SYNTHESIS OF POLYFUNCTIONAL STABLE NITRILE OXIDES OF THE THIOPHENE SERIES AND THEIR RELATIVE REACTIVITIES IN 1,3-DIPOLAR CYCLOADDITION WITH STYRENE

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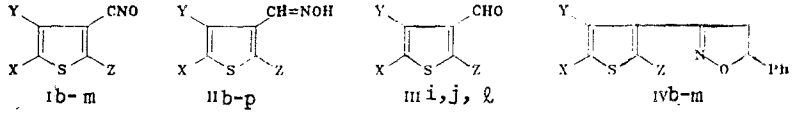
Stable 2-alkylthio- and 2-alkylsulfonylthiophene-3-carbonitrile oxides that contain various functional groups in the 4 and 5 positions of the thiophene ring (Br, OCH_3, SCH_3, SO_2CH_3) were synthesized. It is shown that the introduction of electron-acceptor substituents into any position of the ring of thiophene-3-carbonitrile oxides gives rise to acceleration of cycloaddition to styrene. The reactivities of o-substituted thiophene-3-carbonitrile oxides of the thiophene series in 1,3-dipolar cycloaddition reactions are determined by the overall effect of the electronic and steric factors of the substituents.

The study of the effect of substituents on stabilities and reactivities is one of the principal problems of the chemistry of nitrile oxides [1, p. 13], although the electronic effect of substituents on the stabilities of aromatic nitrile oxides is not clearly expressed [2, 3] and is often overlapped by other effects (for example, steric effects [4-6]). Kinetic investigations of the reaction of substituted benzonitrile oxides with styrene have made it possible to establish a regularity in the change in the reaction rate constants as a function of the nature and position of the substituents in 1,3-dipoles [7-9]. Information of this sort is extremely limited for compounds of the thiophene series, and only the effect of electronic [10] and steric [11] factors on the reactivities of a number of thiophenecarbonitrile oxides has been noted.

In the present research we describe the synthesis of nitrile oxides Ib-m substituted in the 4 and 5 positions of the thiophene ring with various functional groups and the study of the effect of the nature of the substituent on their stabilities and reactivities in 1,3-dipolar cycloaddition with styrene.

Nitrile oxides Ib-m were obtained by the method that we previously described for 2-methylsulfonyl-5-methylthiophene-3-carbonitrile oxide (Ia) [12] starting from the oximes of the corresponding substituted alkylmercapto-, methoxy-, or alkyl-sulfonyl-substituted aldehydes IIb-p. 4-Bromo-substituted aldehydes IIIi, j, ℓ were obtained in good yields by the action of N-bromo-succinimide (NBS) on the corresponding α,α'-disubstituted 3-formyl-thiophenes III (Y = H).



I—IV b X=OCH_3, Y=H, Z=SO_2CH_3; c X=Z=SO_2CH_3, Y=H; d X=Y=H, Z=$SO_2CH_2CH_3$; e X=Y=H, Z=$SO_2C(CH_3)_3$; f X=CH_3, Y=Br, Z=SO_2CH_3; g X=OCH_3, Y=Br, Z=$SOCH_3$; h X=Z=SO_2CH_3, Y=Br; i X=CH_3, Y=Br, Z=SCH_3; j X=OCH_3, Y=Br, Z=SCH_3; k X=Z=SCH_3, Y=Br; ℓ X=SCH_3, Y=Br, Z=OCH_3; m X=SO_2CH_3; Y=Br, Z=OCH_3; n X=Y=H, Z=SCH_2CH_3; i X=Z=SCH_3; Y=H; p X=OCH_3, Y=H, Z=SCH_3

All of the synthesized nitrile oxides were found to be stable (at 20°C) crystalline compounds with definite melting points (with decomposition). They were characterized by data from the IR, PMR, and mass spectra and the results of elementary analysis, as well as by obtaining cycloadducts with styrene (IVb-m) in high yields from them. We have previously noted the stabilities of thiophene-3-carbonitrile oxides that contain an alkylsulfonyl group in the adjacent α position and the instabilities of the 2-alkylthio derivatives [12].

