Curie temperature ??

Ideally measured with low magnetic field since High field shifts the Tc of ferro to High temperature

Hypothesis mean field theory and low field

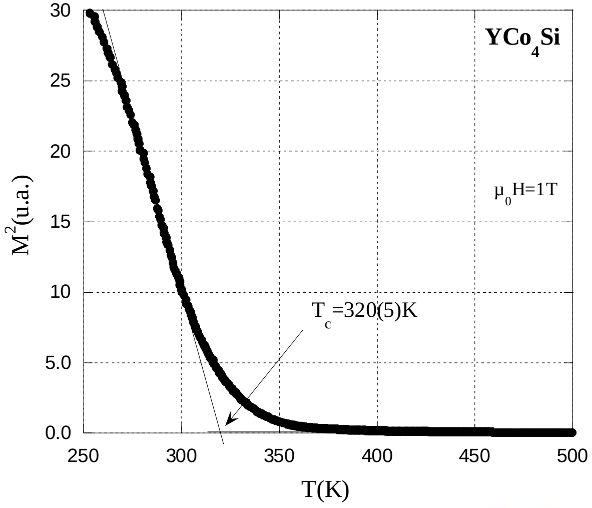
$$\begin{cases} m = \mathcal{B}_J(x) \simeq a\,x\left(1 - b\,x^2\right) \\ m = a\,t\,x - \dfrac{H}{w M_0} \end{cases}$$

with $t = T/T_C$ and $b = (J^2 + (J+1)^2)/(30 J^2)$

Then for H=0

$$m_s^2 = \left(\frac{M_s}{M_0}\right)^2 = \frac{a^2}{b} t^2 (1-t) \simeq \frac{a^2}{b}(1-t) = \frac{10}{3}\frac{(J+1)^2}{J^2 + (J+1)^2}\left(1 - \frac{T}{T_C}\right)$$

So that one use $M^2 = f(T)$ extrapolate linearly to T_c



Avoid using M (T) and the derivative

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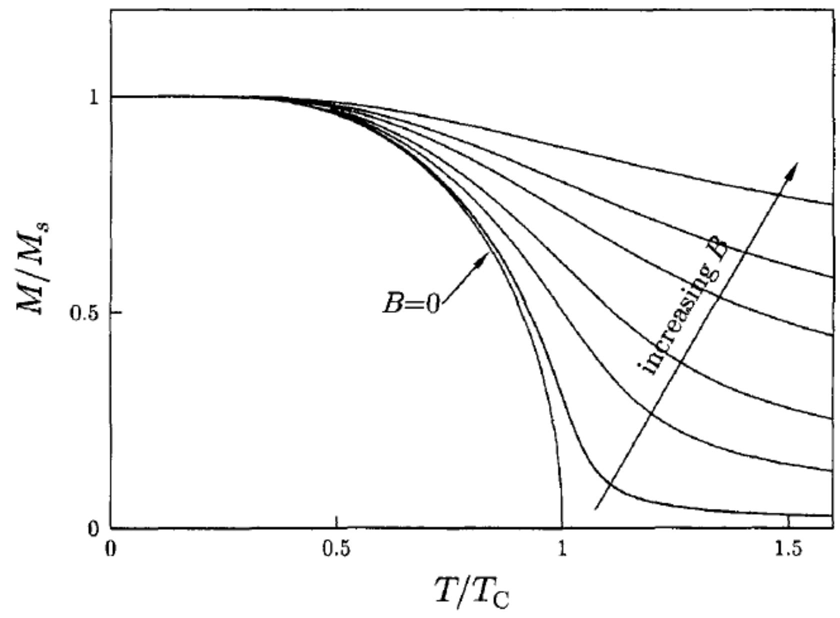
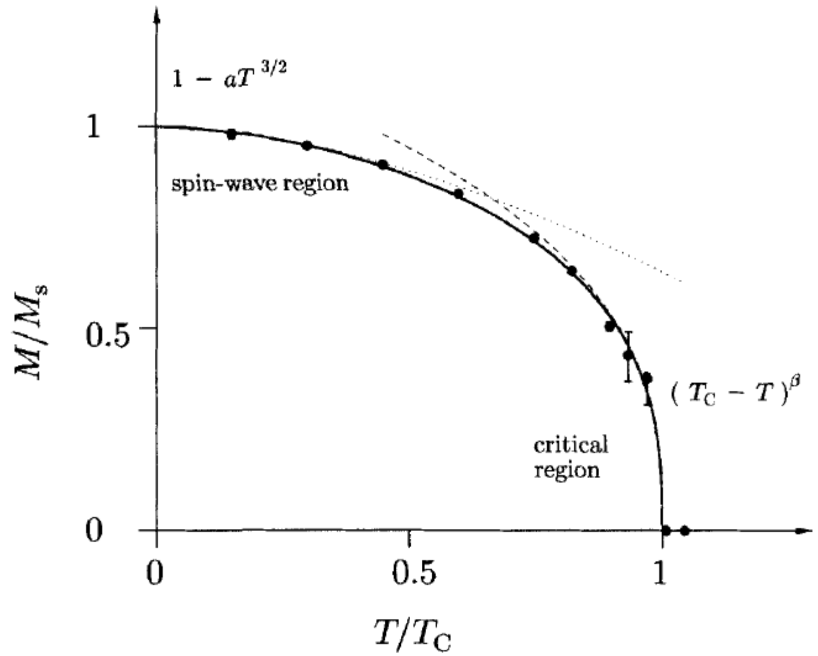
Low applied magnetic field necessary





