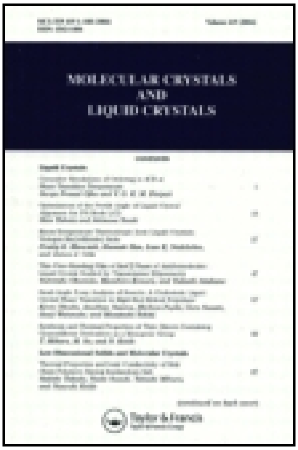

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Experimental Test of Hydrodynamic Theories for Nematic Liquid Crystals

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Experimental Test of Hydrodynamic Theories for Nematic Liquid Crystals†

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For nematic phases of pentacyanobiphenyl (5CB) and 4-n-methoxybenzoate-4-n-pentylphenyl (MBPP) the viscosity coefficients have been determined by means of a flat capillary viscometer. The detailed information on the experimental set-up has been published elsewhere.[1,2] The measurements enable the calculation of all Leslie coefficients α_i $i = 1 - 6$.[3,4,5] Having the Leslie coefficients determined, the twist viscosity coefficient γ_1 can be calculated. The comparison of the calculated and experimentally determined[6,7,8] twist viscosity coefficient may serve as a test of validity of the Parodi relaxation:[9] $\alpha_2 + \alpha_3 = \alpha_6 - \alpha_5$. The validity of this relation was additionally proved by means of comparison of the results of the viscometric measurements and the results of measurements of the attenuation of longitudinal ultrasound waves.[2]

INTRODUCTION

As known elsewhere the viscosity of nematic liquid crystals is determined by the orientation of the nematic director with respect to the walls.[10] This orientation in a capillary can be described by two angles[1] Θ and ϕ shown in Figure 1.

The viscosity coefficients were determined by the following director orientations (in a magnetic field):

1. $\Theta = \Pi/2,\ \phi = \Pi/2,\ \eta_a = \alpha_4/2$
2. $\Theta = 0,\ \eta_b = (\alpha_3 + \alpha_4 + \alpha_6)/2$
3. $\Theta = \Pi/2,\ \phi = 0,\ \eta_c = (-\alpha_2 + \alpha_4 + \alpha_5)/2$
4. $\Theta = \Pi/4,\ \phi = 0,\ \eta_{45} = (\alpha_1 - \alpha_2 + \alpha_3 + 2\alpha_4 + \alpha_5 + \alpha_6)/2$

†Paper presented at the 10th International Liquid Crystal Conference, York, 15th–21st July 1984.

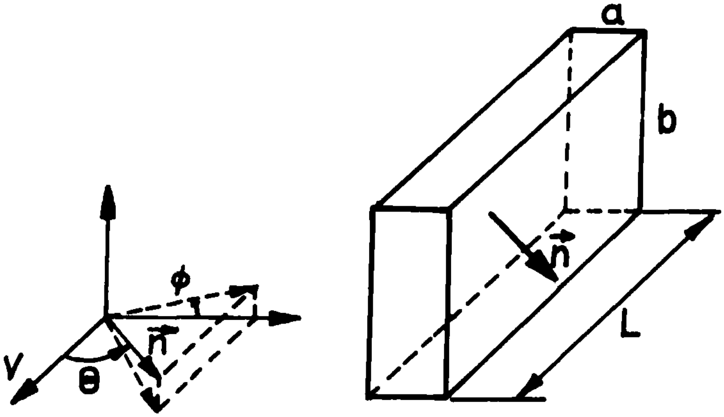

FIGURE 1 The director orientation with respect to the capillary walls.

Independently, the η_0 coefficient characteristic for the flow in absence of the orienting magnetic field was determined. In such a case[11,12] angles Θ_0 and ϕ_0 are given by:

$$\phi_0 = 0$$

$$\cos 2\,\Theta_0 = \frac{\alpha_2 - \alpha_3}{\alpha_2 + \alpha_3}$$

and the viscosity coefficient:

$$\eta_0 = (\alpha_2 + \alpha_4 + \alpha_5)/2 + \frac{\alpha_1\,\alpha_2\,\alpha_3}{(\alpha_2 + \alpha_3)^2}$$

There are five equations following formulae for η_0, η_a, η_b, η_c and η_{45}; together with Parodi relation they enable the calculation of all Leslie coefficients.

RESULTS AND DISCUSSION

The temperature dependence of the viscosity coefficients in nematic and isotropic phases is shown in Figure 2 and 3 for 5CB and MBPP, respectively.