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TABLE 1. Relative Rates of the Reaction of Nitrile Oxides (NO) Ia-ℓ with Styrene in CH_2Cl_2 at 20°C

Compound	Reagent ratio, moles		K_{rel}	K_{av}	Compound	Reagent ratio, moles		K_{rel}	K_{av}
	NO/ styrene	Standard/ NO				NO/ styrene	Standard/ NO		
Ia	1,1	12,5	28	26	Ih	1,5	15,4	134	135,5
	1,1	9,0	24			1,5	22,8	137	
Ic	1,3	17,0	54	57	Ii	2,0	5,0	35	34
	1,5	25,1	60			2,4	11,2	33	
Id	1,1	12,7	33	32	Ij	2,4	5,9	22	24
	1,5	7,0	31			1,6	11,2	26	
Ie	1,7	6,5	10	11,5	Ik	1,6	7,8	50	49
	1,5	10,4	13			1,7	16,3	48	
If	1,8	10,3	62	61	Iℓ	1,3	11,9	57	57
	1,7	5,1	60			2,1	7,0	57	

The relative reactivities of the nitrile oxides obtained in cycloaddition with styrene were studied by the method of competitive reactions decribed in [11]; mesitonitrile oxide was used as the standard. The ratios of the cycloadducts of the thiophene series and mesitonitrile oxide were determined by PMR spectroscopy by integration of the signals of the protons of the isoxazoline ring (4-H) with CH_2Br_2 as the internal standard. The yields of the cycloadducts based on the styrene used exceeded 98% in all cases (see Table 1).

The data obtained provide evidence that the presence of electron-acceptor groups (Br, SO_2R) in the thiophene ring of nitrile oxides I significantly increases their reactivity in the reaction with styrene as compared with the previously described alkyl-substituted nitrile oxides of the thiophene series [11]. If the range of K_{rel} for the latter is 1.2-8.2, K_{rel} in the case of nitrile oxides Ia-f, h-ℓ ranges from 11.5 to 135.5; the rate of cycloaddition increases with an increase in the electron-acceptor properties of the substituent in the position (CH_3 < H < SO_2CH_3). Whereas K_{rel} = 26 for Ia, K_{rel} is 57 for Ic. Replacement of the methyl group in If by a methylsulfonyl group (Ih) increases the rate of the process by a factor of more than two. The same regularity is also observed for nitrile oxides Ii-k, which contain a methylthio group in the 2 position – K_{ref} increases by a factor of ∿1.5 on passing from Ii to nitrile oxide Ik.

The effect of substituents in the ortho positions relative to the nitrile oxide group is determined by both electronic and steric factors. The appreciable (by a factor of 3) decrease in K_{rel} on replacement of the ethyl group in Id by the bulkier tert-butyl group in Ie constitutes evidence for the substantial "retarding" role of the steric effect of the substantial "retarding" role of the steric effect of the substituent. One might have supposed that the introduction of a bulky substituent – a bromine atom – into the 4 position of nitrile oxides Ia, c should decrease the rate of ring formation with styrene. On the other hand, the halogen atom, being an electron acceptor, may promote an increase in the tendency of these substances to undergo cycloaddition reactions. The observed acceleration of the reaction of tetrasubstituted nitrile oxides If, h by a factor of more than two as compared with the unsubstituted analogs (Ia, c) indicates the more significant contribution of the electron factor as compared with the steric factor. Let us note that in the case of 2,4,5-trimethylthiophene-3-carbonitrile oxide, which contains an electron-donor substituent of the same volume as Br in the 4 position (the van der Waals radii for CH_3 and Br are 2 and 1.95 Å, respectively) the reaction is slowed down by a factor of 2.4 as compared with 2,5-dimethylthiophene-3-carbon nitrile oxide [10]. These data also provide evidence in favor of the concept of the prevailing effect of the electronic factor of the substituent in the 4 position on the reactivities of nitrile oxides If-ℓ.

The higher rate of cycloaddition of sulfide Iℓ as compared with the isomeric Ij can be explained by the coinciding influence of both the steric and electronic effects of the substituent. The certain degree of slowing down of the reaction for Ik as compared with I (K_{rel} 57 and 49) may be associated with predominance of the steric effect of the substituent in the 2 position on passing from OCH_3 to SCH_3.

EXPERIMENTAL

The IR spectra were recorded with UR-20 and Specord IR-275 spectrometers. The PMR spectra were obtained with a Bruker WM-250 spectrometer. The molecular masses were determined with

TABLE 2. Characteristics of Bromo Aldehydes IIIi, j, ℓ and Oximes IIb-p

Compound	Empirical formula (M)	mp, °C*	IR spectrum,[2]* ν, cm^{-1}	PMR spectrum, δ, ppm[3]*	Mass spectrum, m/z (I, %)	Yield, %
IIIi	$C_7H_7BrOS_2$ (251,7)	123...125	1660 (C=O)	2,38 (3H, s, CH_3); 2,56 (3H, s, SCH_3); 9,9 (1H, s, CHO)	252/250 (100), 237/235 (50) 219/217 (83)	53
IIIj	$C_7H_7BrO_2S_2$ (267,2)	110...112	1660 (C=O)	2,58 (3H, s, SCH_3); 4,03 (3H, s, OCH_3); 9,92 (1H, s, CHO)	268/266 (77,5), 253/251 (100), 235/233 (8,1), 225/223 (17,8)	77
IIIℓ	$C_7H_7BrO_2S_2$ (267,2)	86...87	1660 (C=O)	2,33 (3H, s, SCH_3); 4,03 (3H, s, OCH_3); 9,82 (1H, s, CHO)	268/266 (100), 253/251 (81,3), 226/224 (12,5), 197/195 (18,8)	92
IIb	$C_7H_9NO_4S_2$ (235,3)	149...150	3575 (OH); 1325, 1145 (SO_2)	3,18 (3H, s, SO_2CH_3); 3,98 (3H, s, OCH_3); 6,64 (1H, s, 4-H); 7,62 (1H, s, OH); 8,68 (1H, s, CH=N)	235 (100), 218 (35,8), 205 (13,4), 172 (8,9), 156 (46,3), 139 (85)	81
IIc	$C_7H_9NO_5S_3$ (283,3)	225...228	3430 (OH); 1320, 1135 (SO_2)	3,42 and 3,48 (6H, s, 2-SO_2CH_3+5-SO_2CH_3); 8,05 (1H, s, 4-H); 8,56 (1H, s, CH=N); 11,27 (1H, s, OH)	283 (27,1), 266 (100), 253 (84,6), 204 (70,6), 191 (35,3)	84
IId	$C_7H_9NO_3S_2$ (219,3)	96...98	3580 (OH); 1320, 1140 (SO_2)	1,30 (3H, t, CH_3); 3,24 (2H, q, CH_2); 7,52 (1H, s, J=5,2 Hz, 4-H); 7,9 (1H, d, J=5,2 Hz 5-H); 8,60 (1H, s, CH=N)	219 (12,5), 202 (21,9), 189 (15,6), 174 (12,5), 156 (65,5), 126 (100)	82
IIe[4]*	$C_9H_{13}NO_3S_2$ (247,3)	147,5...149	3580 (OH); 1310, 1130 (SO_2)	1,40 (9H, s, $SO_2C(CH_3)_3$); 7,58 (1H, d, J=5,2 Hz, 4-H); 7,68 (1H, d, J=5,1 Hz, 5-H); 8,1 (1H, s, CH=N)	247 (39,6), 191 (85,6), 143 (68,7), 127 (100)	Quant.
IIf	$C_7H_8BrNO_3S_2$ (298,2)	202...204	3260 (OH); 1330, 1140 (SO_2)	2,50 (3H, s, CH_3); 3,39 (3H, s, SO_2CH_3); 8,30 (1H, s, CH=N); 11,19 (1H, s, OH)	299/297 (25), 281/279 (35), 268/266 (35), 220/218 (40), 149 (50), 139 (100)	62
IIg	$C_7H_8BrNO_3S_2$ (298,2)	152	1025 (SO)	2,93 (3H, s, $SOCH_3$); 3,83 (3H, s, OCH_3); 8,49 (1H, s, CH=N)	299/297 (23,8), 284/282 (100), 149 (47)	73
IIh	$C_7H_8BrNO_5S_3$ (362,3)	201...202	3390 (OH); 1335, 1135, 1150 (SO_2)	3,49 and 3,52 (6H, s, 2-SO_2CH_3+5-SO_2CH_3); 8,2 (1H, s, CH=N); 11,66 (1H, s, OH)	363/361 (11,4), 345/343 (57,9), 333/331 (100), 285/283 (38,7), 272/270 (29,6), 149/147 (9,1)	85

