Condensed Matter Nuclear Science : Cold Fusion

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1 A brief history of Cold Fusion

The discovery of "Cold Fusion" has been announced officially by a press conference on March 23rd 1989 at the University of Utah in Salt Lake City. The shock wave produced by the Pons and Fleischmann announcement is probably unique in history, due to the fact that emails and fax machines helped propagate the good and the bad news altogether at light speed. Hundreds laboratories around the world immediately tried to replicate the experiment. However, details of it were not well known and doing electrochemistry and calorimetry altogether is a difficult art and takes time to master. Therefore most nuclear scientists tried to detect the assumed accompanying radiations produced by the well known reaction D+D producing either He-3 and a neutron or tritium and a proton with equal probability. Not surprisingly no neutron or very little compared to the amount expected from the announced excess heat were detected. These types of approaches plus the unwillingness of a portion of the scientific community to accept that electrochemistry under special conditions could produce nuclear reactions pushed "Cold Fusion" in quasi clandestinity.

Several hundred scientists worldwide did careful calorimetry experiments and showed that the effect was real. Certainly simple in the principles, but not necessarily easy to reproduce. Artifacts were numerous, and the sources of error or misinterpretation were many. With a lot of patience, courage and stubbornness, they slowly made progresses, and finally got to a point where the conditions of reproducibility were reached. They met regularly at international meetings, starting with Salt Lake City in 1990, and the last International Conference on Cold Fusion was held in Boston in August 2003. The

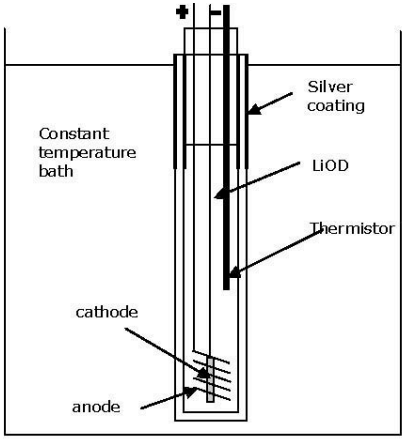
next one will be in Marseilles, France from October 31 to November 5, 2004.

At present a lot has been demonstrated. We know now that the proposed reaction D +D → He-4 + 23 MeV is not the only possible reaction. Under other conditions not only fusion, but also transmutation is occurring. People have measured X-rays, gamma rays, neutrons, protons, He-4, He-3, anomalous isotopic distributions. This is why the name of the field has been changed to "Condensed Matter Nuclear Science" which fits better to the reality of the observations. A web site : www.lenr-canr.org has a large collection of papers that can be downloaded.

The purpose of this presentation is to give an overview of some key experiments that have been published.

2 The original Pons & Fleischmann experiment

Figure 1 is a schematic of the original Pons and Fleischman experiment. The cell is a Dewar 25 mm inner diameter and about 25 cm long. It is transpartent at the bottom, and the top is silver coated, so that radiation is limited to the uncoated portion of the glass, and therefore less sensitive to electrolyte level variations. It is an open cell, therefore deuterium and oxygen gas are lost during electrolysis. Temperature of the cell is measured by a single calibrated thermistor. The temperature of the cell is uniform to within one hundredth of a degree, because the gas produced by the electrolysis stirrs the electrolyte and uniformizes the temperature. The palladium cathode, usually 2mm diameter, and 12mm long is at the center of the platinum cathode for better current flow uniformity. The cell is placed in a constatnt temperature bath. Input power is calculated by multiplying current and voltage, and output power is deduced from measurement of the temperature of the cell and the one of the bath. Almost all heat is dissipated by radiation and follows the temperature fourth power law. The cell is calibrated with a platinum cathode. Those results have been positively duplicated with similar designs by Lonchampt et al. [3], Miles [4].