The straight lines are the result of least square fitting the equation:

$$\eta = a \exp W/kT$$

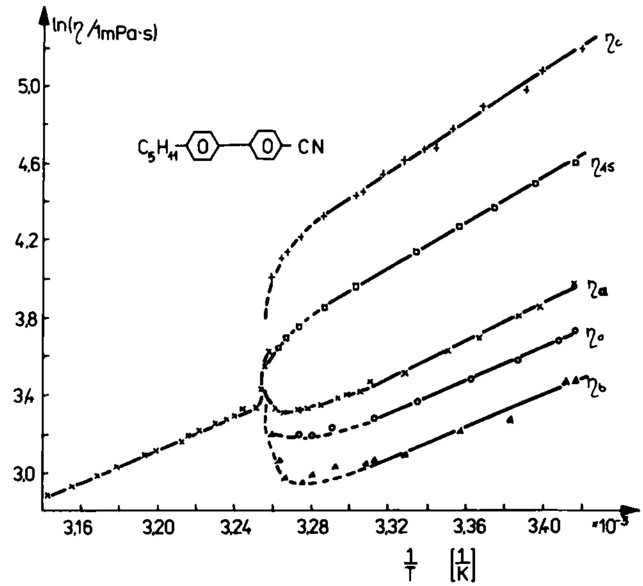

FIGURE 2 Temperature dependence of viscosity coefficients in nematic and isotropic phases for 5CB.

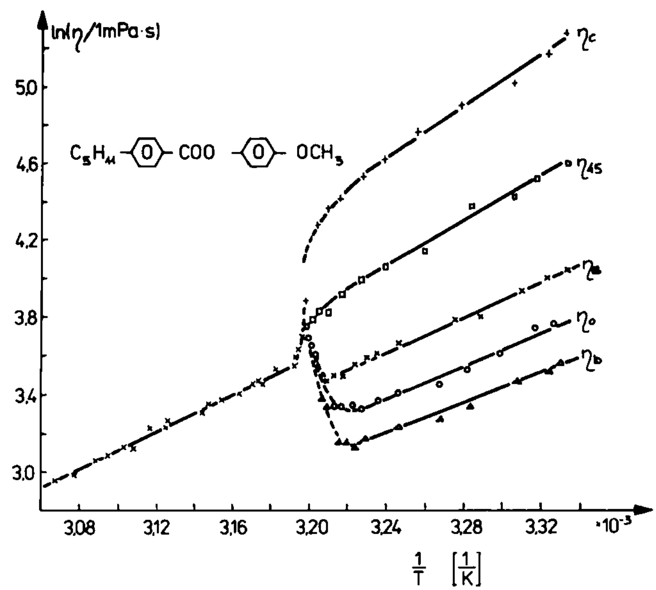

FIGURE 3 Temperature dependence of viscosity coefficients in nematic and isotropic phases for MBPP.

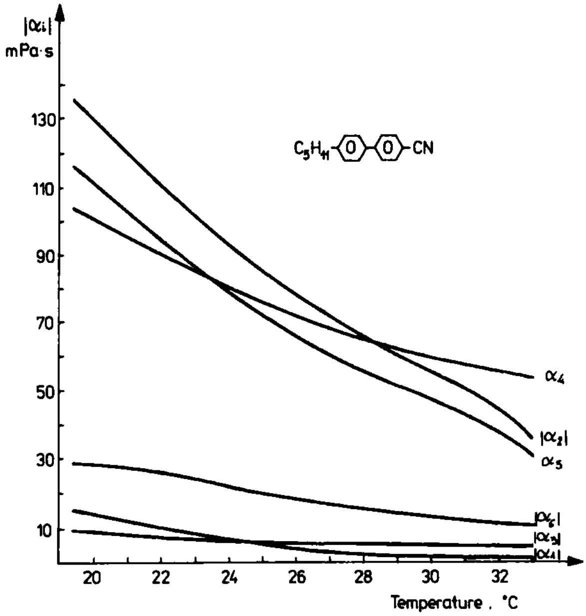

FIGURE 4 Temperature dependence of absolute values of Leslie coefficients for 5CB.

