Methoxycarbonyltrifluoromethylthioketene

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A new method was developed for the synthesis of methoxycarbonyltrifluoromethylthioketene by thermal cleavage of *tert*-butyl 1,3,3,3-tetrafluoro-2-methoxycarbonylpropenyl sulfide in the presence of P_2O_5. This thioketene was demonstrated to exhibit high reactivity in reactions with nucleophiles as well as in ene and diene syntheses.

Key words: thioketenes, *tert*-butyl polyfluoroalkenyl sulfides, methoxycarbonyltrifluoromethylthioketene, ene reactions, [4+2]-cycloaddition.

Thioketenes exhibit high reactivity and, as a consequence, lability. The first stable representative of this class of compounds, *viz.*, bis(trifluoromethyl)thioketene, was synthesized and characterized in 1966.[1] Its reactions with usual nucleophilic reagents proceed with retention of the thiocarbonyl group, whereas reactions with various unsaturated compounds either afford products of the ene reaction or lead to cycloaddition with its participation.[2—4] Later on, some other thioketenes were also synthesized. Their stability is provided primarily by the shielding effect of bulky substituents (for example, bis(*tert*-butyl)thioketene).[5]

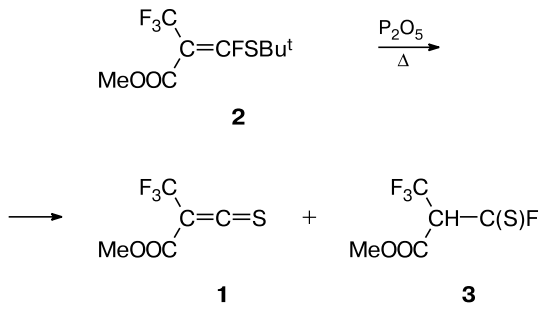
The aim of the present study was to synthesize previously unknown stable fluorine-containing thioketene, *viz.*, methoxycarbonyltrifluoromethylthioketene (**1**), and study its properties.

Results and Discussion

It is evident that the known procedure for the synthesis of bis(trifluoromethyl)thioketene[2] by pyrolysis of the corresponding dimer having the 1,3-dithiethane structure at 650—750 °C is unsuitable for the preparation of thioketene **1** containing the methoxycarbonyl fragment, which is labile under these temperature conditions. Hence, we examined a new approach to the synthesis of fluorine-containing thioketenes based on the cleavage of *tert*-butyl polyfluoroalkenyl sulfides with P_2O_5. The procedure for the preparation of the latter sulfides has been described earlier.[6]

It appeared that thermal decomposition of *tert*-butyl 1,3,3,3-tetrafluoro-2-methoxycarbonylpropenyl sulfide (**2**) in the presence of P_2O_5 at 180—200 °C afforded a mixture of thioketene **1** and α-H-α-methoxycarbonyltrifluorothionopropionyl fluoride (**3**) (3 : 2 ratio) and was accompanied by elimination of isobutene and hydrogen fluoride (Scheme 1).

Scheme 1



Fractionation of the resulting mixture over silica gel was demonstrated to substantially decrease the content of acid fluoride **3**. After triple distillation, thioketene **1** was isolated in the individual form. We cannot unambiguously interpret this fact, which could be a consequence of either dehydrofluorination of acid fluoride **3** to yield the target thioketene **1** or its binding on silica gel as a result of some other transformations. An attempt to use NaF for this purpose failed, and the composition of the mixture remained unchanged.

Under analogous conditions, *tert*-butyl perfluoroisobutenyl sulfide (**4a**) and benzyl perfluoroisobutenyl sulfide (**4b**) generated exclusively α-H-hexafluorothionoisobutyryl fluoride (**5**) in good yields (Scheme 2).

Earlier,[7] acid fluoride **5** has been prepared by acidic cleavage of sulfide **4b** by HSO_3F. It has been postulated that the reaction proceeded throught the intermediate formation of enethiol, which was isomerized into a more stable thiocarbonyl derivative through the 1,3-prototropic

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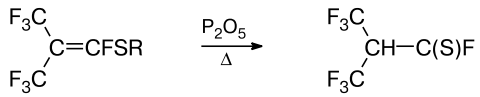
Scheme 2



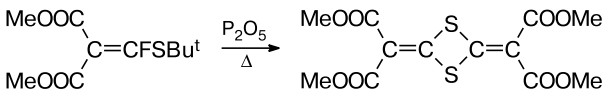
4a,b **5**

R = Bu^t (**a**), Bn (**b**)

shift. Attempts to transform acid fluoride **5** into bis(trifluoromethyl)thioketene by dehydrofluorination failed, because **5** appeared to be resistant to fractionation both over NaF and silica gel.

