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N-Bis(methylthio)methylene-trifluoromethanesulfonylamide $CF_3SO_2N{=}C(SCH_3)_2$: new reagent for the preparation of *N*-trifluoromethylsulfonylimino carbonic and thiocarbonic acids derivatives

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Abstract

We developed the synthesis of $CF_3SO_2N{=}C(SCH_3)_2$: a new building block for the preparation of carbonic and thiocarbonic acids derivatives containing *N*-trifluoromethylsulfonylimino group.

Keywords: *N*-Trifluoromethylsulfonylimino derivatives; Ureas; Thioureas; Guanidines; Chloroformamidine

1. Introduction

In the previous work, we described the preparation of *N*-trifluoromethylsulfonylimino derivatives of aromatic carboxylic acids that showed drastic increase of acidity (up to 14.5 powers of 10) after exchange of the oxygen atom by the $=NSO_2CF_3$ group [1]. Such exchange commonly leads to compounds with unusual properties [2–5]. To the best of our knowledge, *N*-trifluoromethylsulfonylimino derivatives of carbonic and thiocarbonic acids are remain largely uninvestigated. The chemistry of *N*,*N*′-di-Boc- and *N*,*N*′-di-Cbz-*N*″-triflylguanidines were investigated by Goodman and coworkers [6]. Their reactions with amines are accompanied by the splitting of the $=NSO_2CF_3$ group [7–10]. Martinez et al. described unstable 2,3-bis(trifluoromethylsulfonyl)-1,1-dimethylisourea, $(CH_3)_2N{-}C(OTf){=}NTf$, which has been trapped with nucleophiles with the formation of corresponding *N*-trifluoromethylsulfonylimino derivatives [11].

In the present paper, we report a new method for the preparation of carbonic and thiocarbonic acids derivatives, urea, thiourea, and guanidine, containing the strong electron withdrawing group ($=NSO_2CF_3$) employing *N*-bis-(methylthio)methylene-trifluoromethanesulfonylamide as a new reagent.

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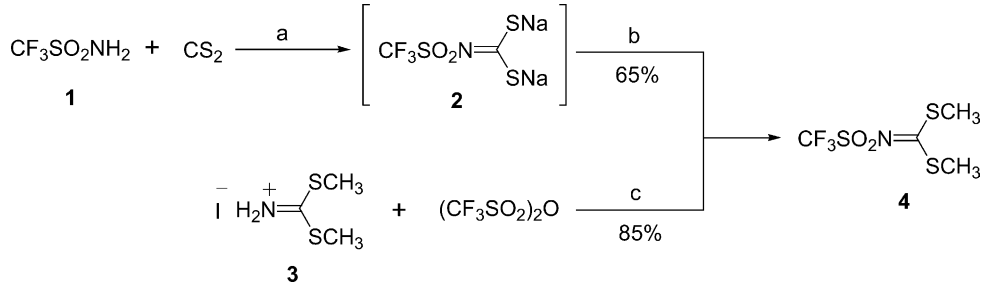
2. Results and discussion

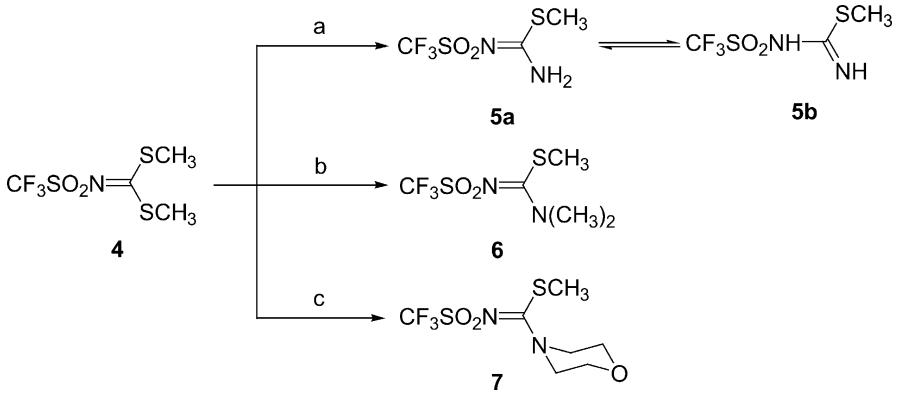
Despite the fact that the trifluoromethylsulfonic substituent strongly withdraws electrons from amino group (pK_a of $CF_3SO_2NH_2$ in water is 5.8 [12]), its disodium salt ($TfNNa_2$) reacts with carbon disulphide in DMF at 5 °C with the formation of red colored solution of the disodium salt of *N*-trifluoromethylsulfonyliminodithiocarbonic acid (**2**). Compound **4** was obtained after the alkylation of **2** with methyl iodide in 65% yield.

We were also able to prepare compound **4** using a different route. Thus, the reaction of the hydroiodide of *S*,*S*-dimethyliminodithiocarbonate (**3**) [13] with trifluoromethanesulfonic acid anhydride in the presence of Et_3N at mild conditions (−78 °C) gave *N*-trifluoromethylsulfonylimino dithiocarbonic acid derivative **4** in 85% yield (Scheme 1).

