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SYNTHESIS AND PROPERTIES OF 3-CYANO-3-HETARYL-YLIDENE-2-OXOPROPYL ETHANETHIOATES AND 4-CYANO-4-HETARYLYLIDENE-3-OXOBUTYL ETHANETHIOATES

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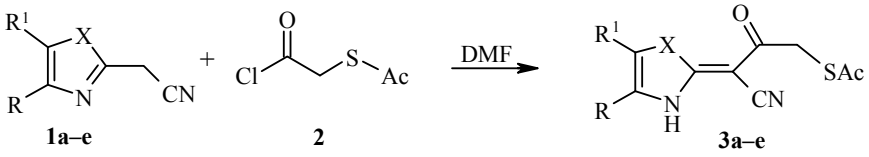
Acylation of hetarylacetonitriles and hetarylylideneacetonitriles with acetylmercaptoacetyl chloride gave 3-cyano-3-hetarylylidene-2-oxopropyl ethanethioates. 2-Amino-3-hetaryl-4(5H)oxothiophenes or 2-hetarylylidene-3-oxo-4-sulfanylbutanenitriles were obtained on treating them with bases. Acylation of hetarylacetonitriles with 3-acetylmercaptopropionyl chloride gave 4-cyano-4-hetaryl-ylidene-3-oxobutyl ethanethioates, deacetylation of which gave 2-hetarylylidene-3-oxo-5-sulfanyl-pentanenitriles.

Keywords: acetylmercaptoacetyl chloride, 3-acetylmercaptopropionyl chloride, 2-amino-3-hetaryl-4(5H)oxothiophene, 4-cyano-4-hetarylylidene-3-oxobutyl ethanethioates, 3-cyano-3-hetarylylidene-2-oxo-propyl ethanethioates, hetarylacetonitriles, hetarylideneacetonitriles, 2-hetarylylidene-3-oxo-4-sulfanyl-butanenitriles, 2-hetarylylidene-3-oxo-5-sulfanylpentanenitriles, lanthanide shift reagents, stereo-selective synthesis.

Previously we carried out the interaction of hetarylacetonitriles **1a**,**b** with acetylmercaptoacetyl chloride (**2**) and studied the spectroscopic properties of the 3-cyano-3-hetarylylidene-2-oxopropyl ethanethioates **3a**,**b** obtained. In the present work we have broadened the series acylated substrates; in the reactions we have involved hetarylacetonitriles **1c-e** (Scheme 1) and also hetarylideneacetonitriles **4a-f** (Table 1) obtained by alkylation of compounds **1a-c**,**f** with dialkyl sulfates with subsequent treatment with aqueous NaOH solution (Scheme 2). Compounds **4a**,**c**,**d** were previously obtained by a method described elsewhere [4-6].

Scheme 1



1–**3** **a**–**c** R + R^1 = CH=CH–CH=CH; **1**,**3** **a** X = NMe, **b** X = S, **c** X = $NCHF_2$;
d R + R^1 = CH=C(Me)–C(Me)=CH, X = NMe, **e** R = R^1 = H, X = NCH_2Ph

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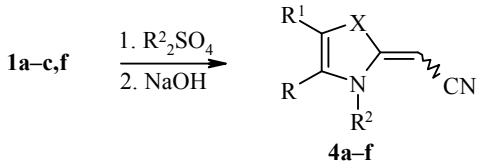
The electronegativity of the substituents on the nitrogen atoms and in the aromatic ring, and also the nature of the heteroatom in X affected the ratio of the (*Z*)- and (*E*)-isomers formed.

Scheme 2



4a–f

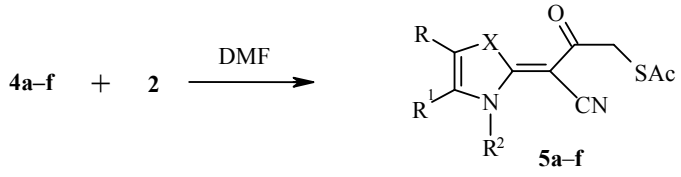
4 a–e R + R^1 = CH=CH–CH=CH, **a** R^2 = Me, X = NMe, **b** R^2 = Et, X = NMe, **c** R^2 = Me, X = S, **d** R^2 = Et, X = S, **e** R^2 = Me, X = $NCHF_2$; **1f**, **4f** R + R^1 = CH=C(Me)–CH=CH, X = NMe; **4f** R^2 = Me

The structures of the isomers and their ratios were determined by ^{1}H NMR spectra. Thus the products **4c**,**d** were formed exclusively as the (*Z*)-isomers in which the CN groups are in *trans* position relative to the NR^2 unit. From compound **1a** a symmetrical product **4a** is formed, while the remaining unsymmetrical nitrogen-containing hetarylylidene acetonitriles were isolated as mixtures: **4e** 1:1.67 (*E:Z*), **4b** 1:1.46 (*E:Z*), and **4f** 1:1.1 (*E:Z*), in which the isomers with the nitrile *trans* to the NR^2 predominated.

