Abstract

In this thesis, we present the construction of an experimental apparatus enabling the cooling of ^{39}K, ^{40}K, ^{41}K, and ^{133}Cs atoms, as well as their mixtures, to temperatures in the range of 5−20 µK. The key components of the setup are discussed, including the vacuum system, laser systems, and magnetic field coils.

Cooling in the apparatus is realized using several laser-cooling techniques: magneto-optical trapping, compression, sub-Doppler gray molasses cooling, and trapping in either a magnetic trap or an optical dipole trap.

The developed cooling procedures were successfully applied to all of the above isotopes, achieving efficiencies comparable to, and in some cases exceeding, the best results reported worldwide. A particularly notable achievement is the cooling of the fermionic isotope ^{40}K. To the best of our knowledge, this represents the first demonstration of sub-Doppler cooling and magnetic trapping of ^{40}K in a single-chamber vacuum system without the use of isotopically enriched dispensers.

The high efficiency of the implemented procedures also enabled the production of a cold ^{39}K-^{133}Cs mixture in an optical dipole trap and the performance of Feshbach spectroscopy on this system. Although this mixture had previously been realized and investigated by H. C. Nägerl's group in Innsbruck, the results presented here reveal a number of previously unexplored aspects, including several spectroscopic resonances observed for the first time.

In addition, we report the first realization of ^{39}K-^{40}K and ^{41}K-^{133}Cs mixtures, together with the methodology for their preparation and their observed collisional properties. For the heteronuclear mixture of two potassium isotopes, the obtained results also served as a benchmark for the efficiency and reliability of the modular laser system developed in this work.

The creation of the ^{41}K-^{133}Cs mixture constituted the main objective of this thesis, and its characterization has therefore been carried out in the greatest detail. We present measured three-body loss coefficients, compare them with those of the ^{39}K-^{133}Cs mixture, and report the first observations of Feshbach resonances in ^{41}K-^{133}Cs.

This characterization represents an important milestone toward the creation for the first time of ultracold ^{41}K-^{133}Cs molecules, whose properties appear highly promising in the context of quantum simulations.