Liquid Crystals
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713926090

Synthesis and mesomorphic properties of 2,6-disubstituted derivatives of quinoline: amides and esters

J. Belmar

Online publication date: 06 August 2010

To cite this Article Belmar, J.(1999) 'Synthesis and mesomorphic properties of 2,6-disubstituted derivatives of quinoline: amides and esters', Liquid Crystals, 26: 1, 9 — 15
To link to this Article: DOI: 10.1080/026782999205470
URL: http://dx.doi.org/10.1080/026782999205470

LIQUID CRYSTALS, 1999, VOL. 26, NO. 1, 9–15

Synthesis and mesomorphic properties of 2,6-disubstituted derivatives of quinoline: amides and esters

J. BELMAR, M. PARRA, C. ZUÑIGA*, G. FUENTES
Facultad de Ciencias Químicas, Departamento de Química Orgánica,
Universidad de Concepción, Casilla 3-C, Concepción, Chile

M. MARCOS and J. L. SERRANO
Química Orgánica, Facultad de Ciencias-ICMA, Universidad de Zaragoza-CSIC,
50009-Zaragoza, Spain

(*Received 11 November 1997; accepted 3 July 1998*)

The syntheses of *N*-4-*n*-alkoxyphenyl-6-*n*-decyloxyquinoline-2-carboxamide (alkoxy = $C_nH_{2n+1}O$, $n = 4–10$) and 4-*n*-alkoxyphenyl-6-*n*-decyloxyquinoline-2-carboxylate ($n = 4, 6, 8$) are described along with the measurement of their physical properties using DSC and optical methods. The amides all show an enantiotropic smectic A phase while the esters show monotropic mesophases. A study of the structure/mesomorphic activity relationship is also described.

1. Introduction

The structure/mesomorphic activity relationship is a most attractive study area of the chemist devoted to liquid crystal research, and a significant number of papers and monographs dealing with this subject have been published [1, 2]. In many cases this type of study allows important conclusions to be drawn and used to exploit technological applications [3, 4]. Nevertheless, the vast range of synthetic possibilities in organic chemistry means that a variety of structures remain relatively unstudied.

Within the classic calamitic structure some functional groups have proven to be very useful to promote mesomorphic properties, [figure 1 (*a*)]. For example, the ester group is one of the most commonly used central bridging units and is incorporated in many low temperature systems. In addition, the introduction of aromatic groups such as biphenyl or naphthyl has been widely studied because they give rise to very stable mesophases and allow the introduction of substituents into different positions, leading to modification of the liquid crystal properties [5, 6].

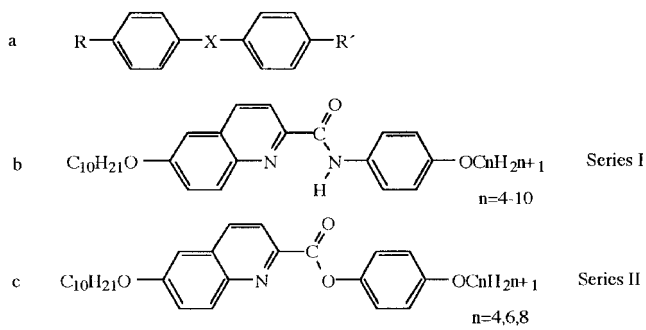


Figure 1. Structures of the compounds studied.

In this paper we present two new series of liquid crystal derivatives which have been synthesized in order to study the effect of two changes in the mesogenic core. Firstly we introduced a quinoline system, which is isoelectronic and isogeometric with the naphthalene aromatic unit [7, 8]. The incorporation of a heteroatom allowed us to introduce a dipole moment perpendicular to the main molecular axis, thus modifying the electronic distribution of the molecule, and consequently changing the mesogenic properties [9, 10].

Secondly, we introduced two different central bridging units. The first bridge considered is an amide [figure 1 (*b*), Series I]. This group is not frequently encountered in liquid crystal derivatives because, in general, it gives rise to significantly higher intermolecular interactions that often preclude mesomorphic behaviour. Indeed the amido group is used in main chain liquid crystal polymers in order to obtain oriented fibres for high mechanical strength applications. The amide group also inhibits the processing of polymers and strong solvents such as sulphuric acid are necessary in order to obtain lyotropic solutions [11]. The strong lateral intermolecular interactions preclude the formation of thermotropic mesophases because the materials decompose at high temperatures before melting.

