SEARCH FOR NUCLEAR PHENOMENA BY THE INTERACTION BETWEEN TITANIUM AND DEUTERIUM

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ABSTRACT

Following the preliminary results obtained in the Spring of 1989 [see ref.3], a second generation of experiments aimed to the detection of nuclear particles from a titanium-deuterium system has been designed. Here very preliminary results from the new (even though not yet complete) experimental setup are presented: neutron burst emission from the system and tritium production in the samples.

INTRODUCTION

In March 1989 the evidence of "cold fusion" phenomena was claimed by two experimental groups in Utah; in both instances an electrolytic cell was used with heavy water. Fleischmann and Pons [1] attributed the excess heat produced during the elctrolysis to nuclear fusion reactions. Jones et al. [2] measured the emission of neutrons of the correct energy (2.45 MeV) during the electrolysis. Our group in Frascati made the assumption that, if a nuclear phenomenon was present in the quoted results, it could be attributed to the interaction between deuterium and some metals - in particular, palladium and titanium - with the electrolysis playing the role of an intermediary. A simple experiment was devised, with the purpose of avoiding the complications of electrolysis; it consisted in putting in contact gaseous deuterium with titanium (in shavings), and then changing the thermodynamical parameters of the system (temperature, pressure, stoichiometric ratio, etcetera) and looking for neutron emission. Positive results were obtained and published in reference 3: we refer to the latter for more details. Here we need to remember only two main features, that have influenced the design of a second generation experiment, which is the object of this communication.

- The neutron emission appeared to be structured in "bursts", i.e., many neutrons were emitted in a short time, of the order of 100 μs.
- Lack of reproducibility characterized our tests (and all the positive tests performed throughout the world): we had a total of 4 positive runs out of about 12 (each lasting roughly a week).

Since then we have been moving in three directions:

- improving the neutron detector,
- searching for tritium in our samples,
- trying to study the thermodynamics of the system.

Here the preliminary results of our second generation experiments are reported.

NEUTRON DETECTION

In detecting neutrons produced in nuclear reactions, like those apparently present in these experiments, four features are important:

- identification of neutrons,
- localization of the source,
- time structure of the bursts,
- energy of the neutrons.

As a first approximation, we decided to solve the first three problems, aiming in the

search for better reproducibility of the experiments, and postponing the measure of the neutrons' energy to a third generation experiment. We follow the solution chosen by the Los Alamos group [4], using a system of many ^{3}He detectors, arranged in a cylindrical geometry and embedded in polyethylene: this ensures high sensitivity. The presence of an outer ring of detectors gives information about the region where the neutrons come from. The use of a veto counter system, consisting in a set of ^{3}He tubes without moderator and connected to the same electric feed, allow us to exclude noise effects, and contributes to a good identification of neutrons. The burst structure is examined by opening a time window - usually 128 μs - every time a neutron is counted and seeing whether other neutrons are present in the window. A comparison with a similar window opened 2 ms later allows us to correct for the case of multiple events present in the background. In this way a multiplicity index n is measured, which is related to the number of neutrons R in the shift register by the expression

$$n = R(R-1)/2$$

If the efficiency of the detector is e, the number of neutrons emitted is, with good approximation,

$$N = e\sqrt{2n}$$

A detector with these characteristics is under construction and will be ready by the end of Spring 1990.

While waiting for the new detector we had the chance to use since last October a standard neutron detector (normally used to detect the amount of plutonium in a sample) with 15 operating ^{3}He tubes and an overall efficiency of about 15% (measured with a ^{252}Cf source). We were not yet able to use an outer ring and a veto counter. We could look at the burst structure of the emission, but with quite a high background. This meant that "meaningful" bursts needed to have multiplicities greater than 35. With this apparatus we performed a series of 19 runs, for a total of about 2100 hours between October 1989 and February 1990. Figure 1 shows the outcome of these runs. In 1a the kinds of sample are listed with the corresponding measurement time; in 1b for every kind of sample the number of runs and the number of bursts is reported. We could measure a total of 19 bursts, ranging from 40 to 320 in multiplicity, 17 of which were obtained in experiments on samples constituted by titanium (or titanium alloy) in the presence of deuterium. No bursts were observed in "blank" samples, i.e.: only the counter, titanium with hydrogen, titanium under vacuum. In one run with deuterium at 50 bar in the experimental cell, but without titanium, 2 bursts (of the minimum multiplicity) were seen. Figure 2 shows the distribution of the bursts with respect to multiplicity. During the tests the samples were subjected to temperature and pressure changes. The stoichiometric ratio in these experiments ranged in a very wide interval of values, from 10 at.% to 190 at.%. The positive data are too few at present to attempt any correlation with these parameters. The only conclusion that we can get is of statistical order: we see bursts when in the system there is deuterium, we do not see bursts when in the system there is no deuterium. The next step will be, with the new detector, to decrease substantially the background, in order to be able to consider multiplicity factors down to less then 10. This has already been done by the Los Alamos group [4], showing that the number of bursts strongly increases at low multiplicities. This seems a reasonable route to pursue in order to aim at reproducibility.

