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THE INVESTIGATION OF THE DEPENDENCE OF THE PARAMETERS OF MUON CATALYZED FUSION ON THE PROTIUM CONCENTRATION IN TRIPLE **H/D/T** MIXTURE AT HIGH TEMPERATURE AND DENSITY

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1 Introduction

The muon catalyzed (MC) fusion is an interesting and unique process having neutron yield of nuclear fusion reactions dependent on the macroscopic parameters of a medium (temperature, density, medium content). MC is characterized by the originality of physical processes and so the investigation of MC itself represents the independent scientific interest. The investigation of MC processes serves the solution of fundamental three body problem with coulomb interaction with relativistic corrections.

The present work is the prolongation of a wide experimental program of thorough study of the muon catalyzed processes. In the scope of the program the experimental run was performed in 1999y with the aim to measure the "effective" parameters (cycling rate λ_c, neutron yield Y_n, muon loss w) of muon catalyzed processes in triple H/D/T mixture of hydrogen isotopes. The dependencies of the "effective" parameters of muon catalyzed processes on the protium concentration in triple mixture of hydrogen isotopes at temperature 300 K was investigated. It is worth mentioning that at present experiment the density of D/T fraction in all exposures was fixed and was equal to $\simeq 0.43$ of that of liquid hydrogen density ($1\ LHD = 4.25 \cdot 10^{22} nuclei/cm^3$).

In previous work of our group dedicated to the muon catalyzed processes in triple gaseous mixture of hydrogen isotopes [1] the temperature dependence of cycling rate at constant density of triple H/D/T mixture was investigated. The aim of the current experiment was to explore the dependence of the "effective" parameters of muon catalyzed processes with respect to protium concentration at temperature 300 K.

It is worth mentioning that the muon catalyzed processes in triple mixture of hydrogen isotopes were not studied at high temperatures till our measurements. Nevertheless in triple mixtures the new channel of $dt\mu$-molecule formation on HD molecules is appeared which rate is not measured by far. The study of this channel plays a great role in the theory.

2 The experimental setup and the experimental conditions

The experimental setup used in performing the investigation is described in the reference [1]. The Tritium High Pressure Target [2] with the working volume 16.5 cm^3 was the central part of the installation. The gas handling was provided by the Gas Mix Preparation System [3]. The detectors of the installation are described in [1,4]. The experimental method is analogous to that found in [5]. All of the measurements were performed at temperature 300 K. The dependence of the "effective" parameters of muon catalyzed processes on the protium concentration C_p in triple mixture was studied at fixed tritium concentration C_t in D/T fraction. Two series of measurements were performed at different tritium content ratios in D/T fraction $C_t/(C_d+C_t)$: 33%; 15%. The conditions of the exposures can be seen in the Table 1.

The duration of the exposures (getting proper statistics of the experimental events) equals $7 - 10$ h. The monitoring of the molecular composition of the mixtures was done with the aid of a chromatography. The analysis showed equilibrium (high temperature) molecular compositions for each mixture exposed to a muon beam.

Table 1: The conditions of exposures. All of the exposures were performed at temperature 300(10) K

RUN	Pressure,	Isotope concentrations, %			Density,	$C_t/(C_d + C_t)$,
	bar	C_p	C_d	C_t	LHD	%
T1	480(20)	0.3(0.1)	67.0(1.0)	32.7(1.0)	0.425(0.020)	33(1)
T2	750(20)	24.0(0.5)	49.3(1.0)	26.7(0.5)	0.588(0.030)	35(1)
T3	1430(40)	53.6(1.0)	30.9(0.5)	15.5(0.5)	0.869(0.040)	33(1)
T4	480(20)	0.4(0.1)	84.2(1.0)	15.4(0.5)	0.434(0.020)	16(1)
T5	740(20)	23.2(0.5)	64.7(1.0)	12.1(0.5)	0.583(0.030)	16(1)
T6	1430(40)	50.5(1.0)	42.0(1.0)	7.5(0.5)	0.869(0.040)	15(1)

3 Analysis

The preliminary data treatment has been done analyzing the time distributions of electrons and "all" neutrons. As a result of the data handling the values of λ_c, Y_n and w have been obtained for 6 exposures with triple H/D/T mixture. The analysis was done using "standard method" [5]. The others methods developed by our group [5] have insufficient accuracy in the case of triple mixture (i.e. at low neutron yield and high effective losses) and so we didn't use them.