*Author for correspondence.

Journal of Liquid Crystals ISSN 0267-8292 print/ISSN 1366-5855 online
http://www.tandf.co.uk/JNLS/lct.htm
http://www.taylorandfrancis.com/JNLS/lct.htm

The second bridging group to be considered is the ester group [figure 1 (*c*), Series II]. This is one of the most commonly used linking groups in liquid crystals and these materials were synthesized to provide a comparative study with the corresponding compounds of series I.

2. Experimental

2.1. *General synthetic procedures*

The synthesis of the compounds is outlined in the scheme. The quinoline precursor **2** was obtained by a condensation between 4-*n*-decyloxyaniline and crotonaldehyde in 6N HCl. Oxidation of **2** using selenium dioxide gave compound **3** in good yield. The oxidation of the aldehyde group of **3** to give the acid derivative **4** was performed using a method described in the literature for the oxidation of 2-formylquinoline. This method employs a mixture of hydrogen peroxide and formic acid and gave the desired product in 83% yield. The acid obtained, **4**, was used without purification in the synthesis of the compounds of Series I and Series II. First the acid chloride derivative **5** was obtained using thionyl chloride; this reacted *in situ* with the corresponding 4-*n*-alkoxyanilines to yield the compounds in Series I, or with 4-*n*-alkoxyphenols to give the compounds in Series II.

In order to assess the mesomorphic behaviour imparted by the quinoline group, a derivative without a second aromatic ring, **8**, was also synthesized.

2.1.1. *4-n-Alkoxyanilines* **1**

These compounds were synthesized according to reference [12].

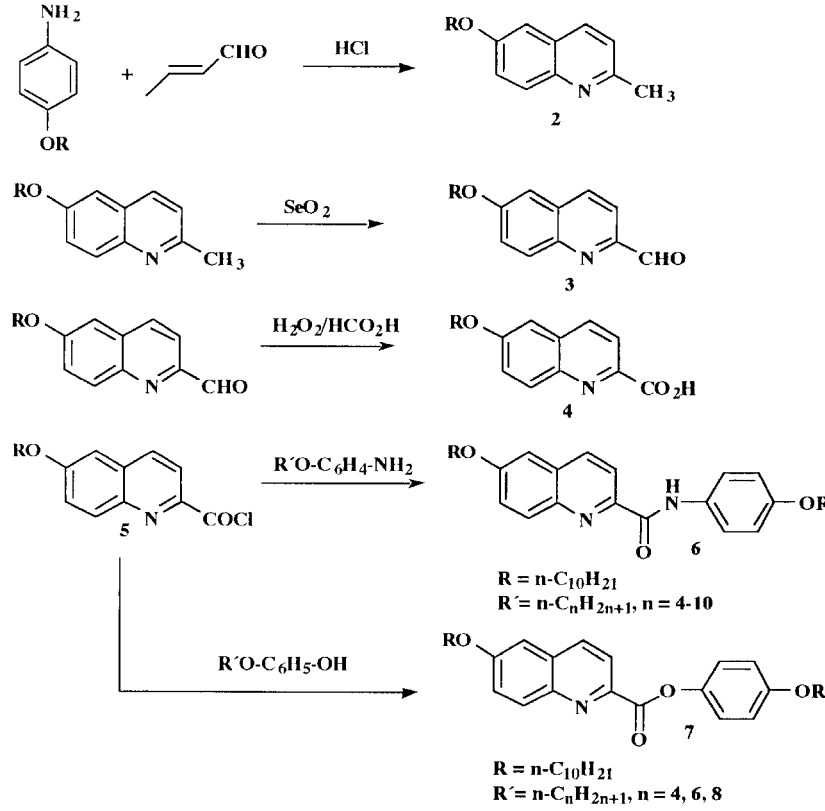
2.1.2. *2-Methyl-6-decyloxyquinoline* **2**

This was prepared according to reference [13] and the product purified by column chromatography on silica gel using hexane/ethyl acetate (8 : 2) as eluent. The solid was recrystallized from *n*-hexane by cooling to 0°C; m.p. 55°C, yield 50%. Elemental analysis: found, C 80.60, H 9.9; calculated for $C_{20}H_{29}NO$, C 80.26, H 9.70%.

