Pressure effects on magnetic properties of LaMnO3 and YMnO3

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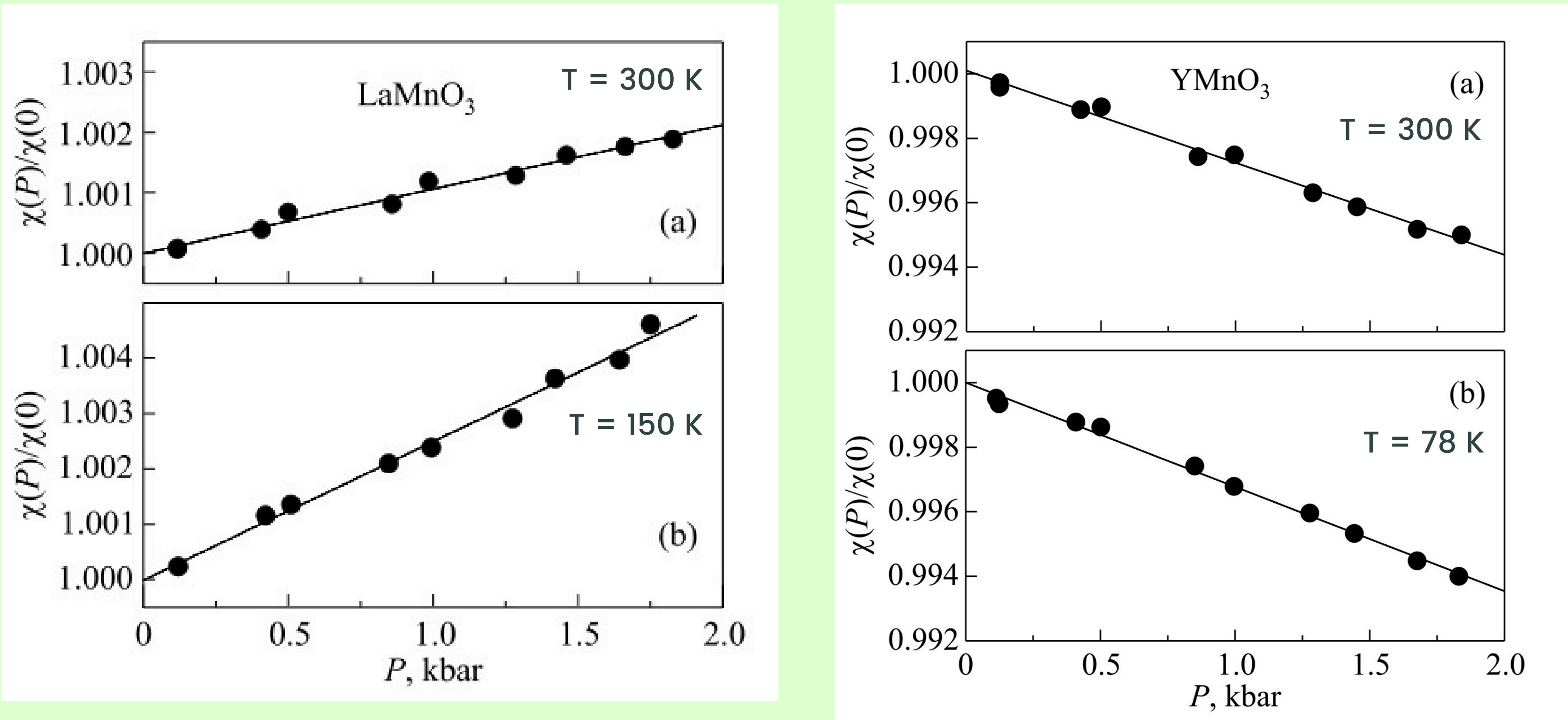
INTRODUCTION:

$LaMnO_3$ and $YMnO_3$ belong to the manganite family and exhibit a range of fascinating properties, notably the colossal magnetoresistance effect. This arises from the complex interplay and coexistence of orbital, charge, and spin degrees of freedom in these materials. Their magnetic properties have been the focus of extensive research. Recent studies indicate that their temperature-dependent magnetic susceptibility adheres to the Curie-Weiss law, with an effective magnetic moment near the spin-only value for the Mn^{3+} ion (S = 2). This χ(T) behavior enables the exploration of pressure effects on susceptibility, offering insights into how pressure influences the Curie temperature Θ and the volume-dependent exchange interactions between the magnetic moments of Mn.

