Magnetic phase transition in multiferroic $Sr_{1-x}Ba_xMn_{1-y}Ti_yO_3$ (with $x \geq 0.43$ and $y \geq 0$) system – specific heat studies

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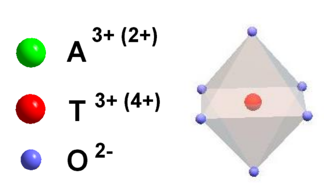
Abstract

The $Sr_{1-x}Ba_xMn_{1-y}Ti_yO_3$ multiferroics are the subject of intensive research, because in them, the same Mn ions are responsible for both the antiferromagnetic and the ferroelectric ordering. Thus, a strong coupling between electric and magnetic order parameters can be expected.
The specific heat studies were performed for a series of ceramic samples differing in Ti and Ba content, over the temperature range 2 – 395 K, in magnetic field up to 9 T. The magnetic contribution was determined by extracting the lattice contribution (estimated by mixing the Debye and Einstein models) from the total specific heat measured and it was analyzed carefully. It was found that for majority of the studied compositions, the anomaly accompanying the magnetic phase transition is symmetric. This evidences the 1st order character of this transition.
This effect was interpreted as the result of a strong coupling between the electric and magnetic degrees of freedom (a large change of electric polarization at the magnetic transition was reported in [1]). Specific heat anomalies were approximated by the Lorentz functions.

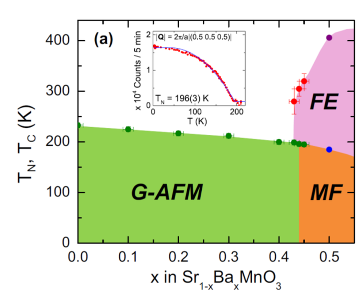
Motivation

The studies were aimed at elucidating the order of the transition to the antiferromagnetic phase and constructing the composition (x, y) - properties phase diagram for the $Sr_{1-x}Ba_xMn_{1-y}Ti_yO_3$ system.

