Muon Transfer from Hydrogen to Helium Isotopes

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Since 1994 we systematically study the muon transfer from hydrogen isotopes (p and d) to helium isotopes at low temperature [1]. This charge-exchange mechanism occurs predominantly via the formation of a metastable mesomolecule $(x\mu He)^*$ (x=p,d,t). Theory predicts [2] isotope and temperature dependences in the formation rates as well as a large isotope effect [3] for the probability of radiative decay of the $(x\mu He)^*$ molecules, where the $(p\mu^3He)^*$ decays at the lowest rate.

The transfer rates from protium and deuterium to ^3He and ^4He have already been successfully measured, preliminary results have been presented at the PANIC-96 conference [4] and the strong isotope dependence of the radiative decay rate has been observed [5,6]. Two runs were performed in 1996 aiming at two different goals, (i) the temperature dependence of the formation rate λ_{d^4He} and (ii) direct evidence for the formation of the $(p\mu^3He)^*$ molecule.

The temperature dependence was measured with binary D_2+^4He mixtures at 30, 45, 90, 120 and 300 K. The time distribution of the decay x rays from $(d\mu^4He)^*$ was measured with Ge and Si(Li) detectors. A preliminary analysis of the data shows higher transfer rates $\lambda_{d\mu^4He}$ for lower temperatures, a trend which corroborates theory.

In the binary $^1H_2$+^3He mixture, the ^3He concentration was optimized for maximum yield of the x rays from mesomolecule $[(p\mu^3He)^*]$ decay. The characteristic line at ~7 keV, obtained by a Ge detector requiring the delayed-electron condition, has been observed for the first time (Fig. 1). A preliminary analysis confirms a strong isotope effect of the branching ratio of radiative over non-radiative decay of the mesomolecule $(p\mu^3He)^*$ and $(p\mu^4He)^*$, respectively, similar to that for the $(d\mu He)^*$ molecules.

With the experiments performed over the last three years, using Ge and Si(Li) detectors, CCDs and electron counters, we have now a complete set of data which allows to determine the transfer rates from hydrogen to helium isotopes at low temperature, extract the temperature dependence of the $(d\mu^4He)^*$ molecule formation and the branching ratios of the radiative over the non-radiative decay mode.

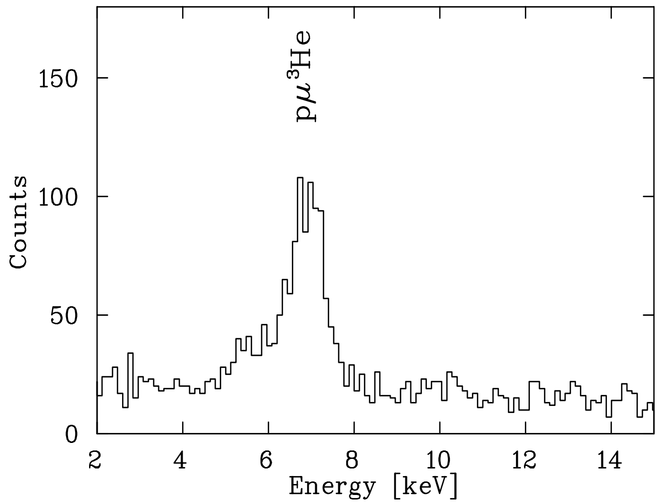

Fig. 1: Delayed energy spectrum of the decay x rays of the $(p\mu^3He)^*$ molecule, requiring the delayed electron condition. Data obtained by a Ge-detector

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References

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