BENZENOID – QUINONOID TAUTOMERISM OF AZOMETHINES AND THEIR STRUCTURAL ANALOGS

IX.* SYNTHESIS AND STRUCTURE OF 2-FORMYL-3-HYDROXYBENZO[b]THIOPHENE ANILS

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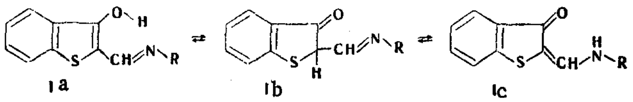
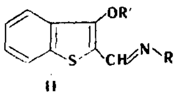
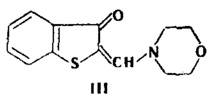
A number of 2-formyl-3-hydroxybenzo[b]thiophene anils and their derivatives, which are models of the individual tautomeric forms, were synthesized. The keto-amine structure was assigned to the anils as a result of a study of the electronic, vibrational, and NMR spectra. 2-Formyl-3-hydroxybenzo[b]thiophene exists in the hydroxy form.

o-Hydroxy- and o-mercaptoazomethines of the aromatic series have been the subjects of detailed investigations [2-4] in connection with the detection of their photochromic, thermochromic, and luminescence properties as well as their ability to form metal chelate complexes. A prototropic benzenoid–quinonoid equilibrium, which is sensitive to changes in the structures of the azomethines and the polarity of the medium, exists in solutions of the indicated compounds. In the heterocyclic series, rather detailed information regarding the structures of the vicinal hydroxy- and mercaptoazomethines is available for furan [5], thiophene [6,7], and pyrazole [8] derivatives.

In the present communication, we describe the synthesis of a series of azomethines from 2-formyl-3-hydroxybenzo[b]thiophene, the structures of which in solution can be represented as a complex tautomeric equilibrium Ia ⇌ Ic, as well as their derivatives of the II and III type, which serve as models for one of the tautomeric forms.




II


III

I, II R=Ar, Alk; II R'=CH_3, $COCH_3$

Information on the character of the tautomeric equilibrium Ia ⇌ Ic was obtained by means of data on the electronic, vibrational, and NMR spectra of I-III.

The electronic and vibrational spectra of azomethines I in the characteristic region are practically insensitive to changes in the polarity of the solvent (Fig. 1), temperature, and structure of substituent R (Table 1). This indicates that azomethines I exist primarily as one of the three possible tautomeric forms. Since the spectra of azomethines I and II differ substantially from one another (Fig. 2), it is clear that form Ia is not the most stable tautomeric structure. Evidence against Ib is the absence in the NMR spectrum of the characteristic AB pattern of splitting of the protons of the $-CH-CH=N$ group (Fig. 3). At the same time, the electronic spectra of I are similar to the spectrum of III, the structure of which models form Ic (Fig. 2).

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*See [1] for communication VIII.

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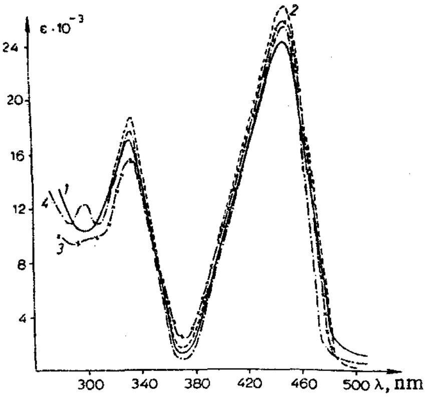


Fig. 1

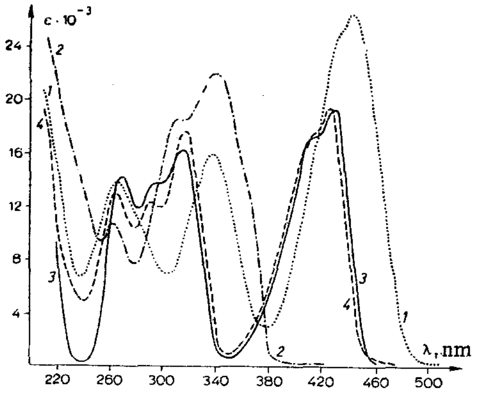


Fig. 2

Fig. 1. Electronic absorption spectra of 2-formyl-3-hydroxybenzo[b]thiophene anil: 1) in carbon tetrachloride; 2) in pyridine; 3) in dimethyl sulfoxide; 4) in acetonitrile.