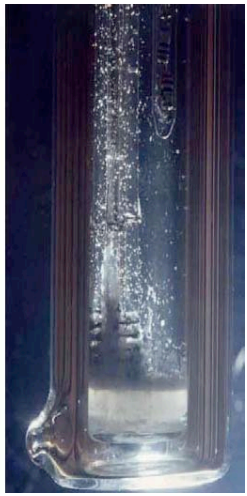


Figure 1
The original Pons and Fleischmann experiment

3 Excess Heat

3.1 The double cathode.

The open cell calorimetry has been criticized, because it needed calibration, and also because the power input had to be corrected for the gases produced. Some people assumed that recombination could occur and produce heat that could be accounted for as excess heat. Therefore, in spite of the fact that measurements have been made showing that this was not the case, it seemed better to do other types of calorimetry. One of them is mass flow calorimetry : the cell is water cooled, and most of the heat is carried away by the cooling system. One need to measure only the temperature difference between input and output and the water mass flow to determine the amount of heat produced by the cell. In addition if a recombiner is added inside the cell, the gases produced by the electrolysis are recombined, and therefore no correction need to be made to determine the input power. Several authors have used such techniques. Arata and Zhang [5] have added another improvement. Instead of using a solid palladium cathode, they have manufac-

tured a hollow palladium cathode that they have filled with nanometric size palladium powder

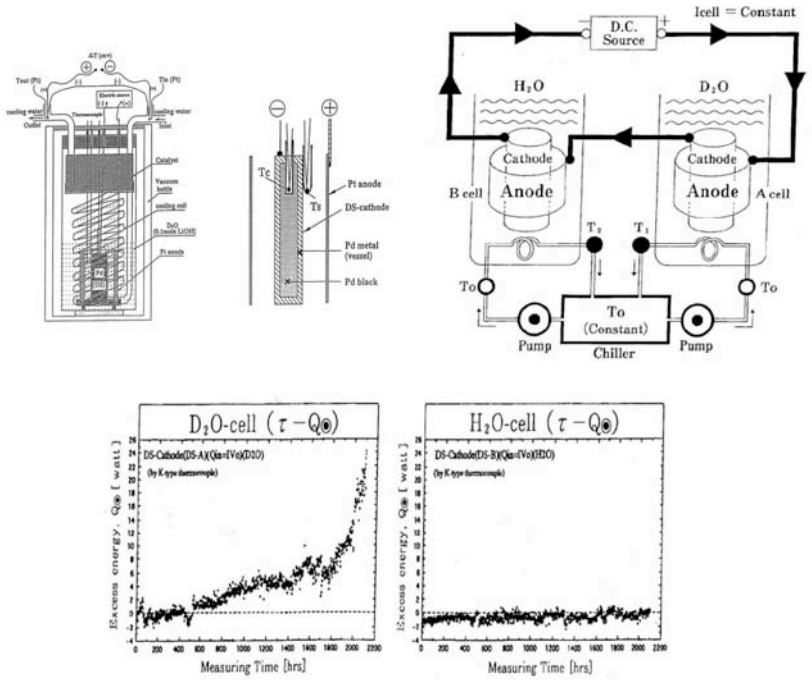


Figure 2 : The Arata Zhang double cathode experiment

The results of these experiments are shown in figure 3, where a comparison is made between a heavy water and a light water cell. Without any doubt, the first cell produces large amounts of heat, up to 24 Watts, whereas the light water one produces no heat at all. The experiments ends when the cathode explodes due to the very high pressure of deuterium gas that builds inside the hollow palladium cathode. This experiment has been duplicated by McKubre et al. from SRI.

3.2 Co-deposition Pd-D..

Miles et al.[6] have co-deposited palladium and deuterium on a copper cathode. They use a Fleischmann and Pons [1] type open cell calorimeter. Palladium is deposited by electrochemical decomposition of palladium chloride in the electrolyte. Excess heat to 300mW is reported on figure 3. Recently, Biberian [7] has done similar experiments with a mass flow calorimeter, producing an excess heat of 500 mW.

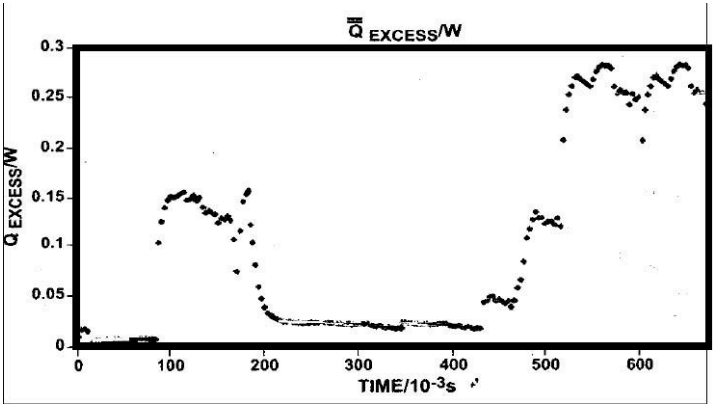


Figure 3 : Excess heat during co-deposition of palladium and deuterium

3.3 Gold plated palladium cathode

Using a Fleischmann and Pons [1] type calorimeter, Biberian [8] has first deposited gold on a palladium cathode by dissolution of a gold anode during electrolysis in LiOD. Then a second platinum anode has been installed, and excess heat of 170 mW has been measured as shown on figure 4.

