FORMATION OF THIENOTHIOPHENES IN THE HIGH TEMPERATURE REACTION OF 2-CHLOROTHIOPHENE WITH COMPOUNDS CONTAINING THE C_2H_5S GROUP*

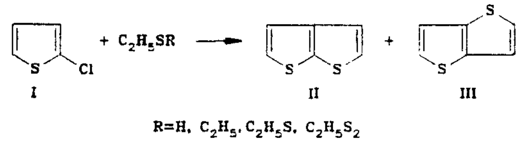
N. A. Korchevin, É. N. Sukhomoazova,
L. P. Turchaninova, G. G. Efremova,
N. A. Kalinina, É. N. Deryagina, and
M. G. Voronkov

UDC 547.737.07:542.915:541.124

The high temperature gas-phase reaction of 2-chlorothiophene with a mixture of diethyl disulfide and diethyl trisulfide constitutes a simple one-step synthesis of a 4:1 mixture of thieno[2,3-b]- and thieno[3,2-b]-thiophenes. Their total yield depends on the nature of the donor of the ethylthio group.

Thienothiophenes are formed in low yield in the cyclization of aliphatic sulfur compounds and difficultly available thiophenic thiols or sulfides [2, 3]. Therefore the search for new synthetic routes to these compounds, especially those based on easily availabe raw material, remains quite timely.

We have shown that in the high-temperature reaction of 2-chlorothiopene (I) with such easily available organic sulfur compounds as ethanethio,l, and diethyl sulfide, disulfide, and trisulfide, a 4:1 mixture of thieno[2,3-b]- and thieno[5,3-b]thiphene (II and (II) forms.

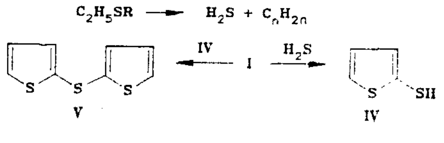


(1)

Their total yield is significantly dependent on the nature of the ethylthio donor, the proportions of starting reagents, and the temperature (Table 1).

At the optimal temperature of 560°C the best sulfur reagents in the reaction with chloride I are diethyl trisulfide and a mixture thereof with diethyl disulfide. The total yields of thienothiophenes II and III are 17-22% and 26-33%, respectively. An increase in their yields is favored by an excess of di- and trisulfide mixture and by an increase in reagent contact time.

Along with the thienothiophenes, in all cases thiophene is formed, along with 2-thiophenethiol (IV) and bis(2-thienyl) sulfide (V); these are products of the gas-phase thylation of 2-chlorothiophene (I) by hydrogen sulfide [4] that is formed in the thermal decomposition of the ethylthio derivatives [5]. Compounds IV and V are the main products of the reaction of 2-chlorothiophene with ethanethiol and diethyl sulfide and disulfide, but here the yield of thienothiophenes does not exceed 3-12%.



(2)

---

*Communication 30 of the series "High temperature organic synthesis." For Communication 29, see [1].

Irkutsk Institute of Organic Chemistry, Siberian Branch, Academy of Sciences of the USSR, Irkutsk 664033. Translated from Khimiya Geterotsiklicheskikh Soedinenii, No. 8, pp. 1041-1044, August, 1988. Original article submitted February 26, 1987; revision submitted September 7, 1987.

0009-3122/88/2408-0857$12.50

TABLE 1. Reaction of 2-Chlorothiophene (I) with Ethylthio Compounds C_2H_5SR (T = 560°C, contact time, 60 sec)

