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Thermal rearrangements of bis-allenyl thiosulfonates. Synthesis of novel thienothiophene and thieno-oxathiine derivatives

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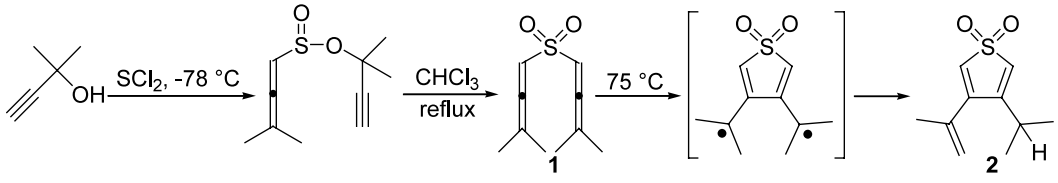
Abstract—The synthesis and thermal rearrangement of bis-allenyl thiosulfonates are described. Bis-γ,γ-disubstituted allenyl thiosulfonates have been prepared by disproportionation of the corresponding allenesulfinic acids. On heating, these compounds unexpectedly rearrange to a mixture of 1*H*,3*H*-thieno[3,4-*d*][1,2]oxathiine-3-oxide **8**, 1*H*,3*H*-thieno[3,4-*c*]thiophene-2,2-dioxide **9**, and 3-alkyl-4-alkenylthiophene **10**. A tentative reaction mechanism involving sequential sigmatropic rearrangements and cyclizations is suggested.

The [2,3]-sigmatropic rearrangements of propargylic sulfenates and sulfinates to allenic sulfoxides and sulfones, respectively, were discovered by us during the mid sixties and have received extensive application in organic synthesis since then.[1–4] In one such application from our own laboratory, a combination of two [2,3]-sigmatropic rearrangements was used to prepare bis-γ,γ-dimethylallenyl sulfone **1**. This sulfone undergoes a facile cyclization on heating to the thiophene-1,1-dioxide **2** via a 2,2′-bisallyl type diradical intermediate (Scheme 1).[5]

Subsequently, we also investigated the rearrangements of diheteroatom bridged bisallenes. Thus, bisallenyl disulfide **3** was found to undergo a tandem [3,3]-sigmatropic rearrangement and a double intramolecular Michael addition to give the bicyclic compound **4** (Scheme 2).[6]

Prompted by these results, we decided to incorporate a thiosulfonate moiety as a bisallenic bridge in order to examine which of the above two reaction modes such compounds would follow. In general, thiosulfonates exhibit interesting properties. They are powerful sulfenylating agents,[7–10] with antimicrobial and fungicidal activities,[11,12] and with some industrial applications both in polymer production and in photographic processes.[13]

Although many synthetic approaches are known for the preparation of symmetrical and unsymmetrical thiosulfonates in general,[10,14] their application for the preparation of allenic thiosulfonates is limited by the lack of appropriate starting materials. The synthesis of bis-γ,γ-dimethyl- and bis-γ-cyclohexylallenyl thiosulfonates, **7a** and **7b**, respectively, has been reported to take place by disproportionation of the corresponding sulfinic acids, which are produced in situ by hydrolysis of allenyl sulfinamides (yields 11–34%).[15] However, we have found it more convenient to use a somewhat different approach. Thus, sodium γ,γ-disubstituted allenesulfinates **6a**,**b** were prepared by hydrolysis of the corre-



Scheme 1.

