объединенный
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исследований
дубна

D15-89-314

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DOES COLD NUCLEAR FUSION EXIST?

Submitted to "Physics Letters A"

1989

INTRODUCTION

Recently (March-April '89) newspaper articles and scientific publications have reported the experimental observation of cold nuclear *fusion* on a *palladium cathode* in the process of heavy water D_2O electrolysis. According to Refs [1,2], it was proved by the following experimental observations:

1. A 3...4-fold excess of the counting rate of neutrons produced in the reaction

$$d + d \rightarrow {}^{3}He + n \text{ (2.45 MeV)} \qquad (1)$$

over the background level.

2. Detection of 2.2 MeV gamma-quanta by a NaJ(Tl) scintillation detector; according to the interpretation of authors [1], they resulted from interaction of neutrons from reaction (1) with water H_2O used for cooling the electrolyzer:

$$ {}^{1}H + n \rightarrow d + \gamma \text{ (2.2 MeV)}. \qquad (2)$$

3. A higher content of tritium *prodused* via the fusion channel

$$d + d \rightarrow {}^{3}H + p \qquad (3)$$

in D_2O. According to the estimation of authors [1] the tritium production rate was 10^4 atoms/s.

4. A great excess of the power released in the electrolyzer over the power applied to it.

These reports encouraged us to investigate the phenomenon.

EXPERIMENTAL SET-UP AND RESULTS

We have carried out 2 series of experiments: with heavy water electrolysis and with saturation of Pd with gaseous deuterium.

Fig.1 shows the experimental lay-out for the whole cycle of investigations. To detect neutrons, two SNM-14 boron-containing detectors were used. The electrolyzer and the neutron detectors were placed into a polyethylene retarder shielded with borated polyethylene against the external neutron radiation. The neutron detection efficiency was experimentally determined with ^{252}Cf and Pu-Be calibrated sources; it was $3.2 \cdot 10^{-3}$ pulses/neutron.

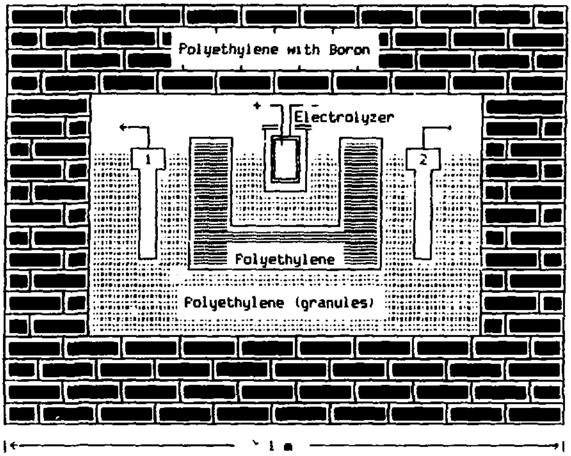

Fig.1. The view of experimental set-up (1, 2 - neutron detectors)

In the first series we carried out electrolysis of heavy water D_2O (99.80% D_2O) and a mixture $D_2O + H_2O$ (1:1). The electrolyzer is schematically shown in Fig.2. Chemically pure Pd was used as a cathode and platinum as an anode. The cathode was a hollow cylinder 30 mm in diameter, 42 mm high, with 1 mm thick walls (volume 4 cm^3). The Pd-cathode was placed between two net cylinder-shaped platinum anodes. The amount of D_2O in the electrolyzer was 160 cm^3.

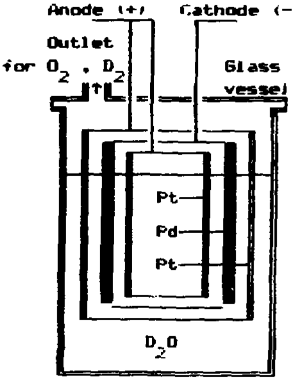

Fig.2. Electrolyzer

In different 50 h exposures the current density varied from 1 mA/cm^2 to 125 mA/cm^2. In exposures with high currents the conductance of D_2O was increased by adding Na_2CO_3 in concentrations from $5 \cdot 10^{-3}$M to $1.9 \cdot 10^{-1}$M. The maximal current was 5 A.

The obtained results are given in Table 1.

Table 1

	electrolysis is on	electrolysis is off
number of events (pulses/min)	$(5.4 \pm 0.4) \cdot 10^{-2}$	$(4.8 \pm 0.6) \cdot 10^{-2}$

From the above results it follows that if cold nuclear fusion exists, then the yield of neutrons produced in reaction (1) is less than

$$Qn \leqslant 2 \cdot 10^{-2} n/s\ cm^3\ Pd$$

at the 95% confidence level.

From the theoretical considerations it follows that the probability of reaction

$$p + d \rightarrow {}^3He + \gamma + 5.5\ MeV \qquad (4)$$

is significantly higher then that of reaction (1).

In view of this, electrolysis of the mixture D_2O(50%) + H_2O(50%) was carried out at the same electrolyzer. To identify process (4) a Ge(Li)-detector 100 cm^3 in volume was used to detect 5.5 MeV gamma-quanta. An analysis of the gamma-spectra measured during 64 hours gave no evidence of the effect. The intensity of the process was found to be less than

$$Q_\gamma \leqslant 2\cdot 10^{-3}\,\gamma/s\ cm^3\ Pd$$

at the 95% confidence level.