In turn, heating of *tert*-butyl 1-fluorovinyl-2,2-bis(methoxycarbonyl) sulfide (**6**) with P_2O_5 afforded the dimer of the corresponding thioketene **7** as the only product in low yield (Scheme 3). The reaction was accompanied by destruction resulting in resinification and gas formation (apparently, due to decarboxylation).

Scheme 3

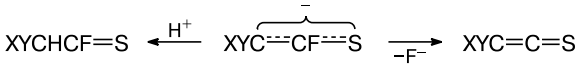


6 **7**

Taking into account these substantial differences in the results of the reactions of such close structural analogs as sulfides **2**, **4**, and **6**, it can be stated that the nature of β-substituents in the alkenyl group has a decisive effect on the direction of the reaction.

The initial step of these reactions may involve either the insertion of the phosphoric anhydride at the Bu^t—S bond analogously to reactions of this anhydride with ethers[8] or protonation of the S atom followed by the formation of enethiols analogously to the cleavage of alkyl polyfluoroalkenyl sulfides by protic acids.[7] In the latter case, the process can be promoted by impurities of polyphosphoric acids and then proceed autocatalytically. For both possible alternatives, mesomeric anionic intermediates should be assumed as direct precursors of thioacyl fluorides and thioketenes.

The further pathway of stabilization of such anions (either protonation or elimination of the fluoride ion) is determined primarily by their basicity, which, in turn, depends on the electronic and steric effects of the substituents.



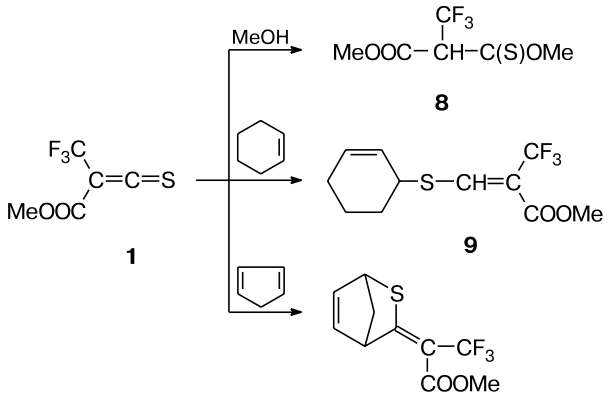
Of two possible pathways of stabilization, only protonation takes place in the case of the most basic of these substituents, *viz.*, of the perfluoroisobutenylthiolate ion ($X = Y = CF_3$). In contrast, elimination of the fluoride ion occurs in the case of the least basic substituent (X = Y = COOMe). In the intermediate case ($X = CF_3$, Y = COOMe), both processes occur competitively to give a mixture of products.

Attempts to synthesize cyano-containing thioketenes under analogous conditions based on *tert*-butyl 2-cyano-1,3,3,3-tetrafluoropropenyl and *tert*-butyl 2-cyano-1,2-difluorovinyl sulfides were unsuccessful and resulted only in resinification.

Thioketene **1** is a storage-stable bright-orange liquid, which can be distilled *in vacuo* without decomposition. Its structure was supported by the ^{19}F NMR spectrum, which has a singlet of the trifluoromethyl group at the double bond (δ 20.4), and the IR spectrum, which shows a signal characteristic of thioketenes ($\nu = 1780\ cm^{-1}$). In addition, the structure of **1** was confirmed by chemical transformations.

Thus, thioketene **1** readily added methanol at the C=C bond to yield ester **8**. The reactions with cyclohexene and cyclopentadiene gave rise to the corresponding products of the ene reaction, *viz.*, sulfide **9** and [4+2]-cycloadduct **10** (Scheme 4). The reaction conditions were analogous to those described earlier for bis(trifluoromethyl)thioketene.[2–4]

Scheme 4



8

1 **9**

10

To summarize, we synthesized methoxycarbonyltrifluoromethylthioketene (**1**) as the second representative of stable fluorine-containing thioketenes. However, this reaction cannot be used as the general procedure. Under analogous conditions, other alkyl polyfluoroalkenyl sulfides produce either acid fluorides of the corresponding thionic acids or dimerization and resinification products.