In the IR spectra of compounds **4a-f** intense absorption bands are present in the 2175-2150 cm^{-1} region, characteristic of a conjugated nitrile group [7], and also stretching bands of a conjugated C=C bond at 1600-1588 cm^{-1}. Sharp singlets of the proton of the =CHCN group were observed in the 3.53-4.15 ppm region in the ^{1}H NMR spectra, recorded in DMSO-d_6.

A single product, either the (*Z*)- or the (*E*)-isomer, **5a-f**, was obtained by acylation of compounds **4a-f** with the acyl chloride **2** (Scheme 3).

Scheme 3



5a–f

5a-f X = R-R^2, cf. compounds **4a-f** respectively (Scheme 2).

The configurations of 3-cyano-3-hetarylylidene-2-oxopropyl ethanethioates were established through ^{1}H NMR spectroscopy using lanthanide shift reagents (LSR).

Thus the use of $Eu(FOD)_3$* showed that in these compounds the CN group is in a *trans* position relative to the fragment X (cf. formulas **5a-f** in Scheme 3). The similarity in structure of compounds **5b**,**d** and **5c**,**f** respectively permits the supposition that the latter have similar configurations.

S-acyl derivatives of compounds **3a-e** and **5a**,**b**,**e**,**f** under influence of bases (alkalis, primary and secondary amines) undergo deacetylation and the mercaptonitriles formed undergo intramolecular cyclization.

In this way the corresponding substituted oxothiophenes **6a-e** were prepared from compounds **3a-e** (with the fragment N(3)H), and in the case of compounds **5a**,**b**,**e**,**f** (with the fragment N(3)R^2) the products of cyclization **7a-d** were isolated as salts.

* FOD is 2,3-dimethyl-6,6,7,7,8,8,8-heptafluoroocta-3,5-dione.

TABLE 1. Characteristics of Compounds Synthesized

Compound	Empirical formula	Found, % / Calculated, %		mp, °C*	Yield, %*[2]
		N	S		
3c	$C_{14}H_{11}F_2N_3O_2S$	12.97 / 13.00	10.02 / 9.92	206	80
3d	$C_{16}H_{17}N_3O_2S$	13.40 / 13.32	10.13 / 10.17	239-240	72
3e	$C_{16}H_{15}N_3O_2S$	13.30 / 13.41	10.22 / 10.23	143-145	30
4b	$C_{12}H_{13}N_3$	21.03 / 21.09	—	90-92	76
4e	$C_{11}H_9F_2N_3$	19.06 / 19.00	—	142-143	59
4f	$C_{12}H_{13}N_3$	20.98 / 21.09	—	158-160	80
5a	$C_{15}H_{15}N_3O_2S$	13.89 / 13.94	10.61 / 10.64	142	60 (72)
5b	$C_{16}H_{17}N_3O_2S$	13.31 / 13.32	10.06 / 10.17	144	80 (67)
5c	$C_{14}H_{12}N_2O_2S_2$	9.14 / 9.20	21.11 / 21.07	225	75 (70)
5d	$C_{15}H_{14}N_2O_2S_2$	8.73 / 8.80	20.10 / 20.14	184-185	79 (65)
5e	$C_{15}H_{13}F_2N_3O_2S$	12.40 / 12.46	9.58 / 9.50	154	78
5f	$C_{16}H_{17}N_3O_2S$	13.27 / 13.32	10.15 / 10.17	140-142	40
6c	$C_{12}H_9F_2N_3OS$	14.94 / 14.94	11.35 / 11.40	240-241 (dec.)	86
6d	$C_{14}H_{15}N_3OS$	15.31 / 15.37	11.80 / 11.73	>300	80
6e	$C_{14}H_{13}N_3OS$	15.54 / 15.49	11.70 / 11.82	122-124	65
7a	$C_{13}H_{14}ClN_3OS$	14.30 / 14.21	10.91 / 10.84	>300	85
7b	$C_{14}H_{16}ClN_3OS$	13.52 / 13.56	10.27 / 10.35	>300	75
7c	$C_{13}H_{12}ClF_2N_3OS$	12.59 / 12.67	9.60 / 9.66	245-246 (dec.)	42
7d	$C_{14}H_{16}ClN_3OS$	13.49 / 13.56	10.41 / 10.35	256-257 (dec.)	78
8a	$C_{12}H_{10}N_2OS_2$	10.60 / 10.68	24.37 / 24.44	180-182 (dec.)	75
8b	$C_{13}H_{12}N_2OS_2$	10.24 / 10.14	22.08 / 23.20	177	80
9	$C_{14}H_{14}N_2OS_2$	9.80 / 9.65	22.00 / 22.08	165-166	71
12a	$C_{15}H_{15}N_3O_2S$	13.99 / 13.94	10.57 / 10.64	201-202	60 (50)
12b	$C_{16}H_{14}N_2O_2S$	9.40 / 9.39	10.82 / 10.75	142	57 (52)
13a	$C_{13}H_{13}N_3OS$	16.24 / 16.20	12.48 / 12.36	198-199	82
13b	$C_{14}H_{12}N_2OS$	10.87 / 10.93	12.46 / 12.51	153	78

