European School on Magnetism 2019 - Practicals

An introduction to magnetism of ferrimagnets

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Tutorial approx. 2 hours

The purpose of this tutorial is to get familiar with some basic knowledge and properties of magnetic systems composed of two magnetic sublattices either ferrimagnets or antiferromagnets. After a theoretical part introducing the formalism some experimental examples of rare-earth transition metal compounds will be presented and discussed.

I. Theoretical background :

Let's consider a compound made of two inequivalent magnetic sublattices , for instance $Yb_3Fe_5O_{12}$ (Ytterbium Iron garnet) or Dy_2Fe_{17} and try to derive the temperature and field dependence of the magnetization.

I.a) Application to rare-earth (R) transition metal compounds (T).

For the heavy rare-earth element the R-T exchange coupling between the R moments and the T moments is antiparrallel.

-What happens qualitatively if you apply a magnetic field to such system?

In the mean field approach the exchange interaction between the R moment and its surrounding magnetic moments is described by a molecular field that is acting on the rare-earth moment.

-Discuss the origins of the molecular field acting on the rare-earth moment and their expected relative amplitude.

I.b) Give the different terms of the energy if such compound is exposed to a magnetic field.

I.c) If the angle between the magnetization of the T and that of the R sublattice is α, simplify the expression of the free energy assuming first that we are dealing with a single crystal that is free to rotate in the field, second that the magnetic anisotropy of the T sublattice is zero and the anisotropy energy is constant.

I.d) Minimising the obtained expression of the energy discuss the two derived solutions and give a schematic plot of the field dependence of the magnetization.

I.e) What happens for an antiferromagnetic compounds? How are the curves modified ?

II. Study of experimental examples:

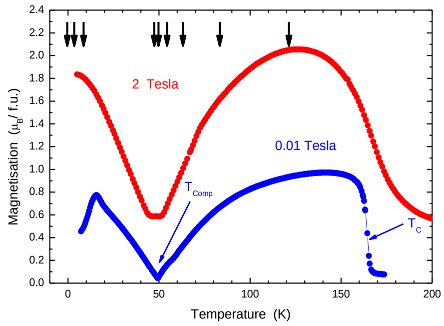
II.a) Calculate the S spin, L orbital, and J total angular momentum magnetic moment of Gd, Dy and Tm in the trivalent state.

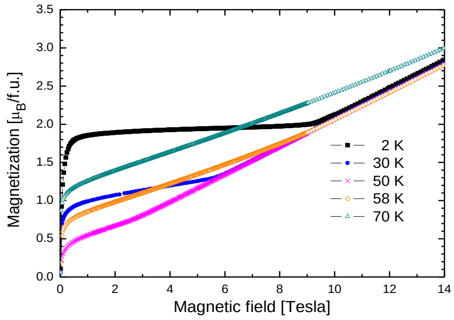
II.b) Compare to the typical magnetization of Fe or Co atoms in the metallic state.

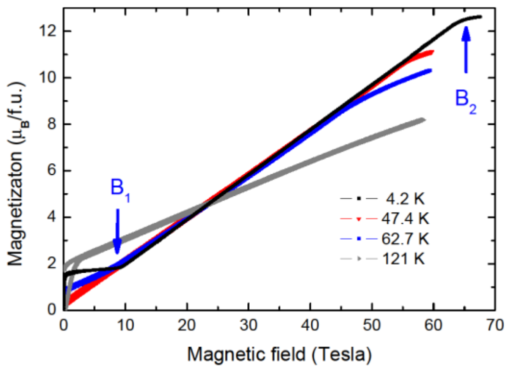
II.c) Comment on the localized versus itinerant character of the R (4f) and T (3d) magnetic moments in the metallic state. What are the electrons involved in the R-T exchange interactions ?

