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Ring-opening Reactions of Heterocyclic Organometallics. IX.* The Opening of Some Chloro-, Methylthio- and Methoxy-substituted 3-Thienyl- and 3-Selenienyllithium Derivatives

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3-Thienyllithium derivatives with electron-withdrawing groups ($-I$-substituents) in the 2-position, *i.e.* 2-chloro-5-methyl-, 2,5-dichloro- and 2-methoxy-5-methyl-3-thienyllithium are stable at room temperature and do not undergo ring-opening to lithium enynethiolates. A strong tendency to undergo Wurtz-Fittig couplings was observed for the chlorinated 3-thienyllithium derivatives.

If the substituent in the 2-position has a weak $-I$-effect (*e.g.* methylthio), ring-opening occurs, as was observed for 5-methyl-2-methylthio-3-thienyllithium and 5-methyl-2-methylthio-3-selenienyllithium. From the latter compound, *1e* (Scheme 1) was obtained in 44 % yield.

Interestingly, 2,5-dichloro-3-selenienyllithium prepared by metalation of 2,5-dichloroselenophene with lithium diisopropylamide was stable, while the reaction of 2,5-dichloro-3-iodoselenophene with ethyllithium at −70 °C *via* ring-opening led to compound *8* (Scheme 2).

When the $-I$-substituent was in the 5-position, as in 5-methoxy-2-methyl-, 5-chloro-2-methyl- and 2-methyl-5-methylthio-3-thienyllithium, ring-opening occurred, although more slowly than with 2,5-dimethyl-3-thienyllithium.

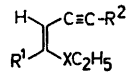
The synthetic applications of the ring-opening reaction are discussed.

It has previously been demonstrated [1,2] that 2,5-dialkyl-3-thienyl- and 2,5-dialkyl-3-selenienyllithium derivatives ring-open in a stereospecific manner to give lithium enynethiolates and lithium enyneselenolates which are alkylated by alkyl halides to give alkylthiovinyl acetylenes and alkylselenovinyl acetylenes. We were therefore interested in examining how other substituents than alkyl groups affected the stability of the 3-lithio heterocycles, and thus ascertaining the scope and limitations of the ring-opening reaction for the syntheses of substituted alkylthiovinyl acetylenes difficultly available by other synthetic approaches.

In the present paper the effect of changing the 2- and/or the 5-alkyl group for methoxy, chloro and methylthio groups will be discussed.

RESULTS

5-Chloro-, 5-methoxy- and 5-methylthio-3-thienyllithium derivatives. The ring-opening of 5-methoxy-2-methyl-3-thienyllithium was followed by GLC (hydrolysed samples), and it was shown that the reaction proceeded rather



1

2

3

Scheme 1. Compounds *1a–f*, *2a–c* and *3a–b*.

Compound	R^1 or R^5	R^2	X
1a	OCH_3	CH_3	S
1b	SCH_3	CH_3	S
1c	SCH_3	C_3H_7	S
1d, 3b	SCH_3	CH_3	Se
1e, 3a	CH_3	SCH_3	Se
1f	CH_3	H	Se
2a			OCH_3
2b			Cl
2c			SCH_3

* Part VIII, see Ref. 2.

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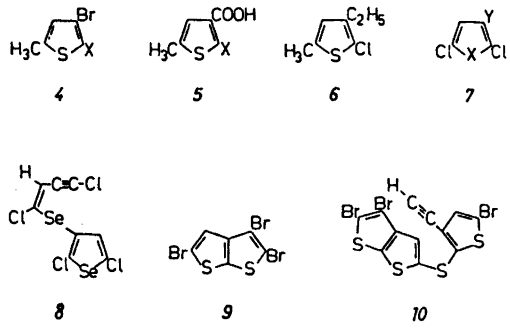
slowly. Even after 4 h at +21 °C, the peak originating from *1a* was still growing larger. Since a precipitate, probably 5-methoxy-2-methyl-3-thienyllithium, was formed immediately when ethyllithium and *2a* were mixed, the reaction became heterogeneous. This could be responsible for the apparently slow ring-opening. In order to make the reaction homogeneous, a small amount of hexamethylphosphoric triamide (HMPA) was added to the reaction mixture. In this way, a 33 % yield of *1a* was obtained and the ring-opening was complete in less than 2 h.

The ring-opening of 5-chloro-2-methyl-3-thienyllithium appeared to be more complex. As much as 21 % of the starting material (*2b*) and 42 % of 2-chloro-5-methylthiophene were present in the crude product, together with 37 % of 1-ethylthio-1,3-pentadiyne [23] (uncalibrated GLC values).

The ring-opening of *2c* and of *3b* has been described previously in a short communication.[24] On treatment of *2c* with ethyllithium followed by ethyl bromide, *1b* and *1c* were formed in 70 and 25 % yields, respectively. The ring-opening of the selenienyllithium derivative gave a more uniform crude product. Thus, *3b* gave an 80 % yield of 90 % pure *1d*. As mentioned previously,[24] these kinds of acetylenic mixed ketene monothioacetals (*1a*), ketene dithioacetals (*1b*) and ketene thioselenoacetals (*1d*) with pre-determined configuration do not seem to have been previously described in the literature, and are hardly available by any other synthetic route. We are pursuing our research on the synthetic possibilities of these types of compounds.

2-Chloro-, 2-methoxy- and 2-methylthio-3-thienyllithium derivatives. Upon treatment with ethyllithium/ethyl bromide at room temperature for 4 h *4a* and *4b* gave *5a* (70 %) and *5b* (36 %), respectively, after carbonation of the reaction mixture. In the latter case, the neutral phase contained about 20 % of *6*. When the reaction mixture was kept at room temperature for 15 h and then hydrolysed the yield of *6* was raised to 51 %.

In an experiment in which *7a* was treated with methyllithium and methyliodide at room temperature for 2 h followed by hydrolysis, only the Wurtz-Fittig product *7b* was formed in 60 % yield, indicating a higher stability of



Scheme 2. Compounds *4a–c*, *5a–b* and *6–10*.

Compound	X	Compound	X	Y
4a, *5a*	OCH_3	*7a*	S	I
4b, *5b*	Cl	*7b*	S	CH_3
4c	SCH_3	*7c*	Se	I
		7d	Se	$SeCH_3$
		7e	Se	H
		7f	Se	COOH

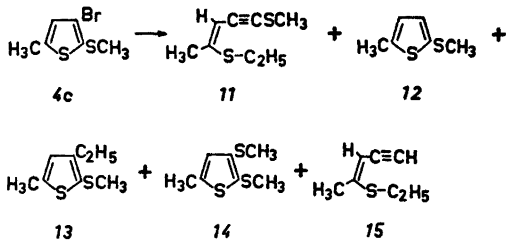
2,5-dichloro-3-thienyllithium than that of 2,5-dimethyl-3-thienyllithium.

