26. Liquid Crystals

Sergei Pestov, Volkmar Vill

Liquid crystals (LCs) are nowadays widely used in electro-optical devices (e.g., liquid crystalline displays), for optical visualization of physical influences (heat, IR, high-frequency radiation, pressure, etc.), for nondestructive testing, as well as for thermography.

26.1 Liquid Crystalline State

Liquid crystals represent an intermediate state of order (mesophase) between crystals and liquids. Crystals have a three-dimensional long-range order of both position and orientation (Fig. 26.1a). Liquids, in contrast, do not show any long-range order (Fig. 26.1b). In plastic crystals (disordered crystals, Fig. 26.1c), the positional order is maintained, but the orientational order is lost.

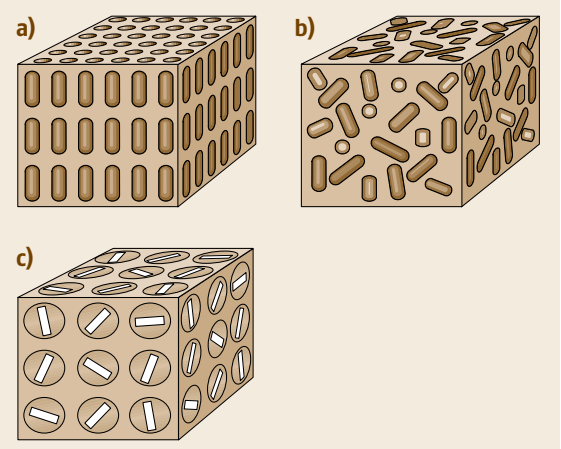

Fig. 26.1a–c Types of states: (a) crystal, (b) isotropic liquid, (c) plastic crystal

In mesophases, imperfect long-range order is observed, and thus they are situated between crystals and liquids. The reasons for the formation of a mesophase include the molecular shape or a microphase separation of amphiphilic compounds.

At present more than 100 000 individual liquid crystals have been synthesized [26.1–6] and about 2000 of these liquid crystals have been tested for physical properties and technical applications [26.3, 7–10]. These materials can be classified according to their chemical structures and physical characteristics (Table 26.1).

Generally, molecules of liquid crystalline substances have the following shapes:

- Rod-like molecules, which form calamitic liquid crystals (nematic and smectic phases)
- Disc-like molecules, which form discotic liquid crystals (discoid nematic and discotic phases)
- Amphiphilic compounds, which form layered columnar or cubic phases in the individual state and in solution.

The simplest and most widespread liquid crystalline phase is the nematic phase. The molecules are statistically distributed within the medium, but the long axes are orientated in one direction, the director (Fig. 26.2a).

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Table 26.1 Classifications of liquid crystals

Shape	Phase structure	Mesophase units
Rod-like molecules	Calamitic liquid crystals	Thermotropic liquid crystals
Disc-like molecules	Discotic liquid crystals	Lyotropic liquid crystals

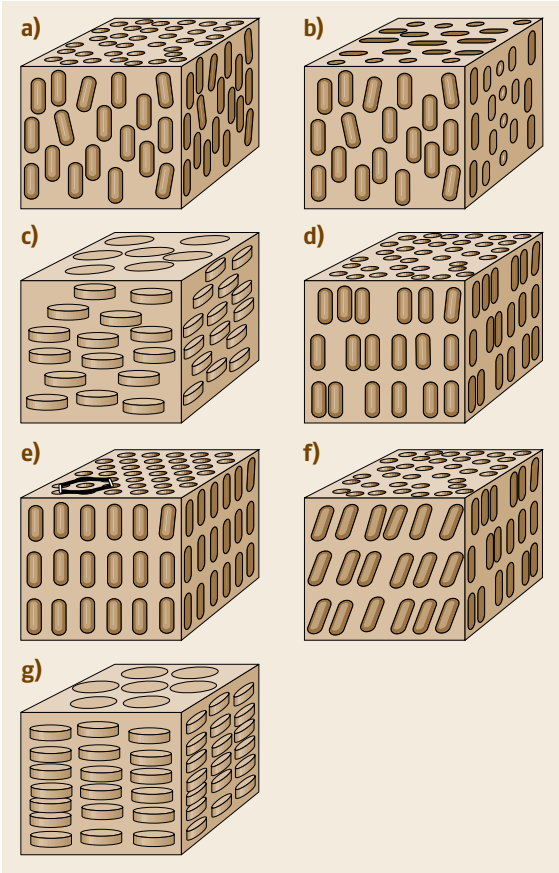


Fig. 26.2a–g Types of mesophases: (a) nematic, (b) cholesteric, (c) discoid nematic, (d) smectic A, (e) smectic B, (f) smectic C, (g) discotic

A special class of nematic phase is the cholesteric phase (Fig. 26.2b). Here the orientation of the director does not apply to the whole medium but rather to a virtual layer. Perpendicular to this layer, the director follows a helix with a certain pitch. In the case of the blue phases such a helical structure is formed not only in one but in all three dimensions. Thus, highly complex arrangements, with chiral cubic symmetry in most cases, are generated. Not only rod-like but also disc-like molecules can form nematic phases. The discoid nematic phase is shown in Fig. 26.2c.

Rod-like molecules arranged in layers form smectic phases. They are subdivided into a considerable number of different species. These classifications result from various arrangements of the molecules within the layers and different restrictions of their movement. The smectic A phase, the simplest smectic phase, can be regarded as a two-dimensional liquid. The molecules are arranged normal to the layers (Fig. 26.2d). The smectic B phase can be interpreted as the closest packing of rod-like molecules, so that within a layer each molecule has a hexagonal environment (Fig. 26.2e). The smectic A phase and the smectic C phase are similar, except that in the latter the molecules are tilted within the layers by a tilt angle (Fig. 26.2f). A particular case of smectic C is the chiral smectic C* phase, where the tilt angle varies from layer to layer, forming a helical structure [26.11]. For discussion of other smectic phases, as well as their further subclassification, the reader should consult the references [26.12–15].

In discotic phases, the disc-like molecules are arranged in columns [26.16, 17]. In this group, again various phases are possible, depending on the orientation of the molecules within the columns and the order between the columns. The simplest phase is the hexagonal columnar discotic phase. It can be regarded as a one-dimensional liquid. The columns have a hexagonal order (Fig. 26.2g).

Lyotropic liquid crystals are formed by aggregation of micelles [26.18]. They are multicomponent systems. Normally they consist of an amphiphilic substance and a solvent. In contrast, thermotropic liquid crystals are individual compounds.

Enantiotropic LC phases are formed during both the heating and the cooling process. Monotropic LC phases exist only in the supercooled state below the melting point. Thus, these phases are observed during cooling only.

26.1.1 Chemical Requirements

A liquid crystalline compound can be divided into the *mesogenic group* and the side groups. The mesogenic group is subdivided into fragments of rings and bridges. The side groups are subdivided into links and terminal groups.

Many other types of liquid crystalline compounds exist besides those with rod-like molecules, e.g., compounds with disc-shaped, banana-shaped, and bowl-shaped molecules [26.10, 19–21]. However, over 80% of all liquid crystals have a rod-like form, i. e., the molecule shown in Fig. 26.3.

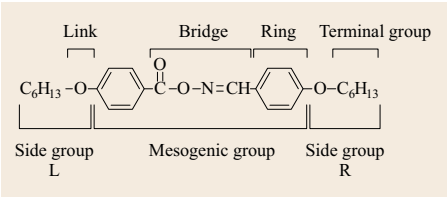


Fig. 26.3 Structure of a calamitic mesogenic compound

26.1.2 Physical Properties of Liquid Crystals

The order parameter $S = 0.5 \cdot (3\langle\cos^2 \Theta\rangle - 1)$ characterizes the long-range order of molecules in a mesophase, where Θ is the momentary angle between the long axis of the molecule and the director. In an ideal crystal the order parameter S equals 1 and it equals 0 in an isotropic liquid. In a nematic phase the order parameter lies in the range between 0.5–0.7.

One of the most useful properties for the application of liquid crystals is the anisotropy of their refractive index $\Delta n = n_e - n_o$, where n_e is the extraordinary and n_o is the ordinary refractive index. For nematics, n_e corresponds to $n_\parallel$ and $n_o = n_\perp$. $n_\perp$ means that the vibration vector of plane-polarized light is perpendicular to the optical axis, i. e., the director, while for $n_\parallel$ the vibration vector of plane-polarized light is parallel to the director. For the majority of LC the value of Δn is positive, but cholesteryl substituted compounds are optically negative ($\Delta n < 0$). On increasing the wavelength, Δn usually decreases. For homologues Δn decreases as the length of alkyl chains increases.

The orientation of molecules in an electric field is determined by the sign of the dielectric anisotropy ($\Delta\varepsilon = \varepsilon_\parallel - \varepsilon_\perp$); $\varepsilon_\parallel$ and $\varepsilon_\perp$ are the dielectric constants measured parallel and perpendicular to the director. Some nematic LC can change the sign of $\Delta\varepsilon$, depending upon the frequency of the applied field.

The majority of mesogens are diamagnetic. The diamagnetic anisotropy ($\Delta\chi$) characterizes the behavior of LC under the influence of a magnetic field; $\Delta\chi = \chi_\parallel - \chi_\perp$, where $\chi_\parallel$ and $\chi_\perp$ are the diamagnetic susceptibilities parallel and perpendicular to the director.

The basic methods for the determination of phase transition temperatures (T^{tr}) are DSC (differential scanning calorimetry), DTA (differential thermal analysis), and polarization microscopy. Every method has its advantages and restrictions. DSC allows one to determine the enthalpies of phase transitions (ΔH^{tr}). Microscopy allows one both to determine the phase transition temperatures and to identify the type of mesophase. DTA gives reliable results for melting temperatures of LC having solid-state polymorphism and of LC mixtures. The differences in T^{tr} that can be found in publications by different authors arise from different measurement techniques and the presence of impurities. We have selected the data with the higher T^{tr} values in such cases.

The temperature dependence of density (ρ) is practically linear, with the exception of jumps near phase transitions. The volume changes are 3–9%, 0.1–0.4%, and 0.01–0.2% for the crystal–mesophase, nematic–isotropic, and smectic A–nematic transitions, respectively.

The kinematic (ν) and dynamic (η) viscosities can be determined by a capillary viscometer of the Ubbelohde or Ostwald type ($\nu = \eta/\rho$).

The surface tension (γ_{LV}) influences the angle between the surface and the nematic phase director. It plays an important role in the selection of coatings for the creation of homeotropic alignment (where the molecules are perpendicular to the cell surfaces) or planar alignment (where the molecules are parallel to the surfaces) of LC. The Friedel–Creagh–Kmetz rule states that if γ_L (energy of LC–surface interaction) > γ_S (solid surface energy), then a homeotropic alignment is induced; otherwise, a parallel alignment is induced.

26.1.3 Applications

The main requirements of LC materials (LCM) for electro-optics are high clearing ($T^{N\text{-}Is}$) and low melting temperatures, i. e., a wide temperature range of definite liquid crystalline phases, and a low viscosity for reducing the switching time of electro-optical effects. Wide usage of LCM in displays has become possible since the discovery of mesogenic cyanobiphenyls. At present, a great number of homologous series of LC are synthesized for display application purposes [26.22–26]. Phenylcyclohexane- and bicyclohexane-substituted LC are used as components in LCM; they have low viscosity and, accordingly, fast switching. Fluorinated three-ring LC containing two cyclohexane rings and a phenyl ring are used in LCM with high dielectric anisotropy, which are used at low voltages. For the application of LCM as a material in LC displays, many properties have to correspond to rigid specifications. For this reason LCM consists typically of 7 to 15 components. Sometimes LCM contain nonmesogenic additives, e.g., to reduce the viscosity of the mixture.

The main electro-optic effects in liquid crystals are described in [26.27–29]. In the twist structure, the molecules are parallel to the cell surfaces and the angle between the boundary directors is 90°. In the S-effect (Frederics effect), a planar structure is transformed to a homeotropic one, and in the B-effect, a homeotropic structure is transformed to a planar one. In the twist-effect (or twisted nematic, TN effect) a twist structure

turns into a homeotropic one. The disadvantage of the TN effect is the necessity to use polarizers. The *dynamic scattering mode* depends on the influence of an electrical current on the orientation of the molecules. At a high enough voltage, transparent nematic cells becomes turbid. A disadvantage of this effect is that the lower the voltage, the longer the switching time. One of the modern uses of this effect is the application of the dynamic scattering mode for data storage. After the applied voltage is switched off, the mode of the planar cell does not return to its initial state. The cell can be stored in the turbid state for a long time (from some minutes to some months).

The host–guest effect results from a reorientation of dye dopants (1–2% in the LC matrix) in an electric field. In this case the wavelength of maximum absorption of light is shifted and the color of the LC cell changes.

The sign of the dielectric anisotropy of an LCM determines the type of electro-optical effect. LCM with $\Delta\varepsilon > 0$ are used for TN, STN (supertwisted nematic), and TFT (thin film transistor) effects. LCM with low negative values of $\Delta\varepsilon$ have been formerly used for the dynamic scattering mode. Now LCM with negative anisotropy $\Delta\varepsilon$ are utilized for MVA-TFT (multidomain vertical alignment thin film transistor) displays. The higher the value of $\Delta\varepsilon > 0$, the smaller is the working voltage. The MVA-TFT and IPS (in-plane-switching) technologies provide the possibility of improving the viewing angles of displays for television [26.28–32].

Electric current leads to degradation of an LCM and reduces the lifetime of the display. Impurities influence the stability of the material and accelerate electrodegradation. Therefore, a multistage purification (e.g., recrystallization and column chromatography) to remove conducting impurities (intermediate products, water, and CO_2) is necessary. Usually the specific conductivity of an LCM is lower than 10^{-11}–10^{-12} Cm/cm and corresponds to the intrinsic conductivity.

The elastic constants (K_i) determine the switching time of the electro-optical effects. The elastic constant K_1 corresponds to the S-effect, K_3 to the B-effect, K_2 to the TN effect; here K_1 corresponds to splaying, K_2 to twisting, K_3 to bending.

Cholesteryl compounds were the first materials that found application in thermography. A huge number of other applications exist, where the chemical and physical requirements are totally different. These applications include reflectors, temperature measurement with thermochromic materials, nonlinear optics, polymer materials, self-assembled monolayers, LB (Langmuir–Blodgett) films, and the use of liquid crystals in template synthesis of porous materials, drug delivery, and many more.

26.1.4 List of Abbreviations

Cr, Cr′	Crystalline phases
S	Smectic
A, B, C, E, F, G, H	Specific smectic mesophases
C*	Chiral smectic C (ferroelectric)
D	Discotic
Dh, Dho, Dhd	Hexagonal columnar discotic (ordered or disordered)
Dr, Dt	Rectangular, tilted columnar discotic
N	Nematic
N*	Cholesteric
Is	Isotropic

Examples:

Cr 95.0 C 99.0 N 107.5 Is Crystals melt at 95 °C, smectic C transforms to nematic at 99 °C and to isotropic liquid at 107.5 °C

Cr′ 5.0 Cr 67.3 (N 30.3) Is Crystals melt at 67.3 °C. Compound has a monotropic nematic phase on cooling below 30.3 °C and polymorphism (solid–solid transition) at 5 °C

T^{tr}	Temperatures of phase transitions
$T^{N\text{-}Is}$	Temperature of nematic–isotropic transition (in kelvin)
(extra)	Data were extrapolated from 10–20 wt% solution in nematic mixture
dec	Substance decomposes on heating

Relative temperatures (e.g., $T = 0.977T^{N\text{-}Is}$) are assumed to be in kelvin only. Inverse temperatures are always given in 1/kelvin (e.g., $1000/T = 2.4$).

Some data are given for the supercooled mesophase ($T < T_{melting}$).

CAS-RN registration number of the Chemical Abstract Service (CAS).

Common names are historical names, and trade names of BDH, Licristal® Merck, and Hoffmann-La Roche [26.22, 23, 25].

Δn	Anisotropy of the refractive index ($n_e - n_o$)
$\Delta\varepsilon$	Dielectric anisotropy
ΔH^{tr}	Enthalpies of phase transitions (kJ/mol)
C_p	Heat capacity at constant pressure (J/(mol K))
v	Sound velocity (m/s)
p	Helix pitch (for N* phase)
P_s	Spontaneous polarization (for ferroelectric LC) (nC/cm^2)
D	Diffusion coefficient (m^2/s)
C_6H_{12}	Cyclohexane

26.1.5 Conversion Factors

Molar weight

$$1\,\mathrm{g/mol} = 1\times10^{-3}\,\mathrm{kg/mol}$$

Temperatures of phase transitions

$$T(^\circ\mathrm{C}) = T\,(\mathrm{K}) - 273.15$$

Density

$$1\,\mathrm{g/cm^3} = 1\times10^{3}\,\mathrm{kg/m^3}$$

Dynamic viscosity η

$$1\,\mathrm{mPa\,s} = 1\times10^{-3}\,\mathrm{Pa\,s} = 1\,\mathrm{cP}$$

(centi-Poise)

Kinematic viscosity $\nu = \eta/\rho$

$$1\,\mathrm{mm^2/s} = 1\times10^{-6}\,\mathrm{m^2/s} = 1\,\mathrm{cSt}$$

(centi-Stokes)

Thermal conductivity

$$1\,\mathrm{W/(m\,K)} = 1\times10^{-2}\,\mathrm{W/(cm\,K)}$$

Diamagnetic anisotropy $\Delta\chi$

$$1\,\mathrm{m^3/kg} = 1\times10^{3}\,\mathrm{cm^3/g} \quad \text{(CGS unit)}$$

Dipole moment

$$1\,\mathrm{D\,(Debye)} = 3.33564\times10^{-30}\,\mathrm{C\,m}$$

(Coulomb meter)

26.2 Physical Properties of the Most Common Liquid Crystalline Substances

The compounds are arranged in the tables on the basis of the number and priority of fragments. The order principles for mesogenic groups are the number of rings and bridges, and the priority of rings, bridges, and side groups.

Priority of rings: benzene > cyclohexane > heterocycles > halogen-substituted benzenes.

Priority of bridges: C_nH_m > CH=N > N=N > N=N(O) > COO.

Homologues are arranged in order of increasing number of carbon atoms in the alkyl chains.

We have attempted to include all of the most common liquid crystals, from the traditional *model substances* (e.g., 5CB, MBBA, and PAA) to substances used in modern applications.