Fig. 2. Electronic absorption spectra: 1) 2-formyl-3-hydroxybenzo[b]thiophene anil (I, R = C_6H_5); 2) 2-formyl-3-methoxybenzo[b]thiophene anil (II, R' = CH_3, R = C_6H_5); 3) 3-thionaphthenone-2-morpholinomethide (III); 4) 2-formyl-3-hydroxybenzo[b]thiophenebenzylimine (I, R = $CH_2C_6H_5$) (methanol).

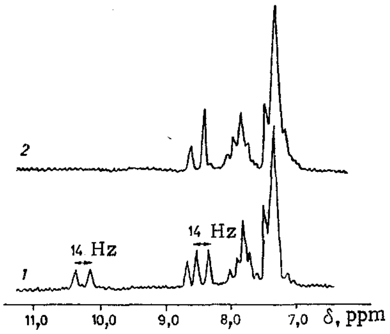


Fig. 3

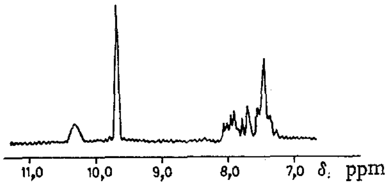


Fig. 4

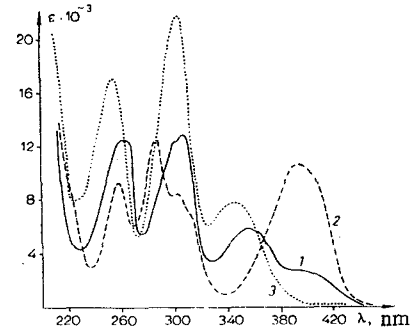


Fig. 5

Fig. 3. NMR spectra of I (R = C_6H_5) in dimethyl sulfoxide: 1) undeuterated; 2) deuterated.

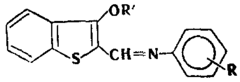
Fig. 4. NMR spectrum of 2-formyl-3-hydroxybenzo[b]thiophene (IV) in methylene chloride.

Fig. 5. Electronic absorption spectra in methanol: 1) 2-formyl-3-hydroxybenzo[b]thiophenes (IV); 2) sodium salt of IV; 3) 2-formyl-3-methoxybenzo[b]thiophene (V).

TABLE 1. Spectral Characteristics of the Azomethines

Comp. No. (see Table 2)	UV spectra in methanol, λ_{max}, nm ($\varepsilon \cdot 10^{-3}$)	IR spectra in mineral oil, ν, cm^{-1}
1	265 (13,7); 340 (16,0); 445 (26,4)	1595, 1660
3	270 (11,5); 345 (12,0); 450 (24,4)	1585, 1610, 1655
7	270 (9,5); 340 (15,6); 445 (19,2)	1595, 1660
11	272 (9,0); 358 (12,7); 460 (17,3)	1610, 1670
12	265 (13,1); 291 (12,3); 318 (17,5); 427 (19,2)	1600, 1655
13	263 (8,5); 312 (18,5); 340 (22,0)	1560, 1630