Analogously, we therefore expected 2,5-dichloro-3-selenienyllithium to be more stable towards ring-opening than 3-selenienyllithium [7] and 2,5-dimethyl-3-selenienyllithium.[8] Surprisingly, this was not the case. Even at −70 °C and after 5 min, an acetylenic derivative (*8*) was formed in 50–70 % yield (NMR) when *7c* was treated with ethereal ethyllithium. The acetylenic derivative was too labile to survive isolation and purification attempts by TLC. For its structure determination, *cf.* below.

Unexpectedly, however, *7e* gave a 78 % yield of *7f* upon reaction with lithium diisopropylamide at −70 °C (2 h) followed by carbonation of the reaction mixture. The 2,5-dichloro-3-selenienyllithium thus prepared gave a 51 % yield of *7d* upon reaction with dimethyl diselenide.

In contrast to the behaviour of *4a* and *4b*, *4c* underwent ring-cleavage when reacted with ethyllithium and ethyl bromide and mainly *11* was obtained in 61 % yield. However, not only the type of by-products already observed in the ring-opening of 2,5-dialkyl-3-thienyllithium derivatives,[8] such as *12* [13] and the Wurtz-Fittig product *13*, were present in the crude product, but also *14* and what is believed to be *15* (*cf.* Table 1). No attempts to isolate *11* or *15* were made, but small enriched samples were

Table 1. Reaction product analysis of the reaction between *4c* and ethyllithium in the presence of ethyl bromide. Reaction time at +21 °C: 4 h, then hydrolysis. Uncalibrated GLC values.



4c *11* *12*

13 *14* *15*

Conditions		Products (%)				
C_2H_5Li (equiv)	Temp. (°C)	*11*	*12*	*13*	*14*	*15*
1	21	61	5	10	6	18
2	21	21	13	2	6	57
1	−70→21	33	9	19	27	12

obtained by TLC, which showed the expected spectroscopic properties. The structure of *14* was proven by comparison with an authentic sample prepared by halogen-metal exchange between *4c* and butyllithium at −70 °C followed by reaction with dimethyl disulfide.

In the selenophene series the reaction with one equivalent of ethyllithium at room temperature was cleaner. Thus, a 44 % yield of *1e* could be isolated (GLC yield 80 %) when *3a* was the substrate. Combined GLC-MS analysis showed that also in this case the methylthio group could be lost, giving about 10 % of *1f*. Four other unidentified compounds amounting to less than 10 % were also formed.

DISCUSSION

5-Methyl-2-methylthio-3-thienyllithium. Some indications of how the by-products in the ring-opening of 5-methyl-2-methylthio-3-thienyllithium may have been formed were obtained in the following way.

When two equivalents of ethyllithium were used together with *4c*, compound *15* was the main component, which made it likely that ethyllithium attacked the sulfur atom [14] of the acetylenic methylthio group of *11* or that of lithium 5-methylthio-2-penten-4-yne-2-thiolate, causing fission of the carbon-sulfur bond with formation of ethylmethyl sulfide and the salt of *15*. It also seems likely that 5-methyl-2-methylthio-3-thienyllithium acts as a nucleophile similar to ethyllithium, which explains the formation of the bis(methylthio) derivative *14*. Some further evidence for this was obtained from an experiment in which the halogen-metal exchange was carried out at −70 °C, whereupon the reaction mixture was allowed to reach room temperature. In this case, the amount of *14* formed increased to 27 %. This indicates that the thienyllithium derivative had time enough for the nucleophilic attack at sulfur to become rather extensive at temperatures where the ring-opening was slow. If *14* was formed only through a nucleophilic attack by the 3-thienyllithium derivative on the acetylenic methylthio derivative, the amount of *14* would be less than or equal to the amount of *15* (Table 1). A thermal decomposition of *15* in the injector of the gas chromatograph might be responsible for the actual values, since no calibration was made, and it is well known that terminal acetylenes are sensitive to heat.[15,16]

From a preparative point of view, this reaction was apparently too complex to be of value. Furthermore, *11* could probably be prepared by the addition of ethylthiolate to 1-methylthio-1,3-pentadiyne, since methylthiolate was reported to add so as to yield (*Z*)-2,5-bis(methylthio)-2-penten-4-yne.[17]

Gol'dfarb *et al.*[18] demonstrated that 5-methyl-2-methylthio-3-thienyllithium was stable enough at 0 °C to give a 42 % yield of 3,5-dimethyl-2-(methylthio)thiophene upon treatment with dimethyl sulfate after 1 h. The relatively low yield could be indicative of a ring-opening reaction, but no report of the formation of acetylenes was made. It was also possible to metalate 2-methyl-5-methylthiothiophene in the 4-position with butyllithium at room temperature in low yield.[19] These results thus indicate that 5-methyl-2-methylthio-3-thienyllithium is considerably more stable towards ring-opening than 2,5-dimethyl-3-thienyllithium.[1]

5-Chloro-2-methyl-3-thienyllithium. By assuming that 5-chloro-2-methyl-3-thienyllithium is rapidly formed, when ethyllithium is added to *2b*, a subsequent ring-opening should yield lithium (*Z*)-1-chloro-1-penten-3-yne-1-thiolate,

which should be able to eliminate hydrogen chloride in the presence of base (*cis* elimination) to give 1-ethylthio-1,3-pentadiyne. The base could of course be either ethyllithium or the thienyllithium derivative or both, but the results implied at least that ethyllithium was the base, since a substantial amount of the starting material was recovered.

2-Chloro-5-methyl-, 2-methoxy-5-methyl- and 2,5-dichloro-3-thienyllithium. In the case of 2-chloro-5-methyl-3-thienyllithium the relatively low yield of *5b* is attributed to the concurrent Wurtz-Fittig coupling with ethyl bromide to give *6*, which was the main product after longer reaction times.

The Wurz-Fittig reaction was even more pronounced with 2,5-dichloro-3-thienyllithium than with 2-chloro-5-methyl-3-thienyllithium, and it could be argued that the chlorine atoms might speed up this reaction, consuming all of the 2,5-dichloro-3-thienyllithium before any ring-opening could occur. By using phenyllithium instead of methyllithium and quenching the reaction mixture with dimethyl sulfate, it could be shown that no ring-opening had occurred after 2 h at room temperature, and that *7b* was formed in 99 % yield (GLC). It is thus obvious that 2,5-dichloro-3-thienyllithium is more stable towards ring-opening than 2,5-dimethyl-3-thienyllithium [1] and 3-thienyllithium.[7]

The high stability of 2-methoxy-5-methyl-3-thienyllithium could perhaps be expected from Sicé's metalation of 2-methoxy-5-methylthiophene.[4] After reaction of this compound with ethereal butyllithium at room temperature followed by reaction with carbon dioxide, he obtained *5a* in 50 % yield. However, it was quite likely that the ring-opened product, if it were formed in Sicé's experiment, would have escaped detection since no alkylating agent was present. In the experiments performed in this work no acetylenic compounds could be detected, despite the presence of an alkylating agent, which indicated that neither 2-methoxy-5-methyl-3-thienyllithium nor 2-chloro-5-methyl-3-thienyllithium underwent ring-cleavage.