2.1.3. *6-n-Decyloxy-2-formylquinoline* **3**

This compound was prepared according to reference [8] and the product purified by column chromatography on silica gel using hexane/ethyl acetate (9.5 : 0.5) as eluent; m.p. 57°C, yield 80%. Elemental analysis: found, C 76.43,

Scheme



H 8.22; calculated for $C_{20}H_{27}NO_2$ calculated, C 76.68, H 8.63%.

2.1.4. *6-n-Decyloxyquinoline-2-carboxylic acid* **4**

This was prepared according to the method described for the oxidation of 2-formylquinoline [14]. A solution of 3.0 g (96 mmol) of **3** in 25 ml of formic acid was stirred and cooled to 0°C; 14 ml of 30% H_2O_2 was then added slowly. The reaction mixture was stirred overnight at 4°C. Water was added and the resulting white precipitate filtered off; it was washed with 10% HCl to give the crude product (chlorhydrate) in 83% yield. This crude product was used in the next step without further purification. ^{1}H NMR (DMSO-d_6), $\delta = 10.2$ (s, CO_2H–); ^{13}C NMR (DMSO-d_6), the signal at 193 ppm corresponding to the carbonyl carbon of the precursor aldehyde is not observed in the spectrum of the product and a signal at 165.2 ppm, corresponding to the carboxylic acid carbon, is observed.

2.1.5. *N-4-n-Alkoxyphenyl-6-n-decyloxyquinoline-2-carboxamide* **6**

A mixture of 1.1 g (3 mmol) of 6-*n*-decyloxyquinoline-2-carboxylic acid hydrochloride and 10 ml of thionyl chloride was heated under reflux for 2 h. Excess thionyl chloride was removed under vacuum and the residue diluted with 5 ml of $CHCl_3$. A mixture of 3 mmol of 4-*n*-alkoxyaniline and 1 ml of triethylamine diluted with 5 ml of chloroform was added dropwise to the above solution. The resulting mixture was heated under reflux for 2 h and then poured into water. The product was purified by column chromatography on silica gel using hexane/ethyl acetate (9.5 : 0.5) as eluent, and then recrystallized from ethanol. Yield 60% with respect to the aldehyde.

2.1.6. *4-n-Alkoxyphenols*

These were prepared from hydroquinone according to the reported procedure [12]. A solution of 110.11 g (0.8 mol) of hydroquinone and 0.6 mol of *n*-alkylbromide in 96 ml of ethanol; was heated to reflux and a solution of 44.8 g (0.8 mol) of KOH in 140 ml of water was added dropwise during 1 h. The reaction mixture was heated under reflux for a further 6 h. It was allowed to cool and the organic product was extracted with ether. The ethereal phase was extracted several times with 10% KOH. The combined aqueous layers were acidified with 10% HCl. The precipitate was filtered off, dried and recrystallized from petroleum ether (b.p. 40–60°C), yield 30–35%.

2.1.7. *4-N-Alkoxyphenyl-6-n-decyloxyquinoline-2-carboxylate* **7**

A solution of 1 ml of triethylamine and 0.0055 mol of 4-*n*-alkoxyphenol in 5 ml of benzene was added dropwise to a stirred mixture of 1.83 g (0.005 mol) of crude acid chloride **5** and 20 ml of benzene. The mixture was heated under reflux for 2 h and allowed to cool. The solid product was filtered off, washed with water, and purified by column chromatography on silica gel using hexane/ethyl acetate (9 : 1) as eluent. The product was finally recrystallized from *n*-hexane, yield 50–60%.

