Organic Chemistry

Reactions of polyfluoroalkenylsulfenyl chlorides with carbonyl compounds

*A. N. Kovregin, A. Yu. Sizov, A. F. Ermolov, and A. F. Kolomiets**

A. N. Nesmeyanov Institute of Organoelement Compounds, Russian Academy of Sciences, 28 ul. Vavilova, 117813 Moscow, Russian Federation. Fax: +7 (095) 135 5085

Polyfluorinated 1-fluoroalk-1-enylsulfenyl chlorides react with ketones $RCOCH_2R'$ to give unsaturated sulfides. The latter undergo smooth cyclization into 2-alkylidene-1,3-oxathioles in the presence of $BF_3 \cdot NEt_3$.

Key words: polyfluorinated α,β-unsaturated sulfenyl chlorides, ketones, sulfenylation, cyclization, 2-alkylidene-1,3-oxathioles.

Reactions of saturated polyfluoroalkylsulfenyl chlorides with enolizable carbonyl compounds are well studied.[1] However, the only example of similar transformations for α,β-unsaturated sulfenyl chlorides documented so far is the reaction of 1,3,3,3-tetrafluoro-2-methoxycarbonylpropenylsulfenyl chloride (**1**) with acetone, which yields a normal sulfenylation product.[2] In the present work, reactions of various carbonyl compounds with 1,3,3,3-tetrafluoro-2-(trifluoromethyl)propenylsulfenyl chloride (**2**) and sulfenyl chloride **1** were studied. The reactivity of compounds **1** and **2** are due to the presence of a sulfenyl chloride group and a labile α-F atom.

We showed that sulfenyl chlorides **1** and **2** react smoothly with various enolizable carbonyl compounds (acyclic and cyclic ketones, β-diketones, and β-oxo esters) to give monosulfenylation products **3**—**17** (compounds **8**, **16**, and **17** were not isolated in individual states and were used in subsequent transformations without purification) (Scheme 1).

Usually, the reaction is carried out without a solvent at ~20 °C or on slight cooling (−10 to 0 °C, in the case of nonfluorinated β-dicarbonyl compounds). Fluorinated ketones react with much greater difficulty. Thus, hexafluoroacetylacetone and ethyl trifluoroacetoacetate react with sulfenyl chloride **1** only at 70 °C, while methyl perfluorohexyl ketone did not react even at 140 °C.

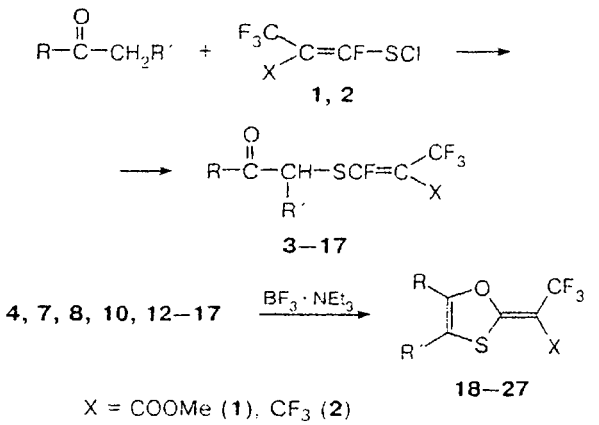
According to ^1H NMR data, sulfides **6**—**8** and **11**—**17** obtained from β-diketones and β-oxo esters exist in the enol form only, which is characteristic of such compounds.[1] They can be isolated from the reaction mixtures only under mild conditions; *e.g.*, sulfides **6**, **7**, and **11**—**14** were obtained by freezing from solutions in hexane. When heated, these compounds mostly undergo intramolecular cyclization with elimination of HF to give substituted 1,3-oxathioles.

It was found that $BF_3 \cdot NEt_3$ is a convenient reagent for this type of selective cyclization and acts not only as an acceptor of HF, but also as a base for the generation of enolate anions. Thus β-dicarbonyl compounds **7**, **8**, and **12**—**17** at ~20 °C are transformed into oxathioles **19**, **20**, and **22**—**27** in ether in the presence of this reagent in high yields. Under these conditions, sulfide **13** with two different enolizable carbonyl groups gives a

Published in *Izvestiya Akademii Nauk. Seriya Khimicheskaya*, No. 10, pp. 1770—1773, October, 2000.