Upon attempted metalation of 2-methoxy-5-methylselenophene it was not possible to isolate any carboxylic acid after reaction with carbon dioxide. Elemental selenium was deposited from the aqueous extract, which should have contained acidic products.

2,5-Dichloro-3-selenienyllithium. The unexpected formation of *8* could have occurred by the chlorinated lithium enyneselenolate, formed by ring-opening, attacking *7c* in a nucleophilic aromatic substitution. We found indeed that nucleophilic substitution of *7c* with lithium-methylselenolate gave *7d*. However, this reaction was incomplete, even after several hours at room temperature in ether or in liquid ammonia at -33 °C, which possibly could be due to the heterogenous reaction conditions. It is obvious that additional experiments are necessary before the mode of formation of *8* is understood. A similar kind of reaction is indicated in Bugge's [12] reaction of *9* with butyllithium which gave the acetylene derivative *10* or an isomer thereof. From a preparative point of view it should be emphasized that the use of lithium diisopropyl amide made it possible to obtain 2,5-dichloro-3-selenienyllithium as a potential reagent for preparing 3-substituted 2,5-dichloroselenophenes from the easily available 2,5-dichloroselenophene. This might indicate a stabilizing effect of diisopropylamine on 2,5-dichloro-3-selenienyllithium due to complex formation. It should be pointed out that since diisopropylamine is formed at the reaction centre, the proximity of the amine to the lithium atom could be very favourable for complexation, as it is not necessary to displace any solvent molecules.[38]

Spectroscopic data of 8. The following spectroscopic data for the crude product of the reaction between *7c* and ethyllithium indicated that the main component was *8*:

(1) By using the direct inlet system of the mass spectrometer the most heavy fragment appeared at *m/e* 398, the isotopic composition of which indicated a content of four chlorine atoms and two selenium atoms. The simulated mass distribution of $C_8H_2Se_2Cl_4$ was almost identical with the experimental one.

(2) Absorptions at 2180 cm^{-1} (strong) and 2260 cm^{-1} (weak) were observed in the IR spectrum. The absence of absorptions around 3200 cm^{-1} indicated the substance to be a non-terminal acetylene.

(3) An ^1H NMR spectrum showed the absorption of the starting material and two singlets at δ 6.96 (aromatic) and 6.10 (vinylic) with the intensities 1:1. No absorptions in the

region of terminal acetylenic protons were observed.

(4) The decoupled ^{77}Se NMR spectrum of the crude product showed the peak originating from the starting material (see below) together with one line at 129.6 ppm lower field and one line at 146.3 ppm higher field than the selenium resonance of selenophene, which was used as a reference. The low-field line was well inside the region where the aromatic selenium resonance was expected to appear.[9,10] The high-field line was on the borderline between the aromatic selenium and the selenide resonances,[11] which was also as expected for the side-chain selenium in compound *8* (see below). The non-decoupled spectrum showed two doublets; J(Se1,H4) 2.4 Hz and J(Se side-chain, H vinylic) 9.0 Hz.

Since the crude product contained *7c*, a decoupled spectrum of this compound was recorded. A single line appeared at 139.8 ppm lower field than the reference. The non-decoupled spectrum showed a doublet with a spacing of 2.0 Hz [*i.e.* J(Se, H4) 2.0 Hz]. In order to estimate where the absorption of the side-chain selenium would appear, a decoupled spectrum of *7d* was recorded. The aromatic selenium absorption was at 117.3 ppm lower field and the side-chain selenium absorbed at 434.5 ppm higher field than the reference. The non-decoupled spectrum showed that the low-field band was a doublet [J(Se1, H4) 2.40 Hz], and that the high-field band was a doublet with fine structure [J(Se3,CH_3) 12 Hz, J(Se3,H4) 0.4 Hz]. Now, since the side-chain selenium in compound *8* besides being attached to an aromatic ring was also in a vinylic position, it could be expected to give a resonance signal at lower field than that of the methylseleno group in *7d*.

CONCLUSIONS

Previous observations concerning the relative rate of the ring-opening reaction indicate that $+I$ substituents enhance the rate.[7] Disregarding steric effects one would then assume that $-I$ substituents should work in the opposite direction, especially if these substituents were situated in the *ortho* positions to lithium, *e.g.* 2-substituted 3-thienyllithium derivatives. On the other hand, if such substituents were placed in the *meta* position, *i.e.* in the 5-position, the $-I$ effect should have less influence. These ideas seem to be supported by the above presented results.

The introduction of strong inductively electron-withdrawing groups ($-I$ substituents), such as Cl and OCH_3 (F parameters[20] 0.690 and 0.413, respectively), in the 2-position of 3-thienyllithium derivatives, strongly enhances the stability of these derivatives, so that ring-opening does not occur. A weaker $-I$ substituent such as SCH_3 (F value[20] 0.332) cannot prevent ring-opening, but slows it down markedly compared to 2,5-dimethyl-3-thienyllithium. However, these substituents also have non-bonded electrons, and it has been generally accepted that the selective *ortho*-metalation of aromatics containing such substituents is due to complexation of the organolithium derivative to the free electron pair of the substituent.[21,22] This complexation both directs the metal-introducing reagent, such as butyllithium, to the *ortho*-position, and increases the rate of metalation, by making the *ortho*-hydrogen more acidic. It is possible that intermolecular association (dimerization) of such 3-thienyllithium derivatives also contribute to their increased stability towards ring-opening. Intramolecular chelation would involve four-membered rings and therefore seems less likely. However, the cleavage of the methylthio derivative leaves little doubt of the importance of the $-I$ effect for preventing ring-opening. Other factors may, however, complicate the picture, *cf.* 2,5-dichloro-3-selenienyllithium.

STARTING MATERIALS

A few comments are worth making about the synthesis of some of the intermediates and starting materials.

Selective bromination of 2-methoxy-5-methylthiophene in the 3-position with *N*-bromosuccinimide in acetic acid gave *4a* (34 %). Attempts to prepare 3-bromo-2-methoxy-5-methylselenophene in the same way were unsuccessful due to decomposition. By treating 2-iodo-5-methylselenophene with excess sodium methoxide in HMPA in the presence of copper(II) oxide at room temperature a 47 % yield of 2-methoxy-5-methylselenophene was obtained.

The use of HMPA as a solvent gave a better yield under milder conditions and shorter reaction time as compared to methanol (23 % after 6 days).

The direct chlorination of 2,4-dibromothiophene with one equivalent of *N*-chlorosuccinimide in acetic acid leads to a mixture consisting of 2-chloro-3,5-dibromothiophene (77 %), 3-bromo-2,5-dichlorothiophene (13 %) and 2,3,5-tribromothiophene (3 %).[3] We therefore used the following route to obtain *4b*. Bromination of 3-bromo-2-chlorothiophene [27] with *N*-bromosuccinimide in acetic acid yielded 2-chloro-3,5-dibromothiophene in 51 % yield. Subsequent halogen-metal exchange at −70 °C with butyllithium followed by reaction with dimethyl sulfate gave *4b* (85 %).

