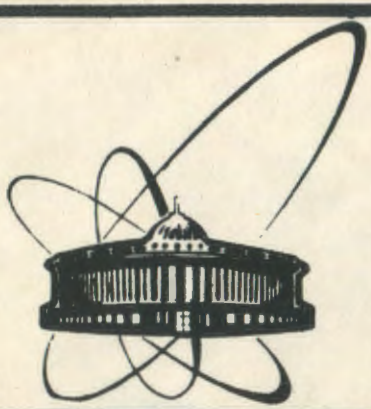

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ЕЩЕ РАЗ О ХОЛОДНОМ ЯДЕРНОМ СИНТЕЗЕ

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Introduction

In Ref.[1] we described the results of the experiments that checked the existence of cold nuclear fusion discovered in Refs.[2,3]. For this purpose we carried out electrolysis of heavy water D_2O and of mixture $D_2O + H_2O$ (1:1) with a Pd-cathode, and saturation of Pd with gaseous deuterium. The nuclear fusion processes were to be identified by registration of neutrons, gamma-quanta and KX-radiation of palladium due to charged products of the reactions

$$d + d \rightarrow {}^3He + n + 3.27\ MeV, \quad (1)$$

$$d + d \rightarrow t + p + 4.03\ MeV, \quad (2)$$

$$p + d \rightarrow {}^3He + \gamma + 5.5\ MeV. \quad (3)$$

Our results do not prove the data of Refs.[2,3] and indicate that if cold nuclear fusion really occurs under the conditions existed during the investigations, its probability is extremely small.

Refs.[2,3] also spoke about titanium as an alternative material where cold nuclear fusion could occur. We have carried out a round of experiments on electrolysis of heavy water with a titanium cathode and on saturation of titanium with gaseous deuterium.

Experimental procedure

The heavy water (99.80% D_2O) electrolysis experiment was carried out with the cylinder-shaped electrolyser (Fig.1). The cathode was a cylinder of chemically pure (99.8%) compacted titanium 5 mm in diameter and 40 mm long. Around the cathode there was a platinum net anode. The working volume of the electrolyte was 160 cm^3. The electrolyser and boron-containing detectors of thermal neutrons SNM-14 were placed in a polyethylene retarder. To reduce the external neutron background,

the whole installation was surrounded with borated polyethylene (see ref.[1]). During measurements the neutron background level varied from 2 to 5 pulses per hour. The neutron detection efficiency was experimentally determined with reference Pu-Be and ^{252}Cf sources put in turn the place of the titanium sample to be investigated; it was $3 \cdot 10^{-3}$ pulses/neutron. The measurements were carried out at current densities varying from 1 to 125 mA/cm^2. To increase the coductance, soda (Na_2CO_3) was added to D_2O in concentrations from $5 \cdot 10^{-3}$ M to $1.9 \cdot 10^{-1}$ M.

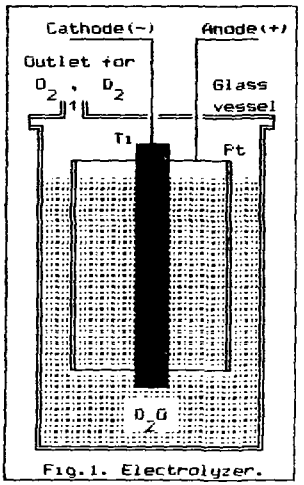

Fig.1. Electrolyzer.

The analysis of the experimental data showed that the intensity of the hypothetical neutron source at the 95% confidence level is less than

$$Q_n \leq 2 \cdot 10^{-2} \text{ n/s cm}^3 \text{ Ti}.$$

Following this value, one can estimate the d-d fusion reaction rate per deuteron:

$$\lambda_f \leq 4 \cdot 10^{-25} \text{ s}^{-1}.$$

Comparison between the results of the previous [1] and the present work shows that the limiting values obtained for Pd and Ti do not differ from each other and are almost completely determined by the level and fluctuations of the neutron background.

The experiments on titanium saturation with gaseous deuterium were stimulated by the report made by Prof. C.Guaraldo (IFNF, Frascati, Italy) at a scientific seminar in the Laboratory of Nuclear Problems, JINR, and by the articles in Italian newspapers describing the results of investigation of cold nuclear fusion by a team of physicists in Frascati.

The main idea of the above report was as follows.

1. If deuterium-saturated titanium is cooled to 77 K at the constant gaseous deuterium pressure of 40 atm, detectors will show that neutrons appear. In 50 hours the effect of the neutron counting rate excess over the background level practically disappears.

2. If the titanium temperature is raised from 77 K to 300 K (P = 40 atm) the effect disappears.

3. If the temperature is raised from 77 K to 300 K while the deuterium pressure is decreased from 40 atm to 1 atm, a sharp increase in the neutron counting rate was observed.