Experimental

The ^{19}F NMR spectra were recorded on a Bruker AC-200F spectrometer (188.31 MHz). The ^1H NMR spectra were mea-

sured on a Bruker AC-300SF instrument (300.13 MHz). The chemical shifts (δ) are given in the δ scale relative to CF_3COOH (^{19}F, external standard) and Me_4Si (^1H, internal standard). The NMR spectra of compounds **1**, **3**, and **5** were recorded for samples sealed in glass inserts without a solvent. The NMR spectra of all other compounds were measured in solutions in DMSO-d_6 or $CDCl_3$. The mass spectra (EI, 70 eV) were obtained on an HP 5890 gas chromatograph equipped with an HP 5972 mass-selective detector. The IR spectra were recorded on a Perkin—Elmer 1720X instrument in CCl_4.

Methoxycarbonyltrifluoromethylthioketene (1). A mixture of *tert*-butyl 1,3,3,3-tetrafluoro-2-methoxycarbonylpropenyl sulfide (**2**) (7.8 g, 30 mmol) and P_2O_5 (12.8 g, 90 mmol) was heated at 180—200 °C for 10 min. Then volatile products were distilled off under gradually increased vacuum (to 10 Torr), the temperature of the reaction mixture being maintained at 180—200 °C. A mixture of thioketene **1** and α-H-α-methoxycarbonyltrifluorothionopropionyl fluoride (**3**) was obtained in a yield of 2.3 g (3 : 2 ratio). The ^{19}F NMR spectrum of compound **3**, δ: 13.0 (m, 3 F, CF_3); 157.0 (m, 1 F, C(S)F). After triple fractionation of the resulting mixture over silica gel (1.0 g), thioketene **1** was obtained in a yield of 1.1 g (20%), b.p. 65—68 °C (30 Torr). Found (%): C, 32.43; H, 1.60. $C_5H_3F_3O_2S$. Calculated (%): C, 32.61; H, 1.63. ^1H NMR, δ: 3.86 (s, OMe). ^{19}F NMR, δ: 20.4 (s, CF_3). IR, ν/cm^{-1}: 1780 (C=C=S); 1710 (C=O).

2-Hydrohexafluorothionoisobutyryl fluoride (5). A mixture of *tert*-butyl 1,3,3,3-tetrafluoro-2-trifluoromethylpropenyl sulfide (**4a**) (5.4 g, 20 mmol) and P_2O_5 (14.2 g, 100 mmol) was heated to 200 °C, and the distilled products were collected into a cooled receiver. Repeated distillation afforded acid fluoride **5** in a yield of 2.4 g (56%), b.p. 42—43 °C (*cf.* lit. data[9]). ^1H NMR, δ: 4.52 (sept, 1 H, $CH(CF_3)_2$, J = 7 Hz). ^{19}F NMR, δ: 11.2 (t, 6 F, 2 CF_3, J = 7 Hz); 117.5 (m, 1 F, C(S)F).

2,4-Bis[bis(methoxycarbonyl)methylidene]-1,3-dithiethane (7). A mixture of *tert*-butyl 1-fluorovinyl-2,2-bis(methoxycarbonyl) sulfide (**6**) (7.5 g, 30 mmol) and P_2O_5 (12.8 g, 90 mmol) was heated *in vacuo* (10 Torr) to 200 °C and the distilled products were collected. The distillate crystallized, after which it was washed with hexane, filtered off, and recrystallized from dioxane. Dithiethane **7** was obtained in a yield of 0.6 g (11.5%), m.p. 224—225 °C. Found (%): C, 41.07; H, 3.32. $C_{12}H_{12}O_8S_2$. Calculated (%): C, 41.38; H, 3.45. MS, m/z: 348 $[M]^+$. ^1H NMR (DMSO-d_6), δ: 3.92 (s, OMe).

Methyl 3,3,3-trifluoro-2-methoxycarbonylthionopropionate (8). Thioketene **1** (1.8 g, 10 mmol) was added dropwise with stirring to MeOH (5 mL). The reaction mixture was kept at 30 min, poured into water, and extracted with Et_2O. The organic layer was separated, dried over Na_2SO_4, and fractionated. Ester **8** was obtained in a yield of 1.5 g (71%), b.p. 39—40 °C (3 Torr). Found (%): C, 33.47; H, 3.20. $C_6H_7F_3O_3S$. Calculated (%): C, 33.33; H, 3.24. MS, m/z: 216 $[M]^+$. ^1H NMR (DMSO-d_6), δ: 3.77 (s, 3 H, OMe); 4.17 (s, 3 H, OMe); 5.46 (q, 1 H, CH, J = 9 Hz).

