SYNTHESIS AND SPECTRAL CHARACTERISTICS OF ACENAPHTHENE DERIVATIVES OF BENZO[f]QUINOLINE

N. S. Kozlov, G. S. Shmanai, and Dang Ny Tai

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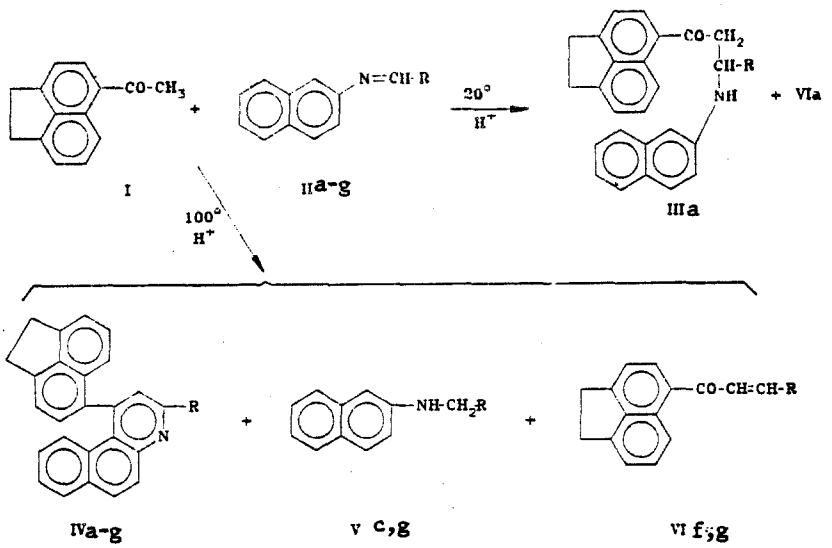
The catalytic interaction of 5-acetylacenaphthene with arylidene-2-naphthylamines leads to the formation of adducts to the C=N bond (aminoketones) or 1-(5-acenaphthenyl)-3-aryl-(heteroaryl)benzo[f]quinolines. In several instances they are accompanied by 1-(5-acenaphthenyl)-3-R-2-propen-1-ones or N-substituted 2-naphthylamines. The ratio of the products depends on the condensation conditions and the structure of the starting azomethine. Using the 3-(p-fluorophenyl)-substituted derivative as an example, it has been shown that in the absence of dihydrogenating agents β-aminoketones undergo dehydrocyclization with formation of benzoquinolines and 1,2,3,4-tetrahydroquinolines.

Interest in the synthesis and properties of benzo[f]quinoline derivatives has been occasioned by the possibility of using them as complexing agents and biologically active substances [1-3]. Condensation of 5-acetylnaphthene (I) with arylidene-2-naphthylamines or with 6-[N-(2-naphthyl)-formylimidoyl]quinoline (II a-g) in ethanol in the presence of an acidic catalyst allowed us to realize the synthesis of 1-(5-acenaphthenyl)-3-aryl-3-(2-naphthylamino)propan-1-one (IIIa) and 1-(5-acenaphthenyl)-3-aryl(heteroaryl)benzo[f]quinolines (IV a-g).



II—VI a R=4-FC_6H_4, b R=C_6H_5, c R=4-ClC_6H_4, d R=4-BrC_6H_4, e R=4-$CH_3OC_6H_4$, f R=4-$NO_2C_6H_4$, g R=6-quinolyl

β-Aminoketone IIIa, which is the first intermediate in the synthesis of benzoquinolines, was obtained at room temperature. The heterocyclization of the adduct takes place during condensation in the boiling solvent to yield up to 50% of benzo[f]quinolines IV (Table 1). The hydrogen generated during this process is partially consumed for hydrogenation of the azomethine to give N-substituted 2-naphthylamines (V). The target products are also accompanied by α,β-unsaturated ketones of the acenaphthene series (VI). In the case of fluoro- and nitrobenzylidene-2-naphthylamines and 6-quinoline azomethine and in the presence

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TABLE 1. Characteristics of 1-(5-Acenaphthenyl)-3-aryl (heteroaryl)benzo[f]quinolines IVa-g

