

SYNTHESIS AND STRUCTURE OF MESOMORPHIC

2-CYANO-5-[p-ALKYL(ALKOXY)PHENYL]-
PYRIDINES

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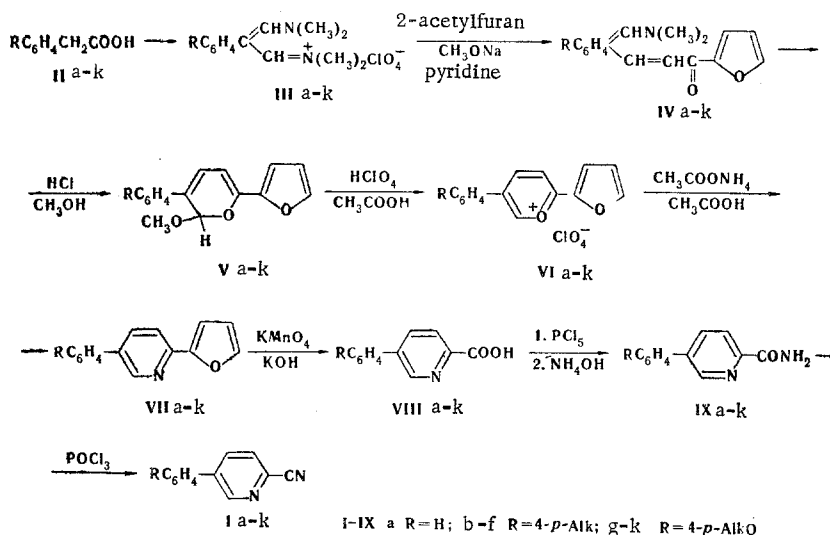
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Liquid-crystal 2-cyano-5-[p-alkyl(alkoxy)phenyl]pyridines were synthesized by the reaction of 1-dimethylamino-3-dimethylimmonia-2-[p-alkyl(alkoxy)phenyl]propene perchlorates with 2-acetylfuran and subsequently through 2-furyl-5-[p-alkyl(alkoxy)phenyl]pyrylium perchlorates and 2-(2-furyl)-5-[p-alkyl(alkoxy)phenyl]pyridines by conversion of the latter to 5-alkyl(alkoxy)phenylpyridine-2-carboxylic acids, from which the cyano derivatives were obtained by the usual scheme through the amides. The intermediate arylfurylpyridines and arylpyridine-2-carboxylic acid imides also display liquid-crystal properties.

In connection with the wide application of liquid crystals of the p-alkyl(alkoxy)-p'-cyanobiphenyl series in technology, the effect of the replacement of a benzene ring in them by a pyridine ring, specifically, the synthesis of 2-cyano-5-(p-alkylphenyl)- and 2-cyano-5-(p-alkoxyphenyl)pyridines (I), on the mesomorphic properties seems of interest. The heteroatom in these compounds, which is in the α position relative to the cyano group, should not have a substantial effect on the positive dielectric anisotropy of the liquid crystal as a consequence of the approximately equal contributions to the longitudinal and transverse components of the dipole moment of the molecule.

β -Phenyl-substituted pyridines are relatively difficult-to-obtain compounds. The known methods for their synthesis, viz., by the reaction of β -vinylpyridines with isoprene [1], through organolithium compounds [2], via the Chichibabin reaction from phenylacetaldehyde [3], by the condensation of phenyl β -chlorovinyl ketones with α -phenylcyanoacetic ester [4], and by the Jutz method [5], are unsuitable in a preparative respect because of their laboriousness and the low yields of products.

We have accomplished the synthesis of Ia-k (Table 1) via the following scheme:



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TABLE 1. 2-Cyano-5-/p-alkyl (alkoxy) phenyl/pyridines

