B.5.7. Bound States of Positrons with Li and Na--*Jianmin Yuan, Brett Esry, Toru Morishita and C.D. Lin*

A positron does not bind with atomic hydrogen. An electron can bind with atomic hydrogen with a binding energy of 0.75 eV. In the meanwhile, the binding energy of Li^- is 0.623 eV and that for Na^- is 0.547 eV. Since the e^- and H binding is larger than the e^- and Li binding, but e^+ and H do not form a bound state, at first sight one may expect that e^+ and Li also do not bind together. Thus when a bound e^+-Li system was first predicted by the stochastic variational method [1], it was quite a surprise to us.

To confirm that the variational calculation was indeed correct, we performed (Publication #98) the hyperspherical calculation for the "three-body" system, consisting of e^+, e^- and Li^+, where the interactions between the electron and positron with the Li^+ core are represented by model potentials. By calculating the hyperspherical adiabatic potential curves, we found that the potential curve is indeed attractive enough to support a bound state for e^++Li. The binding energy was calculated to be 58 meV, to be compared with the energy of 59 meV obtained by [1]. The binding energy for e^++Na, was calculated to be 7 meV. Interestingly, the e^+ +K was found to have no bound state.

To understand the reason why a positron cannot be bound to H or to K, but to Li and to Na, we investigated the geometry of the density distribution of the ground state for each system. For e^++H, the positron stays outside the electron cloud thus the binding has to come from the polarization potential between e^+ and H, which is too weak. In other words, the electron is bound to the proton first and then the positron is trying to attach itself to H. For e^++Li, on the other hand, the e^+ and e^- form a positronium in the ground state, which has the size of about 2 a.u. In the meanwhile the average distance between the electron and Li^+ is about 2 to 3 a.u. such that the three particles can be arranged close to an equilateral triangle. For e^++Na, the geometry is nearly the same except that Na^+ has a larger core so the shape would be closer to an isosceles triangle, with the e^+-e^- distance being the short base side. This explains the weaker binding energy for e^++Na, and why e^++K no longer forms a bound state due to the larger K^+ core.

The bound states discussed above are stable against radiative transitions but they still decay by annihilation, with lifetimes of the order of nano-seconds. It has since been shown that positrons can be bound to many atomic systems [2], but there is no experimental confirmation of these theoretical predictions to date. Since slow positrons can be accumulated in an electromagnetic trap and Li and Na atoms can be cooled and confined in a MOT trap, it is likely that such bound states can be identified in the future.

References

1. G.G. Ryzhikh and J. Mitroy, Phys. Rev. Lett. 79, 4124 (1997).
2. G.G. Ryzhikh and J. Mitroy, J. Phys. B 31, L401 (1998).