Table 26.2 Acids

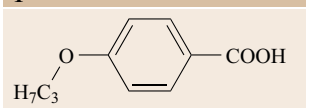
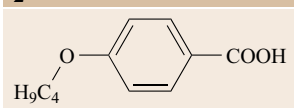
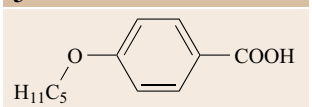
Number/common name	1	2	3
Substance			
Formula	$C_{10}H_{12}O_3$	$C_{11}H_{14}O_3$	$C_{12}H_{16}O_3$
Molar weight (g/mol)	180.205	194.232	208.26
CAS-RN	5438-19-7	1498-96-0	15872-41-0
Temperatures of phase transitions T^{tr} (°C)	Cr 146.0 N 156.0 Is	Cr 147.5 N 161.0 Is	Cr 124.4 N 151.4 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	16.7 (Cr–N), 2.5 (N–Is)	19.7 (Cr–N), 2.4 (N–Is)	18.0 (Cr–N), 1.8 (N–Is)
Crystallographic space group	$P2_1/c$	$P\bar{1}$	$P2_1$
Order parameter S	0.533 (149 °C)	0.538 (154 °C)	0.587 (137 °C)
Density ρ (g/cm^3)	1.0095 (N, 150 °C) 1.0008 (Is, 159 °C)	1.0079 (N, 150 °C) 0.9883 (Is, 165 °C)	0.9945 (N, 145 °C) 0.9721 (Is, 155 °C)
Refractive index n	n_e 1.632 n_o 1.457 (N, 546 nm, 140.5 °C)	n_e 1.615 n_o 1.449 (N, 589 nm, 149 °C)	n_e 1.602 n_o 1.456 (N, 546 nm, 140.5 °C)
Dielectric anisotropy $\Delta\varepsilon$	–	$\Delta\varepsilon$ 0.079 $T = 0.977T^{NI}$	$\Delta\varepsilon$ 0.042 $T = 0.977T^{NI}$
Dynamic viscosity η (mPa s)	1.81 (N, 149 °C), 2.63 (Is, 159 °C)	1.88 (N, 151 °C), 2.62 (Is, 165 °C)	2.37 (N, 145 °C), 3.30 (Is, 155 °C)
Diffusion coefficient D (m^2/s)	–	$D_\perp 4\times10^{-10}$, $D_\parallel 14\times10^{-10}$ $1000/T = 2.38$	$D_\perp 4\times10^{-10}$, $D_\parallel 12\times10^{-10}$ $1000/T = 2.45$

Table 26.2 (continued)

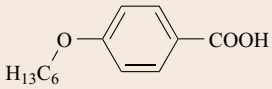
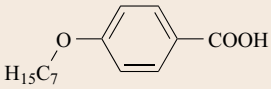
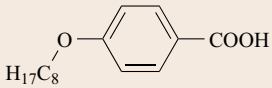
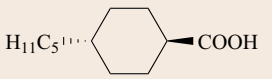
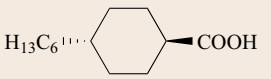
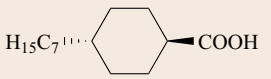
Number/common name	4	5 (HOBA)	6 (OOBA)
Substance			
Formula	$C_{13}H_{18}O_3$	$C_{14}H_{20}O_3$	$C_{15}H_{22}O_3$
Molar weight (g/mol)	222.287	236.314	250.341
CAS-RN	1142-39-8	15872-42-1	2493-84-7
Temperatures of phase transitions T^{tr} (°C)	Cr′ 75 Cr 105.4 N 153.2 Is	Cr 94.0 C 102.0 N 147.5 Is	Cr 100.5 C 107.5 N 147.0 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	13.8 (Cr–N), 3.3 (N–Is), 6.7 (Cr′–Cr)	19.2 (Cr–C), 2.5 (N–Is)	12.7 (Cr–C), 1.1 (C–N), 2.1 (N–Is)
Crystallographic space group	$P2_1/c$ (Cr), $P\bar{1}$ (Cr′)	$P\bar{1}$	$P\bar{1}$
Order parameter S	0.611 (129 °C)	0.626 (123 °C)	0.615 (128 °C)
Density ρ (g/cm^3)	0.983 (N, 146 °C) 0.969 (Is, 156 °C)	0.970 (N, 140 °C) 0.959 (Is, 150 °C)	0.961 (N, 140 °C) 0.945 (Is, 150 °C)
Refractive index n	n_e 1.595 n_o 1.453 (546 nm, N, 142.5 °C)	n_e 1.580 n_o 1.452 (546 nm, N, 137.5 °C)	n_e 1.578 n_o 1.450 (546 nm, N, 138.5 °C)
Dielectric anisotropy $\Delta\varepsilon$	$\Delta\varepsilon$ 0.052 $T = 0.977\ T^{NI}$	$\Delta\varepsilon$ 0.038 $T = 0.977\ T^{NI}$	$\Delta\varepsilon$ 0.037 $T = 0.977\ T^{NI}$
Dynamic viscosity η (mPa s)	2.61 (N, 146 °C), 3.46 (Is, 157 °C)	3.02 (N, 137 °C), 3.95 (Is, 150 °C)	3.19 (N, 140.5 °C), 3.97 (Is, 151 °C)
Thermal conductivity (W/(m K))	0.137 (N, 115 °C) 0.159 (Is, 157 °C)	0.146 (N, 130 °C) 0.162 (Is, 159 °C)	–
Sound velocity v (m/s)	972 (3.36 GHz, 141 °C)	1021 (3.40 GHz, 135 °C)	1050 (3.63 GHz, 137 °C)
Diffusion coefficient D (m^2/s)	$D_\perp 2\times10^{-10}$, $D_\parallel 8\times10^{-10}$ $1000/T = 2.45$	–	–
Number/common name	**7**	**8**	**9**
Substance			
Formula	$C_{12}H_{22}O_2$	$C_{13}H_{24}O_2$	$C_{14}H_{26}O_2$
Molar weight (g/mol)	198.308	212.335	226.362
CAS-RN	32829-29-1	38289-30-4	32829-31-5
Temperatures of phase transitions T^{tr} (°C)	Cr 53.0 (B 45.0) N 105.0 Is	Cr 31.7 B 47.2 N 96.4 Is	Cr′ 31.0 Cr 54.0 B 77.0 N 104.0 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	20.9 (Cr–N), 1.1 (N–Is)	15.7 (Cr–B), 1.0 (B–N), 0.5 (N–Is)	13.4 (Cr′–Cr), 5.2 (Cr–B), 2.3 (B–N), 1.1 (N–Is)
Dielectric anisotropy $\Delta\varepsilon$ (N, 90 °C, 500 kHz)	0.05	–	0.05

Table 26.3 Two-ring systems without bridges

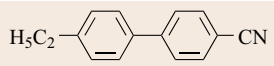
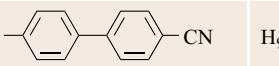
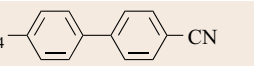
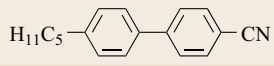
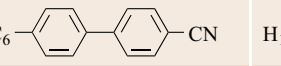
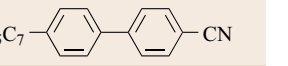
Number/common name	**10 (2CB, K6, RO-CM-5106)**	**11 (3CB, K9, RO-CM-5109)**	**12 (4CB, K12, RO-CM-5112)**
Substance			
Formula	$C_{15}H_{13}N$	$C_{16}H_{15}N$	$C_{17}H_{17}N$
Molar weight (g/mol)	207.278	221.305	235.332
CAS-RN	58743-75-2	58743-76-3	52709-83-8
Temperatures of phase transitions T^{tr} (°C)	Cr 75.0 (N 22.0) Is	Cr 67.3 (N 30.3) Is	Cr 48.0 (N 16.5) Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	17.2 (Cr–Is)	26.8 (Cr–Is), 0.3 (N–Is)	23.0 (Cr–Is)
Crystallographic space group	$P2_1/c$	$P2_1/c$	$P2_1/c$
Anisotropy of refractive index Δn	Δn 0.206	Δn 0.211	Δn 0.202
Dielectric constant ε	$\Delta\varepsilon$ +18.9	$\varepsilon_{\parallel}$ 25.8 $\varepsilon_{\perp}$ 6.9 (20 °C)	$\Delta\varepsilon$ +17
Kinematic viscosity ν (mm^2/s)	ν 5 (70 °C)	ν 23 (extra, 20 °C), 7 (70 °C)	ν 7.5 (70 °C)
Dipole moment μ (D), 25 °C	4.81 (CCl_4), 4.96 (C_6H_{14}), 4.90 (C_6H_{12}), 5.01 (C_6H_6)	4.72 (CCl_4), 5.02 (C_6H_{14}), 4.93 (C_6H_{12}), 4.93 (C_6H_6)	4.73 (CCl_4), 5.04 (C_6H_{14}), 4.94 (C_6H_{12}), 4.99 (C_6H_6)
Number/common name	**13 (5CB, K15, RO-CM-5115)**	**14 (6CB, K18, RO-CM-5118)**	**15 (7CB, K21, RO-CM-5121)**
Substance			
Formula	$C_{18}H_{19}N$	$C_{19}H_{21}N$	$C_{20}H_{23}N$
Molar weight (g/mol)	249.359	263.386	277.413
CAS-RN	40817-08-1	41122-70-7	41122-71-8
Temperatures of phase transitions T^{tr} (°C)	Cr 24.0 N 35.3 Is	Cr 14.3 N 30.1 Is	Cr′ 15.0 Cr 30.0 N 42.8 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	17.2 (Cr–N), 0.4 (N–Is)	24.3 (Cr–N), 0.4 (N–Is)	25.9 (Cr–N), 0.9 (N–Is)
Crystallographic space group	$P2_1/a$	$P1$	$P1$
Order parameter S	0.64 (24 °C)	–	0.65 (29 °C)
Density ρ (g/cm^3)	1.022 (N, 24 °C) 1.016 (N, 30 °C)	1.017 (N, 20 °C)	1.001 (N, 29 °C) 0.991 (N, 39 °C)
Refractive index n (589 nm)	n_e 1.716 n_o 1.533 (N, 24 °C, 589 nm)	n_e 1.687 n_o 1.531 (N, 20 °C, 633 nm)	n_e 1.679 n_o 1.522 (N, 32 °C, 589 nm)
Dielectric constant ε	$\varepsilon_{\parallel}$ 20 $\varepsilon_{\perp}$ 7 (25 °C, 1.5 kHz)	$\varepsilon_{\parallel}$ 14.45 $\varepsilon_{\perp}$ 7.2 (28 °C, 1 kHz)	$\varepsilon_{\parallel}$ 13.55 $\varepsilon_{\perp}$ 6.8 (41 °C, 1 kHz)
Viscosity	η 28 mPa s (25 °C)	ν 46 mm^2/s (20 °C)	ν 26 mm^2/s (20 °C)
Surface tension (mN/m)	33 (N, 20 °C), 28 (N, 30 °C), 28.3 (Is, 40 °C)	27.4 (N, 22 °C) 28.0 (Is, 32 °C)	26.3 (N, 37 °C) 27.5 (Is, 47 °C)
Thermal conductivity (W/(m K)) (N, 25 °C)	$k_{\perp}$ 0.124 $k_{\parallel}$ 0.242	$k_{\perp}$ 0.126 $k_{\parallel}$ 0.223	$k_{\perp}$ 0.127 $k_{\parallel}$ 0.269
Magnetic susceptibility $\Delta\chi$ (10^{-12} m^3/kg)	113.5 (25.6 °C)	101.5 (20 °C)	102.0 (33 °C)
Sound velocity v (m/s)	$v_{\parallel}$ 1740 $v_{\perp}$ 1680 (14.75 GHz, 30 °C)	$v_{\parallel}$ 1776 $v_{\perp}$ 1712 (14.75 GHz, 25 °C)	$v_{\parallel}$ 1675 $v_{\perp}$ 1640 (14.75 GHz, 38 °C)
Diffusion coefficient D (m^2/s)	$D_{\perp}$ 6.8 ×10^{-8}, $D_{\parallel}$ 12.7 ×10^{-8} (25 °C)	$D_{\perp}$ 6.4 ×10^{-8}, $D_{\parallel}$ 10.9 ×10^{-8} (25 °C)	$D_{\perp}$ 6.8 ×10^{-8}, $D_{\parallel}$ 14.4 ×10^{-8} (25 °C)
Dipole moment μ (D), 25 °C	4.85 (CCl_4), 5.08 (C_6H_{14}), 4.95 (C_6H_{12}), 4.93 (C_6H_6)	4.83 (CCl_4), 5.09 (C_6H_{14}), 5.01 (C_6H_{12}), 4.98 (C_6H_6)	4.74 (CCl_4), 5.11 (C_6H_{14}), 4.94 (C_6H_{12}), 4.97 (C_6H_6)

Table 26.3 (continued)

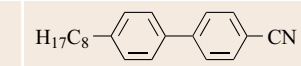
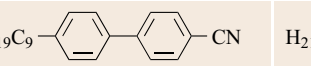
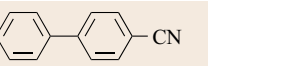
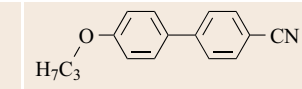
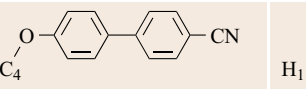
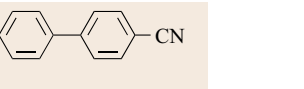
Number/common name	16 (8CB, K24)	17 (9CB, K27)	18 (10CB, K30)
Substance			
Formula	$C_{21}H_{25}N$	$C_{22}H_{27}N$	$C_{23}H_{29}N$
Molar weight (g/mol)	291.44	305.467	319.494
CAS-RN	52709-84-9	52709-85-0	59454-35-2
Temperatures of phase transitions T^{tr} (°C)	Cr 21.5 A 33.5 N 40.5 Is	Cr 42.0 A 48.0 N 49.5 Is	Cr 44.0 A 54.5 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	28.3 (Cr–A), 0.2 (A–N), 0.7 (N–Is)	33.5 (Cr–A), 0.6 (A–N), 1.7 (N–Is)	33.1 (Cr–A), 2.8 (N–Is)
Crystallographic space group	$P2_1/n$	$P\bar{1}$	$P2_1/n$
Density ρ (g/cm^3)	0.991 (A, 32.5 °C), 0.981 (N, 40 °C), 0.978 (Is, 41 °C)	0.973 (A, 47.7 °C) 0.968 (N, 49.5 °C)	–
Refractive index n (589 nm)	n_e 1.657 n_o 1.524 (N, 37.4 °C)	n_e 1.638 n_o 1.519 (N, 49 °C)	–
Dielectric constant ε (1 kHz)	$\varepsilon_\parallel$ 12.8 $\varepsilon_\perp$ 5.3 (N, 34 °C) $\varepsilon_\parallel$ 12.4 $\varepsilon_\perp$ 4.8 (A, 28 °C)	$\varepsilon_\parallel$ 12.5 $\varepsilon_\perp$ 5.1 (44 °C)	ε 8.8 (Is, 64.5 °C)
Dynamic viscosity η (mPa s)	η 35 (N, 33.5 °C)	–	–
Surface tension (mN/m)	25.5 (N, 35 °C) 26.2 (Is, 41 °C)	–	–
Thermal conductivity (W/(m K))	$k_\perp$ 0.130 $k_\parallel$ 0.276 (A, 30 °C) $k_\perp$ 0.132 $k_\parallel$ 0.254 (N, 35 °C)	$k_\perp$ 0.130 $k_\parallel$ 0.310 (40 °C)	–
Magnetic susceptibility $\Delta\chi$ (10^{-12} m^3/kg)	88 (35 °C)	88.5 (48.9 °C)	–
Sound velocity v (m/s)	$v_\parallel$ 1596 $v_\perp$1545 (14.75 GHz, 39 °C)	$v_\parallel$ 1740 $v_\perp$1680 (14.75 GHz, 44.5 °C)	–
Diffusion coefficient D (m^2/s)	$D_\perp$ 6×10^{-8}, $D_\parallel$ 12×10^{-8} (A, 30 °C), $D_\perp$ 5.8×10^{-8}, $D_\parallel$ 10×10^{-8} (N, 35 °C)	$D_\perp$ 6.6×10^{-8}, $D_\parallel$ 15.2×10^{-8} (A, 40 °C)	–
Dipole moment μ (D), 25 °C	4.78 (CCl_4), 5.12 (C_6H_{14}), 4.93 (C_6H_{12}), 5.00 (C_6H_6)	4.73 (CCl_4), 5.11 (C_6H_{14}), 4.94 (C_6H_{12}), 4.94 (C_6H_6)	4.76 (CCl_4), 5.10 (C_6H_{14}), 5.00 (C_6H_{12}), 5.00 (C_6H_6)
Number/common name	**19 (3OCB, M9, RO-CM-5309)**	**20 (4OCB, M12)**	**21 (5OCB, M15, RO-CM-5315)**
Substance			
Formula	$C_{16}H_{15}NO$	$C_{17}H_{17}NO$	$C_{18}H_{19}NO$
Molar weight (g/mol)	237.304	251.331	265.368
CAS-RN	52709-86-1	52709-87-2	52364-71-3
Temperatures of phase transitions T^{tr} (°C)	Cr 71.5 (N 64.0) Is	Cr 78.0 (N 75.5) Is	Cr′ 48.0 Cr 53.0 N 68.0 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	19.2 (Cr–Is)	23.4 (Cr–Is)	28.9 (Cr–N), 0.2 (N–Is)
Crystallographic space group	$P2_1/c$	$Pca2_1$	$P2_1/n$
Order parameter S	–	–	0.63 (55 °C)
Density (g/cm^3)	1.19 (Cr)	1.14 (Cr)	1.042 (N, 61.5 °C) 1.029 (Is, 70 °C)
Refractive index n (589 nm)	–	–	n_e 1.697 n_o 1.528 (N, 55 °C)
Dielectric constant ϵ (1 kHz)	–	$\Delta\varepsilon$ +28.7 $\varepsilon_\perp$7.5 (20 °C, extra)	$\Delta\varepsilon$ +8.5 $\varepsilon_\parallel$16.7 $T = 0.98\ T^{NI}$
Kinematic viscosity (mm^2/s)	ν 10 (Is, 80 °C)	ν 10 (75 °C)	ν 20 (53 °C), 10 (85 °C)
Surface tension (mN/m)	–	–	33.2 (N, 51 °C) 31.9 (Is, 70 °C)
Magnetic susceptibility $\Delta\chi$ (10^{-12} m^3/kg)	–	–	87 (58 °C), 98 (50 °C)
Dipole moment μ (D)	–	5.1	–