Compound	R	Temp. of the phase transition, °C*			Found, %			Empirical formula	Calc. %			Yield, %
		C-N (S) or mp	S-N (S-I)	N-I	C	H	N		C	H	N	
Ia	H	95	—	—	80.2	4.3	15.5	C ₁₂ H ₈ N ₂	80.0	4.5	15.5	80
Ib	C ₄ H ₉	64	—	—	81.2	6.8	12.0	C ₁₆ H ₁₆ N ₂	81.3	6.8	11.9	76
Ic	C ₅ H ₁₁	73	—	—	81.3	7.1	11.6	C ₁₇ H ₁₈ N ₂	81.6	7.2	11.2	79
Id	C ₆ H ₁₃	58	—	44†	81.5	7.9	10.6	C ₁₈ H ₂₀ N ₂	81.8	7.6	10.6	91
Ie	C ₇ H ₁₅	66	—	56†	82.2	7.6	10.2	C ₁₉ H ₂₂ N ₂	82.0	7.9	10.1	83
If	C ₈ H ₁₇	61	58†	—	82.1	8.5	9.4	C ₂₀ H ₂₄ N ₂	82.1	8.3	9.6	80
Ig	C ₄ H ₉ O	97	—	81†	76.1	6.5	11.1	C ₁₆ H ₁₆ N ₂ O	76.2	6.4	11.1	85
Ih	C ₅ H ₁₁ O	69	—	82	76.5	7.1	10.4	C ₁₇ H ₁₈ N ₂ O	76.7	6.8	10.5	79
Ii	C ₆ H ₁₃ O	80	—	90	77.0	7.1	10.3	C ₁₈ H ₂₀ N ₂ O	77.1	7.2	10.0	77
Ij	C ₇ H ₁₅ O	61	86	91	77.5	7.8	9.6	C ₁₉ H ₂₂ N ₂ O	77.5	7.5	9.5	75
Ik	C ₈ H ₁₇ O	84	97	—	78.0	7.9	9.3	C ₂₀ H ₂₄ N ₂ O	77.9	7.8	9.1	80

* Symbols: C-N (S) pertains to the temperature of melting with the formation of, respectively, a nematic or smectic mesophase, S-N (S-I) pertains to the temperature of the transition from a smectic mesophase to a nematic or isotropic liquid, and N-I pertains to the temperature of the transition from a nematic mesophase to an isotropic liquid.

† The monotropic liquid crystal.

Furyl ketones IV were obtained by condensation of trimethyldiyne salts III [6] with acetylfuran via the well-known method. The ketones are usually converted to phenylpyridines through salts of the X type ($\text{Me}_2\text{NCH}=\text{CHCR}=\text{CHCR}=\text{NMe}_2\text{BF}_4^-$) obtained by reaction with triethyloxonium tetrafluoroborate, work with which is difficult because of its high hygroscopicity. It has been shown [7] in the case of the acetophenone analog of IV that 2-methoxy-2H-pyran, which is converted quantitatively to a pyrylium salt on treatment with perchloric acid in acetic acid, is formed in high yield by its protonation in methanol. We have previously used this method for the preparation of p-substituted 2,5-diphenylpyridines and 2-(2-thienyl)-5-(p-alkylphenyl) pyridines [8]. The reaction was found to be simple in a preparative respect also for the synthesis of furan derivatives, and salts VI were obtained in 60-70% overall yields without isolation of intermediates V. 2-Furyl-5-arylpyridines (VII) were obtained by refluxing salts VI in acetic acid with ammonium acetate; pronounced resinification is observed in the case of small volumes of acetic acid, and the yields of VII decrease sharply. 5-Arylpicolinic acids (VIII) were obtained in low yields (~5%) by oxidation of VII in an aqueous neutral medium, in analogy with furylpyrazoles [9], and also in an aqueous dioxane medium; we obtained acids VIIa-k in ~80% yields only in an alkaline medium, which is usually employed for the oxidation of the pyridine ring (Table 2). 5-Phenylpicolinic acid, which, with respect to its melting point and IR spectrum was identical to the compound described in [3], is formed in the case of VIIa (R = H).

In contrast to the benzene analogs, acids VIII do not display liquid-crystal properties. We assume that, as in the case of 5-alkoxypicolinic acids [10, 11], their behavior is due to the formation of an intramolecular hydrogen bond that prevents the existence of the linear dimers that are necessary for the manifestation of mesomorphic properties. This is confirmed by a study of the IR spectra of the acids in carbon tetrachloride, in which an intense absorption band in the region of the stretching vibrations of the O-H bond is observed at 3340 cm^{-1} , and in which a narrow intense band is observed in the region of the stretching vibrations of the carbonyl group at 1772 cm^{-1} .