Dithiocarbonate **4** reacts readily with various nucleophiles. Thus, the reactions with primary and secondary amines are accompanied by the splitting of the mercapto group and formation of trifluoromethylsulfonylimino substituted *S*-methylthiourea derivatives (Scheme 2). Compound **5** was obtained in high yield (92%) after passing gaseous NH_3 through the solution of **4** in benzene at 60 °C. ^1H NMR spectroscopic investigations showed that compound **5** exists in the solution as a mixture of two tautomers: **5a** and **5b**. Reaction of compound **4** with dimethylamine hydrochloride and triethylamine in THF at −40 °C leads to the formation of isothiourea **6**. Morpholine reacts with



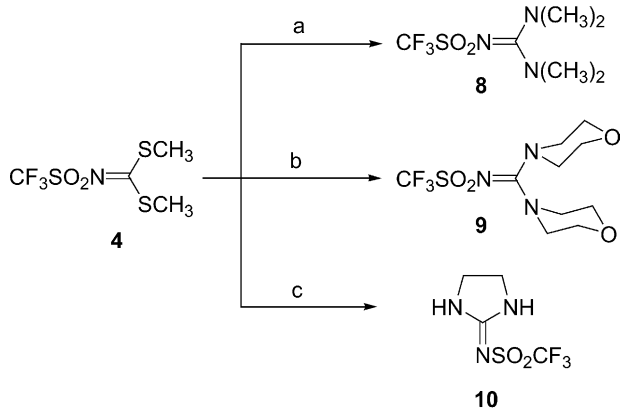
Scheme 1. Reagents and conditions (a) NaH (2 eq.), DMF, −5 °C; (b) CH_3I, DMF, 0–5 °C; (c) Et_3N, CH_2Cl_2, −78 °C.



Scheme 2. Reagents and conditions (a) NH_3, C_6H_6, 60 °C; (b) $(CH_3)_2N^+H_2Cl^-$, Et_3N, THF, −40 °C; (c) morpholine, C_6H_6, 50 °C.

dithiocarbonate **4** in benzene at 50 °C with the formation of compound **7**.

Reactions of compound **4** with amines at higher temperatures lead to the evolution of methylmercaptan and formation of *N*-trifluoromethylsulfonyl substituted derivatives of guanidine (Scheme 3). Compound **8** was obtained by the reaction of dithiocarbonate **4**, dimethylamine hydrochloride, and triethylamine in boiling THF. Guanidine **9** forms after heating of compound **4** with morpholine at 100 °C without any solvent. Dithiocarbonate **4** reacts with ethylenediamine in acetonitrile at 80 °C with the formation of compound **10**,



Scheme 3. Reagents and conditions (a) $(CH_3)_2N^+H_2Cl^-$ (2 eq.), Et_3N, THF, 70 °C; (b) morpholine (2 ml), 100 °C; (c) $H_2N(CH_2)_2NH_2$, CH_3CN, 80 °C.

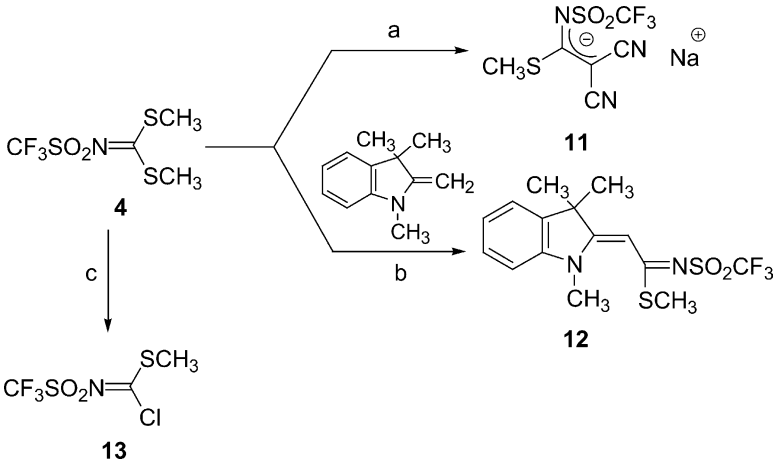
an analog of imidazolidone with oxygen atom instead of the $=NSO_2CF_3$ group.

The ^1H NMR spectrum of compound **10** in DMSO-d_6 shows a singlet at 3.6 ppm for the protons of CH_2 groups and a broad signal at 7.98 ppm (two NH groups). The ^{19}F NMR spectrum in DMSO-d_6 shows a singlet at −78.13 ppm for fluorine atoms of the CF_3 group.

We studied the reactions of dithiocarbonate **4** with C-nucleophiles, malonodinitrile and Fisher's base (Scheme 4). No reaction of malonodinitrile and reagent **4** was observed in boiling acetonitrile. However, its sodium salt reacts with **4** with the formation of compound **11**. The ^1H NMR spectrum of salt **11** shows a singlet for protons of the SCH_3 group, and the ^{19}F NMR spectrum shows a singlet for fluorine atoms of the CF_3 group. Reaction of dithiocarbonate **4** with Fisher's base takes place in boiling acetonitrile.

Dithiocarbonate **4** reacts with SO_2Cl_2 in dichloromethane at 20 °C with the evolution of sulfur dioxide and formation of *N*-(chloro-methylthio)methylene-trifluoromethylsulfonylamide (**13**) (Scheme 4). Chlorination of **4** with Cl_2 in dichloromethane at 20 °C gave *N*-trifluoromethylsulfonylisocyanodichloride [14,15], which, however, we were not able to separate by distillation from the by-products formed after the chlorination reactions of methylsulfenylchloride.

Compound **4** reacts even with such a weak nucleophile as $CF_3SO_2NH^-$. Thus, the reaction of **4** with the sodium salt of trifluoromethylsulfonylamide in dioxane at 80 °C leads to the evolution of methylmercaptan and formation of the sodium salt of *S*-methylthiourea (**14**) (Scheme 5).



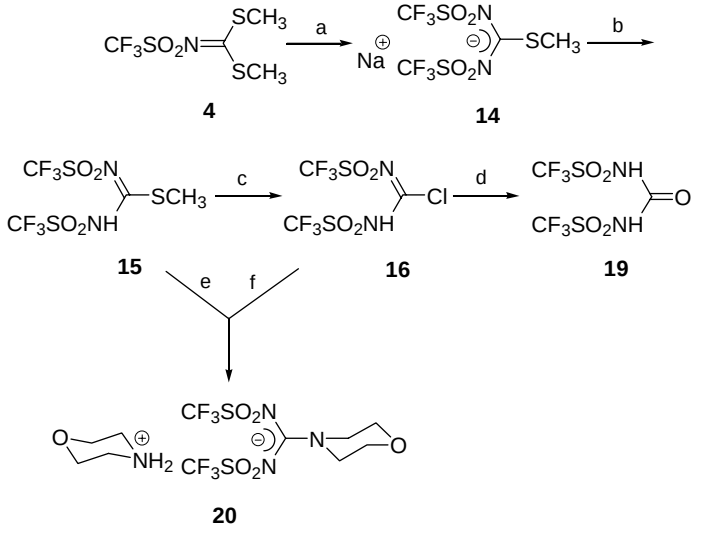
Scheme 4. Reagents and conditions (a) $H_2C(CN)_2$, NaH (2 eq.), CH_3CN, 0–80 °C; (b) CH_3CN, reflux; (c) SO_2Cl_2, CH_2Cl_2, 25 °C.

