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Calculation of francium hyperfine anomaly

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In recent years, the precision achieved in resonant ionization spectroscopy experiments coupled with advances in atomic theory has enabled new atomic physics based tests of nuclear models. The measurements of hyperfine constants and isotope shifts are highly sensitive to the changes of the nuclear charge and magnetic radii because they depend on the behavior of the electron wave function near the nucleus. The hyperfine structure splitting measurements can serve as a very useful tool for the understanding of changes in the nuclei shape in isotopic series of heavy elements. Magnetic hyperfine constants are usually assumed to be proportional to the nuclear magnetic moments. However, this is true only for the point-like nucleus. For the finite nucleus, we need to take into account both distribution of the magnetization inside the nucleus and dependence of the electron wave function on the nuclear charge radius. Together, these corrections are known as the hyperfine anomaly. In this report, we discuss how to calculate the hyperfine anomaly for many-electron atoms with the available atomic packages. All francium isotopes are unstable, it making difficult to carry out measurements of their nuclear g-factors by conventional techniques. Calculation of the hyperfine anomalies in this case can substantially improve the accuracy for nuclear g factors of francium isotopes, obtained from the ratios of the magnetic hyperfine constants.
In this work the magnetic hyperfine constants for low-lying states of neutral Fr atom are calculated within the configuration interaction (CI) method, the CI plus many-body perturbation theory (CI+MBPT) method, and the CI plus all-order (CI+AO) method. The effect of the Breit corrections and spin-polarization of the core are considered. Contribution of spin-polarization of the core significantly change the hyperfine anomaly for the $7p_{3/2}$ state.
We conclude, that for the precision measurements of g factors it is preferable to use the hyperfine constants for s and $p_{1/2}$ states, while the $p_{3/2}$ states are least useful.
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