EXPERIMENTAL RESULTS:

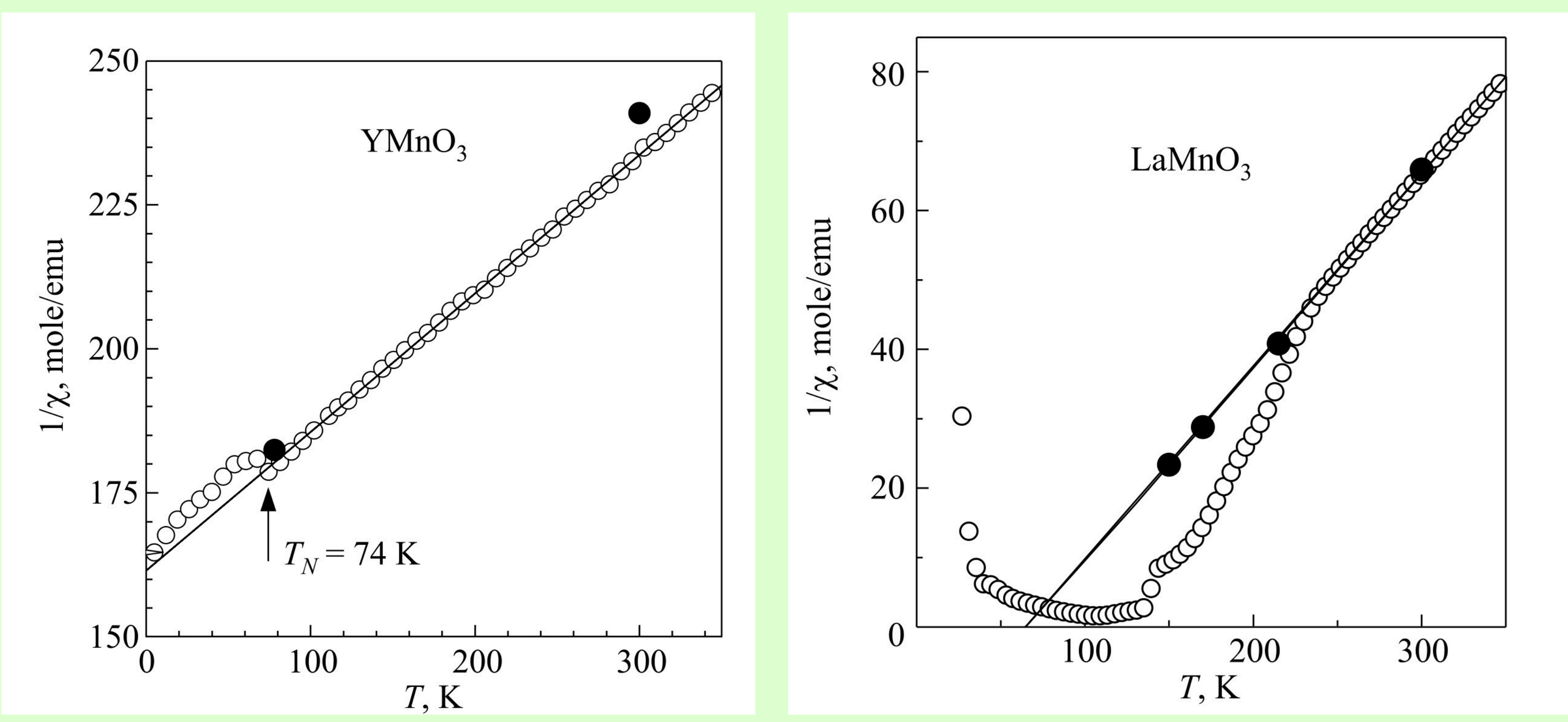
Fig.1 Pressure dependences of magnetic susceptibility of LaMnO3 and YMnO3, normalized to its value at P = 0



Compound	T, K	χ	$d\ln\chi/dP$
$LaMnO_3$	300	15.2	1.1±0.2
	215	24.5	1.8±0.3
	170	34.7	2.51±0.4
	150	42.7	3.0±0.5
$YMnO_3$	300	4.15	–2.8±0.5
	78	5.48	–3.2±0.5

Table. 1. Magnetic susceptibilities χ (10^{-3} emu/mole) of LaMnO3 and YMnO3 at P = 0 and their pressure derivatives d ln χ/dP ($Mbar^{-1}$) at different temperatures

Fig.2 Temperature dependences of inverse magnetic susceptibility in magnetic fields H = 0.05 (◦) and 1.7 (•) T, the latter corresponds to pendulum measurements at P = 0. Solid line shows the Curie–Weiss fit for the experimental low/high field data



DISCUSSION:

The χ(T) dependence of LaMnO3 and YMnO3 in the paramagnetic phase is satisfactorily described by the Curie–Weiss law χ(T) ≃ C/(T -Θ) According to this, the pressure effect on χ(T) can be described as

$$\frac{d\ln\chi(T)}{dP}=\frac{d\ln C}{dP}+\frac{1}{T-\Theta}\frac{d\Theta}{dP}\simeq\frac{\chi(T)}{C}\frac{d\Theta}{dP}$$

Fig.3 Pressure derivative of magnetic susceptibility at different temperatures, d lnχ (T) /dP, as a function of χ(T) at P = 0.

