Heteroatom Chemistry
Volume 9, Number 2, 1998

1-(Alkylthio)-polyfluoroalkynes. Reactions with Mercaptans and Thermal Transformations

Yuri G. Shermolovich, Vadim M. Timoshenko, Rostislav Ya. Musyanovich, Mark I. Povolotsky, Vladimir V. Pirozhenko, and Leonid N. Markovsky*

Institut of Organic Chemistry, National Academy of Sciences, Murmanskaya str., 5 253660, yiv-94, Ukraine

Received 15 April 1997; revised 20 June 1997

ABSTRACT

1-(Alkylthio)difluoropropynes regioselectively add dialkylamines and mercaptans with formation of 1-(alkylthio)-2-dialkylamino(alkylthio)ethenes, which exist only in the form of one (presumably the trans isomer) geometrical isomer. Thermal transformation of 1-(alkylthio)difluoropropynes occurs at a temperature of under 100°C and leads to the formation of 2,4-bis(polyfluoroalkyl)-3-(alkylthio)thiophenes. © 1998 John Wiley & Sons, Inc.Heteroatom Chem 9:151–154, 1998

INTRODUCTION

The introduction of polyfluoroalkyl groups into acetylene molecules activates the C≡C bond. The result of this activation is a high reactivity to nucleophilic reagents [1] and the ability of the adducts to be transformed into fluorine-containing aromatic compounds [2] or polymers with unique properties [3] that can be obtained only with difficulty by another method. In this connection, the synthesis and investigation of the properties of fluorine-containing acetylenes, RfC≡C–X, with different functional groups at the *sp*-hybridized carbon atom, seem to be of possible value[4].

In developing these investigations, we have recently reported on a method of synthesis of 1-(alkylthio)polyfluoroacetylenes (**1a,d**) [5] that have been obtained by dehydrofluorination of 1,1-dihydro-(polyfluoroalkyl)sulfides (**2a,d**). Only one representative of fluorine-containing acetylene sulfides, 1-(phenylthio)trifluoropropyne, is known at the present time [6].

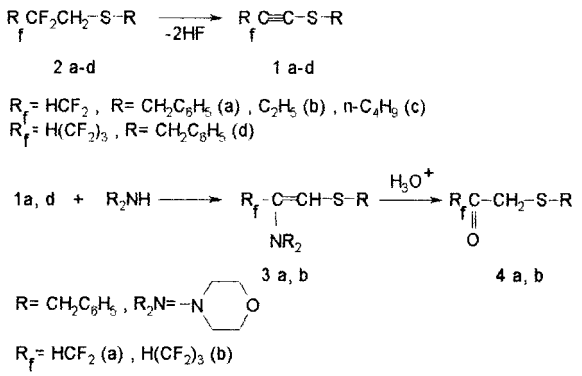
Recently, we have shown [5] that, due to the influence of a polyfluoroalkyl substituent, the compounds **1a,d** add morpholine readily. The reaction proceeds easily at room temperature and results in the formation of only one geometric isomer of an enamine (**3a,b**). These compounds are suitable starting materials for the synthesis of fluorine-containing ketones (**4a,b**), which, in turn, can be used for the synthesis of biologically active compounds [7].

It should be noted that the direction of morpholine addition to compounds **1a,d** is opposite to that of amine addition to trifluoropropyne [8] and thioacetylenes containing a phosphoryl group [9]. In both cases, the amino group adds to the carbon atom that is in the β position to the electron-with drawing substituent. In our work, we have investigated the addition of mercaptans to 1-(alkylthio)difluoropropynes.

Dedicated to Prof. William E. McEwen on the occasion of his seventy-fifth birthday.

*To whom correspondence should be addressed.

