Study of dμd and pμd Fusion in D_2 and H/D Mixtures

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In 1996 we have completed our new investigation of μCF in D_2 and H/D mixtures. The principal goal was to study the fusion cycles dμd and pμd with greatly improved absolute precision, to solve several open problems and to gain more insight in resonance formation of mesic molecules. For this purpose a redesigned high pressure ionization chamber from Gatchina with a sensitive volume of 15 cm^3 acted as detector of muons and charged reaction products. Using a specially developed chemical gas-treatment facility the chamber was operated with pure D_2, pure HD, and mixtures of H_2+D_2 and H_2+HD+D_2 gases at densities from 3% to 10% of liquid hydrogen. The measurements were performed at precisely stabilized temperatures from 28K to 350K. Preliminary results are reported in two previous newsletters and in literature [1]. Here we present two new results produced in 1996:

(1) In continuation of the pure HD measurements, 5% ^{3}He was added to search for the fusion reaction

μd + ^{3}He $\rightarrow$ dμ^3He $\rightarrow$ p + α + μ + 18.35 MeV

producing a 14.6 MeV proton and a 3.7 MeV α particle. This highly interesting reaction is strongly suppressed by the small lifetime of the dμ^3He molecule ($\sim 10^{-12}$ s). Theoretical expectations for the fusion rate λ_f range from 10^2 to 10^8 s^{-1}. Selecting from 10^8 muon stops only clear p-α signatures (detection efficiency ~7%), we obtained the distribution of candidate events shown in Fig. 1. In the region of interest (which is located due to recombination at reduced energy) we found no events. Thus, we can quote a new upper limit

$\lambda_f \leq 6 \cdot 10^5$ s^{-1} (90% confidence).

The background events seen in Fig. 1 were produced by muon capture reactions on nitrogen impurities.

(2) A long-standing question of the dμd cycle concerns the nature of the μd spin flip

μd(F=3/2) + d $\rightarrow$ μd(F=1/2) + d' (rate $\lambda_{3/2,1/2}$).

The usual process is inelastic scattering; however, resonant dμd formation followed by backdecay is an additional channel. It's existence was disputed, because theory never could reproduce the experimentally observed spin-flip rates. Now we succeeded with a dedicated experiment, measuring the spin-flip rate in two H/D mixtures with identical concentrations c_p=c_d=0.5, but different molecular species: (a) c_{H_2}=c_{D_2}=0.5 (non-equilibrated), (b) c_{H_2}=c_{D_2}=0.25, c_{HD}=0.5 (equilibrated). In the non-equilibrated mixture, the resonant spin-flip channel is expected to be twice enhanced. As Fig. 2 demonstrates, the time slope of dμd fusion events (which is dominated by spin flip) shows for the non-equilibrated mixture a significant slope increase by $\sim$ 10 standard deviations, proving beyond doubt the existence of the resonant spin-flip channel. We evaluated for the spin-flip rate $\lambda^{res}_{3/2,1/2} \sim (5.0 \pm 0.5) \cdot 10^6$ s^{-1}.

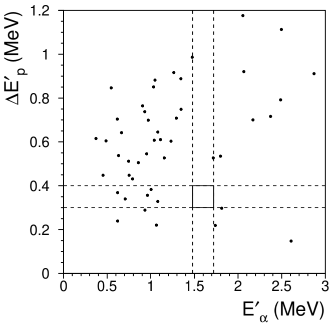

Fig. 1: Scatter plot of p-α events in the plane E'_α vs. $\Delta E_{p'}$ (energy deposit on the anode next to the μ stop).

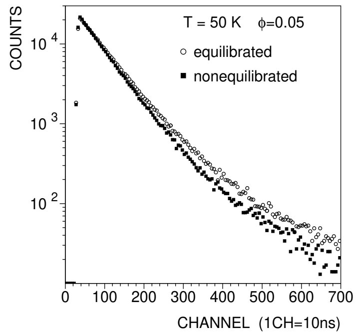

Fig. 2: Time distribution of dμd $\rightarrow$ n + ^{3}He + μ events in equilibrated and non-equilibrated H/D gas mixtures (c_p=c_d=0.5, gas density 5% of liquid).

References

[1] C. Petitjean *et al.*, Hyp. Int. **101/102** (1996) 1; G. G. Semenchuk *et al.*, ibidem, p. 547.