SEARCH FOR TRITIUM

If tritium is produced within the deuterated titanium sample because of a nuclear reaction, it is most probable that it is absorbed in the metal, with few chances of escaping. Thus, it is possible to search for tritium in samples even days or months after the experiment has been performed.

The technique used has been set up by one of us (FL) and is described in detail in reference 5. Here a short description of the method is presented. The metal sample is slowly heated up to 1000 °C in a slow flow of helium gas (roughly 1 cm^3 NTP/s). The outgoing gas passes through a catalyzer (CuO heated to a temperature of 400 °C), where the hydrogen and its isotopes are changed in water, and then through two scrubbers in series, where the water is condensed and collected: each scrubber is a glass tube containing distilled water, kept at a temperature of 4 °C (in order to have a low vapor pressure). Water from each scrubber is then mixed with a scintillator cocktail, and its disintegration rate is measured. The second scrubber normally does not show tritium: this is a check that all tritium and deuterium have been condensed in the first scrubber. Two independent measurements from the same sample are performed, using for each test 5 to 10 grams of metal. The amount of deuterium extracted is obtained by weighing the sample before and after heating it.

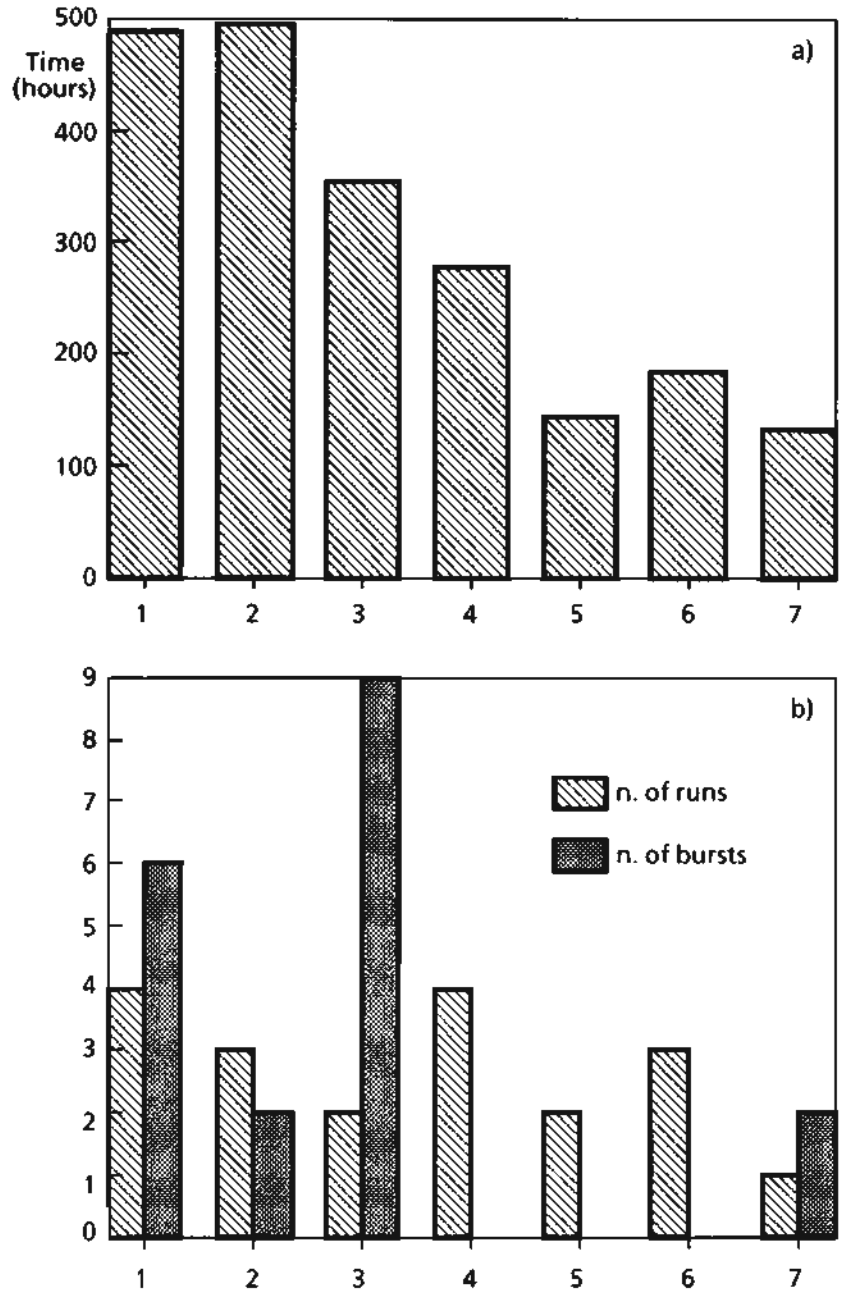

Figure 1. Emission of neutron bursts. (a) The number of hours of neutron detection for every kind of samples. N.1: titanium shavings with deuterium. N.2: titanium alloy 6-6-2 (6% Va, 6% Al, 2% Sn) with deuterium. N.3: titanium sheet (1 mm thick) with deuterium. N.4: blank with the detector containing a piece of metal of the same mass of the experimental cell, in order to keep the number of neutrons produced by cosmic rays constant. N.5: blank with the cell containing titanium and hydrogen. N.6: blank with titanium under vacuum in the cell. N.7: the cell, without titanium, with 50 bars of deuterium inside. (b) For each kind of sample the corresponding number of runs (each lasting roughly one week) is shown on the left, and the number of bursts on the right.

Previous to all measurements, the amount of tritium contained in the original deuterium must be determined. This is obtained with a similar procedure, in which the first step is substituted by flowing gas from the deuterium bottle, mixed with an appropriate amount of helium, which acts as the carrier. We found that the tritium content in commercial deuterium bottles can be quite different. The first bottle we used contained up to 360 Bq/g (becquerel per gram of deuterium), quite a high value. A second bottle contained only 9 Bq/g and with this one we