The ^{19}F NMR spectrum of salt **14** shows a singlet for the fluorine atoms of two CF_3 groups, which provides evidence of delocalization of the negative charge between the central carbon atom and two nitrogens. Passing of anhydrous hydrogen chloride through the suspension of salt **14** in CH_2Cl_2 gives *N*,*N*-bis(trifluoromethylsulfonyl)-*S*-methylthiourea (**15**) in high yield. The ^{19}F NMR spectrum of compound **15** in $CDCl_3$ shows two singlets for fluorine atoms of equal intensity (CF_3 groups) at −75.21 ppm (–NHTf), and −78.35 ppm (=NTf). In polar solvents, such as CH_2Cl_2, Me_2CO and Me_2SO, only one singlet for fluorine atoms of the two CF_3 groups was observed. This observation demonstrates fast migration of the proton between the two nitrogen atoms. Isothiourea **15** reacts with chlorine under mild conditions (−70 °C). As a reaction product we obtained chloroformamidine (**16**), a crystalline substance, highly sensitive to moisture in the air, forming *N*,*N*-bis(trifluoromethylsulfonyl)-urea (**19**) after complete hydrolysis (Scheme 5).

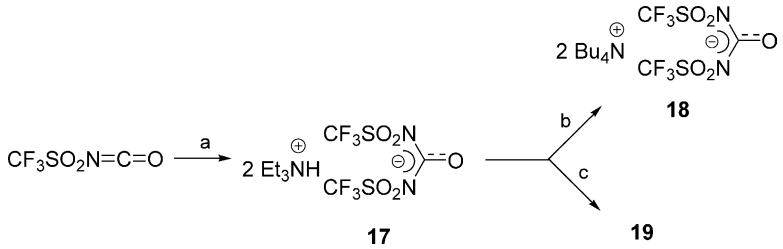
We were able to prepare compound **19** using a different route also, by the reaction of trifluoromethylsulfonylisocyanate [14–17] with trifluoromethanesulfamide in the presence of Et_3N. Passing an aqueous solution of the trimethylammonium salt of *N*,*N*-bis(trifluoromethylsulfonyl)urea (**17**) through a column with Dowex 50 WX8-200 gave *N*,*N*-bis-(trifluoromethylsulfonyl)urea (**19**) in good yield (Scheme 6).

The tetrabutylammonium salt of *N*,*N*′-bis(trifluoromethylsulfonyl)urea (**18**) was prepared by the reaction of an aqueous solution of the triethylammonium salt **17** with a solution of tetrabutylammonium hydroxide in methanol at 80 °C (Scheme 6).

Chloroformamidine **16** reacts with an excess of morpholine forming the morpholinium salt **20** (Scheme 5). We suggest, that the first stage of the reaction proceeds most likely via the formation of the morpholinium salt of chloroformamidine **16**, which reacts further by nucleophilic substitution of the chlorine atom with the morpholine



Scheme 5. Reagents and conditions (a) $CF_3SO_2NH_2$, NaH (1 eq.), THF, reflux; (b) HCl, CH_2Cl_2, 20 °C; (c) Cl_2 (3 eq.), CH_2Cl_2, −70 °C; (d) CH_3CN/H_2O, 20 °C; (e) morpholine (2 eq.), THF, reflux; (f) morpholine (3 eq.), THF −40 °C.



Scheme 6. Reagents and conditions (a) $CF_3SO_2NH_2$, Et_3N, CH_3CN, 20 °C; (b) Bu_4NOH, H_2O, 80 °C; (c) Dowex 50 WX8-200, H_2O, 20 °C.

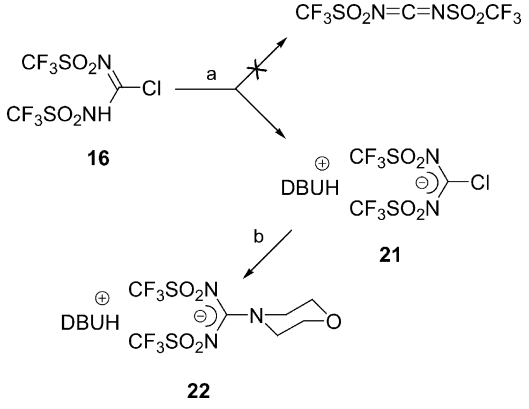
group. Compound **20** can also be obtained from isothiourea **15** and a two-fold excess of morpholine in boiling THF. Most likely the reaction proceeds via the same mechanism.

Interestingly, the reaction of chloroformamidine **16** and 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU) proceeds without hydrogen chloride evolution (Scheme 7). This fact could be explained taking into account that the chlorine atom has a high positive charge dues the influence of two electron withdrawing groups, which prevents its elimination as Cl^- anion.

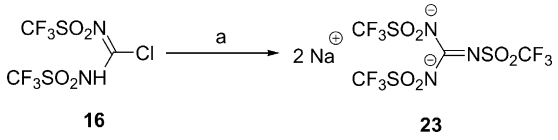
However, substitution of chlorine takes place after the reaction with morpholine and formation of guanidine derivative **22**.

Reaction of chloroformamidine **16** with disodium salt of amide $TfNNa_2$ takes place in THF at 20 °C. After work-up, the disodium salt of *N*,*N*′,*N*″,-tris(trifluoromethylsulfonyl)-guanidine was isolated in good yield (Scheme 8).