Compound	* mp, °C	Found				Molecular formula	Calc.				Yield %
		C, %	H, %	N, %	M^+		C, %	H, %	N, %	M	
IVa	206—207	—	—	3,4	425	$C_{31}H_{20}FN$	—	—	3,3	425	40
IVb	178—179	91,8	5,4	3,7	407	$C_{31}H_{21}N$	91,4	5,2	3,4	407	26
IVc	256—257	84,5	4,8	3,2	441	$C_{31}H_{20}ClN$	84,3	4,5	3,2	441	49
IVd	265—266	—	—	3,0	486	$C_{31}H_{20}BrN$ †	—	—	2,9	486	46
IVe	240—241	88,2	5,5	3,0	437	$C_{32}H_{23}NO$	87,9	5,3	3,2	437	25
IVf	309—310	82,4	4,7	6,0	452	$C_{31}H_{20}N_2O_2$	82,3	4,4	6,2	452	9
IVg	230—231	89,3	5,1	5,9	458	$C_{34}H_{22}N_2$	89,1	4,8	6,1	458	27

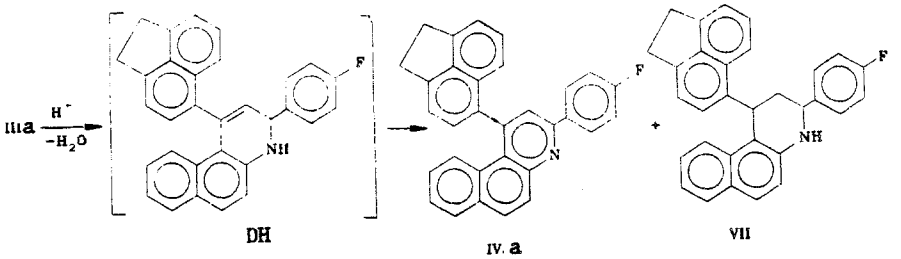
*Solvents for recrystallization: for IVa,f — dioxane, for IVb-e, g — benzene.
†Found: Br 16.3%. Calc: Br 16.4%.

of hydrochloric acid as catalyst, they are the predominant reaction products.

Formation of propen-1-ones (VI a,f,g) is possible as a result of hydrolytic cleavage of β-aminoketones. The ease of elimination of the amine can be explained by formation of the energetically favorable conjugated electron system in the propenone molecule. In order to suppress this competitive reversible process we added to the reaction mixture an equimolar amount of 2-naphthylamine in the form of its hydrochloride. This allowed us to lower the yield of the 6-quinolyl-substituted propenone VIg from 60 to 4%.

In the case of fluoro- and nitrophenyl derivatives VIa,f, the effect of 2-naphthylamine hydrochloride has not been detected. Moreover, it has been found that upon refluxing of β-aminoketone IIIa for 3 h in the presence of hydrochloric acid only benzoquinoline IVa and its 1,2,3,4-tetrahydro derivative (VII) were formed; the cleavage products of aminoketone have not been detected. This indicates that α,β-unsaturated ketones with electron-withdrawing substituents (VIa,f) constitute products of the aldol condensation of 5-acetylacenaphthene with the aldehydes formed during the hydrolysis of azomethines in the acidic medium.

Formation of tetrahydrobenzoquinoline VII, along with heteroaromatic compound IVa, should be explained by the disproportionation of the product of dehydrocyclization of the amino-ketone, 3,4-dihydrobenzoquinoline (DH), in the absence of a dehydrogenating agent. This is in accord with the available literature data [4, 5].

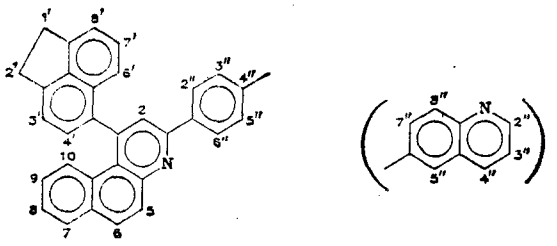


DH IV. a VII

The structure of the obtained compounds was proven by IR, UV, PMR, and mass spectra, as well as by elemental analysis (Tables 1 and 2). Thus, the IR spectra of synthesized products contain absorption bands of C—C and C—H bonds of the aromatic rings in the region of 1600-1590 and 3100-3000 cm^{-1}. The methylene groups of the acenaphthene substituent give an absorption band at 2930 cm^{-1}. The spectrum of compound IIIa has strong bands of the stretching vibrations of the CO and NH groups. These bands are absent in the spectra of the final reaction products, benzo[f]quinolines IVa-g. IR spectrum of the tetrahydro derivative VII manifests absorption of the NH group.