TABLE 2



Comp. No.	R′	R	mp, °C	Empirical formula	Found, %			Calc., %			Synthetic method	Yield, %
					C	H	S	C	H	S		
1	H	H	179	$C_{15}H_{11}NOS$	71,0	4,3	12,6	71,1	4,4	12,7	A	85
					70,8	4,5	12,2				B[15]	71
2	H	*p*-N(CH$_3$)$_2$	244—245	$C_{19}H_{16}N_2OS$	68,7	5,4	10,7	68,9	5,4	10,8	A	73
3	H	*p*-OCH$_3$	178	$C_{16}H_{13}NO_2S$	67,6	4,8	11,0	67,8	4,6	11,3	A	83
4	H	*m*-CH$_3$	168—169	$C_{16}H_{13}NOS$	71,9	5,1	11,8	71,9	4,9	12,0	B	59
5	H	*p*-CH$_3$	199	$C_{16}H_{13}NOS$	71,8	5,1	11,9	71,9	4,9	12,0	A	79
					72,4	4,8	11,9				B	49
6	H	*m*-Cl	209—210	$C_{15}H_{10}ClNOS$	62,5	3,8	10,6	62,6	3,5	11,1	A	75
7	H	*p*-Cl	222	$C_{15}H_{10}ClNOS$	62,9	3,6	10,8	62,6	3,5	11,1	B	63
8	H	*p*-Br	208—209	$C_{15}H_{10}BrNOS$	54,5	3,2	9,7	54,2	3,0	9,6	B	64
9	H	*p*-COOC$_2$H$_5$	229—230	$C_{18}H_{15}NO_3S$	66,2	4,7	9,7	66,4	4,6	9,8	B	55
10	H	*m*-NO$_2$	212	$C_{15}H_{10}N_2O_3S$	60,6	3,5	10,5	60,4	3,4	10,8	A	81
11	H	*p*-NO$_2$	273	$C_{15}H_{10}N_2O_3S$	60,7	3,5	10,6	60,4	3,4	10,8	A	85
12	H	*	119—120	$C_{16}H_{13}NOS$	71,7	4,6	11,8	71,9	4,9	12,0	A	55
13	CH$_3$	H	70	$C_{16}H_{13}NOS$	71,6	5,1	12,0	71,9	4,9	12,0	A	85
14	CH$_3$	*p*-OCH$_3$	109—110	$C_{17}H_{15}NO_2S$	68,6	5,2	10,6	68,7	5,1	10,8	A	83
15	CH$_3$	*p*-Cl	114—115	$C_{16}H_{12}ClNOS$	63,4	4,0	10,4	63,7	4,0	10,6	A	83
16	CH$_3$	*p*-CH$_3$	119—120	$C_{17}H_{15}NOS$	72,3	5,4	11,3	72,6	5,4	11,4	A	92
17	COCH$_3$	*m*-Cl	134—135	$C_{17}H_{12}ClNO_2S$	61,8	3,9	9,6	61,9	3,7	9,7	A	77
18	COCH$_3$	*m*-NO$_2$	168	$C_{17}H_{12}N_2O_4S$	59,8	3,7	9,4	60,0	3,6	9,4	A	81
19	COCH$_3$	*p*-NO$_2$	212	$C_{17}H_{12}N_2O_4S$	60,3	3,8	9,7	60,0	3,6	9,4	A	71

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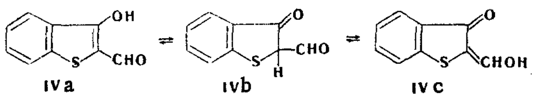
*A benzyl group is attached to the nitrogen in place of an aryl ring.

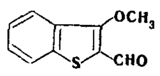
The data from the NMR spectra in dimethyl sulfoxide provide distinct proof of the preferableness of the quinonoid structure. As seen from Fig. 3, two spin doublets of the CH– and NH– protons with J = 14 Hz, which coincides in magnitude with the analogous constant observed in the spectra of quinonoid tautomers of mercapto and hydroxy aldehydes of furan and thiophene [5-7], are present in the spectrum of I (R = C_6H_5). The spectrum of I at 8.70 ppm in the vicinity of the CH doublet of tautomer Ic contains a singlet that is retained on deuteration (repeated recrystallization from deuteroethanol) and is probably affiliated with trans isomer Ib, in which the intramolecular hydrogen bond is absent, and rapid exchange of protons in dimethyl sulfoxide leads to elimination of the spin splitting.