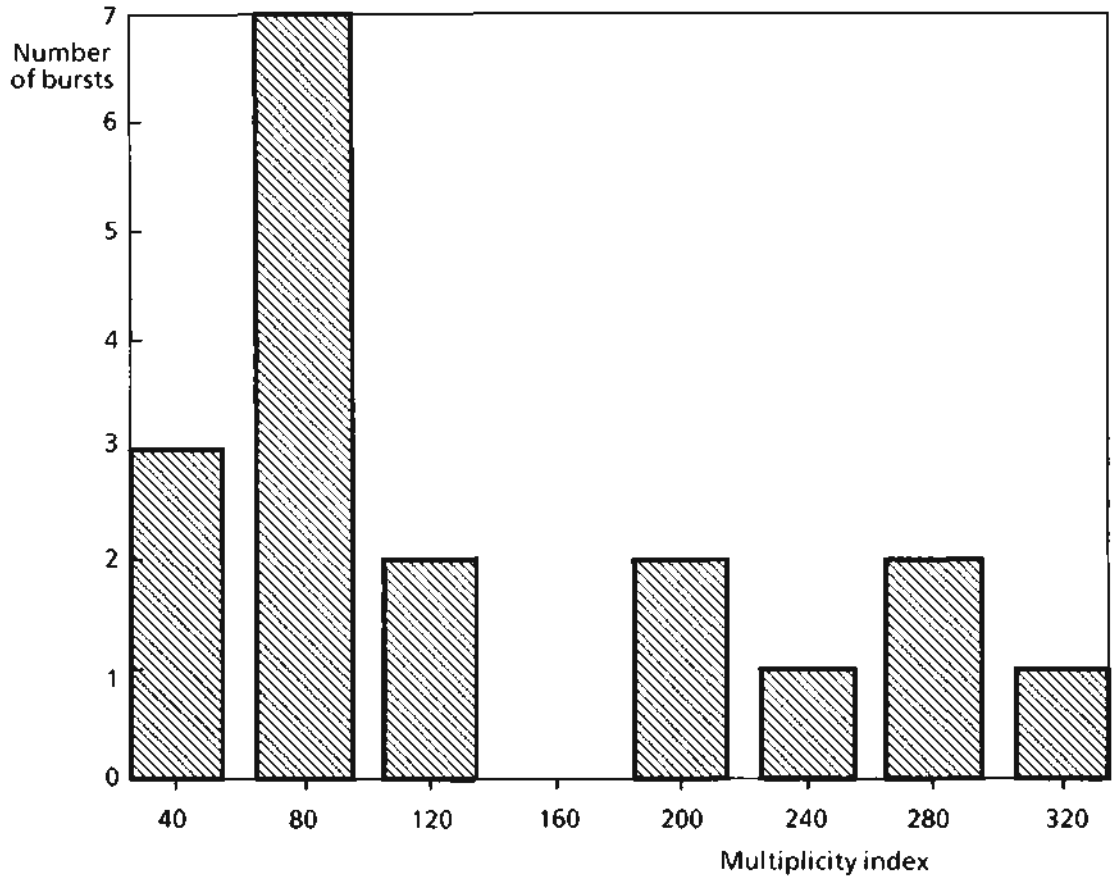

Figure 2. The distribution of the bursts as a function of multiplicity. Multiplicities lower than 35 have not been considered as "meaningful" bursts. The two bursts found in sample 7 of Figure 1 have multiplicity 40.

performed a few preliminary experiments. In order to have enough deuterium to minimize errors, in these experiments we strongly deuterated the titanium samples, with stoichiometric ratios higher than 140 at.%.

Table 1 shows the results obtained in the first 5 tests. The data reported have already been corrected for the tritium content in the original deuterium, by subtracting 9 Bq/g from the readings of the scintillator. Even in these experiments it is almost impossible to look for correlations between the results and the other parameters, such as the thermal cycles of the sample, the kind of material (shavings or powder), the stoichiometric ratio, etcetera. In all cases but one (n.1) we were not looking for neutrons during the experiment. We did not measure any neutron emission in experiment n.1. The only conclusions that we can draw at this point is that it seems that it is possible to form tritium during the interaction of deuterium gas with titanium, in amounts well above the standard deviation.

Table 1. The amount of tritium found in titanium samples that have been subjected to experiments of interaction with deuterium gas. The values reported under "T-production", expressed in becquerel per gram of deuterium, have been already corrected, by subtracting 9 Bq/g, for the tritium content in the original deuterium. All samples were Ti shavings, with the exception of sample 1, consisting of Ti powder. Samples 2 and 3 had no low temperature thermal cycle (see Reference 3). In all samples the stoichiometric ratio was more than 140 at.% of deuterium. 1 Bq/g corresponds to about 5×10^8 atoms of tritium.

Sample N.	T-Production Bq/g	Standard Dev. Bq/g
1	13.68	1.26
2	26.91	0.89
3	4.60	0.92
4	7.29	0.93
5	3.11	0.85

THERMODYNAMICS

We are convinced that the main problem to face is the correlation between the nuclear phenomena described above and the thermodynamical features of the metal-deuterium system. By this we mean all the microscopic transformations that the interaction between deuterium and the metal lattice can produce. This kind of research has proved up to now quite difficult, because of the lack of reproducibility of the experiments. This justifies our present effort aimed at increasing reproducibility. If and when this target will be reached, we think that it is very important to look for correlations between nuclear phenomena and these parameters, i.e.: temperature; pressure; deuterium concentration; temperature, pressure and concentration gradients; changing rate of these parameters; phase transformations; purity and thermal history of the material; and considering materials other than titanium.

At present we are building a new cell in which we will be able to change the temperature of the sample in a programmed way, while looking for neutron emission. This cell should be operating with the new neutron detector next Summer.

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