Toward a coherent ultracold chemistry: controlling ultracold collisions of NaLi molecules

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Ultracold NaLi molecules represent a fascinating frontier in the study of quantum chemistry and physics. These molecules, cooled to temperatures near absolute zero, exhibit behavior that transcends classical understanding, allowing us to explore the quantum mechanical nature of matter. With their distinctive blend of sodium (Na) and lithium (Li) atoms, ultracold NaLi molecules serve as an ideal platform for probing the interactions and dynamics at ultralow temperatures. Among the myriad ultracold molecules, NaLi stands out due to its unique characteristics. It exhibits a notably small van der Waals radius, leading to diminished cross sections for inelastic collisions despite its high reactivity. Achieving control over chemical reactions at the quantum level through external fields remains a key ambition in modern chemistry. This ambition fuels the ongoing search for Feshbach resonances within molecular frameworks. Nonetheless, the existence of such resonances in many systems may be hampered by the brief lifetimes of collisional complexes or a crowded state density, making it difficult to identify distinct resonances. To date, the observation of molecule-molecule resonances has been limited, with a singular detection in collisions involving triplet NaLi molecules. When it comes to atom-molecule interactions, resonances have been identified solely in NaLi + Na and NaK + K collisions. In this presentation, I will delve into our investigation of Feshbach resonances encountered with NaLi. We uncovered a complex array of 25 resonances during NaLi + Na collisions, decipherable through cutting-edge quantum-chemical calculations. These findings are associated with collisional complexes measuring 30 to 40 Bohr radii, emerging from the interplay of spin-rotation and spin-spin couplings, alongside anisotropic atom-molecule interactions. Our studies on the inelastic collisions involving NaLi molecules present a puzzle, suggesting that even highly reactive molecules lacking a reaction barrier may form stable, long-lived collisional complexes.