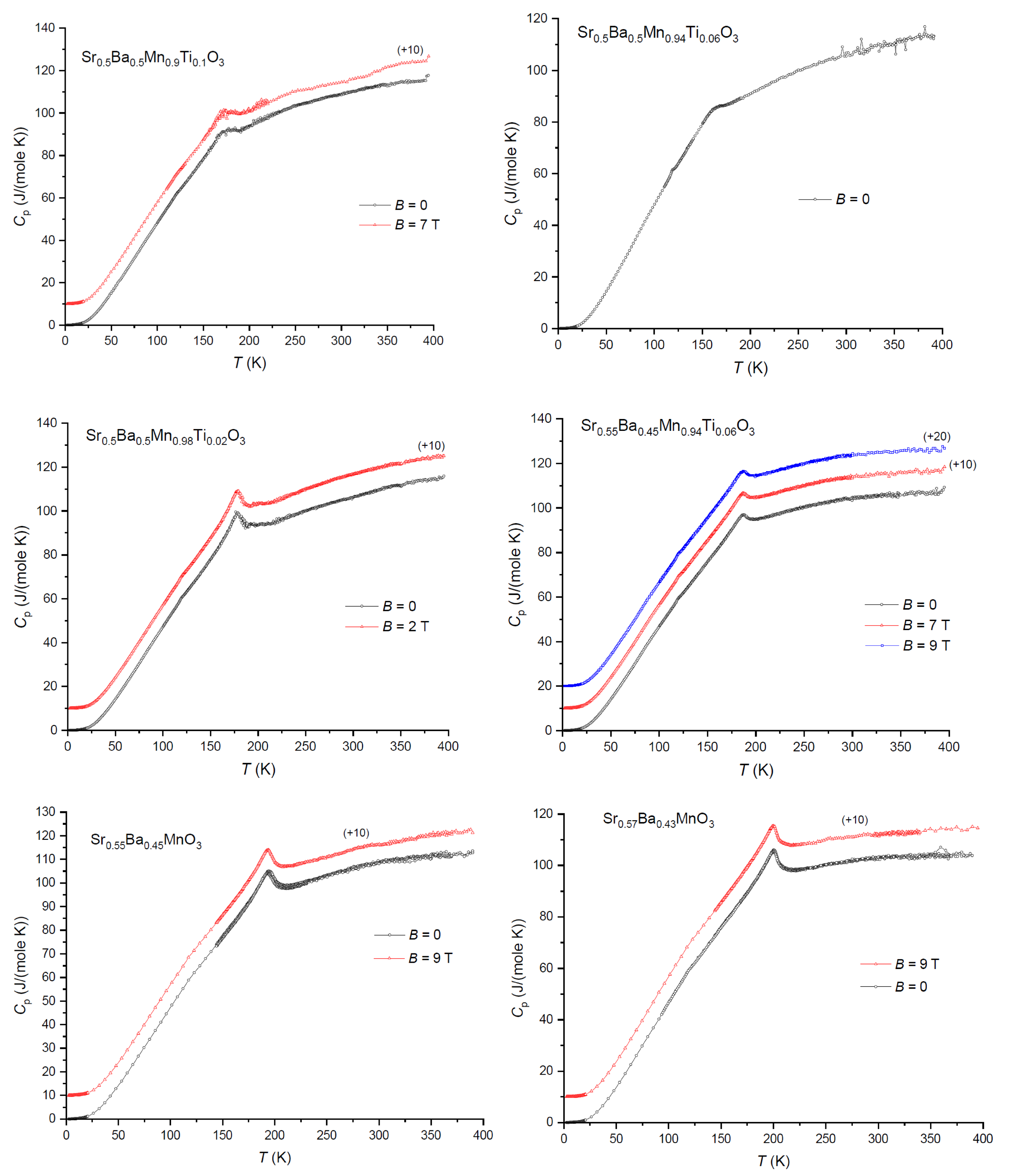


Cubic structure of the ideal perovskite ATO_3 ; T = transition metal, A = Ba, Sr

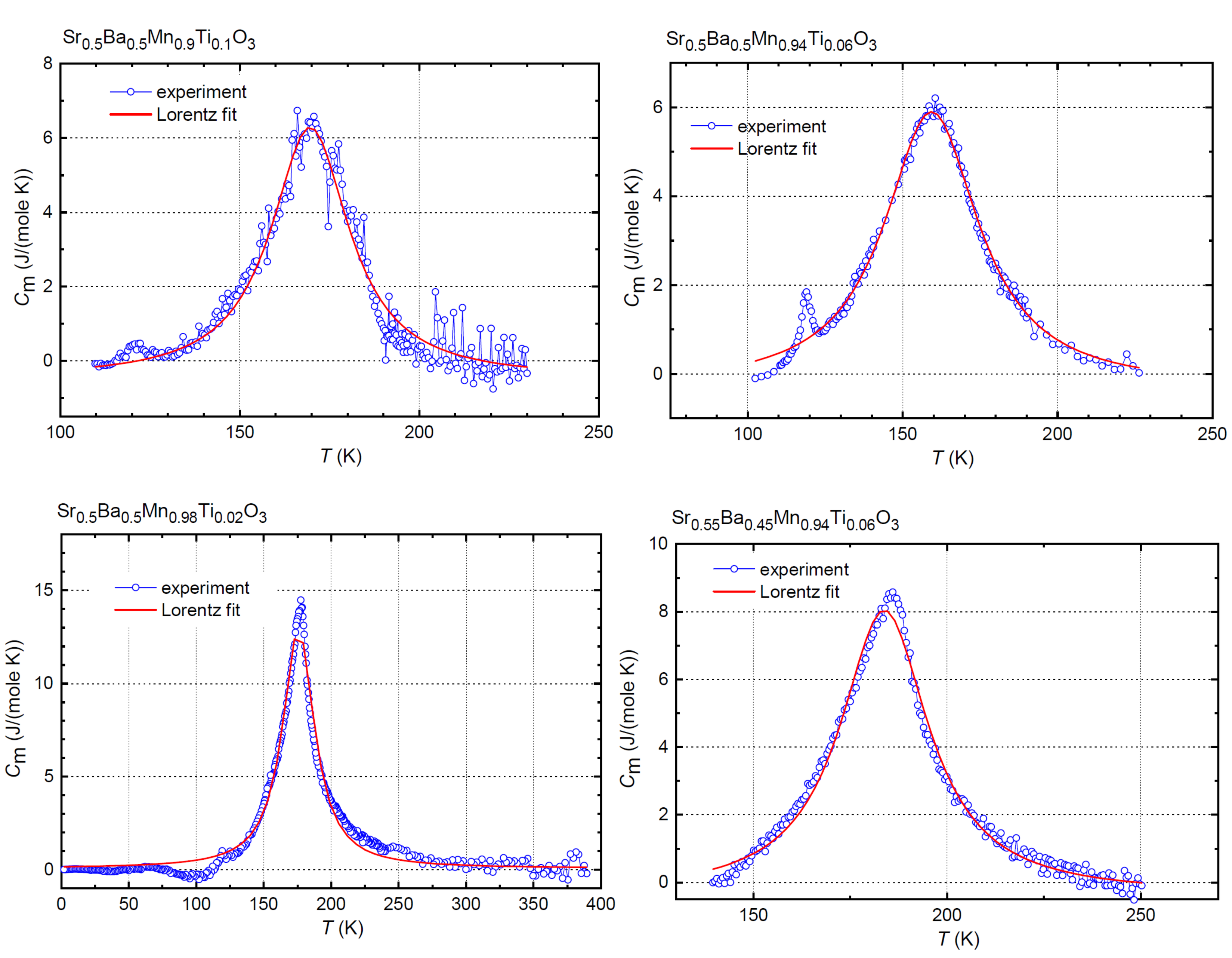
Phase diagram for the $Sr_{1-x}Ba_xMnO_3$