The data from IR spectroscopy (Table 1) confirm the conclusion of a keto-amine structure for 2-formyl-3-hydroxybenzo[b]thiophene anils (I). The spectra of compounds of the I type contain an intense band of the ring carbonyl group at ~1660 cm^{-1}, which appears at 1645 cm^{-1} for III, and a band at 1590-1600 cm^{-1}, which corresponds to the vibrations of the exocyclic C=C bond. As should have been expected, the absorption at ~1660 cm^{-1} is absent for azomethines of the III type, which have a fixed imine structure, but the spectra do contain bands at 1620-1630 cm^{-1}, which are characteristic for the C=N bond [9]. A carbonyl absorption band with an unusually high frequency (1770-1780 cm^{-1}), which is characteristic for vinyl esters of aliphatic acids [10], is present along with a band of stretching vibrations of the C=N bond in the spectra of azomethines II (R' = $COCH_3$). This indicates the extremely high degree of double bond character of the C=C bond of the thiophene ring in II.

In addition to a study of the structure of anils I, it seemed of interest to carry out a more detailed examination of the structure of the starting 2-formyl-3-hydroxybenzothiophene (IV).



IVa IVb IVc



V

The NMR spectrum of aldehyde IV (Fig. 4) contains a distinct singlet (δ 9.66 ppm) of the proton of the aldehyde group and a broad signal (10.3 ppm) of the proton of the OH group, which vanishes after deuteration of the compound by the addition of deuterium oxide. This spectrum excludes structure IVb and corresponds to IVa, since the aldehyde proton might have appeared as a doublet in the case of IVc. It is easy to choose between tautomers IVa and IVc on the basis of the IR and UV spectra. Absorption bands at

1625 and 1630 cm^{-1}, respectively, which correspond to the stretching vibrations of the aldehyde carbonyl group in IVa and are substantially lower than the vibrations of the ring carbonyl group in structures of the IVc type, appear in the IR spectra of IV and V. The UV spectra of aldehydes IV and V (Fig. 5) are completely analogous, except for the weak absorption of IV at 400 nm. It is clear from a comparison with the spectrum of aldehyde IV in alkaline media that this absorption is caused by partial ionization of the hydroxy aldehyde. Thus, in contrast to the anils formed by it, aldehyde IV exists in hydroxy aldehyde form IVa.

EXPERIMENTAL

2-Formyl-3-hydroxybenzo[b]thiophene (IV). This compound was obtained by the method in [11] from thiosalicylic acid and bromoacetal. It was purified by sublimation to give colorless crystals with mp 110°

2-Formyl-3-methoxybenzo[b]thiophene (V). This compound was obtained via the method in [12] in 80% yield and had mp 85°.

2-Formyl-3-acetoxybenzo[b]thiophene Diacetate. A 4-ml sample of acetic anhydride was added to a solution of 1 g (0.06 mole) of 2-formyl-3-hydroxybenzo[b]thiophene in 2 ml of pyridine, and the mixture was allowed to stand overnight. It was then poured over ice, and the solid precipitate was removed by filtration, washed with water, and recrystallized from ethanol to give colorless plates with mp 107°. Found: C 56.3; H 4.2; S 9.5%. $C_{15}H_{13}O_6S$. Calculated: C 56.1; H 4.1; S 10.0%.

The NMR spectrum (in methylene chloride) contains signals of the methyl protons of the diacetate group (δ 2.05 ppm), the 3-acetoxy group (2.37 ppm), and the methylidyne proton (8.01 ppm).