1066-5285/00/4910-1749 $25.00

Scheme 1



X = COOMe (**1**), CF_3 (**2**)

Compound	R	R′
	X = CF_3	
3	Me	H
4, **18**	Ph	H
5	R + R′ = $-CH_2CH_2CH_2-$	
6	Me	MeC(O)
7, **19**	Ph	COOEt
8, **20**	Me	COOEt
	X = COOMe	
9	Et	Me
10, **21**	Ph	H
11	R + R′ = $-CH_2CH_2CH_2-$	
12, **22**	Me	MeC(O)
13, **23**	Ph	MeC(O)
14, **24**	CF_3	$CF_3C(O)$
15, **25**	CF_3	COOEt
16, **26**	Me	COOEt
17, **27**	Ph	COOEt

mixture of cyclization products. However, when refluxed in acetonitrile, sulfide **13** selectively gives only one of the possible products, namely, oxathiole **23**. The reaction conditions depend on the content of the enol form in the carbonyl compound. For example, cyclization of substituted acetophenones **4** and **10**, which exist in the ketone form (^{1}H NMR), requires refluxing in chloroform in the presence of $BF_3 \cdot NEt_3$. Under similar conditions, aliphatic and cyclic monoketone derivatives **3**, **5**, **9**, and **11** also undergo cyclization (according to ^{1}H NMR data), but the corresponding oxathioles could not be isolated in the individual state because of resinification of the reaction mixtures. It is of note that compound **24** (Table 1) proved to be a mixture of isomers, though all other reactions resulted in pure oxathioles. (The reasons for these differences will be analyzed later).

Colorless crystalline alkylideneoxathioles **18**—**27** represent a new type of O,S-acetals of fluorinated ketenes. Their structures were confirmed by ^{1}H and ^{19}F NMR spectroscopy.

Experimental

^{19}F NMR spectra were recorded on a Bruker AC-200F spectrometer (188.31 MHz), ^{1}H NMR spectra were recorded on a Bruker AC-300SF instrument (300.13 MHz). ^{19}F and ^{1}H chemical shifts (δ) are referred to CF_3COOH (external standard) and Me_4Si (internal standard), respectively. Reaction conditions, physical and spectral characteristics, and elemental analysis data for compounds **3**—**7**, **9**—**15**, and **18**—**27** are given in Table 1.

The starting polyfluoroalkenylsulfenyl chlorides **1** and **2** were prepared according to the known procedures.[2,3]

Reactions of sulfenyl chlorides 1 and 2 with carbonyl compounds (general procedure). A mixture of sulfenyl chloride **1** or

Table 1. Reaction conditions, yields, physicochemical properties, spectral characteristics, and elemental analysis data for compounds **3**—**7**, **9**—**15**, and **18**—**27**

Compound	τ/h	T/°C (solvent)	M.p./°C [b.p./°C] (p/Torr)	Yield (%)	Found / Calculated (%) C	H	Molecular formula	δ ^{19}F ($J_{F,F}$/Hz)*	δ ^{1}H ($J_{H,H}$/Hz)*
3	5	10—20	35—37	72	31.26 31.11	1.87 1.85	$C_7H_5F_7OS$	−20.2 (m, 3 F, CF_3); −19.5 (m, 3 F, CF_3); −9.4 (m, 1 F, CF)	2.32 (s, 3 H, Me); 3.89 (s, 2 H, CH_2)
4	10	10—20	49—51	70	43.21 43.37	2.06 2.11	$C_{12}H_7F_7OS$	−22.2 (m, 3 F, CF_3); −21.9 (m, 3 F, CF_3); −14.8 (m, 1 F, CF)	5.11 (s, 2 H, CH_2); 7.55 (m, 2 H); 7.69 (m, 1 H); 8.02 (m, 2 H)
5	20	10—20	[78—80] (2)	65	36.38 36.49	2.39 2.36	$C_9H_7F_7OS$	−21.0 (m, 3 F, CF_3); −19.9 (m, 3 F, CF_3); −10.4 (m, 1 F, CF)	1.98 (m, 2 H); 2.20 (m, 1 H); 2.37 (m, 2 H); 2.60 (m, 1 H); 3.87 (t, 1 H, CHS, J = 6)
6	5	−10—0	—	61	34.75 34.62	2.30 2.24	$C_9H_7F_7O_2S$	−20.1 (m, 3 F, CF_3); −19.2 (m, 3 F, CF_3); −8.6 (m, 1 F, CF)	2.40 (s, 6 H, 2 Me); 17.4 (s, 1 H, OH)
7	5	−10—0	—	58	44.71 44.55	2.66 2.72	$C_{15}H_{11}F_7O_3S$	−20.0 (m, 3 F, CF_3); −19.3 (m, 3 F, CF_3); −8.4 (m, 1 F, CF)	1.40 (t, 3 H, Me, J = 7); 4.43 (q, 2 H, CH_2, J = 7); 7.50 (m, 5 H, Ph); 14.2 (s, 1 H, OH)