^{19}F NMR spectroscopic studies of guanidine **23** showed one singlet for the fluorine atoms of the CF_3 group. This observation indicates delocalization of the negative charge between three nitrogen atoms.



Scheme 7. Reagents and conditions (a) DBU, CH_2Cl_2, −40 °C; (b) morpholine (2 eq.), CH_2Cl_2, −25 °C.



Scheme 8. Reagents and conditions (a) $CF_3SO_2NNa_2$, THF, −50 °C.

In conclusion, we have described the synthesis of carbonic and thiocarbonic acids derivatives, urea, thiourea, and guanidine, containing the electron withdrawing $=NSO_2CF_3$ group instead of oxygen atoms, employing $CF_3SO_2N{=}C(SCH_3)_2$ as a new convenient electrophilic reagent.

3. Experimental

3.1. General

All chemicals were of reagent grade or were purified by standard methods before use. Benzene was distilled from sodium wire and stored in a bottle containing sodium wire. THF was freshly distilled from sodium/benzophenone. Acetonitrile and CH_2Cl_2 were distilled from P_2O_5 and CaH_2. TLC analyses were performed with silica gel Kieselgel 60 F/UV_{254} plates (Merck); spots were visualized with UV light. ^1H, ^{19}F and ^{13}C NMR spectra were recorded at 299.95, 282.2 and 75.43 MHz, respectively with a Varian VXR-300 spectrometer. Chemical shifts are given in ppm relative to Me_4Si and CCl_3F, respectively, as internal standards. Coupling constants are given in Hz. IR spectra were recorded with a VR-20 instrument (KBr or CH_2Cl_2). Melting points were determined in open capillaries and are uncorrected.

3.2. Preparative procedures

3.2.1. S,S-Dimethyliminodithiocarbonate hydroiodide (3) [13]

9.96 g (0.07 mol, 4.40 ml) of methyl iodide were added to a solution of 5.00 g (0.05 mol) of methyl dithiocarbamate [18] in 10 ml of acetonitrile. Reaction mixture was stirred at room temperature (25 °C) for 24 h. The precipitate was filtered off, washed with small amount of acetonitrile, and dried in vacuum. Yield: 10.67 g (92%), mp 137–139 °C. ^1H NMR (DMSO-d_6): δ 7.36 (s, 2H, $=NH_2^+$), 3.03 (s, 6H, $2SCH_3$).

3.2.2. N-Bis(methylthio)methylene-trifluoromethanesulfonylamide (4)

3.2.2.1. Method A. A solution of 3.00 g (0.02 mol) of trifluoromethanesulfamide in 10 ml of DMF was placed

in three-necked flask, and 1.76 g (0.04 mol) of NaH was added at −5 °C. The reaction mixture was stirred until hydrogen evolution had ceased. The resulting suspension of the disodium salt of trifluoromethanesulfamide was cooled to −10 °C, and 4 ml (0.06 mol) of carbon disulphide were added. Reaction mixture was stirred for 4 h at −10 °C, until a red solution formed. 8.58 g (0.06 mol) of methyl iodide were added dropwise, and the color of the solution turned yellow. The reaction mixture was allowed to warm up to 20 °C, stirred for an additional 12 h, mixed with water, and extracted with Et_2O (5 × 25 ml). Combined ether extracts were washed with water and dried over $MgSO_4$. Solvent was evaporated in vacuum, and the residue crystallized from pentane, resulting dithiocarbonate **4** (2.20 g, 65% yield).

3.2.2.2. Method B. 11.00 g (0.04 mol) of *S*,*S*-dimethyliminodithiocarbamate hydroiodide was placed into three-necked flask, and 15 ml of dichloromethane were added. The resulting suspension was cooled to −20 °C at inert gas (Ar) atmosphere, followed by the addition of 4.47 g (6.16 ml, 0.04 mol) of triethylamine. Reaction mixture was stirred for 15 min at −20 °C, and cooled to −78 °C. The second portion of triethylamine (0.04 mol) was added at this temperature, followed by the solution of 12.46 g (7.43 ml, 0.04 mol) of Tf_2O in 5 ml of dichloromethane. Resulting solution was stirred for 1 h at −78 °C, warmed slowly to room temperature (25 °C), and stirred for an additional 10 h. All volatiles were removed in vacuum, and the residue treated with 5% solution of Na_2SO_3. The precipitate was filtered off, dissolved in ether, and dried over $MgSO_4$. Ether was evaporated in vacuum resulting in compound **4** (9.50 g, 85% yield) as a colorless solid. Melting point 66–67 °C. ^{1}H NMR ($CDCl_3$): δ 2.64 (s, SCH_3). ^{13}C NMR ($CDCl_3$): δ 193.48, 119.07 (q, J = 320 Hz, CF_3), 16.88. ^{19}F NMR ($CDCl_3$): δ −78.84 (s, CF_3). Anal. Calcd. for $C_4H_6F_3NO_2S_3$: C, 18.97; H, 2.39; N, 5.53. Found: C, 19.07; H, 2.32; N, 5.81.

*3.2.3. N-Trifluoromethylsulfonyl-S-methylthiourea (**5**)*

NH_3 was passed through the solution of 0.30 g (1.00 mol) of dithiocarbonate **4** in 3 ml of benzene at 60 °C. The end of the reaction was monitored by TLC using benzene as an eluent. All volatiles were removed in vacuum and the residue crystallized from hexane and benzene in a ratio of 3:1 mixture resulting in compound **5** (0.24 g, 92% yield) as pale yellow crystals, mp 61–63 °C. IR (KBr): 3475 (NH_2), 3330 (NH_2), 3220 (=NH), 1620 (C=N), 1500 (C–N) cm^{-1}. ^{1}H NMR (DMSO-d_6): δ 9.25 (s, 2H, NH_2), 7.27 (s, 1H, NH), 6.96 (s, 1H, NH), 2.41 (s, 3H, SCH_3). ^{19}F NMR (DMSO-d_6): δ −78.17 (s, CF_3). Anal. Calcd. for $C_3H_5F_3N_2O_2S_2$: C, 16.21; H, 2.27; N, 12.61. Found: C, 16.27; H, 2.25; N, 12.60.

