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On the behavior of the ${}_{n_1}(K,T)^A_{n_2}$ series of doubly excited states in He-like atoms immersed in weakly coupled plasmas

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Synopsis The stability of resonant states in Helium-like atoms while under the influence of a plasma environment is studied. We analyze the variation of resonance parameters (energies and lifetimes) against the strength of the screening parameter within the Debye-Hückel model. We use a Feshbach-like projection formalism with explicitly correlated CI-wave functions to uncover the evolution of resonance parameters until they cross the upper A^{q+} (N=2) threshold, and a complex scaling method to analyze the survival of these *Feshbach* resonances across the threshold, which eventually makes them behave as *shape* resonances.

The interest in the fundamental problem of atoms immersed in plasmas stems from its potential application in atomic physics, plasma physics, solid-state physics, and astrophysics. Plasma embedded He-like atoms represent here also a benchmark to understand the physics involved. The Hamiltonian for a two-electron atom immersed into a weakly coupled plasma reads

$$\mathcal{H} = -\frac{\nabla_1^2}{2} - \frac{\nabla_2^2}{2} - \frac{Z\exp(-r_1/D)}{r_1} - \frac{Z\exp(-r_2/D)}{r_2} + \frac{\exp(-r_{12}/D)}{r_{12}}. \quad (1)$$

Here, the Debye length $D=(k_BT/4\pi e^2\rho)^{1/2}$ (a function of the plasma electron temperature T and density ρ) characterizes the interaction strength of the atomic system with the surrounding plasma. We use a Hylleraas configuration interaction (HyCI) method to compute accurate energies and wave functions, the latter consisting of antisymmetrized correlated configurations $\psi_i(\mathbf{x}_1,\mathbf{x}_2)=\mathcal{A}\{\phi(\mathbf{r}_1,\mathbf{r}_2)\chi(s_1,s_2)\}$ where the spatial part of the wave function is built in terms of correlated Slater type orbitals $\phi = r_1^{n_1}r_2^{n_2}r_{12}^{n_{12}}\mathrm{e}^{-\alpha r_1-\beta r_2}\mathcal{Y}_{L,M}(\Omega_1,\Omega_2)$. Their advantage is that all integrals required for the solution of the plasma free ($D=\infty$) as well as for finite values of D may be calculated in closed form [1, 2].

We have also implemented a Feshbach-like projection method (at variance with previous extensive work by Ho *et al* [3] that uses the stabilization method) by solving separately the resonant $\mathcal{QHQ}$ (resonance energies), the non-resonant $\mathcal{PHP}$ (continuum discretized energies) eigenvalue problems and the $\mathcal{QHP}$ couplings (from which the Auger widths are extracted). For instance, we perform a systematic study on the behavior of resonance parameters (energies, lifetimes and interelectronic angle) of the lowest series of plasma-embedded He ${}^{1,3}S^e$, ${}^{1,3}P^o$ and ${}^{1,3}D^e$ doubly excited states located below the $He^+(N=2)$ ionization threshold, as a function of the Debye characteristic length D. At variance with one-electron atoms (where *shape* resonance widths vary monotonically with the screening strength) the evolution of the Auger width with respect to screening is found to be different for each series of $(K,T)^A$ Herrick-Sinanoğlu-Lin pseudo-quantum numbers, until resonances cross the upper $He^+(2s,2p)$ thresholds, then merging into new open electronic continuum channels. The geometrical distribution of the electron pair as a function of the screening is also analyzed through the interelectronic angle for each resonance state. In addition, to shed light on the survival of Feshbach resonances (below the threshold) transforming into shape resonances (above the threshold) we also implement the complex rotation method for the problem at hand. This transformation of the resonant character across the threshold [4] may involve dramatic changes in the wave function structure and particularly in the Auger widths.

References

[1] R.J. Tweed (1972) *J. Phys. B: At. Mol. Phys.*, **5**, 810; J.C. Cardona and J.L. Sanz-Vicario (2008) *J. Phys. B: At. Mol. Opt. Phys.*, **41**, 055003

[2] J.L. Calais and P.-O. Löwdin (1962) *J. Mol. Spectrosc.*, **8**, 203

[3] S. Kar and Y.K. Ho (2005) *Chem. Phys. Lett.*, **402**, 544; (2009) *J. Phys. B: At., Mol. Opt. Phys.*, **42**, 044007

[4] S.B. Zhang, J.G. Wang and R.K. Janev (2010) *Phys. Rev. Lett.*, **104**, 023203; (2010) *Phys. Rev. A*, **81**, 032707

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