Table 26.3 (continued)

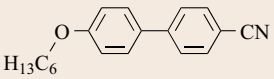
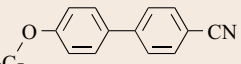
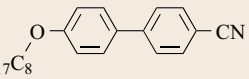
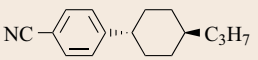
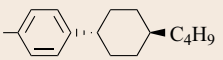
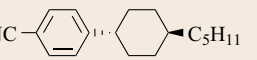
Number/common name	22 (6OCB, M18)	23 (7OCB, M21)	24 (8OCB, M24, RO-CM-5324)
Substance			
Formula	$C_{19}H_{21}NO$	$C_{20}H_{23}NO$	$C_{21}H_{25}NO$
Molar weight (g/mol)	279.385	293.412	307.44
CAS-RN	41424-11-7	52364-72-4	52364-73-5
Temperatures of phase transitions T^{tr} (°C)	Cr′ 44.0 Cr 57.0 N 75.5 Is	Cr′ 47.5 Cr 53.5 N 75.0 Is	Cr′ 46.0 Cr′ 51.0 Cr 54.5 A 67.0 N 80.0 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	29.7 (Cr–N), 0.8 (N–Is)	28.9 (Cr–N), 0.6 (N–Is)	28.5 (Cr–A), 0.1 (A–N), 0.8 (N–Is)
Crystallographic space group	$P2_1/a$	$P2_1/c$, $P\bar{1}$	$P2_1/a$, $P\bar{1}$
Order parameter S	–	0.61 (63 °C)	
Density ρ (g/cm^3)	1.017 (N, 71 °C) 1.025 (N, 63 °C)	1.0051 (N, 63 °C) 0.9869 (Is, 79.5 °C)	0.990 (N, 75 °C) 0.977 (Is, 85 °C)
Refractive index n (589 nm)	n_e 1.72 n_o 1.50 (60 °C)	n_e 1.6734 n_o 1.5155 (60 °C)	n_e 1.647 n_o 1.509 (71 °C)
Dielectric constant ε (1 kHz)	$\Delta\varepsilon$ +8.0 $\varepsilon_\parallel$ 15.8 $T = 0.98T^{NI}$	$\Delta\varepsilon$ +7.5 $\varepsilon_\parallel$ 15.0 $T = 0.98\,T^{NI}$	$\Delta\varepsilon$ +8.0 (N, 74 °C)
Kinematic viscosity (mm^2/s)	ν 17 (60 °C), 12 (85 °C)	ν 10 (70 °C), 30 (50 °C)	ν 16 (70 °C), 12 (85 °C)
Surface tension (mN/m)	–	–	36.5 (A, 60) 35.4 (N, 70) 30.5 (Is, 80)
Magnetic susceptibility $\Delta\chi$ (10^{-12} m^3/kg)	88 (67 °C), 80 (71 °C)	71 (70 °C), 87.5 (60 °C)	83 (70.6 °C)
Dipole moment μ (D)	5.2	4.9	5.2 (CCl_4)
Number/common name	**25 (PCH-3)**	**26 (PCH-4)**	**27 (PCH-5)**
Substance			
Formula	$C_{16}H_{21}N$	$C_{17}H_{23}N$	$C_{18}H_{25}N$
Molar weight (g/mol)	227.352	241.38	255.407
CAS-RN	61203-99-4	61204-00-0	61204-01-1
Temperatures of phase transitions T^{tr} (°C)	Cr 42.7 N 45.9 Is	Cr 41.0 N 39.0 Is	Cr 30.0 N 55.0 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	19.0 (Cr–N), 0.7 (N–Is)	22.2 (Cr–Is)	18.0 (Cr–N), 0.9 (N–Is)
Crystallographic space group	$C2/c$	$P2_1/c$, $P\bar{1}$	–
Order parameter S	0.64 (43 °C)	–	0.54 (43 °C)
Density (g/cm^3)	0.9672 (N, 43 °C) 0.9571 (Is, 46.5 °C)	0.962 (N, 35 °C) 0.951 (Is, 43 °C)	0.967 (N, 25 °C) 0.932 (Is, 60 °C)
Refractive index n (589nm)	n_e 1.582 n_o 1.492 (N, 43 °C)	n_e 1.579 n_o 1.498 (N, 37 °C)	n_e 1.600 n_o 1.492 (N, 40 °C)
Dielectric constant ε (1 kHz)	$\varepsilon_\parallel$ 19.3 $\varepsilon_\perp$ 5.5 ($T = 0.95T^{NI}$)	$\Delta\varepsilon$ +11 (20 °C)	$\varepsilon_\parallel$ 14.4 $\varepsilon_\perp$ 5.2 (39 °C)
Viscosity (20 °C)	η 19.2 mPa s	ν 23 mm^2/s	ν 23 mm^2/s
Dipole moment μ (D)	3.9	–	4.1

Table 26.3 (continued)

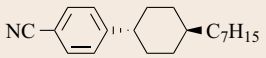
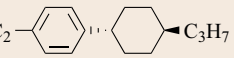
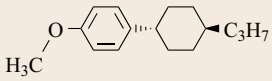
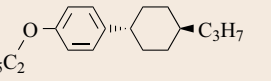
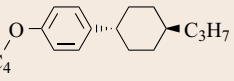
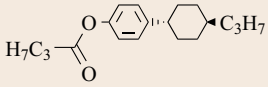
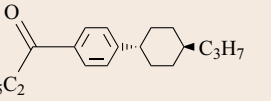
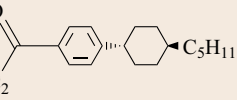
Number/common name	**28 (PCH-7)**	**29 (PCH-8)**	**30 (PCH-32, RO-CM-4232, ZLI-1484)**
Substance			
Formula	$C_{20}H_{29}N$	$C_{21}H_{31}N$	$C_{17}H_{26}$
Molar weight (g/mol)	283.461	297.488	230.397
CAS-RN	61204-03-3	83626-40-8	82991-47-7
Temperatures of phase transitions T^{tr} (°C)	Cr 30.0 N 57.8 Is	Cr 37.0 N 55.0 Is	Cr −1 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	25.5 (Cr–N), 1.0 (N–Is)	–	18.4 (Cr–Is)
Crystallographic space group	–	$P2_1/c$, $P\overline{1}$ (Cr′)	–
Order parameter S	0.47 (47 °C)	–	–
Density (g/cm^3)	0.952 (N, 30 °C) 0.915 (Is, 67 °C)	0.941 (N, 37 °C) 0.915 (Is, 62 °C)	0.909 (20 °C)
Refractive index n (589 nm)	n_e 1.590 n_o 1.482 (47 °C)	–	n 1.514 (20 °C)
Dielectric constant ε (1 kHz)	$\varepsilon_\parallel$ 12.9 $\varepsilon_\perp$ 4.2 (31 °C)	–	ε 2.293, $\Delta\varepsilon$ +0.5 (20 °C, extra)
Kinematic viscosity (mm^2/s)	28 (extra, 20 °C)	–	4 (extra, 20 °C)
Number/common name	**31 (PCH-301, ZLI-2446)**	**32 (PCH-302, ZLI-1476)**	**33 (PCH-304, ZLI-1477)**
Substance			
Formula	$C_{16}H_{24}O$	$C_{17}H_{26}O$	$C_{19}H_{30}O$
Molar weight (g/mol)	232.369	246.396	274.45
CAS-RN	81936-32-5	80944-44-1	79709-84-5
Temperatures of phase transitions T^{tr} (°C)	Cr 32.0 (N 10.0) Is	Cr 40.8 N 37.8 Is	Cr 35.5 N 33.0 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	17.6 (Cr–Is)	26.4 (Cr–Is), 0.7 (N–Is)	30.6 (Cr–Is), 0.5 (N–Is)
Anisotropy of refractive index Δn (20 °C, 589 nm)	Δn 0.09 (extra)	Δn 0.09 (extra)	Δn 0.09 (extra)
Dielectric anisotropy $\Delta\varepsilon$ (20 °C, 1 kHz)	$\Delta\varepsilon$ −0.5 (extra)	$\Delta\varepsilon$ −0.5 (extra)	$\Delta\varepsilon$ −0.5 (extra)
Kinematic viscosity (mm^2/s)	ν 6 (extra, 20 °C)	ν 7 (extra, 20 °C)	ν 10 (extra, 20 °C)
Number/common name	**34 (H33, ZLI-1305)**	**35**	**36**
Substance			
Formula	$C_{19}H_{28}O_2$	$C_{18}H_{26}O$	$C_{20}H_{30}O$
Molar weight (g/mol)	288.434	258.407	286.462
Temperatures of phase transitions T^{tr} (°C)	Cr 11.0 B 26.1 N 30.3 Is	Cr 49.2 N 56.5 Is	Cr 56.6 N 68.8 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	16.4 (Cr–B), 4.9 (B–N), 0.4 (N–Is)	–	–
Refractive index n (589 nm)	Δn 0.09 (20 °C)	n_e 1.589 n_o 1.497 $T = 0.95T^{NI}$	n_e 1.574 n_o 1.487 $T = 0.95T^{NI}$
Dielectric constant ε (1 kHz)	$\Delta\varepsilon$ −1.5 (20 °C)	$\varepsilon_\parallel$ 9.0 $\varepsilon_\perp$ 7.6 $T = 0.95\,T^{NI}$	$\varepsilon_\parallel$ 8.3 $\varepsilon_\perp$ 6.9 $T = 0.95\,T^{NI}$
Viscosity ν (20 °C)	ν 15 mm^2/s (extra)	–	–
Diamagnetic anisotropy $\Delta\chi$ (10^{-12} m^3/mol)	–	$\Delta\chi$ 25.3	$\Delta\chi$ 26.1
Dipole moment μ (D)	–	3.02	3.1

Table 26.3 (continued)

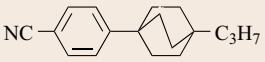
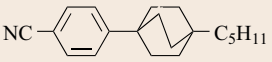
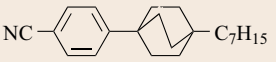
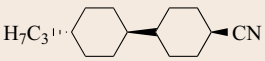
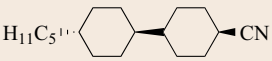
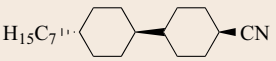
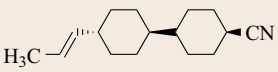
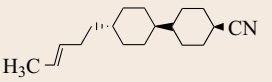
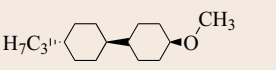
Number/common name	**37**	**38**	**39**
Substance			
Formula	$C_{18}H_{23}N$	$C_{20}H_{27}N$	$C_{22}H_{31}N$
Molar weight (g/mol)	253.391	281.445	309.499
CAS-RN	–	74385-67-4	–
Temperatures of phase transitions T^{tr} (°C)	Cr 66.5 N 88.0 Is	Cr 62.0 N 100.0 Is	Cr 61.0 N 95.0 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	17.4 (Cr–N)	20.7 (Cr–N)	32.7 (Cr–N)
Density (g/cm^3)	1.007 (N, 66 °C)	0.993 (N, 60 °C)	0.975 (N, 65 °C)
Refractive index n (633 nm)	n_e 1.614 n_o 1.492 (66 °C)	n_e 1.616 n_o 1.490 (60 °C)	n_e 1.598 n_o 1.489 (65 °C)
Dielectric constant ε (10 kHz)	$\varepsilon_\perp$ 5.2 $\varepsilon_\parallel$ 15.4 (66 °C)	$\varepsilon_\perp$ 4.6 $\varepsilon_\parallel$ 13.1 (60 °C)	$\varepsilon_\perp$ 4.4 $\varepsilon_\parallel$ 12.0 (65 °C)
Viscosity ν (mm^2/s)	–	ν 7.8 (70 °C)	–
Dipole moment μ (D)	–	4.1	–
Number/common name	**40 (CCH-3)**	**41 (CCH-5)**	**42 (CCH-7)**
Substance			
Formula	$C_{16}H_{27}N$	$C_{18}H_{31}N$	$C_{20}H_{35}N$
Molar weight (g/mol)	233.4	261.454	289.509
CAS-RN	65355-35-3	65355-36-4	65355-37-5
Temperatures of phase transitions T^{tr} (°C)	Cr 58.0 (S 18.0 S 44.0 S 48.0 B 57.0) N 80.0 Is	Cr′ 59.2 Cr 63.4 (S 40.5 B 49.1) N 86.4 Is	Cr 71.0 N 83.0 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	26.8 (Cr–N), 1.1 (N–Is)	26.8 (Cr–N), 1.3 (N–Is)	33.9 (Cr–N), 0.9 (N–Is)
Crystallographic space group	$P\bar{1}$	$P2_1/c$, $P2_12_12_1$ (Cr′)	$P2_12_12_1$
Density (g/cm^3)	0.902 (N, 73 °C) 0.885 (Is, 87 °C)	0.902 (N, 72 °C)	0.893 (N, 70 °C)
Order parameter S	0.53 (73 °C)	0.62 (72 °C)	0.52 (71 °C)
Refractive index n (589 nm)	n_e 1.4930 n_o 1.4553 (N, 73 °C)	n_e 1.5061 n_o 1.4568 (N, 72 °C)	n_e 1.502 n_o 1.456 (N, 70 °C)
Dielectric constant ε (1 kHz)	$\varepsilon_\perp$ 5.5 $\varepsilon_\parallel$ 10.0 (73 °C)	$\varepsilon_\perp$ 4.75 $\varepsilon_\parallel$ 9.25 (73 °C)	$\varepsilon_\perp$ 3.89 $\varepsilon_\parallel$ 7.17 (74 °C)
Viscosity ν (mm^2/s) (20 °C)	ν 63 (extra)	ν 66 (extra)	ν 78 (extra)
Dipole moment μ (D)	–	3.8 (xylene)	–
Number/common name	**43 (RO-CM-4513)**	**44 (RO-CM-4535)**	**45 (CCH-301)**
Substance			
Formula	$C_{16}H_{25}N$	$C_{18}H_{29}N$	$C_{16}H_{30}O$
Molar weight (g/mol)	231.384	259.439	238.417
CAS-RN	122705-86-6	–	–
Temperatures of phase transitions T^{tr} (°C)	Cr 64.9 N 99.7 Is	Cr 79.5 (A 45.0) N 100.0 Is	Cr 10.0 N 17.0 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	–	–	18.8 (Cr–N)
Refractive index n (589 nm)	Δn 0.066 n_o 1.457 (89.7 °C)	Δn 0.065 n_o 1.456 (89.7 °C)	–
Dielectric constant ε (1 kHz)	$\varepsilon_\perp$ 4.35 $\Delta\varepsilon$ +5.03 (89.7 °C)	$\varepsilon_\perp$ 4.12 $\Delta\varepsilon$ +4.61 (89.7 °C)	$\Delta\varepsilon$ −0.3 (20 °C)
Viscosity ν (mm^2/s) (20 °C)	–	–	ν 7 (extra)
Dipole moment μ (D)	3.76	3.83	–

Table 26.3 (continued)

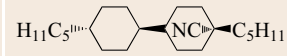
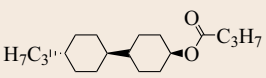
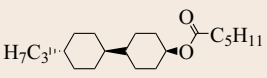
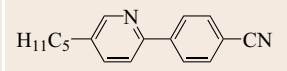
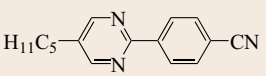
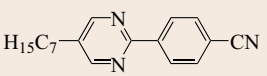
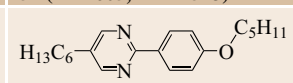
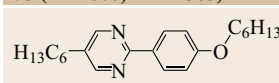
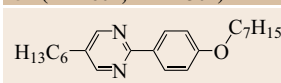
Number/common name	46 (CCN55, ZLI-2395)	47 (C33)	48 (C35)
Substance			
Formula	$C_{23}H_{41}N$	$C_{19}H_{34}O_2$	$C_{21}H_{38}O_2$
Molar weight (g/mol)	331.59	294.482	322.536
CAS-RN	88510-89-8	–	–
Temperatures of phase transitions T^{tr} (°C)	Cr 25.0 B 30.0 N 66.0 Is	Cr 41.0 B 69.0 N 73.0 Is	Cr 44.0 S 46.0 N 74.0 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	22.6 (Cr–S)	22.6 (Cr–S)	23.8 (Cr–S)
Anisotropy of refractive index Δn (extra., 20 °C, 589 nm)	Δn 0.03	Δn 0.04	Δn 0.03
Dielectric anisotropy $\Delta\varepsilon$ (20 °C, 1 kHz)	$\Delta\varepsilon$ −8.4 (extra)	$\Delta\varepsilon$ −1.6 (extra)	$\Delta\varepsilon$ −0.8 (extra)
Viscosity ν (mm^2/s) (20 °C)	ν 67 (extra)	ν 11 (extra)	ν 13 (extra)
Number/common name	**49**	**50 (RO-CM-7035)**	**51 (RO-CM-7037, RO-CP-7037)**
Substance			
Formula	$C_{17}H_{18}N_2$	$C_{16}H_{17}N_3$	$C_{18}H_{21}N_3$
Molar weight (g/mol)	250.346	251.334	279.388
CAS-RN	77782-82-2	59855-05-9	59854-97-6
Temperatures of phase transitions T^{tr} (°C)	Cr 33.6 N 43.5 Is	Cr 71.0 (N 52.0) Is	Cr 45.0 N 51.0 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	20.9 (Cr–N)	–	0.4 (N–Is)
Density (g/cm^3)	1.0483 (N, 30.0 °C)	–	–
Anisotropy of refractive index Δn	Δn 0.176 $T = 0.95T^{NI}$	Δn 0.220 (extra, 20 °C)	Δn 0.2098
Dielectric constant ε	$\varepsilon_\parallel$ 28.7 $\Delta\varepsilon$ +17.8 (27.7 °C)	$\Delta\varepsilon$ +21.3 $\varepsilon_\parallel$ 31.3 $T = 0.98\ T^{NI}$ 1.592 kHz	$\Delta\varepsilon$ +16.0 $\varepsilon_\parallel$ 24.6 $T = 0.98\ T^{NI}$
Viscosity	ν 50 mm^2/s (extra, 20 °C)	ν 55 mm^2/s (extra, 20 °C)	η 25 mPa s (38 °C)
Magnetic susceptibility $\Delta\chi$ ($10^{-12}\ m^3/kg$)	–	–	90.7 ($T = 0.98\ T^{NI}$)
Dipole moment μ (D)	6.0	6.0	6.7
Number/common name	**52 (PYP605, ZLI-2543)**	**53 (PYP606, ZLI-2303)**	**54 (PYP607, ZLI-2304)**
Substance			
Formula	$C_{21}H_{30}N_2O$	$C_{22}H_{32}N_2O$	$C_{23}H_{34}N_2O$
Molar weight (g/mol)	326.486	340.513	354.54
CAS-RN	57202-28-5	51518-75-3	57202-29-6
Temperatures of phase transitions T^{tr} (°C)	Cr 43.0 N 53.0 Is	Cr 30.5 N 60.8 Is	Cr 35.5 N 58.3 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	29.4 (Cr–N), 1.2 (N–Is)	19.2 (Cr–N), 1.4 (N–Is)	32.7 (Cr–N), 1.5 (N–Is)
Density (g/cm^3)	0.9899 (N, 48.0 °C) 0.9673 (Is, 68.0 °C)	0.9857 (N, 48.0 °C) 0.9618 (Is, 68.0 °C)	0.9806 (N, 48.0 °C) 0.9562 (Is, 68.0 °C)
Refractive index n (589 nm)	n_e 1.6217 n_o 1.5042 (48 °C)	n_e 1.6435 n_o 1.4939 (48 °C)	n_e 1.6305 n_o 1.4940 (48 °C)
Dielectric constant (1 kHz)	$\Delta\varepsilon$ +1.2 (extra, 20 °C)	$\varepsilon_\parallel$ 3.92 $\varepsilon_\perp$ 3.14 $T = 0.97\ T^{NI}$	$\varepsilon_\parallel$ 3.79 $\varepsilon_\perp$ 3.10 $T = 0.97\ T^{NI}$
Viscosity ν (mm^2/s) (20 °C)	ν 50 (extra)	ν 43 (extra)	ν 49 (extra)

Table 26.3 (continued)

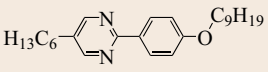
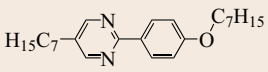
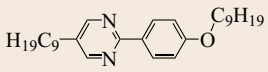
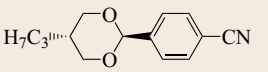
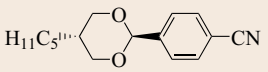
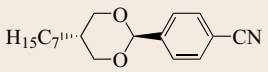
Number/common name	55 (PYP609, ZLI-2306)	56 (PYP707, ZLI-2710)	57 (PYP909, ZLI-2713)
Substance			
Formula	$C_{25}H_{38}N_2O$	$C_{24}H_{36}N_2O$	$C_{28}H_{44}N_2O$
Molar weight (g/mol)	382.594	368.567	424.676
CAS-RN	51462-26-1	–	99895-85-9
Temperatures of phase transitions T^{tr} (°C)	Cr 35.0 N 61.0 Is	Cr 44.0 C 44.0 A 49.0 N 68.0 Is	Cr 34.0 C 61.0 A 75.0 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	35.1 (Cr–N), 1.7 (N–Is)	35.5 (Cr–A), 2.0 (N–Is)	35.1 (Cr–C)
Density (g/cm^3)	0.9707 (N, 48.0 °C) 0.9454 (Is, 68.0 °C)	–	0.9650 (C, 48.0 °C) 0.9494 (N, 68.0 °C)
Refractive index n (589 nm)	n_e 1.6191 n_o 1.4886 (48 °C)	Δn 0.14 (20 °C)	Δn 0.13 (20 °C)
Dielectric anisotropy $\Delta\varepsilon$	$\Delta\varepsilon$ +0.49 (56.0 °C)	$\Delta\varepsilon$ +1.1 (extra, 20 °C)	$\Delta\varepsilon$ +0.9 (extra, 20 °C)
Viscosity ν (mm^2/s) (20 °C)	ν 63 (extra)	ν 53 (extra)	ν 110 (extra)
Number/common name	**58 (PDX3, ZLI-1906)**	**59 (PDX5, ZLI-1908)**	**60 (PDX7, ZLI-1910)**
Substance			
Formula	$C_{14}H_{17}NO_2$	$C_{16}H_{21}NO_2$	$C_{18}H_{25}NO_2$
Molar weight (g/mol)	231.397	259.351	287.405
CAS-RN	–	–	97128-75-1
Temperatures of phase transitions T^{tr} (°C)	Cr 52.9 (N 39.3) Is	Cr 56.0 (N 49.0) Is	Cr 54.0 (N 53.0) Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	20.9 (Cr–Is)	21.0 (Cr–Is), 0.4 (N–Is)	26.4 (Cr–Is), 0.8 (N–Is)
Crystallographic space group	–	–	$P2_12_12_1$
Anisotropy of refractive index Δn (589 nm, 20 °C)	Δn 0.13	Δn 0.14	Δn 0.13
Dielectric constant ε (1 kHz)	$\Delta\varepsilon$ +32 (20 °C)	$\Delta\varepsilon$ +29.6 $\varepsilon_\perp$ 8.2 (20 °C)	$\Delta\varepsilon$ +32 (20 °C) $\Delta\varepsilon$ +7.9 $T = 0.98\,T^{NI}$
Kinematic viscosity (mm^2/s)	ν 33 (20 °C)	ν 29.4 (25 °C)	ν 34.7 (25 °C)
Dipole moment μ (D)	4.1	6.2 (C_6H_{12})	6.2 (C_6H_{12})

Table 26.4 Two-ring systems with bridges

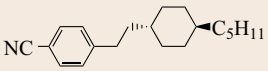
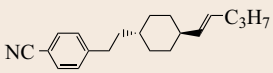
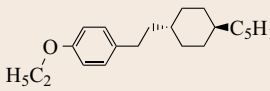
Number/common name	61	62	63 (RO-CM-3952)
Substance			
Formula	$C_{20}H_{29}N$	$C_{20}H_{27}N$	$C_{21}H_{34}O$
Molar weight (g/mol)	283.461	281.445	302.505
Temperatures of phase transitions T^{tr} (°C)	Cr 31.0 N 52.5 Is	Cr 25.1 N 47.5 Is	Cr 27.0 (B 8.0) N 47.0 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	14.6 (Cr–N), 2.0 (N–Is)	15.2 (Cr–N)	–
Dielectric anisotropy $\Delta\varepsilon$ (1 kHz)	$\varepsilon_\perp$ 4.98 $\Delta\varepsilon$ +9.77 (42.5 °C)	$\varepsilon_\perp$ 4.61 $\Delta\varepsilon$ +11.13 (22 °C)	$\Delta\varepsilon$ −0.24$\varepsilon_\perp$ 2.98 (36.6 °C)
Dynamic viscosity η (mPa s)	η 22.4 (22 °C)	η 22.8 (22 °C)	η 12.0 (22 °C)

Table 26.4 (continued)

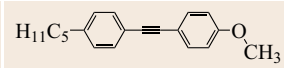
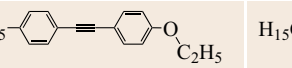
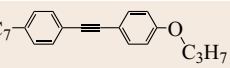
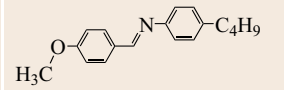
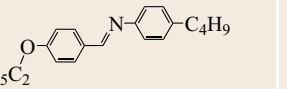
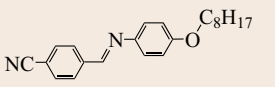
Number/common name	64	65	66
Substance			
Formula	$C_{20}H_{22}O$	$C_{21}H_{24}O$	$C_{24}H_{30}O$
Molar weight (g/mol)	278.398	292.425	334.506
Temperatures of phase transitions T^{tr} (°C)	Cr 47.0 N 58.0 Is	Cr 60.0 N 80.0 Is	Cr 41.0 N 65.0 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	18.0 (Cr–N), 0.6 (N–Is)	23.2 (Cr–N), 1.0 (N–Is)	22.6 (Cr–N), 0.9 (N–Is)
Refractive index n (589 nm)	n_e 1.735 n_o 1.526 (44.5 °C)	n_e 1.726 n_o 1.517 (70 °C)	n_e 1.683 n_o 1.510 (60 °C)
Dielectric constant ε (1 kHz)	$\varepsilon_\perp$ 3.58 $\Delta\varepsilon$ −0.11 (50 °C)	$\Delta\varepsilon$ +0.2 (extra, 20 °C)	$\varepsilon_\perp$ 3.67 $\Delta\varepsilon$ −0.18 (55 °C)
Kinematic viscosity (mm^2/s)	–	ν 20 (extra, 20 °C)	–
Surface tension (mN/m)	25 (22 °C)	–	–
Number/common name	**67 (MBBA)**	**68 (EBBA)**	**69 (CBOOA)**
Substance			
Formula	$C_{18}H_{21}NO$	$C_{19}H_{23}NO$	$C_{22}H_{26}N_2O$
Molar weight (g/mol)	267.374	281.401	334.465
CAS-RN	26227-73-6	29743-08-6	65756-96-9
Temperatures of phase transitions T^{tr} (°C)	Cr 22.0 N 48.0 Is	Cr 36.5 N 79.8 Is	Cr 73.1 A 83.3 N 107.9 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	15.1 (Cr–N), 0.4 (N–Is)	17.2 (Cr–N), 0.6 (N–Is)	27.6 (Cr–N), 0.7 (N–Is)
Crystallographic space group	–	$P2_1/c$	$P2_1/c$
Order parameter S	0.55 (25 °C)	0.39 (55 °C)	–
Density (g/cm^3)	1.042 (N, 25 °C) 1.015 (Is, 60 °C)	1.020 (N, 40 °C) 0.988 (Is, 80 °C)	1.009 (A, 83 °C), 1.003 (N, 90 °C), 0.981 (Is, 110 °C)
Refractive index n	n_e 1.764 n_o 1.549 (589 nm, 25 °C)	n_e 1.763 n_o 1.524 (578 nm, N, 43.5 °C)	–
Dielectric constant ε	$\varepsilon_\parallel$ 4.72 $\varepsilon_\perp$ 5.31 (30 °C, 1.6 kHz)	$\varepsilon_\parallel$ 4.37 $\varepsilon_\perp$ 4.50 (73.8 °C)	$\varepsilon_\parallel$ 14.4 $\varepsilon_\perp$ 7.5 (95 °C, 1 kHz)
Dynamic viscosity η (mPa s)	η 23 (N, 30 °C)	η 11 (N, 69 °C)	η 13 (N, 84 °C)
Surface tension (mN/m)	34.0 (N, 22 °C) 32.6 (Is, 50 °C)	23.8 (N, 45 °C) 23.3 (Is, 80 °C)	26.1 (A, 80 °C), 26.7 (N, 90 °C), 26.6 (Is, 110 °C)
Thermal conductivity (W/(m K))	0.125 (N, 20 °C), 0.128 (N, 30 °C), 0.145 (N, 50 °C)	0.135 (N, 125 °C) 0.157 (Is, 140 °C)	–
Heat capacity C_p (J/(mol K))	509 (N, 37 °C) 507 (Is, 49 °C)	540 (N, 37 °C) 590 (Is, 82 °C)	401 (A, 80 °C), 474 (N, 100 °C), 514 (Is, 120 °C)
Magnetic susceptibility $\Delta\chi$ (10^{-12} m^3/kg)	116 (N, 23 °C)	47 ($T = T^{NI}$)	–
Sound velocity v (m/s)	1200 (N, 33 °C)	1375 (N, 73 °C, 4.8 GHz)	1340 (N, 90 °C, 2 MHz)
Diffusion coefficient D (m^2/s)	$D_\perp$ 8×10^{-10}, $D_\parallel$ 13×10^{-10} $1000/T = 3.3$	D 2.5×10^{-10} (Is, 89 °C)	$D_\perp$ 6.6×10^{-8}, $D_\parallel$ 13.5×10^{-8} (N, 88 °C)
Dipole moment μ (D)	3.2 (22 °C)	$\mu_\parallel$ 1.28 $\mu_\perp$ 1.35 (73.8 °C)	5.21 (C_6H_6, 25 °C)

Table 26.4 (continued)

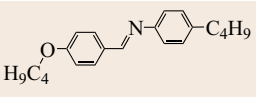
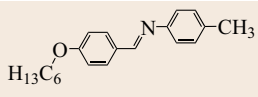
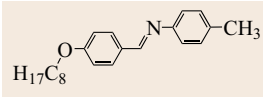
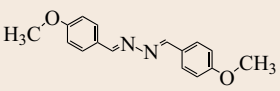
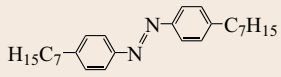
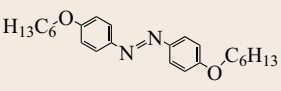
Number/common name	70 (BBBA)	71 (HBT)	72 (OBT)
Substance			
Formula	$C_{21}H_{27}NO$	$C_{20}H_{25}NO$	$C_{22}H_{29}NO$
Molar weight (g/mol)	309.455	295.428	323.483
CAS-RN	29743-09-7	25959-51-7	–
Temperatures of phase transitions T^{tr} (°C)	Cr 8.0 G 41.0 B 45.0 A 45.5 N 75.0 Is	Cr 58.0 (G 44.0 B 53.0) N 76.0 Is	Cr 70.0 (B 61.5 A 69.0) N 78.5 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	3.3 (Cr–G), 0.7 (G–B), 2.9 (B–A), 0.4 (A–N), 0.9 (N–Is)	29.3 (Cr–N), 5.4 (B–N), 1.0 (N–Is)	–
Crystallographic space group	–	–	$P\bar{1}$
Order parameter S	0.36 (52 °C)	–	–
Density (g/cm^3)	1.007 (B, 40 °C), 0.990 (N, 50 °C), 0.964 (Is, 75 °C)	0.985 (N, 70 °C) 0.976 (Is, 77 °C)	0.9714 (N, 71 °C) 0.9576 (Is, 81 °C)
Refractive index n (589 nm)	n_e 1.670 n_o 1.527 (52 °C)	n_e 1.692 n_o 1.525 (71 °C)	n_e 1.688 n_o 1.500 (72.5 °C)
Dielectric constant ε (68 °C)	$\varepsilon_{\parallel}$ 3.99 $\varepsilon_{\perp}$ 4.01 (1 MHz)	$\varepsilon_{\parallel}$ 4.41 $\varepsilon_{\perp}$ 4.25 (10 kHz)	–
Dynamic viscosity η (mPa s)	18 (N, 57 °C)	6.5 (N, 70 °C) 7.0 (Is, 80 °C)	8.6 (N, 71 °C) 8.3 (Is, 80 °C)
Heat capacity C_p (J/(mol K))	–	689 (N, 67 °C) 624 (Is, 90 °C)	–
Magnetic susceptibility $\Delta\chi$ (10^{-12} m^3/kg)	49 ($T = T^{NI}$)	–	–
Sound velocity v (m/s)	1467 (G, 40 °C) 1405 (N, 60 °C), 2 MHz	1358 (N, 70 °C) 1328 (Is, 82 °C), 2 MHz	1360 (N, 70 °C) 1332 (Is, 80 °C), 2 MHz
Number/common name	**73**	**74**	**75**
Substance			
Formula	$C_{16}H_{16}N_2O_2$	$C_{26}H_{38}N_2$	$C_{24}H_{34}N_2O_2$
Molar weight (g/mol)	268.318	378.606	382.551
CAS-RN	2299-73-2	37592-97-5	10225-93-1
Temperatures of phase transitions T^{tr} (°C)	Cr 173.0 N 186.0 Is	Cr 40.0 (A 21.4) N 47.3 Is	Cr 102.6 N 116.2 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	38.7 (Cr–N), 1.6 (N–Is)	24.4 (Cr–N), 1.1 (N–Is)	39.0 (Cr–N), 1.5 (N–Is)
Crystallographic space group	*Cc*	–	–
Order parameter S	0.656 (154.2 °C), 0.410 (180 °C)	–	0.676 (105.7 °C)
Density (g/cm^3)	1.044 (N, 178 °C) 1.023 (Is, 195 °C)	0.9430 (40.6 °C)	0.9493 (Is, 115 °C)
Refractive index n (589 nm)	n_e 1.791 n_o 1.549 (178 °C)	n_o 1.5095 Δn 0.191 (40.3 °C)	–
Dielectric constant ε	−0.124 (172.5 °C, 0.8 MHz)	$\varepsilon_{\parallel}$ 2.8 $\varepsilon_{\perp}$ 2.5 (23 °C, extra)	$\varepsilon_{\parallel}$ 3.254 $\varepsilon_{\perp}$ 3.219 (106 °C, 650 kHz)
Dynamic viscosity η (mPa s)	130 (N, 175 °C) 170 (Is, 197 °C)	–	–
Surface tension (mN/m)	34.6 (N, 180 °C) 32.9 (Is, 190 °C)	–	–
Heat capacity C_p (J/(mol K))	572 (N, 180 °C) 606 (Is, 220 °C)	–	–
Diamagnetic anisotropy $\Delta\chi$ (10^{-11} m^3/kg)	–	10.0 (N, 35 °C)	–
Diffusion coefficient D (m^2/s)	D 1.3×10^{-9} (N), D 2.0×10^{-9} $1000/T = 2.15$ (Is)	–	–
Dipole moment μ (D)	–	–	1.87 (C_6H_6)

Table 26.4 (continued)

