ULTRACOLD STATES WITH DIFFERENT HELIUM ISOTOPES

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The development of new experimental techniques to diffract atomic beams from fine artificial gratings [1] allows the investigation of a new class of extremely weakly bound objects, such as helium trimers. Theoretically, there are excellent models of the interaction of two He atoms. All this, as well as the near-Efimov behavior of three-body bound states, makes a system of few He atoms extremely attractive object for detailed theoretical and computational investigation. Whereas there are many known results concerning states of $^4He_3$, the systems involving the ^3He isotope are not so well investigated. Here, we present the latest results of bound state and scattering calculations for three ^4He and ^3He atoms.

In the present work, we investigate $^4He_3$ and $^4He_2{}^3He$ systems. The binding energies of these systems are calculated. We also study the elastic scattering processes $^4He_2+He \to {}^4He_2+He$ at ultracold collision energies. Two different approaches are employed: the localized component method (LCM) and the hyperspherical adiabatic description [2].

Within the localized component method, we solve a modification of Faddeev equations that allows a reduction of the region in the configuration space where the equations must be solved numerically. We obtain a three-component vector of square integrable functions from which the Faddeev components can be recovered, allowing the wave function itself to be constructed uniquely. This approach is especially effective for the systems of a few particles with weakly bound two-body subsystems.

In the adiabatic hyperspherical description, a modified version of Smith-Whitten coordinate system [2] is used. The hyperspherical coordinates consist of one hyperradius R and five dimensionless hyperangles Ω. First, the fixed-R Schrödinger equation — adiabatic equation — is solved in order to obtain the adiabatic hyperspherical potential curves and nonadiabatic couplings. These allow us to construct coupled hyperradial equations. These coupled equations are then solved to obtain bound state energies of helium trimer or its isotope. We use the R-matrix approach in order to calculate the low-energy scattering parameter, i.e. scattering length, corresponding to the process $^4He_2+He \to {}^4He_2+He$. The same potentials and couplings can be used to calculate the bound state energies.

The two methods agree quite well for the binding energies of $^4He_3$ using HFDB3FC11 potential [3]. The adiabatic hyperspherical representation give 129.70 mK and 1.037 mK for the ground and excited states, respectively, using 30 channels. The corresponding LCM results are 129.67 mK and 1.030 mK. We note, that the hyperspherical calculations are variational, while the LCM are not. The agreement for $^4He_2{}^3He$ is not yet as good: the hyperspherical adiabatic description gives the binding energy of 8.5 mK whereas LCM description gives 14.8 mK. Comparisons for the ^3He-$^4He_2$ scattering length will also be presented

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