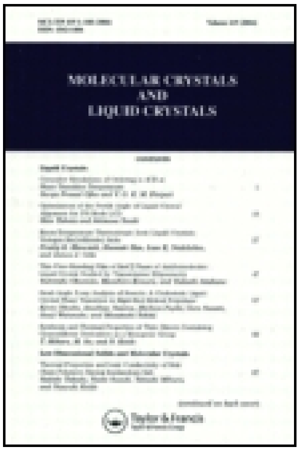


Molecular Crystals and Liquid Crystals
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl16

Experimental Data on the Elasticities and Viscosities of Some Nematics

D. C. Van Eck [a] & M. Perdeck [a]
[a] Fysisch Laboratorium der Rijksuniversiteit Utrecht, The Netherlands
Version of record first published: 08 Feb 2011.

Mol. Cryst. Liq. Cryst. Vol. 49 (Letters), pp. 39-45

EXPERIMENTAL DATA ON THE ELASTICITIES AND VISCOSITIES OF SOME NEMATICS

D.C. VAN ECK and M. PERDECK
Fysisch Laboratorium der Rijksuniversiteit Utrecht, The Netherlands

(Submitted for publication September 1, 1978)

We have measured the elastic ratios of two types of nematic liquid crystals: 4 methoxy 4' azoxybenzene (N_4) and p-p' dibutyl azoxy benzene (Dibab). The experiments involved the use of a light scattering technique and analysis of the scattered light versus the scattering angle. From these measurements and the results of other investigators (De Jeu[1], Prost[2], Van Eck[3]) we were able to extract and to discuss the coefficients of elasticity and viscosity.

INTRODUCTION

There are several ways of obtaining information about the viscosities and elasticities of an nematic liquid crystal (n.l.c.). A very effective tool for this purpose is the Rayleigh light scattering technique. A laser beam is strongly scattered by an n.l.c. due to director fluctuations[4].

From an analysis of the light intensity measured versus the scattering angle, ratios of the elastic constants can be determined. In addition from the measured linewidths of the scattered light, visco-elastic ratios can be deduced[3,4].

This letter describes such measurements on 4 methoxy 4' azoxy benzene (N_4) and p-p' dibutyl azoxy benzene (Dibab) which have their clearing temperature T_c at 347 K and 304 K respectively. Visco-elastic and elastic ratios were determined from the experimental results using essentially De Gennes theory.

THEORY AND MEASUREMENTS

The differential cross-section for light scattering from an nematic is given by[5]:

$$\frac{d\sigma}{d\Omega} = V\cdot\{(\varepsilon_a\omega_0{}^2)/(4\pi c^2)\}^2\cdot \sum_{\alpha=1,2} \frac{k_B\cdot T}{K_\alpha(q)}\cdot G_\alpha{}^2 \qquad (1)$$

where V is the scattering volume, ε_a the anisotropic dielectric constant, c the velocity of light, ω_0 the angular frequency of light, T the absolute temperature and k_B is Boltzmann's constant. In addition $K_\alpha(q) = K_{\alpha\alpha}q_\perp^2 + K_{33}q_{//}^2$ ($\alpha = 1, 2$) where K_{ii} are the three elastic constants associated with the splay, twist and bend deformation respectively; $q_\perp$ and $q_{//}$ are the normal and parallel components of the scattering vector $\vec{q}$ with respect to the director $\vec{n}_0$. $G_\alpha = i_\alpha f_0 + f_\alpha i_0$ ($\alpha = 1, 2$) is a geometrical factor, where $\vec{i}$ and $\vec{f}$ are unit vectors giving the polarizations of the incoming and scattered light respectively. The subscripts α and 0 indicate components with respect to an orthonormal system of reference defined by $\vec{e}_0 = \vec{n}_0$, $\vec{e}_2 = (\vec{n}_0 \times \vec{q})/|\vec{n}_0 \times \vec{q}|$ and $\vec{e}_1 = \vec{e}_2 \times \vec{e}_0$.

If one takes $\vec{f}$ normal to the observation plane defined by the wave vectors $\vec{k}_0$ and $\vec{k}_s$ of the incoming and the scattered light respectively, $\vec{i}$ in the plane of observation and $\vec{n}_0$ parallel to $\vec{f}$, eq. (1) becomes

$$\frac{d\sigma}{d\Omega} \sim 1/q_\perp^2 \cdot \sum_{\alpha=1,2} G_\alpha^2/K_{\alpha\alpha} \tag{2}$$

If however $\vec{n}_0$ is taken in the plane of observation normal to $\vec{k}_0$, and $\vec{i}$ and $\vec{f}$ remain in the same position with respect to the plane of observation as before eq. (1) becomes

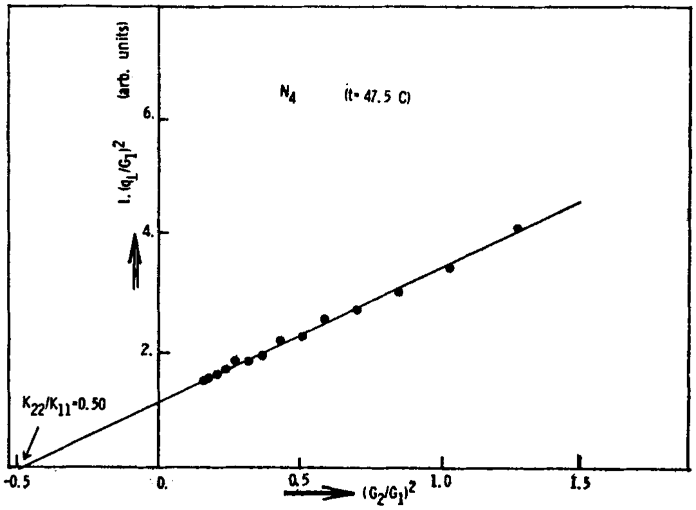
$$\frac{d\sigma}{d\Omega} \sim G_2^2/(K_{22}q_\perp^2 + K_{33}q_{//}^2) \tag{3}$$

From intensity measurements taken as a function of the scattering angle θ we can derive two elastic ratios with the help of eqs. (2) and (3) by plotting $I\cdot(q_\perp^2/G_1^2)$ versus (G_2^2/G_1^2), and $G_2^2/(q_{//}^2\cdot I)$ versus $(q_\perp^2/q_{//}^2)$ respectively, where I is the scattered light intensity measured with a photomultiplier tube.

Figures 1a, b show the two results for N_4. Both show a straight line, and from the intercept with the abscissa we can immediately read the elastic ratios.

In figure 2 we have plotted the elastic ratios of N_4 versus reduced temperature $(T - T_c)/T_c$. Note that only close to the n-i transition a slight temperature dependency does occur.

Using the results of Prost[2] who measured γ_1 of N_4 as a function of temperature we have calculated K_{22} from the visco-elastic ratio γ_1/K_{22} obtained from the spectra of the light intensity fluctuations[3]. Then the values for K_{11} and K_{33} could be obtained separately from the measured elastic ratios. Figure 3 gives the results of the twist, splay and bend elasticities as a function of reduced temperature. We have added the results of Aronishidze et al.[6], who have measured the twist elasticity with doped N_4 material (open triangles in figure 3).



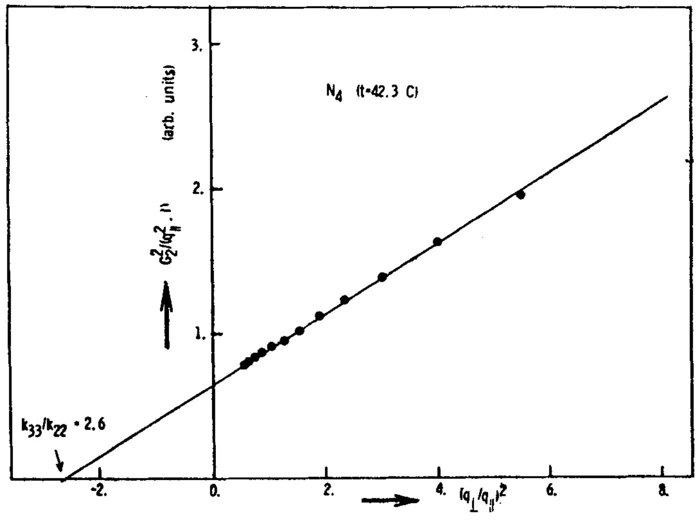


FIGURE 1a, b. The linear behaviour between $I(q_\perp/G_1)^2$ versus $(G_2/G_1)^2$ and $G_2{}^2/(q_{//}{}^2 \cdot I)$ versus $(q_\perp/q_{//})^2$ respectively.

