THE EXPERIMENTAL INVESTIGATION OF MUON CATALYZED dd AND pd FUSION

D. V. Balin, V. N. Baturin, Yu. A. Chestnov, Yu. A. Grigoriev,
V. S. Dubogray, A. I. Ilyin, P. A. Kapinos, S. M. Kozlov,
E. M. Maev, A. A. Markov, G. E. Petrov, L. B. Petrov,
V. I. Poromov, G. G. Semenchuk, Yu. V. Smirenin, V. A. Trofimov,
A. A. Vasilyev, A. A. Vorobyov, An. A. Vorobyov, N. I. Voropaev

In 1988—1989, we continued the investigation of d—μ—d catalyzed fusion in pure deuterium and in hydrogen-deuterium mixtures. Evaluation of the d—μ—d temperature dependence was completed on the basis of the data taken from an experiment with the cryogenic ionization chamber constructed in 1987 /1/. The chamber was filled with pure deuterium up to 90 atm, and operated as a target and as a detector of the incoming muons and charged fusion products. An electronic temperature control system stabilized the temperature of the chamber with a precision of ± 0.2 K. The experiment was performed at temperatures in the interval of 52—293 K. The results are shown on figures 1 and 2 and are described below.

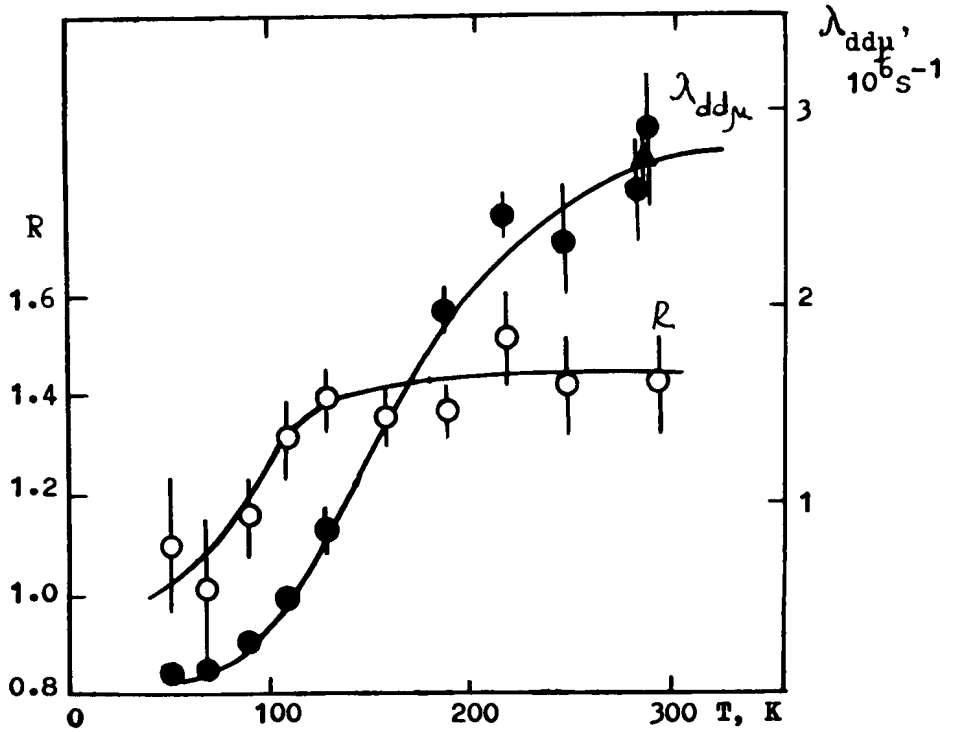

Fig. 1. Right scale. Temperature dependence of ddμ-mesomolecule formation rate. Theoretical curve was drawn under conditions: $|\varepsilon_{11}|=1.965$ eV — binding energy of ddμ-molecules in J=1, v=1 state, $\lambda_f=0.39\times$ $\times 10^9 s^{-1}$ — dd-fusion rate in ddμ-molecules, $\lambda_{nr}=0.48\ 10^5 s^{-1}$ — nonresonant ddμ-molecules formation rate. All experimental values were normalized to liquid hydrogen density. Left scale. Temperature dependence of branching ratio of dd-fusion channels, $R=Y(^3He+n)\ /\ Y(^3H+p)$