*3.2.4. N-Trifluoromethylsulfonyl-N′,N′-dimethylamino-S-methylthiourea (**6**)*

0.20 g (1.97 mmol) of triethylamine was added to a solution of 0.16 g of dimethylamine hydrochloride and 0.50 g (1.97 mmol) of dithiocarbonate **4** in 10 ml of THF at −40 °C. Reaction mixture was stirred for 1 h at −40 °C, warmed up to room temperature, and stirred for an additional 2 h. All volatiles were removed in vacuum, and the residue crystallized from hexane and benzene in a ratio of 3:1 mixture resulting in compound **6** (0.43 g, 88% yield) as a colorless solid, mp 78–79 °C. ^{1}H NMR (acetone-d_6): δ 3.40 (s, 6H, NMe_2), 2.66 (s, 3H, SCH_3). ^{19}F NMR (acetone-d_6): δ −79.19 (s, CF_3). Anal. Calcd. for $C_5H_9F_3N_2O_2S_2$: C, 23.99; H, 3.62; N, 11.20. Found: C, 24.02; H, 3.52; N, 11.31.

*3.2.5. N-(Morpholine-methylthio)methylene-trifluoromethylsulfonylamide (**7**)*

0.17 g (2.00 mmol) of morpholine was added to the solution of 0.50 g (1.97 mmol) of dithiocarbonate **4** in 5 ml of benzene at room temperature. Reaction mixture was stirred at 50 °C until methylmercaptan evolution had ceased. The end of the reaction was monitored by TLC using benzene as an eluent. All volatiles were removed in vacuum, and the residue crystallized from hexane and benzene in a ratio of 3:1 mixture resulting in compound **7** (0.44 g, 76% yield) as a colorless solid. Melting point 52–54 °C. ^{1}H NMR (acetone-d_6): δ 3.96 (m, 4H, $2CH_2$), 3.82 (m, 4H, $2CH_2$), 2.69 (s, 3H, SCH_3). ^{19}F NMR (acetone-d_6): δ −78.94 (s, CF_3). Anal. Calcd. for $C_7H_{11}F_3N_2O_3S_2$: C, 28.76; H, 3.79; N, 9.59. Found: C, 29.04; H, 3.70; N, 9.72.

*3.2.6. N-Trifluoromethylsulfonyl-N′,N′,N″,N″,-tetramethylaminoguanidine (**8**)*

A mixture of 0.50 g (1.97 mmol) of dithiocarbonate **4** and 0.32 g (3.94 mmol) of diethylamine hydrochloride in 10 ml of THF was placed into a tube, and 0.40 g (3.94 mmol) of Et_3N was added at room temperature. Reaction mixture was stirred for 3 h at 70 °C. All volatiles were removed in vacuum, resulting in compound **8** (0.38 g, 78% yield) as a colorless solid. Melting point 62–63 °C. ^{1}H NMR (acetone-d_6): δ 3.07 (s, $N(CH_3)_2$). ^{19}F NMR (acetone-d_6): δ −79.45 (s, CF_3). Anal. Calcd. for $C_6H_{12}F_3N_3O_2S$: C, 29.14; H, 4.89; N, 17.00. Found: C, 29.44; H, 5.03; N, 16.62.

*3.2.7. N-Bis(morpholine)methylene-trifluoromethylsulfonylamide (**9**)*

A mixture of 0.50 g (1.97 mmol) of dithiocarbonate **4** and 2 ml of morpholine was stirred for 5 h at 100 °C without any solvent. All volatiles were removed in vacuum, and the residue crystallized from hexane and benzene in a ratio of 1:2 mixture, resulting in compound **9** (0.41 g, 63% yield) as a colorless solid. Melting point 200–201 °C. ^{1}H NMR (acetone-d_6): δ 3.77 (m, 4H, $2CH_2$), 3.58 (m, 4H, $2CH_2$). ^{19}F NMR (acetone-d_6): δ −79.11 (s, CF_3). Anal. Calcd. for $C_{10}H_{16}F_3N_3O_4S$: C, 36.25; H, 4.87; N, 12.68. Found: C, 36.28; H, 5.00; N, 12.65.

*3.2.8. N-Trifluoromethylsulfonyliminoimidazolidine (**10**)*

A mixture of 0.40 g (1.58 mmol) of dithiocarbonate **4** and 0.10 g (1.58 mmol) of ethylenediamine in acetonitrile was

heated at 80 °C until methymercaptan evolution had ceased. The end of the reaction was controlled by TLC using benzene as an eluent. Solvent was removed in vacuum, and the residue crystallized from hexane and benzene in a ratio of 1:1 mixture, resulting in compound **10** (0.31 g, 91% yield) as a colorless solid. Melting point 204−206 °C. ^{1}H NMR (DMSO-d_6): δ 7.98 (s, 2H, 2NH), 3.56 (s, 4H, 2CH_2). ^{19}F NMR (DMSO-d_6): δ −78.13 (s, CF_3). Anal. Calcd. for $C_4H_6F_3N_3O_2S$: C, 22.12; H, 2.78; N, 19.35. Found: C, 22.23; H, 2.95; N, 19.74.

3.2.9. Sodium salt of N-(malonodinitrile-methylthio)methylene-trifluoromethylsulfonylamide (11)

0.04 g (1.67 mmol) of NaH was added to the solution of 0.05 g (0.79 mmol) of malonodinitrile in 5 ml of acetonitrile at 0 °C. Reaction mixture was stirred until hydrogen evolution had ceased, and 0.20 g (0.79 mmol) of dithiocarbonate **4** was added as a solid, followed by stirring for 6 h at 80 °C. Precipitate was filtered off, and all volatiles removed in vacuum. The residue was washed with benzene, resulting in compound **11** (0.18 g, 78% yield) as a colorless solid. Melting point 252−254 °C. ^{1}H NMR (DMSO-d_6): δ 2.40 (s, CH_3). ^{19}F NMR (DMSO-d_6): δ −78.88 (s, CF_3). Anal. Calcd. for $C_6H_3F_3N_3NaO_2S_2$: C, 24.58; H, 1.03; N, 14.33. Found: C, 24.20; H, 1.28; N, 14.31.

