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Transfer ionization and double capture of helium dimers

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Synopsis We employed the COLTRIMS (cold target recoil ion momentum spectroscopy) technique to investigate the collision of alpha particles with an energy of 150 keV/u and helium dimers (He2).

Because of their small binding energy of only 90 nano electron volts helium dimers [1,2] can be considered as the most weakly bond atomic systems. Investigating them in atomic scattering experiments requires special constraints for the setup. The fact that - though the existence of helium dimers was theoretically predicted in 1928 [3] - they could be observed experimentally for first time in 1994 [4] gives an idea for these difficulties. However, following these results and also further experimental studies on this subject [2,5,6] the use of a precooled supersonic gas jet system provides good conditions for the production of helium dimers [5]: In a small region following the nozzle the density of the expanding gas is sufficiently high so that dimers can be created in three-body collisions. Having passed this region all particles have nearly the same velocity and move within a short distance (within the so called “zone of silence”) without interaction.

Compared to usual internuclear distances in molecules and also other Van-der-Waals bound clusters the distance between the two atoms in a helium dimer is huge. Theoretical calculations predict an average bond length of 52 angstroms and a maximum interatomic distance of 200 angstroms [4,7]. In this case the mutual interaction of the fluctuating dipole in one atom with the dipole induced in the other atom can not be considered as instantaneous. In fact the propagation speed of the electric dipole field is limited by the speed of light which means that also the propagation time is finite (retardation). According to theoretical studies [7] this relativistic effect should have a significant influence on the potential energy curve of the dimer and therefore on the distribution of internuclear distances. The goal of the presented measurement was to determine the interatomic distance experimentally.

The principal idea of achieving this is based on the so called reflection approximation: If the helium dimer is doubly ionized and dissociates into two ionic fragments the interatomic distance R at the instant of ionization can be determined experimentally from the kinetic energy of both fragments in the center-of-mass frame (i.e. from the kinetic energy release (KER)). The Coulomb repulsion of the ions is proportional to 1/R, thus different internuclear distances result in different KERs.

In the presented measurement transfer ionization and double capture were chosen as processes leading to double ionization of the dimer:

1.) transfer ionization:
   \[ \text{He}^+ + \text{He}_2 \rightarrow \text{He}^+ + \text{He}^+ + \text{He}^+ + e^- \]

2.) double capture.
   \[ \text{He}^+ + \text{He}_2 \rightarrow \text{He}^+ + \text{He}^+ + \text{He}^+ \]

The projectiles which we used were alpha particles with an energy of 150 keV/u. The COLTRIMS (cold target recoil ion momentum spectroscopy) technique was utilized to measure the momenta of all particles in coincidence with 4π solid-angle coverage. From the momenta of the fragments the KER was determined.

The results show several unexpected peaks in the distribution of interatomic distances which can be related to three different processes: radiative charge transfer, Interatomic Coulombic Decay [8] and a two step process. These will be presented in detail.

References
[1] A. R. Janzen et al., J. Chem. Phys. 103, 9626 (1995).
[2] R. E. Grisenti, et al., Phys. Rev. Lett. 85, 2284 (2000).
[3] J. C. Slater, Phys. Rev. 32, 349 (1928).
[4] W. Schöllkopf et al., Science 266, 1345 (1994).
[5] R. Kariotis et al. J. Chem. Phys. 121, 3044 (2004).
[6] L. W. Bruch et al., J. Chem. Phys. 117, 1544 (2002).
[7] F. Luo, et al., J. Chem. Phys. 98, 3564 (1993).
[8] L. S. Cederbaum et al., Phys. Rev. Lett. 79, 4778 (1997).

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