Test no.	R	Molar ratio of chloride I to sulfur reagent	Conversion of chloride I, %	Yield of reaction product based on reacted chloride I, % (GLC data)			
				thiophene	thienothiophenes II + III	thiol IV	sulfide V
1	H	1 : 1,3	84,6	Trace	3,9	21,9	60,8
2	H	1 : 2,6	88,7	3,0	6,6	27,5	52,0
3	C_2H_5	1 : 1,3	36,6	18,2	2,3	17,3	53,0
4	C_2H_5	1 : 2,6	63,0	22,0	7,6	21,7	43,0
5	SC_2H_5	1 : 1,3	87,0	5,1	9,9	28,8	42,0
6	SC_2H_5	1 : 2	88,6	14,5	12,1	33,7	21,4
7	$S_2C_2H_5$	1 : 1,3	97,3	15,7	17,5	29,4	24,4
8	$S_2C_2H_5$	1 : 2	97,9	18,4	22,0	37,7	13,5
9	$SC_2H_5—S_2C_2H_5$, 1 : 1	1 : 1,6	97,0	17,4	26,3	33,0	29,2
10	$SC_2H_5—S_2C_2H_5$, 1 : 3	1 : 1,3	97,6	19,4	30,0	28,3	30,5
11	$SC_2H_5—S_2C_2H_5$, 1 : 1	1 : 0,7	95,8	16,0	18,7	27,9	42,1
12*	$SC_2H_5—S_2C_2H_5$, 1 : 1	1 : 1,3	98,6	18,2	32,8	22,2	34,0
13**	$SC_2H_5—S_2C_2H_5$, 1 : 1	1 : 1,3	96,2	19,1	26,2	30,1	33,6
14***	$SC_2H_5—S_2C_2H_5$, 1 : 3	1 : 1,3	95,2	13,4	18,9	31,0	41,4

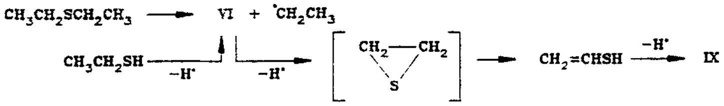
---

*Contact time 80 sec.
**Contact time 40 sec.
***Temperature 540°C.

At 560°C along with compounds IV and V, 3-thiophenethiol and 2,3-dithienyl sulfide are formed by the mechanisms previously discussed in detail [6]. Thiophene is the product of the thermal reduction of IV and V [6], as well as of the thermal decomposition of the starting ethylthio derivatives [7, 8]. This is evidenced by the lack of agreement material balance between the consumption of 2-chlorothiophene and the formation of products (over 100%) when an excess of disulfide—trisulfide mixture is used. Furthermore, it has been shown [7, 8] that the reaction of chlorobenzene with diethyl sulfide and disulfide at 600-650°C gives benzothiophene in low yield (3-10%). Benzothiophene results from the reaction of chlorobenzene with vinylthiyl radicals, which are converted concurrently to thiophene. Analogously, 2-chlorothiophene is apparently an even more efficient trap for vinylthiyl radicals, when the latter are generated by thermal decomposition of organic compounds containing the C_2H_5S group, by the general mechanism (3):

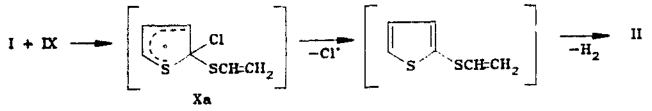
$$\begin{gathered}
CH_3CH_2SSCH_2CH_3 \rightarrow \underset{VI}{2CH_3CH_2S^{\cdot}} \\
CH_3CH_2SSSCH_2CH_3 \rightarrow VI + \underset{VII}{{}^{\cdot}SSCH_2CH_3} \\
VI + CH_3CH_2SSCH_2CH_3 \rightarrow CH_3CH_2SH + CH_3\dot{C}HSSCH_2CH_3 \\
VI + CH_3CH_2SSSCH_2CH_3 \rightarrow CH_3CH_2SH + \underset{VIII}{CH_3\dot{C}HSSSCH_2CH_3} \\
CH_3\dot{C}HSSCH_2CH_3 \rightarrow CH_3CH_2SH + \underset{IX}{{}^{\cdot}SCH{=}CH_2} \\
VIII \rightarrow \underset{\downarrow\, -H^{\cdot}}{CH_2{=}CHSH} + VII \\
VII \xrightarrow{-H_2S} IX \\
CH_3CH_2SH \rightarrow CH_2{=}CH_2 + H_2S
\end{gathered} \qquad (3)$$

According to this scheme diethyl trisulfide is a richer source of vinylthiyl radicals than diethyl disulfide, because one trisulfide molecule is converted via radical VIII to two IX radicals. The generation of radical IX is apparently favored by the presence of diethyl disulfide, the source of the VI radicals. Efficient thermolysis of ethanethiol and diethyl sulfide takes place only at 600-650°C. Here the possible generation of IX radicals from them is limited by the lower amount of sulfur in these molecules, and by the fact that the H—S and C—S bonds are stronger than the $S—S_n$ bonds (n = 1, 2), as follows:



(4)

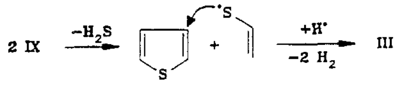
This may be the reason for the difference in the yields of thienothiophenes II and III when 2-chlorothiophene reacts with ethylthio derivatives. The proposed mechanism for thienothiophene formation, as exemplified by compound II in scheme (5), includes the following steps: addition of radical IX to the thiophene ring of chlorothiophene (I), decomposition of the sigma complex to vinylthienyl sulfides, and the cyclization of the latter.



