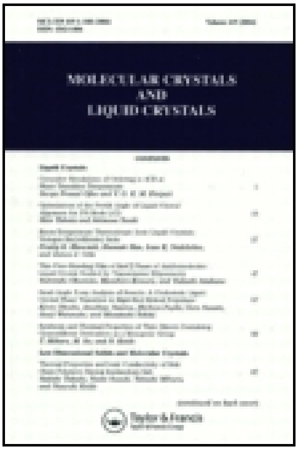


Molecular Crystals and Liquid Crystals
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl16

Soliton Quenching in the One-Dimensional Ising System

Ludwlk Komorowski [a]
[a] Institute of Organic and Physical Chemistry, Technical University of Wrocław, Wyb. Wyspiahskiego 27, 50-370, WROCLAW, Poland
Version of record first published: 17 Oct 2011.

To cite this article: Ludwlk Komorowski (1985): Soliton Quenching in the One-Dimensional Ising System, Molecular Crystals and Liquid Crystals, 120:1, 191-194

To link to this article: http://dx.doi.org/10.1080/00268948508075786

Mol. Cryst. Liq. Cryst. 1985, Vol. 120, pp. 191-194
0026-8941/85/1204-0191/$10.00/0

SOLITON QUENCHING IN THE ONE-DIMENSIONAL ISING SYSTEM

Ludwik KOMOROWSKI

Institute of Organic and Physical Chemistry,
Technical University of Wrocław,
Wyb. Wyspiańskiego 27, 50-370 WROCŁAW, Poland.

Abstract Local excitations of the soliton- and exciton-type in a uniform one-dimensional Ising chain have been indicated. The response of that system to the temperature decrease has been analysed.

Quasi one-dimensional organic materials have been known to show peculiar magnetic property: at low temperature a "Curie tail" is frequently observed in the magnetic susceptibility $\chi(T)$.[1] Numerous arguments have been found that contradict a common belief that this phenomenon might be caused by mere impurity.[2-4] This study aims to provide arguments that similiar behaviour can be predicted even for a simple 1-D Ising chain under a suitable cooling regime. In contrast to the profound statistical analysis by Glauber,[5] and Reiss,[6] the local excitations will only be considered here. Two lowest one-site excitations are:

$$\ldots \uparrow \underline{\downarrow \uparrow \uparrow} \downarrow \ldots \qquad \ldots \uparrow \underline{\downarrow \downarrow \downarrow} \uparrow \ldots$$

the first being simply a domain wall or a kink. They will be called, somewhat arbitrarily, "soliton" and "exciton", respectively, troughout this work, to manifest a fundamental difference between both. In contrast to the exciton (E), annihilation of a soliton (S) cannot occur unless by collision with another partner, i. e.: S + S → E → ground state. consequently, the annihilation rate for solitons can be approximated as :

$$\frac{dx}{dt} = -N\nu_0 \exp(-J/kT)\, x^2 P_s \; ; \qquad P_s = (\tfrac{1}{2})^{1/x}$$

P_s denotes probability of collision of two solitons by stochastic hopping with frequency $\nu = \nu_0 \exp(-J/kT)$. Temperature is changed hyperbolically in time: $1/T = 1/T_0 + \beta t$.[6]

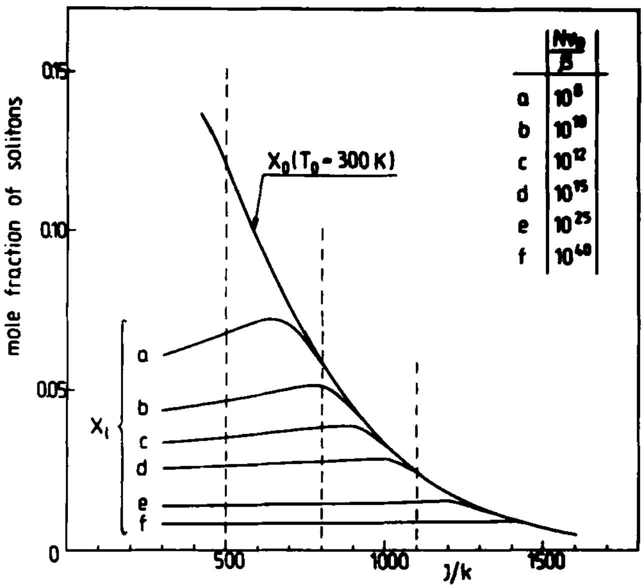
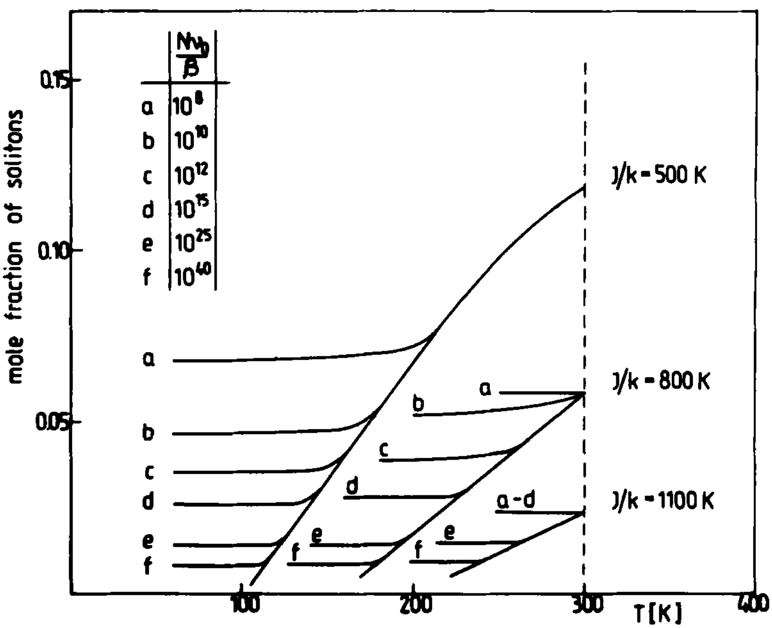


