

# Ferromagnetic Materials

## Advanced

Here is a list of ferromagnetic (including **ferrimagnetic**) materials (from the "Kittel"). Besides the chemical formula, the [Curie temperature](#)  $T_C$  and the [magnetic moment](#)  $m_m$  of the molecules (in units of the [Bohr magneton](#)  $m_B$ ) is listed

Material	$T_C$ [K]	$m_m$
Fe	1043	2.22
Co	1388	1.72
Ni	627	0.606
Gd	292	7.63
Dy	88	10.2
CrO <sub>2</sub>	386	2.03
MnAs	318	3.4
MnBi	630	3.52 + 3.6 Mn −0.15 Bi
EuO	69	6.8
NiO / Fe (Ferrit)	858	2.4
Y <sub>3</sub> Fe <sub>5</sub> O <sub>12</sub>	560	5.0

The list could be much longer, but we see a number of interesting facts.

- There exist more **elemental** ferromagnets than just the common trio **Fe**, **Ni**, **Co** - but not at room temperature!
- Elements that do **not** form a ferromagnetic elemental crystal, may become from ferromagnetic crystals in combination with some other atoms. This is especially true for **Mn** and **Cr** compounds.
- There are many "strange" oxides or mixtures of oxides of non-magnetic elements (**EuO**) or magnetic elements that are ferri- or ferromagnetic. Most compounds with the composition **MOFe<sub>2</sub>O<sub>3</sub>** and **M** being some bivalent metal (including **Fe**) are **ferrimagnets**.
- The total magnetic moment carried by the atoms or molecules can be rather large; it is a combination of the moments of the atoms (and, if applicable, whatever free electrons contribute). It is constructed from positive and negative contributions for ferrimagnets (as shown for the **MnBi** case), It is, however not obvious, if the total magnetic moment from some compound is "ferro" (all contributions same direction or sign) or "ferri" (different signs). While most oxides are "ferro", some (e.g. **CrBr<sub>3</sub>**, **EuO**, **EuS**) are "ferro".

Here is a list of **anti-ferromagnetic materials**;  $T_C$  is now the [Néel temperature](#)

Material	$T_C$ [K]
Cr	308
MnO	116
MnS	160
NiO	525
FeCl <sub>2</sub>	24
FeO	198
CoCl <sub>2</sub>	25

CoO	291
NiCl <sub>2</sub>	50

- We find the by now usual suspects **Fe**, **Ni**, **Co**, **Mn**, **Cr** and their oxides, but also plenty of other compounds (mostly not listed).
- While anti-ferromagnetic ordering provides endless challenges for solid state physicists, it appears that there are no practical uses for this magnetic property at present.