The received values of λ_c include the improvement due to the neutron pile-up effect [6], resulting in the increase of neutron detection efficiency. The determination of the neutron detection efficiency (in our experiment we use neutron detectors of large volume) is properly elaborated in the work [7]. In present experiment we had the efficiency to neutrons $\simeq 22\%$.

4 Results

The process of data handling is not finished yet. In this paper we present the preliminary values of the cycling rate, the effective muon losses and the neutron yield. They are given in the Table 2 and in the Fig.1,2. The values of cycling rate are normalized on mixture density. The experimental errors of the given values of the cycling rates and the muon losses we estimate $5 - 8\%$.

The dependencies of the cycling rate of MC processes with respect to tritium concentration in D/T fraction and protium concentration in triple H/D/T mixture are shown in the Fig.1. The obtained values of the neutron yield of MC processes with respect to protium concentration in triple H/D/T mixture are shown in the Fig.2.

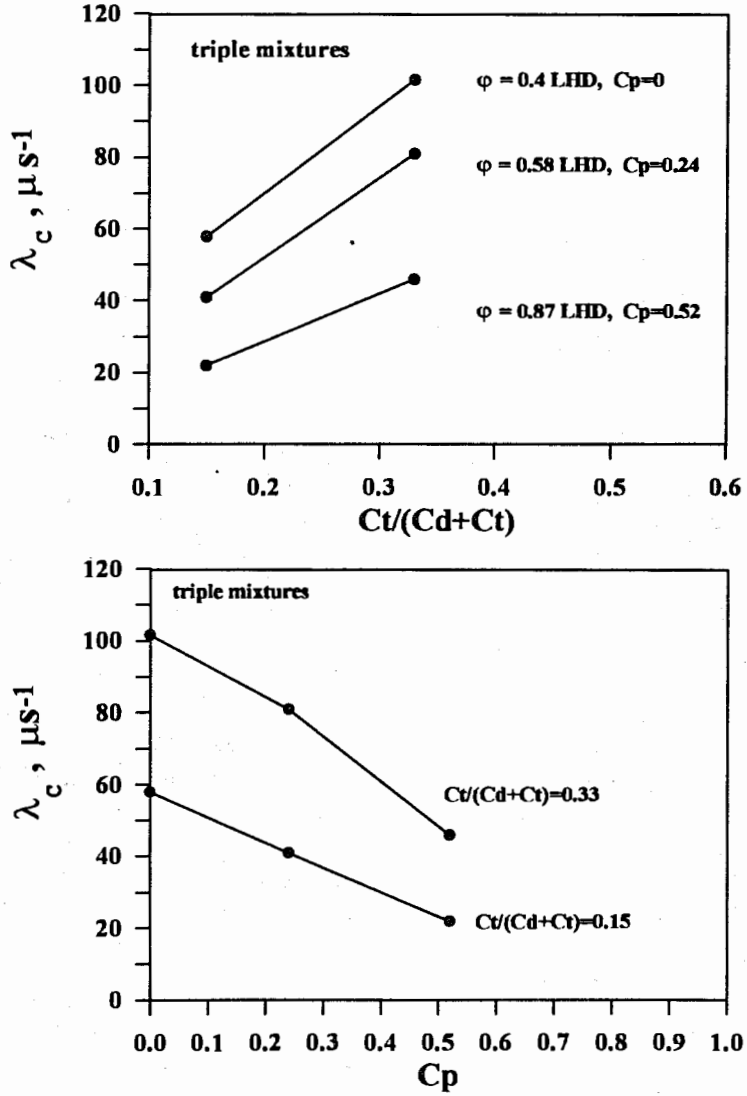

Figure 1: The dependencies of the cycling rate of MC processes measured in the experiment with triple H/D/T mixture with the respect to the tritium concentration in the D/T fraction (up) and with the respect to the protium concentration in triple H/D/T mixture (down)

