Relativistic calculations of the nuclear recoil effect in highly charged few-electron ions

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As is known, in the nonrelativistic atomic theory the one-electron nuclear recoil effect can be easily evaluated using the reduced electron mass. Full relativistic theory of the recoil effect can be formulated only within quantum electrodynamics [1-4]. However, the lowest-order relativistic recoil corrections can be calculated within the Breit approximation employing a relativistic nuclear recoil operator.

The main goal of the present work is to evaluate the nuclear recoil corrections to the energy levels of highly charged Li- and B-like ions by perturbation theory to zeroth and first orders in the parameter \(1/Z\). The calculations are restricted to the Breit approximation, where the nuclear recoil effect can be described by the following operator (see, e.g., Ref. [4]):

\[
H = \frac{1}{2M} \sum_{i,k} \left[ \vec{p}_i \cdot \vec{p}_k - \frac{\alpha Z}{r_i} \left( \vec{\alpha}_i + \frac{(\vec{\alpha}_i \cdot \vec{r}_i) \vec{r}_i}{r_i^2} \right) \cdot \vec{p}_k \right].
\]

To simplify the derivation of formal expressions of the perturbation series, we employ the quantum field formalism with the closed shells regarded as belonging to a redefined vacuum. The numerical calculations of these expressions to zeroth and first orders in \(1/Z\) are performed using the finite basis set method. Alternatively, the interelectronic-interaction corrections to the recoil effect can be evaluated employing the configuration-interaction and multiconfiguration Dirac-Fock methods [5,6], the results of our calculations are compared with related predictions of Ref. [5,6].

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References: