How can I distinguish an antiferromagnet from a paramagnet experimentally probably in the presence of ferromagnetic phase in the same system ?

Different possibilities :

•General => Neutron diffraction experiments reveal the true ordering if any

Use of spectroscopies complementary techniques microscopic scale)

•Fe containing => measure Mössbauer spectra doublets or sextets

•Co, Mn => NMR spectroscopy

Magnetic measurements

•Magnetic measurements => thermomagnetic studies in a wider T range

•Magnetic measurements in different orientation (if single crystal available)

•Measurements at higher field => step in magnetization curves?
Spin flip? Spin flop?

•ac susceptibility => signature of AF para transition

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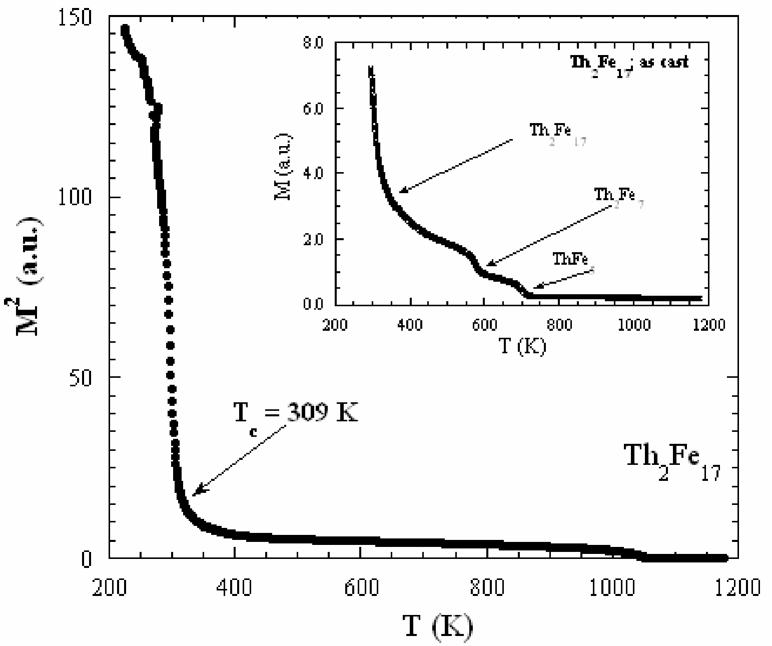
•**Magnetic measurements => thermomagnetic studies in a wider T range**

Identify the different transitions

To obtain the intrinsic magnetic properties
Record M (H) at several temperature

Honda-Owen plots extrapolation to 1/H→

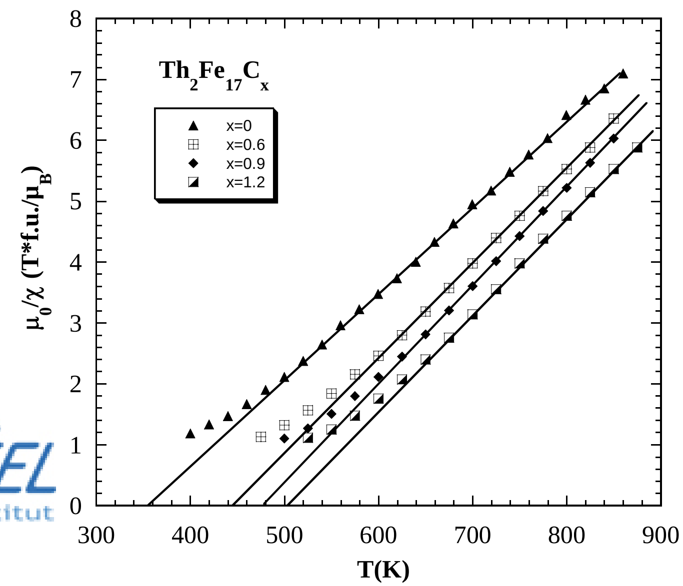
$$\chi = \chi_p + cM_s/H$$



Remove the contribution of the impurity at each T

1/X = f(T) extract the μ_{eff} by fitting
the data according to a Curie–Weiss law,

$$\chi = C/(T - \theta_p) \qquad C = n\mu_0 \frac{\mu_{eff}^2}{3k_B}$$



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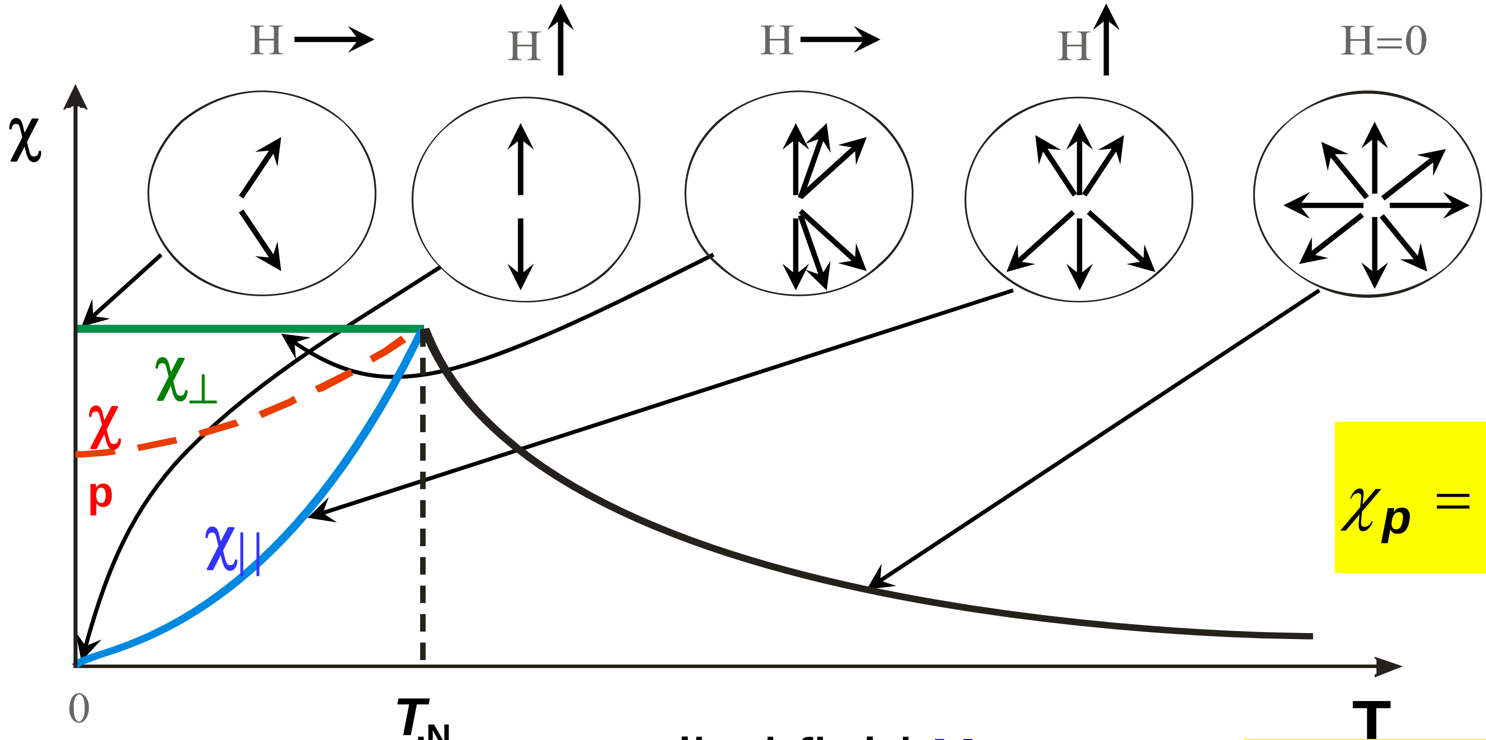
Magnetic measurements in different orientations (if single crystal available)