A 47 % yield of 2,5-dichloroselenophene was obtained by treating selenophene with sulfuryl chloride in benzene. This method is better than that previously published by Suginome and Umezawa.[28]

Since some methylselenophene derivatives showed a tendency to decompose under halogenation conditions,[2,8] somewhat greater care had to be taken with these compounds than with their sulfur analogs. Thus 4-bromo-2-methylselenophene was brominated with bromine in a mixture of carbon disulfide and acetic acid at −30 °C. The hydrogen bromide formed in the reaction was removed (at least to some extent) by passing a current of nitrogen rapidly through the reaction mixture while it was reaching room temperature. In this way a 63 % yield of 2,3-dibromo-5-methylselenophene was obtained. The α-bromine atoms of 2,3-dibromo-5-methylthiophene [27] and 2,3-dibromo-5-methylselenophene were substituted by lithium in halogen-metal exchange reactions with butyllithium. By adding the lithiated heterocycles to dimethyl disulfide in ether,[30] *4c* and *3a* were obtained in 66 % and 56 % yields, respectively. Gol'dfarb *et al.*[18] previously synthesized *4c* by brominating 2-methyl-5-methylthiothiophene with a bromide-bromate solution. The possible formation of the isomer *2c* [24] was not examined, and compound *4c* was not fully characterized so it was considered more suitable to prepare it free of the isomer by introducing the methylthio group in the last step.

EXPERIMENTAL

General remarks. See Ref. 2 (Part VI).

2-Methoxy-5-methylthiophene was prepared by refluxing 44.8 g (0.200 mol) of 2-iodo-5-methylthiophene,[25] 16 g (0.20 mol) of copper(II) oxide and 0.600 mol of sodium methoxide [from 13.8 g (0.600 mol) of sodium and 220 g of methanol]. After 6 days, 10 % of the starting material remained. After work-up and distillation, 13.9 g (54 %) of the title compound was obtained, b.p. 12 mmHg 58 – 60 °C (lit.[4] b.p. 10 mmHg 51 – 52 °C).

2-Iodo-5-methylselenophene. To a mixture of 43.5 g (0.300 mol) of 2-methylselenophene in 300 ml of CCl_4, 200 ml of acetic acid, 300 ml of water and 2.0 ml of conc. H_2SO_4 were added, followed by 30.0 g (0.118 mol) of iodine and 12.3 g (0.0700 mol) of iodic acid dissolved in water. The latter two reagents were added in portions. This mixture was stirred vigorously at room temperature for 4 h, whereupon it was poured into aqueous sodium thiosulfate and extracted with CCl_4. The organic phases were washed with 1 N NaOH, water and dried. Evaporation and distillation gave 65.7 g (81 %) of the title compound, b.p. 59 – 60 °C/0.6 mmHg. NMR (CCl_4): δ 7.15 (1 H, d, H3), 6.42 (1 H, d, q, H4), 2.50 (3 H, d, CH_3). J(H3, H4) 3.6 Hz, J(H4, CH_3) 1.2 Hz. Anal. C_5H_5ISe: C 22.21; H 1.88; Se 29.21.

2-Methoxy-5-methylselenophene. To a mixture of 25 ml of dry HMPA and 9 ml of methanol, 1.3 g (0.057 mol) of sodium was added. When all of the sodium was consumed, the methanol was evaporated at 10 mmHg, and 5.00 g (0.0185 mol) of 2-iodo-5-methylselenophene together with 2.0 g of copper(II) oxide, were added. After 48 h at room temperature, the starting material was consumed as shown by GLC (column SE 30, 3 %, 100 – 200 °C, 10 °C/min) on a hydrolysed sample. The reaction mixture was poured into water and extracted with ether. The ethereal phase was washed with water and dried. Evaporation and distillation gave 1.53 g (47 %) of the title compound, b.p. 73 – 76 °C/12 mmHg. The NMR spectrum (CCl_4) was identical with that of an authentic sample.[5] When the same method as for the preparation of 2-methoxy-5-methylthiophene was used, only a 23 % yield was obtained. Extensive decomposition took place during the reaction, which was evident from the formation of elemental selenium.

3-Bromo-2-methoxy-5-methylthiophene (4a). To 12.8 g (0.100 mol) of 2-methoxy-5-methylthiophene in 100 ml of acetic acid, 19.6 g (0.110 mol) of *N*-bromosuccinimide was added in portions at +17 °C (ice cooling). When the addition was complete, the mixture was stirred for 1/2 h, whereupon it was poured into water. The aqueous phase was neutralized with $NaHCO_3$ and extracted with ether. The ethereal phase was filtered through alumina (Brockm. I, neutral) in order to remove some black solid

material, and dried. Evaporation and distillation gave 7.0 g (34 %) of the title compound, b.p. 115–117 °C/20 mmHg (decomp.). The substance darkened rapidly at room temperature, and even at −25 °C in the dark. NMR (CCl_4): δ 6.31 (1 H, q, H4), 2.32 (3 H, d, CH_3), 3.83 (3 H, s, OCH_3). J(H4, CH_3) 1.2 Hz. Anal. C_6H_7BrOS: C 34.8; H 3.46; S 15.0.

Attempted preparation of 3-bromo-2-methoxy-5-methylselenophene. When 2-methoxy-5-methylselenophene was treated with *N*-bromosuccinimide as in the preceding experiment, only black, unidentified material was formed immediately upon the NBS addition.

2-Chloro-3,5-dibromothiophene. A mixture of 10.6 g (0.0537 mol) of 3-bromo-2-chlorothiophene [3,26] and 11.0 g (0.0618 mol) of *N*-bromosuccinimide in 100 ml of acetic acid was refluxed for 2.5 h and was then neutralized with $NaHCO_3$. The aqueous mixture was extracted with ether and the collected ethereal portions were washed with 1 N NaOH, dried and evaporated. Distillation gave 7.6 g (51 %) of the title compound, b.p. 108–110 °C/10 mmHg (lit.[3] b.p. 104–108 °C/10 mmHg).

3-Bromo-2-chloro-5-methylthiophene (4b). To 7.0 g (0.025 mol) of 2-chloro-3,5-dibromothiophene [3] in 50 ml of ether, 18 ml (0.026 mol) of 1.42 M butyllithium in hexane was added at −70 °C (yellow precipitate), followed by 3.27 g (0.026 mol) of dimethyl sulfate in 25 ml of ether. The mixture was stirred at −70 °C for 1.5 h and was then allowed to reach room temperature, whereupon conc. ammonium hydroxide was added. The usual work-up gave 4.5 g (85 %) of the title compound after distillation, b.p. 89–91 °C/10 mmHg. NMR (CCl_4): δ 6.50 (1 H, q, H4), 2.40 (3 H, d, CH_3). J(H4, CH_3) 1.1 Hz. Anal. C_5H_4BrClS: C 28.40; H 2.00; S 15.10.

