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The Nuclear Fusion for the Reactions $^2H(d,n)^3He$, $^2H(d,\gamma)^4He$ at Low Deuterons Energy and «Cold» Nuclear Fusion.

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Summary. — The measurements of (d + d)-fusion on palladium target saturated with gaseous deuterium were taken at the energy of incident deuterons from 6 keV to 20 keV. The results are in good agreement with the known data about (d + d) cross-sections, extrapolated to the low-energy region. The possible «cold» nuclear fusion contribution to (d + d) cross-sections at low energy were not observed.

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The papers [1, 2] report that the cold nuclear fusion has been experimentally observed on the palladium cathode through heavy water electrolysis with neutrons detection from reaction

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

This reaction is supposed to be observed without electrolysis [3] through titanium saturation with heavy hydrogen at high pressure (up to 50 bar) and low temperature (~ 77 K).

If in the saturated with gaseous deuterium titanium or palladium target the probability for (dd)-fusion is really increasing when feeding deuterium from outside, the singularities are likely to appear in the energy dependence of reaction (1) at low energies (about a few keV) of incident deuterons.

It is reported in [1,2] that the neutrons yield from the reaction (1) is many orders of magnitude ($\sim 10^{-8}$) less than it is expected to be from the observable heat release. This could be explained by the fact that the relative probability of the alternative reaction

$$d+d \rightarrow {}^3H\ (1.01\,MeV)+p(3.02\,MeV) \tag{2}$$

increases under experimental conditions. This is also true even for strongly suppressed reaction due to the littleness of electromagnetic interaction and conditions of isotopic invariance and symmetry [4] of reaction

(3) $$\mathrm{d}+\mathrm{d}\rightarrow{}^4\mathrm{He}+\gamma\ (23.8\,\mathrm{MeV}).$$

The present paper covers the measurements of energy dependence of reactions (1), (3) on the palladium target saturated with heavy hydrogen at deuterons energy less than 20 keV where now there are no experimental data.

Figure 1 shows a schematic drawing of the apparatus. The pulsed deuterons beam ($_1\mathrm{d}^+\sim 95\%$ and $_2\mathrm{d}^+\sim 5\%$) with energy ranging from 6 to 20 keV, pulsed current from 1 to 6 mA, repetition rate of 25 Hz and pulse duration of 140 μs, irradiates the palladium thin-wall tubes target with an excess pressure of gaseous deuterium inside. Immediately adjacent to the target chamber the neutron is located which comprises 5 counters of 3 cm diameter and 32 cm length, filled with ^{3}He up to 3 atm and put into polyethylene block. The total neutrons detection efficiency was determined with a standard Pu-Be—source and equalled $1.3\cdot 10^{-2}$. The experimental neutrons lifetime in the detector was equal to $\sim 10\,\mu$s.

Just behind a neutron detector a scintillation γ one with a NaJ(Tl) crystal is located. Its diameter and height are 15 cm and the calculated total detection efficiency of γ-rays in the energy region $(10\div 30)$ MeV is about $1.07\cdot 10^{-4}$.

The energy spectrum of neutrons detector and γ-one was detected by the 1024-channel analyzers strobbed by accelerator pulses. The background was measured simultaneously in the intervals between accelerator pulses and proved to be $5\cdot 10^{-5}$ n/pulse for neutron detector.

The obtained counting rates for neutrons and γ-rays were normalized to accelerator beam current and time of measurement. Then after taking into account the background and making the same corrections for detection efficiency, they were normalized on the cross-section σ (d, d, n) in the region of 18.3 keV, which were obtained by extrapolating the known experimental data above 50 keV. Figures 2, 3 show a curve of energy dependence of σ (d, d, n) in the region below 200 keV. The experimental points are taken from [5-7].

The data obtained are in good agreement (fig. 3) with the given dependence of σ (d, d, n) on E_d. Experimental accuracy (systematic + statistic errors) varies from 3% for $E_\mathrm{d} = 18.3$ keV to $\sim 13\%$ for $E_\mathrm{d} = 6.8$ keV.

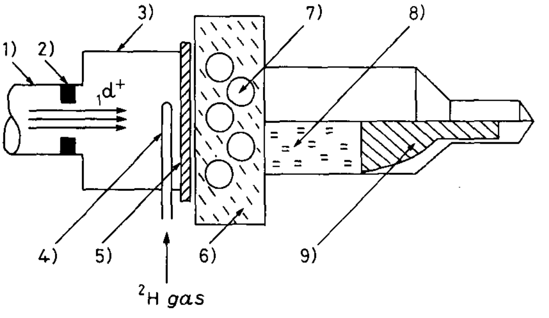

Fig. 1. – Layout of the experimental set-up: 1) acceleration tube, 2) diaphragms, 3) target chamber, 4) target saturated with deuterium, 5) window of acrylic plastic, 6) polyethylene moderator, 7) neutron counters filled with ^{2}He, 8) Na-J(Tl) - scintillation crystal of 15 cm diameter and 15 cm length, 9) photomultiplier.