The mass spectrum of aminoketone IIIa contains besides the molecular ion (M^+) intensive peaks of the $C_{12}H_9CO^+$, $[C_{12}H_9COCH_3]^+$, $[C_{12}H_9]^+$, $[C_{10}H_7NH_2]^+$, ions and the peak of the maximal intensity corresponds to the $[C_{10}H_7N = CHR]^+$ ion.

TABLE 2. PMR Spectra of 1-(5-Acenaphthenyl)-3-aryl(heteroaryl)benzo[f]quinolines IVb-g ($CDCl_3$ solutions)



Compound	Chemical shift, δ, ppm (J, Hz)														
	2-H, s	5-H, d	6-H, d	7-H, d	8-H, m	9-H, m	10-H, d	1'-H и 3'H (m)	3'-H	4'-H, d	6'-H, d	7'-H	8'-H, d	2"-H and 6"-H (m)	3"-H and 5"-H
IVb*	7,87	8,19 (9,2)	8,00 (9,2)	7,80 (7,8)	7,34	6,93	7,60 (8,8)	3,55			7,28 (6,8)	7,21 t (7,5)	7,10 (8,4)	8,21	7,41 tt (6,8)
IVc	7,84	8,17 (9,2)	8,02 (9,2)	7,86 (7,8)	7,39	6,97	7,59 (8,8)	3,55	7,45 d (6,9)	7,49 (6,9)	7,32 (6,9)	7,25 t (7,5)	7,08 (8,4)	7,47	8,18 m
IVd	7,86	8,18 (9,3)	8,02 (9,3)	7,87 (7,8)	7,41	6,97	7,60 (8,9)	3,57	7,46 d (6,9)	7,50 (6,9)	7,33 (6,9)	7,27 t (7,6)	7,10 (8,4)	7,63	8,20 m
IVe†	7,81	8,16 (9,3)	8,08 (9,3)	7,82 (7,7)	7,35	6,95	7,58 (8,7)	3,55	7,44 d (6,8)	7,48 (6,8)	7,29 (6,8)	7,24 t (7,6)	7,13 (8,4)	7,02	8,18m
IVf	7,94	8,20 (9,2)	8,08 (9,2)	7,88 (7,8)	7,37	7,00	7,63 (8,8)	3,57	7,47 m	7,51 (6,8)	7,33 (6,8)	7,26m	7,08 (8,5)	8,37	8,43m
IVg‡	8,02	8,18 (9,2)	8,01 (9,2)	7,83 (7,7)	7,38	6,95	7,64 (8,8)	3,51	7,43d (6,8)	7,49 (6,8)	7,29 (6,7)	7,23 t (7,6)	7,12 (8,4)		

*3'-H, 4'-H, and 4"-H protons give a multiplet centered at δ 7.46 ppm (3H).
†Signal of the methoxy group: 3.88 ppm (3H, s, CH_3).
‡Signals of the protons of the quinolinyl substituent: 8.90 (1H d of d, 2"-H); 8.65 (1H, d, 8"-H); 8.63 (1H, s, 5"-H); 8.23 (2H, m, 4"-H, 7"-H); and 7.36 ppm (1H, m, 3"-H).

In mass spectra of 1-(5-acenaphthenyl)-3-R-benzo[f]quinolines IVa-g the M^+ peaks are of highest intensity. There are also less intensive peaks indicating fragmentation of the para substituents in the phenyl ring, and peaks of $[M - R]^+$ ions. UV spectra of compounds IVa-g are similar to the spectra of 1-aryl-3-R derivatives of this series [6, 7]. They represent a system of three absorption bands: β (253-270 nm), p (283-289 nm), and α (327-370 nm). The vibrational structure of the α-band is somewhat smoothened.

