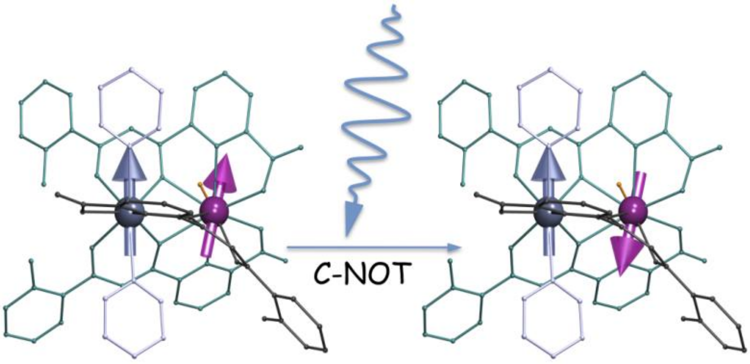
Molecular prototypes for spin-based quantum logic gates

F. Luis,[1,*] A. Repollés,[1] M. J. Martínez-Pérez,[1] D. Aguilà,[2] O. Roubeau,[1] D. Zueco,[1] P. J. Alonso,[1] M. Evangelisti,[1] A. Camón,[1] J. Sesé,[3] L. A. Barrios,[2] and G. Aromí[2]

[1] Instituto de Ciencia de Materiales de Aragón (ICMA), CSIC–Universidad de Zaragoza, and Departamento de Física de la Materia Condensada, Universidad de Zaragoza, E-50009 Zaragoza, Spain
[2] Departament de Química Inorgànica, Universitat de Barcelona, Diagonal 647, 08028, Barcelona, Spain
[3] Instituto de Nanociencia de Aragón, Universidad de Zaragoza, and Departamento de Física de la Materia Condensada, Universidad de Zaragoza, E-50018 Zaragoza, Spain

Abstract:
In recent years, magnetic molecular clusters have been proposed as suitable materials for the realization of the quantum computer hardware [1]. Here, we show, via a combination of ac susceptibility, magnetization and heat capacity studies performed in the vicinity of the absolute zero, that molecular clusters containing two Tb^{3+} ions meet the ingredients required to implement a CNOT quantum logic gate [2]. 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. Electronic paramagnetic resonance experiments confirm that CNOT and SWAP transitions are not forbidden.



Although we have only considered Tb_2, for which the magnetic asymmetry can be easily determined on account of its large angular momentum, the same molecular structure can be realized with other lanthanide ions [3,4]. This flexibility enables a vast choice of quantum gate designs. These molecular clusters are stable in solution, which opens the possibility of depositing them onto devices able to manipulate its quantum spin state [5,6]. Chemically engineered molecular quantum gates can therefore open promising avenues for the realization of scalable quantum computing architectures.

[1] A. Ardavan, et al, Phys. Rev. Lett. **98**, 057201 (2007); S. Bertaina et al, Nature **453**, 203 (2008); G. Timco et al, Nature Nanotechnology **4**, 173 (2009).
[2] F. Luis, et al, Phys. Rev. Lett. **107**, 117203 (2011).
[3] D. Aguilá, et al, Inorg. Chem. (communication) **49**, 6784 (2010).
[4] G. Aromí, D. Aguilà, P. Gámez, F. Luis, and O. Roubeau, Chem Soc. Rev. (2012). DOI: 10.1039/c1cs15115k
[5] A. Imamoglu, Phys. Rev. Lett. **102**, 083602 (2009).
[6] M. Urdampilleta, S. Klyatskaya, J-P. Cleuziou, M. Ruben, and W.Wernsdorfer, Nature Mater. **10**, 502 (2011).