Fig. 2 presents our experimental lay-out, and Fig. 3 schemati-

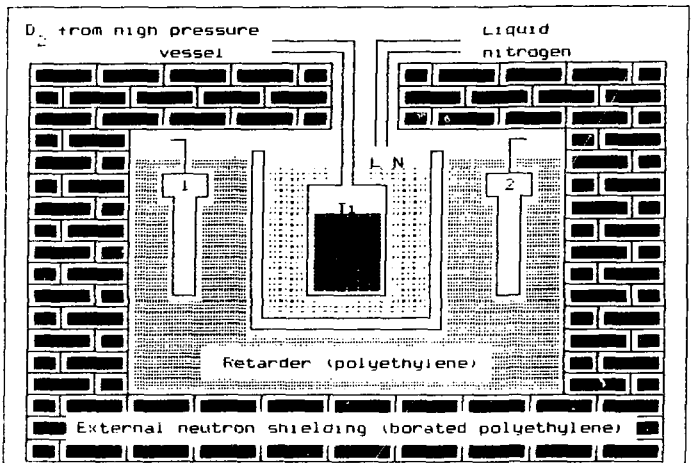

Fig.2. Experimental set-up
(1,2 - neutron detectors SNM-14).

cally shows how gaseous deuterium was purified and supplied to a vessel with titanium chips or tablets 5 mm in diameter and 1 mm thick made by sintering the titanium iodide powder in vaquum at 800...900°C. Owing to high porosity (30...50%) the real surface of this gas ansorber is hundreds of times large than the geometric one, which greatly affects kinematics of gas absorption. The mass of the titanium chips, like the mass of the tablets, was 70 g. The titanium underwent a vaquum-thermal training in a special vessel beforehand. The end mark of the training was the residual gas pressure which did not exceed $5 \cdot 10^{-2}$ mbar at 750°C with evacuation cut off. Then the vessel was cooled to the liquid nitrogen temperature (77 K) and deuterium, purified by means of zeolitic absorbers (the total admixture content was $\leq 2 \cdot 10^{-7}$ ppm), was supplied up to the

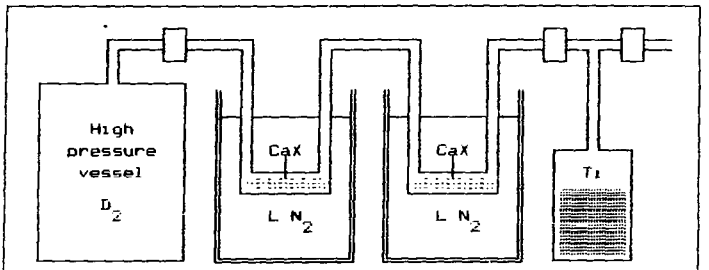

Fig.3. Titanium saturation with deuterium of high purity.

pressure of 50 atm. At this temperature and pressure measurements were carried out for 25 hours both with the titanium chips and with the tablets.

The data obtained in the exposures with titanium saturated with deuterium at T = 77 K and with titanium without deuterium show that there is no difference between the results of these experiments within the measurement errors. In the experiments with titanium heated from 77 K to 300 K at the constant deuterium pressure 50 atm neutrons were not found as well.

In the next experiment the vessel was filled with deuterium at the pressure of 50 atm and temperature T = 77 K, and an hour later the pressure was released to 1 atm, the temperature was being slowly raised to 300 K for 8 hours. The analysis of the experimental data also indicates that the neutron count does not exceed the background level within the experimental errors.

Finally, an experiment at the pressure up to 600 atm was carried out. A special 100 mm high vessel of heat-resistant alloy with the internal diameter of 70 mm and wall 10 mm thick was used. 70 g of titanium tablets were put into the vessel, and vacuum-thermal activation was performed. The vessel was cooled by liquid nitrogen, then the titanium was being saturated with deuterium for about an hour at the pressure of 150 atm; the vessel was kept at 77 K for 12 hours and then was gradually heated to 300 K (for 10 hours), the pressure increasing from 150 to 600 atm. The vessel was cooled by liquid nitrogen again and after the pressure release it was heated for 10 hours to 300 K (the pressure was 1 atm).

Table 1

Mass of Ti (g)	Temperature (K)	Pressure (atm)	Counting rate (10^{-2} puls./min)		Neutron yield Q_n * (n/s cm^3 Ti)	d-d fusion rate (1) λ_f^* (1/s)
			Ti + D	Ti		
70	77	150	6.2±0.9	6.0±0.8	$\leqslant 6\cdot10^{-3}$	$\leqslant 6\cdot10^{-26}$
	77 → 300	150 → 600	10.1±1.7	10.0±0.8	$\leqslant 1\cdot10^{-2}$	$\leqslant 1\cdot10^{-25}$
	77 → 300	1	3.7±0.5	4.3±0.6	$\leqslant 3\cdot10^{-3}$	$\leqslant 3\cdot10^{-26}$

(*) - The values Q_n and λ_f are given at the 95% confidence level.

During the above procedures the neutron counting rate was continuously measured, it did not differ from the background (the results obtained are shown in Table 1).

To obtain a more accurate upper limit for λ_f, we carried out an experiment according to the above method with a much larger amount of titanium. The results are shown in Table 2.

