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Magnetic exchange disorder in low-dimensional quantum magnets

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Introduction

Low-dimensional quantum magnetism is currently of great interest due to the fact that reduced dimensionality can support strong quantum fluctuations, which may lead to unusual phenomena and quantum-critical behavior. The effect of random exchange strengths [1] in two-dimensional (2D) antiferromagnets is still not fully understood despite much effort. This project aims to rectify this by investigating the high-field properties of the 2D coordination polymer $(QuinH)_2Cu(Cl_xBr_{1-x})_4.2H_2O$. The exchange pathway is through Cu-Halide-Cu bonds, and by randomizing the proportion of chlorine and bromine atoms in the unit cell, disorder can be introduced into the system.

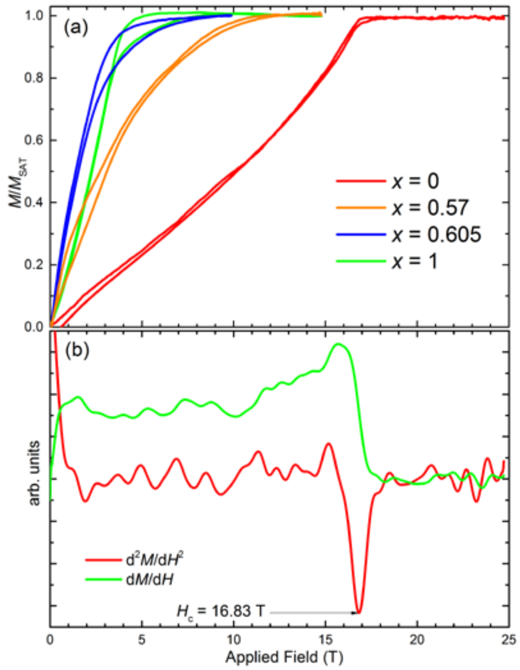

Fig.1: (a) Magnetisation of a selection of concentrations of $(QuinH)_2Cu(Cl_xBr_{1-x})_4.2H_2O$. (b) dM/dH and d^2M/dH^2 of the $x = 0$ sample.

Experimental

Pulsed-field magnetization measurements of single crystals of $(QuinH)_2Cu(Cl_xBr_{1-x})_4.2H_2O$ with different values of x were performed using the short-pulse 65 T magnet at NHMFL Los Alamos. The samples were cooled and measurements made at a variety of temperatures in the range $0.3 < T < 15$ K using a ^3He cryostat.

Results and Discussion

Magnetisation measurements of the Br-only ($x = 0$) and Cl-only ($x = 1$) samples show a concave rise to saturation indicative of low-dimensionality [Fig. 1(a)], while the disordered materials show a more convex rise to saturation. In most cases a saturation field, H_C, can be obtained from the position of the minimum in d^2M/dH^2 [Fig. 1(b)]. Using this method, the saturation fields for a variety of concentrations were obtained and are shown in Fig. 2. Initially from $x = 0$, there is a slow decline from $H_C = 17$ T until $x = 0.4$, where the critical field drops to zero between $0.4 < x < 0.6$. Above $x = 0.6$, H_C rises again to $H_C = 4$ T at $x = 1$. The strength of magnetic interactions (J) is directly proportional to H_C via the formula $nJ = g\mu_B\mu_0H_C$ [2]. We find that $J = 6$ K for $x = 0$ and $J = 1.5$ K for $x = 1$. No clear saturation field could be obtained from the samples close to $x = 0.5$, which suggests that long-range order does not exist in most disordered region.

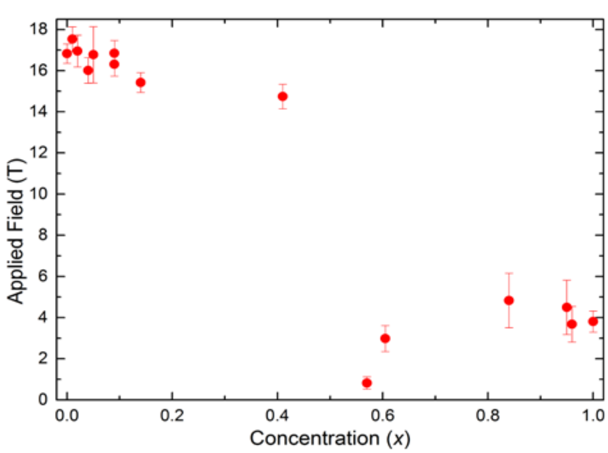

Fig.2: Phase diagram of $(QuinH)_2Cu(Cl_xBr_{1-x})_4.2H_2O$, showing how H_C varies with x.

Conclusions

The effects of magnetic exchange disorder in 2D antiferromagnets has been investigated using high magnetic fields. For small amounts of disorder, there is little change in the overall exchange strength, but H_C drops rapidly in the region of high disorder around $x = 0.5$.

Acknowledgements

A portion of this work was performed at the National High Magnetic Field Laboratory, which is supported by National Science Foundation Cooperative Agreement No. DMR-1157490 and the State of Florida. WJAB and PAG would like to thank EPSRC for funding.

References

[1] Tsvelik, A.M., Quantum Field Theory in Condensed Matter Physics (CUP) (2007).
[2] Goddard, P. A., *et al.*, Phys. Rev. Lett., **108**, 077208 (2012).