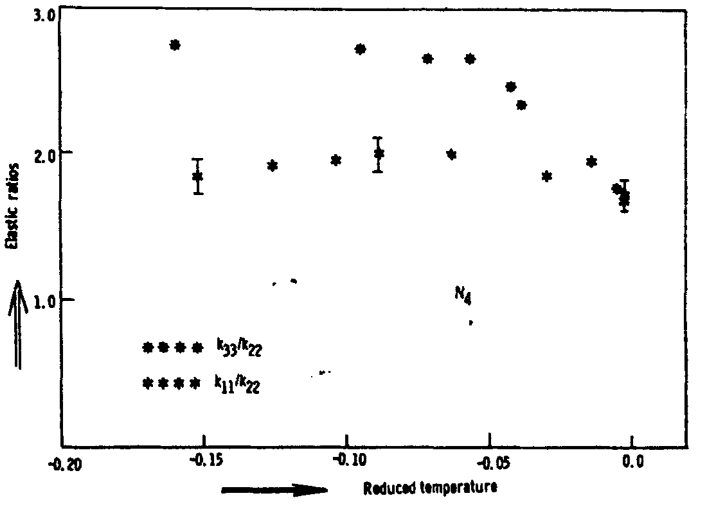


FIGURE 2. The elastic ratios (K_{33}/K_{22}) and (K_{11}/K_{22}) of N_4 plotted versus reduced temperature.

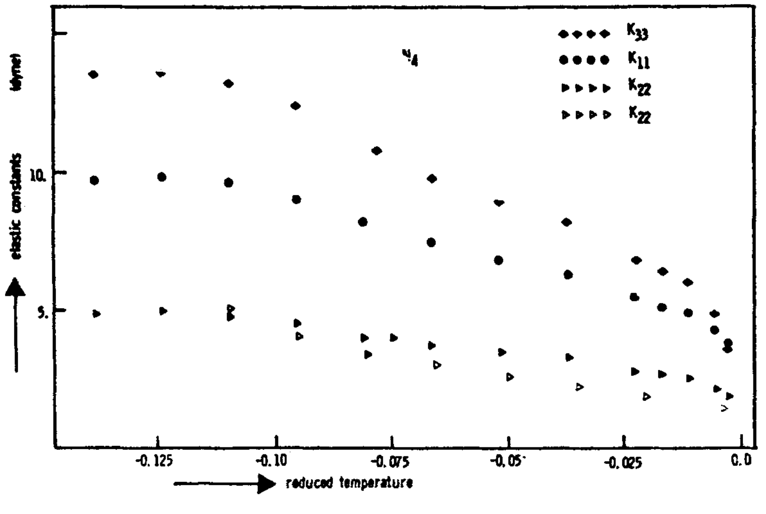


FIGURE 3. The splay (K_{11}), twist (K_{22}) and bend (K_{33}) elastic constant of N_4 versus reduced temperature.

In addition we have calculated the three principal viscosities which are connected with the visco-elastic ratios obtained from the spectra of the scattered light fluctuations[3,4].

We have the twist viscosity $\eta_{twist} = \gamma_1 = \alpha_3 - \alpha_2$

$$\begin{aligned} &\text{the splay viscosity } \eta_{splay} = \gamma_1 - \alpha_3^2/\eta_b \\ &\text{the bend viscosity } \eta_{bend} = \gamma_1 - \alpha_2^2/\eta_c \end{aligned} \qquad (4)$$

where α_2 and α_3 are the Leslie coefficients and η_b and η_c the positive Miesowicz constants of an n.l.c. Figure 4 shows an example for Dibab. Here we have used the results of De Jeu[1] and Van Eck[3] who measured the elasticities and the visco-elastic ratios respectively.

