Orbital Switching in a Kagome Lattice

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The physics of Heisenberg spins on the kagome lattice has been extensively studied for the last few decades. Due to strong frustration, it is believed that there is an opportunity to discover an unprecedented ground state that lies between conventional long-range order and a singlet-based state with a large spin gap. We study the ground-state magnetic properties of the spin-1/2 quasi-kagome compound volborthite $Cu_3V_2O_7(OH)_2{\cdot}2H_2O$.[1,2] Magnetic susceptibility reveals a fingerprint for a spin gap below a temperature corresponding to the quarter of the nearest-neighbor antiferromagnetic interaction J and finally reaches a large finite value as temperature approaches zero, indicating a certain gapless state. Instead of a conventional long-range order, however, a peculiar state appears below 1 K, which is characterized by dense low-energy excitations such as found in a metal, extremely slow spin fluctuations, and spin-wave like excitations, as evidenced by heat capacity and V NMR experiments.[3-6]

One of difficulties in the previous experiments is that all of them have been carried out using polycrystalline samples. Recently, we were successful in preparing a single crystal of volborthite with half mm size and have observed alternative ground state completely different from that of the previous polycrystalline samples. The difference must come from the presence of a structural transition at around room temperature, which is not observed in polycrystalline samples but in single crystals. Interestingly, at the transition, one of two Cu sites changes its d orbital from d_{z2} at high temperature to $d_{x2\text{-}y2}$ at low temperature, which is not orbital order but orbital switching. Associated changes in Js or symmetry lowering may suppress frustration and lead the compound to a complete long-range order. This fact illustrates the fragility of frustration realized in a delicate balance of magnetic interactions in the kagome lattice.

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