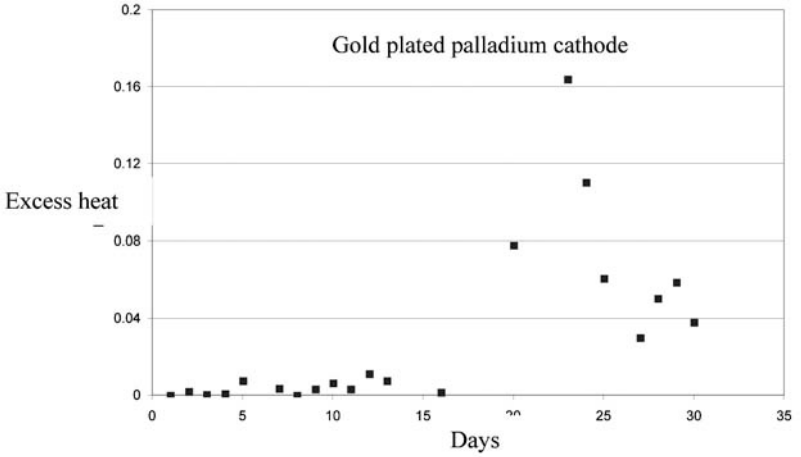


Figure 4 : Excess heat measured with a gold plated palladium cathode

3.4 Laser stimulation

Letts and Cravens [9] have shown that by shining an Ar-Ne laser beam on an active cathode increases the excess heat. Figure 5 shows the effect of a 30 mW laser. The amplification is more that ten-fold.

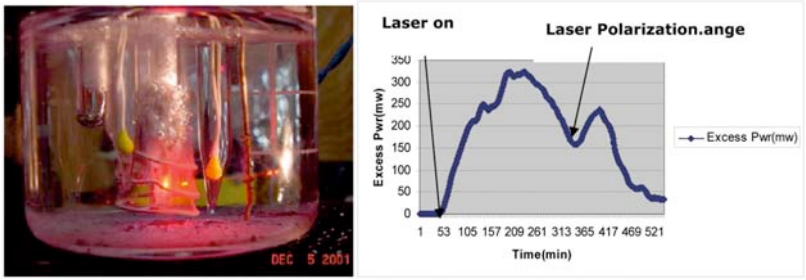


Figure 5 : Excess heat amplification by laser stimulation

4 Helium detection

At the initial press conference, Pons and fleischmann claimed that they had measured helium-4 proving therefore that the reaction was D + D → He-4 + gamma 24 MeV. However it is not easy to measure helium at low level, and several groups have done so succesfully. Miles et al. (4, 10) were the first ones to give acurate measurements of helium-4, and a ggod correlation between excess heat and amount of helium detected. A few years later, Gozzi et al.[11] have also shown a correlation between excess heat and helium-4 measurement.

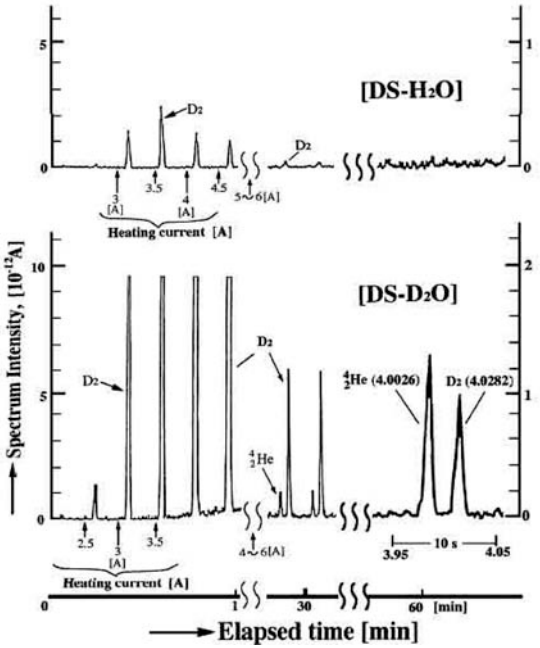


Figure 6 : Mass spectroscopy measurement of He-4 in the double cathode experiment

On figure 6, Arata et al. [5] show the production of helium-4 during electrolysis with the double cathode design in heavy water. No helium is observed in the light water experiment.

