Condensed matter nuclear science (cold fusion): an update

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Abstract: Seventeen years after the announcement by Professors Stanley Pons and Martin Fleischmann of the discovery of cold fusion in March 1989, the scientific community does not acknowledge this field as a genuine scientific research theme. However, the scientific demonstration of cold fusion was made long ago by showing the evidence of excess heat production in electrolytic cells and other devices. Also, nuclear ashes have been observed, mainly the formation of helium-4 along with the production of excess heat. What makes this field difficult to accept is the lack of the usual particle emission observed in nuclear science or high-energy physics. In some instances low-level neutron production, X-ray emission and transmutation of elements have been measured. At this point there is no satisfactory theory explaining the unique characteristics of condensed matter nuclear science. Many models have been proposed, several of them using textbook physics.

Keywords: cold fusion; condensed matter nuclear science; low-energy nuclear reaction; excess heat; transmutations.

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Biographical notes: Jean-Paul Biberian is an Associate Professor of Physics at the University of Marseilles, France, Chairman of the *11th International Conference on Condensed Matter Nuclear Science* organised in Marseilles in November 2004, and Editor of the online *Condensed Matter Nuclear Science Journal*. He has been working for the past 13 years in the field of cold fusion and biological transmutations. He has published more than 50 papers related to surface science and cold fusion, and filed three international patents, one of which is related to micro tips flat television screens.

1 A brief history of cold fusion

The discovery of cold fusion was announced officially at a press conference on 23 March 1989 at the University of Utah in Salt Lake City. The shockwave produced by the Pons and Fleischmann announcement is probably unique in history, because e-mails and fax machines helped to propagate the good and the bad news altogether at light-speed. Hundreds of laboratories around the world immediately tried to replicate the experiment.

However, details of it were not well-known and doing electrochemistry and calorimetry together 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, which produces either He-3 and a neutron or tritium and a proton with equal probability. Not surprisingly, no neutrons, or very few compared with 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 into quasi clandestinity.

Several hundred scientists worldwide did careful calorimetry experiments and showed that the effect was real, and certainly simple in principle, but not necessarily easy to reproduce. Artefacts were numerous, and the sources of error or misinterpretation were many. With a lot of patience, courage and stubbornness, they slowly made progress, and finally got to a point where the conditions of reproducibility were reached. They meet regularly at international meetings, starting with Salt Lake City in 1990, and more recently Boston in August 2003 and Marseilles in 2004.

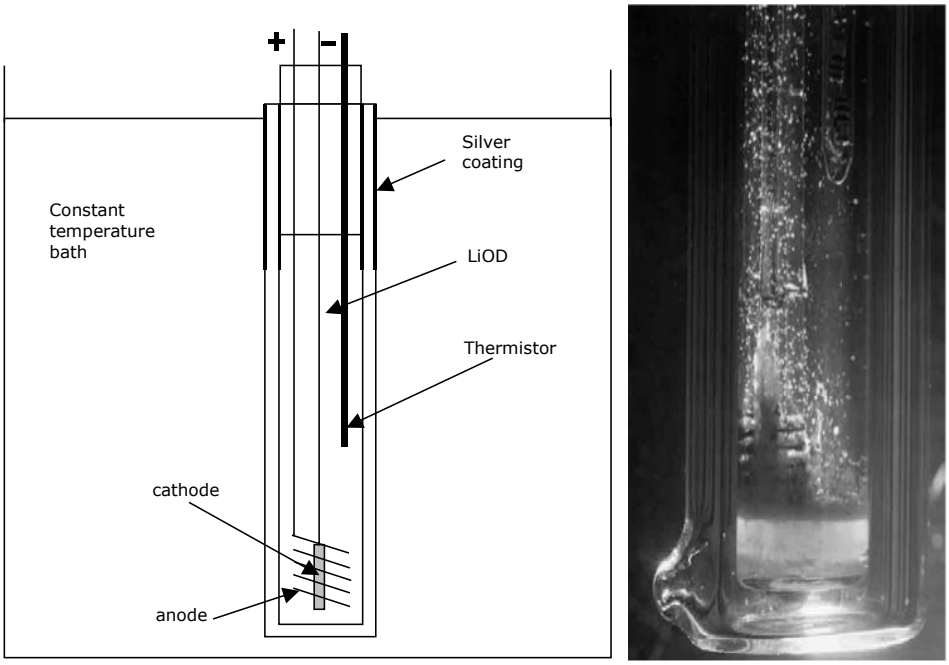
At present a lot has been demonstrated. We know now that the proposed reaction D + D $\rightarrow$ He-4 + 23 MeV is not the only possible reaction. Under other conditions not only fusion but also transmutation is occurring. People have measured X-rays, gamma rays, neutrons, protons, He-4, He-3 and anomalous isotopic distributions. This is why the name of the field has been changed to 'condensed matter nuclear science', which better fits the reality of the observations. The website www.lenr-canr.org has a large collection of papers that can be downloaded.

