Vibrational sympathetic cooling of $BaCl^+$ by Ca atoms: theoretical study

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The internal structure of molecules offers a host of scientific and technological opportunities, including the manipulation of quantum information, critical insight into quantum chemistry, and improved tests of the Standard Model. To utilize this potential of molecules typically requires the preparation of molecular samples at very low temperatures, where only a single quantum state is occupied. Unfortunately, experiments attempting to reach these temperatures by buffer gas cooling have found that though the molecular motion and rotation are quickly cooled to the cryogenic temperature [Hutzler-2012,Hansen-2014], the molecular vibration relaxes at impractically long timescales [Campbell-2008]. Here, we theoretically explain the recently observed exception to this rule: efficient vibrational cooling of $BaCl^+$ by a laser-cooled Ca buffer gas [Rellergert-2013]. We perform intense close-coupling calculations that agree with the experimental result, and use both quantum defect theory and a statistical capture model to provide an intuitive understanding of the system. This result establishes that, in contrast to the commonly held opinion, there exists a large class of systems that exhibit efficient vibrational cooling and therefore supports a new route to realize the long-sought opportunities offered by molecular structure.

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