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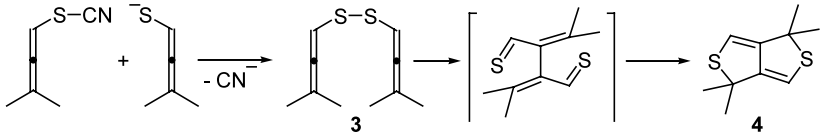
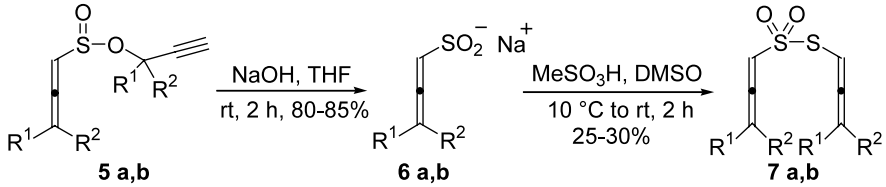
sponding sulfinate esters **5a**,**b** under basic conditions (Scheme 3). The latter are readily available from the reaction of sulfur dichloride with the appropriately substituted propargylic alcohols (Scheme 1). Sodium allenesulfinates **6a**,**b** were isolated in 80–85% yields as white solids (mp >300°C), which were sensitive to atmospheric moisture.[16] Treatment of **6a**,**b** with an excess of methanesulfonic acid in DMSO generated the corresponding sulfinic acids whose well known disproportionation[17] afforded thiosulfonates **7a**,**b** (Scheme 3). DMSO was found to be the best solvent for the above transformation. Using methanol or biphasic systems such as diethyl ether–water, large amounts of α,β-unsaturated γ-sultines[18–20] were obtained as by-products. In a typical procedure, sodium allenesulfinate (5 mmol) was slowly added to a cooled solution (10°C) of CH_3SO_3H (1 mL) in DMSO (5 mL). After 3 h under vigorous stirring the reaction mixture was diluted with CH_2Cl_2, followed by usual work-up. Thiosulfonates **7a**,**b** were then purified by chromatography (silica gel, ether–hexane 2:3).

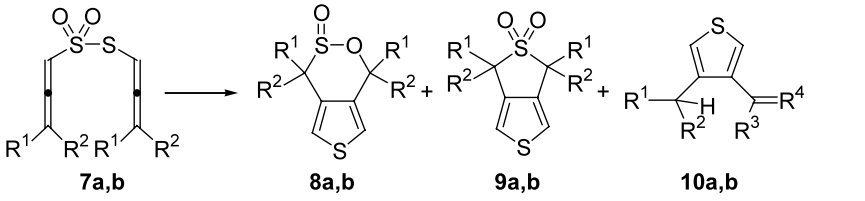
Previously, it was reported that bis-γ,γ-dimethylallenyl thiosulfonate **7a** is unstable at room temperature.[15] However, we have found that thiosulfonates **7a**,**b** under heating, undergo a series of rearrangement and cyclization reactions. Moreover, reaction rates and product ratios are quite dependent on the nature of solvent and temperature, respectively. Thus, we found that on heating in chloroform **7a** afforded a mixture of 1,1,4,4-tetramethyl-1*H*,3*H*-thieno[3,4-*d*][1,2]oxathiine-3-oxide **8a**, 1,1,3,3-tetramethyl-1*H*,3*H*-thieno[3,4-*c*]thiophene-2,2-dioxide **9a** and 3-isopropyl-4-isopropenylthiophene **10a** (Scheme 4, Table 1, entry 1). When bis-γ,γ-dimethylallenyl thiosulfonate **7a** was heated below 40°C only the first two products were formed (Table 1, entries 3 and 4). Furthermore, the reaction times decrease with increasing polarity of the solvents. For example,



Scheme 2.



Scheme 3.



Scheme 4.

Table 1. Rearrangement products of bis-allenyl thiosulfonates **7a**,**b**

Entry	Compd	Solvent	*T* (°C)	Time (h)	Products (ratio, %)			Yield (%)[a]
1	**7a**	$CHCl_3$	55	12	**8a** (47)	**9a** (6)	**10a** (47)	50
2	**7a**	Me_2CO	55	10	**8a** (66)	**9a** (8)	**10a** (26)	75
3	**7a**	$CHCl_3$	40	120	**8a** (91)	**9a** (9)	–	60
4	**7a**	DMSO	40	12	**8a** (72)	**9a** (28)	–	80
5	**7b**	$CHCl_3$	40	120	**8b** (40)	**9b** (8)	**10b** (52)	80
6	**7b**	DMSO	40	60	**8b** (42)	**9b** (17)	**10b** (41)	85