 CCC 1042-7163/98/020151-04



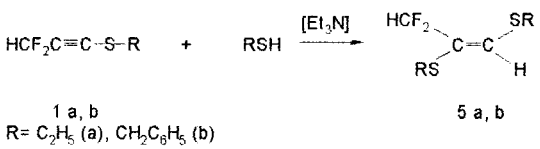
SCHEME 1

RESULTS AND DISCUSSION

We have established that ethyl mercaptan and benzyl mercapnan add to acetylene sulfides **1b** and **1a** at 20°C only in the presence of a catalytic amount of triethylamine. As in the case with morpholine [5], the reaction proceeds with high regioselectivity, with formation of only one of two possible geometric isomers (**5a,b**). This is confirmed by the presence of only one set of signals in the 1H and 19F NMR spectra of the compounds obtained (**5a,b**). According to known data [10], constants of the spin–spin interaction of H and F 22 for the *trans* isomer, containing the fragment CF–C=C–H, is equal to about 2 Hz, but, for the *cis* isomer, this constant is in the region of 0. Based on these data, we consider the compounds **5a,b** to have the transconfiguration, because, for these compounds, the constants of this spin–spin interaction are seen in the region of 1.8 Hz.

Additional evidence for the geometry of **5a,b** was obtained by the investigation of the ^{13}C NMR spectra of compound **5a**. The APT methods [11] for the investigation of compound **5a** confirm the fact that the carbon atom of the ethene fragment bonded to the hydrogen atom has the constant of spin–spin interaction with the fluorine nucleus of 8.6 Hz. Also, the corresponding constant J_{FC} for the second ethene carbon atom is 22.9 Hz. Such parameters of the constants of spin–spin interactions are only possible for the structure **5a**.

The finding of the direction of addition of morpholine and mercaptans to polyfluoroalkylacetylenes (**1a,b,d**) and the structures of the products of these reactions presented us with the possibility to interpret the structures of the products of thermal transformations of compounds **1** on a more firmly grounded basis.



SCHEME 2

Acetylenes that contain only polyfluoroalkyl groups undergo thermal transformations only at high temperature. Polyfluoro-containing cyclobutadienes or aromatic compounds are the products of such thermolysis [1,2]. Thermal transformations of acetylenes **1a,c** take place under heating up to 100°C. A mixture of compounds, from which thiophenes **6a,b** in about 30% yield are obtained by vacuum distillation, is formed.

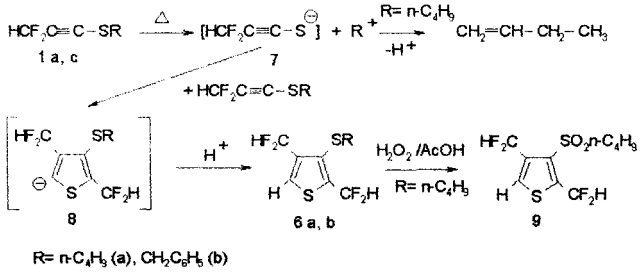
Thiophenes **6a,b** are stable red liquids. The structure of the compound **6b** is in accord with the data of ^{1}H, ^{19}F, ^{13}C NMR spectra, analytical analysis, and mass spectroscopy (see Experimental part). According to the NMR spectroscopic data, the thiophene fraction (**6a**) obtained by distillation contains approximately 15% of by-products. That is why the compound **6a** was identified by conversion to the sulfone **9**, which was isolated as a crystalline product after oxidation of the contaminated thiophene by hydrogen peroxide in acetic acid.

The scheme for the formation of compounds **6a,b** includes the dissociation of the S–C bond in the first stage of the reaction. The anion **7** is formed as a result of this process. The anion **7** reacts with a second molecule of acetylene (**1**) to give a cyclic carbanion (**8**), which, due to the addition of a proton, forms thiophene (**6**). The source of the proton is probably an alkyl cation, which is formed at the stage of acetylene dissociation and is transformed into the corresponding alkene. In the case of the compound **1c**, the evolution of butene is observed during thermolysis. This fact adds support to the proposed scheme for the thermolysis of thioacetylenes (**1**). Additional investigations of the thermolysis of acetylenes (**1**) are being carried out.