2,5-Dichloroselenophene (7e). To a solution of 80.0 g (0.611 mol) of selenophene [33] in 100 ml of dry benzene, 168 g (1.24 mol) of sulfuryl chloride was added during 2 h, whereupon the mixture was refluxed for 6 h. After cooling, the benzene solution was neutralized with $NaHCO_3$, washed with water and dried. Evaporation of the solvent and distillation gave 56.8 g (46 %) of the title compound, b.p. 68–69 °C/14 mmHg (lit.[28] b.p. 67 °C/12 mmHg). NMR (CCl_4): δ 6.74 (s, H3) (lit.[34] 6.70).

2,5-Dichloro-3-iodothiophene (7a). A mixture of 25.0 g (0.163 mol) of 2,5-dichlorothiophene,[27] 14.0 g (0.0551 mol) of iodine, 9.6 g (0.055 mol) of iodic acid, 40 ml of acetic acid, 50 ml of water, 30 ml of CCl_4 and 5 ml of conc. H_2SO_4 was refluxed for 72 h, whereupon it was poured into aqueous sodium thiosulfate and extracted with CCl_4. The collected organic phases were washed with water, dried, and the solvent was evaporated to give a crude product, which was distilled. Thus 31.8 g (70 %) of the title compound was obtained, b.p. 123–126 °C/15 mmHg (lit.[3] b.p. 112–114 °C/11 mmHg). NMR (CCl_4): δ 6.69 (s, H4).

2,5-Dichloro-3-iodoselenophene (7c) was prepared as described above from 20.0 g (0.100 mol) of 2,5-dichloroselenophene, 8.9 g (0.035 mol) of iodine, 6.2 g (0.035 mol) of iodic acid, 40 ml of acetic acid, 50 ml of water, 30 ml of CCl_4 and 1 ml of conc. H_2SO_4; yield 21.4 g (66 %), b.p. 89–93 °C/1.0 mmHg. NMR (CCl_4): δ 6.85 (s, H4). Anal. C_4HCl_2ISe: C 14.85; H 0.40; Se 24.20.

2,5-Dichloro-3-(methylseleno)selenophene (7d) (a) A solution of lithium diisopropylamide was prepared from 10.1 g (0.100 mol) of diisopropylamine in 50 ml of ether and 68 ml (0.10 mol) of 1.50 M butyllithium in hexane. This solution was cooled to −70 °C and 10.0 g (0.0500 mol) of 2,5-dichloroselenophene in 100 ml of ether was added at such a rate that the temperature did not exceed −65 °C. After the addition, the reaction mixture was stirred at −70 °C for 4 h, whereupon 18.8 g (0.100 mol) of dimethyl diselenide [35] in 50 ml of ether was added (−65 °C). After stirring for 1 h, the reaction mixture was allowed to reach room temperature. Water was added and the organic layer was washed with 2 N HCl, water and dried. Evaporation and distillation yielded 7.5 g (51 %) of the title compound, b.p. 95–97 °C/0.7 mmHg. ^{1}H NMR (CCl_4): δ 6.83 (1 H, s, H4), 2.28 (3 H, t, $SeCH_3$). J(Se-CH_3) 12 Hz. ^{77}Se NMR (19.14 MHz, acetone-d_6): see discussion. Anal. $C_5H_4Cl_2Se_2$: C 20.60; H 1.40; Cl 24.28; Se 53.80.

(b) Lithium methylselenolate was prepared according to Ref. 36 in 100 ml of liquid ammonia from 0.28 g (0.040 mol) of lithium and 3.8 g (0.020 mol) of dimethyl diselenide. The solvent was evaporated and 100 ml of ether was added to the white residue. To this suspension, 3.26 g (0.0100 mol) of 2,5-dichloro-3-iodoselenophene in 25 ml of ether was added. Samples were withdrawn, hydrolysed and analysed by GLC (column OV 17, 3 %, 80–200 °C, 8 °C/min). It was evident upon mixing with authentic samples that the reaction was rather slow, and after 2.5 h about 30 % conversion to *7b* had occurred. When the reaction was performed entirely in liquid ammonia, about the same result was achieved, except that some 2,5-dichloroselenophene was also formed.

4-Bromo-2-methylselenophene. To 96.0 ml (0.125 mol) of 1.30 M butyllithium in hexane cooled to −70 °C 35.5 g (0.123 mol) of 2,4-dibromoselenophene [29] in 150 ml of ether was added in a slow stream. The temperature was thereafter allowed to rise to −40 °C and 44 g (0.35 mol) of dimethyl sulfate in 50 ml of ether was added at such a rate that the reaction temperature did not exceed −30 °C. After warming to room temperature the reaction mixture was stirred with ammonia to destroy the excess of dimethyl sulfate. The organic phase was separated, washed with water and dried with magnesium sulfate. After evaporation of the solvent, part of the residue

(26.3 g, 95 % crude yield) was distilled to give the pure title compound, b.p. 83–85 °C/15 mmHg. NMR (CCl_4): δ 2.50 (3 H, d, CH_3), 6.75 (1 H, pentet, H3), 7.45 (1 H, d, H5). J(H3, H5) 1.4 Hz, J(CH_3, H3) 1.2 Hz. Anal. C_5H_5BrSe: C 26.80; H 2.20; Se 35.22.

2,3-Dibromo-5-methylselenophene. To a solution of 18.8 g (0.0839 mol) of crude 4-bromo-2-methylselenophene in 200 ml of carbon disulfide, 13.5 g (0.084 mol) of bromine in 50 ml of acetic acid was added dropwise at −30 °C. When the addition was complete, nitrogen gas was led through the reaction mixture while it was allowed to reach room temperature. In this way some of the hydrogen bromide, formed in the reaction, was quickly removed. The mixture was poured into aq. sodium thiosulfate and extracted with carbon disulfide. The organic portions were washed with water and dried. After evaporation of the solvent, 15.9 g (63 %) of homogeneous crude product remained (GLC: column BDS, 10 %, 100–195 °C, 12 °C/min), part of which was distilled to give the pure title compound, b.p. 75–76 °C/1.0 mmHg. NMR (CCl_4): δ 2.43 (3 H, d, CH_3), 6.64 (1 H, q, H4). J(H4, CH_3) 1.2 Hz. Anal. $C_5H_4Br_2Se$: C 19.76; H 1.24; Br 52.89; Se 26.00.