* Solvents for recrystallization: *n*-BuOH (compounds **3b**,**d**, **5d**, **6c**,**d**); 2-PrOH (compounds **3e**, **4b**,**e**,**f**, **5a**,**b**,**e**,**f**, **6e**, **8a**,**b**, **9**, **12a**,**b**, **13a**,**b**); HOAc (compound **5c**); aqueous 2-PrOH (compounds **7a-d**).

*[2] The yields in brackets are for samples obtained from compounds synthesized in this paper – acylation of compounds **8a**,**b** and **13a**,**b** and alkylation of compound **3a**.

TABLE 2. Spectral Characteristics of the Compounds Synthesized

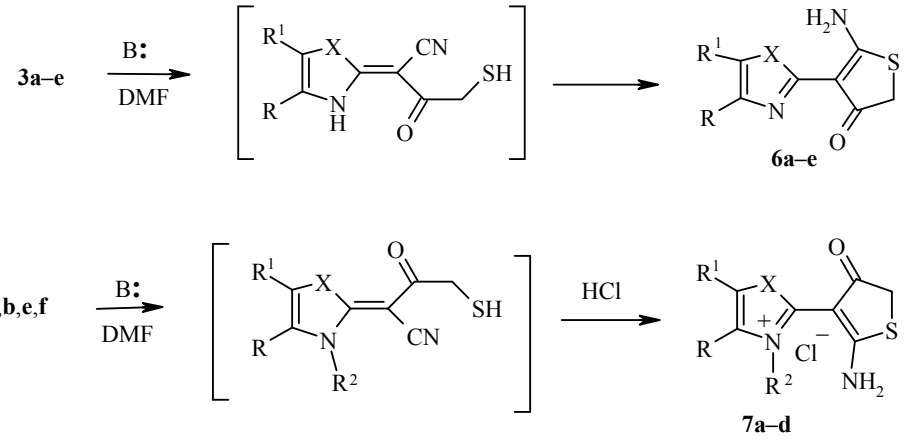
Com-pound*	IR cpectrum, ν, cm^{-1}	^1H NMR spectrum, δ, ppm (*J*, Hz)	Mass spectrum, *m/z* $[M+H]^+$
1	2	3	4
3c	3131.65 (N-H); 2196.07 (C≡N); 1683.91 $(C=O)_{SAc,}$ 1630.76 (C=O)	2.38 (3H, s, $COCH_3$); 4.09 (2H, s, CH_2); 7.34 (2H, m, H-5,6); 7.62 (1H, m, H-4); 7.72-7.74 (1H, m, H-7); 8.28 (1H, t, ^2J = 57.6, CHF_2); 13.63 (1H, br. s, NH)	324.0
3d	3187.67 (N-H); 2190.47 (C≡N); 1700.69 $(C=O)_{SAc,}$ 1586.01 (C=O)	2.32 (3H, s, 6-CH_3); 2.35 (3H, s, 5-CH_3); 2.37 (3H, s, $COCH_3$); 3.93 (3H, s, NCH_3); 4.04 (2H, s, CH_2); 7.32 (1H, s, H-7); 7.37 (1H, s, H-4); 13.08 (1H, s, NH)	316.0
3e	3215.68 (N-H); 2179.27 (C≡N); 1692.30 $(C=O)_{SAc,}$ 1580.41 (C=O)	2.33 (3H, s, $COCH_3$); 3.94 (2H, s, CH_2); 5.49 (2H, s, NCH_2); 7.08-7.37 (7H, m, C_6H_5, H-4,5); 13.05 (1H, br. s, NH)	314.0
4b	2150.61 (C≡N)	(*E*)-Isomer 1.13 (3H, t, *J* = 6.8, $CH_2C\underline{H}_3$); 3.62 (1H, s, CHCN); 3.69 (3H, s, NCH_3); 3.84 (2H, q, *J* = 6.8, NCH_2); 7.05 (2H, m, H-4,7); 7.17 (2H, m, H-5,6)	200.0
	2173.66 (C≡N)	(*Z*)-Isomer 1.29 (3H, t, *J* = 6.8, $CH_2C\underline{H}_3$); 3.28 (3H, s, NCH_3); 3.53 (1H, s, CHCN); 4.25 (2H, q, *J* = 6.8, NCH_2); 7.05 (2H, m, H-4,7); 7.17 (2H, m, H-5,6)	
4e	2156.24 (C≡N)	(*E*)-Isomer 3.32 (3H, s, NCH_3); 3.88 (1H, s, CHCN); 7.05 (1H, m, H-4); 7.17 (2H, m, H-5,6); 7.31 (1H, m, H-7); 8.03 (1H, t, ^2J =58.0, CHF_2)	222.0
	2173.66 (C≡N)	(*Z*)-Isomer 3.73 (3H, s, NCH_3); 4.15 (1H, s, CHCN); 7.05 (1H, m, H-4); 7.17 (2H, m, H-5,6); 7.31 (1H, m, H-7); 7.72 (1H, t, ^2J =57.2, CHF_2)	
4f	2151.26 (C≡N)	2.36 (3H, s, 5-CH_3); 3.26 (3H, s, N(3)CH_3); 3.34 (1H, s, CHCN); 3.69 (3H, s, N(1)CH_3); 6.81 (1H, d, *J* = 8.0, H-4); 6.92 (2H, m, H-6,7)	200.4
5a	2173.66 (C≡N); 1683.91 $(C=O)_{SAc,}$ 1602.79 (C=O)	2.37 (3H, s, $COCH_3$); 3.75 (6H, s, NCH_3); 4.00 (2H, s, CH_2); 7.45 (2H, m, H-4,7); 7.71 (2H, m, H-5,6)	302.0
5b	2173.66 (C≡N); 1686.71 $(C=O)_{SAc,}$ 1602.79 (C=O)	1.45 (3H, t, *J* = 6.8, $CH_2C\underline{H}_3$); 2.37 (3H, s, $COCH_3$); 3.70 (3H, s, NCH_3); 3.99 (2H, s, $COCH_2$); 4.42 (2H, q, *J* = 6.8, $C\underline{H}_2CH_3$); 7.48 (2H, m, H-4,7); 7.78 (2H, m, H-5,6)	316.0
5c	2184.87 (C≡N); 1695.10 $(C=O)_{SAc,}$ 1613.98 (C=O)	2.39 (3H, s, $COCH_3$); 4.15 (2H, s, CH_2); 4.19 (3H, s, NCH_3); 7.40 (1H, t, *J* = 8.0, H-5); 7.56 (1H, t, *J* = 8.0, H-6); 7.72 (1H, d, *J* = 8.0, H-4); 7.91 (1H, d, *J* = 8.0, H-7)	305.2
5d	2190.47 (C≡N); 1681.11 $(C=O)_{SAc,}$ 1613.98 (C=O)	1.54 (3H, t, *J* = 7.2, $CH_2C\underline{H}_3$); 2.39 (3H, s, $COCH_3$); 4.16 (2H, s, CH_2); 4.81 (2H, q, *J* = 7.2, $C\underline{H}_2CH_3$); 7.39 (1H, t, *J* = 8.0, H-5); 7.55 (1H, t, *J* = 8.0, H-6); 7.74 (1H, d, *J* = 8.0, H-4); 7.91 (1H, d, *J* = 8.0, H-7)	318.8
5e	2184.87 (C≡N); 1695.10 $(C=O)_{SAc,}$ 1605.59 (C=O)	2.37 (3H, s, $COCH_3$); 3.85 (3H, s, NCH_3); 4.04 (2H, s, CH_2); 7.51-7.54 (2H, m, H-5,6); 7.56 (1H, t, ^2J = 56.5, CHF_2); 7.74 (1H, d, *J* = 7.6, H-4); 7.83 (1H, d, *J* = 7.4, H-7)	338.0
5f	2168.06 (C≡N); 1686.71 $(C=O)_{SAc,}$ 1602.79 (C=O)	2.37 (3H, s, $COCH_3$); 2.5 (3H, s, 5-CH_3); 3.72 (3H, s, N(3)CH_3); 3.73 (3H, s, N(1)CH_3); 3.99 (2H, s, CH_2); 7.27 (1H, d, *J* = 8.0, H-6); 7.53 (1H, s, H-4); 7.60 (1H, d, *J* = 8.0, H-7)	316.0
6c	3187.67 $(N-H)_{as,}$ 3058.82 $(N-H)_{sim,}$ 1588.81 (C=O)	3.79 (2H, s, CH_2); 7.27-7.30 (2H, m, H-5,6); 7.61-7.67 (2H, m, H-4,7); 7.95 (1H, t, ^2J = 58.0, CHF_2); 9.31 (1H, br. s, NH); 9.49 (1H, br. s, NH)	282.0

TABLE 2 (continued)

1	2	3	4
6d	3327.73 (N-H)$_{as,}$ 3254.90 (N-H)$_{sim,}$ 1611.18 (C=O)	2.32 (3H, s, 6-CH_3); 2.36 (3H, s, 5-CH_3); 3.69 (5H, s, NCH_3, CH_2); 7.14 (1H, s, H-7); 7.28 (1H, s, H-4); 8.98 (2H, br. s, NH_2)	274.2
6e	3372.54 (N-H)$_{as,}$ 3249.29 (N-H)$_{sim,}$ 1611.18 (C=O)	3.61 (2H, s, SCH_2); 5.31 (2H, s, NCH_2); 6.95-7.04 (4H, m, 4,5-H, $CH_2C_6\underline{H}_5$-3,5); 7.20-7.25 (3H, m, $CH_2C_6\underline{H}_5$-2,4,6); 8.55 (1H, br. s, NH); 8.72 (1H, br. s, NH)	272.2
7a	3512.60 (N-H)$_{as,}$ 3260.50 (N-H)$_{sim,}$ 1622.37 (C=O)	3.90 (6H, s, $2NCH_3$); 3.96 (2H, s, CH_2); 7.66 (2H, m, *J* = 3.2, H-4,7); 7.99 (2H, m, *J* = 3.2, H-5,6)	260.0
7b	3422.96 (N-H)$_{as,}$ 3109.24 (N-H)$_{sim,}$ 1641.95 (C=O)	1.42 (3H, t, *J* = 6.8, $NCH_2C\underline{H}_3$); 3.86 (3H, s, NCH_3); 3.92 (2H, s, SCH_2); 4.42 (2H, m, NCH_2); 7.63 (2H, m, H-4,7); 8.01 (2H, m, H-5,6); 9.59 (1H, s, NH); 9.77 (1H, s, NH)	274.0
7c	3428.57 (N-H)$_{as,}$ 3126.05 (N-H)$_{sim,}$ 1630.76 (C=O)	3.95 (3H, s, NCH_3); 3.96 (2H, s, CH_2); 7.74 (2H, m, H-4,7); 7.89 (1H, t, ^2J = 55.6, CHF_2); 7.96 (1H, m, H-5); 8.09 (1H, m, H-6); 9.76 (1H, s, NH); 9.98 (1H, s, NH)	296.0
7d	3434.17 (N-H)$_{as,}$ 3204.48 (N-H)$_{cum,}$ 1639.16 (C=O)	2.58 (3H, s, 5-CH_3); 3.82 (3H, s, N(3)CH_3); 3.83 (3H, s, N(1)CH_3); 3.93 (2H, s, CH_2); 7.45 (1H, d, *J* = 8.0, H-6); 7.76 (1H, s, H-4); 7.83 (1H, d, *J* = 8.0, H-7); 9.38 (1H, s, NH); 9.61 (1H, br. s, NH)	274.13
8a	2565.82 (S-H); 2190.47 (C≡N); 1616.78 (C=O)	2.55 (1H, t, *J* = 8.0, SH); 3.65 (2H, d, *J* = 8.0, CH_2S); 4.20 (3H, s, NCH_3); 7.40 (1H, t, *J* = 8.0, H-5); 7.55 (1H, t, *J* = 8.0, H-6); 7.73 (1H, d, *J* = 8.0, H-4); 7.93 (1H, d, *J* = 8.0, H-7)	263.0
8b	2565.82 (S-H); 2196.07 (C≡N); 1630.76 (C=O)	1.53 (3H, t, *J* = 7.2, $CH_2C\underline{H}_3$); 2.59 (1H, t, *J* = 8.0, SH); 3.65 (2H, d, *J* = 8.0, CH_2S); 4.80 (2H, q, *J* = 7.2, $NC\underline{H}_2CH_3$); 7.40 (1H, t, *J* = 8.0, H-5); 7.56 (1H, t, *J* = 8.0, H-6); 7.75 (1H, d, *J* = 8.0, H-4); 7.93 (1H, d, *J* = 8.0, H-7)	277.5
9	2184.87 (C≡N); 1616.78 (C=O)	1.25 (3H, t, *J* = 7.2, $CH_2C\underline{H}_3$); 2.59 (2H, q, *J* = 7.2, $C\underline{H}_2CH_3$); 3.55 (2H, s, CH_2S); 4.17 (3H, s, NCH_3); 7.37 (1H, t, *J* = 8.0, H-5); 7.53 (1H, t, *J* = 8.0, H-6); 7.69 (1H, d, *J* = 8.0, H-4); 7.88 (1H, d, *J* = 8.0, H-7)	291.2
12a	3193.27 (N-H); 2190.47 (C≡N); 1686.71 (C=O)$_{SAc,}$ 1591.60 (C=O)	2.31 (3H, s, $COCH_3$); 2.91 (2H, t, *J* = 6.8, CH_2S); 3.13 (2H, t, *J* = 6.8, $COCH_2$); 3.96 (3H, s, NCH_3); 7.26 (2H, m, H-5,6); 7.51 (1H, d, *J* = 8.0, H-7); 7.66 (1H, d, *J* = 8.0, H-4), 13.32 (1H, br. s, NH)	302.2
12b	3434.17 (N-H); 2190.47 (C≡N); 1683.91 (C=O)$_{SAc,}$ 1633.56 (C=O)	2.32 (3H, s, $COCH_3$); 2.97 (2H, t, *J* = 6.8, CH_2S); 3.14 (2H, t, *J* = 6.8, $COCH_2$); 7.32 (1H, d, *J* = 9.2, H-3); 7.50 (1H, t, *J* = 7.6, H-6); 7.76 (1H, t, *J* = 7.6, H-7); 7.87 (1H, d, *J* = 7.6, H-8); 7.89 (1H, d, *J* = 7.6, H-5); 8.37 (1H, d, *J* = 9.2, H-4); 15.50 (1H, br. s, NH)	299.2
13a	2560.22 (S-H); 2179.27 (C≡N); 1597.20 (C=O)	2.02 (1H, t, *J* = 8.0, SH); 2.76 (2H, q, *J* = 8.0, CH_2S); 2.94 (2H, t, *J* = 8.0, $COCH_2$); 3.98 (3H, s, NCH_3); 7.23 (2H, m, H-5,6); 7.52 (1H, d, *J* = 8.0, H-7); 7.66 (1H, d, *J* = 8.0, H-4); 13.38 (1H, br. s, NH)	260.0
13b	2521.00 (S-H); 2196.07 (C≡N); 1630.76 (C=O)	2.11 (1H, t, *J* = 8.0, SH); 2.82 (2H, q, *J* = 8.0, CH_2S); 3.14 (2H, t, *J* = 8.0, $COCH_2$); 7.32 (1H, d, *J* = 9.2, H-3); 7.50 (1H, t, *J* = 7.6, H-6); 7.76 (1H, t, *J* = 7.6, H-7); 7.87 (1H, d, *J* = 7.6, H-8); 7.89 (1H, d, *J* = 7.6, H-5); 8.37 (1H, d, *J* = 9.2, H-4); 15.59 (1H, br. s, NH)	257.2

