

# Selforganization Processes In Some Organic Acids With Liquid Crystal Structure

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**Abstract**—This paper presents some considerations regarding the selforganization processes that occur in some organic acids with liquid crystal structure. As result of the selforganization, the system switches from a disordered state to an ordered one. The study was performed by thermodynamic means, using the Landau theory of the phase transition.

**Keywords**—liquid crystal; bifurcation; selforganization

## I. INTRODUCTION

The thermodynamic study of a system shows that the order in a system may be induced by a synergetic action that assures a selforganization of the system. The selforganization is determined by the cooperation between the micro-components (constituents) of the system. As result, the macroscopic state is a periodic spatial structure.

The transition of such system from the disorder state to the order state occurs by a bifurcation, in consequence the system selforganize; the coherence of the components action in carried out by their cooperation [1-3].

## II. EXPERIMENTAL FACTS

As an example of such selforganization is the behavior of the arachidic acid, a fatty saturated organic acid, essential in the constitution of the cellular systems. At the room temperature that acid is a polycrystalline powder.

Experimentally [4], one observes that when the arachidic acid is heated up from low temperature it undergoes some phase transitions. The way in which the process evolves in time depends on the

temperature rate,  $r = \frac{dT}{dt}$ .

Thus, if  $r$  is greater than  $r_0 = 4^\circ\text{C}/\text{min.}$ , at the temperature  $T_{C1} = 76^\circ\text{C}$  the substance changes from the solid crystal state (SC) in the isotropic liquid state (LI).

If  $r$  is lower than  $4^\circ\text{C}/\text{min.}$ , the substance presents a critical temperature  $T_{C2} = 69^\circ\text{C}$ , when a phase transition from the SC phase into the smectic crystal liquid (LCS) occurs, and then, at  $T_{C1}$  the transition  $\text{LCS} \rightarrow \text{LI}$  occurs also.

Schematically, the phenomenon may be presented as follows:

TABLE I.

$r < 4^\circ\text{C}/\text{min}$	$T_{C2} = 69^\circ\text{C}: \text{SC} \rightarrow \text{LCS}$
	$T_{C1} = 76^\circ\text{C}: \text{LCS} \rightarrow \text{LI}$
$r > 4^\circ\text{C}/\text{min}$	$T_{C1} = 76^\circ\text{C}: \text{SC} \rightarrow \text{LI}$

The LCS state, in that the analyzed substance arrives in the above conditions can be explained by a selforganization phenomenon: at  $T_{C2}$  the molecules of the arachidic acid start to cooperate so that most of them align on a certain direction; the cooperation at microscopic level has as result the obtaining of a liquid crystal state at macroscopic level.

## III. THERMODYNAMIC APPROACH AND RESULTS

Thermodynamically, the phenomena can be analyzed on the base of Landau theory for the second order phase transitions [5-7]. In that framework, it is shown that the thermodynamic potential (Gibbs) one can be written as:

$$G(p, T, \lambda) = G_0(p, T) + A(p, T) \cdot \lambda^2 + C(p, T) \cdot \lambda^4 \quad (1)$$

where  $p$  is the system pressure,  $T$  - the temperature and  $\lambda$  - the order parameter, that, in this case is a functional  $f(\cos\theta)$ , where  $\theta$  is the molecule's orientation angle, relative to a certain preferential direction.

From physical considerations,  $C > 0$ , and  $A > 0$  in higher symmetry phase and  $A < 0$  in lower symmetry phase.

For a transition at a certain fixed pressure, in the vicinity of the transition point  $T_c$ , one can write:

$$A(T) = a \cdot (T - T_c) \quad (2)$$

where  $a = \left. \frac{\partial A}{\partial T} \right|_{T=T_c}$  is constant.

Also,  $C(T)$  may be considered equal to a constant,  $C(T_c)$ .