2.1.8. *n-Hexyl-6-n-decyloxyquinoline-2-carboxylate* **8**

This ester was prepared using the procedure described for compound **7**. Recrystallization from ethanol afforded white crystals, m.p. 72°C, yield 70%. Elemental analysis: found, C 75.81, H 9.71, N 3.80; calculated for $C_{26}H_{39}NO_3$, C 75.54, H 9.14, N 3.39 %. δH($CDCl_3$) 8.19 (1H, d, $J_{87} = 9.3$, H-8), 8.12 (2H, s, H-3, 4), 7.42 (1H, dd, $J_{78} = 9.3$, $J_{75} = 2.7$, H-7), 7.08 (1H, d, $J_{57} = 2.6$, H-5), 4.46 (2H, t, OC–OCH_2), 4.09 (2H, t, OCH_2), 1.7–2.1 (4H, m, OCH_2 CH_2), 1.1–1.7 (20H, m, $(CH_2)_{10}$), 0.8–1.0 (6H, m, $(CH_3)_2$). δC($CDCl_3$) 165.50 (COO–), 158.85 (C-6), 145.55 (C-2), 143.65 (C-9), 135.36 (C-4), 132.16 (C-8), 130.72 (C-10), 123.56 (C-7), 121.35 (C-3), 105.14 (C-5), 68.40 (OC–OCH_2), 66.05 (OCH_2), 31.82, 31.41, 29.48, 29.26, 28.62, 25.99, 25.53, 22.60, 22.43, 13.93 (CH_3). IR (KBr) cm^{-1} 3065 (=C–H), 1736 (C=O), 1617.6 (C=C).

2.2. *Characterization of materials*

The chemical structures of the intermediates and the final products were determined by a combination of IR spectroscopy (Perkin Elmer 577) and NMR spectroscopy (Bruker AC-250P) (see table 1). The purity of the compound synthesized was evaluated by thin layer chromatography and elemental analysis (table 2). The transition temperatures and phase assignments for the final products were determined by thermal polarizing optical microscopy using a Nikon polarizing microscope fitted with a Mettler FP-82 hot stage and a Mettler FP-80 control unit. Temperatures and enthalpies of transitions were investigated by differential scanning calorimetry (DSC) using a Perkin Elmer DSC-7 calorimeter. Samples were encapsulated in aluminium pans and studied at a scanning rate of 10°C min^{-1} on both heating and cooling cycles. The instrument was calibrated using an indium standard (156.6°C, 28.44 J g^{-1}).

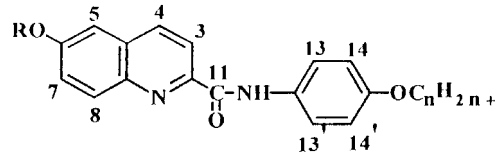
3. Results and discussion

3.1. *Mesomorphic properties*

The optical, thermal and thermodynamic data for the compounds of Series I are gathered in table 3.

All of the compounds in Series I show mesomorphic properties. In each case a SmA mesophase is observed over a similar temperature range (approximately 20°C). Curiously, the enthalpy of the SmA–I transition shows a steady increase as the number of carbon atoms in the

Table 1. ^{1}H and ^{13}C NMR spectral data of the compounds **6** ($n = 6$) and **7** ($n = 8$).



Chemical shifts of ^{1}H NMR ($CDCl_3$)

3	4	5	7	8	N–H	13–13′	14–14′
8.15 (d) $J = 8.6$	8.30 (d) $J = 8.5$	7.07 (d) $J = 2.6$	7.41 (dd) $J_{78} = 9.2$ $J_{75} = 2.7$	8.01 (d) $J = 9.2$	10.02 (s)	7.73 (d) $J = 9.0$	6.93 (d) $J = 9.0$

a	a′	b + b′	c + c′	d + d′
3.95 (t) $J = 6.5$	4.06 (t) $J = 6.5$	1.72–1.88 (m)	1.5–1.30 (m)	0.94–0.86 (m)

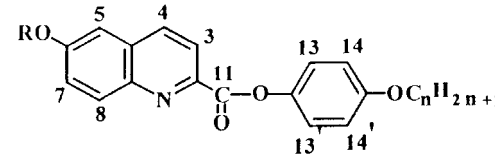
Chemical shifts of ^{13}C NMR ($CDCl_3$)

C–2	C–3	C–4	C–5	C–6	C–7	C–8
148.07	119.72	136.74	105.53	159.22	124.37	131.71

C–9	C–10	C–11	C–12	C–13–13′	C–14–14′	C–15
142.93	131.62	162.80	131.42	121.89	115.54	156.56

Alkyl group = 69.15; 68.98; 32.56; 32.28; 30.23; 30.05; 29.98; 29.78; 26.73; 26.40; 23.34; 29.28; 14.77; 14.70.