Crucial when critical exponents are looked for

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Another method plot M^2 versus (H/M)

Belov K P and Goryaga A N 1956 *Fiz. Met. Metalloved.* 2 3

A. Arrott, Phys. Rev. B 108 (1957) 1394.

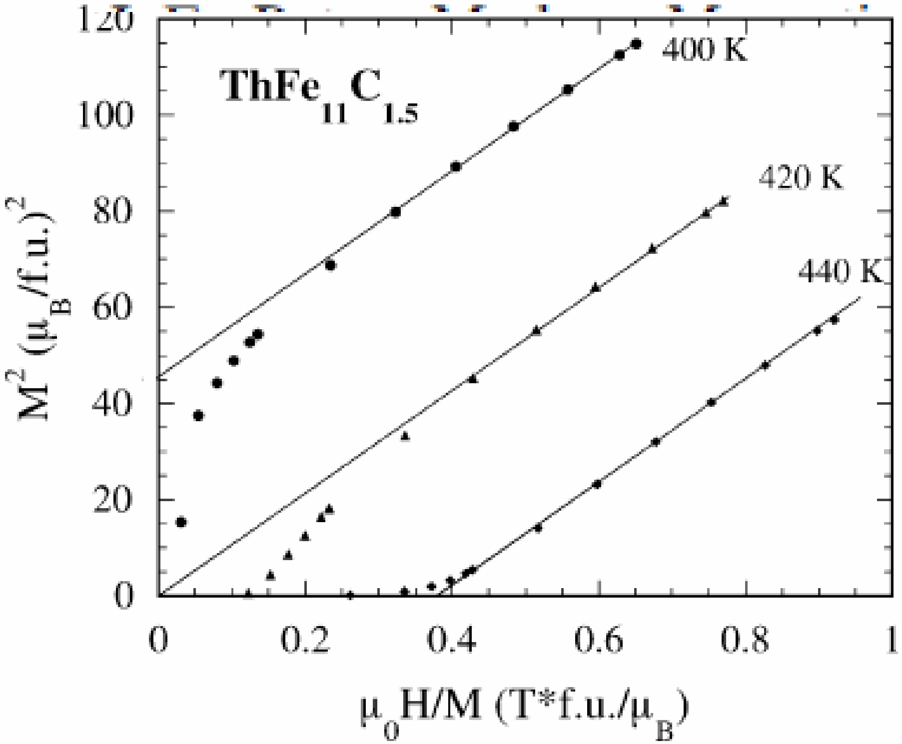
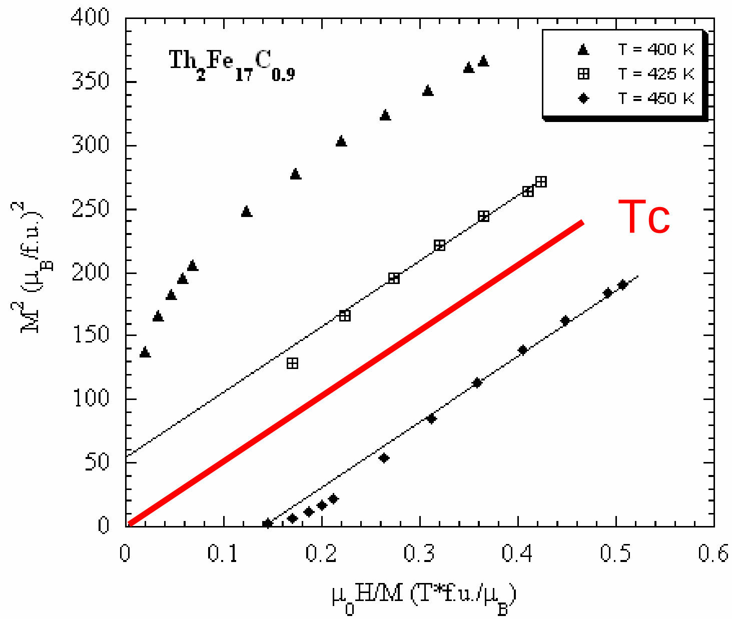