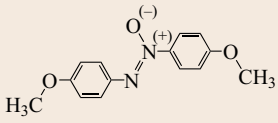
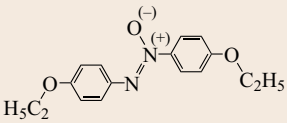
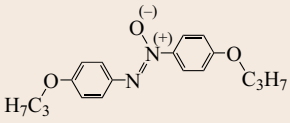
Number/common name	76 (PAA)	77 (PAP)	78
Substance			
Formula	$C_{14}H_{14}N_2O_3$	$C_{16}H_{18}N_2O_3$	$C_{18}H_{22}N_2O_3$
Molar weight (g/mol)	258.279	286.333	314.388
CAS-RN	51437-65-1	51437-64-0	104746-32-9
Temperatures of phase transitions T^{tr} (°C)	Cr 119.5 N 136.5 Is	Cr 136.8 N 168.4 Is	Cr 118.3 N 124.0 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	29.6 (Cr–N), 0.6 (N–Is)	26.9 (Cr–N), 1.5 (N–Is)	26.9 (Cr–N), 0.7 (N–Is)
Crystallographic space group	$P2_1/c$	Cc	$P2_1/n$
Order parameter S	0.50 (N, 122 °C)	0.57 $T = 0.90\,T^{NI}$	0.605 $T = 0.90\,T^{NI}$
Density (g/cm^3)	1.165 (N, 120 °C) 1.140 (Is, 140 °C)	1.096 (N, 142 °C) 1.032 (Is, 198 °C)	1.067 (N, 114 °C) 1.046 (Is, 134 °C)
Refractive index n	n_e 1.804 n_o 1.572 (589 nm, N, 130 °C)	n_e 1.784 n_o 1.522 (589 nm, N, 160 °C)	n_o 1.534 (N, 114 °C, 546 nm)
Dielectric constant ε	$\varepsilon_\parallel$ 5.53 $\varepsilon_\perp$ 5.69 (126 °C)	$\varepsilon_\parallel$ 4.77 $\varepsilon_\perp$ 4.97 (160 °C, 1.2 MHz)	$\Delta\varepsilon$ −0.22 (118.4 °C, 0.8 MHz)
Dynamic viscosity η (mPa s)	2.5 (N, 120 °C), 2.5 (151 °C)	5.2 (N, 164.6 °C)	9.6 (N, 121.2 °C)
Surface tension (mN/m)	38.8 (N, 126 °C) 38.0 (Is, 136 °C)	29.7 (N, 159 °C) 28.8 (Is, 170 °C)	–
Thermal conductivity (W/(m K))	0.135 (N, 125 °C) 0.157 (Is, 140 °C)	–	–
Heat capacity C_p (J/(mol K))	399 (Cr, 100 °C), 507 (N, 120 °C), 508 (Is, 150 °C)	548 (Cr, 126 °C), 682 (N, 160 °C), 643 (Is, 169 °C)	609 (Cr, 100 °C), 696 (N, 117 °C), 665 (Is, 128 °C)
Diamagnetic anisotropy $\Delta\chi$ (10^{-11} m^3/kg)	9.7 (130.8 °C)	13.7 (N, 136 °C)	10.8 (N, 112 °C)
Sound velocity v (m/s)	1240 (N, 130 °C, 3 MHz)	1128 (N, 160 °C, 4.2 MHz)	1247 (N, 121 °C, 3.1 MHz)
Diffusion coefficient D (m^2/s)	$D_\perp$ 5.5 ×10^{-10}, $D_\parallel$ 9 ×10^{-10} 1000/T = 2.55	$D_\perp$ 7.5 ×10^{-10}, $D_\parallel$ 12 ×10^{-10} 1000/T = 2.45	$D_\perp$ 4 ×10^{-10}, $D_\parallel$ 7 ×10^{-10} 1000/T = 2.60
Dipole moment μ (D)	2.3	2.42	2.41

Table 26.4 (continued)

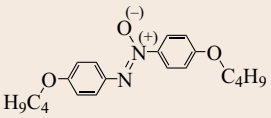
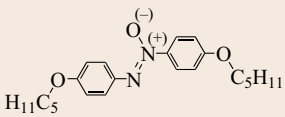
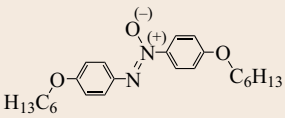
Number/common name	79	80	81
Substance			
Formula	$C_{20}H_{26}N_2O_3$	$C_{22}H_{30}N_2O_3$	$C_{24}H_{34}N_2O_3$
Molar weight (g/mol)	342.442	370.496	398.55
CAS-RN	113787-54-5	107266-21-7	122055-52-1
Temperatures of phase transitions T^{tr} (°C)	Cr 105.8 N 136.6 Is	Cr′ 68.0 Cr 76.0 N 124.0 Is	Cr 81.0 (C 74.0) N 129.0 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	20.9 (Cr–N), 1.0 (N–Is)	14.6 (Cr–N), 0.7 (N–Is)	41.4 (Cr–N), 1.0 (N–Is)
Crystallographic space group	–	$P\bar{1}$	–
Order parameter S	$0.590\ T = 0.90\ T^{NI}$	$0.590\ T = 0.90\ T^{NI}$	$0.610\ T = 0.90\ T^{NI}$
Density (g/cm^3)	1.031 (N, 127 °C) 1.007 (Is, 147 °C)	1.072 (N, 120 °C) 1.063 (Is, 123 °C)	0.990 (N, 125 °C) 0.979 (Is, 132 °C)
Refractive index n (589 nm)	n_o 1.516 (127 °C)	n_e 1.812 n_o 1.518 (103.3 °C)	n_e 1.731 n_o 1.505 (107.5 °C)
Dielectric anisotropy $\Delta\varepsilon$	$\Delta\varepsilon$ −0.38 (110 °C, 0.8 MHz)	$\Delta\varepsilon$ −0.29 (105 °C)	$\Delta\varepsilon$ −0.65 (99.5 °C, 0.8 MHz)
Dynamic viscosity η (mPa s)	6.9 (N, 131.7 °C)	13.5 (N, 120 °C)	10.5 (N, 128.1 °C)
Surface tension (mN/m)	32.0 (N, 110 °C), 29.4 (Is, 140 °C)	30.9 (N, 120 °C), 30.6 (Is, 140 °C)	28.4 (N, 120 °C), 27.4 (Is, 140 °C)
Heat capacity C_p (J/(mol K))	759 (N, 120 °C), 761 (Is, 143 °C)	718 (Cr, 70 °C), 808 (N, 100 °C), 854 (Is, 125 °C)	828 (Cr, 69 °C), 978 (N, 120 °C), 917 (Is, 155 °C)
Diamagnetic anisotropy $\Delta\chi$ (10^{-11} m^3/kg)	10.2 (N, 122 °C)	8.9 (N, 112 °C)	9.5 (N, 109 °C)
Sound velocity v (m/s)	1235 (N, 125 °C, 3.1 MHz)	1205 (N, 122 °C, 3.1 MHz)	1160 (N, 125 °C, 3.1 MHz)
Diffusion coefficient D (m^2/s)	$D_\perp$ 5.5×10^{-8}, $D_\parallel$ 12×10^{-8} (N, 117.6 °C)	$D_\perp$ 6.0×10^{-8}, $D_\parallel$ 12×10^{-8} (N, 110 °C)	$D_\perp$ 6.0×10^{-8}, $D_\parallel$ 13×10^{-8} (N, 113.6 °C)
Dipole moment μ (D)	2.38	2.35	2.35

Table 26.4 (continued)

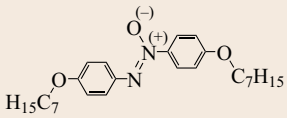
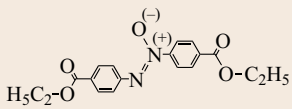
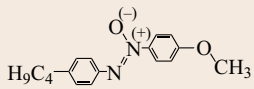
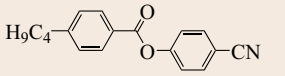
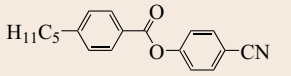
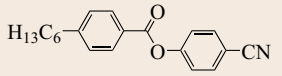
Number/common name	82	83 (EPAB)	84 (N-4)
Substance			
Formula	$C_{26}H_{38}N_2O_3$	$C_{18}H_{18}N_2O_5$	$C_{17}H_{20}N_2O_2$
Molar weight (g/mol)	426.604	342.355	284.361
CAS-RN	70906-50-2	6421-04-1	102135-46-6
Temperatures of phase transitions T^{tr} (°C)	Cr 74.4 C 95.4 N 124.2 Is	Cr′ 102.0 Cr 115.8 A 123.1 Is	Cr 16.0 N 76.0 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	40.9 (Cr–C), 1.6 (C–N), 1.0 (N–Is)	19.7 (Cr–A), 5.0 (A–Is)	–
Crystallographic space group	$P\bar{1}$	$C2/c$, $P\bar{1}$ (Cr′)	–
Order parameter S	0.615 $T = 0.90\,T^{NI}$	–	0.65 (19 °C)
Density (g/cm^3)	0.994 (C, 94 °C) 0.985 (N, 105 °C)	1.146 (Is, 123 °C) 1.138 (Is, 135 °C)	1.1217 (N, 20 °C) 1.1067 (N, 40 °C)
Refractive index n	n_e 1.673 n_o 1.512 (589 nm, N, 117 °C)	–	Δn 0.45 (450 nm), 0.34 (550 nm), 0.30 (650 nm), 20 °C
Dynamic viscosity η (mPa s)	15.1 (N, 123.5 °C)	–	–
Surface tension (mN/m)	–	26.0 (A, 120 °C), 26.3 (Is, 160 °C)	37.3 (N, 23 °C), 35 (N, 76 °C)
Heat capacity C_p (J/(mol K))	887 (C, 77 °C), 1004 (N, 102 °C), 987 (Is, 127 °C)	675 (A, 116.2 °C), 676 (Is, 130 °C)	511 (N, 61 °C)
Diamagnetic anisotropy $\Delta\chi$	7.5×10^{-11} m^3/kg (116 °C)	–	6.9×10^{-10} m^3/mol (75.3 °C)
Sound velocity v (m/s)	1300 (80 °C), 1250 (100 °C) 12 MHz	1276 (2 MHz, 117.4 °C)	–
Diffusion coefficient D (m^2/s)	$D_\perp 3.7\times10^{-10}$, $D_\parallel 6\times10^{-10}$ $1000/T = 2.60$	–	–
Dipole moment μ (D)	2.36	–	–
Number/common name	**85 (RO-CM-1500)**	**86 (RO-CM-1530)**	**87 (RO-CM-1510)**
Substance			
Formula	$C_{18}H_{17}NO_2$	$C_{19}H_{19}NO_2$	$C_{20}H_{21}NO_2$
Molar weight (g/mol)	279.342	293.369	307.396
CAS-RN	38690-77-6	49763-64-6	50793-85-6
Temperatures of phase transitions T^{tr} (°C)	Cr 67.1 (N 42.6) Is	Cr 64.4 (N 55.4) Is	Cr 44.4 N 48.6 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	28.0 (Cr–Is)	25.1 (Cr–Is)	40.2 (Cr–N)
Crystallographic space group	–	$P2_1/n$	–
Density (g/cm^3)	1.095 (N, 40 °C) 1.061 (Is, 80 °C)	1.076 (N, 47.4 °C) 1.053 (Is, 67.4 °C)	1.064 (N, 36.6 °C) 1.043 (Is, 56.6 °C)
Refractive index n	n_e 1.639 n_o 1.525 (589 nm, N, 39 °C)	n_e 1.669 n_o 1.512 (546 nm, N, 47.4 °C)	n_e 1.657 n_o 1.514 (546 nm, N, 36.6 °C)
Dielectric constant ε (1.592 kHz $T = 0.98\,T^{NI}$)	$\varepsilon_\parallel$ 34.3 $\varepsilon_\perp$ 12.0	$\varepsilon_\parallel$ 30.2 $\varepsilon_\perp$ 10.2	$\varepsilon_\parallel$ 29.3 $\varepsilon_\perp$ 9.7
Surface tension (mN/m)	–	28.2 (N, 38 °C) 30.7 (53 °C)	–
Dipole moment μ (D)	5.77	–	–

Table 26.4 (continued)

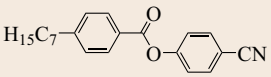
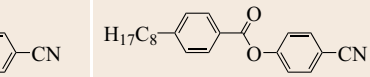
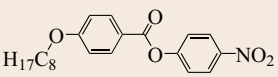
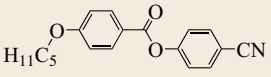
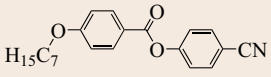
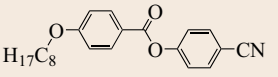
Number/common name	88 (RO-CM-1540)	89	90
Substance			
Formula	$C_{21}H_{23}NO_2$	$C_{22}H_{25}NO_2$	$C_{21}H_{25}NO_5$
Molar weight (g/mol)	321.423	335.45	371.437
CAS-RN	38690-76-5	50793-86-7	52910-78-8
Temperatures of phase transitions T^{tr} (°C)	Cr 44.0 N 56.5 Is	Cr 47.0 N 55.0 Is	Cr′ 47.5 Cr 50.5 A 61.4 N 68.1 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	31.5 (Cr–N), 1.0 (N–Is)	38.5 (Cr–N)	18.4 (Cr–A), 0.2 (A–N), 0.4 (N–Is)
Crystallographic space group	$P2_1/n$	–	$P2_1/c$
Order parameter S	0.574 (44 °C) 0.42 (56 °C)	–	0.605 (A, 44 °C) 0.31 (N, 66 °C)
Density (g/cm^3)	1.050 (N, 48 °C) 1.034 (Is, 60 °C)	1.042 (N, 45.8 °C) 1.021 (Is, 65.8 °C)	1.123 (A, 52 °C), 1.110 (N, 66 °C), 1.106 (Is, 70 °C)
Refractive index n	n_e 1.649 n_o 1.505 (546 nm, N, 45 °C)	n_e 1.627 n_o 1.508 (546 nm, N, 50.8 °C)	n_e 1.644 n_o 1.504 (589 nm, N, 55 °C)
Dielectric constant ε	$\varepsilon_\parallel$ 26.4 $\varepsilon_\perp$ 8.7 (1.592 kHz $T = 0.98T^{NI}$)	$\varepsilon_\parallel$ 24.3 $\varepsilon_\perp$ 8.5 (1.592 kHz $T = 0.98T^{NI}$)	$\Delta\varepsilon$ 11.1 (60 °C), $\Delta\varepsilon$ 11.4 (65 °C), 1 kHz
Dynamic viscosity (mPa s)	η 22 (50 °C), 22 (60 °C)	–	–
Surface tension (mN/m)	27 (22 °C), 25.4 (45 °C)	19.6 (43 °C), 22.5 (58 °C)	–
Sound velocity v (m/s)	1235 (N, 125 °C, 3.1 MHz)	–	1372 (58 °C, 4.74 GHz)
Dipole moment μ (D)	6.1 (CCl_4)	–	6.04
Number/common name	**91**	**92**	**93**
Substance			
Formula	$C_{19}H_{19}NO_3$	$C_{21}H_{23}NO_3$	$C_{22}H_{25}NO_3$
Molar weight (g/mol)	309.368	337.422	351.449
CAS-RN	50649-73-5	50793-88-9	50793-89-0
Temperatures of phase transitions T^{tr} (°C)	Cr 87.0 (N 78.0) Is	Cr 71.5 N 82.0 Is	Cr 75.6 N 88.0 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	32.2 (Cr–Is)	34.3 (Cr–N)	40.6 (Cr–N)
Crystallographic space group	*Pnam*	$P2_1/a$	$P\bar{1}$
Density (g/cm^3)	1.093 (N, 69 °C) 1.075 (Is, 85.5 °C)	1.061 (N, 73 °C) 1.045 (Is, 88 °C)	1.044 (N, 79 °C) 1.028 (Is, 94 °C)
Refractive index n (546 nm)	n_e 1.662 n_o 1.513 (76.7 °C)	n_e 1.633 n_o 1.508 (73.3 °C)	n_e 1.627 n_o 1.502 (79 °C)
Dielectric constant ε	$\varepsilon_\parallel$ 27.8 $\varepsilon_\perp$ 11.7 (71.8 °C)		
Surface tension (mN/m)	29.1 (76 °C), 26.4 (91 °C)	25.0 (73 °C), 22.9 (88 °C)	23.2 (76 °C), 21.1 (91 °C)
Sound velocity v (m/s)	1359 (83 °C, 2 MHz)	–	–
Dipole moment μ (D)	6.6 (CCl_4)	–	–

Table 26.4 (continued)

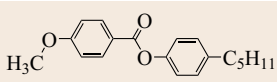
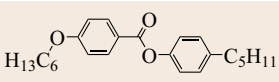
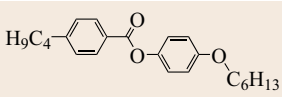
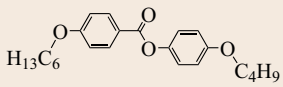
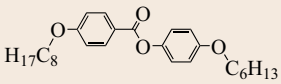
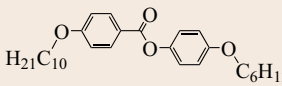
Number/common name	94 (ME105, ZLI-0245)	95 (ME605, ZLI-1004)	96
Substance			
Formula	$C_{19}H_{22}O_3$	$C_{24}H_{32}O_3$	$C_{23}H_{30}O_3$
Molar weight (g/mol)	298.385	368.521	354.494
CAS-RN	–	38444-15-4	38454-28-3
Temperatures of phase transitions T^{tr} (°C)	Cr 29.5 N 43.5 Is	Cr 50.0 N 63.0 Is	Cr 31.3 N 48.6 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	17.6 (Cr–N), 0.6 (N–Is)	21.9 (Cr–N)	17.6 (Cr–N)
Density (g/cm^3)	1.078 (N, 31 °C) 1.061 (Is, 45 °C)	1.019 (N, 50 °C) 1.001 (Is, 65 °C)	1.020 (N, 41 °C) 1.006 (Is, 53 °C)
Refractive index n (589 nm)	n_e 1.639 n_o 1.515 (35 °C)	n_e 1.613 n_o 1.490 (47.4 °C)	n_e 1.599 n_o 1.498 (41 °C)
Dielectric anisotropy $\Delta\varepsilon$	$\Delta\varepsilon$ +0.11 (38 °C)	$\Delta\varepsilon$ +0.1 (20 °C, 1 kHz)	–
Kinematic viscosity (mm^2/s)	ν 38 (20 °C)	ν 87 (20 °C)	–
Surface tension (mN/m)	24.5 (20 °C)	–	27.5 (41.5 °C)
Dipole moment μ (D)	$\mu_\parallel$ 2.18 $\mu_\perp$ 2.15 (38 °C)	–	2.3 (CCl_4)
Number/common name	**97**	**98**	**99**
Substance			
Formula	$C_{23}H_{30}O_4$	$C_{27}H_{38}O_4$	$C_{29}H_{42}O_4$
Molar weight (g/mol)	370.493	426.602	454.656
CAS-RN	38454-24-9	54963-63-2	68162-09-4
Temperatures of phase transitions T^{tr} (°C)	Cr 66.0 N 89.5 Is	Cr 55.0 C 66.0 N 89.0 Is	Cr 62.5 (E 38.0 B 44.5) C 77.5 A 83.3 N 88.9 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	35.0 (Cr–N), 1.3 (N–Is)	38.0 (Cr–C), 0.4 (C–N), 2.1 (N–Is)	45.3 (Cr–C), 4.7 (B–C), 0.7 (A–N), 2.1 (N–Is)
Order parameter S	0.49 (84 °C)	0.49 (84.5 °C)	0.51 (84 °C)
Density (g/cm^3)	1.015 (N, 88 °C)	0.9821 (N, 83 °C)	0.9735 (N, 84.9 °C)
Refractive index n	n_e 1.518 n_o 1.394 (80 °C, 650 nm)	n_e 1.5811 n_o 1.4828 (83.5 °C, 589 nm)	–
Dielectric constant ε (1 kHz)	$\Delta\varepsilon$ −0.27 (79 °C)	$\Delta\varepsilon$ −0.20 (84 °C)	$\varepsilon_\parallel$ 3.85 $\varepsilon_\perp$ 4.05 (85 °C)
Dynamic viscosity η (mPa s)	–	η 11.4 (80 °C)	–
Sound velocity v (m/s)	–	1383 (83 °C, 0.36 MHz)	1285 (80 °C, 0.36 MHz)
Dipole moment μ (D), 25 °C	2.67 (CCl_4)	2.86 (C_6H_6)	3.31 (CCl_4)