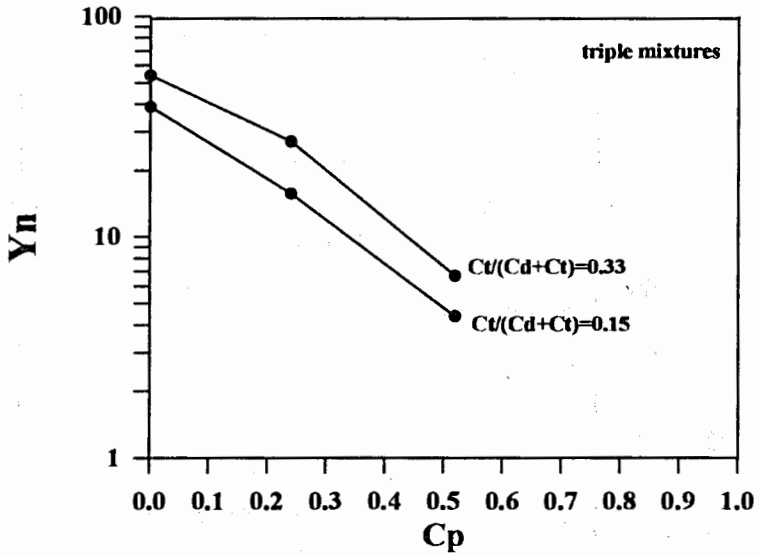

Figure 2: The obtained values of the neutron yield of MC processes with respect to protium concentration in triple H/D/T mixture at two different concentrations of tritium in D/T fraction.

Table 2: The values of the main parameters of MC processes in triple H/D/T mixture at temperature 300 K

RUN	T1	T2	T3	T4	T5	T6
$\lambda_c(\mu s^{-1})$	102(7)	81(5)	46(3)	58(4)	41(3)	22(2)
w, %	0.9(0.1)	2.7(0.3)	12.4(1.2)	0.9(0.1)	4.3(0.4)	18.6(1.9)
Y_n	54(5)	27(3)	7(1)	39(4)	16(2)	4(1)

5 Conclusion

The values of the cycling rates of MC processes obtained in the present experiment are in a good agreement with those given in our previous paper [1]. We plan to conduct an analysis of the parameters measured in the experiment choosing sound models for a cascade stage of μ-atoms and for a character of change of the $dt\mu$-molecule formation rates with the temperature.

The simple and effective methods for the determination of the parameters of MC process in triple H/D/T mixture are not elaborated till now. With this aim we plan to get the appropriate theoretical expression and to check it in the Monte-Carlo calculations of the whole kinetics of the MC process. The task of the analysis of the results for H/D/T mixture seems to be especially important for the determination of the $dt\mu$-molecule formation rate on HD molecules which is not measured till now. At the same time according to the theory this very channel is dominant in the $dt\mu$-molecule formation at high temperatures. So it seems important to conduct a new systematic investigation with triple mixture at highest available temperatures (up to 1000 K).

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References

1. V.R. Bom et al., Hyp. Int. **118**(1998)103.
2. V.V. Perevozchikov et al., Prib. Tekn. Eksp. **1**(1999)28;
V.V. Perevozchikov et al., Hyp. Int. **119**(1998)353.
3. A.A. Yukhimchuk et al., Hyp. Int. **119**(1998)341.
4. Yu.P. Averin et al., Hyp. Int. **118**(1998)121.
5. Yu.P. Averin et al., Hyp. Int. **118**(1998)111.
6. V.V. Filchenkov, Neutron detection efficiency of the multiple muon catalysis, to be published.
7. V.R. Bom and V.V. Filchenkov, Hyp. Int. **119**(1999)365.

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