3-Bromo-5-methyl-2-(methylthio)thiophene (4c). To 28.3 g (0.110 mol) of 2,3-dibromo-5-methylthiophene [27] in 100 ml of ether, 70 ml (0.11 mol) of 1.60 M butyllithium in hexane was added at −70 °C, whereupon this mixture was pressed with nitrogen into a stirred solution of 10.5 g (0.112 mol) of dimethyl disulfide in 100 ml of ether.[35] A white precipitate was formed immediately. The mixture was stirred at room temperature for 3 h and then hydrolysed with water. The ethereal phase was separated, washed with dilute sodium hydroxide solution and water, dried over magnesium sulfate and fractionated to yield 16.2 g (66 %) of the title compound, b.p. 75–80 °C/1.0 mmHg, (lit.[18] 86–87 °C/2 mmHg). NMR (CCl_4): δ 2.33 (s, SCH_3), 2.38 (d, CH_3), 6.59 (q, H4). J(H4, CH_3) 1.1 Hz.

3-Bromo-5-methyl-2-(methylthio)selenophene (3a) was prepared as above in 56 % yield (5.28 g) from 10.6 g (0.0350 mol) of 2,3-dibromo-5-methylselenophene in 100 ml of ether, 21 ml (0.036 mol) of 1.70 M butyllithium in hexane and 3.8 g (0.040 mol) of dimethyl disulfide, b.p. 100–110 °C/3 mmHg. NMR (CCl_4): δ 2.40 (3 H, s, SCH_3), 2.49 (3 H, d, CH_3), 6.72 (1 H, q, H4). J(H4, CH_3) 1.4 Hz. Anal. C_6H_7BrSSe: C 26.71; H 2.56; Br 29.68; S 11.81; Se 29.22.

5-Methyl-2,3-bis(methylthio)thiophene (14). From 2.23 g (0.0100 mol) of *4c* in 50 ml of ether, 7.0 ml (0.011 mol) of 1.60 M butyllithium in hexane and 1.13 g (0.012 mol) of dimethyl disulfide in 25 ml of ether, 1.60 g of crude title compound was obtained according to the preceding procedure. Distillation gave 0.72 g (38 %) of pure *14*, b.p. 94–96 °C/1.0 mmHg. NMR (CCl_4): δ 2.38 (d, CH_3), 6.51 (q, H4), 2.32 and 2.36 (s, SCH_3). J(H4, CH_3) 1.0 Hz. Anal. $C_7H_{10}S_3$: C 44.10; H 5.27; S 50.47.

3-Bromo-5-methoxy-2-methylthiophene (2a). To a solution of 28.6 g (0.112 mol) of 3,5-dibromo-2-methylthiophene [13] in 150 ml of ether, 68 ml (0.12 mol) of 1.69 M butyllithium in hexane was added at −70 °C, followed by 27 g (0.12 mol) of tributylborate after 15 min. The reaction temperature was allowed to rise to −10 °C during 1 h, whereupon 14 ml (0.12 mol) of 30 % hydrogen peroxide was added. The mixture was refluxed for 1 h and then poured into water. The alkaline aqueous layer was extracted with 50 ml of ether and acidified with 1 N HCl. The acidic aqueous solution was extracted with ether and the ethereal portions were dried. Evaporation of the solvent gave 18.7 g of the crude "hydroxythiophene"; IR (film): 1695 cm^{-1}. This crude product (~0.10 mol) and 25 g (0.20 mol) of dimethyl sulfate were dissolved in 100 ml of $CHCl_3$, and a mixture of 33.0 g (0.097 mol) of tetrabutylammonium hydrogensulfate, 8.0 g (0.20 mol) of NaOH and 97 ml of water was added with stirring (ice cooling). When the addition was complete, the mixture was stirred for 1 h, whereupon the organic layer was separated, washed with water and dried.[31,32] Evaporation of the solvent and distillation yielded 7.5 g (32 %) of the title compound, b.p. 57–61 °C/0.7 mmHg. NMR (CCl_4): δ 5.88 (1 H, s, H4), 2.23 (3 H, s, CH_3), 3.77 (3 H, s, OCH_3). Anal. C_6H_7BrOS: C 34.96; H 3.49; S 15.40.

3-Bromo-5-chloro-2-methylthiophene (2b) was prepared in analogy with its isomer *4b* from 14.8 g (0.0536 mol) of 2,3-dibromo-5-chlorothiophene [3] in 100 ml of ether, 40 ml (0.057 mol) of 1.42 M butyllithium in hexane and 7.56 g (0.0600 mol) of dimethyl sulfate in 50 ml of ether; yield 7.7 g (68 %), b.p. 84–85 °C/10 mmHg. NMR (CCl_4): δ 6.67 (1 H, s, H4), 2.32 (3 H, s, CH_3). Anal. C_5H_4BrClS: C 28.34; H 1.95; S 15.17.

General method for the ring-opening of 3-lithioheterocycles (G). See Ref. 2 (Part VI).

2-Methoxy-5-methyl-3-thiophenecarboxylic acid (5a). A solution of 2.07 g (0.0100 mol) of *4a* in 30 ml of ether was treated with 17 ml (0.010 mol) of 0.60 M ethereal ethyllithium and 5.45 g (0.0500 mol) of ethyl bromide according to the general method G, except that the reaction mixture was poured onto solid carbon dioxide in ether after 4 h. The usual work-up gave 1.2 g (70 %) of the title compound, m.p. ~145 °C, which after recrystallization from water had m.p. 146–148 °C (lit.[4] m.p. 147–148 °C, 50 %). NMR (acetone-d_6): δ 6.75 (1 H, q, H4), 2.32 (3 H, d, CH_3), 3.98 (3 H, s, OCH_3). J(H4, CH_3) 1.3 Hz. No signs of acetylenes were observed (IR) in the neutral phase, which amounted to 0.1 g of (mainly) 2-methoxy-5-methylthiophene (NMR).

2-Chloro-5-methyl-3-thiophenecarboxylic acid (5b). A solution of 1.0 g (4.7 mmol) of *4b* in 25 ml of ether was treated with 10.0 ml (4.7 mmol) of 0.47 M ethereal ethyllithium and

2.2 g (20 mmol) of ethyl bromide according to the general method G, except that the reaction mixture was poured onto solid carbon dioxide in ether after 4 h. Thus, 0.3 g (36 %) of the title compound was obtained after the usual work-up. The acid was recrystallized from ethanol:water, m.p. 165 – 168 °C. IR (KBr): 1680 cm^{-1}. NMR ($CDCl_3$): δ 7.06 (1 H, q, H4), 2.40 (3 H, d, CH_3), 11.25 (1 H, s, COOH). J(H4, CH_3) 1.1 Hz. Anal. $C_6H_5ClO_2S$: C 40.76; H 2.80; S 18.19.

The neutral ethereal phases contained 2-chloro-5-methylthiophene and *6* in the proportions 4:6 according to GLC analysis (OV 17, 3 %, 100 – 200 °C, 15 °C/min) and comparison of the retention times with those of authentic samples. Evaporation of the solvent gave 0.4 g of an oil, which showed no signs of acetylenes (IR).