Results of Specific Heat Measurements



The paramagnetic – antiferromagnetic phase transition Lorentz fit



Lattice contribution to the specific heat

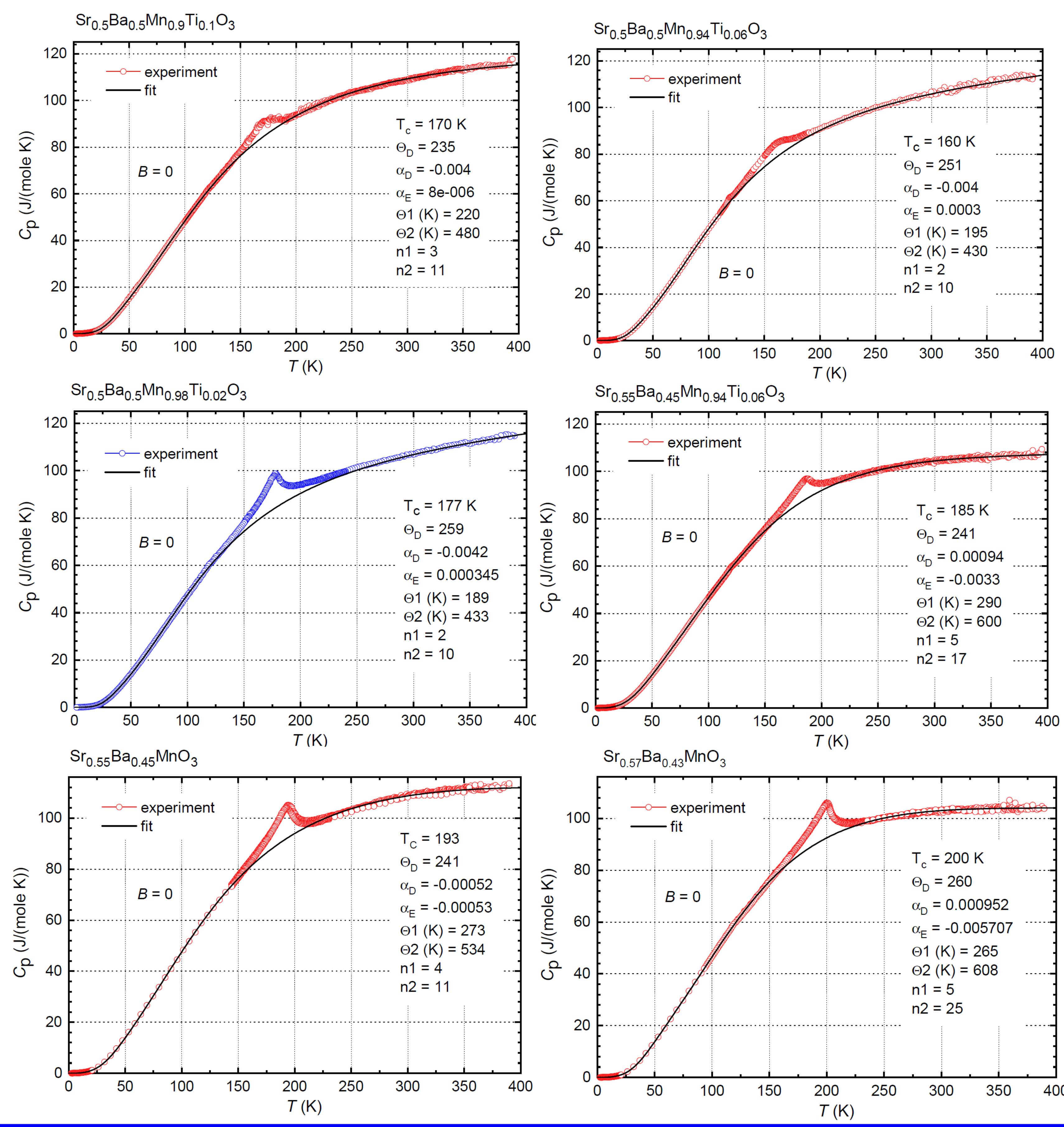
$$C_{ph}(T)=\frac{9k_BN_A}{(1-\alpha_D)}\left[\left(\frac{T}{\Theta_D}\right)^3\int_0^{\frac{\Theta_D}{T}}\left[\frac{x^4e^x}{(e^x-1)^2}\right]dx\right]+\frac{k_BN_A}{(1-\alpha_E)}\left[\frac{n1\left(\frac{\Theta 1}{T}\right)^2e^{\frac{\Theta 1}{T}}}{\left(1-e^{\frac{\Theta 1}{T}}\right)^2}+\frac{n2\left(\frac{\Theta 2}{T}\right)^2e^{\frac{\Theta 2}{T}}}{\left(1-e^{\frac{\Theta 2}{T}}\right)^2}\right]$$

phonon modes considered within the Debye model.

