

ABSTRACT

This thesis examines the spectroscopic fingerprints of HHe_n^+ ($n = 2 - 6$) and $\text{CH}_3^+ - \text{He}_n$ ($n = 1 - 2$). The rotation-vibrational spectra are recorded for HHe_n^+ with a narrow-bandwidth (≈ 10 MHz) quantum cascade laser (QCL) in the infrared (IR) region from $1284 - 1355 \text{ cm}^{-1}$ and for $\text{CH}_3^+ - \text{He}_n$ with a continuous-wave optical parametric oscillator (cw-OPO) from $3094 - 3139 \text{ cm}^{-1}$. Additionally, high-resolution pure rotational transitions of the vibrational ground state of $\text{CH}_3^+ - \text{He}$ are measured from $60 - 415$ GHz. All experiments are carried out at cryogenic temperatures (4 K) using the 22-pole ion trap apparatus COLTRAP in combination with action spectroscopic methods.

HHe_2^+ is investigated by using laser-induced inhibition of complex growth (LIICG) as it is relatively strongly bound ($\approx 0.55 \text{ eV} \approx 4400 \text{ cm}^{-1}$). In contrast, all other aforementioned species are weakly bound complexes ($\approx 50 \text{ meV} \approx 400 \text{ cm}^{-1}$) and thus are examined with the IR predissociation (IRPD) technique. These complexes are of high interest for molecular physics because of their floppy nature. This is especially seen in the rotational spectrum of $\text{CH}_3^+ - \text{He}$, measured with rotational-predissociation double resonance. The observed splitting of the $K = 1$ levels in the order of 1 MHz is unexpected for symmetric top rotors. To explain this phenomenon, an asymmetric top Hamiltonian is compared to a symmetric top Hamiltonian, where $\text{CH}_3^+ - \text{He}$ is treated as a perturbed complex including Coriolis interaction between the involved angular momenta.

For future examinations, a procedure is established to determine state-specific transition dipole moments and kinetic ion temperatures by simple power broadening measurements on the exemplary case of $\text{CH}_3^+ - \text{He}$. Beyond, the design of a potential calcium source for producing CaH^+ is discussed in order to outline a possible spectroscopy of CaH^+ and therefore other metal hydrides.