IR cm^{-1} = ν 3348 (N–H); 1640 (C=O).



Chemical shifts of ^{1}H NMR ($CDCl_3$)

3	4	5	7	8	13–13′	14–14′
8.25 (d) $J = 8.5$	8.18 (d) $J = 8.7$	7.11 (d) $J = 2.6$	7.46 (d,d) $J_{78} = 9.3$ $J_{75} = 2.7$	8.24 (d) $J = 9.3$	7.20 (d) $J = 9.0$	6.94 (d) $J = 9.0$

a	a′	b + b′	c + c′	d + d′
4.10 (t) $J = 6.5$	3.96 (t) $J = 6.5$	1.74–1.94 (m)	1.20–1.60 (m)	0.85–0.95 (m)

Chemical shifts of ^{13}C NMR ($CDCl_3$)

C–2	C–3	C–4	C–5	C–6	C–7	C–8
145.48	122.54	136.29	105.91	159.90	124.63	131.79

C–9	C–10	C–11	C–12	C–13–13′	C–14–14′	C–15
145.11	131.79	165.32	144.46	123.10	115.99	157.71

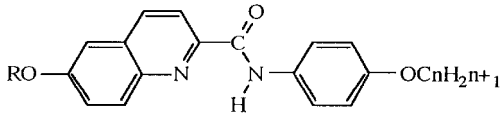
Alkyl group = 69.20; 69.06; 32.58; 32.51; 30.26; 30.25; 30.06; 30.01; 29.98; 29.94; 29.77; 26.75; 23.37; 23.36; 14.81.

IR cm^{-1} = ν 1756 (C=O); 1098 (C–O).

Table 2. Elemental analysis of *N*-4-*n*-alkoxyphenyl-6-*n*-decyloxyquinoline-2-carboxamides (Series I) and 4-*n*-alkoxyphenyl-6-*n*-decyloxyquinoline-2-carboxilates (Series II).

n	Empirical formula *R*: $-OC_nH_{2n+1}$	C/%		H/%		N/%	
		Calculated	Found	Calculated	Found	Calculated	Found
Amides							
4	$C_{30}H_{40}N_2O_3$	75.63	75.45	8.40	8.44	5.88	6.25
5	$C_{31}H_{42}N_2O_3$	75.92	75.58	8.57	8.67	5.71	6.18
6	$C_{32}H_{44}N_2O_3$	76.19	75.95	8.73	8.61	5.55	5.90
7	$C_{33}H_{46}N_2O_3$	76.45	76.07	8.88	8.84	5.40	5.84
8	$C_{34}H_{48}N_2O_3$	76.69	76.39	9.02	9.22	5.26	5.72
9	$C_{35}H_{50}N_2O_3$	76.92	76.70	9.19	8.95	5.13	5.41
10	$C_{36}H_{52}N_2O_3$	77.14	76.69	9.28	9.49	5.00	5.37
Esters							
4	$C_{30}H_{39}NO_4$	75.47	75.93	8.18	8.43	2.93	3.27
6	$C_{32}H_{43}NO_4$	76.04	75.72	8.51	8.63	2.77	3.26
8	$C_{34}H_{47}NO_4$	76.54	76.39	8.82	8.92	2.63	3.05

Table 3. Transition temperatures and enthalpies data of quinoline amides, $R = C_{10}H_{21}$, Series I.



