Using Precision Feshbach Resonance Spectroscopy to Determine Cesium Ground State Interaction Parameters

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Ultracold ground state collisions of cesium atoms are important for precision experiments, atomic clocks, and attempts to achieve Bose-Einstein condensation. These collision properties are determined by the complex Cs_2 molecular energy structure near the dissociation limit, which has been the subject of a large number of experimental [1] and theoretical [2] studies. However, these studies have not as yet allowed the determination of this energy structure, and therefore the crucial interaction parameters such as the singlet and triplet scattering lengths or even their signs.

Here we present high-resolution Feshbach resonance spectroscopy as a direct method to determine the molecular structure close to the dissociation limit. Using our measured spectra and a coupled channel calculation, we extract for the first time a consistent set of long-range interaction parameters which reproduce 25 of 29 observed resonances. Our results improve the accuracy of the van der Waals interaction coefficient C_6 by more than an order of magnitude over previous measurements [3], and constitute the first unambiguous and precise determination of the singlet and triplet scattering lengths, and the indirect spin-spin interaction strength.

In Feshbach resonance spectroscopy with a cold atomic sample, molecular levels are brought into degeneracy with the scattering continuum by means of an external magnetic field and are observed through dramatic changes in the elastic and inelastic atomic collision cross-sections. We prepare 10^8 cesium atoms in a far-detuned dipole trap at a density of $5 \times 10^{12} cm^{-3}$ and a temperature below $5\mu K$. We observe Feshbach spectra for samples which are either spin-polarized up to 95% in a single magnetic sublevel, or prepared in various combinations of magnetic sublevels. Inelastic resonances are observed directly as a density-dependent trap loss, while changes in the elastic collision cross section are detected sensitively through a variation in the thermalization-induced evaporative loss from a shallow trap. These resonances are observed at fields up to 230 G, and their positions are measured with an absolute accuracy of 30mG.

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