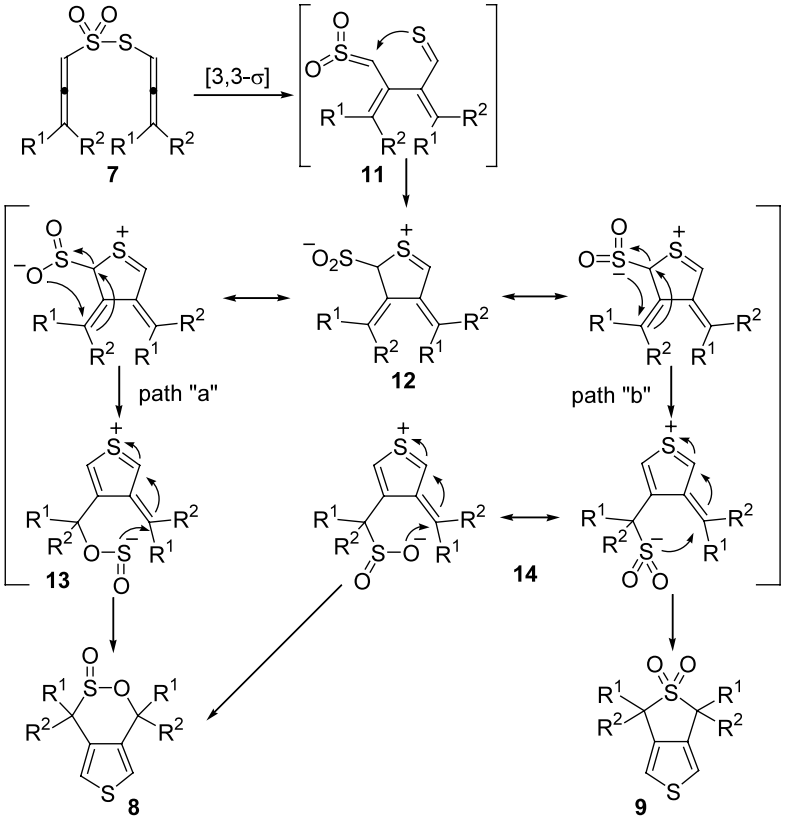
[a] Total yield for isolated products.

changing the solvent from $CHCl_3$ to DMSO decreases the reaction time by a factor of ten. Bis-γ-cyclohexyl-allenyl thiosulfonate **7b** rearranged in a similar manner to **7a** (Scheme 4). Structure assignments of reaction products have unequivocally been determined by 2D NMR analysis.[21]

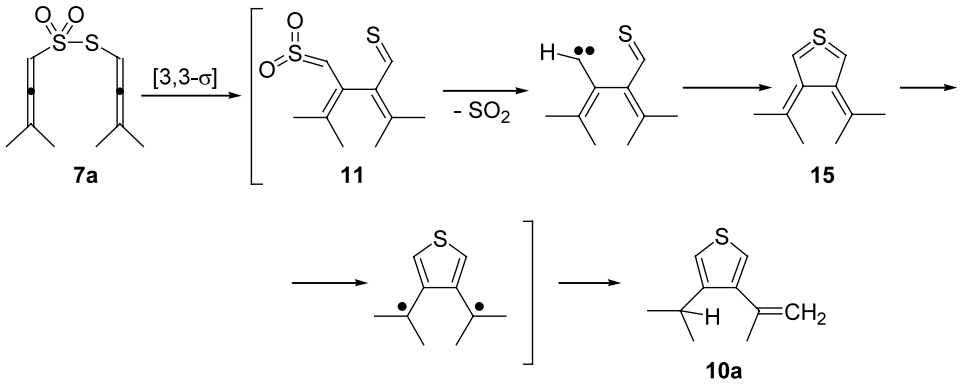
Although no experimental evidence in support of a detailed reaction mechanism for the formation of the various products is available, the effect of solvent polarity on reaction rates seems to favour an ionic mechanism. A tentative mechanism for the thermal rearrangement of bis-allenyl thiosulfonates is shown in Scheme 5. We assume that first, thiosulfonates **7a**,**b** undergo a [3,3]-sigmatropic rearrangement to give intermediate **11**. However, instead of rotation around the central C–C σ bond and cyclization similar to that observed for bis-allenyl disulfides (Scheme 2),[6] this intermediate reacts by a different route. Intermediate **11** contains a sulfene moiety, which is well known for its electrophilicity.[22] Thus, an intramolecular nucleophilic attack by the thioaldehyde sulfur atom on the sulfene carbon atom generates the zwitterionic intermediate **12**, which has both a five-membered sulfonium ring and a sulfinate anion moiety.

We suggest that subsequent cyclizations of **12** proceed by two routes. [2,3]-Sigmatropic rearrangement of this intermediate via path a leads to the formation of **13**, which then undergoes cycloaromatization to give product **8** (Scheme 5). Alternatively, a [1,3]-sulfinate migration of **12** via path b leads to formation of intermediate **14**, which on cyclization can afford both **8** and **9**. The experimental data shows that in all cases greater amounts of **8** are formed than **9**. The ambident character of the sulfinate anion is well known.[23–25] Thus, the ring closure in intermediate **14** can proceed by either sulfur or oxygen nucleophilic attack. Although, the former is usually the more favored route with neutral electrophiles the latter is the more dominant with positively charged electrophiles. This, as well as the formation of **8** via both mechanistic paths, may account for the higher percentages of this product relative to **9**.