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

2 The original Pons and Fleischmann experiment

Figure 1 is a schematic of the original Pons and Fleischmann experiment (Fleischmann *et al*., 1989; 1990). The cell is a Dewar 25 mm in inner diameter and about 25 cm long. It is transparent 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. The temperature of the cell is measured by a single calibrated thermistor. It is uniform to within one-hundredth of a degree, because the gas produced by the electrolysis stirs the electrolyte and equalises the temperature. The palladium cathode, usually 2 mm in diameter and 12 mm long, is at the centre of the platinum anode for better current flow uniformity. The cell is placed in a constant-temperature bath. Input power is calculated by multiplying current and voltage, and output power is deduced from the measurement of the temperature of the cell and that of the bath. Almost all the heat is dissipated by radiation and follows the temperature fourth power law. The cell is calibrated with a platinum cathode. The results have been positively duplicated with similar designs by Lonchampt *et al.* (1996) and Miles *et al*. (1993).

Figure 1 The original Pons and Fleischmann experiment

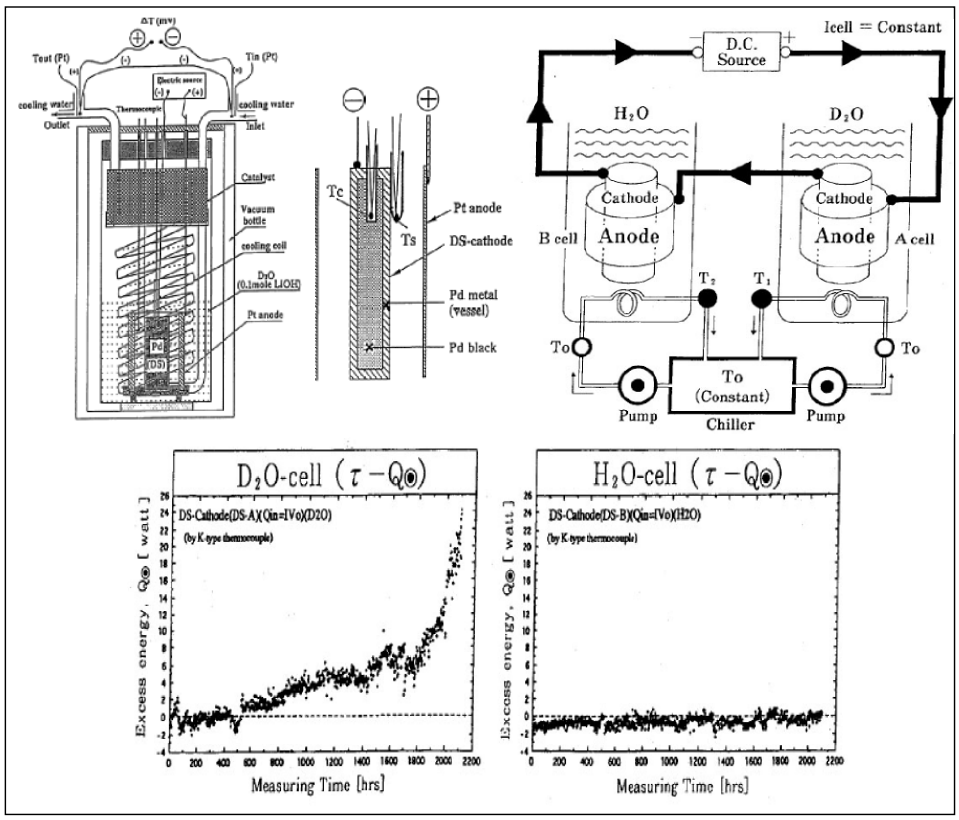


3 Excess heat

3.1 The double cathode