(*to be continued*)

Table 1 (*Continued*)

Compound	τ/h	T/°C (solvent)	M.p./°C [b.p./°C] (p/Torr)	Yield (%)	Found / Calculated (%) C	H	Molecular formula	δ ^{19}F ($J_{F,F}$/Hz)*	δ ^{1}H ($J_{H,H}$/Hz)*
9	10	10—20	[120—125] (3)	67	41.82 41.67	4.11 4.17	$C_{10}H_{12}F_4O_3S$	−22.5 (d, 3 F, CF_3, J = 30); −19.0 (q, 1 F, CF, J = 30)	1.10 (t, 3 H, Me, J = 7.0); 1.53 (d, 3 H, Me, J = 7.5); 2.61 (q, 2 H, CH_2, J = 7.0); 3.82 (s, 3 H, MeO); 4.27 (q, 1 H, CH, J = 7.5)
10	5	10—20	120—122	83	48.54 48.45	3.07 3.11	$C_{13}H_{10}F_4O_3S$	−22.9 (d, 3 F, CF_3, J = 30); −19.4 (q, 1 F, CF, J = 30)	3.85 (s, 3 H, MeO); 4.50 (s, 2 H, CH_2); 7.54 (m, 2 H); 7.69 (m, 1 H); 8.00 (m, 2 H)
11	20	10—20	[130—133] (3)	64	41.99 41.96	3.55 3.50	$C_{10}H_{10}F_4O_3S$	−23.0 (d, 3 F, CF_3, J = 30); −17.6 (q, 1 F, CF, J = 30)	1.98 (m, 2 H); 2.30 (m, 3 H); 2.55 (m, 1 H); 3.85 (m, 4 H, MeO and CHS)
12	5	−10—0	49—51	82	39.80 39.74	3.26 3.31	$C_{10}H_{10}F_4O_4S$	−23.5 (d, 3 F, CF_3, J = 30); −18.2 (q, 1 F, CF, J = 30)	2.35 (s, 6 H, 2 Me); 4.85 (s, 3 H, MeO); 17.35 (s, 1 H, OH)
13	5	−10—0	—	63	49.53 49.45	3.26 3.30	$C_{13}H_{12}F_4O_4S$	−23.1 (d, 3 F, CF_3, J = 30); −18.5 (q, 1 F, CF, J = 30)	2.48 (s, 3 H, Me); 3.80 (s, 3 H, MeO); 7.50 (m, 5 H, Ph); 17.50 (s, 1 H, OH)
14	50	70	76—78	51	29.37 29.27	1.05 0.98	$C_{10}H_4F_{10}O_4S$	−20.0 (m, 3 F, CF_3); −14.5 (m, 1 F, CF); −7.9 (m, 6 F, 2 CF_3)	3.90 (s, 3 H, MeO); 17.5 (s, 1 H, OH)
15	20	70	43—45	68	32.35 32.26	1.82 1.88	$C_{10}H_7F_7O_5S$	−20.5 (d, 3 F, CF_3, J = 30); −15.2 (q, 1 F, CF, J = 30); −11.3 (s, 3 F, CF_3)	1.32 (t, 3 H, Me, J = 7.0); 3.85 (s, 3 H, MeO); 4.40 (q, 2 H, CH_2, J = 7.0); 14.2 (s, 1 H, OH)
