Magnetism in materials

Solution - Week 11

Let's suppose that you have a crystal, and you already know the following properties :

- The structure is cubic and the atoms are linked by an oxygen on the z axis.
- The magnetic moment per atom is $\mu = 2.2\mu_B$ and is along the z-axis
- The lattice structure parameter is $a = 5$Å

But you do not know in what configuration the magnetic moments get ordered. You conduct an $\mu - \mathrm{SR}$ experiment. You know that the muons will stop and decay near the oxygen atom, at $R = 1$Å in the xy plane. You measure a $\mu - \mathrm{SR}$ frequency $f = (190 \pm 20)\mathrm{MHz}$.

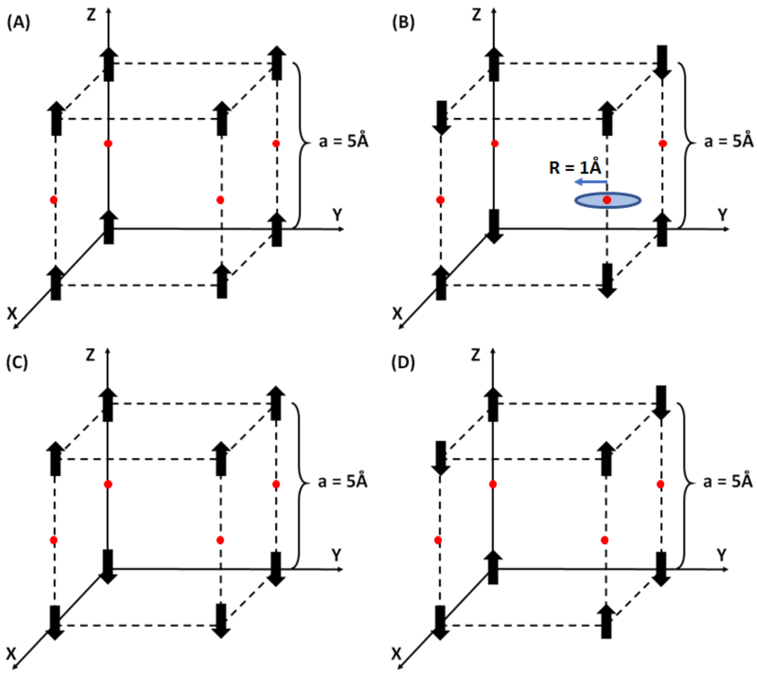

Figure 1: The different possible interaction. The red dot represent the oxygen. (A) ferromagnetic. (B)-(C) antiferromagnetic. On (B) the possible locations of the muons are represented.

1. What is the magnetic B field around the oxygen ?

Solution The gyromagnetic ratio for muon is $\gamma_\mu = 851.615\mathrm{MHz/T}$. The magnetic field is then :

$$B = f/\gamma_\mu = (0.223 \pm 0.024)\mathrm{T}$$

2. It is possible to estimate the field in a cubic lattice by just adding the dipole field. The script Dipole_sum.ipynb perform the sum of the magnetic field generated at the muon position by the dipoles on N shells of unit cells around the muon position. Increase the number of shells considered in the calculation until you see that the results of the calculation converges. Use this result to determine the magnetic order in the crystal.

   Solution Fig. 2 shows the values of the calculated magnetic fields as a function of the number of shells used. Just a few shells are sufficient to make the result converge.

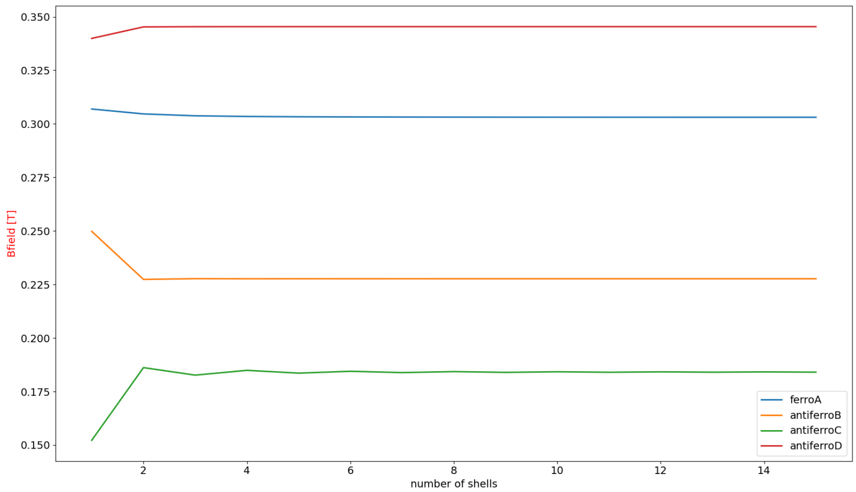

Figure 2: Magnetic field create by dipole superposition, at the position $\left(\frac{1}{\sqrt{2}}\text{Å}, \frac{1}{\sqrt{2}}\text{Å}, 2.5\text{Å}\right)$