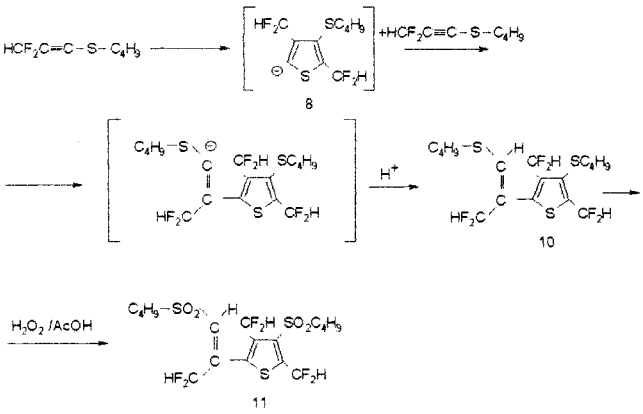
The thermolysis of acetylene (**1c**) in the presence of a catalytic quantity of KOH results in the formation of the thiophene **10** that was identified as the disulfone **11**.

Based on NMR spectroscopy, thiophene **6a** is formed under these conditions only as a by-product, in 5% yield. Probably, a cyclic carbanion formed (**8**) under the conditions of basic catalysis reacts with the starting acetylene (**1c**) to give the compound **10**. The addition of a proton to the cyclic carbanion (**8**) under these conditions does not take place readily, and the formation of the thiophene (**10**) is the major course of the reaction.

The structure of compound **11** is confirmed by



SCHEME 3



SCHEME 4

the data of analytical analysis and NMR spectroscopy. The constant of spin–spin interaction of the nucleus of the acyclic carbon atom bonded to hydrogen with the nuclei of the fluorine atoms ($^3J_{FCH}$), determined by the APT method, equals 8.0 Hz; that is a characteristic feature for compounds containing the F–C–C=C– fragment [12].

EXPERIMENTAL

Melting points were measured on a Nagema melting-point apparatus and are uncorrected. ^{1}H, ^{19}F, and ^{13}C NMR spectra were recorded on a Varian VXR (300 MHz) spectrometer as solutions in $CDCl_3$ with TMS and CCl_3F as internal standards. Mass spectra were obtained at 70 eV with the AMD-604 spectrometer.

Sulfides (**2a,c,d**) are described in Ref. [5]. The sulfide **2b** was obtained by the method described in Ref. [5]. Yield 70%, bp 118°C, ^{1}H NMR, δ 1.23 (3H, t, $^3J_{HH}$ = 7.5 Hz, CH_3), 2.63 (2H, q, $^3J_{HH}$ = 7.5 Hz, CH_2), 2.96 (2H, t, $^3J_{HF}$ = 16.5 Hz, CH_2), 5.94 (1H, tt, $^2J_{HF}$ = 53.7 Hz, $^3J_{HF}$ = 4.0 Hz, CF_2H); ^{19}F NMR, δ −138.09 (2F, d, $^2J_{FH}$ = 53.7 Hz, CF_2H), −116.10 (2F, t, $^3J_{FH}$ = 16.5 Hz, CF_2); found: S, 19.14%. $C_5H_8F_4S$ requires: S, 18.19%.

1-(Alkylthio)difluoropropynes (**1a,d**) are described in Refs. [5] and [7]. Compounds **1b, c** were obtained by the method similar to that given in Ref. [5]. 1-(Ethylthio)difluoropropyne (**1b**), yield 70%, bp 30°C (0.1 mm Hg). ^{1}H NMR, δ 1.36 (3H, t, $^3J_{HH}$ = 7.2 Hz, CH_3), 2.77 (2H, q, $^3J_{HH}$ = 7.2 Hz, CH_2), 6.20 (1H, t, $^2J_{HF}$ = 55.2 Hz, CF_2H); ^{19}F NMR, δ −104.91 (2F, d, $^2J_{FH}$ = 55.2 Hz, CF_2H); found: S, 22.98%. $C_5H_6F_2S$ requires: S, 23.55%.

1-*n*-(Butylthio)difluoropropyne (**1c**), yield 60%, bp 27–28°C (0.05 mm Hg). ^{1}H NMR, δ 0.91 (3H, t, $^3J_{HH}$ = 7.2 Hz, CH_3), 1.41 (2H, m, CH_2), 1.43 (2H, m, CH_2), 2.62 (2H, t, $^3J_{HH}$ = 7.2 Hz, CH_2), 6.09 (1H, t, $^2J_{FH}$ = 52.8 Hz, CF_2H), ^{19}F NMR, δ −104.97 (2F, d, $^2J_{FH}$ = 52.8 Hz, CF_2H); found: C, 50.92; H, 5.95; S, 19.55%. $C_7H_{10}F_2S$ requires: C, 51.19; H, 6.14; S, 19.53%.

