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Experiments with Ultracold KRb and Rb_2 Molecules[1]

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Ultracold molecules are of interest for a number of applications including ultracold chemistry, novel quantum degenerate systems, precision spectroscopy, and quantum computation. Photoassociation (PA) of ultracold atoms is a useful means of producing various diatomic molecular species at sub-mK temperatures. Heteronuclear systems have garnered particular attention because of their permanent electric dipole moments. We use PA to form both KRb and Rb_2, typically in high vibrational levels of either the singlet ground state ($X\ ^1\Sigma^+$) or lowest-lying triplet state ($a\ ^3\Sigma^+$). In KRb, a novel depletion spectroscopy is used to detect the molecules with both vibrational (v) and rotational (J) resolution. Monitoring the population of a specific X-state vibrational level v'' with pulsed two-photon ionization, we observe depletion when a cw laser drives a bound-bound transition from (v'', J'') to an excited rovibrational level. This high-resolution spectroscopy is helping to guide Raman schemes to transfer ultracold molecules from high-v'' levels, produced by PA, to the absolute ground state, which is stable against inelastic collisions. We also use this depletion spectroscopy to precisely measure the ground-state dissociation energy of KRb. In Rb_2, we observe the effects of resonant coupling between excited 0_u^+ states on ground-state molecule formation. We photoassociate to 0_u^+ levels below the $5S + 5P_{1/2}$ limit and state-selectively detect the resulting ground-state molecules by two-photon ionization. In the absence of resonant coupling between the two 0_u^+ potentials (converging to the $5S + 5P_{1/2}$ and $5S + 5P_{3/2}$ limits), the excited molecules would spontaneously decay overwhelmingly to the highest v'' levels, bound by < 1 cm^{-1}. The effect of resonant coupling is to provide selected 0_u^+ wavefunctions with increased short-range amplitude, which enhances their decay to more deeply bound levels. Progress towards optical trapping and collisional studies of Rb_2 will also be reported.

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