18	5	61 ($CHCl_3$)	65—67	76	46.27 46.15	1.96 1.92	$C_{12}H_6F_6OS$	−22.0 (m, 3 F, CF_3); −21.0 (m, 3 F, CF_3)	7.48 (m, 3 H); 7.52 (s, 1 H, CH); 7.70 (m, 2 H)
19	10	20 (ether)	76—78	84	46.94 46.88	2.56 2.60	$C_{13}H_{10}F_6O_3S$	−22.3 (m, 3 F, CF_3); −21.1 (m, 3 F, CF_3)	1.28 (t, 3 H, Me, J = 7.0); 4.25 (q, 2 H, CH_2, J = 7.0); 7.52 (m, 3 H); 7.85 (m, 2 H)
20	10	20 (ether)	39—41	77	37.38 37.27	2.43 2.48	$C_{10}H_8F_6O_3S$	−22.1 (m, 3 F, CF_3); −21.2 (m, 3 F, CF_3)	1.32 (t, 3 H, Me, J = 7.0); 2.57 (s, 3 H, Me); 4.30 (q, 2 H, CH_2, J = 7.0)
21	5	61 ($CHCl_3$)	134—136	89	51.77 51.66	2.91 2.98	$C_{13}H_9F_3O_3S$	−23.5 (s, CF_3)	3.87 (s, 3 H, MeO); 6.70 (s, 1 H, CH); 7.45 (m, 3 H); 7.69 (m, 2 H)
22	10	20 (ether)	80—82	79	42.67 42.55	3.14 3.19	$C_{10}H_9F_3O_4S$	−21.2 (s, CF_3)	2.45 (s, 3 H, Me); 2.55 (s, 3 H, Me); 3.85 (s, 3 H, MeO)
23	15	81 (MeCN)	49—51	56	52.46 52.33	3.23 3.20	$C_{15}H_{11}F_3O_4S$	−21.6 (s, CF_3)	2.25 (s, 3 H, Me); 3.90 (s, 3 H, MeO); 7.60 (m, 5 H, Ph)
24	10	20 (ether)	88—90	60	30.84 30.77	0.81 0.77	$C_{10}H_3F_9O_4S$	−23.5 (s, 3 F, CF_3); −17.7 and −13.0 (s, 3 F, CF_3, ratio 2 : 1); −5.5 and 5.2 (s, 3 F, CF_3, ratio 1 : 2)	4.0 (s, 3 H, MeO)
25	10	20 (ether)	53—55	72	36.18 36.07	2.14 2.19	$C_{11}H_8F_6O_5S$	−21.3 (s, 3 F, CF_3); −15.3 (s, 3 F, CF_3)	1.38 (t, 3 H, Me, J = 7.0); 3.90 (s, 3 H, MeO); 4.41 (q, 2 H, CH_2, J = 7.0)
26	10	20 (ether)	82—84	73	42.40 42.31	3.47 3.53	$C_{11}H_{11}F_3O_5S$	−20.9 (s, CF_3)	1.35 (t, 3 H, Me, J = 7.0); 2.58 (s, 3 H, Me); 3.87 (s, 3 H, MeO); 4.31 (q, 2 H, CH_2, J = 7.0)
27	10	20 (ether)	90—92	71	51.45 51.34	3.44 3.48	$C_{16}H_{13}F_3O_5S$	−21.1 (s, CF_3)	1.30 (t, 3 H, Me, J = 7.0); 3.87 (s, 3 H, MeO); 4.32 (q, 2 H, CH_2, J =7.0); 7.50 (m, 3 H); 7.90 (m, 2 H)