* Compounds **4b**,**e**,**f** were isolated as mixtures of (*Z*)- and (*E*)-isomers.
*[2] Molecular ions have the form $[M+H]^+$ (for compounds **3c-e**, **4b**,**f**,**e**, **5a-f**, **6c-e**, **8a**,**b**, **9**, **12a**,**b**, **13a**,**b**) and $[M-Cl]^+$ (for compounds **7a-d**).

Scheme 4

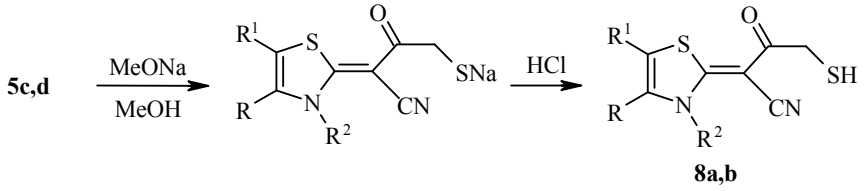


6a–e R, R^1, X cf. compounds **3a–e** (Scheme 1).
7 a–c R + R^1 = CH=CH–CH=CH, **a** R^2 = Me, X = NMe, **b** R^2 = Et, X = NMe, **c** R^2 = Me, X = $NCHF_2$; **d** R + R^1 = CH=C(Me)–CH=CH, R^2 = Me, X = NMe

We had prepared compounds **6a** and **6b** previously [2, 3].

Deacetylation of compounds **5c**,**d**, in contrast to compound **3c**, was not accompanied by cyclization. On acidification of the basic solutions 2-hetarylylidene-3-oxo-4-sulfanylbutanenitriles **8a**,**b** were isolated (Scheme 5).