For and **antiferromagnetic compound** $\chi_{\perp} > \chi_{||}$



$$\chi_p = \frac{1}{3}(\chi_{\|} + 2\chi_{\perp})$$

Zeeman energy in an applied field **H**,

$E = - \mu_0 HM = -\chi\mu_0 H^2$,

$$\chi_p(0) = \frac{2}{3}\chi_{\perp} = \frac{2}{3}\chi_N$$

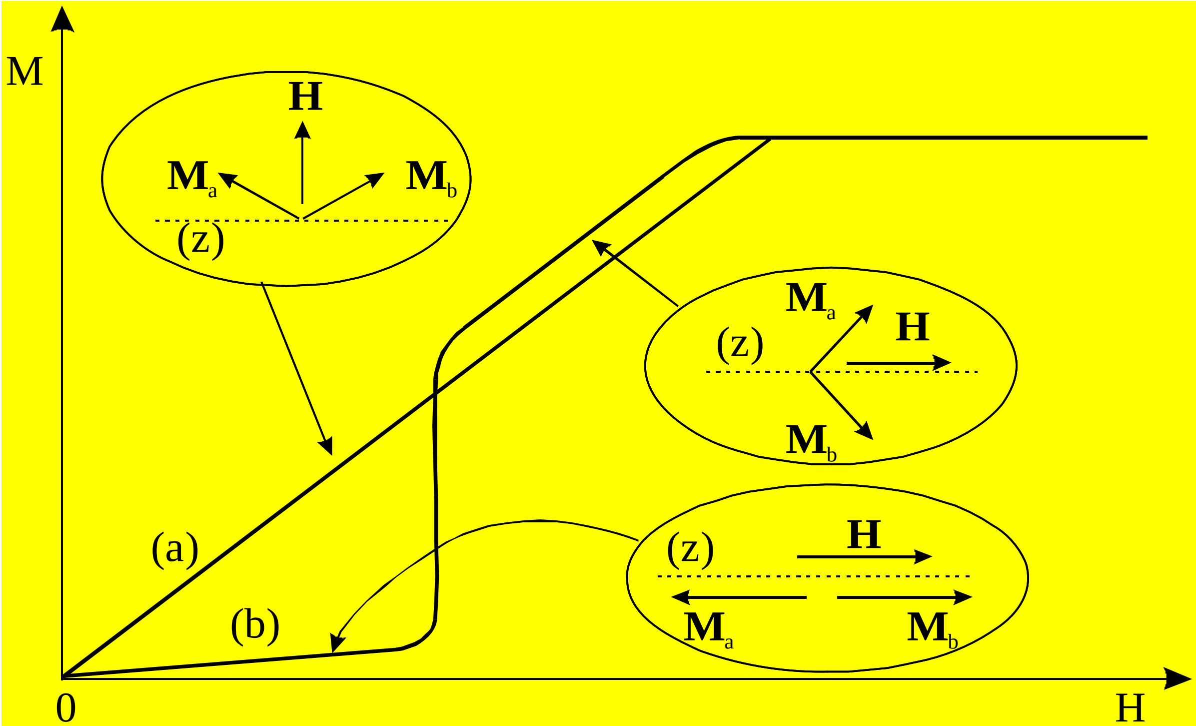
O. Isnard

The state with the field H perpendicular to the easy magnetization the two sublattices is more stable (favorable energetically) than with H parrallel to the easy magnetization

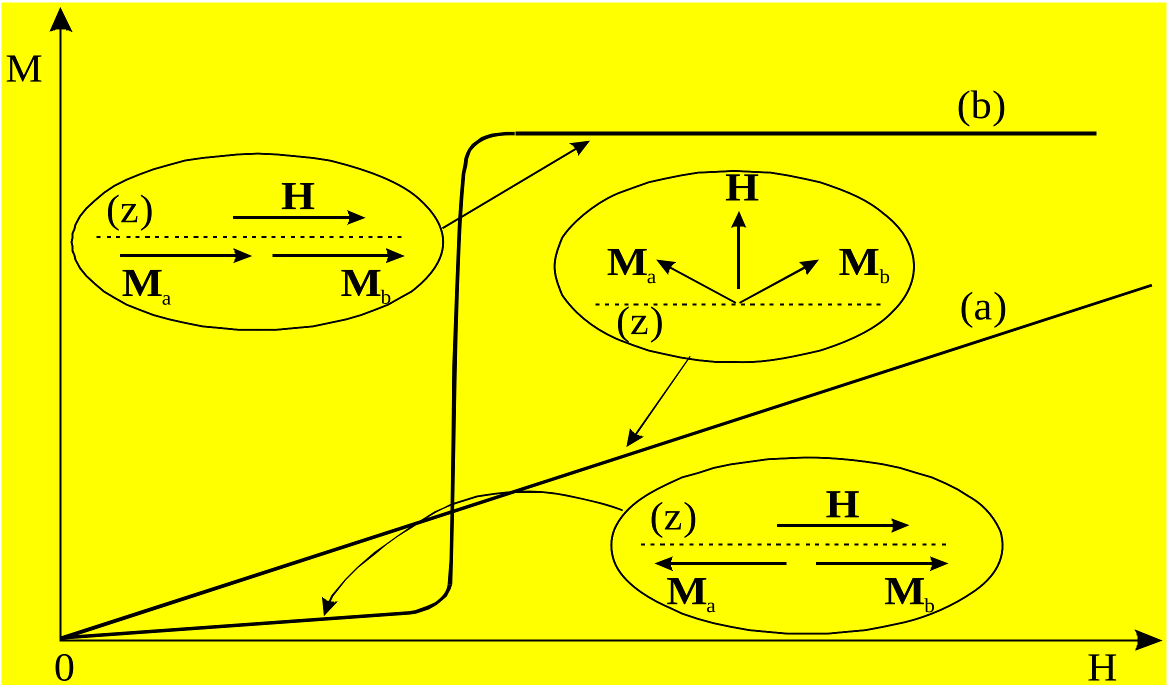
When applying a magnetic field parrallel to the magnetization direction it tends to rotate the magnetization perpendicular to the applied field. That is perpendicular to the easy magnetization direction.

