Single crystal growth and characterization of the complex cage compound $Gd_3Co_4Ge_{13}$

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The intermetallic family of ternary compounds with the general formula $R_3T_4X_{13}$ (R = rare earth, T = transition metal, X = Ge, Sn) crystallizes in a complex cubic structure with an atomic arrangement that categorizes them as cage compounds. The effects related to their complex cage-like structure make this family an object of broad interest for various physical phenomena and applications. Within a rare earth series of compounds, the Gd-based member is typically a reference magnetic compound. In this context, the main goals of this work are to produce single crystals of $Gd_3Co_4Ge_{13}$ and perform basic characterizations beginning with a study of their crystal structures, including structural transitions that occur at low temperatures. Single crystals were grown by the self-flux method using excess Ge and had their structural characteristics probed through X-ray diffraction at room temperature using Mo Kα1 radiation. Rietveld refinement analysis established that our samples crystallize in the cubic space group Pm-3n with lattice parameter a=8.781Å. However, some weak reflections could not be indexed in this space group, which is suggestive of a superlattice distortion as already reported for others compounds of the series. For thermodynamic characterizations, a Quantum Design Physical Properties Measurement System (PPMS) was used to measure specific heat, which revealed a lambda-like anomaly at 8.0K suggesting a phase transition which was confirmed as antiferromagnetic by the magnetization measurements in a QUantum Design Magnetic Property Measurement System (MPMS). From the Curie-Weiss linear fits, we have extracted an effective moment μ_{eff}= 8.4μ_B for Gd^{3+} and Curie-Weiss temperature θ_{CW}=-13 K. Using $Lu_3Co_4Ge_{13}$as non-magnetic compound, the calculated magnetic entropy shows that completely recovers its entropy at 12K. Acknowledgements: We thank the support of FAPESP (#2017/10581-1, #2017/20989-8, #2021/03640-7), CNPq, CEM/UFABC and GPOMS/Unicamp.