Observation of Individual Feshbach Resonance states in Metastable Neon and HD Collisions

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Our microscopic understanding of inelastic and reactive scattering mechanisms relies on the synergy between state-of-the-art quantum calculations and high-resolution experimental observations. In a previous experiment [1], using ion-electron coincidence velocity map imaging, we observed the decay dynamics of Feshbach resonance states in Penning ionization collisions between metastable neon (Ne^*, ^3P) and H_2 molecules. It was hypothesized that limiting the number of accessible partial waves could provide a clearer dynamical picture of Feshbach resonance decay, which remains largely elusive.

Here, we report the direct observation of Feshbach resonance states in Ne^*–HD collisions. The Ne^*–HD system provides an ideal platform for studying Feshbach dynamics, as it features a well-isolated p-wave ($\ell = 1$) resonance at 22 mK [2], enabling access to a regime dominated by a single partial wave. By employing a merged beam setup combined with ion-electron coincidence velocity map imaging, we performed state-resolved measurements of vibrationally excited HD^+ product ions.

For each vibrational state of HD^+, we resolved the corresponding rotational levels. Within each rotational level, we observed distinct substructures corresponding to individual Feshbach resonance states of the triatomic Ne–HD^+ complex. Signatures of these Feshbach states appeared not only in the *inelastic scattering channel* (HD^+), but also in the *reactive channels* (NeH^+ and NeD^+), highlighting a rich interplay between inelastic and reactive processes mediated by the Feshbach complex. Such high-resolution measurements of Feshbach states offer a stringent benchmark for evaluating the accuracy of theoretical interaction potentials.

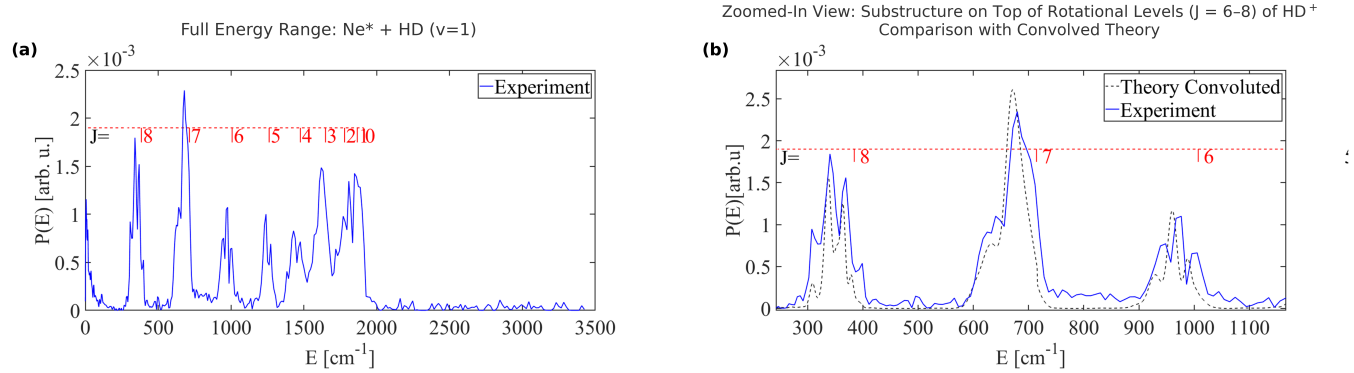

Figure 1: (a) Full kinetic energy distribution of HD^+ product ions following Ne^* + HD ($v = 1$) collisions. (b) Zoomed-in view highlighting rotational substructure and comparison with convolved theoretical predictions. The observed substructure arises from individual Feshbach resonance states of the Ne–HD^+ triatomic Feshbach complex.

References

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[2] B. Margulis, P. Paliwal, W. Skomorowski, M. Pawlak, P.S. Żuchowski, and E. Narevicius, *Phys. Rev. Research* **4**, 043042 (2022).