Table 2. (continued)

IIi	$C_7H_8BrNOS_2$ (266,2)	182...184	3320 (OH)	2,33 (3H, s, CH_3); 2,44 (3H, s, SCH_3); 8,03 (1H, s, OH); 8,32 (1H, s, CH=N)	267/265 (60), 234/232 (80), 154 (100), 149 (40)	95
IIj	$C_7H_8BrNO_2S_2$ (282,2)	139...141	3580 (OH)	2,45 (3H, s, SCH_3); 4,00 (3H, s, OCH_3); 8,40 (1H, s, CH=N); 9,08 (1H, s, OH)	283/281 (86,5), 268/266 (100), 251/249 (62,1), 236/234 (32,4)	99
IIk	$C_7H_8BrNOS_3$ (298,3)	121...122	3580 (OH)	2,42 and 2,55 (6H, s, 2-SCH_3+5-SCH_3); 8,12 (1H, s, CH=N); 8,65 (1H, s, OH)	299/297 (100), 266/264 (37,6) 252/250 (100)	89
IIℓ	$C_7H_8BrNO_2S_2$ (282,2)	187...189	3580 (OH)	2,40 (3H, s, SCH_3; 4,03 (3H, s, OCH_3); 8,15 (1H, s, CH=N); 9,32 (1H, s, OH)	283/281 (90,4), 268/266 (100), 251/249 (32,7), 236/234 (15,4)	92
IIm	$C_7H_8BrNO_4S_2$ (314,2)	177...178	3580 (OH)	3,46 (3H, s, SO_2CH_3); 3,82 (3H, s, OCH_3); 8,45 (1H, s, CH=N)	315/313 (62,2), 283/281 (100), 265/263 (13,5)	27
IIn	$C_7H_9NOS_2$ (187,2)	57...59	3580 (OH)	1,22 (3H, t, CH_3); 2,78 (2H, q, CH_2); 7,3...7,4 (2H, s, J=5,0 Hz, 4-H, 5-H); 8,32 (1H, s, CH=N)	187 (64), 170 (85,6), 155 (100), 142 (25), 141 (34,2)	62
IIo	$C_7H_9NOS_3$ (219,3)	80...82	3580 (OH)	2,47 and 2,51 (6H, s, 2-SCH_3+5-SCH_3); 7,27 (1H, s, 4-H); 8,12 (1H, s, OH); 8,33 (1H, s, CH=N)	219 (79,1), 204 (11,6), 187 (100) 186 (21), 172 (23,3)	95
IIp	$C_7H_9NO_2S_2$ (203,3)	86...87	3585 (OH)	2,40 (3H, s, SCH_3); 3,92 (3H, s, OCH_3); 6,44 (1H, s, 4-H); 8,44 (1H, s, CH=N)	203 (100), 188 (61,5), 171 (100) 170 (18), 156 (36), 149 (7,7)	94

[1]*The solvents used were as follows: alcoholfor IIf-h, j, k, m and IIIi, j, heptane for IIp and IIIℓ, chloroform for IIb, i, ℓ, benzene–hexane for IIn, o, benzene for IId, aqueous alcohol for IIe, and butanol for IIc. The decomposition temperature is presented for IIg.

