実験報告書様式（一般利用課題・成果公開利用）

（ ※本報告書は英語で記述してください。ただし、産業利用課題として採択されている方は日本語で記述していただいても結構です。 ）

MLF Experimental Report

提出日 Date of Report

課題番号 Project No. 2012B0194

実験課題名 Title of experiment

Investigation of the magnetic states in new quantum-spin systems of spin tri-angular Cu(OH)Cl and spin-tetrahedral $K_4Cu_4Cl_{10}O$

実験責任者名 Name of principal investigator

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所属 Affiliation

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装置責任者 Name of responsible person

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装置名 Name of Instrument/（BL No.）

D1

実施日 Date of Experiment

2012.12.7-10

試料、実験方法、利用の結果得られた主なデータ、考察、結論等を、記述して下さい。（適宜、図表添付のこと）

Please report your samples, experimental method and results, discussion and conclusions. Please add figures and tables for better explanation.

1. 試料 Name of sample(s) and chemical formula, or compositions including physical form.

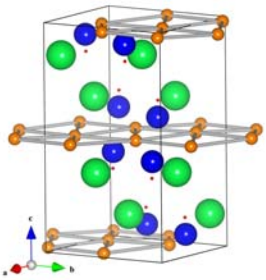
Cu(OH)Cl, $K_4Cu_4Cl_{10}O$

2. 実験方法及び結果（実験がうまくいかなかった場合、その理由を記述してください。）

Experimental method and results. If you failed to conduct experiment as planned, please describe reasons.

Geometrically frustrated magnets, in which localized magnetic moments on triangular, kagome or pyrochlore lattices interact through competing exchange interactions, have been of intense recent interest due to the diversity in the exotic ground states that they display. The diverse experimental reports of unconventional magnetic properties provide challenge and testing ground for theoretical models. Among them S-1/2 quantum systems receive particular attention.

Recently we have synthesized two new S-1/2 quantum systems of spin-triangular Cu(OH)Cl and spin-tetrahedral $K_4Cu_4Cl_{10}O$, where the magnetic moments (Cu^{2+} spins), respectively, occupy a triangular lattice and tetrahedral lattice as shown in Figs 1 and 2.



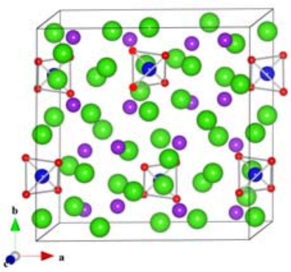


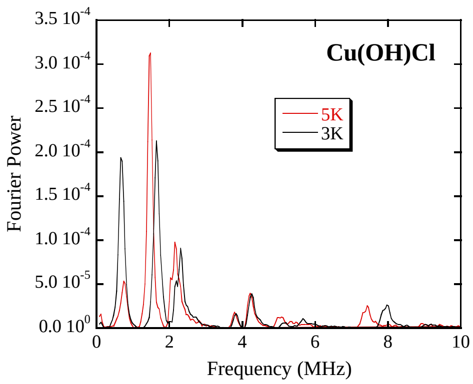
Fig. 1: Triangular lattice in Cu(OH)Cl. Fig.2: Tetrahedral lattice in $K_4Cu_4Cl_{10}O$.

2. 実験方法及び結果（つづき） Experimental method and results (continued)

Except our susceptibility and specific heat measurements which have depicted unusual magnetic behaviors, no research has been done on their magnetism. Therefore, it is of high interest to investigate the magnetism in these two quantum spin systems with a micro probe.

The spin-triangular CuOHCl showed magnetic frustration, as depicted by the large ratio of the Curie-Weiss temperature to the transition temperature, and an anomalous low-temperature phase below 5 K. Because Cu^{2+} is the S=1/2 quantum spin, it presents an ideal triangular lattice for studying quantum spin behaviors in frustrated magnets. The spin-tetrahedral $K_4Cu_4Cl_{10}O$ showed a very broad susceptibility maximum centered around 10 K and rapid increase below 5 K.

μSR measurements for the two systems were tested in J-PARC and performed in detail at TRIUMF. For Cu(OH)Cl, up to eight frequencies were observed (Fig. 3). Long-range order developed below 11.5 K (Fig. 4), and new frequency added at low temperatures, suggesting change of the state from anti-parallel Neél state to weak ferromagnetism.



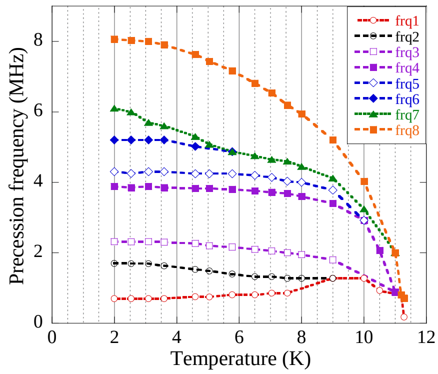


Fig. 3: Fourier transform for Cu(OH)Cl. Fig. 4: Muon spin precession in Cu(OH)Cl.

For $K_4Cu_4Cl_{10}O$, no change appeared around 10 K, which is in consistency with a spin-singlet state theoretically predicted for isolated spin-tetrahedra. Long-range order was observed below 4.4 K, but with broad distribution in the precession frequency (Fig. 5), which is interpreted as an evidence for an imcommensurate order.

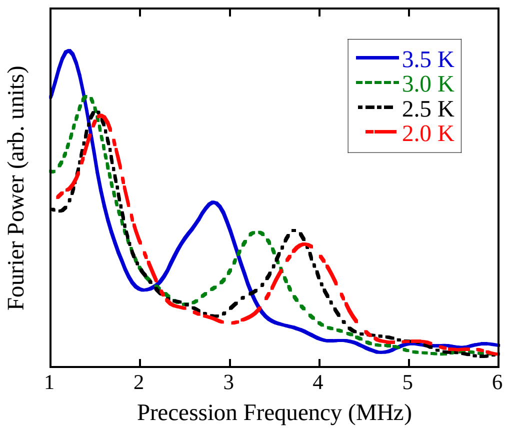


Fig. 5: Examples of Fourier transform for $K_4Cu_4Cl_{10}O$.