The open-cell calorimetry has been criticised 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 needs 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 needs to be made to determine the input power. Several authors have used such techniques. Arata and Zhang (1998) have added another improvement. Instead of using a solid palladium cathode, they have manufactured a hollow palladium cathode that they have filled with nanometre-sized palladium powder.

Figure 2 The Arata-Zhang double cathode experiment

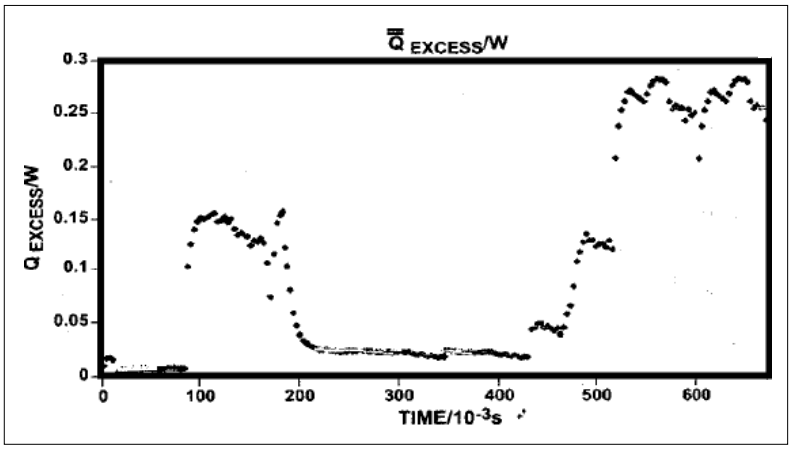


The results of these experiments are shown in Figure 2, where a comparison is made between a heavy water and a light water cell. Without any doubt, the heavy water cell produces large amounts of heat, up to 24 watts, whereas the light water one produces no heat at all. The experiment ends when the cathode explodes owing to the very high pressure of deuterium gas that builds inside the hollow palladium cathode. This experiment has been duplicated by McKubre *et al.* (2002) from SRI.

3.2 Co-deposition of Pd-D

Miles *et al.* (2002) co-deposited palladium and deuterium on a copper cathode. They used a Fleischmann-and-Pons-type open-cell calorimeter. Palladium is deposited by the electrochemical decomposition of palladium chloride in the electrolyte. Excess heat up to 300 mW was reported (Figure 3). Recently, Biberian[1] did similar experiments with a mass flow calorimeter, producing an excess heat of 500 mW.