[2]*The IR spectra for IIIi, j, ℓ and IIb, d, e, j-p were recorded from solutions in chloroform, while the IR spectra for IIc, f-i, m were recorded from KBr pellets.

[3]*The PMR spectra for IIIi, j, ℓ and IIb, e, i-k,ℓ, o, p, were recorded in $CDCl_3$, the PMR spectra of IIc, d, f, h,n were recorded in $(CD_3)_2CO$, and the PMR spectra of IIm, g were recorded in pyridine.

[4]*Compound IIe was obtained in our laboratory by O. O. Mamaeva.

TABLE 3. Characteristics of Nitrile Oxides Ib-m

Compound	Empirical formula (M)	mp,[1] °C*	IR spectrum (in $CHCl_3$), ν, cm^{-1}	PMR spectrum (in $CDCl_3$), δ, ppm	Mass spectrum, m/z (I, %)	Yield, %
Ib	$C_7H_7NO_4S_2$ (233,3)	110	2310 (C≡N); 1390 (NO); 1330, 1140 (SO_2)	3,22 (3H, s, SO_2CH_3); 4,00 (3H, s, OCH_3); 6,39 (1H, s, 4-H)	233 (98), 218 (32,6), 217 (37), 203 (43,5), 173 (26,1), 170 (41,3), 154 (80,5), 144 (100), 139 (63)	56
Ic	$C_7H_7NO_5S_3$ (281,2)	100	2335 (C≡N); 1370 (NO); 1330, 1140 (SO_2)	3,28 and 3,34 (6H, s, 2-SO_2CH_3+5-SO_2CH_3); 7,81 (1H, s, 4-H)	281 (100), 266 (24,2), 265 (45,1) 264 (50), 251 (98,1), 236 (42), 202 (72,5), 156 (72,5), 149 (67)	69
Id	$C_7H_7NO_3S_2$ (217,3)	65...67	2310 (C≡N); 1370 (NO); 1310, 1140 (SO_2)	1,40 (3H, t, J=7,2 and, CH_3); 3,32 (2H, q, J=7,2 Hz, CH_2); 7,32 (1H, d, J=5,2 Hz, 4-H); 7,77 (1H, d, J=5,2 Hz, 5-H)	217 (12,5), 201 (7,8), 187 (43,7), 159 (100), 131 (42,2), 109 (64)	68
Ie	$C_9H_{11}NO_3S_2$ (245,3)	106...108	2310 (C≡N); 1370 (NO); 1310, 1140 (SO_2)	1,47 (1H, s, SO_2CH_3); 7,31 (1H, d, J=5,2 Hz, 4-H); 7,8 (1H, d, J=5,2 Hz, 5-H)	245 (10), 159 (100), 149 (20)	72
If	$C_7H_6BrNO_3S_2$ (296,2)	113...115	2305 (C≡N); 1375 (NO); 1340, 1155 (SO_2)	2,53 (3H, s, CH_3); 3,25 (3H, s, SO_2CH_3)	297/295 (35,8), 282/280 (14,5), 281/279 (12,5), 267/265 (56), 252/250 (32,2), 234/232 (17,9), 218/216 (35,8), 142 (100), 128 (82)	98
Ig	$C_7H_6BrNO_3S_2$ (296,2)	91,5...92,0	2300 (C≡N); 1390 (NO); 1010 (SO)	2,98 (3H, s, $SOCH_3$); 4,10 (3H, s, OCH_3)	297/295 (10), 282/280 (35), 267 (95), 266 (40), 265 (82,5), 264 (32,6), 254 (100), 252 (45), 250 (25), 224/222 (25), 149 (20)	68
Ih	$C_7H_6BrNO_5S_3$ (360,2)	162...163	2300 (C≡N); 1345, 1150 (SO_2)	3,34 and 3,36 (6H, s, 2-SO_2CH_3+5-SO_2CH_3)	361/359 (56), 345/343 (16), 344/342 (17), 329/327 (80), 314/312 (20,9), 253/251 (27,9), 208/206 (100)	52
Ii	$C_7H_6BrNOS_2$ (264,2)	64,0...64,5	2310 (C≡N); 1375 (NO)	2,38 (3H, s, CH_3); 2,54 (3H, s, SCH_3)	265/263 (87), 250/248 (34), 249/247 (35), 232/230 (33), 168 (18,8), 154 (100)	80
Ij	$C_7H_6BrNO_2S_2$ (280,2)	73,0...74,5	2310 (C≡N); 1390 (NO)	2,49 (3H, s, SCH_3); 4,00 (3H, s, OCH_3)	281/279 (77), 266/264 (100), 249/247 (8), 237/235 (16)	98
Ik	$C_7H_6BrNOS_3$ (296,2)	71...72	2300 (C≡N); 1375 (NO)	2,49 and 2,59 (6H, s, 2-SCH_3+5-SCH_3)	297/295 (100), 282/280 (84), 266/264 (14,5), 252/250 (18,9), 171 (8,7)	98
Il	$C_7H_6BrNO_2S_2$ (280,2)	71...72	2315 (C≡N); 1400 (NO)	2,40 (3H, s, SCH_3); 4,04 (3H, s, OCH_3)	281/279 (75), 266/264 (100), 250/248 (18)	98
Im	$C_7H_6BrNO_4S_2$ (312,2)	114...115	2315 (C≡N); 1400 (NO); 1340, 1150 (SO_2)	3,26 (3H, s, SO_2CH_3); 4,13 (3H, s, OCH_3)	313/311 (100), 297/295 (14,5), 296/294 (10,9), 281/279 (9,1), 250/248 (20), 234 (18,2), 149 (18)	98