Cyclohexen-2-yl 3,3,3-trifluoro-2-methoxycarbonylprop-1-en-1-yl sulfide (9). Thioketene **1** (1.8 g, 10 mmol) was added dropwise with stirring to cyclohexene (1 g, 12 mmol) at 5—10 °C. The reaction mixture was kept at 20 °C for 15 h and then fractionated. Sulfide **9** (mixture of the *Z* and *E* isomers) was obtained in a yield of 1.1 g (42%), b.p. 121—123 °C (3 Torr). Found (%): C, 49.80; H, 4.95. $C_{11}H_{13}F_3O_2S$. Calculated (%): C, 49.62; H, 4.89. ^{19}F NMR (DMSO-d_6), δ: 15.7 and 19.3 (both s, CF_3, 2 : 3 isomer ratio). ^1H NMR (DMSO-d_6), δ: 1.68—2.13 (m, 6 H, 3 CH_2); 3.83 (m, 4 H, OMe + CHS); 5.69 and 6.02 (both m, 1 H each, —CH=CH—); 8.02 and 8.32 (both s, 1 H, SCH=C, 2 : 3 isomer ratio).

3-(1-Methoxycarbonyltrifluoroethylidene)-2-thiabicyclo[2.2.1]hept-5-ene (10). Thioketene **1** (1.8 g, 10 mmol) was added with stirring to a solution of cyclopentadiene (0.65 g, 10 mmol) in CH_2Cl_2 (5 mL) at 15—20 °C. The reaction mixture was kept for 3 h and then fractionated. Heptene **10** (mixture of the *Z* and *E* isomers) was obtained in a yield of 1.2 g (49%), b.p. 87—88 °C (3 Torr). Found (%): C, 48.12; H, 3.63. $C_{10}H_9F_3O_2S$. Calculated (%): C, 48.00; H, 3.60. MS, m/z: 250 $[M]^+$. ^{19}F NMR ($CDCl_3$), δ: 24.3 and 28.8 (both s, CF_3, 4 : 5 isomer ratio). ^1H NMR ($CDCl_3$), δ: 1.95 (m, 2 H, C(7)H_2); 4.40 and 4.48 (both s, 1 H, C(1)H, 5 : 4 isomer ratio); 4.81 and 4.87 (both s, 3 H, OMe, 5 : 4 isomer ratio); 4.70 and 5.05 (both s, 1 H, C(4)H, 5 : 4 isomer ratio); 6.24 and 6.63 (both m, 1 H each, C(5)H, C(6)H).

References

1. M. S. Raasch, *Chem. Commun.*, 1966, 577.
2. M. S. Raasch, *J. Org. Chem.*, 1970, **35**, 3470.
3. M. S. Raasch, *J. Org. Chem.*, 1972, **37**, 1347.
4. M. S. Raasch, *J. Org. Chem.*, 1978, **43**, 2500.
5. E. Schaumann and W. Walter, *Chem. Ber.*, 1974, **107**, 3562.
6. A. N. Kovregin, A. Yu. Sizov, and A. F. Ermolov, *Izv. Akad. Nauk, Ser. Khim.*, 2001, 1000 [*Russ. Chem. Bull., Int. Ed.*, 2001, **50**, 1044].
7. R. A. Bekker and V. Ya. Popkova, *Izv. Akad. Nauk SSSR, Ser. Khim.*, 1990, 1898 [*Bull. Acad. Sci. USSR, Div. Chem. Sci.*, 1990, **39**, 1725 (Engl. Transl.)].
8. D. Purdela and R. Vilceanu, *Chimia compuşilor organici ai fosforului şi ai acizilor lui* [*Chemistry of Organophosphorus Compounds*], Editura Academiei Republicii Socialiste România, 1965, 539 pp. (in Rumanian).
9. I. L. Knunyants, L. T. Lantseva, E. P. Lur´e, and Yu. V. Zeifman, *Izv. Akad. Nauk SSSR, Ser. Khim.*, 1977, 231 [*Bull. Acad. Sci. USSR, Div. Chem. Sci.*, 1977, **26** (Engl. Transl.)].

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