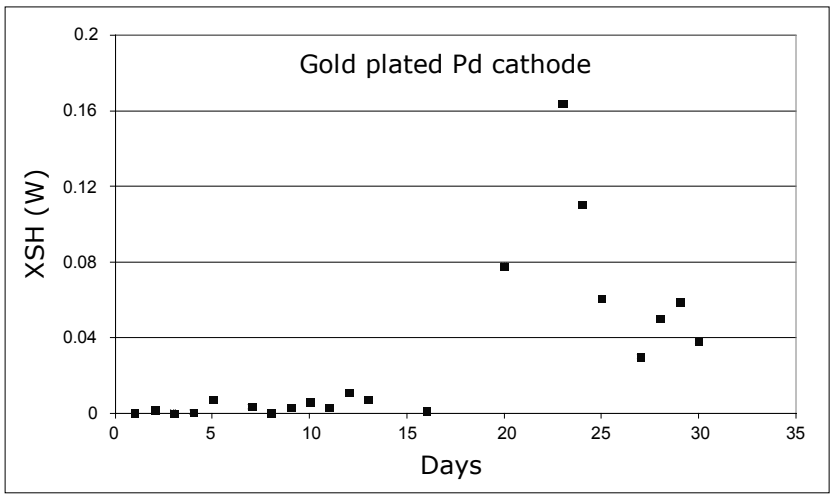
Figure 3 Excess heat during co-deposition of palladium and deuterium



3.3 Gold-plated palladium cathode

Using a Fleischmann-and-Pons-type calorimeter, Biberian[2] deposited gold on a palladium cathode through the dissolution of a gold anode during electrolysis in LiOD. Then a second platinum anode was installed, and excess heat of 170 mW was measured, as shown in Figure 4.

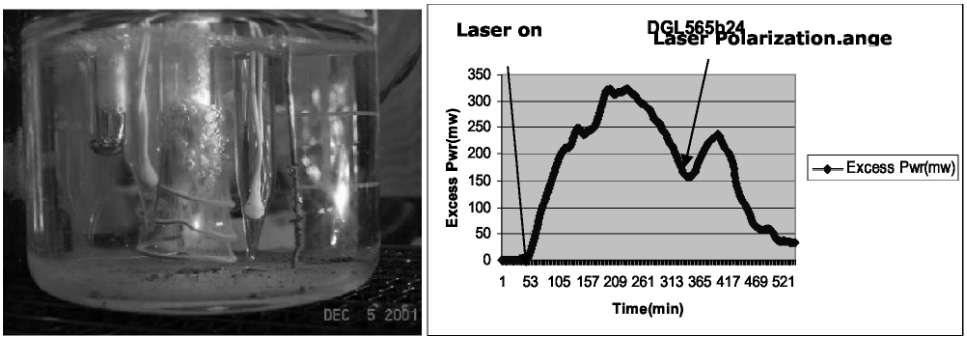
Figure 4 Excess heat observed with a palladium gold plated cathode



3.4 Laser stimulation

Letts and Cravens (2003) have shown that 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 than tenfold.

Figure 5 Excess heat amplification by laser stimulation

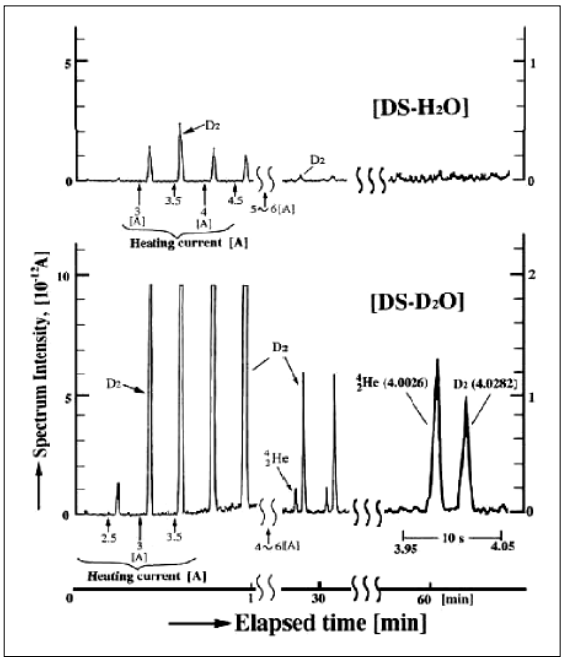


4 Helium detection

At the initial press conference, Pons and Fleischmann claimed that they had measured helium-4, thereby proving that the reaction was D + D $\rightarrow$ He-4 + gamma 24 MeV. While it is not easy to measure helium at low levels, several groups have done so successfully. Miles *et al.* (1993) and Bush *et al*. (1991) were the first to give accurate measurements of helium-4 and a good correlation between excess heat and amount of helium detected. A few years later, Gozzi *et al.* (1998) also showed a correlation between excess heat and helium-4 measurement.