Azomethines (I). A. Equimolecular amounts of 2-formyl-3-hydroxybenzo[b]thiophene and the appropriate amine were condensed in ethanol with subsequent crystallization from a suitable solvent (ethanol, butanol, or pyridine). Crude aldehyde IV, obtained by cyclization of S-(formylmethyl)thiosalicylic acid in acetic anhydride [11], probably contains a considerable amount of 3-acetoxy-2-formylbenzo[b]thiophene diacetate. A mixture of O-acetylated azomethine and the corresponding anil I is therefore formed in the reaction of the crude aldehyde with arylamines of low basicity.

B. The corresponding N,N'-diarylformamidines, synthesized in accordance with [14, 15], were condensed with 3-hydroxybenzo[b]thiophene. The resulting azomethines were recrystallized from alcohol or 50% aqueous pyridine. As a rule, the products were yellow-green, crystalline compounds (see Table 2).

Azomethines (II). These were obtained by condensation of 2-formyl-3-methoxybenzo[b]thiophene (V) and 3-acetoxy-2-formylbenzo[b]thiophene diacetate with amines in alcohol. The azomethines were recrystallized from ethanol to give yellow-green crystalline compounds.

3-Thionaphthenone-2-morpholinomethide (III). A mixture of 0.5 g (0.03 mole) of aldehyde IV and 0.24 g (0.03 mole) of morpholine was refluxed for 3 h in 25 ml of toluene. The solvent was removed by vacuum distillation, and the residue was recrystallized from alcohol with clarification by activated charcoal to give 0.4 g (58%) of light-green prisms with mp 193-194°. Found: C 63.4; H 5.5; S 12.8%. $C_{13}H_{13}NO_2S$. Calculated: C 63.1; H 5.3; S 13.0%.

The electronic absorption spectra were recorded with a VSU-2P spectrophotometer. The IR spectra were obtained with a UR-20 spectrometer. The NMR spectra of 15% solutions of the compounds were obtained with an RYa-2305 spectrometer (60 MHz) with tetramethylsilane as the internal standard.

LITERATURE CITED

1. V. I. Minkin, L. P. Olekhnovich, and B. Ya. Simkin, Zh. Organ. Khim., 7, 2364 (1971).
2. L. A. Kazitsyna, N. B. Kupletskaya, L. L. Polstyanko, B. S. Kikot', and A. P. Terent'ev, Zh. Obshch. Khim., 31, 313 (1961).
3. W. F. Richey and R. S. Becher, J. Chem. Phys., 49, 2092 (1968).
4. V. I. Minkin, L. P. Olekhnovich, L. E. Nivorozhkin, Yu. A. Zhdanov, and M. I. Knyazhanskii, Zh. Organ. Khim., 6, 348 (1970).
5. V. S. Bogdanov, Ya. L. Danyushevskii, and Ya. L. Gol'dfarb, Izv. Akad. Nauk SSSR, Ser. Khim., 675 (1970).
6. V. S. Bogdanov, M. A. Kalik, and Ya. L. Gol'dfarb, Izv. Akad. Nauk SSSR, Ser. Khim., 2413 (1970).
7. V. S. Bogdanov, M. A. Kalik, I. P. Yakovlev, and Ya. L. Gol'dfarb, Zh. Obshch. Khim., 40, 2102 (1970).
8. I. Ya. Kvitko and B. A. Porai-Koshits, Zh. Obshch. Khim., 5, 1685 (1969).
9. F. H. Suydam, Anal. Chem., 35, 193 (1963).

10. L. Bellamy, Infra-Red Spectra of Complex Molecules, Methuen (1958).
11. V. M. Rodionov, Z. S. Kazakova, and B. M. Bogoslovskii, Izv. Akad. Nauk SSSR, Ser. Khim., 536 (1948).
12. F. Krollpfeiffer, Ann., 462, 46 (1928).
13. N. N. Sveshnikov and I. I. Levkoev, Zh. Obshch. Khim., 10, 274 (1940).
14. P. Zochon, Bull. Soc. Chim. France, 393 (1965).
15. H. J. Backer and W. L. Wanmaker, Rec. Trav. Chim., 68, 247 (1949).