Recent Scattering Results for Helium Three-Atom Systems

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The exact treatment of scattering processes in the $^4He_3$ and $^3He^4He_2$ triatomic systems is numerically quite demanding. Due to the low energy of the ^{4}He dimer, very large domains with a characteristic size of hundreds of Ångstroems have to be considered. This concerns especially the scattering length for collisions of ^{4}He atoms with ^{4}He dimers. As a consequence, the accuracy achieved for this quantity in our previous calculations [1] appeared somewhat limited. To overcome this limitation, we have enlarged in the present investigation the cut-off radius $\rho_{\max}$ from 600 to 900 Å and employed much more refined grids. Our present calculations are based on the hard-core version of the Faddeev differential equations as in [1].

Unlike the trimer binding energies, the ^{4}He–$^4He_2$ scattering length is much more sensitive to the grid parameters. To investigate this sensitivity, we take increasing values of the cut-off hyperradius $\rho_{\max}$, and simultaneously increase the dimension of the grid $N = N_\theta = N_\rho$. Surely, in such an analysis we can restrict ourselves to $l_{\max} = 0$. The results obtained for the TTY potential one can find in [6]. Inspection of these results shows that, when increasing the dimension N of the grid, convergence of the ^{4}He–$^4He_2$ scattering length $\ell_{\rm sc}$ is essentially achieved, however, with different limiting values of $\ell_{\rm sc}$ for different choices of $\rho_{\max}$. This concerns, in particular, the transition from $\rho_{\max} = 600$ Å to $\rho_{\max} = 700$ Å, while the transition to 800 Å or even 900 Å has practically no effect. Bearing this in mind, we feel justified to choose $\rho_{\max} = 700$ Å when going over from $l_{\max} = 0$ to $l_{\max} = 2$ and 4. The corresponding results are presented in Table 1. There we also show our previous results [1] where, due to lack of computer facilities, we had to restrict ourselves to $\rho_{\max} = 460$ Å and $N = 605$. We see that an improvement of about 10% is achieved in the present calculations.

Table 1: The ^{4}He–$^4He_2$ scattering length $\ell_{\rm sc}$ (Å) on a grid with $N_\rho = N_\theta$=2005 and $\rho_{\max}$=700 Å.

Potential	$l_{\max}$	This work	[1]	[2]	[3]	[5]	[4]
LM2M2	0	158.2	168				
	2	122.9	134				
	4	118.7	131	126	115.4	114.25	113.1
TTY	0	158.6	168				
	2	123.2	134				
	4	118.9	131		115.8		114.5
HFD-B	0	159.6	168				
	2	128.4	138				
	4	124.7	135		121.9		120.2

Table 1 also contains the fairly recent results by Blume and Greene [2] and Roudnev [3]. The treatment of [2] is based on a combination of the Monte Carlo method and the hyperspherical adiabatic approach. The one of Ref. [3] employs the three-dimensional Faddeev differential equations in the total angular momentum representation. Our results agree rather well with these alternative calculations.

The results presented in this report have been published in [6] and [7].

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References

[1] A. K. Motovilov, W. Sandhas, S. A. Sofianos, and E. A. Kolganova, Eur. Phys. J. **D 13**, 33 (2001).

[2] D. Blume and C. H. Greene, J. Chem. Phys. **112**, 8053 (2000).

[3] V. Roudnev, Chem. Phys. Lett. **367**, 95 (2003).

[4] E. Braatem and H.-W. Hammer, Phys. Rev. A **67**, 042706 (2003).

[5] F. M. Pen'kov, JETP **97**, 536 (2003).

[6] E. A. Kolganova, A. K. Motovilov, and W. Sandhas, Phys. Rev. A **70**, 052711 (2004).

[7] W. Sandhas, E. A. Kolganova, A. K. Motovilov, and Y. K. Ho, Few-Body Syst. **34**, 137 (2004).