1,2-Bis(alkylthio)-3,3-difluoropropynes (**5a,b**). The mixture of 0.01 mol of acetylene **1a** or **1b**, 0.01 mol of the corresponding mercaptan, and 0.02 g of triethylamine was stirred for 10 hours at room temperature and then distilled in vacuo. 1,2-Bis(benzylthio)-3,3-difluoropropene-1 (**5b**). Yield 55%, bp 130–135°, C (0.05 mm Hg). ^{1}H NMR, δ 3.74 (2H, s, CH_2), 3.81 (2H, s, CH_2), 5.68 (1H, t, $^1J_{HF}$ = 56.0 Hz, CHF_2), 6.98 (1H, t, $^3J_{HF}$ = 1.7 Hz, CH=), 7.17 (5H, m, C_6H_5); ^{19}F NMR, δ −110.43 (2F, dd, $^2J_{FH}$ = 56.0 Hz, $^3J_{FH}$ = 1.7 Hz, CF_2H); found: S, 19.21%; $C_{17}H_{16}F_2$ requires: S, 19.88%. 1,2-Bis(ethylthio)-3,3-difluoropropene-1 (**5a**). Yield 50%, bp 68–70°C (0.045 mm Hg). ^{1}H NMR, δ 1.19 (3H, t, $^3J_{HH}$ = 7.0 Hz, CH_3), 1.28 (3H, t, $^3J_{HH}$ = 7.0 Hz, CH_3), 2.73 (2H, q, $^3J_{HH}$ = 7.0 Hz, CH_2); 2.76 (2H, q, $^3J_{HH}$ = 7.0 Hz, CH_2), 6.03 (1H, t, $^2J_{HF}$ = 56.6 Hz, CHF_2), 7.52 (1H, t, $^3J_{HF}$ = 1.8 Hz, CH=); ^{19}F NMR, δ −109.84 (2F, dd, $^2J_{FH}$ = 56.6 Hz, $^4J_{FH}$ = 1.8 Hz, CF_2H); ^{13}C NMR, δ 14.61 (s, CH_3), 15.25 (s, CH_3), 27.29 (s, CH_2), 27.73 (s, CH_2), 114.71 (t, $^1J_{CF}$ = 239.5 Hz, CHF_2), 120.96 (t, $^2J_{CF}$ = 22.9 Hz, *C*-CF_2H), 143.91 (t, $^3J_{CF}$ = 8.6 Hz, CH=); found: S, 31.98%. $C_7H_{11}F_2S_2$ requires: S, 32.51%.

2,4-Bis(difluoromethyl)-3-(alkylthio)thiophenes (**6a,b**). A solution of 0.01 mol of the acetylene **1a** or **1c** in 5 mL of toluene was heated for 4 hours at 100–110°C and then distilled in vacuum. 2,4-Bis(difluoromethyl)-3-(benzylthio)thiophen (**6b**), yield 30%, bp 116–118°C (0.05 mm Hg). ^{1}H NMR, δ 3.84 (2H, s, CH_2), 6.57 (1H, t, $^2J_{HF}$ = 54.0 Hz, CHF_2), 6.71 (1H, t, $^2J_{HF}$ = 54.0 Hz, CHF_2), 7.10 (5H, m, C_6H_5), 7.60 (1H, s, CH=); ^{19}F NMR, δ −110.35 (2F, d, $^2J_{FH}$ = 54.0 Hz, CF_2H), −111.52 (2F, d, $^2J_{FH}$ = 54.0 Hz, CF_2H); found: S, 19.95%; m/z 306. $C_{13}Hl_0F_4S_2$ requires: S, 20.93%; M 306.33. 2,4-Bis(difluoromethyl)-3-*n*-(butylthio)thiophene (**6a**), yield 30%, bp

