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Tunnelling and Quantum Reflection Resonances in Cold Elastic Collisions

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Colliding particles at low temperatures (few-Kelvin to milli-Kelvin range) reveals quantum nature of interaction between any atoms or molecules. At these temperatures, the de Broglie wavelength of the collisional system becomes comparable to the effective range of the interaction and the collisions are dominated by a few partial waves. Quantum effects such as shape resonances become observable at this regime and lead to sharp increase in collision cross section. These resonance states can be formed by two different mechanisms. Sharp, long lived states arise due to tunneling through a potential barrier whereas quantum reflection leads to a formation of short-lived resonances located above a potential barrier. In this work, we report the first experimental identification of these two mechanisms.

We use merged beam method [1] in combination with velocity map imaging technique [2] to probe the dynamics of He^*-D_2 collisions in the range 1.0 to 50.0 K. In our studies, we are able to distinguish between the two mechanisms by comparing the elastic and Penning ionization cross sections (see Fig. 1a). Our results show resonances at 2.0, 4.0 and 8.0 K in the elastic cross section whereas only the 2.0 K resonance is visible in the Penning ionization spectra. Shape resonances appear as sharp peaks in both processes whereas quantum reflection resonances only appear in the elastic cross section since the probability of finding particles at short separation, where ionization takes place, is small (see Fig 1b).

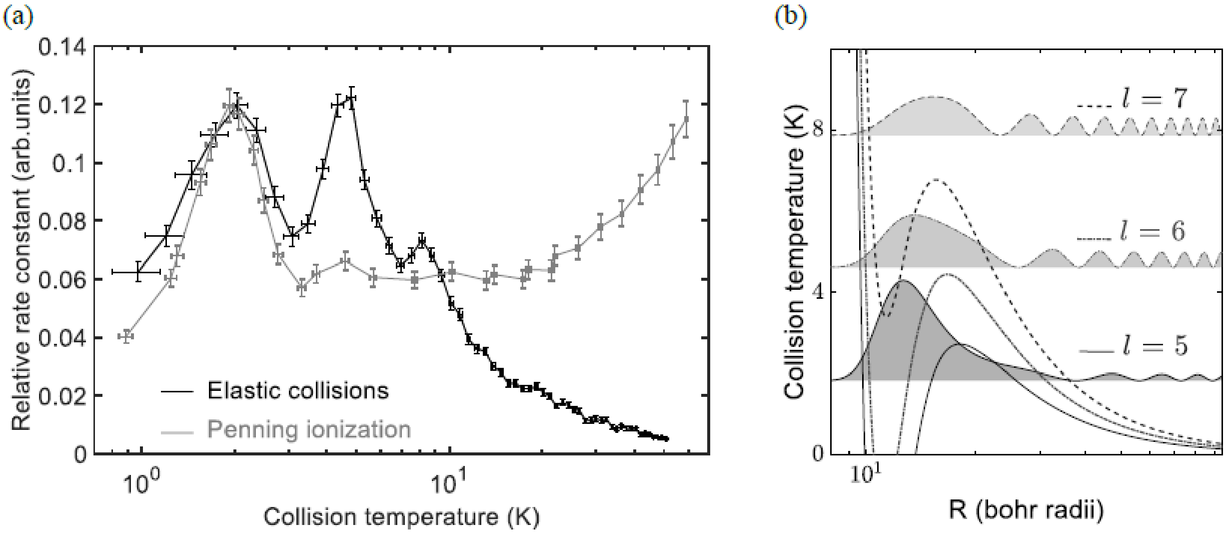

Fig. 1 (a) Relative rate constant of He^*-D_2 elastic collisions with collision energy (black), and Penning ionization process for the same system (gray) [3]. (b) The partial wave $\ell = 5$ corresponds to the resonance at 2.0 K (below the barrier); the partial waves $\ell = 6$ and $\ell = 7$ corresponds to the resonances at 4.0 and 8.0 K (above barrier resonances).

References

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[3] E. Lavert-Ofir, Y. Shagam, A. B. Henson, S. Gersten, J. Klos, P. S. Zuchowski, J. Narevicius and E. Narevicius, Nat. Chem. **6**, 332, (2014)

Hörsaal G **14:00 Uhr** **15.11.2019**