(5)

Such a scheme is confirmed by the known tendency of vinyl compounds under analogous conditions to undergo dehydrocyclization to form aromatic systems (see, e.g., [9]). The formation of thienothiophenes II and III by scheme (5) with participation of C_2H_5S radicals is less likely, because in the thermolysis of ethyl 2-thienyl sulfide (XI) under analogous conditions the yield of thienothiophenes II and III does not exceed 8%.

An excess of the diethyl disulfide–diethyl trisulfide mixture favors the acceleration of thienothiophene formation without substantially changing the yield of thiophene. This may be due to the parallel formation of thienothiophenes II and III by reaction of thiophene with vinylthiyl radicals, e.g.,



Indeed when thiophene is copyrolyzed with a disulfide–trisulfide mixture, thienothiophenes II and III appear in the condensate (4% by weight).

Thus the gas-phase reaction of 2-chlorothiophene with a mixture of diethyl disulfide and trisulfide can serve as a simple one-step synthesis of a mixture of thienothiophenes II and III.

EXPERIMENTAL

NMR spectra of thienothiophenes II and III were recorded with a Tesla BS-567A instrument (100 MHz) in acetone-D_6 solution (HMDS internal standard). Mass spectra were obtained on a MAT-212 chromato mass spectrometer at 70 eV ionization voltage (SE-54 liquid phase).

2-Chlorothiophene (I) was reacted with ethylthio derivatives in a quartz tube with a 650 × 30 mm heating zone, bypassing the reagent mixture in the prescribed proportion (see Table 1) in a stream of dry nitrogen. Carrier gas flow and reagent feed rates were regulated so as to assure the necessary contact time of reagents (see Table 1). Contact time was calculating starting from the volume consumption of nitrogen and reagents in the vapor state and the volume of the reaction zone. Condensate was collected in a receiver and in a trap cooled to −50°C. Liquid products were determined by GLC with a LKhM-8MD-5 chromatograph, with OV-17 liquid phase, 5% on Chromaton, and XE-60 on Chesasorb, with linear temperature programming of the column (3 × 2000 mm) over the 30-230°C range, 12°C/min heating rate, and helium carrier gas.

Thiophene, 2-thiophenethiol (IV), and bis(2-thienyl) sulfide (V) were distilled from the condensate and characterized by standard methods [4, 6].

Identification of Thienothiophenes II and III. The fraction of bp 90-120°C (14 mm Hg) obtained by vacuum distillation of condensate contained more than 80% of the thienothiophenes. A mixture of pure II and III was separated by preparative GLC on a PAKhV-07 chromatograph on a stainless steel column (10 × 5000 mm) with Lukoprene G-1000 on Chromaton N-AW-DMCS, at a separation temperature of 115°C. The mixture is a bright yellow oil. Mass spectrum: 140 $[M^+]$ (100), 96 $[M - CS]^+$ (55). Found: C 51.4; H 3.2; S 45.0%. $C_6H_4S_2$. Calculated: C 51.4; H 2.9; S 45.7%. Compound II, ^1H NMR spectrum (cf. [3]): 7.41 (2–H, 5–H), 7.20 (3–H, 4–H), $J_{23} = J_{45} = 5.1$; ^{13}C NMR spectrum (cf. [10]): 128.1 ($C_{(2)}$, $C_{(5)}$), 119.7 ($C_{(3)}$, $C_{(4)}$), 137.3 ($C_{(7)}$), 147.0 ($C_{(8)}$). Compound III, ^1H NMR spectrum (cf. [3]): 7.44 (2–, 5–H), 7.26 (3–H, 6–H), $J_{23} = J_{56} = 5.1$; ^{13}C NMR spectrum (cf. [10]): 127.3 ($C_{(2)}$, $C_{(5)}$), 119.3 ($C_{(3)}$, $C_{(6)}$) 139.4 ($C_{(7)}$, $C_{(8)}$).

