Experimental confirmation of the isotope effect on the branching in mutual neutralization

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Synopsis We studied the mutual neutralization of $^{1,2}H^-$ with $^{7}Li^+$ and $^{16}O^+$ at effective collision temperatures of up to 2000 K, which corresponds to few hundred meV, and obtained branching fractions that show the theoretically predicted yet experimentally unobserved isotope effect.

Hydrogen is the most abundant element in the universe and, as such, one of the most important collision partner in many astrophysical plasma environments, such as e.g. stellar atmospheres [1]. The mutual neutralization with the hydrogen anion can be significant in the accurate determination of element abundances by non-local thermodynamical equilibrium modelling of stellar spectra. This has been demonstrated for the case of Li and Na lines [2, 3]. The low mass of hydrogen poses a technical challenge and hydrogen is often replaced with its heavier isotope, deuterium, in experiments. Hence, it is crucial to understand the isotope effect when experimental data on deuterium shall benchmark theoretical results on hydrogen, particularly at low collision energies of a few hundred meV, which correspond to the typical temperatures in stellar photospheres. As the overall isotope effect is a combination of multiple, opposing isotope effects, its sign and magnitude on absolute and partial cross sections is not easily predicted. In the case of neutralization of $^{1,2}H^-$ with Li^+, all theoretical studies at the energies of interest predict the presence of an isotope effect on both cross section and branching fractions [4, 5, 6]. Our recent experimental results of this collision system confirm the theoretically predicted presence and magnitude of the isotope effect on the branching fraction. Additionally, we pushed our instrumental limits on the reactants' mass ratio and were able to study the mutual neutralization of $^{1,2}H^-$ and O^+. Our results show a strong branching into $O(2s^2 2p^3 3p\ ^3P)$ with a kinetic energy release of 1.88 eV, which stands in contrast to previous experimental results on $^{2}H^-$ and O^+ [7].

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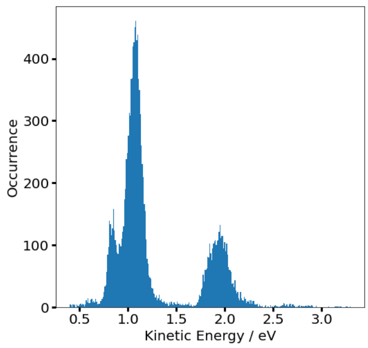

Figure 1. Distribution of the kinetic energy of products from the mutual neutralization between $^{1}H^-$ and O^+.

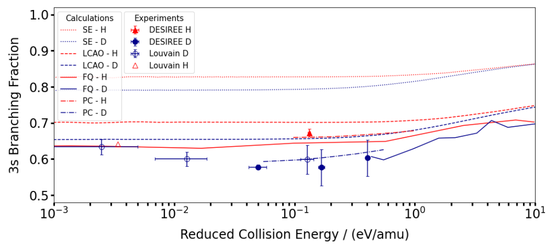

Figure 2. Experimental and theoretical branching fractions into $Li(1s^2 3s)$ for mutual neutralization of $^{1,2}H^-$ with Li^+ at different collision energies.

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