AUTO-IONIZATION OF THE $(1s2s2p)\ ^4P_{5/2}$ LEVEL IN Li AND He^-

Jerry L. Pietenpol*
Columbia University, New York, New York
(Received June 20, 1961)

The negative helium ion has been observed experimentally,[1-3] and Sweetman[4] has obtained a lower bound of 10^{-5} second for its lifetime. Arguments have been advanced[5,6] indicating that the observed metastable state is a $(1s2s2p)$ $^4P_{5/2}$ configuration. The purpose of this note is to report a theoretical estimate of the lifetime of the state for auto-ionization. The calculation has been made both for negative helium and for lithium; the result is of interest in the latter case because of the possibility of measuring the fine and hyperfine structure of the level.

The state is radiatively metastable because of the spin selection rule. Holøien and Midtdal[5] have shown by an elaborate variational calculation that this level in He^- lies below the $1s2s$ level of the helium atom, and have pointed out that the state is therefore not subject to auto-ionization in the usual way. The only available final state consistent with angular-momentum and parity conservation is then $(1s^2kf)\ ^2F_{5/2}$. The Coulomb, spin-orbit, and spin-other-orbit operators have vanishing matrix elements for the transition, but the process can proceed by the magnetic spin-spin interaction between two electrons.

If we write the spin-spin operator in the form

$$H' = -\mu_0^2(\vec{\sigma}_1 \cdot \nabla_1)(\vec{\sigma}_2 \cdot \nabla_1)(1/r_{12}),$$

the matrix element can be evaluated by a double partial integration. (It is necessary to exclude an infinitesimal sphere about the point of singularity, so that one must look for surface terms here. These terms vanish, however, for any matrix element between states of different spin.) We used antisymmetrized product wave functions, with screened hydrogenic functions for the bound electrons and a plane wave for the continuum. The effective Z's and the energy of the initial state were obtained from a variational calculation, including exchange between $2s$ and $2p$. The parameters are as follows:

For Li: initial-state $Z_{1s}=3.0$, $Z_{2s}=2.0$, $Z_{2p}=1.7$, final-state $Z_{1s}=2.69$, kinetic energy of continuum electron $E=3.95$ rydbergs.

For He^-: initial-state $Z_{1s}=2.0$, $Z_{2s}=1.0$, $Z_{2p}=0.67$, final-state $Z_{1s}=1.69$, $E=1.45$ rydbergs.

The integrations were carried out analytically. The result for the lifetime of the state is 1.6×10^{-5} sec for Li, and 1.7×10^{-3} sec for He^-. Variation of the Z parameters within reasonable limits produces a change of no more than a factor of two in the lifetime. In the very simple approximate wave functions employed, the use of a plane wave for the continuum state is justified for helium (since the centrifugal barrier effectively prevents the electron from penetrating the $1s^2$ core), but is questionable for lithium. The initial-state wave function did not include correlation between the $2s$ and $2p$ electrons; this effect would be expected to lengthen the calculated lifetimes.

The author is indebted to Professor H. M. Foley and Professor R. Novick for valuable discussions, and to Professor N. M. Kroll for suggesting the spin-spin interaction as the mechanism of the process.

---

*Quincy Ward Boese Predoctoral Fellow.

[1] J. W. Hiby, Ann. Physik 34, 473 (1939).
[2] V. M. Dukel'skii, V. V. Afrosimov, and N. V. Fedorenko, J. Exptl. Theoret. Phys. (U.S.S.R.) 30, 792 (1956) [translation: Soviet Phys.-JETP 3, 764 (1956)].
[3] P. M. Windham, P. J. Joseph, and J. A. Weinman, Phys. Rev. 109, 1193 (1958).
[4] D. R. Sweetman, Proc. Phys. Soc. (London) 76, 998 (1960).
[5] E. Holøien and J. Midtdal, Proc. Phys. Soc. (London) A68, 815 (1955).
[6] Ta-You Wu, Phil. Mag. 22, 837 (1936).