Besides, in the electrolysis experiments we measured the X-radiation caused by interaction of charged products of reactions (1) and (3) with Pd atoms. To detect the X-radiation, a 1 cm^3 HPGe-detector was used.

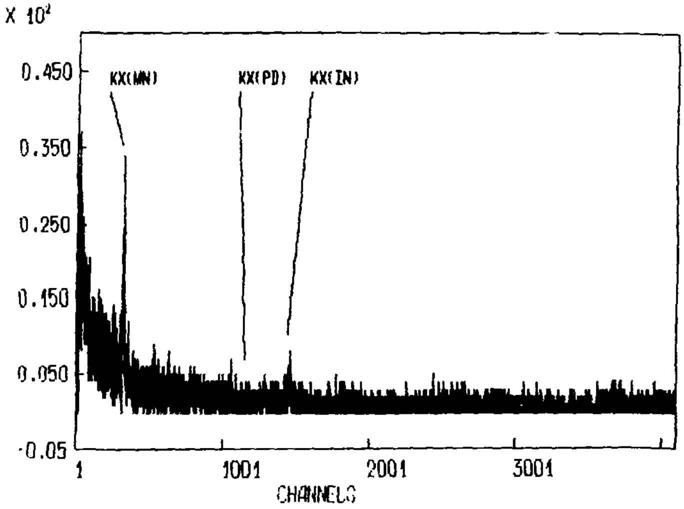

Fig.3. KX-spectrum

Fig.3 shows an X-spectrum obtained in the exposure with the electrolyzer switched on. The measured spectrum did not differ from the background one - no KX-radiation of Pd was found.

In the second series Pd was saturated with gaseous deuterium. First, a vacuum-thermal training of Pd was carried out by heating it

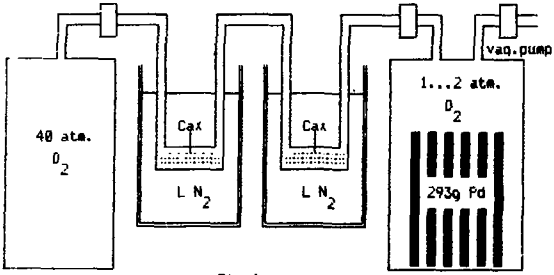

Fig.4.

Experimental set-up for Pd saturation with gaseous deuterium

to 750°C at the residual gas pressure $5\cdot10^{-3}$ mbar. Fig.4 shows the relevant experimental lay-out.

Saturation of Pd (290 g) with deuterium went on at the pressure of 1...2 atm for about 3 hours and resulted in palladium deuteride Pd $D_{0.5}$. Detection of the fusion neutrons took place both during the saturation process and after it. No difference was found in the results. Then the measurements were carried out at 250°C (in this case the deuterium pressure in the system was 20 atm).

The obtained results are given in Table 2.

Table 2

Pd mass (g)	amount of D_2 adsorbed (1 atm)	ratio n_d/n_{Pd}	neutron counting rate (10^{-2} pulses/min)	
			Pd + d	Pd
293 (20°C)	30	0.5	10 ± 2	10 ± 2
293 (250°C)	30	0.5	38 ± 4 *	34 ± 6 *

* Background conditions are changed.

As known, the basic experiments were carried out with heavy water electrolysis, i.e. in a system with electric current. A possible effect of the current taken into account, an "equivalent" experiment was carried out with gaseous deuterium. A current up to 9 A was applied to palladium (130 g) saturated with deuterium and placed in the deuterium atmosphere.

The obtained results are given in Table 3.

Table 2

Pd mass	current	neutron counting rate (10^{-2} pulses/min)	
(g)	(A)	with current	without current
130	4...9	7 ± 2	9 ± 2

From Tables 2 and 3 it follows that the neutron yield is less than 10^{-2} n/s cm^3 Pd at the 95% confidence level.

On the basis of the obtained values of Q_n and Q_γ one can estimate the rates of nuclear reactions (1) and (4) per deuteron and proton, respectively:

$$\lambda_f^{dd} \leqslant 6\cdot 10^{-25}\ s^{-1}, \quad \lambda_f^{pd} \leqslant 1.2\cdot 10^{-25}\ s^{-1} \quad \text{in experiments with electrolysis}$$

$$\lambda_f^{dd} \leqslant 3\cdot 10^{-25}\ s^{-1} \quad \text{in experiments with gaseous deuterium.}$$