In Figure 6, Arata and Zhang (1998) 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.

Figure 6 Mass spectroscopy showing formation of He-4 with D_2O, compare to a blank with H_2O



5 Tritium measurement

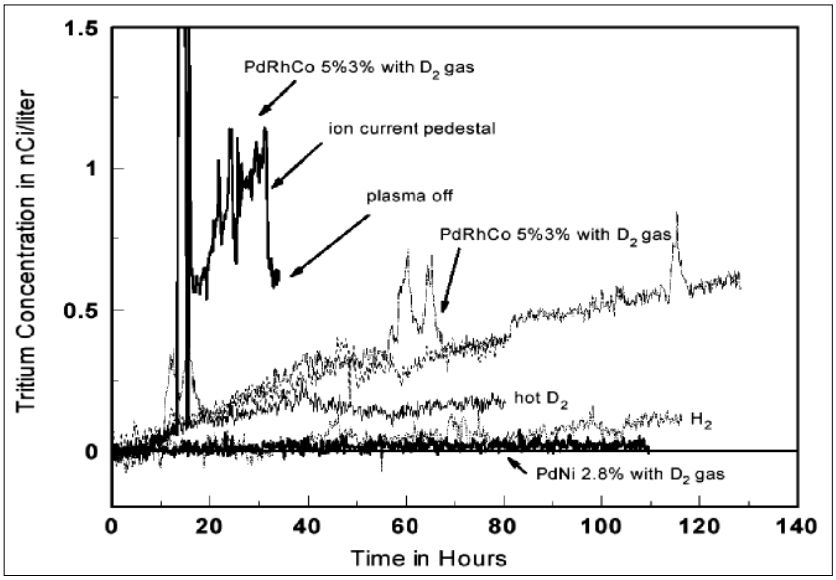
In addition to the helium-producing reaction, which is very rarely observed in high-energy physics (probability 10^{-7}), two major reactions should produce tritium and neutrons:

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

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

In nuclear reactions in condensed matter, it is obvious from the experimental results that little tritium and few neutrons are produced. Claytor *et al.* (1998) 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.

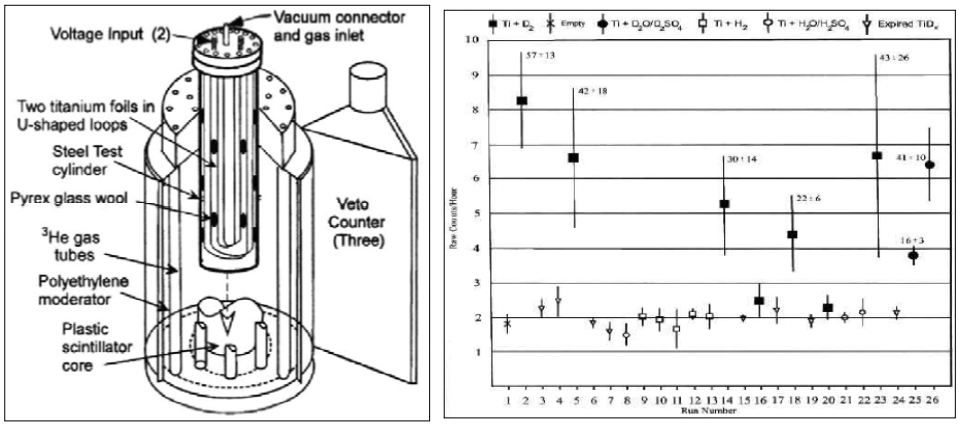
Figure 7 Tritium production in deuterium gas discharge with palladium electrodes