100–115°C (0.06 mm Hg). ^{1}H NMR, δ 0.99 (3H, $^3J_{HH}$ = 7.2 Hz, CH_2), 1.49 (2H, m, CH_2), 1.65 (2H, m, CH_2), 2.75 (2H, t, $^3J_{HH}$ = 7.8 Hz, CH_2), 6.81 (1H, t, $^2J_{HF}$ = 53.3 Hz, CHF_2), 6.98 (1H, t, $^2J_{HF}$ = 53.3, CHF_2), 7.74 (1H, S, CH=); ^{19}F NMR, δ −110.10 (2F, d, $^2J_{FH}$ = 53.3 Hz, CF_2H), −111.29 (2F, d, $^2J_{FH}$ = 53.3, CF_2H).

2,4-Bis(difluoromethyl)-3-(n-butylsulfonyl)thiophene (**9**). The mixture of 0.01 mol of thiophene (**6a**) and 7 mL of 30% hydrogen peroxide in 30 mL of acetic acid was stirred for 24 hours at room temperature and then poured into 150 mL of water. The oil that had formed was separated, washed with water (2 × 30 mL), and purified by recrystallization from hexane after it had solidified. Yield 70%, mp 67–68°C. ^{1}H NMR, δ 0.95 (3H, t, $^3J_{HH}$ = 7.2 Hz, CH_3), 1.45 (2H, m, CH_2), 1.61 (2H, m, CH_2), 3.27 (2H, t, $^3J_{HH}$ = 8.1 Hz, CH_2), 6.90 (1H, t, $^2J_{HF}$ = 54.0 Hz, CHF_2), 7.42 (1H, t, $^2J_{HF}$ = 54.0 Hz, CHF_2), 8.11 (1H, s, CH=); ^{19}F NMR, δ −110.68 (2F, d, $^2J_{FH}$ = 54.0 Hz, CF_2H), −111.52 (2F, d, $^2J_{FH}$ = 54.0 Hz, CF_2H); ^{13}C NMR, δ 13.39 (s, CH_3), 21.42 (s, CH_2), 24.66 (s, CH_2), 58.45 (s, CH_2), 109.10 (t, $^1J_{FC}$ = 238.2 Hz, CF_2H), 109.34 (t, $^1J_{FC}$ = 238.5 Hz, CF_2H), 132.66 (t, $^3J_{FC}$ = 6.9 Hz, CH=), 135.88 (tt, $^2J_{FC}$ = 27.1 Hz, $^3J_{FC}$ = 4.6 Hz, *C*–CF_2H), 136.59 (t, $^2J_{FC}$ = 25.6 Hz, *C*–CF_2H), 143.17 (t, $^3J_{FC}$ = 9.0 Hz, *C*–$SO_2C_4H_9$); found: C, 40.43; H, 3.97; S, 20.97%; m/z 304. $C_{10}H_{12}F_4O_2S_2$ requires: C, 39.47; H, 3.98; S, 21.07%; M 304.32.