Fig. 3. Arrott plots at the indicated temperature around the Curie temperature of $ThFe_{11}C_{1.5}$.



Give similar values than M^2 (T)

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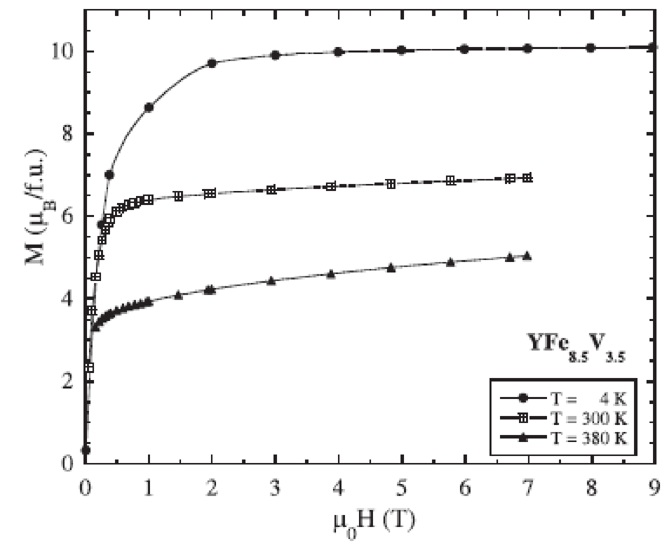
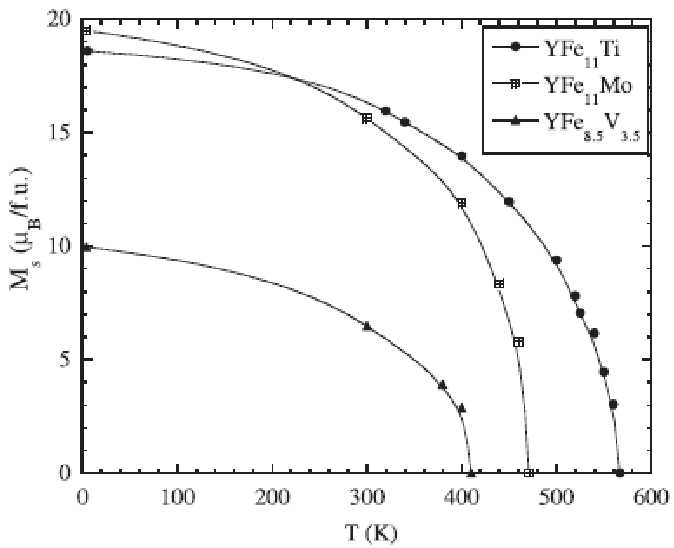
Why two magnetic moments ??
What is the difference ??
Which one do we measure experimentally ??