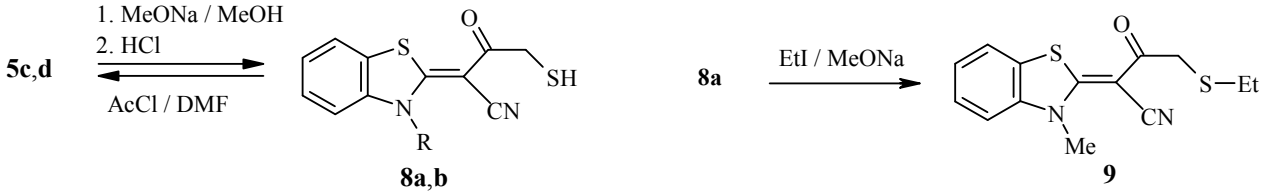
Scheme 5



8a,**b** R + R^1 = CH=CH–CH=CH, **a** R^2 = Me, **b** R^2 = Et

These differences are apparently determined by the different spatial dispositions of the CN and SH groups in the initially formed thiols, which are determined by the nature of the fragment X and the substituent at the atom N(3). For example with X = NMe or $NCHF_2$ (in the thiols from compounds **5a**,**b**,e,**f**) this position is favorable for cyclization, whereas with X = S (in the thiols from compounds **5c**,**d**) it is unfavorable. The ease of formation of the cyclic products **6a-e** from compounds **3a-e** with the fragment N(3)H (and with X= S in compound **3b**) shows the decisive influence of this fragment for cyclization, probably because of the production of a intramolecular hydrogen bond between it and the C=O group, which is possible with the *cis* position of the CN fragment relative to the X fragment.

Scheme 6

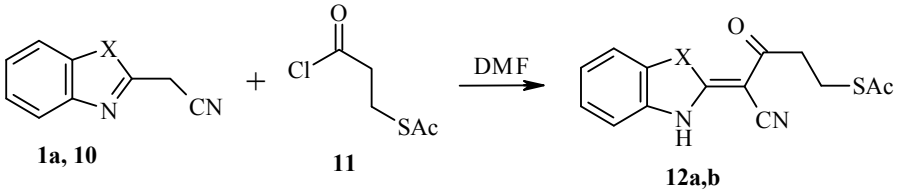


The structures of compounds **8a**,**b** were confirmed from their spectral characteristics (Table 2). In their ^{1}H NMR spectra are signals of protons of the CH_2 group of the thioglycolic group (doublet at 3.65 ppm) and the proton of the SH group (triplet at 2.55-2.60 ppm). In the IR spectra there are weak stretching vibrations of the SH group at 2565 cm^{-1}. Also treatment of compounds with acetyl chloride gave acyl derivatives **5c**,**d**, and treatment of the thiol **8a** with ethyl iodide gave the product of alkylation, **9**.

Compound **3a** is capable of alkylation at the NH group with alkyl halides (MeI, EtI) in DMF in the presence of K_2CO_3 to give compounds **5a**,**b** respectively.

Interaction of the hetarylacetonitriles **1a** and **10** with 3-acetylmercaptopropionyl chloride **11** gave the 4-cyano- 4-hetarylylidene-3-oxobutyl ethanethioates **12a**,**b** (Scheme 7).

Scheme 7

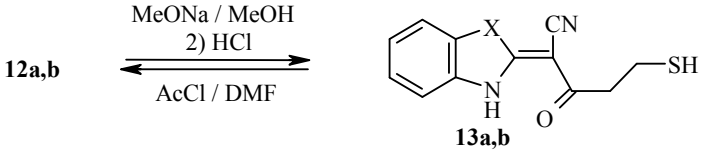


1a, **12 a** X = NMe; **10**, **12 b** X = CH=CH

Like 3-cyano-3-hetarylylidene-2-oxopropyl ethanethioates **3a-e**, compounds **12a**,**b** exist in tautomeric forms with intramolecular hydrogen bonding between the NH fragment of the heterocycle and the conjugated carbonyl group of the acyl fragment CH_2COCH_2.

As in the case of compounds **5c**,**d**, deacetylation of compounds **12a**,**b** is not accompanied by cyclization, but 2-hetarylylidene-3-oxo-5-sulfanylpentanenitriles **13a**,**b** are formed (Scheme 8). The ^{1}H NMR spectra of compounds **13a**,**b**, like those of compounds **8a**,**b**, contain the characteristic signal of the SH proton (a triplet in the 2.0-2.1 ppm range), and a weak stretching band of the SH group is observed at 2560 cm^{-1} in the IR spectra. Completely analogously, treatment of the mercapto derivatives **13a**,**b** with acetyl chloride in DMF leads to acetylation of the sulfhydryl group, regenerating the initial structures of compounds **12a**,**b.**

Scheme 8.



13 a X = NMe, **b** X = CH=CH

Thus increasing the hydrocarbon chain of the acylating agent with a protected mercapto group in the end leads to the impossibility of intramolecular cyclization of the thiols produced.