2-Chloro-3-ethyl-5-methylthiophene (6). A solution of 10.0 g (0.0473 mol) of *4b* in 100 ml of ether was treated with 51 ml (0.048 mol) of 0.94 M ethereal ethyllithium and 16.4 g (0.150 mol) of ethyl bromide, according to the general method G, except that the reaction mixture was stirred at room temperature for 24 h before hydrolysis. Thus, 5.32 g of a crude product remained after work-up and evaporation of the solvent. The title compound was obtained through distillation, b.p. 83 – 85 °C/16 mmHg, 3.9 g (51 %). NMR (CCl_4): δ 6.37 (1 H, q, H4), 2.32 (d, CH_3); (C_2H_5), 2.50 (q) and 1.13 (3 H, t). J(H4, CH_3) 1.1 Hz, J(CH_2-CH_3) 7.0 Hz. Anal. C_7H_9ClS: C 51.7; H 5.51. No traces of acetylenes were found in the crude product (IR).

*2,5-Dichloro-3-methylthiophene (*7b*).* (a) The general method G was followed, except that the reaction mixture was hydrolyzed after 2 h. From 2.79 g (0.0100 mol) of *7a* in 10 ml of ether, 17 ml (0.010 mol) of 0.60 M ethereal methyllithium and 4.3 g (0.030 mol) of methyl iodide, 1.0 g (60 %) of crude *7b* was obtained. GLC (column NPGS, 5 %, 90 – 180 °C, 13 °C/min) and NMR showed the presence of only one component, b.p. 71 – 72 °C/14 mmHg, 0.9 g (55 %), $n_D^{20} = 1.5540$ (lit.[6] 65 °C/11 mmHg, $n_D^{20} = 1.5560$). IR showed no signs of acetylenes. NMR (CCl_4): δ 2.08 (3 H, s, CH_3), 6.45 (1 H, s, H4).

(b) To 11 ml (0.011 mol) of 1.0 M ethereal phenyllithium, 2.79 g (0.0100 mol) of *7a* was added. After 2 h at room temperature, a solution of 1.9 g (0.015 mol) of dimethyl sulfate in 25 ml of ether was added. One hour later the excess dimethyl sulfate was destroyed by adding 25 ml of conc. ammonium hydroxide solution to the reaction mixture. The ethereal layer was washed with water, 2 N HCl and water to neutral reaction. GLC (OV 1, 3 %, 70 – 220 °C, 10 °C/min) showed < 10 % of toluene, 0.5 % of 2,5-dichlorothiophene, 42 % of iodobenzene, and 40 % of *7b*, upon comparison of the retention times with those of authentic compounds. IR showed no signs of acetylenes in the evaporated crude product.

Attempted metalation of 2-methoxy-5-methylselenophene. To a solution of 0.46 g (2.6 mmol) of 2-methoxy-5-methylselenophene,[5] 6.0 ml (3.0 mmol) of 0.50 M ethereal ethyllithium was added at room temperature. The yellow solution darkened rapidly and was black after 1 min. The reaction mixture was poured onto solid carbon dioxide in ether after 15 min, but no selenophenecarboxylic acid could be isolated. Instead elemental selenium precipitated from the acidified alkaline extract. The neutral phase contained 0.2 g of the starting material.

2,5-Dichloro-3-selenienyl 1,4-dichloro-1-buten-3-yn-1-yl selenide (8). To 6.52 g (0.0200 mol) of *7c* 17 ml (0.010 mol) of 0.60 M ethereal ethyllithium was added dropwise at – 70 °C. After 5 min, the reaction mixture was poured onto solid carbon dioxide in ether. No carboxylic acid could be isolated from the alkaline aqueous extracts upon acidification with 2 N HCl. From the neutral, dried ethereal phase, 3.90 g of a brown oil remained after evaporation of the solvent. (Upon standing at room temperature the oil darkened and solidified.) MS of the oil (direct inlet): $m/e = 398$; calc. for $C_8H_2Cl_4{}^{80}Se_2 = 398$. ^1H NMR (CCl_4): singlets at δ 6.96 and 6.10, integrals 1:1. Absorptions from the starting material and 2,5-dichlorothiophene were also present, and the yield of *8* based on the NMR data and the weight of the crude product was ~ 60 %. IR (film): C≡C 2190 and 2265 cm^{-1}; C=C 1550 cm^{-1}. ^{77}Se NMR data are given in the theoretical part. Attempts to isolate *8* by preparative TLC, using a number of eluents, were unsuccessful, mainly due to the instability of the compound. The experiment was repeated several times, which gave mixtures, as mentioned above, containing 50 – 65 % of *8*.

*2,5-Dichloro-3-selenophenecarboxylic acid (*7f*).* Lithium diisopropylamide was prepared from 1.1 g (0.011 mol) of diisopropylamine in 20 ml of ether and 18 ml (0.011 mol) of 0.60 M ethereal ethyllithium. This solution was added dropwise to 2.00 g (0.0100 mol) of *7e* in 30 ml of ether at – 70 °C. After 2 h, the reaction mixture was poured onto solid carbon dioxide in ether. Upon acidification of the alkaline aqueous extracts with 2 N HCl, 1.9 g (78 %) of the title compound was isolated, m.p. ~ 145 °C. Recrystallisation from ethanol:water gave the pure acid, m.p. 151 – 153 °C. IR (KBr): C=O 1690 cm^{-1}. NMR (DMSO-d_6): δ 7.42 (s, H4). Anal. $C_5H_2Cl_2O_2Se$: C 24.70; H 0.91; Se 32.31.

*(Z)-1-Methoxy-1-methylthio-1-penten-3-yne (*1a*).* To 1.82 g (8.80 mmol) of *2a* in 50 ml of ether, 13 ml (9.1 mmol) of 0.70 M ethereal ethyllithium was added, followed by 4.9 g (45 mmol) of ethyl bromide. A white precipitate was formed after the addition of the ethyllithium. On the addition of 2.0 ml of dry HMPA, the precipitate dissolved with heat evolution. Samples of the reaction mixture were withdrawn with a pipette, hydrolysed

and analysed by GLC (OV 17, 3 %, 100–210 °C, 15 °C/min). It appeared that the ring-opening was complete in less than 2 h; 86 % of *1a* and 14 % of a compound with longer retention time were found. After 4 h, the reaction mixture was hydrolysed with water and the ethereal layer was separated, washed with 2 N HCl, water and dried. Preparative TLC (1 mm silica gel, hexane: ether 9:1) of the evaporated crude product (1.20 g) gave 0.45 g (33 %) of the title compound. IR (film): C≡C 2210 and 2040 cm^{-1}. NMR (CCl_4): δ 4.72 (1 H, q, H2), 1.95 (3 H, d, H5), 3.67 (3 H, s, OCH_3); (SC_2H_5), 2.75 (2 H, q) and 1.25 (3 H, t). J(H2, H5) 2.2 Hz, $J(SCH_2\text{-}CH_3)$ 7.0 Hz. Anal. $C_8H_{12}OS$: C 61.39; H 7.63; S 20.35.