Table 26.4 (continued)

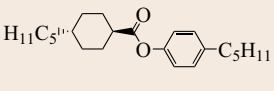
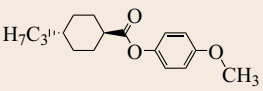
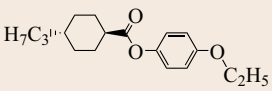
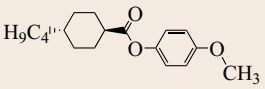
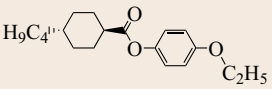
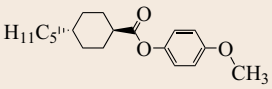
Number/common name	**100 (D55, ZLI-1497)**	**101 (D301, ZLI-2469)**	**102 (D302, ZLI-1496)**
Substance			
Formula	$C_{23}H_{36}O_2$	$C_{17}H_{24}O_3$	$C_{18}H_{26}O_3$
Molar weight (g/mol)	344.542	276.379	290.406
CAS-RN	67589-72-4	–	67589-39-3
Temperatures of phase transitions T^{tr} (°C)	Cr 36.0 (A 29.0) N 48.0 Is	Cr 55.5 N 62.5 Is	Cr 49.0 N 79.8 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	28.9 (Cr–N), 0.55 (N–Is)	28.0 (Cr–N)	27.6 (Cr–N)
Order parameter S	0.67 (39 °C)	–	0.71 (60 °C)
Density (g/cm^3)	0.9508 (N, 36 °C)	–	1.0118 (51 °C)
Refractive index n (589 nm)	n_e 1.5304 n_o 1.4730 (36 °C)	Δn 0.09 (20 °C)	n_e 1.5304 n_o 1.4684 (60 °C)
Dielectric constant ε (1 kHz)	$\varepsilon_{\parallel}$ 2.958 $\varepsilon_{\perp}$ 3.396 (40 °C)	$\Delta\varepsilon$ −1.8 (20 °C)	$\varepsilon_{\parallel}$ 3.28 $\varepsilon_{\perp}$ 4.54 (51 °C)
Kinematic viscosity (mm^2/s) 20 °C	ν 13 (extra)	ν 12 (extra)	ν 14 (extra)
Dipole moment μ (D)	1.99	–	2.17
Number/common name	**103 (D401, ZLI-2470)**	**104 (D402, RO-CM-1942, ZLI-1563)**	**105 (D501, RO-CM-1951, ZLI-1495)**
Substance			
Formula	$C_{18}H_{26}O_3$	$C_{19}H_{28}O_3$	$C_{19}H_{28}O_3$
Molar weight (g/mol)	290.406	304.433	304.433
CAS-RN	67589-46-2	67589-47-3	67589-52-0
Temperatures of phase transitions T^{tr} (°C)	Cr 42.0 N 59.0 Is	Cr 36.3 N 74.6 Is	Cr 40.9 N 71.3 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	23.0 (Cr–N)	21.4 (Cr–N)	21.0 (Cr–N), 0.5 (N–Is)
Order parameter S	–	0.73 (40 °C)	0.71 (50 °C)
Density (g/cm^3)	–	1.059 (40 °C)	1.050 (48 °C)
Refractive index n (589 nm)	Δn 0.09 (20 °C)	n_e 1.5508 n_o 1.4730 (40 °C)	n_e 1.5389 n_o 1.4742 (50 °C)
Dielectric constant ε (1 kHz)	$\Delta\varepsilon$ −1.8 (20 °C)	$\varepsilon_{\perp}$ 4.20 $\Delta\varepsilon$ −0.91 (65.4 °C)	$\varepsilon_{\parallel}$ 3.37 $\varepsilon_{\perp}$ 4.28 (51 °C)
Viscosity	ν 14 mm^2/s (20 °C)	η 20 mPa s (22 °C)	–
Diamagnetic anisotropy $\Delta\chi$ (10^{-11} m^3/kg)	–	3.0 (52 °C)	3.0 (52.5 °C)
Dipole moment μ (D)	–	2.08 (C_6H_6)	2.23 (C_6H_6)

Table 26.4 (continued)

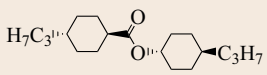
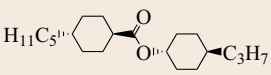
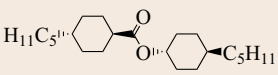
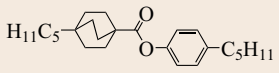
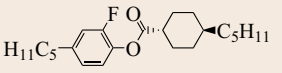
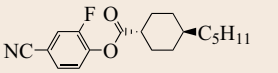
Number/common name	106 (OS33, RO-CM-1633, ZLI-2155)	107 (OS53, RO-CM-1653, ZLI-2256)	108 (OS55, ZLI-2495)
Substance			
Formula	$C_{19}H_{34}O_2$	$C_{21}H_{38}O_2$	$C_{23}H_{42}O_2$
Molar weight (g/mol)	294.482	322.536	350.59
CAS-RN	73255-62-6	73255-65-9	–
Temperatures of phase transitions T^{tr} (°C)	Cr 22.8 N 36.6 Is	Cr 24.5 B 37.5 N 52.0 Is	Cr 52.0 B 72.0 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	–	29.3 (Cr–S)	31.0 (Cr–S)
Anisotropy of refractive index Δn (589 nm)	Δn 0.036 (25 °C)	Δn 0.05 (extra, 20 °C)	–
Dielectric anisotropy $\Delta\varepsilon$ (1 kHz)	$\Delta\varepsilon$ −1.1 (25 °C)	$\Delta\varepsilon$ −1.5 (20 °C)	$\Delta\varepsilon$ −1.6 (20 °C)
Viscosity ν (mm^2/s) (20 °C)	ν 11	ν 14	ν 15
Number/common name	**109**	**110**	**111**
Substance			
Formula	$C_{25}H_{38}O_2$	$C_{23}H_{35}FO_2$	$C_{19}H_{24}FNO_2$
Molar weight (g/mol)	370.58	362.533	317.407
Temperatures of phase transitions T^{tr} (°C)	Cr 31.0 N 64.5 Is	Cr 19.0 N 37.9 Is	Cr 75.5 N 93.5 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	29.8 (Cr–N)	33.5 (Cr–N)	–
Refractive index n	n_e 1.5337 n_o 1.4770 $T = 0.97\ T^{NI}$633 nm	Δn 0.0608 n_e 1.5273 $T = 0.97\ T^{NI}$633 nm	Δn 0.093 $T = 0.95\ T^{NI}$589 nm
Dielectric constant ε (1 kHz)	$\varepsilon_{\parallel}$ 2.79 $\varepsilon_{\perp}$ 3.18 $T = 0.97\ T^{NI}$	–	$\Delta\varepsilon$ +4.4 $T = 0.95\ T^{MI}$
Viscosity (20 °C)	η 35 mPa s (extra)	ν 16 mm^2/s (extra)	–

Table 26.5 Three- and four-ring systems

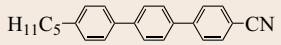
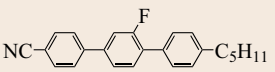
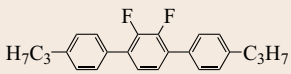
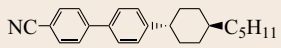
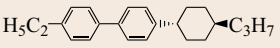
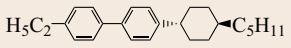
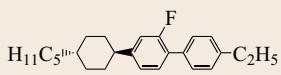
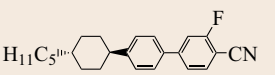
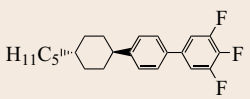
Number/common name	**112 (RO-CM-5515, T15)**	**113**	**114**
Substance			
Formula	$C_{24}H_{23}N$	$C_{24}H_{22}FN$	$C_{24}H_{24}F_2$
Molar weight (g/mol)	325.458	343.448	350.456
CAS-RN	54211-46-0	–	–
Temperatures of phase transitions T^{tr} (°C)	Cr′ 80.0 Cr′ 115.0 Cr 131.0 N 240.0 Is	Cr 97.0 N 189.0 Is	Cr 95.0 N 131.0 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	17.2 (Cr–N), 0.9 (N–Is)	–	24.3 (Cr–N)
Anisotropy of refractive index Δn (extra, 20 °C, 589 nm)	Δn 0.30	Δn 0.343	Δn 0.24
Dielectric anisotropy $\Delta\varepsilon$ (1 kHz)	$\Delta\varepsilon$ +13 $\varepsilon_{\parallel}$ 16.0 $T = 0.75\ T^{NI}$	$\Delta\varepsilon$ +10 (20 °C, extra)	$\Delta\varepsilon$ −1.7 (20 °C, extra)
Kinematic viscosity (mm^2/s)	ν 86 (extra, 20 °C)	ν 195 (extra, 20 °C)	ν 31 (extra, 20 °C)
Number/common name	**115 (BCH5, ZLI-1131)**	**116 (BCH32, ZLI-1409)**	**117 (BCH52, ZLI-1409)**
Substance			
Formula	$C_{24}H_{29}N$	$C_{23}H_{30}$	$C_{25}H_{34}$
Molar weight (g/mol)	331.505	306.496	334.55
Temperatures of phase transitions T^{tr} (°C)	Cr 96.0 N 222.0 Is	Cr 66.0 S 134.0 N 166.0 Is	Cr 34.0 B 146.0 N 164.0 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	21.1 (Cr–N), 0.7 (N–Is)	–	18.5 (Cr–B), 6.8 (B–N), 0.5 (N–Is)
Crystallographic space group	$P2_1/c$	–	$C2/c$
Density (g/cm^3)	1.196 (101 °C)	–	–
Refractive index n	n_e 1.734 n_o 1.515 (101 °C, 546 nm)	Δn 0.18 (20 °C, 589 nm)	Δn 0.18 (20 °C, 589 nm)
Dielectric constant ε (1 kHz)	$\varepsilon_{\parallel}$ 16.8 $\varepsilon_{\perp}$ 4.9 (20 °C, extra)	$\Delta\varepsilon$ +0.5 (20 °C, extra)	$\Delta\varepsilon$ +0.4 (20 °C, extra)
Kinematic viscosity (mm^2/s)	ν 90 (extra, 20 °C)	ν 20 (extra, 20 °C)	ν 20 (extra, 20 °C)
Number/common name	**118 (BCH52F)**	**119**	**120**
Substance			
Formula	$C_{25}H_{33}F$	$C_{24}H_{28}FN$	$C_{23}H_{27}F_3$
Molar weight (g/mol)	352.54	349.496	360.467
CAS-RN	–	–	137019-95-5
Temperatures of phase transitions T^{tr} (°C)	Cr 37.0 N 117.0 Is	Cr 84.0 N 175.4 Is	Cr 30.4 N 58.0 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	23.0 (Cr–N)	–	18.0 (Cr–N), 0.2 (N–Is)
Refractive index n	Δn 0.096, 633 nm $T = 0.97\ T^{NI}$	Δn 0.201 (20 °C, extra, 589 nm)	Δn 0.134 (25 °C, extra, 589 nm)
Dielectric constant ε (1 kHz)	$\varepsilon_{\parallel}$ 2.97 $\varepsilon_{\perp}$ 2.85 $T = 0.97\ T^{MI}$	$\Delta\varepsilon$ +20.3 (20 °C, extra)	$\Delta\varepsilon$ +11.3 (20 °C, extra)
Viscosity (20 °C, extra)	ν 27 mm^2/s	ν 110 mm^2/s	η 32.1 mPa s

Table 26.5 (continued)

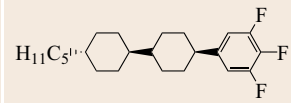
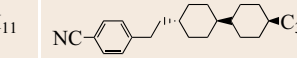
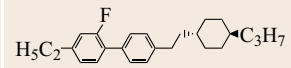
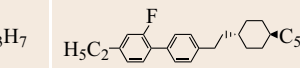
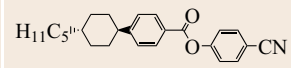
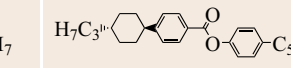
Number/common name	121	122 (BCN55, ZLI-2769)	123
Substance			
Formula	$C_{23}H_{33}F_3$	$C_{29}H_{51}N$	$C_{24}H_{35}N$
Molar weight (g/mol)	366.515	413.737	337.553
Temperatures of phase transitions T^{tr} (°C)	Cr 87.3 N 101.2 Is	Cr 33.0 B 176.0 A 185.0 N 198.7 Is	Cr 69.0 N 196.0 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	26.4 (Cr–N), 0.6 (N–Is)	17.6 (Cr–B)	–
Anisotropy of refractive index Δn (589 nm)	Δn 0.085 (25 °C, extra)	Δn 0.06 (20 °C, extra)	Δn 0.17 (20 °C, extra)
Dielectric anisotropy $\Delta\varepsilon$ (extra, 20 °C, 1 kHz)	$\Delta\varepsilon$ +7.8	$\Delta\varepsilon$ −4.7	$\Delta\varepsilon$ +12
Kinematic viscosity (mm^2/s)	ν 20 (extra, 20 °C)	ν 110 (extra, 20 °C)	ν 75 (extra, 20 °C)
Number/common name	**124 (I32)**	**125 (I35)**	**126 (I52)**
Substance			
Formula	$C_{25}H_{33}F$	$C_{28}H_{39}F$	$C_{27}H_{37}F$
Molar weight (g/mol)	352.54	394.621	380.594
CAS-RN		100497-33-4	95379-18-3
Temperatures of phase transitions T^{tr} (°C)	Cr 27.0 N 97.0 Is	Cr 30.0 N 106.0 Is	Cr 24.0 (B 14.0) N 103.0 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	–	–	14.2 (Cr–N), 1.3 (N–Is)
Density (g/cm^3)	1.0156 (N, 25 °C)	0.9975 (N, 25 °C)	1.003 (N, 25 °C)
Refractive index n $T = 0.95\,T^{NI}$, 633 nm	n_e 1.6108 n_o 1.4893	n_e 1.6021 n_o 1.4851	n_e 1.6013 n_o 1.4824
Dielectric constant ε	$\varepsilon_\parallel$ 2.94 $\varepsilon_\perp$ 2.93 $T = 0.95\,T^{NI}$ 0.5 kHz	$\varepsilon_\parallel$ 2.92 $\varepsilon_\perp$ 2.89 $T = 0.95\,T^{NI}$ 0.5 kHz	$\Delta\varepsilon$ −0.06 $\varepsilon_\parallel$ 2.964 $\varepsilon_\perp$ 3.024 (25 °C, 1 kHz)
Kinematic viscosity (mm^2/s)	ν 19 (20 °C)	ν 24.5 (20 °C)	ν 25.1 (25 °C)
Number/common name	**127 (HP5N, ZLI-1226)**	**128 (HP33, ZLI-1222)**	**129 (HP35, ZLI-2429)**
Substance			
Formula	$C_{25}H_{29}NO_2$	$C_{25}H_{32}O_2$	$C_{27}H_{36}O_2$
Molar weight (g/mol)	375.515	364.533	392.587
Temperatures of phase transitions T^{tr} (°C)	Cr′ 82.0 Cr 111.5 N 226.0 Is	Cr 87.0 N 186.0 Is	Cr 83.0 (S 79.0) N 175.0 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	5.4 (Cr–Cr′), 19.0 (Cr–N), 1.4 (N–Is)	20.9 (Cr–N)	22.0 (Cr–N)
Density (g/cm^3)	–	1.141 (N, 99.5 °C)	–
Refractive index n	Δn 0.16 (20 °C, 589 nm)	n_e 1.655 n_o 1.509 (99.5 °C, 546 nm)	Δn 0.14 (20 °C, 589 nm)
Dielectric constant ε (1 kHz)	$\varepsilon_\parallel$ 24.4 $\varepsilon_\perp$ 7.5 (156.0 °C)	$\Delta\varepsilon$ +0.4 (20 °C)	$\Delta\varepsilon$ +0.6 (20 °C)
Kinematic viscosity (mm^2/s)	ν 220 (extra., 20 °C)	ν 60 (extra., 20 °C)	ν 41 (extra., 20 °C)

Table 26.5 (continued)

