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Hyperfine-induced effects on the linear polarization of the magnetic-quadrupole lines of spin-1/2 Be-like ions excited by electron impact

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The polarization of X-rays has been employed as an effective tool to study various physical effects including the hyperfine interaction. However, most studies mainly focused on the lines emitted from the strong 2p→1s transition. In fact, the 2p→2s transition is more weaker than the 2p→1s transition, and thus its hyperfine-induced effects are more pronounced. For this purpose, we have studied the linear polarization of the magnetic-quadrupole (M2) lines $1s^22s2p_{3/2}\ ^3P_2 \rightarrow 1s^22s^2\ ^1S_0$ and $1s2s^22p_{3/2}\ ^3P_2 \rightarrow 1s^22s^2\ ^1S_0$ following the electron-impact excitation of Be-like ions with nuclear spin I=1/2 by using the density-matrix theory and the relativistic distorted-wave theory [1]. To explore the effects of the hyperfine interaction, detailed calculations are performed for the polarization of the M2 lines emitted from $^AXe^{50+}$ (A = 125, 127, and 129) and $^ATl^{77+}$ (A = 187, 205, and 207) ions with different nuclear magnetic dipole moments μ_I at a series of impact electron energies. It is shown that the hyperfine interaction strongly lowers the polarization of the $1s^22s2p_{3/2}\ ^3P_2 \rightarrow {}^1S_0$ line at all considered impact energies, while its effects behave less and less prominent with increasing impact energy for the $1s2s^22p_{3/2}\ ^3P_2 \rightarrow {}^1S_0$ line. In addition, we also find that the polarization of the $1s^22s2p_{3/2}\ ^3P_2 \rightarrow {}^1S_0$ line is much more sensitive to μ_I than that of the $1s2s^22p_{3/2}\ ^3P_2 \rightarrow {}^1S_0$ line. In particular, for the $1s^22s2p_{3/2}\ ^3P_2 \rightarrow {}^1S_0$ line of spin-1/2 Xe^{50+} ions, the differences in the polarization among the isotopes are significant. These findings indicate that precise polarization measurements of M2 lines of Be-like ions are expected to be used to explore the hyperfine interaction and even the nuclear magnetic dipole moment of nonzero-spin isotopes.

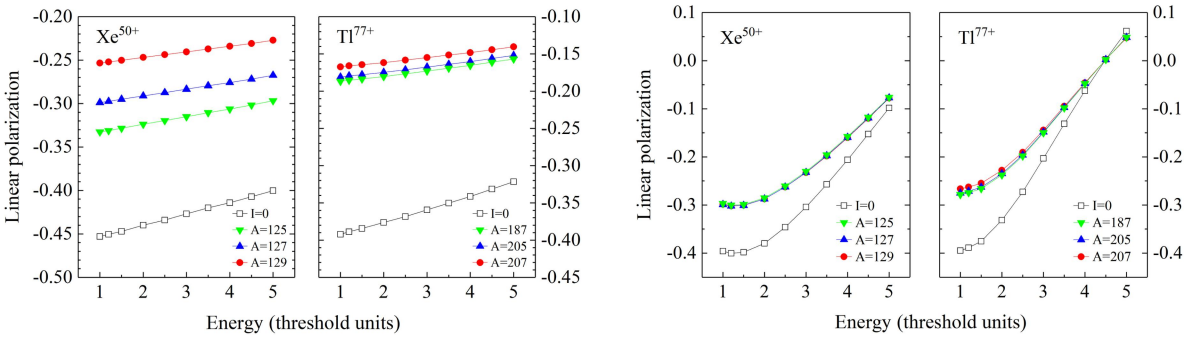

Figure1. Linear polarization of the M2 lines $1s^22s2p_{3/2}\ ^3P_2 \rightarrow {}^1S_0$ (left pane) and $1s2s^22p_{3/2}\ ^3P_2 \rightarrow {}^1S_0$ (right) emitted from zero-spin Be-like ions as well as spin-1/2 Be-like $^AXe^{50+}$ (A = 125, 127, and 129) and $^ATl^{77+}$ (A = 187, 205, and 207) ions at an angle of $\theta = 90^\circ$ relative to the quantization axis as functions of impact electron energy in units of their respective excitation threshold.

[1] Z. Q. Tian, Z. M. Tang, Y. Li, Y. Yang, Z. W. Wu, Y. M. Zou, *J. Quant. Spectrosc. Radiat. Transfer* 311, 108775 (2023).