Acids VIIa-k are converted via the usual scheme to amides (IXa-k) and then to nitriles (Ia-k), the structures of which are confirmed by the PMR spectra. The temperatures of the phase transitions of I (Table 1) are substantially higher than those of the biphenyl analogs. Since the thermal stability of the meso phase depends on the coplanarity of the mesogenic molecule, we determined the angles of rotation between the phenyl and pyridine rings in compounds with alkyl (Ib-f) and alkoxy (Ig-k) groups using the method we described in [12] on the basis of the data from UV spectroscopy and the application of perturbation theory within the framework of the Hückel MO method.

The maxima of the long-wave absorption bands of Ib-f and Ig-k are found at 293 ($\epsilon 2.2 \cdot 10^4$) and 314 nm ($\epsilon 2.9 \cdot 10^4$), as compared with 263, 271, and 268 nm, respectively, for alkylbenzenes, alkoxybenzenes, and α -cyanopyridine [12]. It follows from an analysis of the calculated energies of the upper occupied and lower vacant molecular orbitals of the alkylphenyl, alkoxyphenyl, and 2-cyanopyridine fragments [12] that the ab-

TABLE 2. Temperatures of the Phase Transitions (°C) and Yields (%) of VI-IX

	R	VI		VII			VIII		IX		
		mp	yield	C-S	S-I	yield	mp	yield	C-S	S-I	yield
a	H	200 (dec.)	58	80	—	51	157	76	183	—	90
b	C ₄ H ₉	114	61	75	96	52	160	78	174	196	88
c	C ₆ H ₁₁	146	70	65	106	50	164	70	160	183	93
d	C ₆ H ₁₃	119	64	55	103	49	160	83	176	180	81
e	C ₇ H ₁₅	151	70	48	107	54	159	76	164	180	91
f	C ₈ H ₁₇	127	61	42	102	54	158	85	172	180	90
g	C ₄ H ₉ O	176	71	106	136	47	178	79	190	212	85
h	C ₆ H ₁₁ O	164	56	62	133	51	167	75	190	204	81
i	C ₆ H ₁₃ O	172	44	76	138	48	161	81	190	189*	84
j	C ₇ H ₁₅ O	166	61	63	136	50	162	84	134	192	86
k	C ₈ H ₁₇ O	157	60	54	137	51	160	86	148	192	80

* The monotropic liquid crystal.

sorption maximum of the long-wave band in the electronic spectra of Ib-f and Ig-k is due to charge transfer from the upper occupied molecular orbital (UOMO) of the alkylphenyl or alkoxyphenyl fragment, respectively, to the lower vacant molecular orbital (LVMO) of the 2-cyanopyridine fragment. The calculation shows that the angles are 75 and 64°, respectively, for Ib-f and Ig-k. The conjugation of the π systems of the fragments in molecules with alkoxy groups is consequently greater than in molecules with alkyl groups, which also explains the higher thermal stability of the meso phase formed by the first group of compounds.

EXPERIMENTAL

The electronic spectra of solutions of the compounds (10^{-4} – 10^{-5} M) were recorded with a Hitachi EPS-3T spectrophotometer. The IR spectra of KBr pellets and CCl₄ solutions ($3 \cdot 10^{-3}$ – $5 \cdot 10^{-4}$ M) of the compounds were recorded with a UR-20 spectrometer in the 400–4000 cm⁻¹ region. The PMR spectra of solutions of the compounds in CCl₄ were recorded with a Varian-100 spectrometer at 20°C with tetramethylsilane as the internal standard.

2-Furyl-5-(p-pentylphenyl)pyrylium Perchlorate (VIc). A 20-ml (0.06 mole) sample of a 3 M solution of sodium methoxide was added dropwise with vigorous stirring at 40°C to a solution of 22.4 g (0.06 mole) of 1-dimethylamino-3-dimethylimmonia-2-(p-pentylphenyl)propene perchlorate and 6.6 g (0.06 mole) of 2-acetylfuran in 50 ml of anhydrous pyridine, and the solvent was removed by vacuum distillation after 10 h. Water (100 ml) was added to the residue, and the aqueous mixture was extracted with 300 ml of chloroform. The organic layer was washed with water and chromatographed on activity II aluminum oxide (elution with chloroform). The chloroform was removed by vacuum distillation, and 50 ml of methanol and 10–15 ml of 10% hydrochloric acid were added to the residue (IVc) without prior purification. After 20 min, the reaction mixture was diluted with 300 ml of water and extracted with ether. The extract was washed twice with water, and the ether was removed by distillation. Glacial acetic acid (10 ml), 10 ml of 57% perchloric acid, and, after 15 min, 150 ml of absolute ether were added to the residue (Vc), and the precipitated pyrylium salt VIc was removed by filtration with a glass filter and washed with absolute ether to give 16.8 g (70%) of VIc with mp 146°C (from acetic acid).