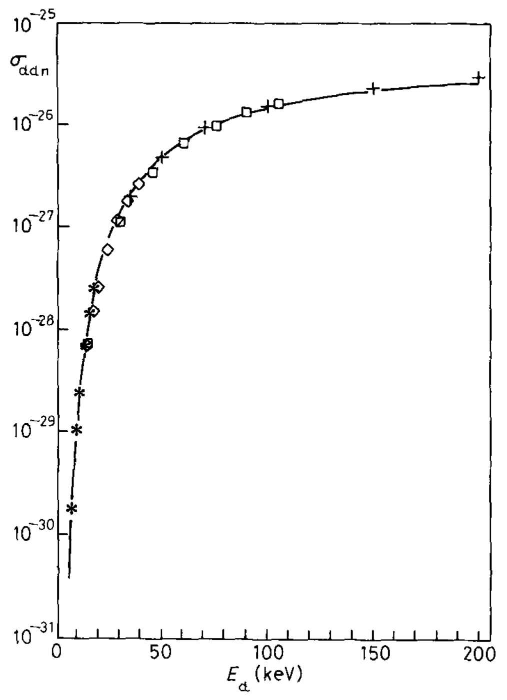

Fig. 2.

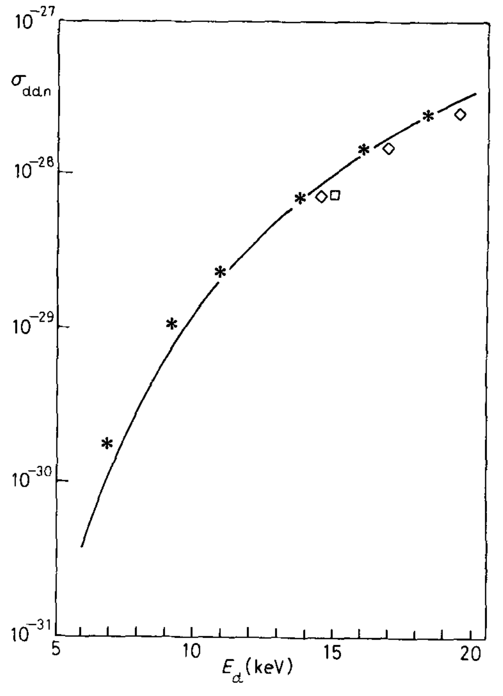

Fig. 3.

Fig. 2. – Cross-section ^{2}H (d, n) ^{3}H in the energy region lower 200 keV: ◇ date of [5], □ date of [6], + date of [7], * date of the present paper.

Fig. 3. – Cross-section ^{2}H (d, n) ^{3}H in the energy region lower 20 keV: ◇ date of [5], □ date of [6], * date of the present paper.

It should be noted that no corrections were made taking into account that

a) a range of beam deuterons in a Pd-target decreases with deuterons energy decreasing,

b) nature of dd-interaction slightly changes due to ionization losses in a Pd-lattice in comparison with measurements on gaseous deuterium targets.

As estimated, in the very low-energy point the maximum correction may lead toward increasing of the obtained value by $1.5 \div 1.7$ times. This can be considered as an evidence for the fact that while energy is decreasing σ (d, dn) decreases not so rapidly as follows from Gamov's formula with adjustment parameters, obtained from the experimental data for higher energies.

From the results obtained it follows that, for example, at $E_d = 6$ keV a dd-fusion rate per one deuteron is $10^8 \div 10^9$ times less than for electrolysis [1, 2] and interaction of deuterium gas with metallic palladium [3]. A rate of alternative nuclear reaction (3) within the whole deuterons energy region is less than $2 \cdot 10^{-39}\,\mathrm{s}^{-1}$ at the 95% c.l.

To estimate the reaction rate (1) through interaction of deuterium gas with metallic palladium, saturated with deuterium, we made the same measurements without beam of accelerator. The neutron background was measured in the absence of palladium target and its value proved to be close to that of the intensity of cosmic-rays neutron component. It was equal to (0.365 ± 0.008) n/s. A mean counting rate of neutrons from the saturated palladium target was about $(5 \pm 9) \cdot 10^{-3}$ n/s·g, which corresponds to a fusion nuclear reaction rate (1) per one deuteron $\leqslant 7 \cdot 10^{-24}$ s^{-1} at the 95% c.l.

In conclusion it should be mentioned that we did not find any peculiarity in the (ddn)-fusion reaction in the Pd-target saturated with deuterium at low energies ($\sim (6 \div 20)$ keV) which are connected with a «cold nuclear fusion» revealed in [1-3].

The measurements without deuteron beam showed that a «cold fusion» probability is likely to be considerably lower than that reported in [1-3] and a reliable observation is practically impossible at a natural level of neutron background in a laboratory.

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