EUROPHYSICS LETTERS 1 June 1989
Europhys. Lett., 9 (3), pp. 221-224 (1989)

Evidence of Emission of Neutrons from a Titanium-Deuterium System.

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(received 24 April 1989; accepted 26 April 1989)

PACS. 20.00 – Nuclear physics.
PACS. 60.00 – Condensed matter: structure, thermal and mechanical properties.

Abstract. – The interaction of deuterium gas with titanium has produced a flow of neutrons in two experiments reported here. This seems to show that it is not necessary to use electrolysis in order to obtain a low-temperature fusion reaction between deuterium nuclei. The experiment confirms also that nonequilibrium conditions are necessary in order to produce such a phenomenon.

The experiments recently reported by Jones (J) and coworkers [1] and by Fleischmann and Pons [2] (FP) are concerned with the production of fusion reactions in an electrolytic cell containing heavy water, using a cathode made from palladium. In the case of (J) (who used both palladium and titanium for electrodes) neutrons were observed from the cell, with an energy spectrum which peaked around 2.4 MeV, the energy of neutrons produced in the fusion reaction

$$D + D \rightarrow {}^3\text{He}\,(0.82\,\text{MeV}) + n\,(2.45\,\text{MeV}). \tag{1}$$

In the case of (FP) there were two kinds of evidence: the energy balance of the system, obtained by a calorimetric method, showed an intense energy production that could not be accounted for in terms of chemical reactions, up to tens of watts per cubic centimeter of palladium, as well as the emission of neutrons and gamma-rays. In terms of the more common reactions, the one shown in eq. (1) and the reaction

$$D + D \rightarrow {}^3\text{H}\,(1.01\,\text{MeV}) + p\,(3.03\,\text{MeV}), \tag{2}$$

the level of radiation emitted is much too low, by a factor of about 10^9, to account for the energy produced. The authors suggest the possibility of other reactions, with by-products not detectable in their actual experimental arrangement.

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It seems from these experiments that a novel, unknown mechanism based on the interaction of the deuterium atoms (or rather ions) with the metal lattice, either in bulk or on the surface, reduces the shielding due to the Coulomb barrier and permits tunnelling effects that eventually produce neutrons. (J) suggest that the systems must be in a condition of nonequilibrium in order to obtain nuclear fusion.

Our approach to the problem was characterized by the following two features:

i) We wondered whether the use of an electrolytic cell was a necessary condition in order to obtain fusion events. Consequently we decided to put deuterium gas in direct contact with a material and, following consideration of the various metals that absorb hydrogen, we chose titanium.

ii) In order to create a condition of nonequilibrium, we decided to change the thermodynamic parameters of the system, in particular temperature and pressure; in this way we could create a dynamic condition for the process of absorption/desorption of deuterium in titanium.

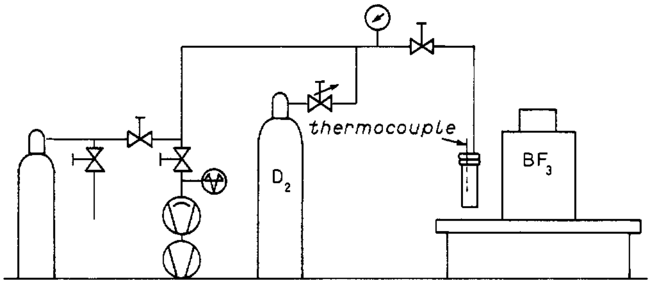

Fig. 1. – Schematic drawing of the apparatus.

Figure 1 shows a schematic drawing of the apparatus. About 100 grams of titanium, in the shape of shavings, is contained in a stainless-steel cell, which was tested for vacuum and high pressure both at room temperature and liquid-nitrogen temperature. The cell was connected to a deuterium cylinder through valves and a pressure regulator. The cell could be evacuated through an auxiliary line. A manometer monitored the pressure in the cell, and a thermocouple in contact with the upper part of the titanium measured the temperature. A special dewar could be placed around the cell, in order to change the cell temperature between room temperature and liquid-nitrogen temperature. A BF_3 neutron counter with high sensitivity was positioned quite close to the cell (typically 20 cm centre to centre). The counter was interfaced with a computer, in order to read integral counts at regular intervals.

We have had two successful runs, in two different experimental conditions, which are described in the following sections.

1. *7-10 April, 1989.* – After degassing the titanium, deuterium was admitted to the cell in steps of increasing pressure. At the same time the temperature was monitored, to check that there was not a relevant absorption reaction. This confirmed that only small amounts of deuterium were absorbed. A pressure around 50 bar (5 MPa) was reached. Then the temperature was lowered to 77 K by immersing the cell in a dewar full of liquid nitrogen. At this point the system was left to itself, at constant pressure, with the aim of obtaining changes of temperature both in time and space while the level of liquid nitrogen in the dewar was going down. The results of this run are shown in fig. 2, where a plot of the neutron counts is reported as a function of time over a period extending from the afternoon of Friday, April 7, to the late morning of Sunday, April 10, a total of more than 60 hours. The

