Ferrimagnetism, Antiferromagnetism

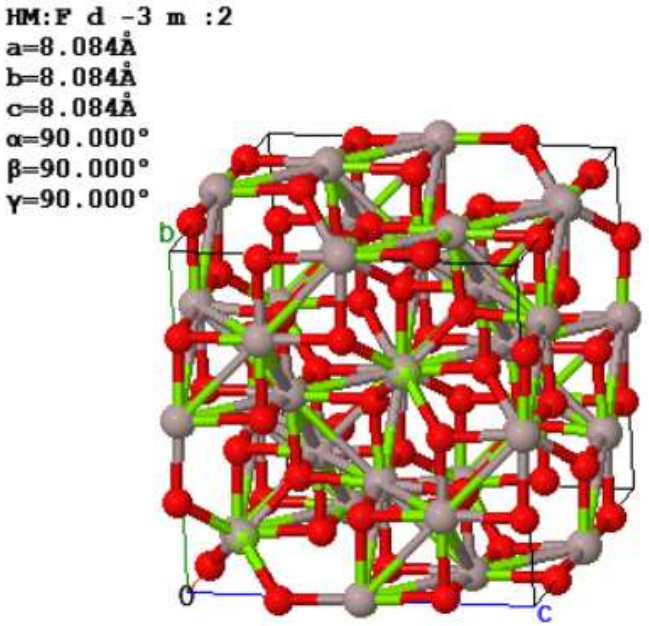
Ferrimagnets

Magnetite Fe_3O_4
(Magneteisen)

Ferrites $MO{\cdot}Fe_2O_3$

M = Fe, Zn, Cd, Ni, Cu,
Co, Mg

Two sublattices A and B.



$MgAl_2O_4$

Spinel crystal structure XY_2O_4

8 tetrahedral sites A (surrounded by 4 O) $5\mu_B \uparrow$

16 octahedral sites B (surrounded by 6 O) $9\mu_B \downarrow$

per unit cell

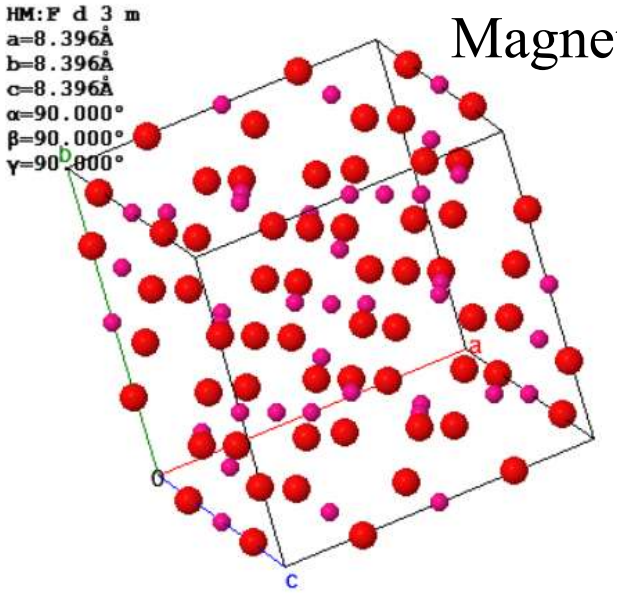
Ferrimagnets

Magnetite Fe_3O_4

Ferrites $MO{\cdot}Fe_2O_3$

M = Fe, Zn, Cd, Ni, Cu, Co, Mg

↑ ↓ ↑ ↓ ↑ ↓ ↑ ↓



Magnetite

Exchange integrals J_{AA}, J_{AB}, and J_{BB} are all negative (antiparallel preferred)

