NEAR-THRESHOLD PHOTODETACHMENT OF HEAVY ALKALI-METAL ATOMS

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Low-energy electron scattering by alkali-metal atoms is strongly affected by a $^3P^o$ shape resonance. Its experimental observation is very difficult because of the limited energy resolution in electron scattering experiments. Photodetachment (PD) studies of corresponding negative ions might be advantageous in this regard. However, due to the dipole selection rules, only the $J = 1$ component of the $^3P^o_J$ ($J = 0, 1, 2$) triplet can be populated in PD experiments with a single photon. Moreover, since the $^1S \rightarrow ^3P$ transition is forbidden in the LS coupling scheme, the process indicative of the $^3P^o$ resonance becomes very sensitive to the spin-orbit interaction, and the role of the theory in interpretation of experimental data becomes especially important.

In the present work we calculate photodetachment of Rb^-, Cs^-, and Fr^- using the Pauli equation method. The Pauli equation is a weak relativistic limit of the exact Dirac equation which includes the spin-dependent potential V_{LS} added to the non-relativistic, spin-independent Coulomb potential V. For a Coulomb potential, V_{LS} contains a non-physical singularity $1/r^3$ at $r = 0$, and the Pauli equation approach breaks down. Various regularization functions have been suggested to remove this singularity [1]. Based on the exact analytic solution of the Dirac equation near the nucleus, we formulate boundary conditions for solving the Pauli equation for an electron interacting with an atom [1]. By integrating the Pauli equation using an effective potential V_{eff} that is adjusted to reproduce scattering phase shifts provided by exact Dirac R-matrix calculations, we calculated total PD cross sections. Our $^3P^o_1$ resonance contribution to the PD cross section of Cs^- agrees (in position and width) with recent experiments [2], after fine-tuning V_{eff}. For Rb^- and Fr^- the resonance contribution is much smaller than for Cs. We therefore also calculate angle-differential cross sections and asymmetry parameters which are much more sensitive to the resonant contribution than the total cross section.

References

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