Periodic table of positronic atoms

V. V. Flambaum[*] [1], **C. Harabati**[*], **V. A. Dzuba**[*], **G. F. Gribakin**[*†] [2]

[*] School of Physics, The University of New South Wales, Sydney NSW 2052, Australia
[†]School of Mathematics and Physics, Queen's University, Belfast BT7 1NN, Northern Ireland, UK

Synopsis The calculation shows that more than half of the atoms in the Periodic Table bind the positron in their ground state. A number of atoms also bind positrons in excited states forming discrete spectrum and low-lying resonances.

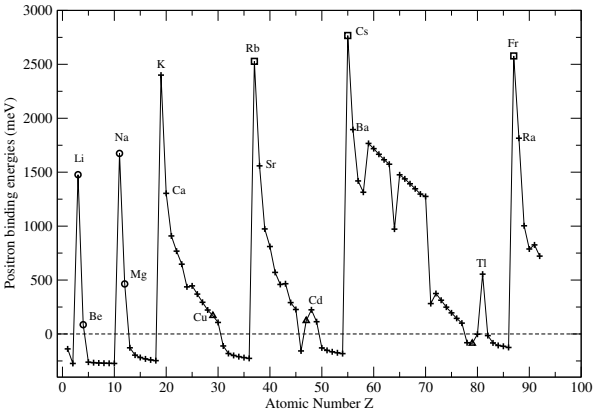

Figure 1. Recommended positron binding energies relative to the dissociation threshold e^++A. The results based on current study are shown with + sign. The ◯ shows the results of the previous best calculations based on configuration interaction (CI) or stochastic variational methods (SVM). △ shows the previous result of the relativistic method MBPT+CI for Cu, Ag, and Au in our group. The binding energies of Rb, Cs, and Fr are obtained by linear extrapolation of the values of Li, Na, and K with respect to the ion(A^+) radius, which are marked by square □

Binding of positron to an atom with several valence electrons is a challenging problem. This is mainly due to the strong electron-positron correlation effects and virtual positronium (Ps) formation [1] . In Ref. [2] we presented calculations of the positron binding energies to all atoms in the Periodic Table. The most accurate previous calculations involving Li, Na, Ag, Cu, Au, Be, Mg, Ca, Zn, Sr and Cd atoms [3, 4] have been included and used to correct our values for the binding energies of positron to other atoms. We hope that the recommended positron binding energies to all atoms in the Periodic Table stimulate the experimentalist to detect the positron-atom bound states. The ordinary Periodic Table is constructed due to the similar chemical properties of atoms with the same number of valence electrons in external subshells. We have obtained similar periodicity in the positron-atom bound states, see the figure.

For atoms with ionization potential I such that $I > 6.80$ eV, the Ps-formation channel is closed. The closest decay channel will be e^++A. On the other hand, for $I < 6.80$ eV the lowest decay channel is Ps+A^+. On the figure, the positron binding energies ε_b have been presented relative to the decay channel e^++A. The binding energies relative to different channels are related by an equation

$$\varepsilon_b = \varepsilon_{Ps} - I + 6.80 \text{ eV}, \qquad (1)$$

where ε_{Ps} is the positron binding energy relative to the channel Ps+A^+, and 6.80 eV is the binding energy of positronium (Ps). We found that more than half of the atoms in the Periodic Table bind the positron in their ground state (i.e. stable relative to both channels). A number of atoms also bind positrons in excited states forming discrete spectrum and low-lying resonances. These resonances may be used for experimental detection of positron-atom bound states via resonant annihilation or scattering [5].

References

[1] V. A. Dzuba, V. V. Flambaum, W. A. King, B.N. Miller, and O. P. Sushkov 1993 *Phys. Scr.* **T46**.

[2] C. Harabati, V. A. Dzuba, and V. V. Flambaum 2014 *Phys. Rev. A***89** 022517

[3] J. Mitroy, M. W. J. Bromley, and G. G. Ryzhikh, in *New Directions in Antimatter Chemistry and Physics*, Eds. G. M. Surko and F. A. Gianturco, (Dordrecht: Kluwer, 2001).

[4] V. A. Dzuba, V. V. Flambaum, G. F. Gribakin, and C. Harabati, 2012 *Phys. Rev. A* **86**, 032503.

[5] V. A. Dzuba, V. V. Flambaum, and G. F. Gribakin 2010 *Phys. Rev. Lett.***105** 203401

[1]E-mail: v.flambaum@unsw.edu.au
[2]E-mail: g.gribakin@qub.ac.uk