$|J_{AB}| > |J_{AA}|,|J_{BB}|$

Ferrimagnetism

gauss = 10^{-4} T
oersted = $10^{-4}/4\pi \times 10^{-7}$ A/m

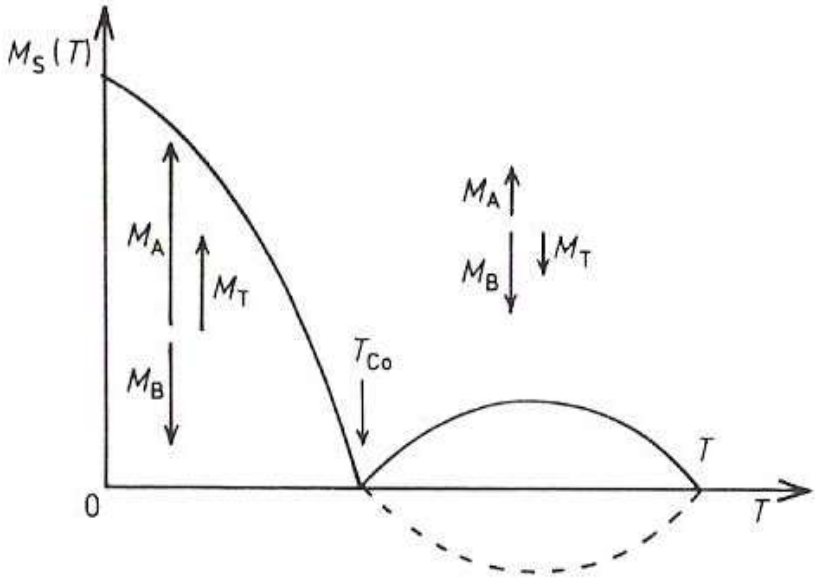


Table 33.3
SELECTED FERRIMAGNETS, WITH CRITICAL TEMPERATURES T_c AND SATURATION MAGNETIZATION M_0

MATERIAL	T_c (K)	M_0 (gauss)[a]
Fe_3O_4 (magnetite)	858	510
$CoFe_2O_4$	793	475
$NiFe_2O_4$	858	300
$CuFe_2O_4$	728	160
$MnFe_2O_4$	573	560
$Y_3Fe_5O_{12}$ (YIG)	560	195

[a] At $T = 0$(K).
Source: F. Keffer, *Handbuch der Physik*, vol. 18, pt. 2, Springer, New York, 1966.

Kittel

D. Gignoux, magnetic properties of Metallic systems

Antiferromagnetism

Negative exchange energy $J_{AB} < 0$.

At low temperatures, below the Neel temperature T_N, the spins are aligned antiparallel and the macroscopic magnetization is zero.

Spin ordering can be observed by neutron scattering.

At high temperature antiferromagnets become paramagnetic. The macroscopic magnetization is zero and the spins are disordered in zero field.

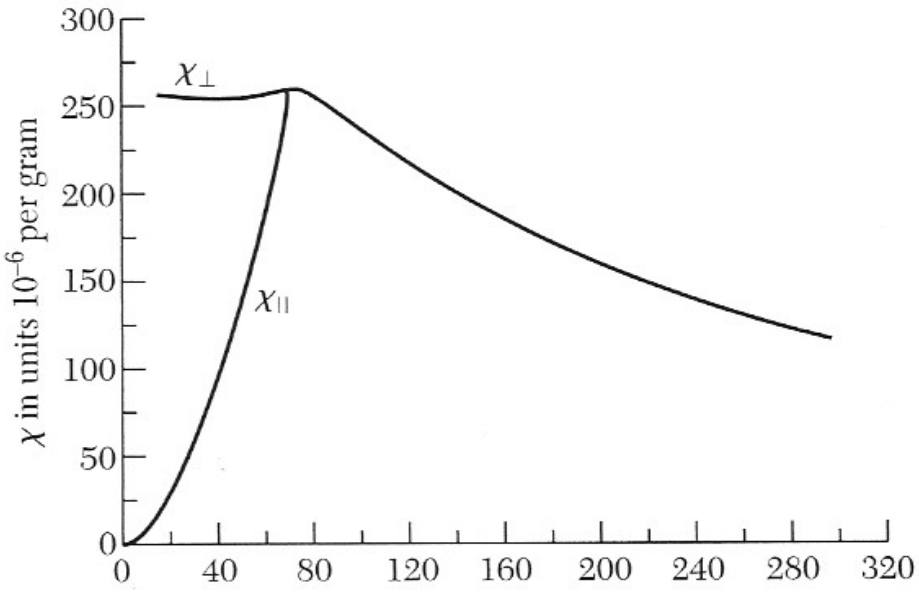
$$\chi = \mu_0 \frac{\vec{M}_A + \vec{M}_B}{\vec{B}_a} = \frac{C}{T + \Theta}$$