5 Tritium measurement

In addition to the helium producing reaction which is very rarely observed in high energy physics (probability 10^{-7}), the two major reactions should produce tritium and neutrons:

$$D + D \rightarrow T + p$$

$$D + D \rightarrow He\text{-}3 + n$$

In nuclear reactions in condensed matter, it is obvious from the experimental results that little tritium and few neutrons are produced. Claytor (12 et al.) have demonstrated the production of low level tritium in gas discharge experiments with palladium electrodes in deuterium gas. Figure 7 shows some of their data.

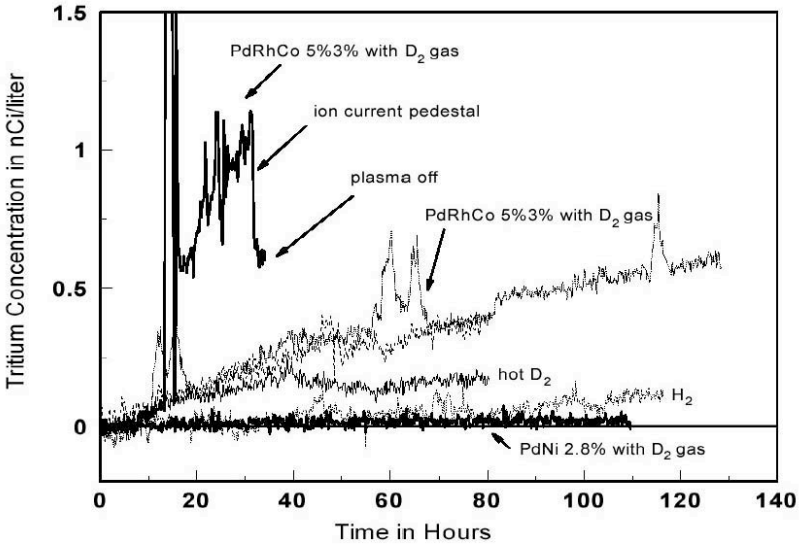


Figure 7 : Tritium production in deuterium gas discharge
With palladium electrodes

6 Neutron detection

When Pons and Fleischmann made their public annoucement, another scientist, Jones [13] from the Brigham Young University, in Utah made a similar declaration, but somehow different. He claimed that he had observed low level neutron emission unexplicable with classical models. He has continued working in the field and has perfected the technique. His new experiment [14] consisted in the electrolysis of titanium electrodes in heavy water, and the whole experiment was surrouded by a high sensitivity neutron counter. The system was located in a tunnel 100 meters below the surface in order to decrease the background counts to a mere 2 counts per day! Figure 8 shows a schematic of the neutron counter and the neutron counts, well above background.

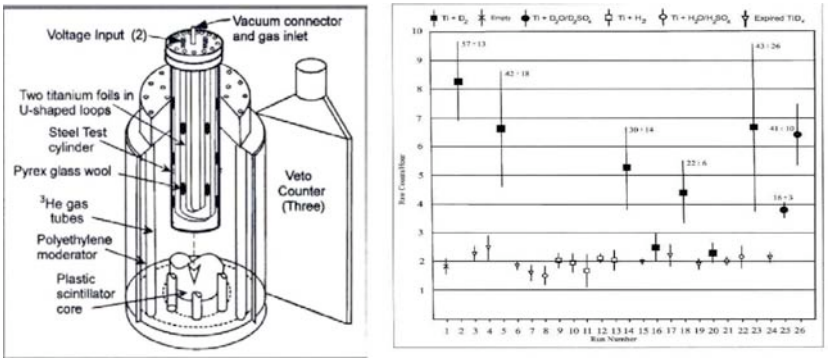


Figure 8 : Neutron measurements

7 X-rays

Several mechanisms are responsible for X-rays production, therefore as energetic particles are produced in an experiment, it is very likely that associated X-rays might occur. Several authors have measured such radiations with sensitive photographic films [11]. Recently Violante et al. [15] have measured X-rays using a germanium detector located at the bottom of an electrolytic cell having a plastic window to prevent absorption of X-rays by the glass of the recipient or the electrolyte. Figure 9 shows the experimental set up as well as a differential spectrum.