Thieno[3,4-*d*][1,2]oxathiine-3-oxides **8a**,**b** were found to be unexpectedly stable under thermal conditions. Even at 160°C they do not undergo isomerization to compounds **9a**,**b** or lose sulfur dioxide. In view of the above, the formation of thiophene derivatives **10a**,**b**, most likely takes place via sulfur dioxide extrusion from intermediate **11**. The carbene formation from sulfene by loss of sulfur dioxide has been previously reported.[26] Expulsion of sulfur dioxide from sulfene **11** generates a carbene which undergoes an addition reaction to the thioaldehyde sulfur atom to give **15** (Scheme 6). The latter rearranges via a radical mechanism to thiophene derivatives **10**, similar to the cyclization of **1** to **2** (Scheme 1).



Scheme 5.



Scheme 6.

Acknowledgements

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References

1. Braverman, S. In *The Chemistry of Sulfones and Sulfoxides*; Patai, S.; Rappoport, Z.; Stirling, C. J. M., Eds.; Wiley: New York, 1988; pp. 665–716 and 717–757.
2. Braverman, S. In *The Chemistry of Double-Bonded Functional Groups. Supplement A*2; Patai, S., Ed.; Wiley: Chichester, 1989; pp. 963–1060.
3. Braverman, S. In *The Chemistry of Sulfinic Acids, Esters and their Derivatives*; Patai, S., Ed.; Wiley: New York, 1990; pp. 297–349.
4. Braverman, S. In *The Chemistry of Sulfenic Acids and their Derivatives*; Patai, S., Ed.; Wiley: New York, 1990; pp. 311–359.
5. Braverman, S.; Segev, D. *J. Am. Chem. Soc.* **1974**, *96*, 1245–1247.
6. Braverman, S.; Freund, M. *Tetrahedron* **1990**, *46*, 5759–5776.
7. Parsons, T. F.; Buckman, J. D.; Pearson, D. E.; Field, L. *J. Org. Chem.* **1965**, *30*, 1923–1926.
8. Palumbo, G.; Ferreri, C.; D'Ambrocio, C.; Caputo, R. *Phosphorus Sulfur Silicon* **1984**, *19*, 235–238.
9. Fujiki, K.; Yoshida, E. Y. *Synth. Commun.* **1999**, *29*, 3289–3294.
10. Fujiki, K.; Akieda, S.; Yasuda, H.; Sasaki, Y. *Synthesis* **2001**, *7*, 1035–1042.
11. Weidner, J. P.; Block, S. S. *J. Med. Chem.* **1964**, *7*, 671–673.
12. Block, S. S.; Weidner, J. P. *Mech. React. Sulfur Compd.* **1967**, *2*, 235–236.
13. Zefirov, N. S.; Zyk, N. V.; Beloglazkina, E. K.; Kutateladze, A. G. *Sulfur Rep.* **1993**, *14*, 223–240.
14. Hogg, D. R. In *Comprehensive Organic Chemistry*; Jones, D. N., Ed.; Pergamon Press: Oxford, 1979; Vol. 3, pp. 299–302.
15. Baudin, J.-B.; Julia, S. A.; Ruel, O.; Toupet, L.; Wang, Y. *Bull. Soc. Chim. Fr.* **1995**, *132*, 79–85.
16. *Sodium γ,γ′-dimethylallenyl sulfinate* ***6a****: typical procedure*: To a solution of sulfinate ester **5a** (1.84 g, 9.3 mmol) in THF (25 mL), an aqueous solution of NaOH (15%, 9.3 mmol) was added. The reaction mixture was stirred at rt until a homogeneous solution was obtained (ca. 2 h). Then, THF and water were evaporated under vacuum at rt and the residue was washed a few times with acetone, filtered and dried in a dessicator to give **6a** as a white solid; yield: 1.14 g (80%); mp >300°C; IR (KBr): 3441, 1985, 1654, 1224, 1130, 1048, 631 cm^{-1}; ^1H NMR (300 MHz, D_2O): δ 1.79 (d, $J=2.9$ Hz, 6H, CH_3), 5.70 (sept., $J=2.9$ Hz, 1H); ^{13}C NMR (75 MHz, D_2O): δ 19.5 (CH_3), 103.8 (Cq), 105.9 (CH), 198.9 (Cq). Anal. calcd for $C_5H_7NaO_2S$ (154.16): C, 38.95; H, 4.58; S, 20.80. Found: C, 38.73; H, 4.45; S, 20.52%.
17. Oae, S. *Organic Chemistry of Sulfur*; Plenum: New York, 1977; p. 614.
18. Braverman, S.; Reisman, D. *J. Am. Chem. Soc.* **1977**, *99*, 605–607.
19. Braverman, S.; Reisman, D. *Tetrahedron Lett.* **1977**, *18*, 1753–1756.
20. Braverman, S.; Duar, Y. *J. Am. Chem. Soc.* **1983**, *105*, 1061–1063.
21. All new compounds gave satisfactory analytical and spectral data in accordance with their structures. Selected analytical and spectral data:
Compound **8a**: white crystals (PTLC, CH_2Cl_2–hexane 3:1, $R_f=0.25$), mp = 87–88°C; IR (KBr): 3072, 2935, 2854, 1745, 1462, 1365, 1258, 1128, 1111, 923, 844 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$): δ 1.45 (s, 3H, CH_3), 1.64 (s, 3H, CH_3), 1.67 (s, 3H, CH_3), 1.82 (s, 3H, CH_3), 7.07 (d, $J=3.2$ Hz, 1H, H-5), 7.22 (d, $J=3.2$ Hz, 1H, H-7); ^{13}C NMR (75 MHz, $CDCl_3$): δ 22.2 (CH_3), 25.8 (CH_3), 33.56 (CH_3), 34.0 (CH_3), 57.6 (Cq), 82.7 (Cq), 120.1 (CH), 122.3 (CH), 135.7 (Cq), 139.1 (Cq). Anal. calcd for $C_{10}H_{14}O_2S_2$ (230.35): C, 52.14; H, 6.13; S, 27.84. Found: C, 51.98; H, 5.94; S, 27.59%.
Compound **9a**: white crystals (PTLC, CH_2Cl_2–hexane 3:1, $R_f=0.37$), mp = 72–73°C; IR (KBr): 3056, 2962, 2853, 1730, 1454, 1365, 1282, 1118, 1094, 1027, 807 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$): δ 1.69 (s, 12H, $4CH_3$), 7.16 (s, 2H, H-4+H-6); ^{13}C NMR (75 MHz, $CDCl_3$): δ 25.6 (CH_3), 62.7 (Cq), 118.9 (CH), 141.6 (Cq). Anal. calcd for $C_{10}H_{14}O_2S_2$ (230.35): C, 52.14; H, 6.13; S, 27.84. Found: C, 52.02; H, 5.98; S, 27.55%.
Compound **10b**: colorless oil (PTLC, CH_2Cl_2–hexane 3:1, $R_f=0.8$); IR (neat): 2924, 2851, 1446, 1267, 923, 786 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 1.34 (m, 4H), 1.74

