INVESTIGATION OF FAST MUON TRANSFER IN $D_2 + {}^3He$ MIXTURE

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Recent theoretical and experimental studies of the muon catalyzed dt-fusion required a detailed knowledge of the fast processes that occur following the muon stop in the gas mixture, such as deexitation, thermalization, and muon exchange of mesoatoms [1,2]. Here we report on the investigation of muon fast transfer from exited states of $d\mu$-atoms to ^3He. The experiment was performed in 1990. A high pressure ionization chamber filled with D + He was used to detect the $dd\mu$-fusions as well as the muon capture reaction $^3He\mu \to t + \nu$. The gas pressure was 87 atm and helium atomic concentration $C_{He} = 11\%$. Fig.1 shows the processes going on in the $D_2 + {}^3He$ mixture when a negative muon stops. Fig.2 demonstrates an energy spectrum measured with the ionization chamber. Two different methods of analysis were applied to the data. The first one determined the population of the $d\mu$-atom ground state, W_D, via the ratio of events with double fusions to those with single fusions:

$$N_{F2}/N_{F1} = W_D \cdot \lambda_{dd\mu} \cdot (1 - \omega_{dd})/(\lambda_{dd\mu} + \lambda_d {}^3\mathrm{He} + \lambda_o) \qquad (1)$$

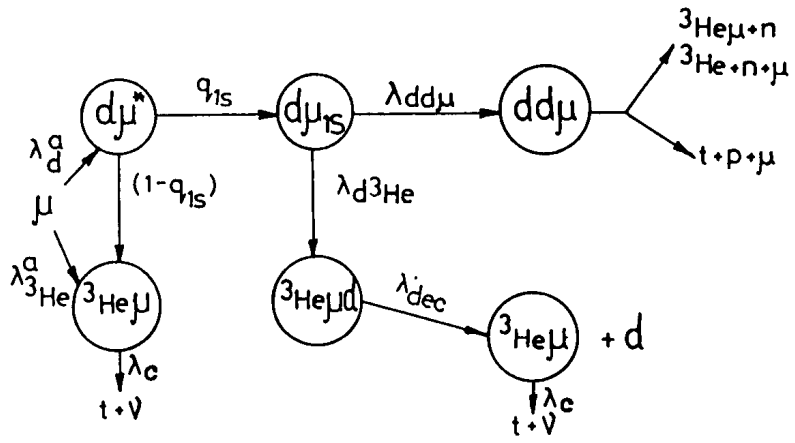

Fig.1. Scheme of processes in $D_2 + {}^3He$ mixture under effect of negative muons. λ_{dec} — velocity of decay of complex $^3He\mu d$ ($\approx 10^{11}\ c^{-1}$)

where $\lambda_{dd\mu}$ is the $dd\mu$ molecule formation rate, $\lambda_d{}^3\mathrm{He}$ is the rate of muon transfer from the ground state of a $d\mu$ atom to ^{3}He, ω_{dd} is the muon sticking probability in $d-\mu-d$ fusion, $\lambda_o = 0.455\ \mu s^{-1}$ is the muon free decay rate.

In the experiment $\lambda_{dd\mu} = \varphi \cdot C_d \lambda^0_{dd\mu}$ and $\lambda_d{}^3He = \varphi \cdot C_{He} \lambda^0_d{}^3He$, where φ=0.088 is the gas density in LHD units, $C_d = 0.89$ and $C_{He} = 0.11$ are the deuterium and helium atomic concentrations, respectively. The values of other parameters in (1) are know from our previous experiments: $\omega_{dd} = 0.123$ [4], $\lambda_{dd\mu} = 2.76\,\mu s^{-1}$ [5]. In this experiment the value of $\lambda_d{}^3He$ was determined with twice improved precision:

$$\lambda_d{}^3He = (1.24 \pm 0.05) \cdot 10^8\ s^{-1}.$$

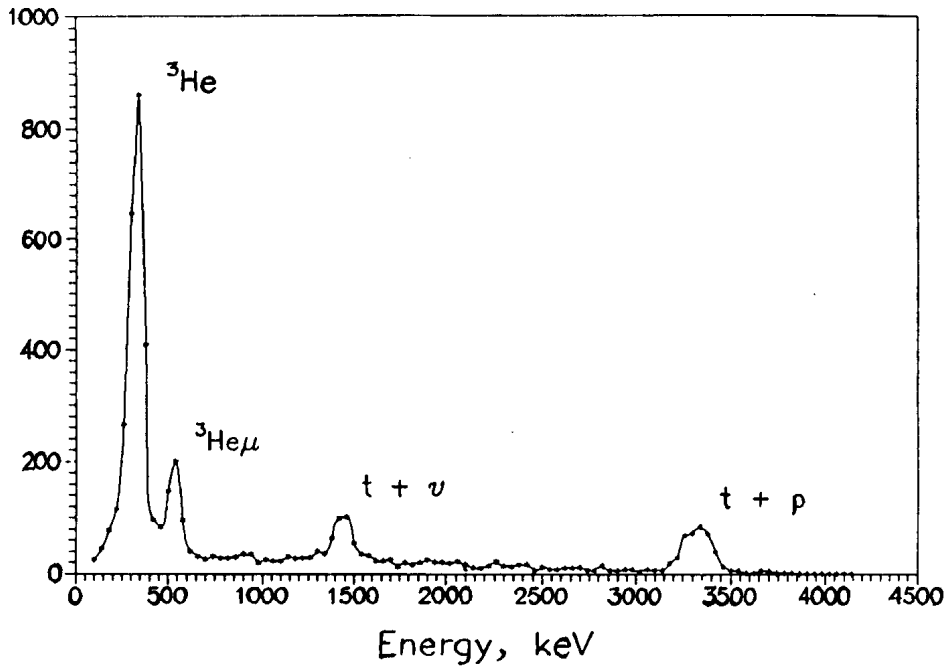

Fig.2. Energy spectrum of products of $dd\mu$ catalysis and μ-capture

The ratio (1) was found to be $N_{F2}/N_{F1} = 0.55 \pm 0.08$. The difference $1-W_D$ is the probability for the muon to be transfered to helium either via initial capture or via fast transfer from the $d\mu$-atom excited states. Unfortunately, these two channels could not be separated in this experiment. One can express W_D as

$$W_D = q_{1s}/(1 + AC)$$

Here A is the ratio of initial populations of $d\mu$ and ^{3}Heμ atoms, $A = C_{He}/C_d$, and q_{1s} is the probability for the muon captured at some high orbit of the $d\mu$ atom to reach its qround state. In fact, the described above method measures the disappearance of muons from the $dd\mu$-fusion channel. On the contrary, our second method determines directly the yield N_t of the 1.9 MeV tritons from the μ-capture reaction. This yield, normalized to the yields of $d-\mu-d$ fusion, is related to the value of W_D according to the formula:

$$\frac{N_t}{N_{F1}} = \frac{\frac{\lambda_0}{\lambda_0+\lambda_0}\left(1 - W_D + W_D \cdot \frac{\lambda_d{}^3He}{\lambda_{dd\mu}+\lambda_d{}^3He+\lambda_0}\right)}{W_D \cdot \frac{\lambda_{dd\mu}}{\left(\lambda_{dd\mu}+\lambda_d{}^3He+\lambda_0\right)}}$$

Here λ_c is the rate of muon capture leading to the $t+\nu$ channel, $\lambda_c = 1.55 \cdot 10^{-3}\,\mu s^{-1}$ [6]. Note, that the first two terms in the brackets reflect the fast muon transfer to ^{3}He while the third term describes the muon

transfer from the ground state of the $d\mu$-atom. In our experimental conditions the contributions from these two channels proved to be comparable. This second method gives the following result:

$$W_D = 0.54 \pm 0.07,$$

in consistency with the result obtained by the first method. For the average value we obtain

$$W_D = 0.54 \pm 0.05.$$

If we consider the recently calculated values of q_{1s} as a function of φ and C_{He} [7], then we get for our experimental conditions: $q_{1s} = 0.66$, and this leads to $A = 1.8$. This is very close to $A = 1.84 \pm 0.09$ obtained in the experiments with pionic atoms [8], where only the fast meson exchange from the excited states takes place. In future experiments the values A and q_{1s} can be decoupled by repeating measurements at various pressures of the deuterium-helium mixture.

References

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