*Compounds Ib-e melted with decomposition.

TABLE 4. Characteristics of Cycloadducts IVb-m

Compound	Empirical formula (M)	mp,[1] °C	PMR spectrum ($CDCl_3$), δ, ppm (J, Hz)	Mass spectrum, m/z (I, %)	Yield, %
IVb	$C_{15}H_{15}NO_4S_2$ (337,4)	90...92	3,39 (3H, s, SO_2CH_3); 3,34 (1H, dd, 4'-H, J=17,8 and 8,9); 3,78 (1H, dd, 4'-H, J=17,8 and 11,9); 3,96 (3H, s, OCH_3); 5,77 (1H, dd, 5'-H, J=11,9 and 8,9); 6,37 (1H, s, 4'-H), 7,35...7,45 (5H, m, Ph)	337 (100), 260 (48,5), 258 (75,5), 241 (48,6) 230 (59,5), 226 (75,6)	93
IVc	$C_{15}H_{15}NO_5S_3$ (385,5)	178...180	3,26 and 3,55 (6H, s, 2-SO_2CH_3+5-SO_2CH_3); 3,37 (1H, dd, 4'-H, J=17,8 and 8,9); 3,82 (1H, dd, 4'-H, J=17,8 and 11,9); 5,85 (1H, dd, 5'-H, J=11,9 and 8,9); 7,35...7,45 (5H, m, Ph); 7,75 (1H, s, 4'-H)	385 (71,8), 384 (61,8), 370 (15,4), 308 (100)	94
IVd	$C_{15}H_{15}NO_3S_2$ (321,4)	Oil	1,36 (3H, t, CH_3, J=7,2); 3,40 (1H, dd, 4'-H, J=17,5 and 9,0); 3,60 (2H, q, CH_2, J=7,2); 3,83 (1H, dd, 4'-H, J=17,5 and 11,0) 5,79 (1H, dd, 5'-H, J=11,5 and 9,0) 7,25 (1H, d, 4-H, J=6,0); 7,35...7,45 (5H, m, Ph); 7,7 (1H, d, 5-H, J=6,0)	321 (83), 320 (70,7), 304 (7,7), 258 (9,3), 244 (100), 228 (21,6)	93
IVe	$C_{17}H_{19}NO_3S_2$ (349,5)	Oil	1,38 (9H, s, $SO_2C(CH_3)_3$); 3,55 (1H, d. d, 4'-H, J=17,7 and 9,2); 3,97 (1H, d. d, 4'-H, J=17,7 and 10,7); 5,78 (1H, dd, 5'-H, J=11,0 and 9,2); 7,37 (6H, m, 4-H+Ph); 7,75 (1H, dd, 5-H, J=5,2)	349 (7.7), 275 (7,7), 175 (100), 149 (20,5)	97
IVf	$C_{15}H_{14}BrNO_3S_2$ (400,3)	97...98	2,52 (3H, s, CH_3); 3,39 (3H, s, SO_2CH_3); 3,41 (1H, dd, 4'-H, J=17,2 and 10,0); 3,80 (1H, d d, 4'-H, J=17,2 and 11,2); 5,82 (1H, dd, 5'-H, J=11,2 and 10,0); 7,35...7,52 (5H, m, Ph)	401/399 (100), 400/398 (67,5), 385/383 (10,3), 351/349 (12,8), 324/322 (69,3)	95
IVg	$C_{15}H_{14}BrNO_3S_2$ (400,3)	121...122	3,03 (3H, and SOCH$_3$); 3,66 (1H, dd, 4'-H, J=17,1 and 10,5); 3,88 (1H, d. d, 4'-H, J=17,1 and 10,0); 4,08 (3H, s, OCH_3); 5,73 (1H, d d, 5'-H, J=10,5 and 10,0); 7,39...7,46 (5H, m, Ph)	401/399 (38), 386/384 (100), 370/368 (6), 166/164 (40), 149 (18)	94
