Molecular Prototypes for Spin-based Quantum Logic Gates

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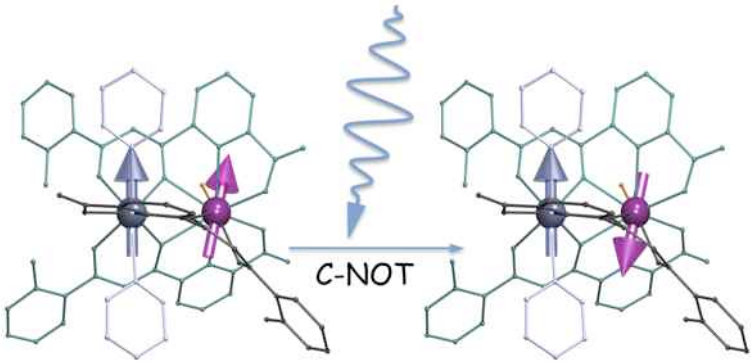
Abstract:



In recent years, magnetic molecular clusters have been proposed as suitable materials for the realization of the quantum computer hardware [1]. Here, we describe experiments performed on molecules containing either one or two lanthanide ions. The magnetic anisotropy, as well as the spin lattice relaxation and quantum tunneling rates, are determined by the local coordination of each lanthanide ion [2,3]. The molecular structure can therefore be used as a parameter to control the underlying physics. The ability to tune the magnetic properties by chemical design provides fascinating perspectives for the application of these molecules as spin qubits [2]. The same strategy can be applied, in molecules made of two magnetic ions, to implement two-qubit quantum logic gates, the second ingredient required to achieve universal quantum computation. In particular, we show that a complex containing two Tb ions fulfills all the ingredients to realize the archetypical CNOT quantum gate [4]. The definition of control and target qubits is based on the strong magnetic anisotropy and the magnetic inequivalence of the two ions, which has been achieved by chemically engineering dissimilar coordination spheres. The magnetic asymmetry also provides a method to realize a SWAP gate in the same cluster. The same molecular structures can be realized with other lanthanide ions [3,5]. This flexibility enables a vast choice of quantum gate designs. Furthermore, these molecular clusters are stable in solution, which opens the possibility of depositing them onto devices able to manipulate its quantum spin state. Chemically engineered molecular quantum gates can therefore open promising avenues for the realization of scalable quantum computing architectures.

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[3] S. Cardona-Serra, et al., JACS **134**, 14982–14990 (2012).
[4] F. Luis, et al, Phys. Rev. Lett. **107**, 117203 (2011).
[5] G. Aromí, D. Aguilà, P. Gámez, F. Luis, and O. Roubeau, Chem Soc. Rev. **41**, 537 (2012).