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REACTION OF 4-R-2-PHENYLTETRA-HYDROBENZO[*b*]PYRYLIUM AND 9-R-*sym*-OCTAHYDROXANTHYLIUM SALTS WITH FURFURAL AND RELATED COMPOUNDS

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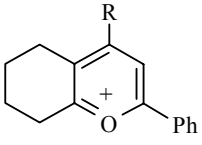
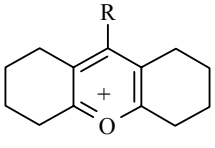
The condensation of furfural, 5-methylfurfural, and 2-thiophenecarbaldehyde with 4-R-2-phenyltetrahydrobenzo[b]pyrylium and 9-R-sym-octahydroxanthylium salts was studied. Condensation conditions under which acidophobic aldehydes of the furan series do not undergo resinification were found. 8-Furfurylidene and 8-thenylidene derivatives of 4-R-2-phenyltetrahydrobenzo[b]pyrylium and bisfurfurylidene and bisthenylidene derivatives of 9-R-sym-octahydroxanthylium salts were obtained for the first time.

Keywords: *5-methylfurfural, 9-R-1,8-bis[thenylidene]-sym-octahydroxanthylium and 9-R-1,8-bis-[R^1-furfurylidene]-sym-tetrahydrobenzo[b]pyrylium, 9-R-sym-octahydroxanthylium and 4-R-2-phenyltetrahydrobenzo[b]pyrylium, 4-R^1-2-phenyl-8-thenylidenetetrahydrobenzo[b]pyrylium and 4-R-2-phenyl-8-(R^1-furfurylidene)tetrahydrobenzo[b]pyrylium salts, thiophenecarbaldehyde, furfural, condensation.*

It is known [1-3] that derivatives of cycloalka[*b*]chalcogenopyrylium salts are used as dyes in passive switches of optical quantum generators OQG [3], are used in photocompositions without silver salts [4], and exhibit biological activity [2]. Earlier we demonstrated that cycloalka[*b*]chalcogenopyrylium salts containing a γ-methyl group in the heterocycle and an α-methylene group in the alicycle react with aromatic aldehydes under harsh conditions at 100°C in a 1:3 mixture of acetic acid and acetic anhydride and form quantitative yields of the corresponding arylidene derivatives [1].



1a,b



2a,b

1 A = BF_4; **2** A = ClO_4; **1**,**2 a** R = H, **b** R = Ph

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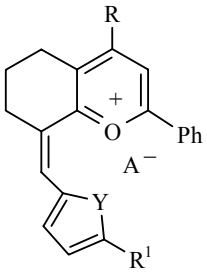
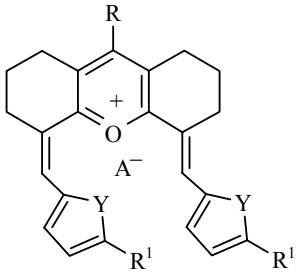
Before the present work furfurylidene derivatives of cycloalka[*b*]chalcogenopyrylium salts had not been described. In so far as furfural is a well known pharmacophore it seemed of interest to study the possibility of synthesizing furfurylidene derivatives of 4-R-2-phenyltetrahydrobenzo[*b*]pyrylium **1a**,**b** and 9-R-*sym*-octahydroxanthylium **2a**,**b** salts.

The aim of the present work was to study the condensation of the above-mentioned salts with furfural, 5-methylfurfural, and thiophenecarbaldehyde and also to develop a preparative method for the synthesis of their furfurylidene derivatives. The conditions in [1] described above are unsuitable for the condensation of chalcogenopyrylium salts **1** and **2** with acidophobic aldehydes of the furan series. In the present work we realized this condensation by boiling the reagents in isopropyl alcohol with phosphorus(V) oxide as dehydrating agent.

Under the developed conditions (method A, see the experimental section) with furfural, 5-methylfurfural, and thiophenecarbaldehyde under mild conditions the salts **1,b** are converted into the corresponding products **3a-f** with yields of 60-80%.



3a–f



4a–d

3 a–**f** A = BF_4, **a**–**d** Y = O; **a** R = R^1= H, **b** R = H, R^1 = Me, **c** R = Ph, R^1= H, **d** R = Ph, R^1 = Me; **e**, **f** Y = S, **e** R = R^1 = H, **f** R = Ph, R^1= H; **4 a**–**d** A = ClO_4, **a**–**c** Y = O, **a** R = R^1 = H, **b** R = Ph, R^1 = H, **c** R = Ph, R^1 = Me; **d** Y = S, R = Ph, R^1 = H