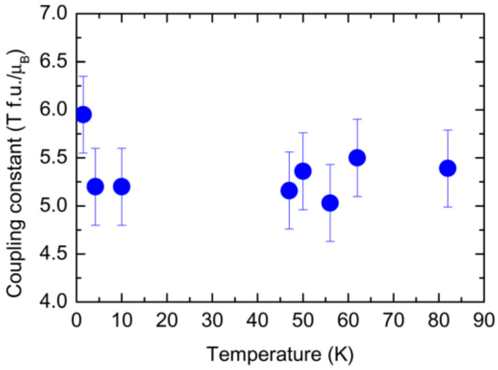
II.d**)** Plot schematically the temperature dependence of the magnetization of both R and T sublattice for a ferrimagnet for $M_R > M_T$ and $M_R < M_T$

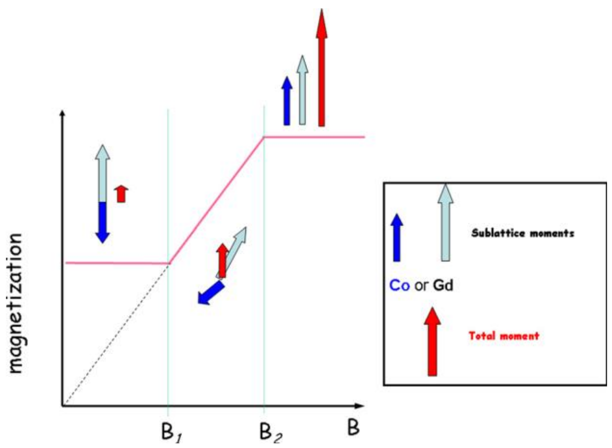
II.e**)** Observe and discuss the behaviour of the magnetization for $GdCo_{12}B_6$ compound





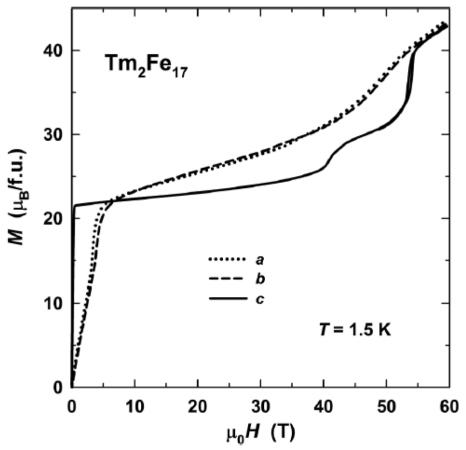


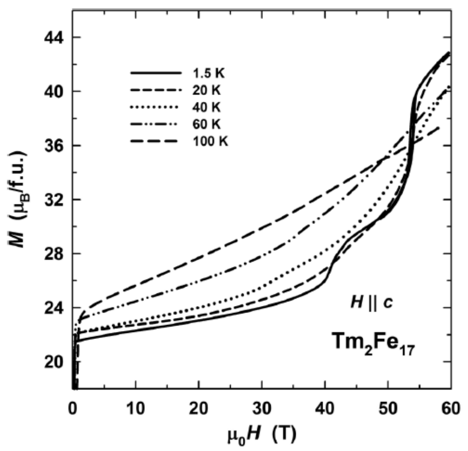


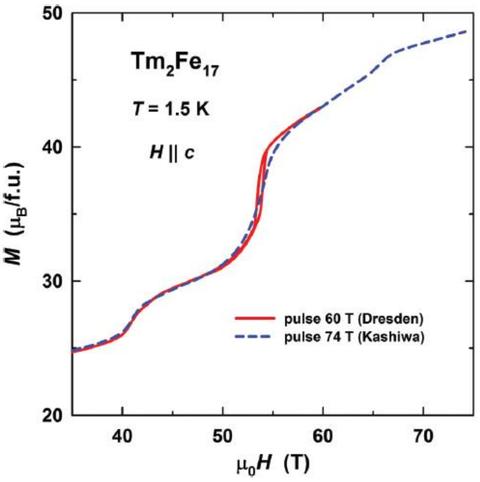


What are the characteristic temperatures and fields.
Comments on the possible experimental or theoretical techniques enabling to access to the exchange constant.

II.f) Observe and discuss the behaviour of the magnetization for Tm_2Fe_{17} and $Tm_2Fe_{17}D_x$ compounds. Easy magnetization direction, anisotropy field, magnetization process….







III. Comments on other unusual magnetization processes :
First order magnetization process
Itinerant electron metamagnetic transition…

Suggested reading :

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