6 Neutron detection

When Pons and Fleischmann made their public announcement, other scientists (Jones *et al*., 1989) from the Brigham Young University in Utah, made a similar declaration, but it was somehow different. They claimed that they had observed low-level neutron emission that was inexplicable with classical models. They has continued working in the field and has perfected the technique. Their new experiment (Jones *et al.*, 2003) consisted in the electrolysis of titanium electrodes in heavy water, and the whole experiment was surrounded by a high-sensitivity neutron counter. The system was located in a tunnel 100 m 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 the background.

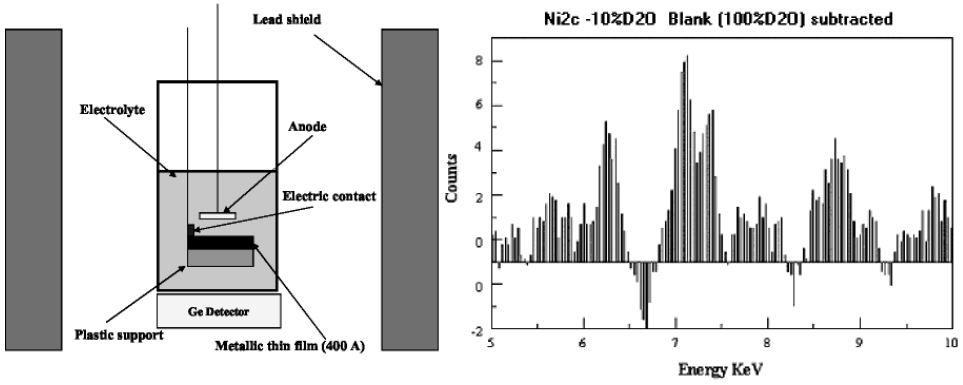
Figure 8 Neutron measurements



7 X-rays

Several mechanisms are responsible for X-ray 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 radiation with sensitive photographic films (Gozzi *et al.*, 1998). Recently, Violante *et al.* (2003) measured X-rays using a germanium detector located at the bottom of an electrolytic cell with 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-ray production during electrolysis



8 Transmutations

Several groups have shown the formation of new elements during electrolysis or plasma discharge experiments. A review of the field has been compiled by Miley and Shrestha (2003).

8.1 Deuterium permeation

The most striking experiments were performed by Iwamura *et al.* (2002). 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 in 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 palladium foil is covered with strontium. Figure 11 shows the decrease in the strontium and the appearance of molybdenum as measured bt XPS *in situ*. Then in another experiment caesium is placed on top. Figure 12 shows this time that the caesium XPS line decreases, and praseodymium is formed.

Figure 10 Iwamura *et al.* experimental set-up

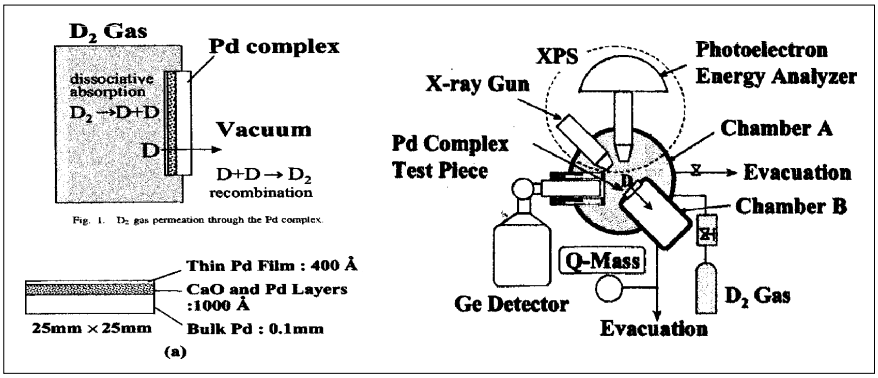


Figure 11 XPS data showing disappearance of strontium, and formation of praseodymium versus deuterium diffusion time