TABLE 1. The Characteristics of the Synthesized Salts **3a-f** and **4a-d**

Compound	Empirical formula	Found, % / Calculated, %			mp, °C	Yield %, in method A (B)
		C	H	S		
3a	$C_{20}H_{17}BF_4O_2$	63.83 / 63.86	4.51 / 4.56		174-176	80 (87)
3b	$C_{21}H_{19}BF_4O_2$	65.37 / 64.64	4.17 / 4.91		222-223	87 (99)
3c	$C_{26}H_{21}BF_4O_2$	69.37 / 69.05	4.81 / 4.68		246-248	60 (72)
3d	$C_{27}H_{23}BF_4O_2$	69.24 / 69.55	4.15 / 4.97		228-229	81 (98)
3e	$C_{20}H_{17}BF_4OS$	59.67 / 61.25	3.89 / 4.37	8.76 / 8.17	195-196	82 (92)
3f	$C_{26}H_{21}BF_4OS$	67.51 / 66.68	5.03 / 4.52	7.12 / 6.85	264-266	80 (88)
4a	$C_{23}H_{21}ClO_7$	62.05 / 62.10	4.96 / 4.76		>300	Quant.
4b	$C_{29}H_{25}ClO_7$	66.53 / 66.86	5.13 / 4.84		>300	Quant.
4c	$C_{31}H_{29}ClO_7$	67.57 / 67.82	5.67 / 5.32		>300	Quant.
4d	$C_{29}H_{25}ClO_5S_2$	63.07 / 62.98	4.75 / 4.56	11.13 / 11.59	>300	Quant.

TABLE 2. The ^{1}H NMR Spectra of the Synthesized Salts **3a-f** and **4a-d**

Com-pound	Chemical shifts, δ, ppm, SSCC (*J*, Hz)					
	H-3, 1H	R (H or Ph)	2-Ph, m	=C<u>H</u>–Het, m	Het	$(CH_2)_3$, m
3a	8.71 (br. d)	8.56 (1H, br. d)	8.38 (2H); 7.81-7.69 (3H)	6.79 (1H)	8.02 (1H, m); 7.93 (1H, m); 7.38 (1H, m)	3.15 (2H); 3.05 (2H); 2.05 (2H)
3b	8.65 (br. d)	8.46 (1H, br. d)	8.40 (2H); 7.75 (3H)	6.51 (1H)	7.88 (1H, m); 7.32 (1H, m); 2.52 (3H, s, Me)	3.14 (2H); 3.05 (2H); 2.04 (2H)
3c	8.62 (s)	8.09 (2H, m, Ph)	8.51 (2H)	6.81 (1H)	8.04 (1H, m); 7.79 (1H, m); 7.25 (1H, m)	3.17 (2H); 3.04 (2H); 2.01 (2H)
		7.72 (6H, m, Ph)				
3d	8.45 (s)	7.75 (3H, m, Ph)	8.41 (2H)	6.51 (1H)	7.94 (1H, m); 7.34 (1H, m); 2.52 (3H, s, Me)	3.17 (2H); 3.01 (2H); 1.94 (2H)
		7.68 (5H, m, Ph)				
3e	8.72 (br. d)	8.58 (1H, br. d)	8.32 (2H); 7.73 (3H)	8.43 (1H)	8.09 (1H, m); 7.95 (1H, m); 7.35 (1H, m)	3.10 (4H); 2.05 (2H)
3f	8.65 (s)	8.12 (2H, m, Ph)	8.55 (2H)	8.48 (1H)	8.07 (1H, m); 7.86 (1H, m); 7.36 (1H, m)	3.30-3.08; 3.03; 2.01-1.89
		7.74 (6H, m, Ph)				
4a		8.32 (1H, s)		7.30 (2H)	7.99 (2H, m); 7.81 (2H, m); 6.77 (2H, m)	3.15 (4H); 2.93 (4H); 1.95 (4H)
4b		7.98 (2H, m, Ph); 7.60 (3H, m, Ph)		6.87 (2H)	7.87 (2H, m); 7.35 (4H, m)	3.10 (4H); 2.55 (4H); 1.91 (4H)
4c		7.58 (5H, m, Ph)		6.46 (2H)	7.81 (2H, m); 7.25 (2H, m); 2.45 (6H, s, Me)	3.16 (4H); 3.05 (4H); 2.00 (4H)
4d		8.04 (2H, m, Ph); 7.62 (3H, m, Ph)		7.95 (2H)	8.44 (2H, m); 7.35 (4H, m)	3.00 (4H); 2.60 (4H); 1.93 (4H)

The yields of the indicated products are increased appreciably if a 1:1 mixture of acetonitrile and isopropyl alcohol is used as reaction medium (method B) (Table 1).

9-R-*sym*-Octahydroxanthylium salts **2a**,**b** react smoothly with the aldehydes in isopropyl alcohol at the two α-methylene groups, forming quantitative yields of compounds **4a-d**.

The composition and structure of the obtained products were supported by the results of elemental analysis and also by the data from ^{1}H NMR and UV spectroscopy. The yields and characteristics of the synthesized substances are presented in Tables 1-3.