DISCUSSION

Our study of the "scattering" viscosities shows that in all cases $\eta_{bend} << \gamma_1$ and γ_1 is of the order of η_{splay}. From eqs. (4) it follows that $(\eta_{bend} - \gamma_1)$ must be negative. Our results are in good agreement with this requirement. On the other hand the quantity $\eta_{splay} - \gamma_1 = -\alpha_3^2/\eta_b$ also requires a negative sign. In all measurements we know there is a slight inconsistency between measurement and theory, because the

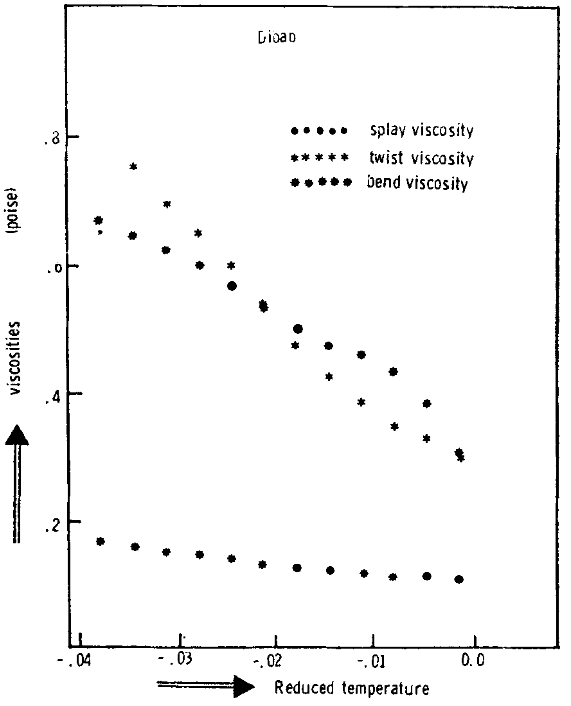


FIGURE 4. The splay, twist and bend viscosities for Dibab versus reduced temperature.

measurements show that $\gamma_1 - \eta_{splay}$ becomes negative (fig. 4). This inconsistency can only be removed by assuming that for all practical purposes α_3 can be put equal to zero in our equations. Then eq. (4) becomes

$$\begin{aligned} \eta_{splay} &= \eta_{twist} = -\alpha_2 \\ \eta_{bend} &= -\alpha_2 - \alpha_2{}^2/\eta_c \end{aligned} \qquad (5)$$

This simplification implies that we can obtain one elastic ratio (K_{11}/K_{22}) directly from the visco-elastic ratios. These measurements give us another method to obtain elastic ratios.

Figure 5 shows the thus obtained results for Dibab compared with the measurements of De Jeu[1] who determined the elastic ratios from the measurements of Frederick transitions.

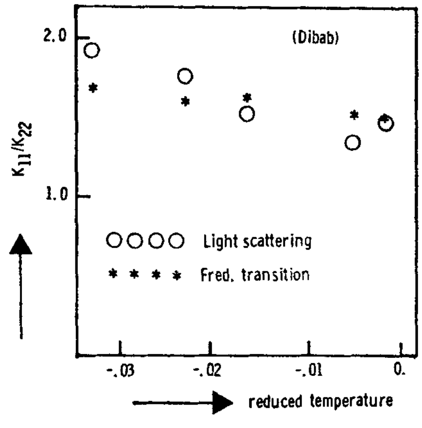


FIGURE 5. Comparison of the elastic ratio (K_{11}/K_{22}) obtained from spectral light-intensity measurements (circles) and measurements of the Frederick-transition (asterisks) respectively versus reduced temperature.

Our conclusion is that there are several methods of measuring elastic ratios with the help of the light scattering technique.

ACKNOWLEDGEMENT

This work was performed as part of the research program of the "Stichting voor Fundamenteel Onderzoek der Materie" (F.O.M.) with financial support from the "Nederlandse Organisatie voor Zuiver-Wetenschappelijk Onderzoek" (Z.W.O.).

REFERENCES

1. W.H. De Jeu and W.A.P. Claassen, J. Chem. Phys., 67, 3705 (1977)
2. J. Prost et al., J. Physique (Fr.) Lettres, 37, L341 (1976)
3. D.C. van Eck and W. Westera, Mol. Cryst. Liq. Cryst. 38, 319 (1977)
4. Orsay Groupe, J. Chem. Phys., 51, 816 (1969)
5. P.G. De Gennes, The physics of liquid crystals (Oxford University Press, 1974)
6. S.N. Aronishidze et al., Sov. Phys. Solid St., 17, 349 (1975)