Table 2

Mass of Ti (g)	Temperature (K)	Pressure (atm)	Counting rate (10^{-2} puls./min)		Neutron yield Q_n * (n/s cm^3 Ti)	d-d fusion rate (1) λ_f^* (1/s)
			Ti + D	Ti		
2000	77	50	4.0±0.6	4.2±0.6	$\leqslant 1.7\cdot10^{-4}$	$\leqslant 1.5\cdot10^{-27}$
	77 → 300	1	3.3±0.5	4.2±0.6	$\leqslant 8\cdot10^{-5}$	$\leqslant 7\cdot10^{-28}$

(*) - The values Q_n and λ_f are given at the 95% confidence level.

Discussion of results

Taking into consideration the results obtained in this paper and in [1], one can draw the following conclusion: if cold nuclear fusion really occurs, its probability in Pd and Ti under the above conditions is extremely small. Thus, it is practically impossible to observe this phenomenon in the laboratories with an ordinary background level.

It is quite possible that the effects observed in Refs.[2,3] and ascribed to cold nuclear d-d fusion have another origin. It is

known, for example, that during sorption-desorption of hydrogen by palladium, titanium and intermetallic compounds their lattice undergoes changes accompanied by cracks (Fig. 4). The following results are possible: total cracking when the shape is lost and a finely divided phase is produced (Fig. 4a); partial cracking (2...3 cracks) with the shape remained or development of the single crack (Fig. 4b); absence of destruction signs on the surface of the sample (Fig. 4c).

In view of what was said above, one may put forward a hypothesis of the mechanism of allegedly observed neutron production in the nuclear d-d fusion reaction. Fusion neutrons can be due to the fact that strong electric fields may occur in the developing cracks [4,5] where deuterons are accelerated to the energies sufficient for the d-d fusion reaction to run [6]. To test this hypothesis, one must experimentally investigate the time correlation of crack development and neutron appearance.

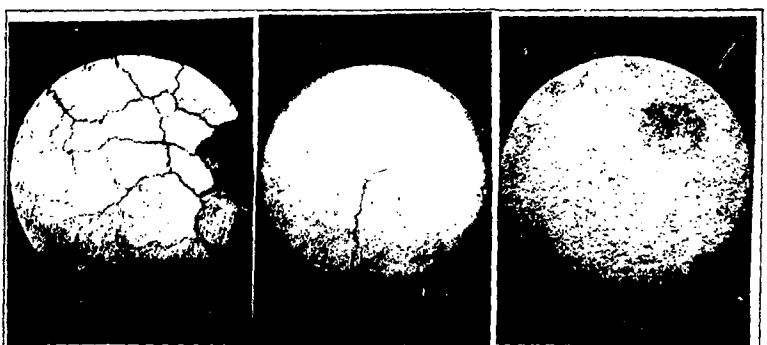

Fig.4a. Fig.4b. Fig.4c.

General view of titanium samples saturated with hydrogen.

The acoustic emission method (AE) provides a real possibility of reliably fixing the moment of cracking of metal hydride samples [7]. Fig.5 presents histograms for variation of AE parameters (N - number of detected AE events; A - signal amplitudes) typical for the cases shown above (Fig.4). It should be mentioned that high-amplitude signals, appearing after the beginning of sample saturation with hydrogen, corresponds to development of macrocracks in the sample. Consequently, using coincedence of sigrals from acoustic emission

transducers and from neutron detectors, one can unambiguously experimentally test the above hypothesis of the d-d fusion mechanism. These experiments should, of course, be performed in special laboratories with a low level of neutron background.

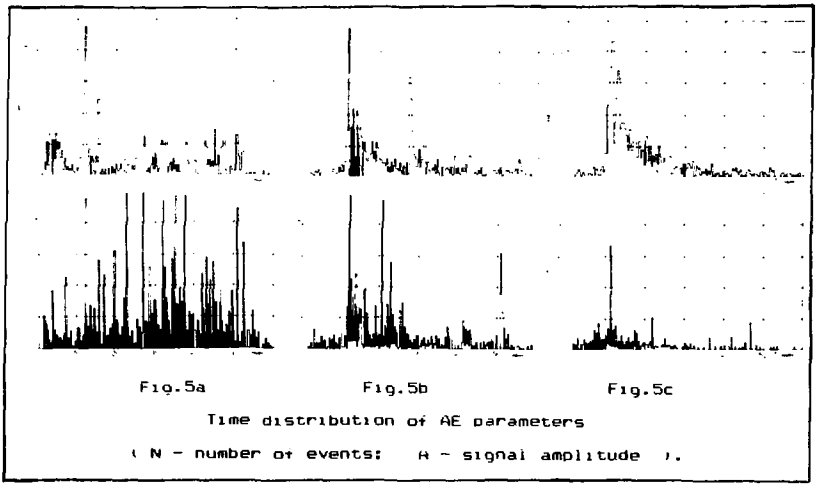

Fig.5a Fig.5b Fig.5c

Time distribution of AE parameters

(N - number of events; A - signal amplitude).

According to the above hypothesis, the intensity of the hypothetical neutron source must quantitatively be in great dependence upon the technique of the sample saturation with deuterium as well as upon many other experimental conditions. So the results obtained in different laboratories of the world will not seem surprising and controversial.

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