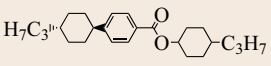
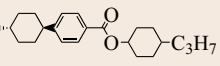
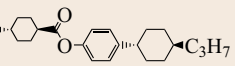
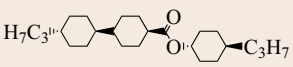
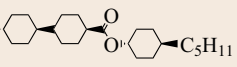
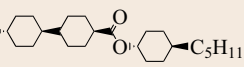
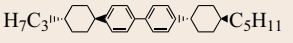
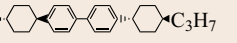
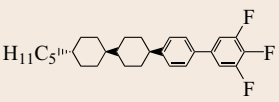
Number/common name	**130 (HH33, ZLI-1224)**	**131 (HH53, ZLI-1223)**	**132 (HD34, ZLI-1749)**
Substance			
Formula	$C_{25}H_{38}O_2$	$C_{27}H_{42}O_2$	$C_{26}H_{40}O_2$
Molar weight (g/mol)	370.58	398.635	384.63
Temperatures of phase transitions T^{tr} (°C)	Cr 94.0 N 158.0 Is	Cr 67.0 (S 43.0 A 55.0) N 155.0 Is	Cr 64.0 S 97.0 S 116.0 N 189.0 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	18.1 (Cr–N)	21.8 (Cr–N)	13.5 (Cr–S)
Crystallographic space group	$P\bar{1}$	$P\bar{1}$	
Anisotropy of refractive index Δn (extra, 589 nm)	Δn 0.19 (20 °C)	Δn 0.092 (N, 80 °C)	Δn 0.11 (20 °C)
Dielectric anisotropy $\Delta\varepsilon$ (20 °C, 1 kHz)	$\Delta\varepsilon$ −1	$\Delta\varepsilon$ −1	$\Delta\varepsilon$ −1.4
Kinematic viscosity (mm^2/s)	ν 130 (extra., 20 °C)	ν 119 (extra., 20 °C)	ν 40 (extra., 20 °C)
Number/common name	**133 (CH33)**	**134 (CH35)**	**135 (CH45)**
Substance			
Formula	$C_{25}H_{44}O_2$	$C_{27}H_{48}O_2$	$C_{28}H_{50}O_2$
Molar weight (g/mol)	376.628	404.682	418.71
Temperatures of phase transitions T^{tr} (°C)	Cr 58.0 S 155.0 N 189.0 Is	Cr 53.0 S 169.0 N 188.0 Is	Cr 38.0 S 181.0 N 186.0 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	24.3 (Cr–S)	30.1 (Cr–S)	22.2 (Cr–S)
Anisotropy of refractive index Δn (extra, 589 nm)	Δn 0.06 (20 °C)	Δn 0.06 (20 °C)	Δn 0.05 (20 °C)
Dielectric anisotropy $\Delta\varepsilon$ (20 °C, 1 kHz)	$\Delta\varepsilon$ −1.8	$\Delta\varepsilon$ −1.6	$\Delta\varepsilon$ −1.7
Kinematic viscosity (mm^2/s)	ν 31 (extra., 20 °C)	ν 34 (extra., 20 °C)	ν 37 (extra., 20 °C)
Number/common name	**136 (CBC53, ZLI-1544)**	**137 (CBC33, ZLI-1987)**	**138**
Substance			
Formula	$C_{32}H_{46}$	$C_{30}H_{42}$	$C_{29}H_{37}F_3$
Molar weight (g/mol)	430.723	402.669	442.613
CAS-RN	80955-71-1	85600-56-2	–
Temperatures of phase transitions (°C)	Cr′ 54.0 Cr 58.0 B 232.0 A 251.0 N 311.0 Is	Cr′ 108.0 Cr′ 127.0 Cr 155.0 B 210.0 A 220.0 N 325.0 Is	Cr 87.8 N > 250.0 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	5.1 (Cr–Cr′), 1.4 (Cr–B), 6.1 (B–A), 0.5 (A–N), 1.1 (N–Is)	12.0 (Cr–B), 5.2 (B–A), 1.2 (N–Is)	–
Anisotropy of refractive index Δn (extra, 589 nm)	Δn 0.19 (20 °C)	Δn 0.19 (20 °C)	Δn 0.144 (25 °C)
Dielectric anisotropy $\Delta\varepsilon$ (extra, 20 °C, 1 kHz)	$\Delta\varepsilon$ +0.4	$\Delta\varepsilon$ +0.5	$\Delta\varepsilon$ +11.3
Viscosity (extra, 20 °C)	ν 42 mm^2/s	ν 53 mm^2/s	η 51.1 mPa s

Table 26.6 Ferroelectric liquid crystals

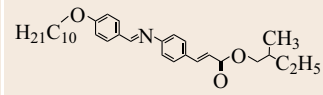
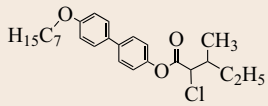
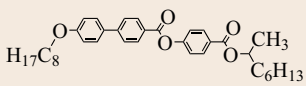
Number/common name	139 (DOBAMBC)	140 (C-7)	141 (MHPOBC)
Substance			
Formula	$C_{31}H_{43}NO_3$	$C_{25}H_{33}ClO_3$	$C_{36}H_{46}O_5$
Molar weight (g/mol)	477.693	416.993	558.765
CAS-RN	97335-57-4	100497-43-6	103376-72-3
Temperatures of phase transitions T^{tr} (°C)	Cr 74.6 (I* 62.0) C* 94.0 A 117.0 Is	Cr 55.0 C* 55.0 A 62.0 Is	Cr 84.0 CA* 118.4 Cγ 119.2 C* 120.9 Cα 122.0 A 148.0 Is
Enthalpies of phase transitions ΔH^{tr} (J/mol)	25.8×10^3 (Cr–C*), 1.67×10^3 (I–C*), 5.15×10^3 (A–Is)	–	14.6 (C*–Cα), 16.4 (CA*–Cγ), 18.8 (Cα–C*), 288 (Cα–A), 6420 (A–Is)
Density (g/cm^3)	0.994 (C*, 92 °C), 0.985 (A, 100 °C), 0.959 (Is, 120 °C)	–	–
Refractive index n	n_e 1.700 n_o 1.490 (A, 110 °C, 633 nm)	–	–
Dynamic viscosity η (mPa s)	6.7 (90 °C)	–	–
P_s (nC/cm^2) (T, °C)	+4.75 (65 °C)	+260 (45 °C)	+70 (139.5 °C)

Table 26.7 Cholesteryl (cholest-5-ene) substituted mesogens

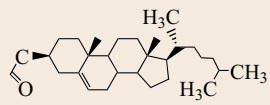
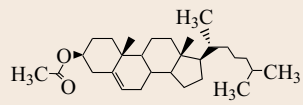
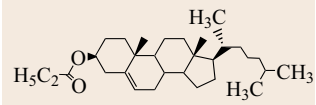
Number/common name	142	143	144 (CP)
Substance			
Formula	$C_{28}H_{46}O_2$	$C_{29}H_{48}O_2$	$C_{30}H_{50}O_2$
Molar weight (g/mol)	414.678	428.705	442.732
CAS-RN	4351-55-7	604-35-3	633-31-8
Temperatures of phase transitions T^{tr} (°C)	Cr 97.5 (N* 60.5) Is	Cr 116.5 (N* 94.5) Is	Cr 101.6 N* 115.2 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	22.6 (Cr–Is)	20.1 (Cr–Is), 0.3 (N*–Is)	23.0 (Cr–N*), 0.5 (N*–Is)
Crystallographic space group	–	$P2_1$	–
Density (g/cm^3)	–	0.951 (100 °C) 0.898 (130 °C)	0.919 (110 °C) 0.901 (130 °C)
Refractive index n	–	n_e 1.482 n_o 1.499 (N*, 95 °C)	n_e 1.472 n_o 1.489 (N*, 589 nm, 107.5 °C)
Dielectric constant ε (10 kHz)	2.45 (80 °C), 3.40 (100 °C)	2.35 (90 °C), 2.90 (130 °C)	2.22 (80 °C), 2.79 (120 °C)
Viscosity	η 44 (71 °C), 25 (100 °C) mPa s	η 53 (105 °C), 17 (125 °C) mPa s	ν 22.1 mm^2/s (117 °C)
Surface tension (mN/m)	28.5 (70 °C)	26.6 (110 °C)	24.7 (110 °C)
Velocity (m/s) (2 MHz)	1030 (95 °C), 990 (100 °C)	1107 (100 °C), 1042 (130 °C)	1245 (113 °C), 1228 (120 °C)
Pitch p (μm)	–	–	0.289 (110 °C)
Dipole moment μ (D)	2.50 (CCl_4), 2.55 (C_6H_6)	2.08 (CCl_4), 1.98 (C_6H_6)	2.30 (CCl_4), 2.16 (C_6H_6)

Table 26.7 (continued)

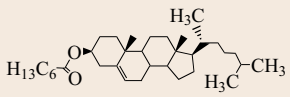
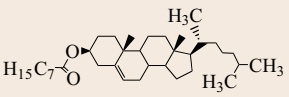
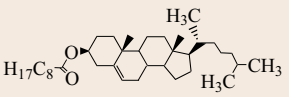
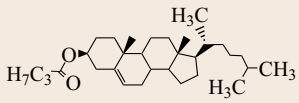
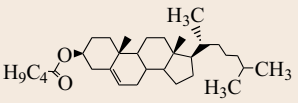
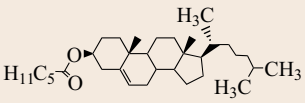
Number/common name	148	149	150 (CN)
Substance			
Formula	$C_{34}H_{58}O_2$	$C_{35}H_{60}O_2$	$C_{36}H_{62}O_2$
Molar weight (g/mol)	498.84	512.867	526.894
CAS-RN	1182-07-6	1182-42-9	1182-66-7
Temperatures of phase transitions T^{tr} (°C)	Cr 114.0 (S <92.5 N* 95.5) Is	Cr 110.0 (S 69.5 N* 96.5) Is	Cr 80.5 (S 77.5) N* 92.0 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	32.2 (Cr–Is), 0.5 (N*–Is)	34.1 (Cr–Is), 0.7 (N*–Is)	23.4 (Cr–N*), 0.7 (N*–Is), 0.5 (S–N*)
Crystallographic space group	$P2_1$	$P2_1$	$P2_1$
Refractive index n (589 nm)	–	–	n_e 1.4728 n_o 1.4895 (N*, 85 °C), n_e 1.5173 n_o 1.4734 (S, 75.5 °C)
Dielectric constant ε	–	–	2.78 (90 °C, 600 kHz)
Dynamic viscosity η (mPa s)	–	η 31 (90 °C)	η 98 (N*, 90.2 °C)
Surface tension (mN/m)	20.4 (120 °C)	21.0 (110 °C)	24 (80 °C), 25 (90 °C)
Velocity (m/s) (2 MHz)	1250 (105 °C), 1208 (120 °C)	–	–
Pitch p (µm)	–	–	0.231 (90 °C)
Dipole moment μ (D), 45 °C	1.78 (C_6H_6)	1.79 (C_6H_6)	1.73 (C_6H_6)
Number/common name	**145**	**146**	**147**
Substance			
Formula	$C_{31}H_{52}O_2$	$C_{32}H_{54}O_2$	$C_{33}H_{56}O_2$
Molar weight (g/mol)	456.759	470.786	484.813
CAS-RN	521-13-1	7726-03-6	1062-96-0
Temperatures of phase transitions T^{tr} (°C)	Cr 102.0 N* 113.0 Is	Cr 93.0 N* 101.5 Is	Cr 99.5 N* 101.5 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	22.0 (Cr–N*), 0.6 (N*–Is)	22.0 (Cr–N*), 0.6 (N*–Is)	30.0 (Cr–N*), 0.7 (N*–Is)
Crystallographic space group	$P2_1$	$P2_12_12_1$	$P2_1$
Density (g/cm^3)	0.992 (110 °C) 0.984 (120 °C)	0.893 (99 °C) 0.853 (119 °C)	–
Refractive index n (589 nm)	n_e 1.4716 n_o 1.4865 (N*, 589 nm, 107.0 °C)	n_e 1.4763 n_o 1.4905 (N*, 589 nm, 92.5 °C)	n_e 1.4735 n_o 1.4880 (N*, 589 nm, 95 °C)
Kinematic viscosity (mm^2/s)	ν 22.3 (117 °C)	ν 39.8 (97.3 °C)	–
Surface tension (mN/m)	24.6 (110 °C)	24.6 (110 °C)	25.0 (100 °C)
Pitch p (µm)	0.260 (109 °C)	0.2588 (96.2 °C)	0.247 (97 °C)
Dipole moment μ (D)	2.21 (CCl_4), 2.12 (C_6H_6)	2.34 (CCl_4), 2.48 (C_6H_6)	1.86 (45 °C, C_6H_6)

Table 26.7 (continued)

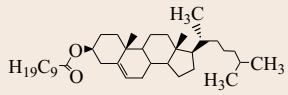
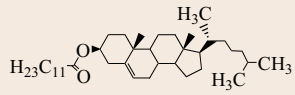
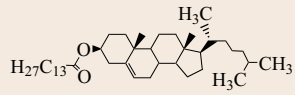
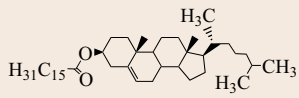
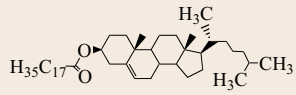
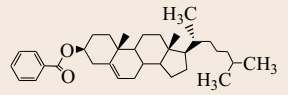
Number/common name	151	152	153 (CM)
Substance			
Formula	$C_{37}H_{64}O_2$	$C_{39}H_{68}O_2$	$C_{41}H_{72}O_2$
Molar weight (g/mol)	540.921	568.976	597.03
CAS-RN	1183-04-6	1908-11-8	1989-52-2
Temperatures of phase transitions T^{tr} (°C)	Cr 85.5 (S 81.5) N* 92.5 Is	Cr 92.4 (A 80.2 N* 88.9) Is	Cr 73.6 A 80.0 N* 85.6 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	31.0 (Cr–N*), 0.8 (N*–Is), 0.6 (S–N*)	37.9 (Cr–Is), 0.9 (N*–Is), 0.6 (S–N*)	46.9 (Cr–A), 1.0 (N*–Is), 1.3 (S–N*)
Crystallographic space group	$P2_1$	$P2_1$	$P2_1$
Density (g/cm^3)	–	0.932 (N*, 86 °C) 0.941 (A, 79 °C)	0.896 (A, 74 °C), 0.890 (N*, 82 °C), 0.885 (Is, 86 °C)
Refractive index n (589 nm)	n_e 1.4724 n_o 1.4863 (N*, 90 °C), n_e 1.5151 n_o 1.4713 (S, 80 °C)	n_e 1.4715 n_o 1.4878 (N*, 85 °C), n_e 1.5148 n_o 1.4705 (S, 80 °C)	n_e 1.4717 n_o 1.4876 (N*, 81 °C), n_e 1.5152 n_o 1.4704 (S, 76 °C)
Dielectric constant ε (10 kHz)	–	2.33 (80 °C)	4.72 (70 °C)
Dynamic viscosity η (mPa s)		η 40 (90.4 °C), 43 (82 °C)	η 41 (88 °C), 126 (79.6 °C)
Heat capacity C_p (J/(mol K))	1300 (N*, 90 °C)	$C_p = 1008 + 3.67\,T$, (S, T (°C) = 69–80)	$C_p = 1033 + 4.84\,T$, (S, T (°C) = 66–71)
Surface tension (mN/m)	24.7 (100 °C), 24.5 (90 °C)	24.7 (100 °C), 24.4 (90 °C)	23.9 (82 °C), 25.0 (94 °C)
Velocity (m/s)	–	1348 (85 °C), 1335 (100 °C) (2 MHz)	1345 (84 °C), 1316 (90 °C)
Diffusion coefficient D (m^2/s)	–	–	1.88×10^{-10} (Is, 90 °C) 1.75×10^{-10} (N*, 80 °C)
Pitch p (µm)	0.225 (90 °C)	0.2125 (82 °C)	0.1994 (83 °C)
Dipole moment μ (D), 45 °C	1.74 (C_6H_6)	1.73 (C_6H_6)	–
Number/common name	**154**	**155**	**156 (CB)**
Substance			
Formula	$C_{43}H_{76}O_2$	$C_{45}H_{80}O_2$	$C_{34}H_{50}O_2$
Molar weight (g/mol)	625.084	653.138	490.776
CAS-RN	601-34-3	35602-69-8	604-32-0
Temperatures of phase transitions T^{tr} (°C)	Cr 79.0 (S 78.5) N* 83.0 Is	Cr 83.0 (S 75.5 N* 79.5) Is	Cr 150.5 N* 182.6 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	59.4 (Cr–N*), 1.3 (N*–Is), 1.7 (S–N*)	67.5 (Cr–Is), 1.7 (N*–Is), 1.8 (S–N*)	22.2 (Cr–N*), 0.6 (N*–Is)
Crystallographic space group	$A2$	$P2_1$	$P2_12_12_1$
Density (g/cm^3)	0.917 (N*, 80 °C) 0.909 (Is, 100 °C)	0.855 (Is, 90 °C)	0.9574 (N*, 159.2 °C) 0.9354 (Is, 185.4 °C)
Refractive index n (589 nm)	n_e 1.4752 n_o 1.4881 (N*, 78 °C)	–	n_e 1.4813 n_o 1.5656 (N*, 160 °C)
Dielectric constant ε (10kHz)	–	2.36 (70 °C)	–
Dynamic viscosity η (mPa s)	η 47 (85 °C), 68 (76.6 °C)	η 78.4 (80 °C), 85.2 (78 °C), 117 (74 °C)	η 35.5 (170 °C), 25.8 (180 °C)
Surface tension (mN/m)	25.0 (90 °C), 24.2 (80 °C)	25.6 (Is, 80 °C), 25.2 (N*, 75 °C), 25.3 (S, 70 °C)	21.8 (Is, 210 °C), 23.8 (N*, 147.4 °C), 22.9 (N*, 177 °C)
Velocity (m/s) (2 MHz)	–	1343 (77 °C), 1332 (85 °C)	1093 (170 °C), 1087 (190 °C)
Pitch p (µm)	0.2215 (77 °C)	–	–
Dipole moment μ (D)	1.69 (45 °C, C_6H_6)	1.62 (45 °C, C_6H_6)	2.08 (CCl_4), 2.11 (C_6H_6)