Curie-Weiss temperature

Antiferromagnetism ↑ ↓ ↑ ↓ ↑ ↓ ↑ ↓

Average spontaneous magnetization is zero at all temperatures.

Source: Kittel



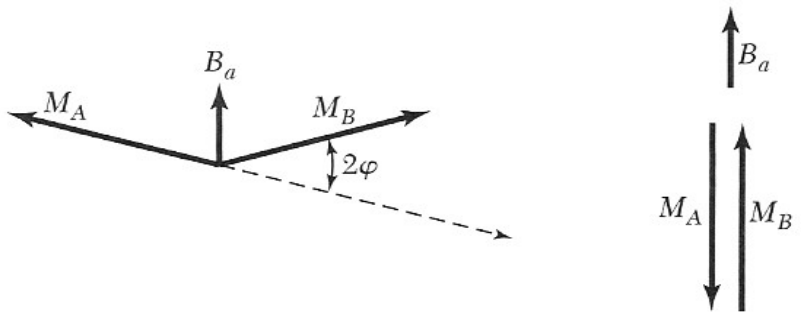
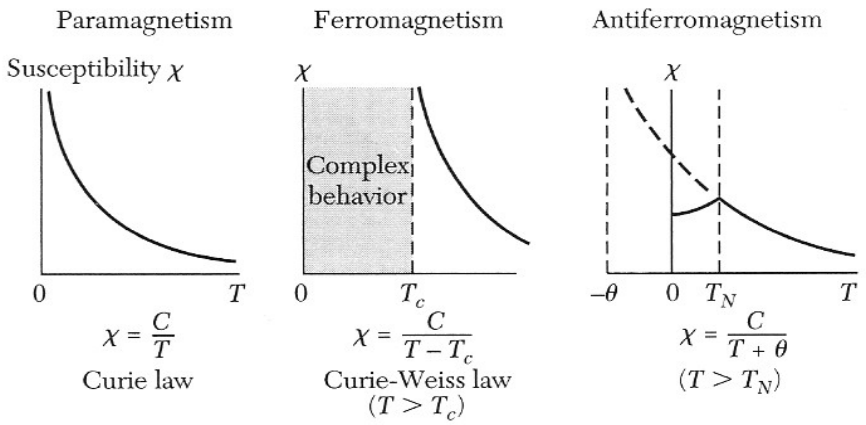


Table 2 Antiferromagnetic crystals

Substance	Paramagnetic ion lattice	Transition temperature, T_N, in K	Curie-Weiss θ, in K	$\frac{\theta}{T_N}$	$\frac{\chi(0)}{\chi(T_N)}$
MnO	fcc	116	610	5.3	$\frac{2}{3}$
MnS	fcc	160	528	3.3	0.82
MnTe	hex. layer	307	690	2.25	
MnF_2	bc tetr.	67	82	1.24	0.76
FeF_2	bc tetr.	79	117	1.48	0.72
$FeCl_2$	hex. layer	24	48	2.0	<0.2
FeO	fcc	198	570	2.9	0.8
$CoCl_2$	hex. layer	25	38.1	1.53	
CoO	fcc	291	330	1.14	
$NiCl_2$	hex. layer	50	68.2	1.37	
NiO	fcc	525	~2000	~4	
Cr	bcc	308			



from Kittel