3.2.10. 1,3,3-Trimethyl-2-(2-methylthio-2-trifluoromethylsulfonylimino-ethylidene)indolenine (12)

A mixture of 0.50 g (1.97 mmol) of dithiocarbonate 4 and 0.34 g (1.97 mmol) of 1,3,3-trimethyl-2-methyleneindoline in acetonitrile was refluxed for 72 h until methylmercaptane evolution had ceased. The end of the reaction was monitored by TLC using benzene as an eluent. Solvent was removed in vacuum, and the residue crystallized from hexane and benzene in a ratio of 2:1 mixture, resulting in compound **12** (0.45 g, 61% yield) as a pale orange crystals. Melting point 168−169 °C. ^{1}H NMR (DMSO-d_6): δ 7.22−7.49 (m, 4H, Ar–H), 5.61 (s, 1H, =CH), 3.61 (s, 3H, NCH_3), 2.70 (s, 3H, SCH_3), 1.70 (s, 6H, 2CH_3). ^{19}F NMR (DMSO-d_6): δ −78.35 (s, CF_3). Anal. Calcd. for $C_{15}H_{17}F_3N_2O_2S$: C, 47.60; H, 4.53; N, 7.40. Found: C, 47.70; H, 4.52; N, 7.42.

3.2.11. N-(Chloro-methylthio-methylene)trifluoromethylsulfonylamide (13)

Three milliliters of sulphuryl chloride were added to the solution of 1.00 g (3.95 mmol) of dithiocarbonate **4** in 3 ml of dichloromethane. Reaction mixture was stirred at 20 °C until sulfur dioxide evolution had ceased. Solvent and methylsulphenylchloride were removed at 50 mm Hg, 50 °C and the residue distilled at 50 mmHg, 113–115 °C resulting in compound **13** (0.76 g, 80% yield) as a pale yellow liquid. ^{1}H NMR ($CDCl_3$): δ 2.56 (s, CH_3). ^{19}F NMR ($CDCl_3$): δ −78.97 (s, CF_3). Anal. Calcd. for $C_3H_3ClF_3NO_2S_2$: C, 15.10; H, 1.27; Cl, 14.86; S, 26.87. Found: C, 15.06; H, 1.23; Cl, 15.10; S, 26.64.

3.2.12. Sodium salt of N,N′-bis(trifluoromethylsulfonyl)-S-methylthiourea (14)

0.14 g (5.92 mmol) of NaH was added to the solution of 0.88 g (5.93 mmol) of trifluoromethanesulphamide in 10 ml of acetonitrile. Reaction mixture was stirred until hydrogen evolution had ceased. To the resulting suspension of $TfNNa_2$ in CH_3CN 1.50 g (5.93 mmol) of dithiocarbonate **4** was added as a solid. Reaction mixture was heated at 80 °C until methylmercaptane evolution had ceased. All volatiles were removed in vacuum, and the residue crystallized from dioxane and hexane in a ratio of 3:1 mixture. The product was dried at 0.02 mmHg, 100 °C for 1 week, resulting sodium salt **14** (1.67 g, 76% yield) as a pale yellow solid. Melting point 198–200 °C. ^{1}H NMR (DMSO-d_6): δ 2.32 (s, CH_3). ^{13}C NMR (DMSO-d_6): δ 174.31, 120.26 (q, J = 322 Hz, CF_3), 67.23 (dioxane), 16.75. ^{19}F NMR (DMSO-d_6): δ −78.27 (s, CF_3).

3.2.13. N,N-Bis(trifluoromethylsulfonyl)-S-methylthiourea (15)

Anhydrous hydrogen chloride was passed through a suspension of 1.00 g (2.65 mmol) of sodium salt **14** in CH_2Cl_2 for 1 h. Sodium chloride precipitate was filtered off, and washed with dichloromethane. All volatiles were removed in vacuum, and the residue crystallized from pentane, resulting in isothiourea **15** (0.88 g, 94% yield) as a colorless solid. Melting point 56−58 °C. ^{1}H NMR ($CDCl_3$): δ 8.51 (br s, 1H, NH), 2.57 (s, 3H, CH_3). ^{19}F NMR ($CDCl_3$): δ −75.20 (s, 3F, CF_3); −78.35 (s, 3F, CF_3). Anal. Calcd. for $C_4H_4F_6N_2O_4S_3$: C, 13.56; H, 1.14; N, 7.91. Found: C, 13.64; H, 1.21; N, 8.02.

3.2.14. N,N′-Bis(trifluoromethylsulfonyl)carbamidic chloride (16)

0.30 g (4.22 mmol) of chlorine was condensed into tube at −70 °C, dried for 24 h, and trapped into the solution of 0.50 g (1.41 mmol) of isothiourea **15** in 5 ml of CH_2Cl_2 at the same temperature. Reaction mixture was stirred for 1 h at −70 °C, slowly warmed up to 20 °C, and stirred for 1 h at this temperature. All volatiles were removed in vacuum, resulting in chloroformamidine **16** (0.47 g, 97% yield) in an analytically pure state. Colourless crystals, highly sensitive to moisture of air. Melting point 92−93 °C. IR (CH_2Cl_2): 3285 (NH), 1640 (C=N) cm^{-1}. ^{19}F NMR ($CDCl_3$): δ −76.10 (s, CF_3). Anal. Calcd. for $C_3HClF_6N_2O_4S_2$: C, 10.52; H, 0.29; N, 8.18; Cl, 10.35. Found: C, 10.74; H, 0.36; N, 8.24; Cl, 10.10.