$m_0 = g\,J$

$m_{eff} = g\,(J\,(J+1))^{1/2}$





Ordered state

$m_0 = g\,J$

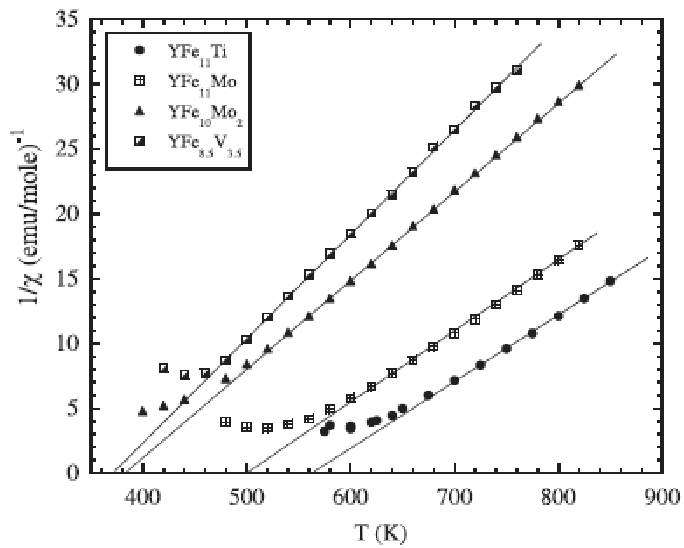
Obtained from saturation magnetization

Paramagnetic state

$$C = n\,\mu_0 \frac{\mu_{eff}^2}{3k_B}$$

$m_{eff} = g\,(J\,(J+1))^{1/2}$

Obtained from Curie –Weiss Law



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Behaviour of the transition metal ions 3d.

Ion	$3d^n$	$^{2S+1}L_J$	g	Moment effective Theoretical $\mu_{ef}(\mu_B) = g_J\sqrt{J(J+1)}$	Moment effective Theoretical $\mu_{ef}(\mu_B) = g_S\sqrt{S(S+1)}$	Moment effective Experimental $\mu_{ef}(\mu_B)$
Ti3+, V4+	**1**	**2D3/2**	**4/5**	**1,55**	**1,73**	**1,7**
Ti2+, V3+	**2**	**3F2**	**2/3**	**1,63**	**2,83**	**2,8**
V2+, Cr3+, Mn4+	**3**	**4F3/2**	**2/5**	**0,77**	**3,87**	**3,8**
Cr2+, Mn3+	**4**	**5D0**	**-**	**0**	**4,90**	**4,9**
Mn2+, Fe3+	**5**	**5S5/2**	**2**	**5,92**	**5,92**	**5,9**
Fe2+, Co3+	**6**	**5D4**	**3/2**	**6,70**	**4,90**	**5,4**
Co2+, Ni3+	**7**	**4F9/2**	**4/3**	**6,64**	**3,87**	**4,8**
Ni2+	**8**	**3F4**	**5/4**	**5,59**	**2,83**	**3,2**
Cu2+	**9**	**2D5/2**	**6/5**	**3,55**	**1,73**	**1,9**
Cu+, Zn2+	**10**	**2S0**	**-**	**0**	**0**	**0**

Behaviour of the rare-earth metal ions 4f

Z	Ion	$4f^n$	S	L	J	$^{2S+1}L_J$	g	m=gJ (μ_B)	$\mu_{ef}(\mu_B) = g_J\sqrt{J(J+1)}$	$\mu_{eff}(\mu_B)$ experi-mental
57	La^{3+}	$4f^0$	0	0	0	$^1S_0$	0	0	0	0
58	Ce^{3+}	$4f^1$	1/2	3	5/2	$^2F_{5/2}$	6/7	2,14	2,54	2,4-2,7
59	Pr^{3+}	$4f^2$	1	5	4	$^3H_4$	4/5	3,2	3,58	3,4-3,6
60	Nd^{3+}	$4f^3$	3/2	6	9/2	$^4I_{9/2}$	8/11	3,27	3,62	3,5-3,7
61	Pm^{3+}	$4f^4$	2	6	4	$^5I_4$	3/5	2,4	2,68	-
62	Sm^{3+}	$4f^5$	5/2	5	5/2	$^6H_{5/2}$	2/7	0,71	0,85	1,4-1,7
63	Eu^{3+}	$4f^6$	3	3	0	$^7F_0$	-	0	0	3,6
63	Eu^{2+}	$4f^7$	7/2	0	7/2	$^8S_{7/2}$	2	7	7,94	7,98
64	Gd^{3+}	$4f^7$	7/2	0	7/2	$^8S_{7/2}$	2	7	7,94	7,98
65	Tb^{3+}	$4f^8$	3	3	6	$^7F_6$	3/2	9	9,72	9,0-9,8
66	Dy^{3+}	$4f^9$	5/2	5	15/2	$^6H_{15/2}$	4/3	10	10,6	10,5-10,8
67	Ho^{3+}	$4f^{10}$	2	6	8	$^5I_8$	5/4	10	10,6	10,3-10,5
68	Er^{3+}	$4f^{11}$	3/2	6	15/2	$^4I_{15/2}$	6/5	9	9,58	9,4-9,6
69	Tm^{3+}	$4f^{12}$	1	5	6	$^3H_6$	7/6	7	7,56	7,2-7,6
70	Yb^{3+}	$4f^{13}$	1/2	3	7/2	$^2F_{7/2}$	8/7	4	4,53	4,4-4,6
71	Lu^{3+}	$4f^{14}$	0	0	0	$^1S_0$	0	0	0	0