Two cases may occur: large of weak anisotropy

Weak anisotropy energy, At a critical magnetic field the two sublattice magnetization rotates suddenly to a direction perpendicular to the easy magnetization direction, (*z*), consequently perpendicular to the applied magnetic field (*b*). This is a ***spin – flop transition***. Then a continuous rotation of the magnetic moment occurs upon increasing H



Large magnetocrystalline anisotropy, The magnetization of the 2 sublattices remains parrallel to the easy magnetization axis up to a critical field. At $\boldsymbol{H} = \boldsymbol{H}_{critic}$ a sudden rotation occurs of the sublattice magnetization antiparrallel to H, towards the field direction resulting to a parrallel arrangements of both magnetic moments. The saturation state is obtained, curve (*b*). This is a ***spin – flip transition.***

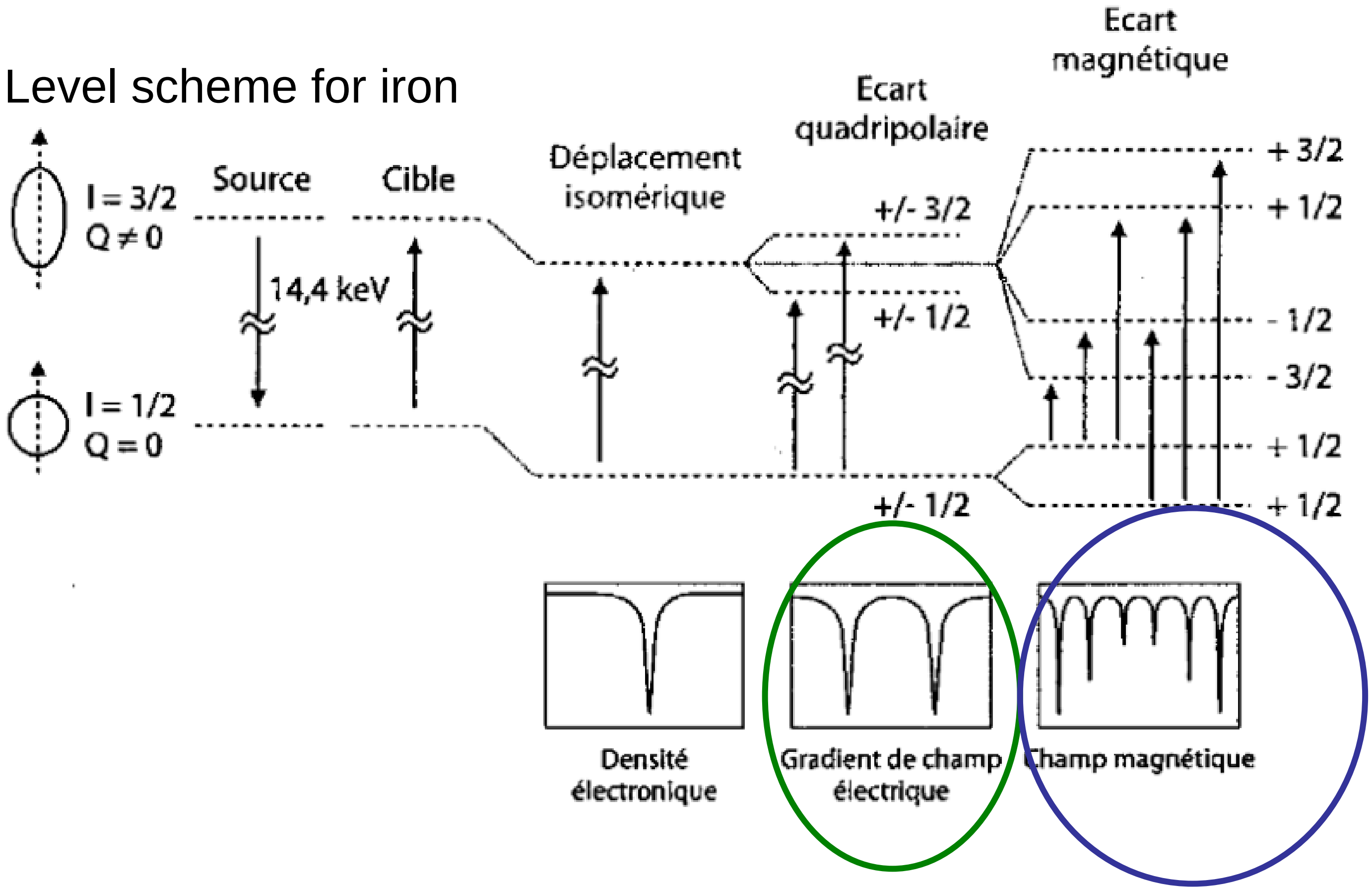


Beware : metamagnetic transition can also occur in non antiferro compounds ferrimagnetic compounds !!

The spin–flip and spin–flop transitions are of *metamagnetic type ones* !

Example of use of Mössbauer spectroscopy

Level scheme for iron



Shape for paramagnetic

Magnetic field inside
=> AF or F