The other VI were similarly obtained (Table 2).

2-(2-Furyl)-5-(p-pentylphenyl)pyridine (VIIc). A mixture of 19 g (0.0485 mole) of crude pyrylium salt VIc, 40 g (0.52 mole) of ammonium acetate, and 210 ml of acetic acid was refluxed for 3 h, after which it was cooled and poured into 700 ml of water. The precipitate was removed by filtration, washed with water, dried in air, and recrystallized from hexane with the addition of aluminum oxide to give 7 g (49.5%) of VIIc with C-S 65°C and S-I 106°C. Found: C 82.5; H 7.4; N 4.7%. C₂₀H₂₁NO. Calculated: C 82.4; H 7.3; N 4.8%.

The remaining VII were similarly obtained (Table 2).

5-(p-Pentylphenyl)pyridine-2-carboxylic Acid (VIIIc). An 8.44-g (0.0535-mole) sample of potassium permanganate was added with vigorous stirring at 25–40°C in the course of 1 h to a solution of 2.91 g (0.01 mole) of VIIc and 2.9 g (0.052 mole) of potassium hydroxide in 40 ml of water and 70 ml of dioxane, and the mixture was stirred at this temperature for 3 h. It was then refluxed for 20 min, and the hot mixture was filtered. The residue was treated several times with boiling water to completely extract the potassium salt

of acid VIIIc, and the filtrates were combined and acidified with hydrochloric acid. The precipitate was removed by filtration, washed with water, dried, and recrystallized from benzene-hexane (1:4) to give 1.9 g (70%) of acid VIIIc with mp 164°C. Found: C 75.9; H 7.3; N 5.0%. $C_{17}H_{19}NO_2$. Calculated: C 75.8; H 7.1, N 5.2%.

The other VIII were similarly obtained (Table 2).

5-(p-Pentylphenyl)pyridine-2-carboxamide (IXc). A 1.9-g (0.09-mole) sample of phosphorus pentachloride was added with stirring to a mixture of 1.6 g (0.06 mole) of acid VIIIc in 10 ml of methylene chloride, and the mixture was stirred for 3 h. It was then poured slowly into 30 ml of ammonium hydroxide at 0°C, and the mixture was stirred for 1 h. The methylene chloride was removed by distillation, and the precipitate was removed by filtration and washed with water and acetone to give 1.5 g (93%) of amide IXc. Recrystallization from benzene gave a product with C-S 160°C and S-I 183°C.

The other IX were similarly obtained (Table 2).

2-Cyano-5-(p-pentylphenyl)pyridine (Ic). A mixture of 1.5 g of crude amide IXc and 15 ml of phosphorus oxychloride was refluxed for 1.5 h, after which it was evaporated in vacuo, and 50 ml of benzene was added to the residue. The resulting mixture was cooled and neutralized with ammonium hydroxide, and the benzene layer was washed with water, dried with anhydrous sodium sulfate, and chromatographed on activity II aluminum oxide (elution with benzene). The benzene was removed by distillation, and the residue was recrystallized from hexane with activated charcoal to give 1.1 g (78.5%) of nitrile Ic with mp 73°C. PMR spectrum (CCl_4): 0.85 (3H, m, CH_3), 1.3-1.6 [6H, m, $(CH_2)_3$], 2.65 (2H, t, $J = 6$ Hz, CH_2Ph), 7.7 (1H, d, $J_{34} = 8$ Hz, 3-H), 7.98 (1H, dd, $J_{46} = 2$ Hz, $J_{34} = 8$ Hz, 4-H), and 8.84 ppm (1H, d, $J_{46} = 2$ Hz, 6-H).

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