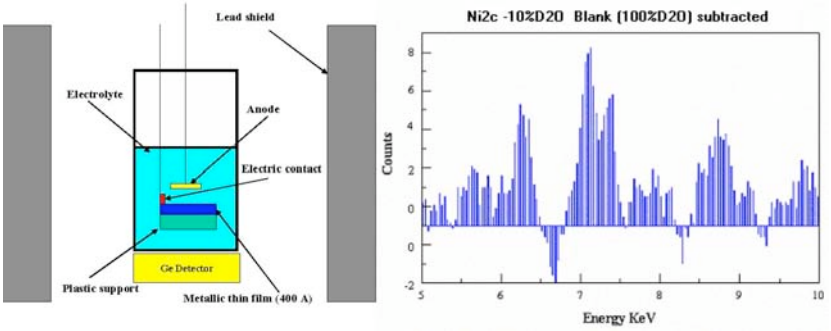


Figure : 9 X-rays production during electrolysis

8 Transmutations

Several groups have shown formation of new elements during electrolysis or plasma discharge experiments. A review of the field has been compliled by Miley et al. [16].

8.1 - Deuterium permeation

However the most striking experiments have been performed by Iwamura et al. [17].

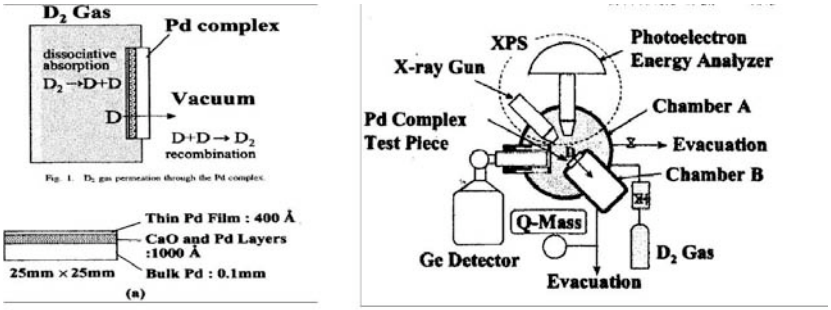


Figure 10 : Iwamura et al. Experimental set-up

Figure 10 shows the experimental set-up. A vacuum chamber is filled with deuterium gas at approximately atmospheric pressure. The gas leaks through a palladium foil treated as described on figure 10. The chamber is evacuated, then refilled at time intervals in order to do surface analysis with

an X-Ray Photoelectron Spectrometer. At first, the top layer of the paaladium foil is covered with strontium. Figure 11 shows the decrease of the strontium and the appearance of molybdenum as measured bt XPS in situ. Then in another experiment cesium is placed on top. Figure 12 shows this time that the cesium XPS line decreases, and praseodinium is formed.

