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Probing a rare material spin state

September 14 2007

A team of international physicists that includes researchers from the National Institute of Standards and Technology has found experimental evidence of a highly sought-after type of arrangement of atomic magnetic moments, or spins, in a series of materials. Their work, one of the very few studies of this particular spin state, which has been postulated as a possible underlying mechanism for high-temperature superconductivity, may eventually serve as a test of current and future theoretical models of exotic spin states.

At the NIST Center for Neutron Research (NCNR) and the Hahn-Meitner Institute in Berlin, Germany, the scientists used intense beams of neutrons to probe a series of antiferromagnets, materials in which each spin—an intrinsic property of an atom that produces a tiny magnetic field called a magnetic "moment"—cancels another, giving the material a net magnetic field of zero.

The results, described in the Aug. 26 online edition of *Nature Materials*, revealed evidence of a rare and pporly understood "quantum paramagnetic" spin state, in which neighboring spins pair up to form "entangled spin singlets" that have an ordered pattern and that allow the material to weakly respond to an outside magnetic field—i.e., become paramagnetic.

The antiferromagnets used in this work are composed mainly of zinc and copper, and are distinguished by their proportions of each, with the number of copper ions determined by the number of zinc ions. At the atomic level, the material is formed of many repeating layers. The atoms of each layer are arranged into a structure known as a “kagome lattice,” a pattern of triangles laid point-to-point whose basic unit resembles a six-point star.

Physicists have been studying antiferromagnets with kagome structures over the last 20 years because they suspected these materials harbored interesting spin structures. But good model systems, like the zinc/copper compounds used by this group, had not been identified.

At the NCNR, the researchers determined how varying concentrations of zinc and copper and varying temperatures affected fluctuations in the way the spins are arranged in these materials. Using a neutron spectrometer at the Hahn-Meitner Institute, they also investigated the effect of external magnetic fields of varying strengths. The group uncovered several magnetic phases in addition to the quantum paramagnetic state and were able to construct a complete phase diagram as a function of the zinc concentration and temperature. They are planning further experimental and theoretical studies to learn more about the kagome system.

Source: National Institute of Standards and Technology