The ^{1}H NMR spectra of compounds **3a-f** contain a signal for the H-3 proton of the pyrylium cation in the region of 8.7-8.5 ppm in the form of a broad doublet for R = H (salts **3a**,**b**,**e**), indicating that this proton is coupled with the H-4 proton. If R = Ph the H-3 signal appears in the form of a singlet, while the H-4 signal is absent. The protons of the other fragments of the compounds resonate in the upfield region. Thus, the multiplets for the protons of the phenyl substituents at the *meta* positions are at 8.5-8.3 ppm while those for the *ortho* and *para* protons are at 7.8-7.7 ppm. The signals for the protons of the hetaryl substituent are observed in the region of 8.4-6.8 ppm, those for the methine proton at 8.5-6.5 ppm, and those for the alicyclic fragment in the region of 3.3-2.0 ppm. The spectra of compounds **4a-d** differ from those described above in twice the intensity for the signals of the protons of the alicyclic and hetaryl fragments and also in the absence of a signal corresponding to the H-3 proton of the pyrylium derivatives **3**. With the exception of the signal for the methine proton the heteroatom of the Het substituent in compounds **3** and **4** does not have an appreciable effect on the position of the signals for the protons of the compounds; replacement of the oxygen atom by a sulfur atom leads to a substantial shift of this signal by 1.64 (cf. compounds **3a** and **3e**), 1.67 (**3c** and **3f**), and 1.02 ppm (**4b** and **4d**), which is explained by the descreening effect of the sulfur atom. The introduction of a methyl substituent into the furan ring leads to a small upfield shift of the methine proton: by 0.28 (cf. compounds **3a** and **3b**), 0.30 (compounds **3c** and **3d**), and 0.41 ppm (compounds **4b** and **4c**), due probably to the induction effect of this substituent.

The most interesting feature of the electronic spectra of the synthesized compounds **3** and **4** is the bathochromic shift of the long-wave band ($\Delta\lambda_{max}$, nm) in relation to its position in the spectra of the initial compounds **1** and **2**, which amounts to 144-305 nm (Table 3). During comparison of the spectral characteristics of compounds **3a** and **3b**, **3c** and **3d**, and **4b** and **4c** it is possible to see a small bathochromic shift (16-36 nm) for the spectra of compounds **3b**,**d** and **4b** having a methyl substituent in Het. The furfurylidene and thenylidene derivatives **3a** and **3e** and **3c** and **3f** do not reveal substantial differences in the position of the long-wave absorption band.

TABLE 3. Long-Wave Absorption in the Electronic Spectra of the Initial Salts **1a**,**b** and **2a**,**b** and Condensation Products **3a-f** and **4a-d** (Solutions in MeOH)

Initial compounds	λ_{max}, nm (log ε)	Condensation product	λ_{max}, nm (log ε)	$\Delta\lambda_{max}$, nm
1a	364 (4.12)	**3a**	513 (4.129)	149
		3b	540 (4.222)	176
		3e	508 (4.417)	144
1b	368 (4.20)	**3c**	528 (3.685)	160
		3d	544 (4.469)	176
		3f	528 (3.742)	160
2a	316 (3.256)	**4a**	584 (3.383)	268
2b	317 (4.026)	**4b**	586 (4.104)	269
		4c	622 (3.805)	305
		4d	582 (3.693)	265

Thus, we have obtained previously unknown 8-furfurylidene and 8-thenylidene derivatives of 4-R-2-phenyltetrahydrobenzo[*b*]pyrylium salts and also bisfurfurylidene and bisthenylidene derivatives of 9-R-*sym*-octahydroxanthylium salts and have proposed conditions for their preparative synthesis.

EXPERIMENTAL

The UV spectra were recorded in methanol on a Specord M-40 spectrophotometer with layer thickness 0.1 cm and concentration 10^{-3} M. The ^{1}H NMR spectra were obtained in DMSO-d_6–CCl_4 solution on a Bruker AC-300 spectrometer (300 MHz).

The initial salts **1a**,**b** and **2a**,**b** were synthesized by known methods [6, 7].

Condensation of Tetrahydrobenzo[*b*]pyrylium Salts (1a,b) with Furfural, 5-Methylfurfural, or Thiophene-2-carbaldehyde (General Method). A. To a solution of P_2O_5 (2.5 mmol) in dry isopropyl alcohol (15 ml) we added the pyrylium salt **1** (2.5 mmol). The mixture was heated until the salt had completely dissolved, the aldehyde (2.5 mmol) was added drop by drop, and the mixture was shaken. The crystals of the product **3** that separated were removed and washed with alcohol and ether.

B. The reaction was conducted as described above with ~10 ml of a 1:1 mixture of isopropyl alcohol and acetonitrile as solvent.

Condensation of 9-R-*sym*-octahydroxanthylium Salts 2a,b with Furfural, 5-Methylfurfural, or Thiophene-2-carbaldehyde. We dissolved the salt **2** (1.3 mmol) in a solution of P_2O_5 (0.37 g, 2.6 mmol) in dry isopropyl alcohol (6 ml) and added the aldehyde (2.6 mmol). The reaction mixture was boiled for 1-10 min. The separated crystals of the product **4** were removed, washed with alcohol and ether, dried, and purified by recrystallization from a 1:1 mixture of isopropyl alcohol and acetonitrile.

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