When the experiment was performed as described above but without HMPA, the peak of the title compound increased in height even after 4 h, as was evident from GLC analyses (the same column as above) of hydrolysed samples from the reaction mixture. The peak originating from 2-methoxy-5-methylthiophene decreased simultaneously.

1-Ethylthio-1,3-pentadiyne. The general method G was followed. From 0.50 g (2.4 mmol) of *2b* in 7 ml of ether, 3.2 ml (2.4 mmol) of 0.75 M ethereal ethyllithium and 1.1 g (10 mmol) of ethyl bromide, 0.3 g of a crude product was obtained. (A yellow precipitate was formed in the reaction mixture.) IR: C≡C 2205 cm^{-1}. Combined GLC-MS analysis (column BDS, 10 %, 100–200 °C, 10 °C/min) of the washed and dried ethereal reaction mixture: 42 % of 2-chloro-5-methylthiophene, (m/e = 132; calc. for $C_5H_5{}^{35}ClS$ = 132); 21 % of the starting material (the same retention time as an authentic sample) and 37 % of the title compound, (m/e = 124; calc. for C_7H_8S = 124). NMR (CCl_4): besides absorptions from *2b* and 2-chloro-5-methylthiophene there were absorptions originating from the title compound: δ 1.95 (s, CH_3) (lit.[23] 1.97 ± 0.02); (SC_2H_5), 2.70 (2 H, q) and 1.40 (3 H, t). UV [cyclohexane] of a purified sample (TLC: 1 mm silica gel, hexane) λ_{max} (nm): 239.5, 255 (sh), 268, 286. Lit.[23] (no solvent given) 242, 253, 268, 284.

Reaction between ethyllithium and 3-bromo-5-methyl-2-methylthiothiophene (4c). (a) *(Z)-2-Ethylthio-5-methylthio-2-penten-4-yne (11).* The general method G was followed. From 2.23 g (0.0100 mol) of *4c*, in 50 ml of ether, 20 ml (0.012 mol) of 0.60 M ethereal ethyllithium and 3.3 g (0.030 mol) of ethyl bromide, 1.47 g of a crude product was obtained. Combined GLC-MS analysis (column BDS, 10 %, 130–190 °C, 16 °C/min) on the washed and dried ethereal reaction mixture showed 5 components (in the order of increasing retention times): 2-methyl-5-methylthiothiophene (*12*) (m/e = 144; calc. for $C_6H_8S_2$ = 144), (*Z*)-2-ethylthio-2-penten-4-yne (*15*) (m/e = 126; calc. for $C_7H_{10}S$ = 126), 3-ethyl-5-methyl-2-methylthiothiophene (*13*) (m/e = 172; calc. for $C_8H_{12}S_2$ = 172), (*Z*)-2-ethylthio-5-methylthio-2-penten-4-yne (*11*) (m/e = 172; calc. for $C_8H_{12}S_2$ = 172) and 5-methyl-2,3-*bis*(methylthio)thiophene (14) (m/e = 190; calc. for $C_7H_{10}S_3$ = 190) (see Table 1). Compound *14* was identified by comparison of its mass spectral data and its retention time with those of an authentic sample. IR (film) of the crude product: ≡CH 3280 cm^{-1}, C≡C 2138 and 2085 cm^{-1}. An enriched sample of *11* was obtained in the following way: (1) Column chromatography (Al_2O_3:hexane) was performed on the crude product. The acetylenes are eluted first. (2) The eluate from (1) was evacuated (1 mmHg) for 2 h. Most of the lower boiling acetylene was removed. (3) TLC (1 mm silica gel, hexane:ether 9:1) was carried out on the residue from (2). NMR (CCl_4): δ 2.01 (d, H1), 5.43 (1 H, q, H3), 2.40 (3 H, s, SCH_3); (SC_2H_5), 2.85 (2 H, q) and 1.28 (3 H, t). J(H1, H3) 1.4 Hz, $J(CH_2\text{-}CH_3)$ 7 Hz.

(b) *(Z)-2-Ethylthio-2-penten-4-yne (15).* The general method G was followed. From 2.23 g (0.0100 mol) of *4c*, 37 ml (0.022 mol) of 0.60 M ethereal ethyllithium and 3.3 g (0.030 mol) of ethyl bromide, 1.0 g of a crude product was obtained. The washed and dried ethereal reaction mixture had the composition presented in Table 1. Distillation of the crude product gave a few drops of almost pure *15*, b.p. 80–90 °C/12 mmHg. NMR (CCl_4): δ 2.06 (3 H, d, d, H1), 5.33 (m, H3), 3.08 (d, d, H5); (SC_2H_5), 2.83 (q) and 1.28 (3 H, t). J(H3, H5) 2.5 Hz J(H1, H3) 1.4 Hz, J(H1, H5) 0.6 Hz, $J(SCH_2\text{-}CH_3)$ 7.3 Hz.

(c) The reaction was repeated as in (a) but the reagents were mixed at −70 °C, after which the temperature was allowed to rise to +21 °C. After 4 h at this temperature, the reaction mixture was hydrolysed and worked-up as in the general method G, which gave 1.1 g of a crude product. The washed and dried ethereal reaction mixture had the composition presented in Table 1.

(Z)-2-Ethylseleno-5-methylthio-2-penten-4-yne (1e). The general method G was followed. From 3.53 g (0.0131 mol) of *3a* in 80 ml of ether, 20 ml (0.014 mol) of 0.70 M ethereal ethyllithium and 9.8 g (0.090 mol) of ethyl bromide, 2.50 g of a crude product was obtained. Combined GLC-MS analysis (column BDS, 10 %, 130–190 °C, 15 °C/min) of the washed and dried ethereal reaction mixture showed six components, of which the two most abundant ones were (*Z*)-2-ethylseleno-2-penten-4-yne (*1f*) (10 %, m/e = 174; calc. for $C_7H_{10}{}^{80}Se$ = 174) and *1e* (80 %, m/e = 220; calc. for $C_8H_{12}S^{80}Se$ = 220). IR(film): ≡CH 3280 cm^{-1}, C≡C 2100 and 2140 cm^{-1}. Distillation of the crude product gave 1.26 g (44 %) of the title compound, b.p. 74–77 °C/2 × 10^{-2} mmHg. IR (film): C≡C 2140 cm^{-1}, C=C 1570 cm^{-1}. NMR (CCl_4): δ 2.13 (3 H, d, H1), 5.70 (1 H, q, H3), 2.40 (3 H, s, SCH_3); (SeC_2H_5), 2.80 (2 H, q) and 1.40 (3 H, t). J(H1, 3H) 1.4 Hz, $J(SeCH_2\text{-}CH_3)$ 7.2 Hz. Anal. $C_8H_{12}SSe$: C 43.70; H 5.41; S 14.68; Se 36.20.

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