On the effect of cascade transitions after electron-impact excitation of Zn by spin-polarized electrons

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Synopsis We investigate the possible effect of cascade transitions from the (4s5p)3P0,1,2 states to the (4s5s)3S1 state of Zn. Our calculations suggest that the excitation cross sections and the polarization of the cascade radiation cannot explain the serious controversy between two existing experimental datasets below the cascade threshold and raise additional questions regarding the measurements at higher energies.

In a recent paper, Clayburn and Gay [1] reported their measurements of the angle-integrated linear polarization $P_2$ in the $(4s5s)3S_1 \rightarrow (4s4p)3P_0$ transition in Zn after impact excitation by a transversally spin-polarized electron beam. With the light detector placed at right angle to the incident beam direction along the direction of the electron polarization $P_e$, $P_1$ and $P_2$ are the linear polarizations for $(0^\circ, 90^\circ)$ and $(45^\circ, 135^\circ)$ transmission, respectively, while $P_3$ is the circular polarization. $P_1$ is independent of $P_e$, while $P_2$ and $P_3$ are proportional to $P_e$.

Clayburn and Gay noted significant disagreement between their $P_2/P_e \approx 0$ data and the $P_2/P_e \approx -10\%$ measurements of Pravica et al. [2] in the cascade-free region of incident electron energies below $\approx 7.6$ eV, while relatively good agreement was found above that threshold. According to Bartschat and Blum [3], one would expect $P_3 \approx 0$, $P_2/P_e \approx 0$, and $P_3/P_e \approx -1$ in the cascade-free region. Above the cascade threshold, significant deviations are only possible for sufficiently large excitation cross sections and strong polarization of the cascade radiation.

We performed fully relativistic convergent close-coupling (RCCC-94) and semi-relativistic B-spline $R$-matrix (BP-BSR-43) calculations with 94 and 43 states, respectively. As seen in Fig. 1, accounting for cascades indeed reduces the magnitude of the circular polarization, in agreement with the measurements. However, we find $P_3/P_e \approx 0$ at all incident energies considered. Our results agree with general theory [3] but are in strong contradiction with both experimental datasets above the cascade threshold.

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Figure 1. $P_1$, $P_2/P_e$, and $P_3/P_e$ for the $(4s5p)3P_1 \rightarrow (4s5s)3S_1$ cascade transition (top), as well as $P_3$ (center) and $P_2$ (bottom) for $(4s5s)3S_1 \rightarrow (4s4p)3P_0$ in Zn. CG-2017 [1]; Prav-2011 [2].

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References
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