n	Transition	Temperature/°C	ΔH/kJ mol^{-1}
4	Cr–SmA	93.8	45.6
	SmA–I	111.2	5.1
5	Cr–SmA	90.9	42.3
	SmA–I	112.3	5.7
6	Cr–SmA	93.9	42.6
	SmA–I	114.2	6.0
7	Cr–SmA	99.3	48.6
	SmA–I	116.2	6.5
8	Cr–SmA	100.1	48.6
	SmA–I	116.7	6.5
9	Cr–SmA	98.0	48.7
	SmA–I	116.5	6.8
10	Cr–SmA	99.4	50.2
	SmA–I	116.9	7.1

alkoxy chain increases, corresponding to an average value of around 0.3 kJ mol^{-1} for each methylene group. This result illustrates the importance of the influence of the terminal chain length on this transition. On the other hand, melting and clearing temperatures are similar in all derivatives and show a similar trend in behaviour in both cases. This phenomenon is especially marked in the last four members of Series I ($n = 7$–10) in which the number of carbon atoms in the terminal chain does not cause any significant change in the melting and clearing temperatures.

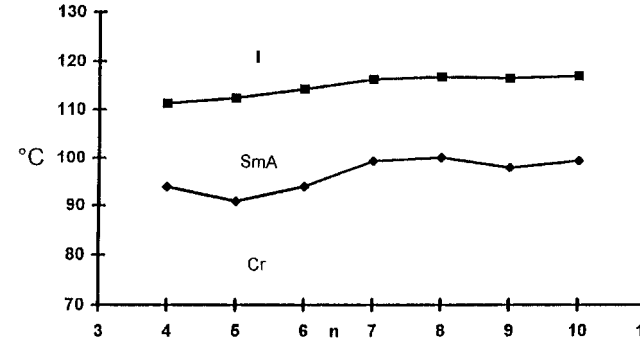


Figure 2. Plot of transition temperatures versus the number of carbon atoms (n) in the alkyl chain (R') of quinoline amides.

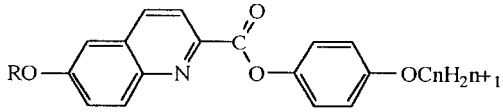
These apparently opposite results can be explained by taking into account that these compounds give rise to a SmA phase and the interactions between the molecules within the SmA layer are very similar in all cases.

The data for the compounds in Series II are gathered in table 4. Only monotropic behaviour is observed in these compounds. Interestingly, the derivative with $n = 4$ shows a nematic phase in addition to the SmA phase which is observed in the other compounds in this series. In compound **8** the quinoline unit is the only aromatic group and this compound is not mesogenic, indicating that the quinoline unit is not long enough or sufficiently polarizable to produce mesogenic behaviour.

3.2. *Textures observed by polarizing optical microscopy*

The mesophases exhibited by these compounds were identified according to their optical textures. The SmA phase of the amides (table 3) was characterized by the formation of batonnets that coalesce to form a fan-shaped texture. Mechanical stress on such a sample leads

Table 4. Transition temperatures and enthalpies data of quinolines esters, $R = C_{10}H_{21}$, Series II.



n	Transition	Temperature/°C	ΔH/kJ mol^{-1}
4	Cr–Cr	97.6	3.1
	Cr–I	118.9	43.8
	I–N	107.7	
	N–SmA	104.6	4.7
	SmA–Cr	99.0	
6	Cr–Cr	92.0	10.2
	Cr–I	118.1	63.2
	I–SmA	108.5	7.5
	SmA–Cr	95.3	
8	Cr–Cr	83.4	3.5
	Cr–I	122.3	57.7
	I–SmA	118.6	
	SmA–Cr	103.8	6.7

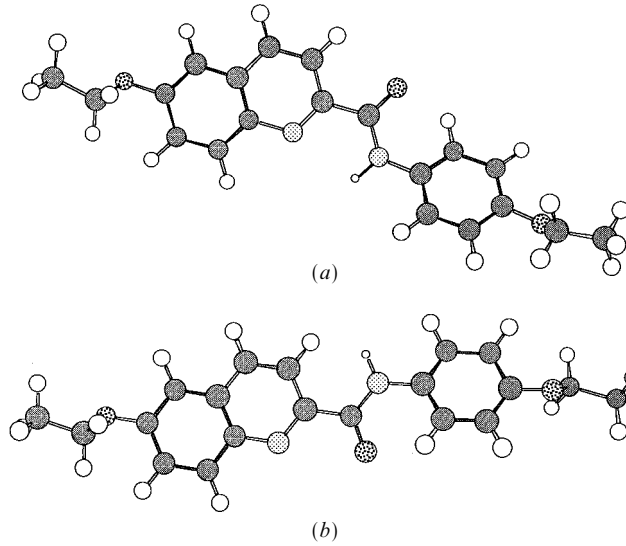


Figure 3. Representation of the two coplanar conformations of the amide group and the quinoline ring. (*a*) Conformation A (Dihedral angle N–C–C–O = 180°); (*b*) conformation B (Dihedral angle N–C–C–O = 0°).