PMR spectrum of benzoquinoline IVe has a singlet of the methoxy group protons at δ 3.88 ppm, a multiplet at 3.50-3.60 ppm formed by the methylene protons of the acenaphthene ring, and signals of the aromatic protons in the region 6.95-8.18 ppm (16 H). The presence of the only singlet in this region at 7.81 ppm and two doublets at 8.08 and 8.16 (J = 9.3 Hz) resulting from the resonance of 6-H and 5-H protons indicates the 1,3-disubstituted angular structure of the benzoquinoline ring. The two doublets at 7.58 (J = 8.7 Hz), 7.82 ppm (J = 7.7 Hz) and two multiplets centered at 6.95 and 7.35 ppm were assigned to the signals of 10-H, 7-H, 9-H, and 8-H protons, respectively. The protons of p-substituted phenyl ring form two symmetric multiplets at 7.02 (2"-H, 6"-H) and 8.18 ppm (3"-H, 5"-H). The 3'-H and 4'-H protons of the acenaphthene ring give two doublets with δ 7.44 and 7.48 ppm (J = 6.8 Hz). They 7'-H proton forms a triplet centered at 7.24 ppm which interacts with doublets at 7.13 (8'-H, J = 8.4 Hz) and 7.29 ppm (6'-H, J = 6.8 Hz). Other acenaphthene derivatives of benzo[f]quinoline have analogous spectra and, consequently, also analogous structure (Table 2).

In the PMR spectrum of tetrahydrobenzoquinoline VII, besides a complex multiplet of aromatic protons in the region of 6.96-8.25 ppm and two multiplets centered at 3.33 and 3.35, formed by the methylene protons of the acenaphthene substituent, there are in the strong field signals of five additional protons. The aliphatic protons of the hydrogenated benzoquinoline ring give four multiplets centered at 2.25, 2.82, 3.58, and 4.47 ppm. A broad singlet at 5.45 ppm is attributed to resonance of the amino proton.

The structure of tetrahydro derivative VII is confirmed by its mass spectrum, which shows intensive M^+ peaks (maximum) and $[M-H]^+$, as well as peaks of the fragments formed as a result of elimination of the acenaphthene and fluorophenyl substituents. Cleavage of the hydrogenated heterocycle leads to the formation of $C_{12}H_9CH_2$, $[CH_{12}H_9CH{=}CH_2]^{+\cdot}$, $FC_6H_4CH_2^+$ and $[FC_6H_4CH{=}CH_2]^{+\cdot}$ ions. The intensity of the secondary ions is low.

Mass spectra of the secondary amines Vc,g and propenones VIa,f,g exhibit peaks of the molecular ion and a number of fragments confirming the structure of these substances.

EXPERIMENTAL

IR spectra were taken on a UR 20 spectrophotometer in KBr pellets. UV spectra were recorded on a Specord UV-vis instrument in ethanol. PMR spectra were taken on a Varian MAT-311 instrument with direct insertion of the substance into the ion source with the ionizing electrons enery of 70 eV. The purity of individual compounds was controlled by TLC on alumina (II activity grade) in benzene. The plates were stained with iodine.

1-(5-Acenaphthenyl)-3-(p-fluorophenyl)-3-(2-naphthylamino)propan-1-one (IIIa) and 1-(5-acenaphthenyl)-3-(p-fluorophenyl)-2-propen-1-one (VIa). To a solution of 1.0 g (5 mmole) of 5-acetylacenaphthene (I) in 10 ml of ethanol was added a solution of 1.25 g (5 mmole) of azomethine IIa in 40 ml of ethanol and 0.9 g (5 mmole) of 2-naphthylamine hydrochloride. The mixture was left for 7 days at room temperature. The precipitate was filtered off, neutralized with NH_4OH, washed with aqueous ethanol, with ether, and then air dried. Yield of aminoketone IIIa was 0.55 g (25%), mp 175-176°C (ethanol-benzene, 1:1). IR spectrum: 1650 (CO), 3380 cm^{-1} (NH). Mass spectrum,* m/z (intensity, %): 445 (2), 250 (38), 249 (100), 248 (75), 196 (90), 182 (20), 181 (96), 153 (37), 152 (30), 143 (36), 127 (25). Found: N 3.0%, M^+ 445. $C_{31}H_{24}FNO$. Calculated: N 3.1%, M 445. The mother and ether solutions were evaporated to 10 ml to obtain 0.6 g (40%) of propenone VIa. mp 96-97°C (hexane). IR spectrum: 1655 cm^{-1} (CO). Mass spectrum, m/z (%): 302 (100), 273, 274, 207, 181, 153, 152, 149, 86, 57, 56. $C_{21}H_{15}FO$. Calculated: M 302.