EXPERIMENTAL

Monitoring of the course of experiments and of the purity of the compounds synthesized was carried out by TLC on Silufol UV-254 plates with 9:1 chloroform–methanol. ^{1}H NMR spectra of DMSO-d_6 solutions with TMS as internal standard were measured with a Varian Mercury 400 (400 MHz) instrument. IR spectra of KBr

tablets were obtained with a Perkin-Elmer BX instrument, mass spectra were observed with an Agilent 1100 Series instrument with and Agilent LC/MSD SL detector. Melting points were measured with a small laboratory Boetius heating plate with a VEB Analytic PNMK 05 observation device.

3-Cyano-3-hetarylylidene-2-oxopropyl Ethanethioates 3a-e, 5a-f, and 4-Cyano-4-hetarylylidene-3-oxobutyl Ethanethioates 12a,b (General Method). Acetylmercaptoacetyl chloride **2** (5.5 mmol) or 3-acetoxymercaptopropionyl chloride **11** (5.5 mmol) was added to a solution of hetarylacetonitrile **1a-e**, **10**, or hetarylylideneacetonitrile **4a-f** (5 mmol) in DMF (5 ml) at 25°C. The reaction mixture was kept at room temperature for 12 h, then the precipitate was filtered off, washed with water, dried and recrystallized from a suitable solvent (Table 1).

Hetarylylideneacetonitriles 4a-f (General Method). A mixture of hetarylacetonitrile **1a-c**, **f** (10 mmol) and the corresponding dialkyl sulfate (11 mmol) was stirred for 40 min at 70°C. Then the reaction mixture was poured into water (10 ml) and a solution of NaOH (25 mmol) in water (20 ml) was added with stirring. The precipitate formed was filtered off, washed with cold water, dried and recrystallized.

2-Amino-3-hetaryl-4(5H)-oxothiophenes 6a-c (General Method). Aqueous ammonia (10 mmol) was added to a solution of compound **3a-e** (5 mmol) in DMF (5 ml) and the mixture was kept at 30-40°C for 24 h. The precipitate was filtered off, washed with water, dried, and recrystallized.

2-Amino-4(5H)-oxothiophenehetaren-3-ium Chlorides 7a-d (General Method). An aqueous solution of NaOH (10 mmol) in water (2 ml) was added to a solution of compound **5a**,**b**,**e**,**f** (5 mmol) in DMF (10 ml) and kept at 30-40°C for 24 h. Aqueous HCl was added until the mixture was slightly acidic, evaporated, and the residue was recrystallized.

2-(3-Alkyl-2,3-dihydro-1,3-benzothiazol-2-ylidene)-3-oxo-4-sulfanylbutanenitriles 8a,**b and 2-Hetarylylidene-3-oxo-5-sulfanylpentanenitriles 13a,b (General Method)**. MeONa (10 mmol) in MeOH (10 ml) was added with stirring at 60°C to a suspension of **6e**,**f** or **12a**,**b** (5 mmol) in MeOH (15 ml). After the reaction mixture had become homogeneous, aqueous HCl was added to an acid reaction, the precipitate was filtered off, washed with water, dried, and recrystallized.

2-(3-Methyl-2,3-dihydro-1,3-benzothiazol-2-ylidene)-3-oxo-4-ethylsulfanylbutanenitrile (9). MeONa (10 mmol) in MeOH (10 ml) was added with stirring at 60°C to a suspension of compound **8a** (5 mmol) in MeOH (15 ml). After the reaction mixture was completely homogenized and cooled, ethyl iodide (10 mmol) was added with stirring. Product **9** precipitated over 8 h, was filtered off, washed with methanol, dried and recrystallized.

Acylation of 2-(3-Alkyl-2,3-dihydro-1,3-benzothiazol-2-ylidene)-3-oxo-4-sulfanylbutanenitriles 8a,b and 2-Hetarylylidene-3-oxo-5-sulfanylpentanenitriles 13a,b (General Method). AcCl (5.5 mmol) was added to a solution of nitrile **8a**,**b** or **13a**,**b** (5 mmol) in DMF (5 ml). The reaction mixture was kept for 12 h at room temperature, the precipitate was filtered off, washed with water, dried and recrystallized. Compounds **5c**,**d** or **12a**,**b** obtained respectively were identical with samples synthesized as described above. No depression of the melting point was observed with mixed samples.

Alkylation of 3-Cyano-3-(1-methyl-2,3-dihydro-1H-benzoimidazol-2-ylidene)-2-oxopropyl Ethanethioate 3a (General Method). Finely dispersed K_2CO_3 (20 mmol) and the corresponding alkyl iodide (10 mmol) were added to a solution of compound **3a** (5 mmol) in DMF (20 ml). The reaction mixture was stirred for 12 h at a temperature of 50°C, cooled to room temperature, filtered, the filtrate evaporated, and the residue was recrystallized. The compounds **5a**,**b** obtained were identical to samples synthesized as described above. No depressions of mixed melting points were observed.

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