IVh	$C_{15}H_{14}BrNO_5S_2$ (464,4)	184...186	3,36 and 3,46 (6H, s, 2-SO_2CH_3+5-SO_2CH_3); 3,42 (1H, dd, 4'-H, J=17,5 and 9,5); 3,82 (1H, dd, 4'-H, J=17,5 and 11,4); 5,87 (1H, d d, 5'-H, J=11,3 and 9,75); 7,37...7,52 (5H, m, Ph)	465/463 (100), 464/462 (81,3), 450/448 (25), 390/388 (87,5)	96
IVi	$C_{15}H_{14}BrNOS_2$ (368,3)	Oil	2,40 (3H, s, CH_3); 2,49 (3H, c, SCH_3); 3,43 (1H, d. d, 4'-H, J=17,6 and 8,8); 3,90 (1H, dd, 4'-H, J=17,6 and 11,6); 5,75 (1H, dd, 5'-H, J=11,7 and 8,8); 7,3...7,5 (5H, m, Ph)	369/367 (5,9), 249/247 (100), 234/232 (70,5), 168 (59), 153 (53), 149 (29,6)	95
IVj	$C_{15}H_{14}BrNO_2S_2$ (384,3)	75...77	2,46 (3H, s, SCH_3); 3,42 (1H, d d, 4'-H, J=17,2 and 8,0); 3,88 (1H, dd, 4'-H, J=17,2 and 11,0); 4,00 (3H, s, OCH_3); 5,76 (1H, dd, 5'-H, J=11,0 and 8,0); 7,32...7,49 (5H, m, Ph)	385/383 (100), 370/368 (40,3), 353 (27,8), 352 (22,2), 351 (25), 350 (19,4)	93
IVk	$C_{15}H_{14}BrNOS_3$ (400,4)	Oil	2,52 and 2,56 (6H, s, 2-SCH_3+5-SCH_3); 3,49 (1H, dd, 4'-H, J=17, and 8,2); 3,97 (1H, dd, 4'-H, J=17, and 11,0); 5,79 (1H, dd, 5'-H, J=10,7 and 9,2); 7,31...7,52 (5H, m, Ph)	401/399 (40), 288/286 (26,7), 281/279 (26,7), 149 (100)	92
IVℓ	$C_{15}H_{14}BrNO_2S_2$ (384,3)	Oil	2,38 (3H, s, SCH_3); 3,35 (1H, dd, 4'-H, J=17, and 8,2); 3,82 (1H, dd, 4'-H, J=17, and 11,0); 3,93 (3H, and OCH_3); 5,64 (1H, dd, 5'-H, J=11,0 and 8,5); 7,3...7,45 (5H, m, Ph)	385/383 (50), 369/367 (26,5), 268/266 (100), 265/263 (41,2), 253/251 (79,4), 250/248 (53), 149 (47)	93
IVm	$C_{15}H_{14}BrNO_4S_2$ (416,3)	137...139	3,30 (3H, s, SO_2CH_3); 3,34 (1H, dd, 4'-H, J=17,25 and 8,4); 3,80 (1H, dd, 4'-H, J=17,25 and 11,0); 4,05 (3H, s, OCH_3); 5,71 (1H, dd, 5'-H, J=11,0 and 8,4); 7,3...7,45 (5H, m, Ph)	417/415 (100), 401/399 (12,9), 387/385 (90,5), 313/311 (90,5), 227 (32,3), 184 (42)	93