Imposing the condition that  $G(\lambda)$  have a minimum in the transition point, one obtain:

$$\lambda(A + 2C\lambda^2) = 0,$$

and hence:

$$\lambda^2 = -\frac{A}{2C} = \frac{a}{2C}(T_c - T) \quad (3)$$

The solution  $\lambda = 0$  corresponds to the higher symmetry phase.

The system entropy near the transition point is therefore:

$$S = -\frac{\partial S}{\partial T} = S_0 - \frac{\partial A}{\partial T} \cdot \lambda^2 \quad (4)$$

In the higher symmetry phase,  $\lambda = 0$  and  $S = S_0$ , while in lower symmetry phase  $\lambda$  is given by (3), so:

$$S = S_0 + \frac{A}{2C} \frac{\partial A}{\partial T} = S_0 + \frac{a^2}{2C} (T - T_C) \quad (5)$$

Taking in account the relation (3), (5) becomes:

$$S = S_0 + \frac{2C\lambda^4}{T - T_C} \quad (6)$$

The entropy evolution near the transition point is plotted in figure 1. The transition point P is a bifurcation point for the synergetic system, in the sense that, at  $T < T_C$ , the system is in higher symmetry states, where  $S = S_0$ , and at  $T > T_C$  the system evolution may occur in two ways: an instable one, for  $S = S_0$  (P→A) that is possible in the condition of a slow temperature increase and the second, a stable one, when  $S = S_0 + \frac{2C\lambda^4}{T - T_C}$  (P→B).

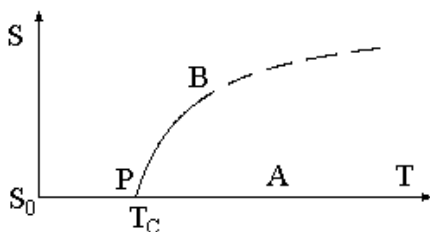


Fig. 1. The evolution of the entropy at the phase transition for  $r > r_0$

On that base, one can ascertain that the arachidic acid behave exactly like in the case described in figure 1, if  $r > 4^\circ\text{C}/\text{min}$ .

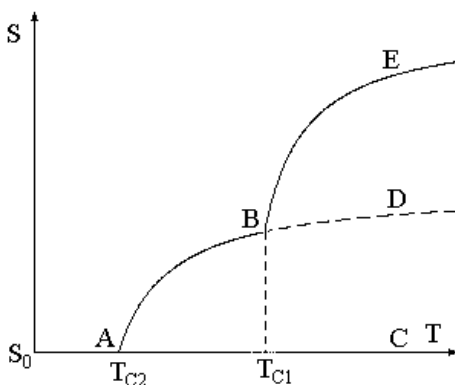


Fig. 2. The evolution of the entropy at the phase transition for  $r < r_0$

When  $r < 4^\circ\text{C}/\text{min}$ , the phenomena are described by the diagram plotted in figure 2, where are two bifurcation points, A and B, at the two critical temperatures,  $T_{C2}$  and  $T_{C1}$ ; the instable trajectories are A→C and B→D, the stable ones are A→B and B→E.

That evolution is described by the entropy expression, as follows:

$$S = \begin{cases} S_{01} + \frac{2C\lambda^4}{T - T_{C1}} & \text{for } T \geq T_{C1} \\ S_0 + \frac{2C\lambda^4}{T - T_{C2}} & \text{for } T_{C1} \geq T \geq T_{C2} \\ S_0 & \text{for } T \leq T_{C2} \end{cases} \quad (7)$$

where  $S_{01} = S_0 + \frac{2C\lambda^4}{T_{C1} - T_{C2}}$ .

The process can be represented in the equilibrium states space,  $S = S(T, r)$ , by a surface that have two boundaries, corresponding to the phase transitions at  $T_{C1}$  and  $T_{C2}$  (figure 3).

As one can see, the surface has three regions, corresponding to the three possible states for the analyzed substance, SC, LCS and LI, separate just by these boundaries.

