

CORRECTION FOR FERROMAGNETIC IMPURITIES IN SUSCEPTIBILITY  
MEASUREMENTS BY THE THORPE-SENFLE METHOD

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The Thorpe-Senftle method /1,2/ of measurement of the magnetic susceptibility depends upon the fact that the area under the curve of the force exerted on a sample versus the distance of the center of the magnet gap from the sample is a function of susceptibility and of the maximum strength of applied magnetic field.

If some ferromagnetic impurities are present, their magnetic effects can be only approximately eliminated by the Honda-Owen correction, due to the fact that the impurities are not saturated within the whole travel interval. For minimizing this problem another correction method is proposed, which involves the extrapolation of the susceptibility vs  $1/(H_m + H_{Om})$  to infinite field strengths.

In non-uniform fields the weak magnetic constituents of a specimen and ferromagnetic impurities experience forces proportional to  $HdH/dz$  and  $dH/dz$ , respectively /3/ so that the area under the curve force vs distance from the position where  $H=H_m$  to the position where  $H=0$ , is

$$A = m \int_0^{H_m} H dH + m_f \int_0^{H_s} \sigma_f dH + m_s \int_{H_s}^{H_m} dH = \frac{m \mathcal{K} H_m^2}{2} + m_f \sigma_s H_m + m_s \int_0^{H_s} (\sigma_f - \sigma_s) dH \quad (1)$$

where  $\mathcal{K}$  is the true susceptibility,  $m$  and  $m_f$  are the masses of the sample and impurities,  $H_m$  and  $H_s$  the maximum applied and saturation fields;  $\sigma_f$  and  $\sigma_s$  are the magnetization and the saturation magnetization of the impurities. From the last equation one obtains the apparent susceptibility

$$\mathcal{K}_a \equiv \frac{2A}{m H_m^2} = \mathcal{K} + \frac{2m_f \sigma_s}{m H_m} + \frac{C}{H_m^2}, \quad C = \frac{2m_s}{m} \left( \int_0^{H_s} \sigma_f dH - \sigma_s H_s \right) \quad (2)$$

where C is an unknown constant when  $H \geq H_s$ , related to the impurities. Therefore only for  $C \ll H_m^2$  the linear relation between  $\chi'_a$  and  $1/H_m$  should be valid so that Honda-Owen plot of  $\chi'_a$  vs  $1/H_m$  gives in the limit of  $1/H_m = 0$  the correct value of  $\chi$ . The behavior of the impurities in low fields may be completely eliminated by the following procedure. Let  $H_{om}$  be any particular value of the field greater than  $H_s$  and let  $A_o$  be the corresponding value of the area; one may then write in accordance with (1)

$$\chi'_a \equiv \frac{2(A - A_o)}{m(H_m^2 - H_{om}^2)} = \chi + \frac{2m_f \sigma_s}{m} \frac{1}{H_m + H_{om}} \quad (3)$$

Here the plot of  $\chi'_a$  determined at a number of field strengths, against  $1/(H_m + H_{om})$  enables  $\chi$  to be determined as the intercept for  $1/(H_m + H_{om}) = 0$ .

The apparatus consisted of a microbalance and an electromagnet movable in vertical plane equipped with interchangeable cylindrical and constant force pole caps. The magnetic field was measured using Hall effect magnetometer.

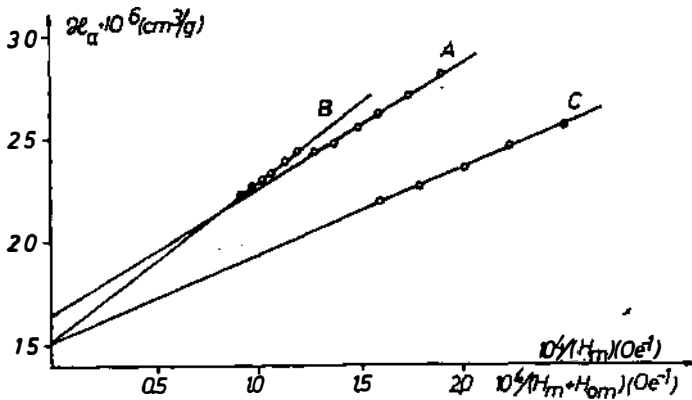


Fig. 1. The apparent susceptibility vs reciprocal field for praseodymium oxide

The apparent susceptibilities of praseodim oxide  $\chi_a$  and  $\chi'_a$  under different fields were determined using Thorpe-Senfle method and equations (2) and (3). The true susceptibility was found by least square method assuming that  $\chi_a$  and  $\chi'_a$  are linear function of  $1/H_m$  and  $1/(H_m+H_{om})$ , respectively. As an additional check of the obtained results, the same sample was measured by the Faraday method in sufficiently high field range to saturate impurities so that Honda-Owen correction method  $\chi_a=f(1/H)$  gives correct results of the true susceptibility. Variation of apparent susceptibilities with reciprocal field is illustrated in Fig.1, and the corresponding values of the true susceptibilities are given in Table I.

Table I. The true susceptibilities of praseodim oxide at room temperature

Method of measurement	Correction plot	Curve in Fig.1	$\chi \cdot 10^6$ (cm <sup>3</sup> /g)
THORPE-SENFTLE	$\chi_a=f(1/H_m)$	A	16,6 ± 0,2
	$\chi'_a=f[1/(H_m+H_{om})]$	B	15,3 ± 0,4
FARADAY	$\chi'_a=f(1/H)$	C	15,1 ± 0,1

The agreement of results obtained by the Thorpe-Senfle and Faraday methods and by linear extrapolation  $\chi'_a=f[1/(H_m+H_{om})]$  and  $\chi'_a=f(1/H)$ , respectively, indicates the usefulness of the  $1/(H_m+H_{om})$  plot in the measurement of susceptibilities by the Thorpe-Senfle method in samples containing ferromagnetic impurities.

#### References:

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