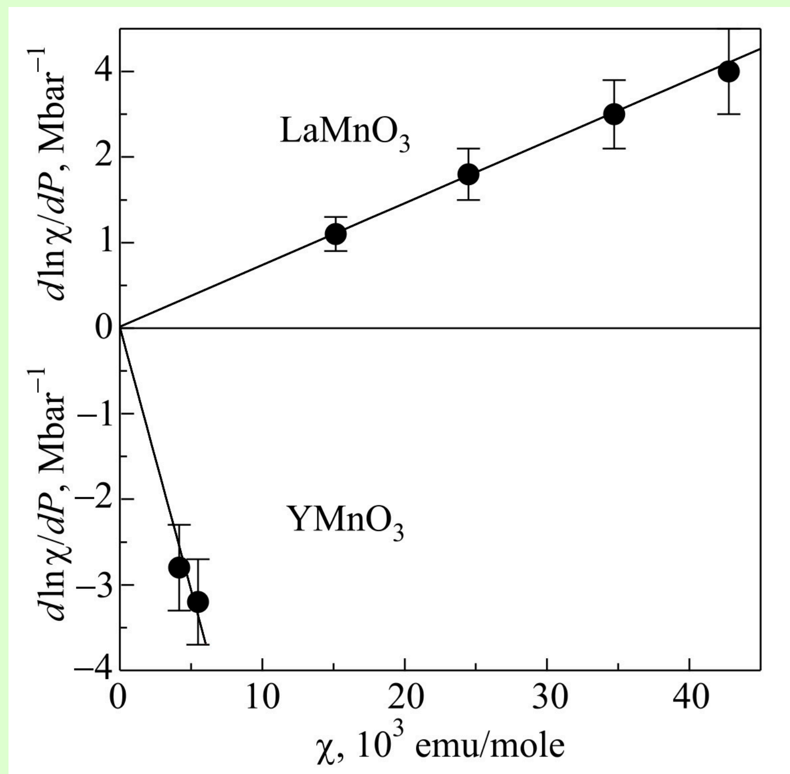


Table 2. Magnetic parameters of RMnO3 and their pressure derivatives: C (K·emu/mole), Θ(K), dΘ/dP(K/kbar), dln|Θ|/dP (Mbar−1)

Compound	C	Θ	$d\Theta/dP$	$d\ln\lvert\Theta\rvert/dP$
$LaMnO_3$	3.5	65	0.25±0.03	3.9±0.4
$YMnO_3$	3.8	–610	–2.4±0.4	3.9±0.6

Table 3. Estimates of magnetic Grüneisen parameter, γ_m = – d lnA/d lnV (A = |Θ| or T_N), for LaMnO3 and YMnO3 based on our results and related literature data

Compound	$-d\ln\lvert\Theta\rvert/dV$	$-d\ln T_N/d\ln V$
$LaMnO_3$	4.2±0.5	4.4±0.6, 4.1±0.5 *
$YMnO_3$	4.4±1.0	4.4±0.8**

The estimated value, $\gamma_m \simeq 4$, turned out to be quite close to the average value of 10/3 observed for a wide range of magnetic insulators with a superexchange type of magnetic interaction. This testifies in favor of the dominant role of superexchange interaction in the magnetism of the investigated compounds.

* J.-S. Zhou and J. B. Goodenough, Phys. Rev. Lett. 89, 087201 (2002)
** T. Lancaster, et al, Phys. Rev. Lett. 98, 197203 (2007).

CONCLUSION:

The experimental study of the effect of hydrostatic pressure on magnetic susceptibility of RMnO3 (R = La and Y) in the paramagnetic phase was carried out for the first time. Based on the Curie–Weiss law, which describes the temperature dependence of the susceptibility, the magnitude of the effect is determined by the pressure dependence of the paramagnetic Curie temperature. The obtained derivatives dΘ/dP made it possible to estimate the magnetic Grüneisen parameter γ_m. Its value in both compounds is practically the same, even though they have significantly different magnitudes of Θ and types of crystal structure.