Table 26.8 Discotic liquid crystals

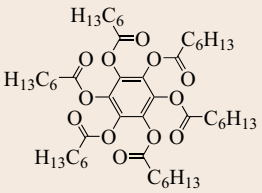
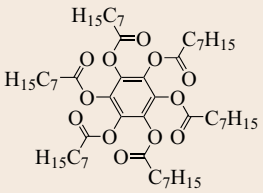
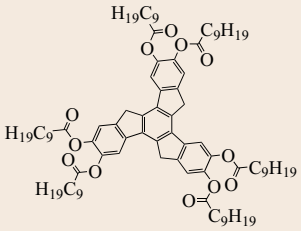
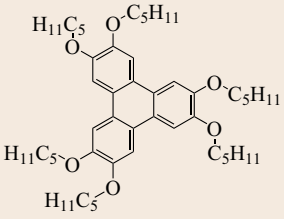
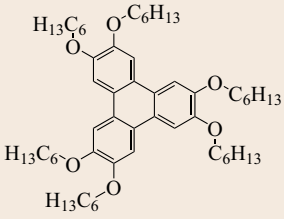
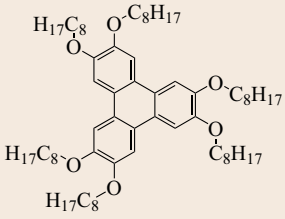
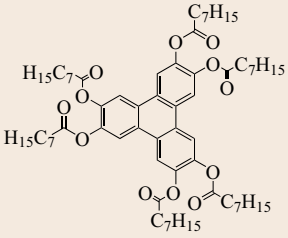
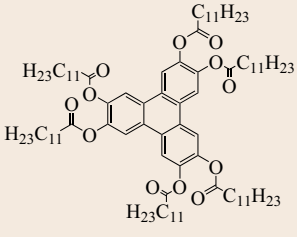
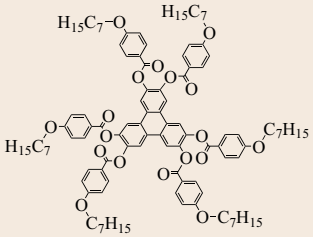
Number/common name	**157**	**158**	**159 (H10TX)**
Substance			
Formula	$C_{48}H_{78}O_{12}$	$C_{54}H_{90}O_{12}$	$C_{87}H_{126}O_{12}$
Molar weight (g/mol)	847.15	931.312	1363.967
CAS-RN	65201-70-9	65201-71-0	86108-14-7
Temperatures of phase transitions T^{tr} (°C)	Cr 81.2 D 87.0 Is	Cr′ 28.8 Cr 82.0 D 84.0 Is	Cr 68 N 85 Drd 138 Dho 280 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	32.2 (Cr–D), 21.5 (D–Is)	46.1 (Cr–D), 19.2 (D–Is), 49.0 (Cr′–Cr)	21.3 (Cr–N), 1.0 (N–D)
Refractive index n	–	–	n_o 1.531, n_e 1.454 $T = 0.999T^{ND}$
Number/common name	**160 (HAT5)**	**161 (HAT6)**	**162 (HAT8)**
Substance			
Formula	$C_{48}H_{72}O_6$	$C_{54}H_{84}O_6$	$C_{66}H_{108}O_6$
Molar weight (g/mol)	745.105	829.268	997.593
CAS-RN	69079-52-3	70351-86-9	70351-87-0
Temperatures of phase transitions T^{tr} (°C)	Cr 69.0 Dho 122.0 Is	Cr 68.0 Dho 97.0 Is	Cr 67.0 Dho 86.0 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	32.6 (Cr–D), 8.1 (D–Is)	36.4 (Cr–D), 3.6 (D–Is)	83.3 (Cr–D), 4.2 (D–Is)
Number/common name	**163n**	**164 (HAT11)**	**165**
Substance			
Formula	$C_{66}H_{96}O_{12}$	$C_{90}H_{144}O_{12}$	$C_{102}H_{120}O_{18}$
Molar weight (g/mol)	1081.494	1418.144	1634.083
CAS-RN	70351-94-9	70187-34-7	75747-38-5
Temperatures of phase transitions T^{tr} (°C)	Cr 66.0 D 126.0 Is	Cr 80.0 Dh 93.0 Dt 111.0 Dh 122.3 Is	Cr′ 117.8 Cr′ 130.9 Cr 169.1 N 253.1 Is
Enthalpies of phase transitions ΔH^{tr} (kJ/mol)	19.7 (Cr–D), 2.8 (D–Is)	59.4 (Cr–D), 2.4 (D–Is)	9.4 (Cr–D)
Anisotropy of refractive index Δn	–	–	Δn −0.09 (200 °C, 633 nm)
Dielectric constant ε	–	–	$\varepsilon_\parallel$ 3.78 $\varepsilon_\perp$ 3.33 (230 °C)
Dynamic viscosity η (mPa s)	–	–	η 350 (230 °C)

Table 26.9 Liquid crystal salts

Na^+	Temperatures of phase transitions (°C)
C_3H_7-COO-	Cr 251.0 S 327.0 Is
C_4H_9-COO-	Cr 241.0 A 344.0 Is
$C_5H_{11}-COO-$	Cr 210.0 S 235.0 A 361.0 Is
$C_6H_{13}-COO-$	Cr 198.0 S 242.0 A 363.0 Is
$C_7H_{15}-COO-$	Cr 189.0 S 243.0 A 360.0 Is
$C_8H_{17}-COO-$	Cr 185.0 S 243.0 A 355.0 Is
$C_9H_{19}-COO-$	Cr 140.0 S 181.0 S 245.0 S 348.0 Is
$C_{10}H_{21}-COO-$	Cr 115.0 S 145.0 S 167.0 S 187.0 S 242.0 A 337.0 Is
$C_{11}H_{23}-COO-$	Cr 100.0 S 141.0 S 182.0 S 220.0 S 255.0 A 336.0 Is
$C_{12}H_{25}-COO-$	Cr 121.0 S 162.0 S 187.0 S 200.0 S 217.0 S 248.0 A 323.0 Is
$C_{13}H_{27}-COO-$	Cr 113.0 S 138.0 S 171.0 S 215.0 S 246.0 A 311.0 Is
$C_{14}H_{29}-COO-$	Cr 121.0 S 160.0 S 187.0 S 203.0 S 251.0 S 277.0 A 307.0 Is
$C_{15}H_{31}-COO-$	Cr 117.0 S 136.0 S 168.0 S 212.0 S 251.0 A 302.0 Is
$C_{16}H_{33}-COO-$	Cr 130.0 S 205.0 S 260.0 A 290.0 Is
$C_{17}H_{35}-COO-$	Cr 117.0 S 132.0 S 167.0 S 198.0 S 257.0 A 288.0 Is
$C_{18}H_{37}-COO-$	Cr 118.0 S 133.0 S 146.0 S 193.0 S 202.0 S 258.0 A 283.0 Is
$C_{19}H_{39}-COO-$	Cr 110.0 S 131.0 S 163.0 S 200.0 A 262.0 Is
Li^+	Temperatures of phase transitions (°C)
$C_{11}H_{23}-COO-$	Cr 229.0 S 239.0 Is
$C_{12}H_{25}-COO-$	Cr 224.0 S 232.0 Is
$C_{13}H_{27}-COO-$	Cr 210.0 S 231.0 S 239.0 Is
$C_{14}H_{29}-COO-$	Cr 206.0 S 229.0 Is
$C_{15}H_{31}-COO-$	Cr 197.0 S 215.0 S 223.0 Is
$C_{17}H_{35}-COO-$	Cr 190.0 S 215.0 S 229.0 Is
$C_{19}H_{39}-COO-$	Cr 189.0 S 226.0 Is
Cs^+	Temperatures of phase transitions (°C)
$C_5H_{11}-COO-$	Cr 359.0 S 399.0 Is
$C_6H_{13}-COO-$	Cr 345.0 S 421.0 Is
$C_7H_{15}-COO-$	Cr 334.0 S 425.0 Is
$C_8H_{17}-COO-$	Cr 325.0 S 424.0 Is
$C_9H_{19}-COO-$	Cr 314.0 S 415.0 Is
$C_{11}H_{23}-COO-$	Cr 278.0 S 355.0 Is
$C_{13}H_{27}-COO-$	Cr 287.0 S 386.0 Is
Rb^+	Temperatures of phase transitions (°C)
C_4H_9-COO-	Cr 367.0 S 430.0 Is
$C_5H_{11}-COO-$	Cr 342.2 S 450.0 Is
$C_6H_{13}-COO-$	Cr 327.0 S 451.0 Is
$C_7H_{15}-COO-$	Cr 312.0 A 440.0 Is
$C_8H_{17}-COO-$	Cr 300.0 A 439.0 Is
$C_9H_{19}-COO-$	Cr 291.0 A 429.0 Is
$C_{11}H_{23}-COO-$	Cr 300.0 A 400.0 Is
$C_{13}H_{27}-COO-$	Cr 212.4 S 217.9 S 240.3 S 277.6 S 394.0 Is

Table 26.9 (continued)

Tl^+	Temperatures of phase transitions (°C)
C_4H_9-COO-	Cr 80.4 S 180.0 A 214.3 Is
$C_5H_{11}-COO-$	Cr 124.4 S 137.2 S 148.5 A 227.1 Is
$C_6H_{13}-COO-$	Cr 140.5 A 226.0 Is
$C_7H_{15}-COO-$	Cr 135.0 A 221.0 Is
$C_8H_{17}-COO-$	Cr 39.5 S 55.8 S 136.5 A 217.9 Is
$C_9H_{19}-COO-$	Cr 30.2 S 49.8 S 128.4 A 207.6 Is
$C_{10}H_{21}-COO-$	Cr 35.8 S 47.0 S 74.4 S 128.7 A 201.6 Is
$C_{11}H_{23}-COO-$	Cr 36.0 S 73.8 S 122.3 A 196.8 Is
$C_{12}H_{25}-COO-$	Cr 53.8 S 58.6 S 97.0 S 125.3 A 192.5 Is
$C_{13}H_{27}-COO-$	Cr 36.5 S 42.0 S 94.8 S 118.9 A 184.4 Is
$C_{14}H_{29}-COO-$	Cr 66.9 S 111.6 S 120.4 A 179.6 Is
$C_{15}H_{31}-COO-$	Cr 54.0 S 114.4 S 116.4 A 175.5 Is
$C_{16}H_{33}-COO-$	Cr 75.3 S 119.4 A 171.5 Is
$C_{17}H_{35}-COO-$	Cr 62.1 S 118.4 A 168.1 Is
$C_{19}H_{39}-COO-$	Cr 70.2 S 120.5 A 158.2 Is
$C_{21}H_{43}-COO-$	Cr 67.2 S 76.8 S 121.8 A 151.8 Is
$C_{25}H_{51}-COO-$	Cr 114.0 S 125.0 Is
K^+	Temperatures of phase transitions (°C)
C_3H_7-COO-	Cr 353.0 S 404.0 Is
C_4H_9-COO-	Cr 313.4 S 443.0 Is
$C_5H_{11}-COO-$	Cr 308.5 S 452.0 Is
$C_6H_{13}-COO-$	Cr 298.1 S 449.0 Is
$C_7H_{15}-COO-$	Cr 287.0 S 439.0 Is
$C_8H_{17}-COO-$	Cr 276.0 S 434.0 Is
$C_9H_{19}-COO-$	Cr 271.0 S 423.0 Is
$C_{10}H_{21}-COO-$	Cr 268.0 S 418.0 Is
$C_{11}H_{23}-COO-$	Cr 268.0 S 406.0 Is
$C_{12}H_{25}-COO-$	Cr 89.9 S 397.6 Is
$C_{13}H_{27}-COO-$	S 271.0 A 375.0 Is
$C_{14}H_{29}-COO-$	Cr 64.0 S 388.5 Is
$C_{15}H_{31}-COO-$	Cr 195.0 S 269.0 A 362.0 Is
$C_{17}H_{35}-COO-$	Cr 170.0 S 238.0 S 264.0 S 356.0 Is
$C_{19}H_{39}-COO-$	Cr 74.1 S 339.9 Is
Cu^{2+}	Temperatures of phase transitions (°C)
C_3H_7-COO-	Cr 195.0 D >200.0 dec
C_4H_9-COO-	Cr 111.0 D >200.0 dec
$C_5H_{11}-COO-$	Cr 95.0 D >200.0 dec
$C_6H_{13}-COO-$	Cr 93.0 D >200.0 dec
$C_7H_{15}-COO-$	Cr 88.0 D >200.0 dec
$C_8H_{17}-COO-$	Cr 102.0 D >200.0 dec
$C_9H_{19}-COO-$	Cr 106.9 D 210.0 dec
$C_{15}H_{31}-COO-$	Cr 122.0 D 220.0 dec

Table 26.9 (continued)

L—⟨⟩—R		Temperatures of phase transitions (°C)
H—	—C_3H_6—COO—Tl	Cr 58.4 A 62.4 Is
H—	—C_5H_{10}—COO—Tl	Cr 34.0 A 93.0 Is
H—	—C_7H_{14}—COO—Tl	Cr 39.0 A 107.5 Is
H—	—C_9H_{18}—COO—Tl	Cr 51.0 A 114.0 Is
C_6H_{13}—	—COO—Tl	Cr 118.0 S 264.0 A 334.0 Is

Table 26.9 (continued)

L—⟨⟩—R		Temperatures of phase transitions (°C)
C_5H_{11}—O—	—COO—Tl	Cr 160.0 S 294.0 A 344.0 Is
C_6H_{13}—O—	—COO—Tl	Cr 27.0 S 114.0 S 284.0 A 343.0 Is
C_7H_{15}—O—	—COO—Tl	Cr 36.0 S 57.0 S 121.0 S 274.0 A 334.0 Is
C_8H_{17}—O—	—COO—Tl	Cr 30.0 S 43.0 S 131.0 S 269.0 A 330.0 Is
C_9H_{19}—O—	—COO—Tl	Cr 57.0 S 62.0 S 135.0 S 264.0 A 322.0 Is

26.3 Physical Properties of Some Liquid Crystalline Mixtures

Table 26.10 Nematic mixtures

Mixture	**E49 (Merck)**	**ZLI-2857 (Merck)**	**ZLI-3086 (Merck)**
Components	Cyanobiphenyls		
Temperatures of phase transitions T^{tr} (°C)	Cr −9 N 100 Is	Cr −19 N 82.3 Is	N 72.0 Is
Anisotropy of refractive index Δn (20 °C)	0.251	0.0776	0.1131
Dielectric anisotropy $\Delta\varepsilon$ (20 °C)		−1.4	0.1
Viscosity (mm^2/s) (20 °C)	46.5	20	
Mixture	**E7 (Merck)**	**ZLI-1132 (Merck)**	**ZLI-4792 (Merck)**
Components	Cyanobiphenyls	Phenylcyclohexanes	Fluorinated LC
Temperatures of phase transitions T^{tr} (°C)	Cr < − 30 N 58 Is	Cr −6 N 71 Is	Cr < − 40 N 92 Is
Δn (589 nm, 20 °C) n_e (589 nm, 20 °C)	0.2253 1.7464	0.1396 1.6326	0.0969 1.5763
Dielectric anisotropy $\Delta\varepsilon$ (1 kHz, 20 °C)	13.8	13.1	5.2
$\varepsilon_\parallel$ (1 kHz, 20 °C)	19.0	17.7	8.3
Kinematic viscosity (mm^2/s)	39 (20 °C), 145 (0 °C)	28 (20 °C), 110 (0 °C)	15 (20 °C), 40 (0 °C)
Surface tension (mN/m)	29.3 (22 °C) $\sigma_\perp$ 14.5 $\sigma_\parallel$ 23.7	31.0 (22 °C) $\sigma_\perp$ 13.6 $\sigma_\parallel$ 26.0	–
Elastic constants ratio K_3/K_1 (20 °C)	1.54	1.95	1.39
V_{10} (V) threshold	1.41	1.77	2.00
V_{50} (V)	1.63	2.05	2.47
V_{90} (V) saturation	1.99	2.49	3.15

Data are taken from [25]. ZLI-4792 is a superfluorinated material; it is recommended for VIP (viewing independent panel) twisted nematic displays. Mixtures E7 and ZLI-1132 are recommended for usage in calculators, wrist watches, and measuring instruments. V_{10}, V_{50}, V_{90} – voltage at 10, 50, and 90%, respectively, of the maximum absorption at 0% viewing angle and 20 °C.

Table 26.11 Ferroelectric mixtures

Mixture	**CS1024**	**CS2004**	**CS4000**
CAS-RN	123967-01-1	135976-66-8	150260-44-9
T^{tr} (°C)	Cr −12 C* 62 A 82 N* 90 Is	Cr < 20 C* 62 N* 71 Is	Cr −10 CA 70.5 Cγ 72.5 C* 74.6 Cα 75.6 A 100 Is
P_s (25 °C) (nC/cm^2)	−46.9	–	–
Tilt Θ (25 °C)	25	44	–
pitch (µm)	>20	–	–
Mixture	**Felix-015-100**	**SCE8**	**SCE9**
CAS-RN	211365-96-7	145380-16-1	126879-69-4
T^{tr} (°C)	Cr −12 C* 72 A 83 N* 86 Is	Cr < 20 C 59 A 79 N 100 Is	Cr < 20 C* 61 A 91 N* 115 Is
P_s (25 °C) (nC/cm^2)	+33	+630	–
Tilt Θ (25 °C)	25.5	–	–
switching τ (25 °C)	–	294 µs	–
Mixture	**SCE10**	**SCE13**	**TKF 8617**
CAS-RN	134499-04-0	133758-42-6	114899-67-1
T^{tr} (°C)	Cr < 20 C* 61 N* 109 Is	Cr < 0 C* 61 A 86 N* 103 Is	Cr 4 C* 54 A 65 Is
P_s (20 °C) (nC/cm^2)	19.5	30.6	–
Tilt Θ (20 °C)	–	29	–
pitch (µm)	–	10−12	–
Mixture	**W22**	**ZhKS-309C**	**ZLI-3654**
CAS-RN	137988-43-3	205599-65-1	116580-90-6
T^{tr} (°C)	Cr 4 C* 51 A 82 N* 92 Is	Cr −1 C* 42 A 91 Is	Cr −30 C* 62 A 76 N 86 Is
P_s (20 °C) (nC/cm^2)	–	+50.8	−29
Tilt Θ (20 °C)	–	26	–
pitch (µm)	–	0.4	3
Mixture	**ZLI-4655-000**	**ZLI-4851-100 Felix-M-4851-100**	**ZLI-5014-100**
CAS-RN	139352-77-5	158854-82-1	172452-16-3
T^{tr} (°C)	Cr < 10 C* 60 A 69 N* 72 Is	Cr <−20 C* 67 A 71 N* 76 Is	Cr <−10 C* 65 A 70 N* 72 is
P_s (20 °C) (nC/cm^2)	+7	+22.8	−20
Tilt Θ (20 °C)	–	30.5	–
pitch (µm)	–	–	10
switching τ (20 °C)	–	38 µs	3

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