DISCUSSION

The results obtained allow the conclusion that both in the experiments with electrolysis of D_2O, $D_2O + H_2O$ and in the experiments with gaseous deuterium the neutron yield in the process of d-d fusion and the gamma-quanta yield in the process of p-d fusion do not exceed $2.0\cdot 10^{-2}$ n/s cm^3 Pd and $2\cdot 10^{-3}$ γ/s cm^3 Pd respectively (at the 95% confidence level). With an effect like this, a detailed consideration of all possible background sources is necessary. Besides the evident background sources, such as cosmic radiation, operating nuclear-physics machines (accelerators, reactors) we shall touch upon some non-trivial situations. For example, the heavy water itself used in experiment is a neutron source due to the effect of gamma-quanta with energy over 2.23 MeV. Besides various kinds of technical contamination, natural radioactive isotopes, which present in building materials, can be a source of these quanta. Our quantitative estamination of this background was based on the table data and on the results of the background gamma-radiation measurement in the laboratory. In our laboratory the intensity of the ^{228}Th γ-line (E_γ= 2.614 MeV) in the background spectrum is 3 γ/s for 160 cm^3 of D_2O in the electrolyzer. This gamma-radiation intensity corresponds to the photoneutron yield of $5\cdot10^{-5}$ n/s. As seen, if one takes into account possible large fluctuations of the natural radionuclide content in building materials, the above estimations confirm the necessity of correct determination of the background.

There is another possible source of the neutron background: the (α, n)-type reactions on carbon and oxygen initiated by α-particles emitted by emanations and their decay products that are present in the air.

According to the estimations, under our conditions the neutron background is 10^{-5} n/s, the concentration of natural radionuclides in the air being 10^{-13} Ku/l.

In Ref.[1] the channel of reaction (3) was identified by accumulation of tritium in the electrolyte. In this case lithium salts must not be used as an electrolyte added to water to increase conductance. Cosmic neutrons initiate the tritium-producing (n,α) reaction on ^6Li nuclei. Besides, old lithium salts may contain noticeable amounts of tritium accumulated during the storage time. Regular calibration of neutron detectors by means of neutron sources speeds up tritium production. If these facts are ignored, the results can be significantly distorted.

All said above allows to make the following conclusion. If cold nuclear fusion really occurs under the conditions existed during our investigations, its probability, nevertheless, is extremely small and can hardly be a power source in the near future.

Are there probably some experimental "secrets" of cold nuclear fusion that are known only to the authors of Refs.[1,2] and affect the fusion efficiency? Many laboratories of the world are now busy with revealing these "secrets". And yet, irrespective of the result, the experimenters must give a correct upper limit of the probability of the cold nuclear fusion process (if it really occurs), its value being determined by the present experimental possibilities. This is a serious independent problem whose solution requires much time and special conditions.

Finally, the authors express their gratitude to Prof. Ts.Vylov, Director of the Laboratory of Nuclear Problems in JINR, for his support and constant interest in the work, to V.B.Belyaev, S.M.Korenchenko, B.S.Neganov and A.N.Perevezentsev for useful discussions.

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Received by Publishing Department
on May 5, 1989.

Бруданин В.Б. и др. Д15-89-314

Существует ли холодный ядерный синтез?

Приводятся результаты исследований холодного ядерного синтеза на палладии как в процессе электролиза тяжелой воды D_2O и смеси $D_2O + H_2O$ (1:1), так и при насыщении его дейтерием из газовой фазы. Исследование возможности существования данного явления производилось путем регистрации нейтронов и γ-квантов из реакций: $d+d \to {}^3He+n+3,27$ МэВ, $p+d \to {}^3He+\gamma+5,5$ МэВ. Кроме этого идентификация указанных реакций осуществлялась путем измерения характеристического рентгеновского излучения палладия, возбуждаемого заряженными продуктами ^3He, p, t. Получены граничные оценки интенсивностей гипотетических источников нейтронов и γ-квантов на 95% уровне достоверности: $Q_n \leq 2\cdot10^{-2}$ n/с·см^3 Pd, $Q_\gamma \leq 2\cdot10^{-3}\gamma$/с·см^3 Pd.

Работа выполнена в Лаборатории ядерных проблем ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1989

Перевод М.И.Потапова

Brudanin V.B. et al. D15-89-314

Does Cold Nuclear Fusion Exist?

The results of investigation of cold nuclear fusion on palladium are given both for electrolysis of heavy water D_2O and mixture $D_2O + H_2O$ (1:1) and for palladium saturation with gaseous deuterium. The possibility of existance of this phenomenon was examined by detection of neutrons and gamma-quanta from reactions: $d + d \to {}^3He + n + 3.27$ MeV, $p + d \to {}^3He + \gamma + 5.5$ MeV. Besides, these reactions were identified by measuring the characteristic X-radiation of palladium due to effect of charged products ^3He, p, t. The upper limits of the intensities of hypothetical sources of neutrons and gamma-quanta at the 95% confidence level were obtained to be $Q_n \leq 2\cdot10^{-2}$ n/s.cm^3 Pd, $Q_\gamma \leq 2\cdot10^{-3}$ γ/s.cm^3 Pd.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.

Preprint of the Joint Institute for Nuclear Research. Dubna 1989

12 коп.

Макет Т.Е.Попеко.

Подписано в печать 16.05.89.
Формат 60х90/16. Офсетная печать. Уч.-изд.листов 0,78.
Тираж 200. **Заказ** 42025.

**Издательский отдел Объединенного института ядерных исследований.
Дубна Московской области.**