Novel mechanism for creating long-lived metastable atomic negative ions

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Synopsis A novel mechanism is proposed for creating long-lived metastable atomic negative ions in complex atoms. It exploits the orbital collapse of the 5d orbital in Gd (Z=64) into the 4f orbital of Tb (Z=65). In the region of collapse the properties of the 5d and 4f orbitals are quite sensitive to the changes in the effective potential. Consequently the collapse phenomenon impacts significantly the core-polarization interaction in the relevant atoms. The mechanism is demonstrated in Tb and Dy through the appearance of long-lived Tb^- and Dy^- anions in the Regge-pole calculated electron elastic cross sections.

The impact of orbital collapse on the inner and outer wells and the potential barrier was discussed in [1, 2], while the importance of the d orbital collapse phenomenon enhancing the influence of the core-polarization has also been demonstrated in the isoelectronic sequence of the singly ionized Yb [1].

In the region of collapse the properties of the 5d and 4f orbitals are quite sensitive to the changes in the effective potential. Consequently the collapse phenomenon impacts the core-polarization interaction significantly in the relevant atom, namely Tb. As a result, a new excited state is induced in the Tb atom. Its TCS resembles that of the ground state TCS with a dramatically sharp resonance appearing in its second R-T minimum at 1.20eV, corresponding to the Tb^- metastable negative ion formation, in excellent agreement with the measured EA [3].

The collapsed 5d orbital in Gd leads to maximum polarization in the Dy atom. Consequently, the proposed mechanism of creating long-lived metastable negative ions should be observable in both the Z=65 and Z=66 atoms through the appearance of dramatically sharp resonances in the newly generated TCSs. The characteristic TCSs for Dy in the presence of the induced long-lived metastable state (blue curve) appearing at the energy of 1.37 eV are displayed in Fig. 1. We expect the mechanism to be general and realizable in other atomic systems where orbital collapse occurs. The isoelectronic sequences of Tb and Dy are also expected to exhibit long-lived metastable anionic TCSs.

Notable from the Fig. is that the metastable could easily be mistaken for the ground state resonance. Indeed, identifying and delineating the resonance structures is essential for understanding the mechanism of electron attachment.

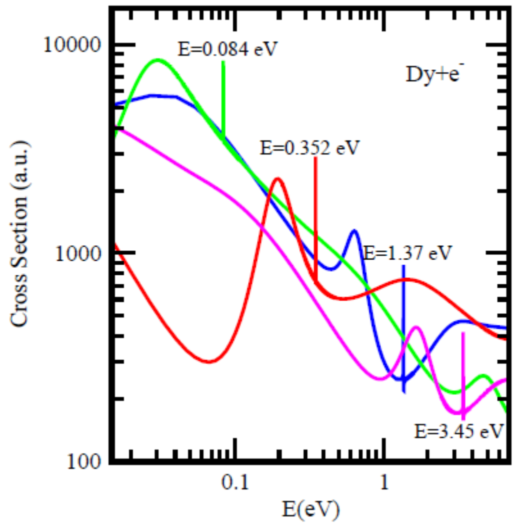

Figure 1: Total cross sections (a.u.) for electron elastic scattering from atomic Dy versus E (eV). The pink, blue, orange and green curves represent TCSs for the ground, induced metastable and first excited and second excited states, respectively. The dramatically sharp resonances correspond to Dy^- negative ions formation during the collisions.

We conclude by noting that the measured EA of Tb [3] actually corresponds to the metastable negative ion resonance Tb^- at 1.20 eV.

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References

[1] J. Migdałek and W. Siegel 2000 *Phys. Rev. A* **61** 062502
[2] J. P. Connerade and V. K. Dolmatov 1998 *J. Phys. B* **31** 3557
[3] V. T. Davis *et al* 2005 *NIMB* **241** 118
[4] Z. Felfli and A. Z. Msezane 2017 *J. Phys. B* (Submitted)

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