Itinerant

$M_0 = g\,J$

$\mu_{eff} = g\,(J\,(J+1))^{1/2}$

May be much different for non ionic cases
band magnetism

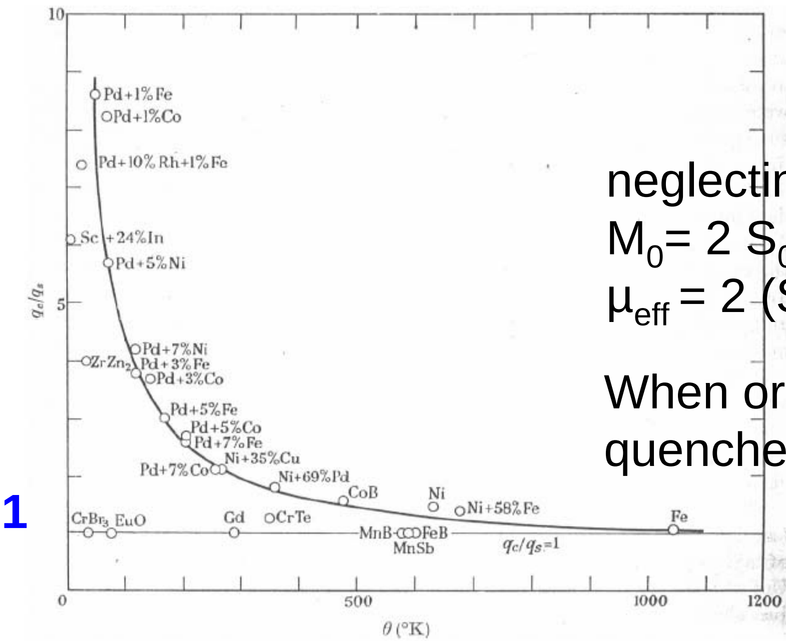

Figure A6-2 : Courbe de Rhodes – Wohlfarth : tracé du rapport $r = q_c / q_s$ en fonction de la température de Curie (θ).

localize → **1**

neglecting L we got

$M_0 = 2\,S_0$

$\mu_{eff} = 2\,(S\,(S+1))^{1/2}$

When orbital moment is quenched

$$\mu_{eff} = \mu_B \sqrt{q_c\,(q_c + 2)}$$

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Table 2. Saturation magnetization M_s, Curie–Weiss constant C, paramagnetic effective moment μ_{eff}, mean number of spins in the ordered S_0 or paramagnetic states S_p and the corresponding ratio $r = S_p/S_0$ for the $YFe_{12-x}M_x$ compounds compared to that of the pure Fe.

Compound	M_s 300 K (μ_B/f.u.)	M_s 4 K (μ_B/f.u.)	M_{Fe} 4 K (μ_B/atom)	S_0	μ_{eff} (μ_B/Fe atom)	S_p	r	C (μ_B K/f.u. T)
$YFe_{11}Ti$	16.3	18.6	1.69	0.845	3.745	1.439	1.70	34.59
$YFe_{11}Mo$	15.6	19.8	1.8	0.90	3.649	1.392	1.55	32.80
$YFe_{10}Mo_2$	5.5	13.1	1.31	0.655	3.412	1.278	1.95	26.07
$YFe_{8.5}V_{3.5}$	6.5	9.96	1.17	0.586	3.409	1.277	2.18	22.12
α-Fe	2.17	2.22	2.22	1.11	3.18	1.17	1.05	2.26