Conversion between cgs and SI units for magnetic measurements

A. T. Boothroyd[1]

[1] *Clarendon Laboratory, Department of Physics, University of Oxford, Oxford, OX1 3PU, United Kingdom*

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This note gives the cgs to SI conversion factors (without derivation) for magnetization and magnetic susceptibility, and the formula for the Curie constant.

I. MAGNETIZATION

The conversion to μ_{B} for magnetization is:

$$
\begin{aligned}
M(\mu_{\mathrm{B}}/\mathrm{f.u.}) &= \frac{M(\mathrm{emu\,mol^{-1}})}{10^3 \mu_{\mathrm{B}} N_{\mathrm{A}}} \\
&= \frac{M(\mathrm{emu\,mol^{-1}})}{5,585}, \qquad (1)
\end{aligned}
$$

where $\mu_{\mathrm{B}} = 9.274 \times 10^{-24}\,\mathrm{JT^{-1}}$ is the Bohr magneton and $N_{\mathrm{A}} = 6.022 \times 10^{23}$ is Avagadro's number, and f.u. stands for *formula unit*, i.e. the atom or group of atoms to which the data were normalised. The conversion to SI units is

$$
\begin{aligned}
M(\mathrm{A\,m^{-1}}) &= 10^3 \rho M(\mathrm{emu\,g^{-1}}) \qquad (2) \\
&= \frac{10^3 \rho}{M_{\mathrm{r}}} M(\mathrm{emu\,mol^{-1}}), \qquad (3)
\end{aligned}
$$

where ρ is the density in $\mathrm{g\,cm^{-3}}$ and M_{r} is the relative formula mass (which is effectively in units of $\mathrm{g\,mol^{-1}}$).

II. SUSCEPTIBILITY

The magnetic susceptibility in SI and cgs units is defined by

$$
\chi(\mathrm{SI}) = \frac{M(\mathrm{Am^{-1}})}{H(\mathrm{Am^{-1}})} \qquad \text{(dimensionless)}
$$

$$
\chi(\mathrm{emu/(mol\,Oe)}) = \frac{M(\mathrm{emu\,mol^{-1}})}{H(\mathrm{Oe})} \qquad (4)
$$

The conversion between units is:

$$
\chi(\mathrm{emu/(mol\,Oe)}) = \frac{N_{\mathrm{A}}}{10 \mu_0 n} \chi(\mathrm{SI}), \qquad (5)
$$

where n is the number density of magnetic ions (i.e. the number of magnetic ions per unit volume, in units of $\mathrm{m^{-3}}$).

The Curie-Weiss law for the magnetic susceptibility is usually written

$$
\begin{aligned}
\chi(\mathrm{SI}) &= \frac{n \mu_0 \mu_{\mathrm{eff}}^2}{3 k_{\mathrm{B}} (T - T_{\mathrm{c}})} \qquad (6) \\
&= \frac{C}{(T - T_{\mathrm{c}})}, \qquad (7)
\end{aligned}
$$

where μ_{eff} is the so-called effective moment, and T_{c} is the magnetic ordering transition temperature which is a positive for ferromagnetism and negative for antiferromagnetism. The factor C in the numerator of eqn (7) is called the Curie constant and is given by

$$
C = \frac{n \mu_0 \mu_{\mathrm{eff}}^2}{3 k_{\mathrm{B}}}. \qquad (8)
$$

If the magnetic ion is in a ground state with total angular momentum quantum number J and associated Landé g-factor g_J then the effective moment is given by

$$
\mu_{\mathrm{eff}}^2 = g_J^2 J(J+1) \mu_{\mathrm{B}}^2. \qquad (9)
$$

By combining eqs (5) and (6) we may write

$$
\begin{aligned}
\chi(\mathrm{emu/(mol\,Oe)}) &= \frac{N_{\mathrm{A}} \mu_{\mathrm{eff}}^2}{30 k_{\mathrm{B}} (T - T_{\mathrm{c}})} \\
&= \frac{C'}{(T - T_{\mathrm{c}})}, \qquad (10)
\end{aligned}
$$

with

$$
C' = \frac{N_{\mathrm{A}} \mu_{\mathrm{eff}}^2}{30 k_{\mathrm{B}}}, \qquad (11)
$$

so that

$$
\begin{aligned}
\frac{\mu_{\mathrm{eff}}^2}{\mu_{\mathrm{B}}^2} &= \frac{30 k_{\mathrm{B}} C'}{N_{\mathrm{A}} \mu_{\mathrm{B}}^2} \qquad (12) \\
&= 8.00 \times C' \qquad (13)
\end{aligned}
$$

Expressions (10)–(13) for the Curie–Weiss law can be used directly to analyse paramagnetic data measured in cgs units in order to determine μ_{eff} and T_{c} from a plot of $\chi^{-1}(\mathrm{emu/(mol\,Oe)})$ vs T.