3.2.15. N,N′-Bis(triethylammonium) salt of N,N′-bis(trifluoromethylsulfonyl)urea (17)

1.00 g (5.71 mmol) of TfNCO was added in small portions as a solid to the mixture of 0.85 g (5.71 mmol) of trifluoromethylmethanesulfonylamide and 3 ml of triethylamine in 5 ml of acetonitrile at 0 °C. Reaction mixture was stirred for 3 h at 20 °C, all volatiles removed in vacuum, and the residue washed with ether, resulting in triethylammonium

salt **17** (2.42 g, 81% yield) as colorless crystals. Melting point 147−150 °C. ^{1}H NMR ($CDCl_3$): δ 9.51 (br s, 1H, $^+NHEt_3$), 3.33 (q, $J = 7.2$ Hz, 6H, $3CH_2$), 1.57 (t, $J = 7.2$ Hz, 9H, $3CH_3$). ^{13}C NMR ($CDCl_3$): δ 163.45, 120.91 (q, $J = 325.2$ Hz, CF_3), 45.50, 8.06. ^{19}F NMR ($CDCl_3$): δ −77.20 (s, CF_3). Anal. Calcd. for $C_{15}H_{32}F_6N_4O_5S_2$: C, 34.22; H, 6.13; N, 10.65. Found: C, 34.28; H, 6.24; N, 10.96.

3.2.16. N,N′-Bis(tetrabuthylammonium) salt of N,N′-bis(trifluoromethylsulfonyl)urea (**18**)

7.6 ml of 0.1 M solution of $Bu_4N^+OH^-$ in methanol were added to a solution of 0.20 g (0.38 mmol) of the salt **17** in 3 ml of distilled water. Reaction mixture was heated for 1 h at 80–90 °C. Solvent was evaporated to the half of the volume, and the precipitated oil extracted with CH_2Cl_2. Extract was washed with water, and dried over $MgSO_4$. Solvent was removed in vacuum, and the residue dried at 0.02 mmHg, 50 °C for 3 h resulting in salt **18** (0.18 g, 69% yield) as a pale yellow solid. Melting point 90−92 °C. ^{1}H NMR ($CDCl_3$): δ 3.28 (m, 2H, CH_2), 1.63 (m, 2H, CH_2), 1.41 (q, $J = 7.2$ Hz, 2H, CH_2), 0.97 (t, $J = 7.2$ Hz, 3H, CH_3). ^{13}C NMR ($CDCl_3$): δ 160.34, 121.2 (q, $J = 326.4$ Hz, CF_3), 58.47, 23.82, 19.40, 13.42. ^{19}F NMR ($CDCl_3$): δ −77.21 (s, CF_3). Anal. Calcd. for $C_{35}H_{72}F_6N_4O_5S_2$: C, 52.09; H, 8.99; N, 6.94. Found: C, 52.28; H, 9.25; N, 7.20.

3.2.17. N,N′-Bis(trifluoromethylsulfonyl)urea (**19**)

3.2.17.1. Method A. 0.2 ml of water was added to the solution of 0.50 g (1.46 mmol) of chloroformamidine **16** in 5 ml of acetonitrile. Reaction mixture was stirred for 0.5 h at 20 °C, solvent removed in vacuum, the residue crystallized from ether and hexane in a ratio 1:3 mixture, and finally dried for 5 h at 0.02 mmHg, 50 °C resulting in compound **19** (0.45 g, 96% yield).

3.2.17.2. Method B. A solution of 0.5 g (0.95 mmol) of the salt **17** in 5 ml of distilled water was passed through a Dowex 50 WX8-200 column, and eluted with water, collecting fractions at pH 1–3. Water was removed in vacuum, and the residue crystallized from hexane and ether in a ratio 10:1 mixture, resulting in compound **19** (0.22 g, 71% yield) as colorless solid. Melting point 129−131 °C. IR (CH_2Cl_2): 3280 (NH), 1750 (C=O) cm^{-1}. ^{1}H NMR (DMSO-d_6): δ 8.51 (br s, NH). ^{19}F NMR (DMSO-d_6): δ −75.40 (s, $2CF_3$). Anal. Calcd. for $C_3H_2F_6N_2O_5S_2$: C, 11.11; H, 0.62; N, 8.64. Found: C, 11.24; H, 0.86; N, 8.62.

3.2.18. Morpholinium salt of N-(morpholine-trifluoromethylsulfonylamino)-methylene-trifluoromethylsulfonylamide (**20**)

3.2.18.1. Method A. A mixture of 0.5 g (1.41 mmol) of isothiourea **15** and 0.25 g (2.87 mmol) of morpholine was refluxed in toluene until methylmercaptane evolution had ceased. Solvent was removed in vacuum, residue washed with pentane, and crystallized from hexane and benzene in a ratio 1:2 mixture, resulting in salt **18** (0.53 g, 84% yield).

3.2.18.2. Method B. 0.37 g (4.25 mmol) of morpholine was added at −50 °C to the solution of chlorophormamidine **16** in 5 ml of THF, which was prepared from 0.50 g (1.41 mmol) of isothiourea **15** and 0.30 g (4.22 mmol) of Cl_2. Reaction mixture was stirred for 1 h at −50 °C, and 1 h at 20 °C. Precipitate was filtered off, solvent removed in vacuum, and the residue crystallized from hexane and benzene in a ratio 1:2 mixture resulting in salt **18** (0.48 g, 76% yield) as a pale yellow crystals. Melting point 184−186 °C. The protons of the NH_2^+ group could not be observed due to the rapid proton–deuterium exchange with the acetone solvent. ^{1}H NMR (acetone-d6): δ 4.00 (m, 4H, $2CH_2$), 3.67 (m, 8H, $4CH_2$), 3.43 (m, 4H, $2CH_2$). ^{19}F NMR (acetone-d6): δ −79.47 (s, CF_3). Anal. Calcd. for $C_{11}H_{18}F_6N_4O_6S_2$: C, 29.47; H, 4.05; N, 12.50. Found: C, 29.27; H, 3.97; N, 12.38.