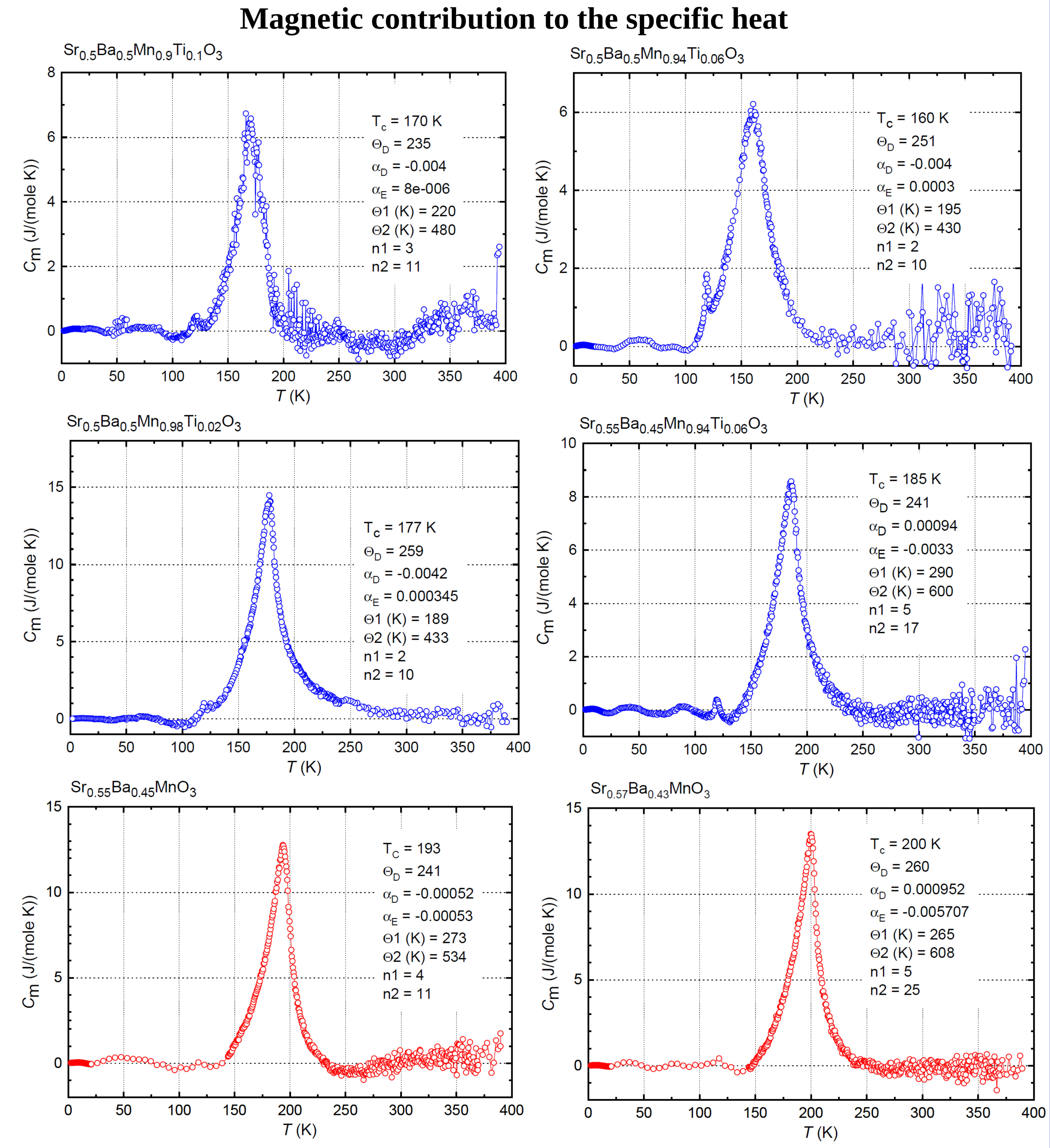
phonon modes considered within the Einstein model.

T_C – temperature of the magnetic phase transition
Θ_D – the Debye temperature
α_D – coefficient of anharmonic effects on the lattice specific heat in the Debye model
α_E – coefficient of anharmonic effects on the lattice specific heat in the Einstein model
n1 – the number of optical modes assigned to the first branch (considered within the Einstein model)
n2 – the number of optical modes assigned to the second branch (considered within the Einstein model)
(The number of optical phonon branches considered within the Einstein model was 2.)

Θ1 – energy of first Einstein's branches (expressed in temperature units),
Θ2 – energy of second Einstein's branches (expressed in temperature units),



The paramagnetic – antiferromagnetic phase transition Magnetic contribution to the specific heat



Acknowledgments

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References

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