Fusion of Deuterium into Helium-4*, Proc. ICCF7, Vancouver, Canada, April 19-24, 1998.

[12] G. C. Fralick, A. J. Decker, and J. W. Blue, NASA Technical Memorandum 102430, 1989.

[13] X. Z. Li, B. Liu, N. Cai, Q. Wei, J. Tian, and D.X.Cao, in *Tenth International Conference on Cold Fusion*, editors Hagelstein, P. L. and Chubb, S. R. World Scientific Publishing Co., Cambridge, MA, 2003, p. 113.

[14] J. P. Biberian, N. Armanet, Proceedings ICCF13, Socchi, Russia 2007.

(Magnetic Monopoles, Physical symmetries, Nodal electric fields.
Fondation Louis de Broglie, Peyresq 9-16 août 2007.)