Calculation of isotope shifts and King plot nonlinearities in Ca^+

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High-precision spectroscopy is currently in the spotlight of experimental research, particularly as a means of testing physics beyond standard model. One of the methods to detect new interactions is King plot analysis [1]. Recently, a significant King-plot nonlinearity has been discovered in Yb^+ transitions [2, 3]. In contrast, King plots in a succession of Ca^+ isotopes were found to be linear within experimental uncertainties [4]. However, if the overall measurement uncertainty reaches 1 Hz level in the future—which is realistic—King-plot linearity in Ca^+ might no longer hold. Our aim is to lay ground for an interpretation of Ca^+ King plot nonlinearity. We calculate energy-level isotope shifts of $4s$, $4p_{1/2}$, $4p_{3/2}$, $3d_{3/2}$ and $3d_{5/2}$ single-electron states of Ca^+ for isotopes A =40, 42, 44, 46, 48 using many-body perturbation theory. We include the leading first-order contributions—mass shift and field shift—as well as smaller corrections such as higher-order field shifts, quadratic mass shift, nuclear polarization contribution and the cross term between field and mass shifts. Additionally, we examine King-plot nonlinearities introduced by the higher-order isotope-shift corrections to the combinations of $3d_{3/2} \to 4s$, $3d_{5/2} \to 4s$, and $4p_{1/2} \to 4s$ transitions. Second-order mass shift and nuclear polarization correction are identified as the dominant sources of possible nonlinearity.

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[1] J. C. Berengut *et al.*, PRL **120** (2018) 091801.
[2] I. Counts *et al.*, PRL **125** (2020) 123002.
[3] J. Hur *et al.*, PRL **128** (2022) 163201.
[4] C. Solaro *et al.*, PRL **125** (2020) 123003.