* In $CDCl_3$ for **3**, **5**—**7**, **9**—**15**, and **21**—**27** and in DMSO-d_6 for **4** and **18**—**20**.

2 (0.01 mol) and a carbonyl compound (0.01 mol) was stirred at a required temperature until evolution of hydrogen chloride ceased. Low-boiling substances were removed *in vacuo* (10 Torr), and the residue was crystallized from hexane or fractionated. This procedure was used to obtain (1,3,3,3-tetrafluoro-2-trifluoromethylpropenylthio)acetone (**3**), 2-(1,3,3,3-tetrafluoro-2-trifluoromethylpropenylthio)acetophenone (**4**), 2-(1,3,3,3-tetrafluoro-2-trifluoromethylpropenylthio)cyclopentanone (**5**), 3-(1,3,3,3-tetrafluoro-2-trifluoromethylpropenylthio)pentane-2,4-dione (**6**), ethyl 2-(1,3,3,3-tetrafluoro-2-trifluoromethylpropenylthio)benzoylacetate (**7**), 2-(1,3,3,3-tetrafluoro-2-methoxycarbonylpropenylthio)pentan-3-one (**9**), 2-(1,3,3,3-tetrafluoro-2-methoxycarbonylpropenylthio)acetophenone (**10**), 2-(1,3,3,3-tetrafluoro-2-methoxycarbonylpropenylthio)cyclopentanone (**11**), 3-(1,3,3,3-tetrafluoro-2-methoxycarbonylpropenylthio)pentane-2,4-dione (**12**), 3-benzoyl-3-(1,3,3,3-tetrafluoro-2-methoxycarbonylpropenylthio)acetone (**13**), 1,1,1,5,5,5-hexafluoro-3-(1,3,3,3-tetrafluoro-2-methoxycarbonylpropenylthio)pentane-2,4-dione (**14**), and ethyl 2-(1,3,3,3-tetrafluoro-2-methoxycarbonylpropenylthio)-4,4,4-trifluoroacetoacetate (**15**).

Synthesis of 2-polyfluoroalkylidene-1,3-oxathioles (general procedure). A solution of $BF_3 \cdot NEt_3$ (0.02 mol) in 20 mL of an appropriate solvent was added with stirring to a solution of (polyfluoroalkenylthio)alkyl ketone (0.01 mol) in 10 mL of the same solvent. The reaction mixture was kept at a required temperature to completion of the reaction and washed with 5% HCl (2×50 mL). The organic layer was separated and dried with Na_2SO_4, the solvent was removed *in vacuo*, and the residue was recrystallized from hexane. Compounds **20**, **26**, and **27** were synthesized without isolation of ketones **8**, **16**, and **17**. This procedure was used to obtain 2-hexafluoroisopropylidene-5-phenyl-1,3-oxathiole (**18**), 4-ethoxycarbonyl-2-hexafluoroisopropylidene-5-phenyl-1,3-oxathiole (**19**), 4-ethoxycarbonyl-2-hexafluoroisopropylidene-5-methyl-1,3-oxathiole (**20**), 2-(2,2,2-trifluoro-1-methoxycarbonylethylidene)-5-phenyl-1,3-oxathiole (**21**), 4-acetyl-2-(2,2,2-trifluoro-1-methoxycarbonylethylidene)-5-methyl-1,3-oxathiole (**22**), 4-trifluoroacetyl-2-(2,2,2-trifluoro-1-methoxycarbonylethylidene)-5-trifluoromethyl-1,3-oxathiole (**24**), 4-ethoxycarbonyl-2-(2,2,2-trifluoro-1-methoxycarbonylethylidene)-5-trifluoromethyl-1,3-oxathiole (**25**), 4-ethoxycarbonyl-5-methyl-2-(2,2,2-trifluoro-1-methoxycarbonylethylidene)-1,3-oxathiole (**26**), and 4-ethoxycarbonyl-5-phenyl-2-(2,2,2-trifluoro-1-methoxycarbonylethylidene)-1,3-oxathiole (**27**).

4-Acetyl-5-phenyl-2-(2,2,2-trifluoro-1-methoxycarbonylethylidene)-1,3-oxathiole (23). A solution of sulfide **13** (0.01 mol) in 30 mL of MeCN was refluxed until evolution of HF ceased. The solvent was removed *in vacuo*, and the residue was recrystallized from hexane.

References

1. A. Yu. Sizov, A. F. Kolomiets, and A. V. Fokin, *Usp. Khim.*, 1992, **61**, 940 [*Russ. Chem. Rev.*, 1992, **61** (Engl. Transl.)].
2. R. A. Bekker, L. A. Rozov, and V. Ya. Popkova, *Izv. Akad. Nauk SSSR, Ser. Khim.*, 1983, 2575 [*Bull. Acad. Sci. USSR, Div. Chem. Sci.*, 1983, **32**, 2317 (Engl. Transl.)].
3. R. A. Bekker and V. Ya. Popkova, *Izv. Akad. Nauk SSSR, Ser. Khim.*, 1982, 1123 [*Bull. Acad. Sci. USSR, Div. Chem. Sci.*, 1982, **31** (Engl. Transl.)].

Received January 20, 2000;
in revised form May 4, 2000