2,4-Bis(difluoromethyl)-3-(n-butylsulfonyl)-5-[1-butylsulfonyl]-3,3-difluoro-2-propenyl]thiophene (**11**). A mixture of 0.02 mol of acetylene (**1c**) and 0.01 g of KOH in 5 mL of toluene was heated for 4 hours at 100–110°C and then distilled in vacuum. The fraction of bp 150–200°C (0.05 mm Hg) was collected. Hydrogen peroxide (10 mL, 30%) was added to the solution of this fraction in 40 mL of acetic acid, and the mixture was stirred for 24 hours at room temperature and then was poured into water (200 mL). The oil that had formed was washed with water (2 × 50 mL), dissolved in 15 mL of $CHCl_3$, and dried over Na_2SO_4. The solvent was evaporated in vacuo (0.05 mm Hg). Yield 30% Oil. ^{1}H NMR, δ 0.91 (6H, t, $^3J_{HH}$ = 7.4 Hz, CH_3), 1.42 (4H, m, CH_2), 1.80 (4H, m, CH_2), 3.10 (2H, t, $^3J_{HH}$ = 8.4 Hz, CH_2), 3.21 (2H, t, $^3J_{HH}$ = 7.8 Hz, CH_2), 6.81 (1H, s, CH=), 6.92 (1H, t, $^2J_{HF}$ = 53.3 Hz, CHF_2), 7.35 (1H, t, $^2J_{HF}$ = 53.3 Hz, CHF_2), 7.55 (1H, t, $^2J_{HF}$ = 53.0 Hz, CHF_2); ^{19}F NMR, δ −106.88 (2F, d, $^2J_{FH}$ = 53.3 Hz, CHF_2), −109.52 (2F, d, $^2J_{FH}$ = 53.3 Hz, CHF_2), −117.21 (2F, d, $^2J_{FH}$ = 53.0 Hz, CHF_2); ^{13}C NMR, δ 12.85 (s, CH_3), 20.88 (s, CH_2), 21.07 (s, CH_2), 21.14 (s, CH_2), 23.53 (s, CH_2), 55.01 (s, CH_2), 57.91 (s, CH_2), 106.74 (t, $^1J_{CF}$ = 240.5 Hz, CHF_2), 108.37 (t, $^1J_{CF}$ = 238.0 Hz, CHF_2), 109.22 (t, $^1J_{CF}$ = 239.1 Hz, CHF_2), 134.55 (t, $^2J_{CF}$ = 25.7 Hz, *C*–CF_2H), 135.38 (t, $^2J_{CF}$ = 27.7 Hz, *C*–CF_2H), 137.27 (t, $^2J_{CF}$ = 26.5 Hz, *C*–CF_2H), 138.83 (t, $^3J_{CF}$ = 8.0 Hz, CH=), 139.70 (s, C–S), 144.27 (t, $^3J_{CF}$ = 8.5 Hz, *C*–$SO_2C_4H_9$); found: S, 18.88%. $C_{17}H_{22}F_6O_4S_3$ requires: S, 19.22%.

REFERENCES

[1] M. G. Barlow, O. R. Taylor, *Fluorocarbon Relat. Chem., 3,* 1976, 49; E. S. Turbanova, A. A. Petrov, *Uspekhi Khimii* (in Russian), *60,* 1991, 1005.

[2] M. I. Bruce, W. R. Cullen: in P. Tarrant (ed): *The Chemistry of Fluorinated Acetylenes,* Fluorine Chem. Rev., Marcel Dekker, New York, vol. 4, pp. 79–118 (1969).

[3] H. Feuer, H. B. Hass, R. D. Lowrey, *J. Org. Chem., 25,* 1960, 2071.

[4] J. Froissarg, J. Greiner, R. Pastor, A. Cambon, *J. Fluor. Chem., 26,* 1984, 47; Y. Shen, J. Zheng, Y. Huang, *J. Fluor. Chem., 36,* 1987, 471.

[5] V. M. Timoshenko, V. V. Listvan, E. B. Rusanov, Yu.G. Shermolovich, L. N. Markovsky, *Zhur. Org. Khimii,* 1997, in press.

[6] A. L. Braga, J. V. Comasseto, N. Petragnani, *Tetrahedron Lett., 25,* 1984, 1111.

[7] Yu. G. Shermolovich, V. M. Timoshenko, V. V. Listvan, L. N. Markovsky, *Zhur. Org. Khimii,* 1997, in press.

[8] R. N. Haszeldine, *J. Chem. Soc.,* 1952, 3490.

[9] W. Hagens, H. T. J. Bos, J. F. Arens, *Recuel, 92,* 1973, 762.

[10] J. W. Emsley, J. Feeney, L. H. Sutcliffe: *High Resolution Nuclear Magnetic Resonance Spectroscopy,* Pergamon Press, New York, London, vol. 2 (1966).

[11] A. E. Derome: *Modern NMR Techniques for Chemical Research,* Pergamon Press, New York, London (1987).

[12] H.-O. Kalinowski, S. Berger, S. Braun: *^{13}C-NMR-Spektroskopie,* Georg Thieme Verlag, Stuttgart, New York (1984).