Relativistic many-body calculation of energies, lifetimes, hyperfine constants, multipole polarizabilities, and black-body radiation shift in $^{137}$Ba II

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Excitation energies of the $[\text{Xe}]ns_{1/2}$, $[\text{Xe}]np_j$, and $[\text{Xe}]nd_j$ ($n \leq 12$ and $[\text{Xe}]=1s^22s^22p^63s^23p^63d^{10}4s^24p^63d^{10}5s^25p^6$) in Ba II are evaluated. First-, second-, third-order, and all-order Coulomb energies and first- and second-order Coulomb-Breit energies are calculated. Electric-dipole ($6s_{1/2} - np_j$, $n = 6–26$), electric-quadrupole ($6s_{1/2} - nd_j$, $n = 5–26$), and electric-octupole ($6s_{1/2} - nf_j$, $n = 4–26$) matrix elements are calculated to obtain the ground state E1, E2, and E3 static polarizabilities. Scalar polarizabilities of the $ns_{1/2}$, $np_j$, and $nd_j$ states, and tensor polarizabilities of the $np_{3/2}$ and $nd_j$ excited states of Ba$^+$ are evaluated. All above-mentioned matrix elements are determined using all-order methods. We investigate the hyperfine structure in $^{137}$Ba II. The hyperfine A- and B-values are determined for the first the first low-lying levels up to $n = 9$. The quadratic Stark effect on hyperfine structure levels of $^{137}$Ba II ground state is investigates. The calculated shift for the $(F = 2, M = 0) \leftrightarrow (F = 1, M = 0)$ transition is $-0.2931 \text{Hz/(kV/cm)}^2$, in agreement with previous theoretical result $-0.284(3)$. These calculations provide a theoretical benchmark for comparison with experiment and theory.

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