Investigation of the magnetic states in new spin-tetrahedral $K_4Cu_4Cl_{10}O$†

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Geometrically frustrated magnets, in which localized magnetic moments on triangular, kagome or pyrochlore lattices interact through competing exchange interactions, have recently attracted a lot of interest owing to the diversity in the exotic ground states that they display. Various reports on unconventional magnetic properties provide a challenging and testing ground for theoretical models. Among the several systems reported, the S-1/2 quantum systems have received particular attention.

While much of the kagome and pyrochlore antiferromagnets, which are much more complicated to theoretically model than the triangular lattice, are still not well understood, the isolated spin tetrahedral system with weak inter-tetrahedral couplings has recently attracted attention because it can directly demonstrate the interplay of inter-tetrahedral couplings with the built-in tetrahedral frustration. Of more wide interest, they also represent an interesting class of magnets consisting of weakly coupled magnetic clusters. Till date, the $Cu_2Te_2O_5X_2$ (X = Cl, Br) family and the related compound $Cu_4Te_5O_{12}Cl_4$ have been considered the only real systems of such tetrahedra, but they have remarkable structural anisotropies both inside and outside the tetrahedra, leading to much controversy about their anisotropic magnetic couplings and dimensionality [1-3]. There are several questions that prompt lot of discussion. The most important one is the magnetic dimensionality of the system due to the notable structural anisotropies inside and between the tetrahedra.

Recently, we have synthesized new S-1/2 quantum systems of spin-tetrahedral $K_4Cu_4Cl_{10}O$, where the magnetic moments (Cu^{2+} spins) occupy a three-dimensional tetrahedral lattice, as shown in Fig. 1.

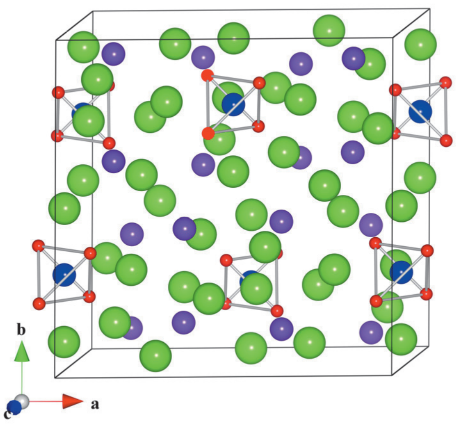

Fig. 1. Tetrahedral lattice in $K_4Cu_4Cl_{10}O$.

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The spin-tetrahedral $K_4Cu_4Cl_{10}O$ showed a very broad susceptibility maximum centered around 10 K and a rapid increase below 5 K. μSR measurements for the system were performed at RIKEN-RAL.

For $K_4Cu_4Cl_{10}O$, no change appeared around 10 K, which is consistent with a spin-singlet state theoretically predicted for isolated spin tetrahedral system. Long-range order was observed below 4.4 K (Fig. 2), but with broad distribution in the precession frequency, which is interpreted as evidence for an incommensurate order.

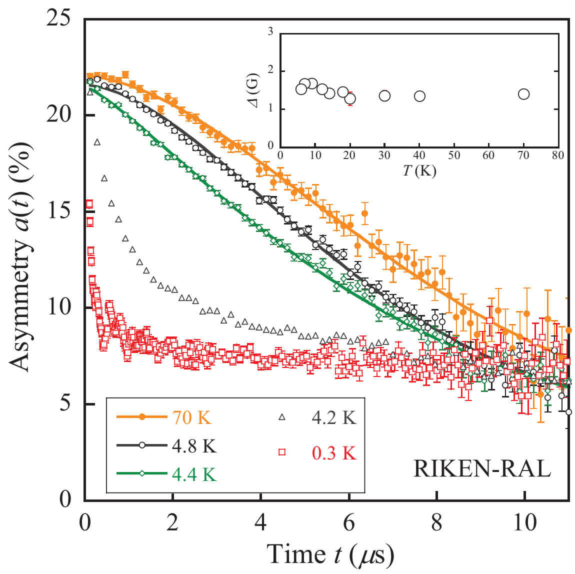

Fig. 2. Zero-field μSR asymmetry spectra at typical temperatures for $K_4Cu_4Cl_{10}O$ obtained from the RIKEN-RAL beam line. The solid lines on the back of the high-temperature data are fitted curves as described in Phys. Rev. B 87, 144425 (2013). The inset plot shows the estimated nuclear field distribution Δ.

Here, our work shows that similar incommensurate ordering also exists in a three-dimensional isolated spin tetrahedral system.

References

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