FIGURE 1 Mole fraction of solitons as a function of the spin exchange energy; x_0 - at 300 K; x_1 - at low temperature limit.

FIGURE 2 Mole fraction of solitons vs. temperature for various parameters of the system.



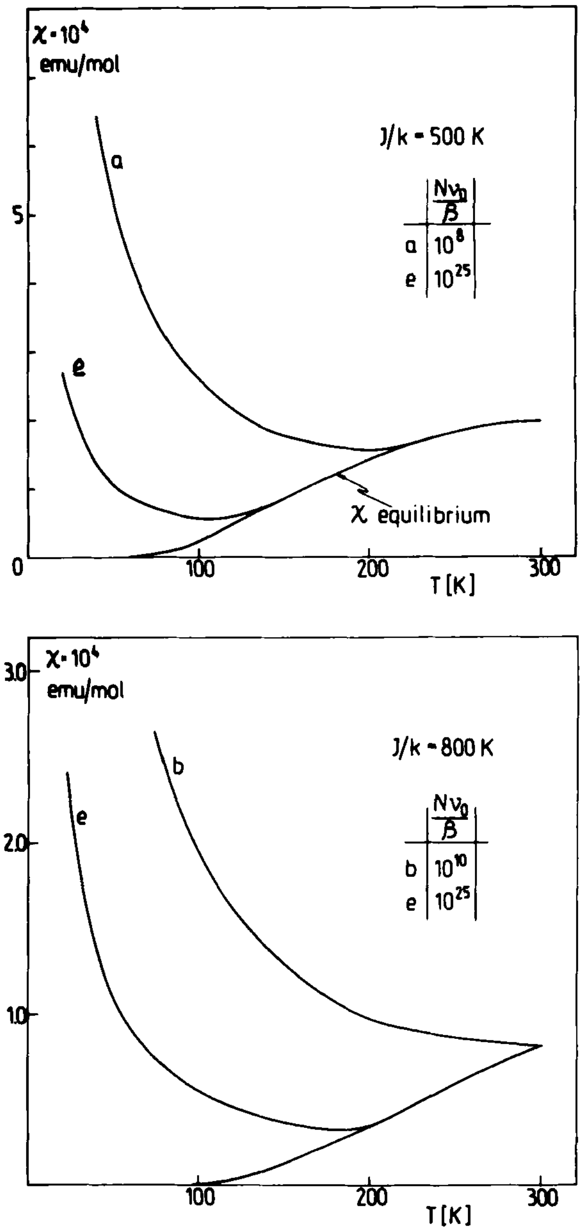


FIGURE 3a, b
Temperature dependence of the magnetic susceptibility; $T_o = 300$ K.

Solution of that kinetic equation leads to results depicted in Figs. 1, 2. Starting from an equilibrium concentration of solitons, x_0 at $T_0 = 300$ K, temperature decrease inevitably produces some non-zero limmiting concentration x_1 at low temperature. This must be regarded as freezing of solitons due to undercooling the system; the equilibrium situation would simply be $x \rightarrow 0$ for $T \rightarrow 0$. Fig. 2 shows the transition from an equilibrium decay of x to the freezing region (flat), where concentration of solitons remains constant. Figs. 3a, b demonstrate appropriate variation of magnetic susceptibility: the "Curie tail" behaviour is readily recognized. Strangely enough, large variation of parameters ($N \nu_0/\beta$) causes relatively minor change in $\chi(T)$ relationship. This tends to suggest that for a given system, where only β can be varied (and usually by no more than 2 ÷ 3 orders of magnitude), changing β will not have much effect on $\chi(T)$ function observed experimentally. The Curie-type behaviour would then appear as an intrinsic property of the system (1). On the other hand, one may expect the experimental curve $\chi(T)$ to be sample dependent, as the chain length parameter N may have some relation to the crystal perfection.

The way to experimental verification of the hypothesis described above remains open; recent reports on quenching phenomena in organic superconductors claim for paying more attention to kinetic effects on experimental data at low temperatures, in particular for the quasi one-dimensional systems.

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