(m, 8H), 1.95 (m, 2H), 2.18 (m, 2H), 2.25 (m, 2H), 2.63 (m, 1H), 5.67 (m, 1H), 6.91 (d, $J=3.3$ Hz, 1H), 6.94 (d, $J=3.3$ Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 22.1 (CH_2), 23.2 (CH_2), 25.6 (CH_2), 26.3 (CH_2), 27.0 (CH_2), 30.5 (CH_2), 34.7 (CH_2), 38.2 (CH), 118.8 (CH), 120.8 (CH), 126.2 (CH), 134.3 (Cq), 145.2 (Cq), 147.4 (Cq). HRMS calcd for $C_{16}H_{22}S$: 246.144223. Found: 246.144269.

22. King, J. F.; Rathone, R. In *The Chemistry of Sulfonic Acids, Esters and their Derivatives*; Patai, S.; Rappoport, Z., Eds.; Wiley: Chichester, 1991; pp. 720–734.
23. Stirling, C. J. M. *Int. J. Sulfur Chem. Part B* **1971**, *6*, 277–320.
24. Kobayashi, M.; Toriyabe, K. *Sulfur Lett.* **1985**, *3*, 117–122.
25. Hambley, T. W.; Harsanyi, M. C.; Norris, R. K. *J. Org. Chem.* **1988**, *53*, 3104–3108.
26. Sarver, B. E.; Jones, M., Jr.; van Leusen, A. M. *J. Am. Chem. Soc.* **1975**, *97*, 4771–4772.