Thermolysis of Ethyl 2-Thienyl Sulfide (XI) was carried out in the apparatus described above at 560°C in a nitrogen stream (5 liter/h); contact time 60 sec. After 15 min, 5 g of compound II was introduced into the reaction and 2.4 g of condensate was obtained. Conversion of XI was 100%. Yield of principal products (according to GLC): thiophene 10%, thiophenethiol IV 11.5%, thienothiophenes II and III 8%, sulfide V 17%. Furthermore dithienyls and dithienothiophenes (cf. [6]) were identified in the reaction mixture by GLC.

The reaction of thiophene with a 1:3 mixture of diethyl disulfide and trisulfide was carried out in the same apparatus at 560°C and 3 liter/h nitrogen flow rate. The reaction gave 11 g of a mixture containing 3 g of thiophene. At the reactor exit 4.1 g of condensate was obtained, which according to GLC contained 96% thiophene and 4% thienothiophenes II and III; diethyl disulfide and trisulfide conversions were 100%.

LITERATURE CITED

1. M. G. Voronkov, É. N. Deryagina, L. K. Papernaya, É. N. Sukhomazova, N. A. Korchevin, and G. G. Efremova, Khim. Geterotsikl. Soedin., No. 12, 1614 (1986).
2. Ya. L. Gol'dfarb (editor), New Trends in Thiophene Chemistry, Nauka, Moscow (1976), p. 190.
3. A. R. Katritzky and A. J. Boulton (editors), V. P. Litvinov and Ya. L. Gol'dfarb, Advances in Heterocyclic Chemistry, Acad. Press, New York, San Francisco, London (1976), Vol. 19, p. 123.
4. M. G. Voronkov, É. N. Deryagina, L. G. Klochkova, and A. S. Nakhmanovich, Zh. Org. Khim., 12, 1515 (1976).
5. T. Hirabayashi, S. Mohmand, and H. Bock, Chem. Ber., 115, 483 (1982).
6. N. A. Korchevin, L. K. Papernaya, L. A. Ostroukhova, É. N. Sukhomazova, G. G. Efremova, É. N. Deryagina, and M. G. Voronkov, Zh. Oshch. Khim., 56, 2087 (1986).
7. M. G. Voronkov, É. N. Deryagina, and É. N. Sukhomazova, Zh. Org. Khim., 18, 1736 (1982).
8. É. N. Sukhomazova, É. N. Deryagina, M. A. Parfenova, N. K. Lyapina, and M. G. Voronkov, Izv. Akad. Nauk SSSR, Ser. Khim., No. 11, 2526 (1979).
9. M. G. Voronkov, É. N. Deryagina, S. V. Amosova, M. A. Kuznetsova, V. V. Kryuchkov, and B. A. Trofimov, Khim. Geterotsikl. Soedin., No. 11, 1579 (1975).
10. S. Gronowitz, I. Johnson, and A. Bugge, Acta Chem. Scand., A30, 417 (1976).

SYNTHESIS AND NITRATION OF SOME 4-CYCLOPROPYL- AND 4-(p-CYCLOPROPYLPHENYL)-2-AMINOTHIOPHENES

T. P. Surikova, V. D. Zakharova,
S. S. Mochalov, and Yu. S. Shabarov

UDC 547.732'734'512:542.958.1

A number of cyclopropyl-substituted crotononitriles have been synthesized by a Knoevenagel condensation. Reaction of these compounds with sulfur in the presence of a base gives substituted 4-cyclopropyl- and 4-cyclopropylphenyl-2-aminothiophenes, while nitration of some acetylaminothiophenes with acetyl nitrate in acetic anhydride at low temperature gives the corresponding nitro derivatives.

The synthesis of 2-aminothiophenes and also their derivatives has up to the present time been associated with certain difficulties. This is due to the fact that traditional methods of "forming" an amino group by modification of suitable substituents in the thiophene ring do not always give satisfactory results. The problem of finding accessible pathways to 2-aminothiophenes that contain a cyclopropane ring is even more complicated since the three-carbon ring is also one of those substituents that can readily be modified by, for example, electrophilic reagents [1, 2]. One of the most effective ways of synthesizing 2-amino-

---

M. V. Lomonosov State University, Moscow 117234. N. I. Pirogov 2nd State Medical Institute, Moscow 119435. Translated from Khimiya Geterotsiklicheskikh Soedinenii, No. 8, pp. 1045-1049, August, 1988. Original article submitted January 20, 1987; revision submitted May 29, 1987.

0009-3122/88/2408-0860$12.50