to the formation of a homeotropic texture. The esters **7** have monotropic mesophases (table 4). A crystal–crystal transition is observed in each case along with a SmA phase. A nematic phase is observed in addition to the SmA phase in the homologue with $n = 4$. A marbled texture was observed on heating the nematic phase, while a schlieren texture appeared on cooling.

3.3. *Structure/mesomorphic activity relationship*

As can be seen in tables 3 and 4, different mesogenic behaviour is observed in the two series of compounds studied. The amide derivatives exclusively show enantiotropic mesophases, whereas the ester derivatives show monotropic mesophases. These results can be explained by considering the structures of the two systems under investigation.

Based on semi-empirical calculations (MOPAC-AM1) [15] using the derivatives with an ethoxy terminal chain as molecular models, we see that the most stable conformation in both the ester and amide derivatives is that with a coplanar arrangement between the quinoline unit and the central bridge. In both cases, conformation A is the most stable and conformation B the least stable, as shown for the amide models in figures 3 (*a*) and 3 (*b*), respectively.

The only significant difference is the different stabilization obtained between the extreme values of these conformers. The rotational barrier around the C(quinoline)–C(carbonyl) bond is approximately 2.5 kcal mol^{-1} (figure 4) in the ester derivatives and three times higher, at approximately 7.5 kcal mol^{-1} (figure 4), for the amide homologues. This significant difference in the values

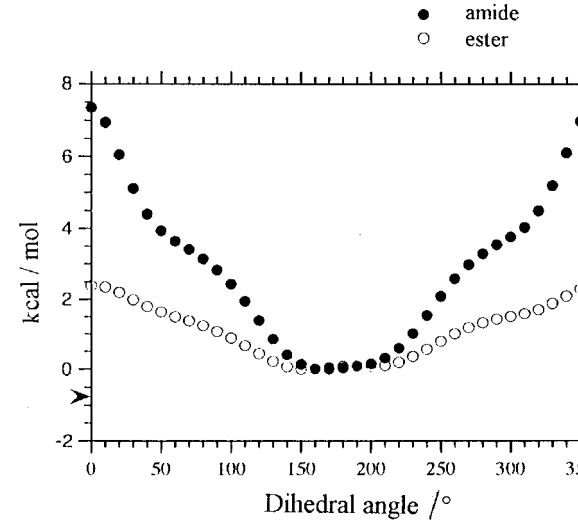


Figure 4. Potential energy curve describing the internal rotation of the central bridge (ester and amide) with respect to the quinoline ring for the chosen models. Dihedral angle considered: N(quinoline)–C(quinoline)–C(carbonyl)–O(carbonyl).

obtained is due to the formation of an intramolecular H-bond between the NH of the amide and the nitrogen of the quinoline ring (figure 5).

The formation of this intramolecular H-bond could explain the low melting points observed for the amide derivatives in comparison with those for the ester homologues, leading to the formation of an enantiotropic mesophase. On melting however, the amide derivatives present intermolecular interactions which are enough to