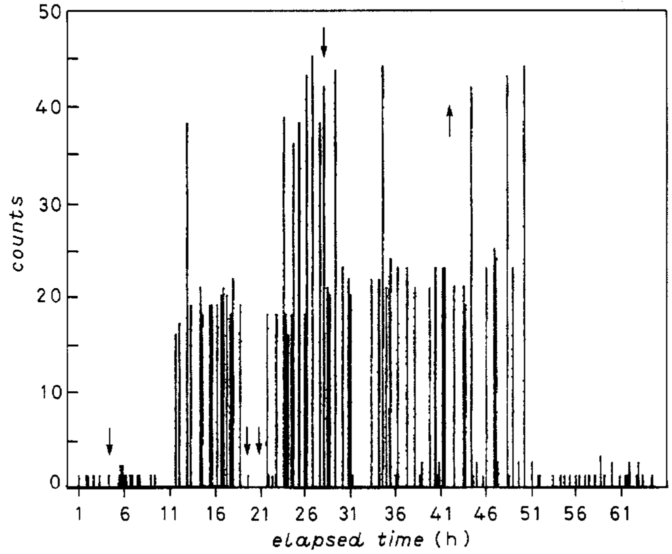

Fig. 2. – Diagram showing the time evolution of the neutron emission during the first run (7-10 April, 1989). The values indicated are integral counts over periods of 10 minutes.

counts reported on the diagram are the integral values corresponding to time intervals of 10 minutes. The down-directed arrows indicate liquid-nitrogen fillings. In the first two fillings the liquid-nitrogen level was quite low and and most of the cell was out of the bath. The up-directed arrow shows the time when the liquid-nitrogen dewar was taken away and the system was thus allowed to rise to room temperature. The correlation between the cooling cycle and the neutron emission is of particular note. Note also the almost «quantized» structure of the counts, as if they were coming in bunches of 20 (± 4). A possible explanation for this behaviour is the saturation of the counter, because of the arrival of a large number of neutrons in a very short time interval. A better time resolution in the neutron detection will be required to confirm this explanation. An accurate measurement of the background neutron emission was made before and after the run (the latter is visible in the figure), yielding an average value of 2.3 counts/h, while the average counting rate during the «active» periods was about 70 counts/h, *i.e.* 35 times above the background.

2. *15-16 April, 1989.* – In this run the deuterium had been in contact with the titanium bed at different temperatures and pressures for roughly one day and counts only just above the background had been detected. In order to examine the behaviour of the system in the desorption phase, the deuterium was evacuated from the system by vacuum pumping and the liquid-nitrogen dewar was also removed, allowing the cell and its content to rise towards room temperature. This moment corresponds to time 0 in fig. 3. Also in this figure the counts are reported as a function of time. Note that about 3 hours after time 0 neutrons begin to show up with a kind of a Gaussian distribution in time. The background level was around 2 counts/h. The average count in the active period was much higher than in the previous run, of the order of 1000 counts/h, a factor 500 above background.

The overall counter efficiency (measured with an AmB neutron source) was about $5 \cdot 10^{-5}$. Thus, in the second, more intense, emission the system emitted more than 5000 neutrons/s.

The characteristics of the experiment did not allow for an accurate energy balance that could provide evidence of heat production. What can be said is that we can exclude a heat production of the order of that seen by (FP). Such heat flow would have produced an anomalous liquid-nitrogen evaporation, and this we did not observe.

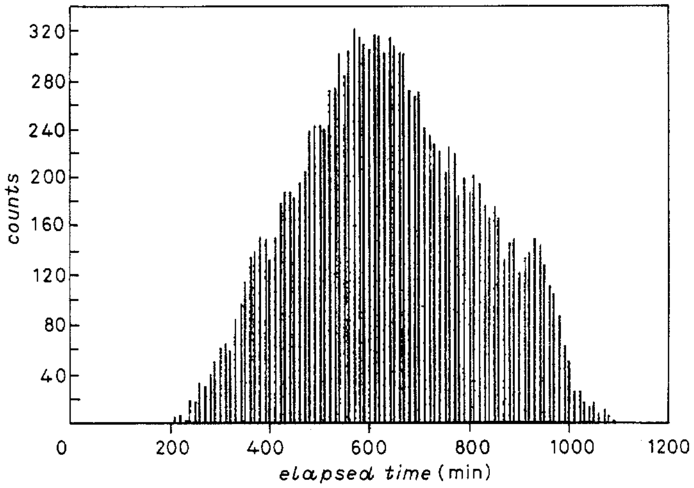

Fig. 3. – Diagram showing the time evolution of the neutron emission during the second run (15-16 April, 1989). The values indicated are integral counts over periods of 10 minutes.

Two main features emerge from our measurements:

1) It is possible to produce neutrons in a process, that could be due to the fusion of two deuterium nuclei, without the help of electrolysis. Our experimental arrangement is very simple and thus should be very suitable for a theoretical approach to the problem.

2) Summing up all our experience during these measurements, we are in agreement with a suggestion made by (J), that a necessary condition for the emission of neutrons is that the system be in a condition of nonequilibrium. In our case the dynamics of the absorption and desorption processes could contain the mechanism that creates this nonequilibrium condition.

To conclude, we believe that all these experiments, the two quoted previously and our own, open an interesting field of scientific investigation, characterized by a close connection between solid-state physics and nuclear physics.

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We wish to acknowledge very useful discussions with Profs. G. Sanna and S. E. Segre concerning these experiments.

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