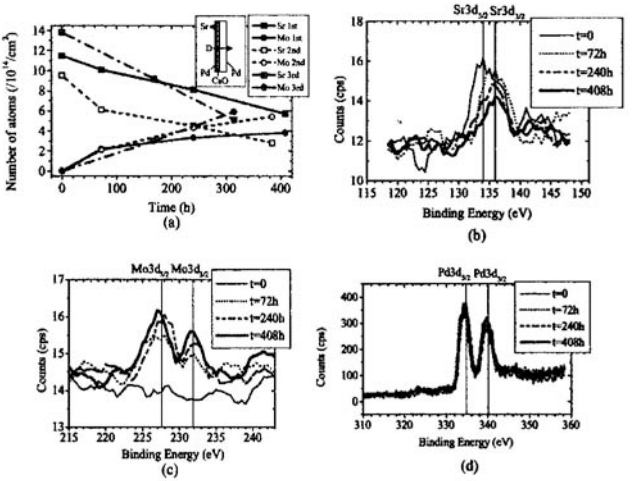


Figure 11 : Molybdenum formation out of strontium

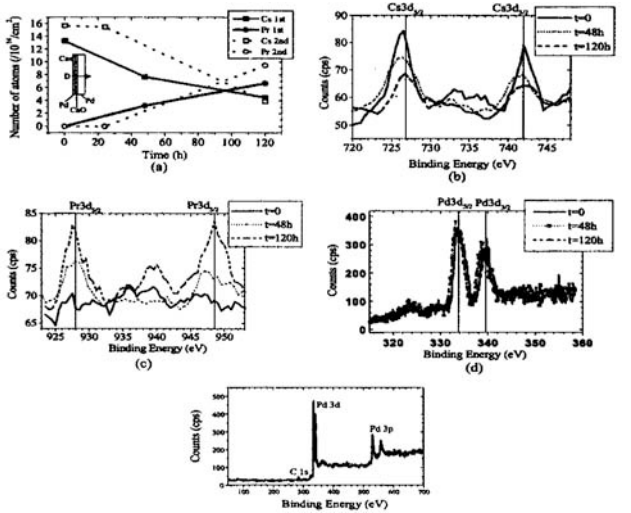


Figure 12 : Praseodium formation out of Cesium

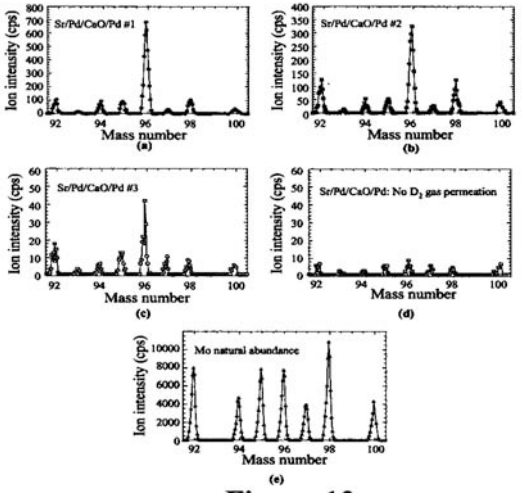


Figure 13 : Mass spectroscopy of the molybdenum

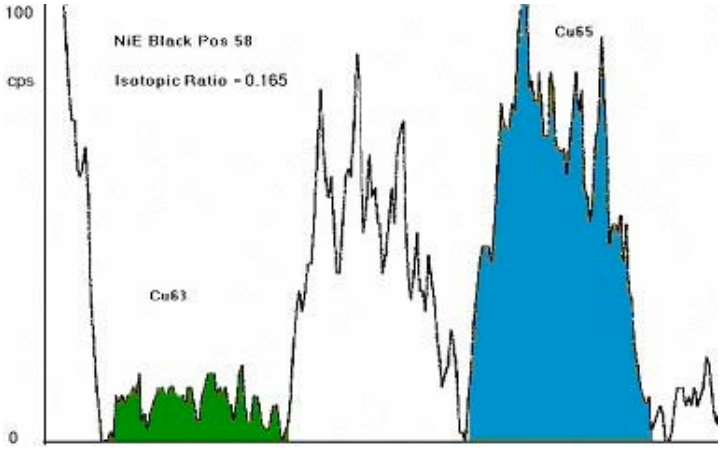
Figure 13a, b, c correspond to Secondary Ion Mass Spectroscopy experiments of threee different runs when strontium was added to the surface. They correspond to molybdenum, but with a very different isotopic distribution as compared to natural molybdenum as shown on figure 13e. A blank run without strontium is shown on figure 13d. The models proposed by the authors are :

$$\text{Cs-133} + 4\ \text{D} \rightarrow \text{Pr-141 Sr 88}$$

$$+ 4\ \text{D} \rightarrow \text{Mo-96}$$

8.2 Electrolysis

Violante et al. [15] during their experiments have analysed traces of copper in the nickel cathode. They show that the isotopic ratio Cu-63/Cu/65 is completely changed as shown on figure 14.



9 Conclusion

After 15 years of intense work by hundreds sientists in fifteen countries, the proofs that nuclear reactions, not predicted by current theories occur in solids, during electrolysis, gas loading, gas discharge.has been established. This presentation is an overview of the field that gives convincing experimental data proving : excess heat and helium production, tritium and neutron detection, X-rays and transmutation.

References

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