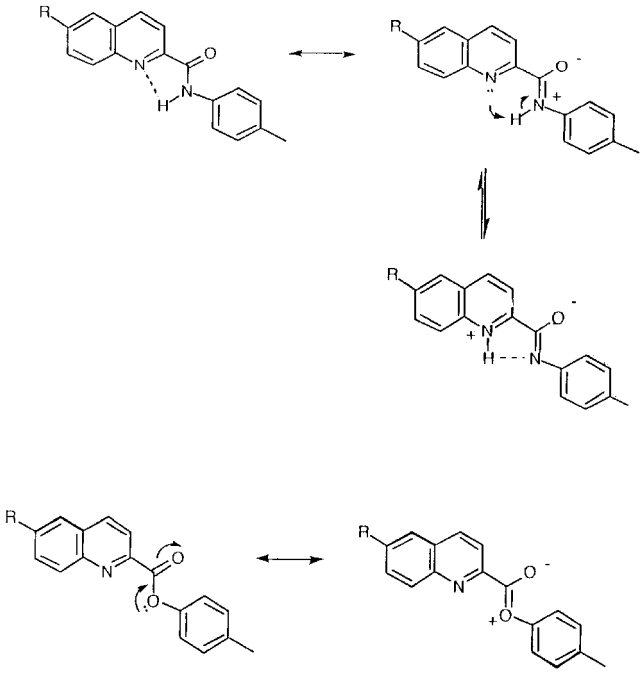


Figure 5. Resonance forms of the central bridge moieties which could contribute to the stability of the proposed planar structure of the molecules and increase their electronic polarizability.

maintain the SmA order. In spite of the similar values obtained for the molecular polarizabilities in both ester and amido arene derivative models†, the possibility of forming intramolecular H-bonds in the amido-quinolinic derivatives allows the appearance of resonance forms which favour conjugation between the aromatic rings and consequently increase the electronic polarizability and mesomorphism.

† Based on semi-empirical calculations (MOPAC-AM1) the average values for the molecular polarizability of 123.0 AU and 127.8 AU have been calculated for the phenylbenzoate and phenylbenzamide models respectively.

In the ester derivatives, the possibility of intramolecular H-bonding does not exist and thus the contribution of these resonance forms is lower; the molecular interactions after melting are therefore insufficient to maintain the order necessary for the appearance of enantiotropic mesogenic behaviour.

This work was financed by Fondecyt of Chile, grant 91/0300 and MAT94-0717-CO2-02 and MAT96-1073-CO2-02 (CICYT, Spain).

References

[1] Gray, G. W., 1979, *The Molecular Physics of Liquid Crystals*, edited by G. R. Luckhurst and G. W. Gray (Academic Press), Chap. 1.
[2] Kobmell, G., and Hoppe, F. D., 1993, *Liq. Cryst.*, **15**, 383.
[3] Eidenschink, R., 1989, *Angew. Chem. int. Ed. Engl. adv. Mater.*, **28**, 1424.
[4] Takashi, T., and Yasumari, K., 1991, Jpn. Kokai Tokyo Koho Jp., 04 345 126.
[5] Lauk, U., Scrabol, P., and Zollinger, H., 1983, *Helv. Chim. Acta*, **66**, 1574.
[6] Sierra, T., Serrano, J. L., Ros, M. B., Ezcurra, A., and Zubia, J., 1992, *J. Am. chem. Soc.*, **114**, 7645.
[7] Markova, G., Vasnev, V., Mamo, A., and Recca, A., 1994, *Polymer.*, **35**, 2007.
[8] Zuñiga, C., Belmar, J., Parra, M., Ramìrez, A., and Decap, J., 1996, *Liq. Cryst.*, **20**, 253.
[9] Gallardo, H., and Favarin, I., 1993, *Liq. Cryst.*, **13**, 115.
[10] Serrano, J. L., Sierra, T., Gonzalez, Y., Bolm, C., Weickardt, K., Magnus, A., and Moll, G., 1995, *J. Am. chem. Soc.*, **117**, 8312.
[11] Tanner, D., Fitzgerald, J. A., and Philips, B. R., 1989, *Angew. Chem. int. Ed. Eng. adv. Mater.*, **28**, 649 and references therein.
[12] Keller, P., and Liebert, L., 1978, *Liquid Crystals*, edited by L. Liebert (Academic Press), p. 36.
[13] Leir, C. M., 1977, *J. org. Chem.*, **42**, 911.
[14] Dood, R. H., and Le Hyriac, M., 1993, *Synthesis*, 295.
[15] Deward, M. J. S., Zoebish, E. G., Healy, E. F., and Stewart, J. J. P., 1985, *J. Am. chem. Soc.*, **107**, 3902.