1-(5-Acenaphthenyl)-3-(6-quinolyl)benzo[f]quinoline (IVg), N-(6-Quinolyl-methyl)-2-naphthylamine (Vg), and(1-(5-Acenaphthenyl)-3-(6-quinolyl)-2-propen-1-one (VIg). A mixture of 1 g (5 mmole) of compound I, 1.41 g (5 mmole) of azomethine IIg, 0.9 g (5 mmole) of 2-naphthylamine hydrochloride, 30 ml of ethanol, and drops of nitrobenzene were refluxed for 3 h. After 24 h the crystals were separated and worked up as described for compounds IIIa and VIa, washed with ether and ethanol (5 × 5 ml), and recrystallized from benzene to give benzoquinoline IVg. The benzene filtrate was diluted with ether (1:1) to yield 0.07 g (4%) of propenone VIg. mp 158-160°C (benzene). IR spectrum: 1655 cm^{-1} (CO). Mass spectrum, m/z (%): 335 (97), 334 (61), 307 (44), 306 (55), 207 (42), 182 (51), 181 (62), 167 (59), 153 (97), 152 (100), 127 (50). Found: C 85.7; H 6.6; N 4.0%; M^+ 335. $C_{24}H_{17}NO$. Calculated: C 85.9; H 6.3; N 4.2%; M 335. From the mother and alcohol-ether solution 0.15 g (10%) of amine Vg was isolated. mp 148-149°C (ethanol). IR spectrum: 3420 cm^{-1} (NH). Found: C 84.1; H 5.9; N 9.7%; M^+ 284. $C_{20}H_{16}N_2$. Calculated: C 84.5; H 5.6; N 9.9%; M 284.

1-(5-Acenaphthenyl)-3-(p-nitrophenyl)benzo[f]quinoline (IVf) and 1-(5-acenaphthenyl)-3-(p-nitrophenyl)-2-propen-1-one (VIf), were obtained analogously. From the precipitate was washed out 0.9 g (55%) of propenone VIf. mp 175-176°C (acetone). IR spectrum: 1658 (CO), 1520, 1343 cm^{-1} (NO_2). Mass spectrum, m/z (%): 330, (39), 329 (100), 301 (35), 207 (13), 182 (16), 181 (91), 154 (18), 153 (78), 152 (70) 151 (21), 141 (18). Found: C 76.8; H 5.1; N4.0%; M^+ 329. $C_{21}H_{15}NO_3$. Calculated C 76.6; H 4.9; N 4.2%; M 329. The precipitate, benzoquinoline IVf, which is insoluble in alcohol, was recrystallized from dioxane.

Using conc. HCl as catalyst (5 drops) under analogous conditions benzoquinolines IVb-e and N-(p-chlorobenzyl)-2-naphthylamine (Vc) were obtained. Yield of amine Vc 0.14 g (11%), mp 104-105°C (ethanol), M^+ 267 [8]. Propenones VIf,g under these conditions were obtained with 62 and 60% yield, respectively.

*The molecular ion peak and 10 most intensive peaks are reported here and in the following procedures.

Heterocyclization of 1-(5-Acenaphthenyl)-3-(p-fluorophenyl)-3-(2-naphthylamino)propan-1-one (IIIa). To a solution of 1 mmole of compound IIIa in 10 ml of ethanol was added 5 drops of conc. HCl. The mixture was refluxed for 3 h, cooled and worked up as described for compounds IIIa and VIa. The precipitate was separated, worked up, and recrystallized from benzene to yield 0.17 g (42%) of 1-(5-acenaphthenyl)-3-(p-fluorophenyl)-1,2,3,4-tetrahydrobenzo[f]quinoline (VII). mp 226-227°C (benzene). IR spectrum: 3420 cm^{-1} (NH). NMR spectrum : 2.25 (1H, m, 2-H); 2.82 (1H, m, 2-H), 3.33, 3.35 (2 × 2H, m, 1'-H, 2'-H); 3.58 (1H, m, 1-H); 4.47 (1H, m, 3-H); 5.45 (br. s, NH); 6.97-8.25 ppm (15H, m, aromatic protons). Mass spectrum, m/z (%): 430, 429 (100), 428, 328, 320, 306, 304, 276, 274, 262, 250. Found: N 3.1%; M^+ 429. $C_{31}H_{24}FN$. Calculated: N 3.3%; M 429. After evaporation of the mother liquor benzoquinoline IVa was obtained. It was washed with alcohol and ether, and recrystallized from dioxane. NMR spectrum: 3.51 (4H, m, 1'-H, 2'-H), 6.93-8.19 ppm (16H, m, aromatic protons).

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