*Compounds IVd, e, i, were washed with pentane. The solvents were methanol for IVb, f, g, j, m and butanol for IVc. Compounds IVk, ℓ were purified by TLC (silica gel L, 100/160), ether–hexane (1:1) as the eluent, Rf 0.5.

a Varian MAT CH-6 mass spectrometer at an ionizing voltage of 70 eV with direct introduction of the substances into the ion source. The constants, yields, and spectral data for the synthesized compounds are presented in Tables 2-4; the results of elementary analysis were correct.

2-Ethylthio-3-formylthiophene was obtained by the method in [13], 2,5-bis(methylthio)-4-bromo-3-formylthiophene was obtained by the method in [14], and oximes IIb-p, nitrile oxides Ib-e, and cycloadducts IVb-m were synthesized by the methods in [12].

Bromo Aldehydes IIIi, j, ℓ. A 1-0-mmole sample of N-bromosuccinimide was added to a solution of 10 mmole of 2-methylthio-5-methyl-, 5-methoxy-2-methylthio-, and 2-methoxy-5-methylthio-3-formylthiophene [15-17] in 20 ml of $CHCl_3$, after which the mixture was refluxed for 30 min, cooled, washed with water, and dried with $CaCl_2$. The solvent was removed by distillation, and the residue was recrystallized.

Synthesis of Nitrile Oxides If-m. A 2-mmole sample* of aqueous NaOCl solution (active Cl 14.5%, NaOH 4.5%)† was added to a suspension of 2 mmole of bromo oxime IIf-m in 10 ml of CH_2Cl_2 at 20°C, and the mixture was stirred vigorously until the solid had dissolved completely. The organic layer was then separated, washed with water, and dried, and the solvent was removed by distillation. Nitrile oxides Ib-h, j, ℓ, m were reprecipitated from benzene by means of pentane. Compounds Ii, k were recrystallized from methanol.

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*The amount was 6 mmole for Ii and 4 mmole for Iℓ.

†Neutral NaOCl was used for Ic and Ih.