The influence of double-exchange and Heisenberg interaction on the magnetization processes in rare-earth tetraborides

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We present a complex model for a description of magnetization processes in rare-earth tetraborides. The model is based on the coexistence of two subsystems, and namely, the spin subsystem described by the XXZ Heisenberg model and the electronic subsystem described by the generalized Hubbard model on the Shastry-Sutherland lattice. Moreover, both subsystems are coupled locally by the anisotropic double-exchange interaction, which besides the usual J_z term of the Ising type takes into account also the J_{xy} term representing the spin-flip processes. The model is solved numerically using the Lanczos/truncated Lanczos method and the special attention is paid on a description of individual and combined effects of the double-exchange interaction J_{xy} and the Heisenberg J'_{xy} interaction on the stabilization of magnetization plateaus with fractional magnetization. We have found that the J_{xy} and J'_{xy} interaction terms exhibit fully opposite effects on the stability of the main 1/2 and 1/3 plateau phases. While the J_{xy} interaction destroys the 1/2 plateau and stabilizes the 1/3 plateau, the $J'xy$ interaction stabilizes the 1/2 plateau and destroys the 1/3 plateau. Combined effects of both terms lead to several different scenarios, but for physically the most interesting case, J_{xy} and J'_{xy} small (corresponding to the real situation in rare earth tetraborides) we observe a significant suppression of the 1/3 plateau and the stabilization of 1/2 plateau in accordance with experimental measurements in these materials.