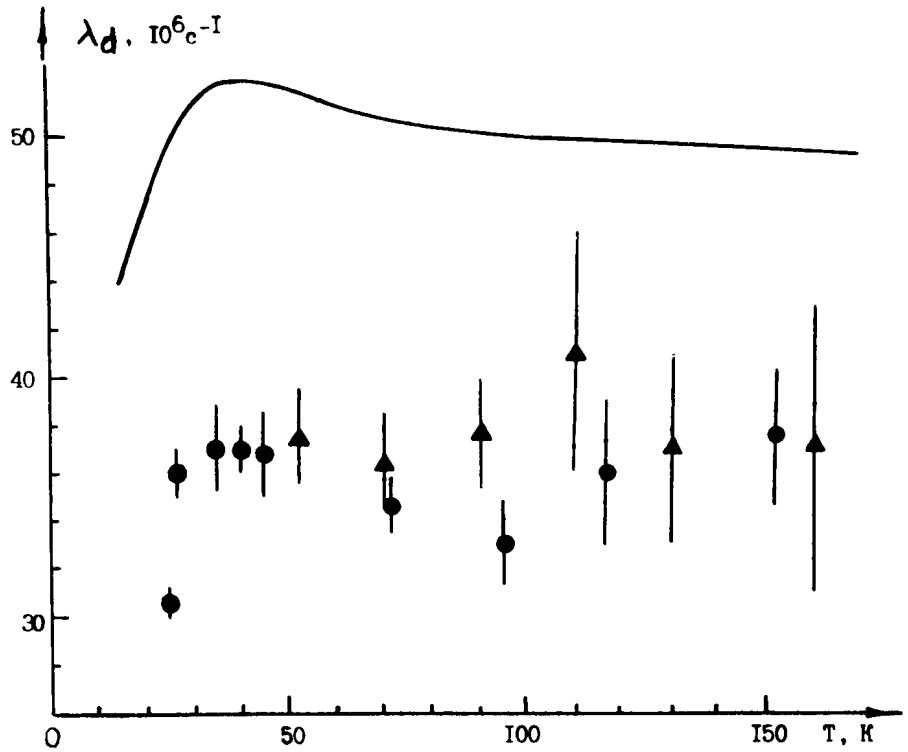

Fig. 2. Temperature dependence of spin-flip process in dμ-atoms. Theoretical curve (solid curve) — /2/: ▲ — present paper, ● —ref. /4/

1. The ddμ-molecule formation rates were determined at various temperatures. These rates refer to the stationary regime with an equilibrium population of F=1/2 and 3/2 states of the dμ atoms, which was reached in our case in 250 ns after their formation. Hence we had selected for fitting the events where the time intervals between muon stop and the first fusion were from 0.8 to 6 μs. The results were compared with the theoretical dependence $\lambda_{dd\mu}(T)$ /2/ which takes into account the hyperfine states of dμ-atoms: $\lambda_{dd\mu}=p_1\lambda_{1/2}+p_2\lambda_{3/2}$, where p_1 and p_2 are the equilibrium populations of the states F=1/2 and 3/2. There is good agreement here with the theoretical calculations. This comparison makes it possible to check the value of the loosely bound level of ddμ molecule (ε=—1.965 eV with an accuracy of about 0.001 eV).

2. We have found previously /3/ a violation of the isotopic symmetry in the d—μ—d fusion at T= =300 K:

$$R=Y(^3He+n)\ /\ Y(t+p)=1.39\pm0.04.$$

In this experiment we see that this ratio approaches R=1.0 with the decrease of temperature, when the non-resonant mechanism of ddμ-molecule formation becomes dominant (fig. 1).

3. The spin flip rate of dμ atoms in pure deuterium due to reaction $d\mu(3/2)+d\rightarrow d\mu(1/2)+d$ has been derived, its mean value has been found to be $(37.3\pm1.5)\cdot10^6\ s^{-1}$ in the temperature range of 50—150 K. This is in good agreement with the only available data /4/, obtained with the neutron detection method. But these experimental results sufficiently differ from the theoretical one: $\lambda_d=50\times\times10^6 s^{-1}$ /2/ (fig. 2).

The study of d—μ—d catalysis has been performed in hydrogen-deuterium mixtures at various deuterium concentrations in equilibrium (H_2+D_2+HD) and non-equilibrium (H_2+D_2) mixtures. In particular, we could determine the p—μ—d molecule formation rate:

$$\lambda_{pd\mu}=(3.5\pm0.5)\cdot10^6 s^{-1}$$

in a non-equilibrium mixture at deuterium concentration C_d=20% and 30%,

$$\lambda_{pd\mu}=(2.3\pm0.5)\cdot10^6 s^{-1}$$

in an equilibrium mixture at C_d=20%. These values are slightly lower than those in other experiments, this requires further investigation.

REFERENCES

1. *Balin D. V. et al.* Muon Cat. Fusion, 2, 1988. 241.
2. *Menshikov L. I., Ponomarev L. I., Strizh T. A., Faifman M. P.* ZHETF 92, 1987. 1173.
3. *Balin D. V. et al.* Phys. Lett. 141 B, 1984. 173.
4. *Breunlich W. H. et al.* Ann. Rev. Nucl. Sci., 39, 1989. 311.