3.2.19. 1,8-Diazabicyclo[5.4.0]undec-7-ene salt of N-(morpholine-trifluoromethylsulfonylamino)methylene-trifluoromethylsulfonylamide (**22**)

0.23 g (1.51 mmol) of DBU was added to the suspension of 0.51 g (1.50 mmol) of chloroformamidine **16** in 5 ml of dichloromethane. Reaction mixture was stirred for 0.5 h at −50 °C, and 1 h at 20 °C. Solvent was removed in vacuum, resulting in salt **21** (0.71 g, 97% yield) as oil. ^{1}H NMR ($CDCl_3$): δ 8.90 (br s, 1H, NH), 3.5 (m, 6H), 2.73 (m, 2H), 2.04−1.75 (m, 8H). ^{19}F NMR ($CDCl_3$): δ −78.99 (s, CF_3). 0.26 g (3.00 mmol) of morpholine was added to the solution of 0.72 g of salt 21 in 5 ml of dichloromethane. Solvent was removed in vacuum, residue washed with water, and dried for 3 h at 0.02 mmHg, 50 °C, resulting in salt **22** (0.59 g, 75% yield) as a colorless crystals. Melting point 127−129 °C. ^{1}H NMR ($CDCl_3$): δ 8.3 (br s, 1H, ^+NH), 3.67 (m, 8H, $4CH_2$), 3.49 (m, 6H, $3CH_2$), 2.77 (m, 2H, CH_2), 2.05 (m, 2H, CH_2), 1.76 (m, 6H, $3CH_2$). ^{13}C NMR ($CDCl_3$): δ 166.41, 156.15, 120.28 (q, $J = 323.21$ Hz, CF_3), 66.46, 54.62, 48.71, 45.69, 38.45, 33.08, 28.78, 26.50, 23.63, 19.26. ^{19}F NMR ($CDCl_3$): δ −80.13 (s, CF_3). Anal. Calcd. for $C_{16}H_{24}F_6N_5O_5S_2$: C, 35.29; H, 4.44; N, 12.86. Found: C, 35.37; H, 4.54; N, 12.92.

3.2.20. Disodium salt of N,N′, N″-tris(trifluoromethylsulfonyl)guanidine (**23**)

A solution of 0.51 g (1.50 mmol) of chloroformamidine **16** in 5 ml of THF was added at −50°C to the suspension of disodium salt of trifluoromethanesulfamide $TfNNa_2$ in 5 ml of THF, which was prepared from 0.22 g (1.50 mmol) of $TfNH_2$ and 0.07 g (3.00 mmol) of NaH respectively. Reaction mixture was stirred for 0.5 h at −50 °C, and 2 h at 20 °C. Precipitate was filtered off, filtrate evaporated in vacuum, the residue crystallized from THF and hexane in a ratio 3:1 mixture, and finally dried at 0.02 mmHg, 90 °C

resulting salt **23** (0.49 g, 67% yield) as a colorless solid. Melting point 199−203 °C. ^{13}C NMR (acetone-d_6): δ 177.74, 160.72, 120.94 (q, $J = 323$ Hz, CF_3), 96.28, 68.64 (THF), 27.71 (THF). ^{19}F NMR (acetone-d_6): δ −76.69 (s, CF_3). Anal. Calcd. for $C_4F_9N_3Na_2O_6S_3{\cdot}(C_4H_8O)$: C, 16.80; H, 1.40; N, 7.30. Found: C, 17.05; H, 1.49; N, 6.94.

References

[1] L.M. Yagupolskii, V.N. Petrik, N.V. Kondratenko, L. Sooväli, I. Kaljurand, I. Leito, I.A. Koppel, J. Chem. Soc., Perkin Trans. 2 (2002) 1950–1955.
[2] L.M. Yagupolskii, R.Yu. Garlyauskajte, N.V. Kondratenko, Synthesis (1992) 749.
[3] R.Yu. Garlyauskajte, S.V. Sereda, L.M. Yagupolskii, Tetrahedron 50 (1994) 6891–6906.
[4] L.M. Yagupolskii, S.V. Shelyazhenko, I.I. Maletina, V.N. Petrik, E.B. Rusanov, A.N. Chernega, Eur. J. Org. Chem. (2001) 1225.
[5] L.M. Yagupolskii, V.N. Petrik, Yu.L. Slominskii, Tetrahedron Lett. 43 (2002) 3957–3959.
[6] K. Feichtinger, K. Zapf, H.L. Sings, M. Goodman, J. Org. Chem. 63 (1998) 3804–3805.
[7] K. Feichtinger, H.L. Sings, T.J. Baker, K. Matthews, M. Goodman, J. Org. Chem. 63 (1998) 8432–8439.
[8] T.J. Baker, N.W. Luedtke, Y. Tor, M. Goodman, J. Org. Chem. 65 (2000) 9054–9058.
[9] K. Zapf, C.J. Creighton, M. Tomioka, M. Goodman, Org. Lett. (2001) 1133–1136.
[10] M. Tamaki, G. Han, V.J. Hruby, J. Org. Chem. 66 (2001) 1038–1042.
[11] A.G. Martinez, A.H. Fernandez, F.M. Jimenez, P.M. Ruiz, L.R. Subramanian, Synlett (1995) 161–162.
[12] I.B. Hendrickson, R. Bergeron, Tetrahedron Lett. 46 (1973) 4607–4610.
[13] M. Yokoyama, H. Hatanaka, Synthesis (1985) 891–892.
[14] E. Behrend, A. Haas, Chem. Ztg. 95 (1971) 1009–1010.
[15] E. Behrend, A. Haas, J. Fluorine Chem. 4 (1974) 83–98.
[16] E. Behrend, A. Haas, J. Fluorine Chem. 4 (1974) 99–106.
[17] M.R.C. Gerstenberger, A. Haas, H. Pauling, Helv. Chim. Acta 46 (1973) 4607–4610.
[18] L. Brandsma, R.L.P. de Jong, H.D. VerKruijsse, Synthesis (1985) 948–949.