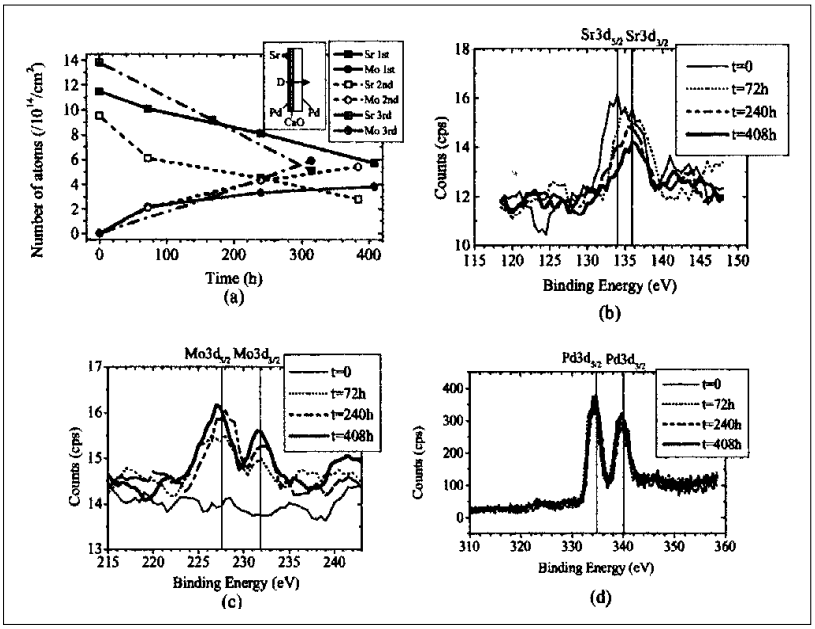


Figure 12 XPS data showing disappearance of caesium, and formation of molybdenum versus deuterium diffusion time

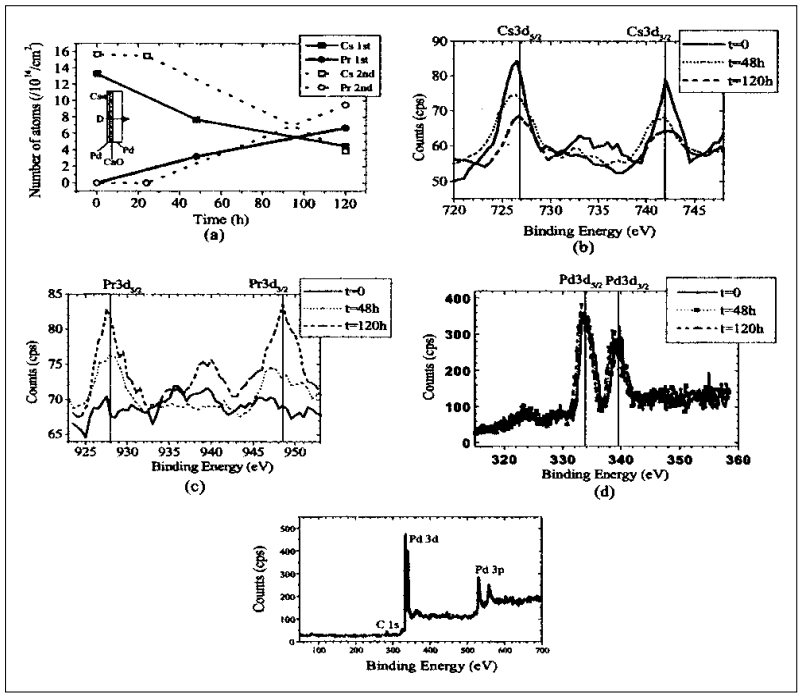


Figure 13 Mass spectroscopy of the molybdenum