In addition, one can observe that the different behavior of the system oneself depending the temperature rate  $r$ , represents a bifurcation phenomenon, having the order parameter this temperature rate. Thus, the value  $r = 4^\circ\text{C}/\text{min}$ . represents a bifurcation point, because at lower, respectively higher values than the temperature rate  $r_0$ , the system behaves differently.

#### IV. CONCLUSIONS

As it is evident from the above discussion, we have a very good concordance between the experimental results and the theory, which shows that it can be used in other similar situations.

The analyzed phenomena show the complexity of the selforganization processes due to the cooperation at the microscopic level of the system components that determine, at macroscopic level, spatial structures. Such phenomena occur in many organic and biological materials.

As result of the selforganization, the system switches from a disordered state to an ordered one. The thermodynamic study, using the Landau theory of the phase transition showed a good concordance with the experimental results.

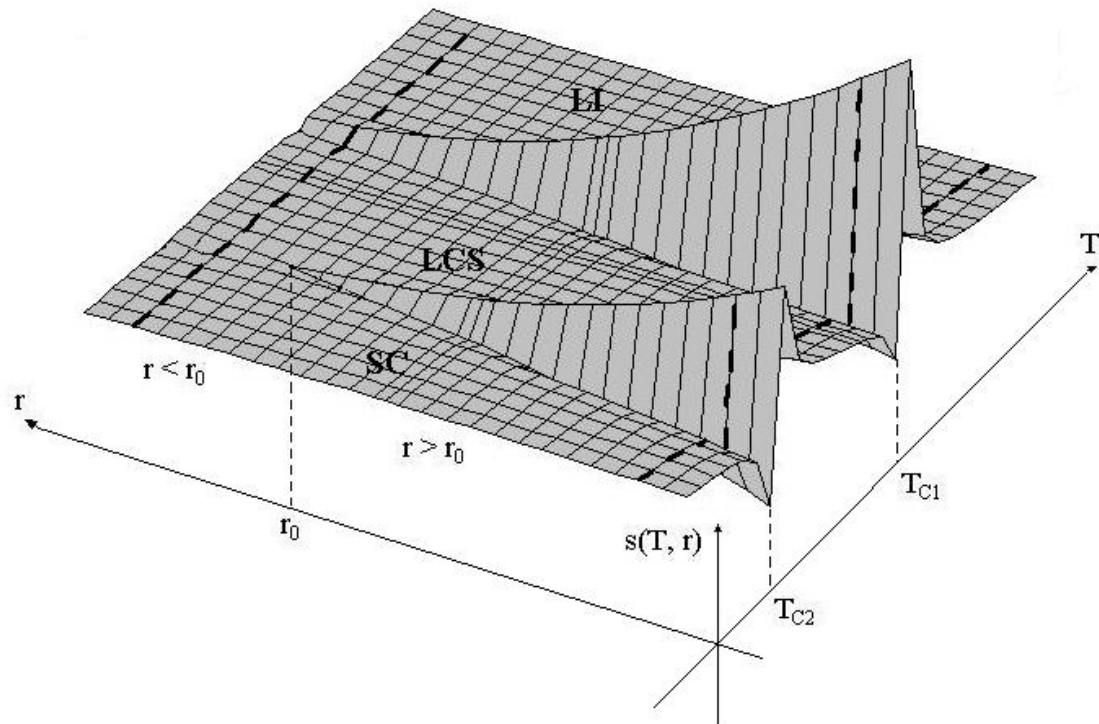


Fig. 3. The equilibrium states surface for the analyzed phenomenon

It is obvious that in biological systems with a more complex structure, these processes play an important role and they may underlie, for example, some effects that are caused by the interaction of electromagnetic fields with biological systems.

Knowing the mechanism for such processes opens wide possibilities to explain complex biological phenomena, as well as a wide field for various applications.

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