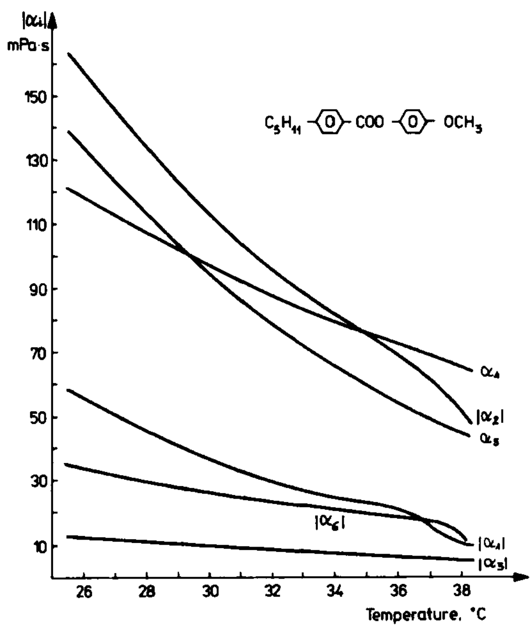

FIGURE 5 Temperature dependence of absolute values of Leslie coefficients for MBPP.

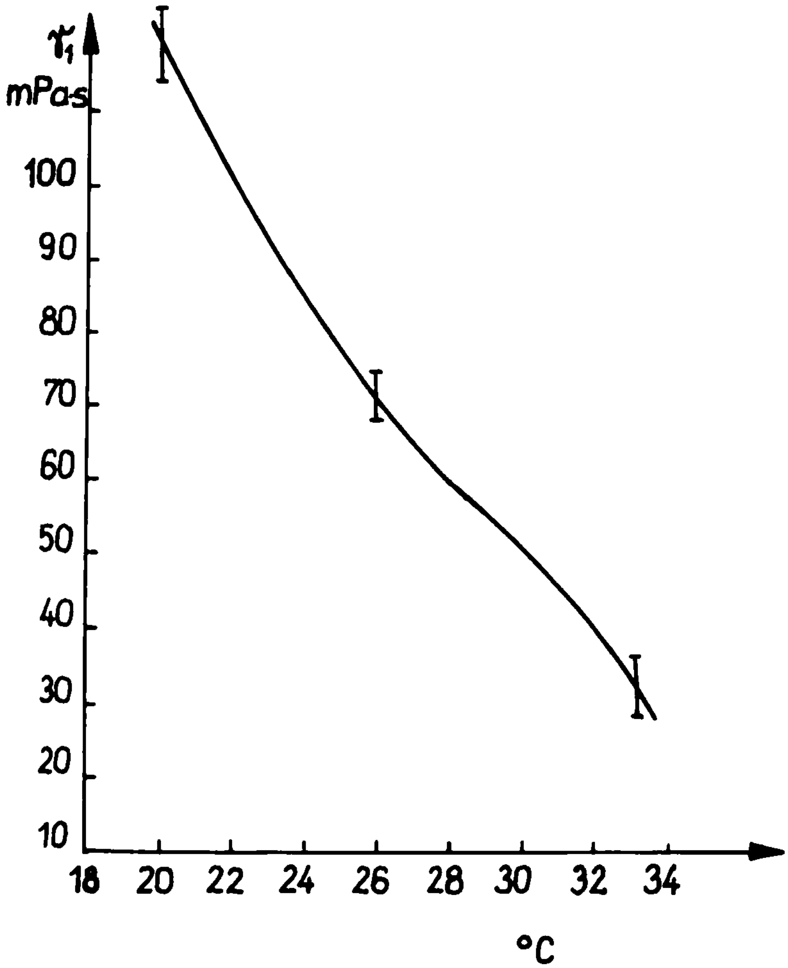

FIGURE 6 Temperature dependence of twist viscosity coefficient γ_1 for 5CB.

apart from the temperature range ± 2 K near the N – I transition point where critical phenomena seem to be dominant.

From the above data, the temperature dependence of the Leslie coefficients was determined. The absolute values of Leslie coefficients for 5CB and MBPP are shown in Figures 4 and 5, respectively. However, α_1, α_2, α_3 and α_6 are negative, α_4 and α_5 are positive.

In Figure 6 the temperature dependence of twist viscosity coefficient γ_1, calculated for 5CB from the above data, is shown. The values are in good agreement with the results of Kneppe,[6] Skarp[7] and Seidler.[8] The knowledge of the Leslie coefficients α_i has enabled the comparison of our data with viscosity data obtained from ultrasound measurements by Kiry and Martinoty.[13] Again, a satisfactory agreement was obtained. In the opinion of the authors, the viscometric and the attenuation of longitudinal waves (5 MHz)[2] measurements have proved the validity of the hydrodynamic description, not only of the macroscopic flow but also of low-signal acoustic wave propagation in nematic liquid crystals.[14]

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