Reactions of *N*-sulfinylfluoroalkanesulfonyl amines with nucleophiles containing reactive hydrogen

Ai-Wen Li, Bin Xu, Chao-Xian Wang, Shi-Zheng Zhu*
Shanghai Institute of Organic Chemistry, Academia Sinica, Shanghai 200032 (China)

(Received July 22, 1993; accepted November 14, 1993)

Abstract

The reactions of *N*-sulfinylfluoroalkanesulfonyl amines, R_fSO_2NSO (**1**), with malonate or dialkyl phosphite gave 1:1 adducts $R_fSO_2NHS(O)Nu$ [$Nu = CH(COOEt)_2$, $P(O)(OMe)_2$], and with alcohols or phenols formed $R_fSO_2NH_2$ and the sulfites $O=S(OR)_2$ by double addition [$R = CH_3$, CMe_3, $H(CF_2)_2CH_2$, C_6H_5, C_6F_5]. Trans-sulfinylation occurred during the reaction of **1** with anilines ($C_6H_5NH_2$, 4-$FC_6H_4NH_2$ and $C_6F_5NH_2$).

1. Introduction

Heterocumulenes containing nitrogen- and sulfur-containing groups such as $R-N=S=O$, $RSO_2N=C=O$, $RSO_2N=S=O$ and $RSO_2N=C=S$ within the cumulene system constitute valuable synthetic building blocks [1]. The chemistry and reactions of these compounds have been studied thoroughly [2, 3]. The fluorine-containing analogues, however, have rarely been reported. The first *N*-sulfinyl perfluoroalkanesulfonyl amine $CF_3SO_2N=S=O$ was synthesized by Roesky et al. [4]. We have previously reported the preparation of the *N*-fluoroalkanesulfonyl aromatic imine $R_fSO_2N=CHAr$, and *N*-fluoroalkanesulfonyl sulfimine, $R_fSO_2N=SMe_2$, by treatment of $R_fSO_2N=S=O$ (**1**) with aromatic aldehydes or dimethyl sulfoxide, respectively [5, 6]. This paper reports the reactions of **1** with some nucleophiles containing reactive hydrogens (NuH).

2. Results and discussion

N-Sulfinylfluoroalkanesulfonyl amines, R_fSO_2NSO, prepared by refluxing $R_fSO_2NH_2$ in excess $SOCl_2$, are reactive compounds. The very polar N=S double bond, which arises from the presence of the strong electron-withdrawing group R_fSO_2-, allows addition reactions to occur easily. For example, alcohols react violently with **1**. At low temperature (−20 °C), excess methanol was added dropwise to **1** giving $R_fSO_2NH_2$ and alkyl sulfites, $(RO)_2SO$ (**4**), quantitatively. Similar results were obtained when other alcohols such as Me_3COH and $H(CF_2)_2CH_2OH$ were used. *N*-Fluoroalkanesulfonylaminosulfinyl esters, $R_fSO_2NHS(O)OR$, which can be considered the primary product in the alcoholysis, are very unstable and react immediately with another molecule of ROH giving **4**.

$$R_fSO_2NSO + ROH \xrightarrow[2\ h]{-20\ ^\circ C\ to\ 0\ ^\circ C} [R_fSO_2NHS(O)OR] \xrightarrow{ROH} R_fSO_2NH_2 + (RO)_2SO$$
(1) (2) (3) (4)

[$R_f = I(CF_2)_2O(CF_2)_2$ (**1a**), $Cl(CF_2)_2O(CF_2)_2$ (**1b**), $H(CF_2)_2O(CF_2)_2$ (**1c**); $R = CH_3$ (**2a**), $(Me)_3C$ (**2b**), $H(CF_2)_2CH_2$ (**2c**)]

Ethylene glycol reacted with **1** in the same way. The intermediate $R_fSO_2NHS(O)OCH_2CH_2OH$ undergoes intramolecular nucleophilic attack at the sulfur atom with concomitant breaking of the N−S bond to give a cyclic sulfite **5** together with **3**.

$$1 + HO(CH_2)_2OH \longrightarrow [R_fSO_2NHS(O)OCH_2CH_2OH] \longrightarrow O=SOCH_2CH_2O + 3$$
(2) (5d)

The less nucleophilic phenol or pentafluorophenol ArOH reacted smoothly with **1** at 20 °C. In this reaction, the first step may involve the protonation of **1** at the nitrogen atom by the more acidic proton of phenol.

$$1 + ArOH \xrightarrow[20\ ^\circ C]{C_6H_6} R_fSO_2NHS(O)OAr \xrightarrow{ArOH} 3 + (ArO)_2SO$$
(6) (7)

[$Ar = C_6H_5$ (**6a**), C_6F_5 (**6b**)]

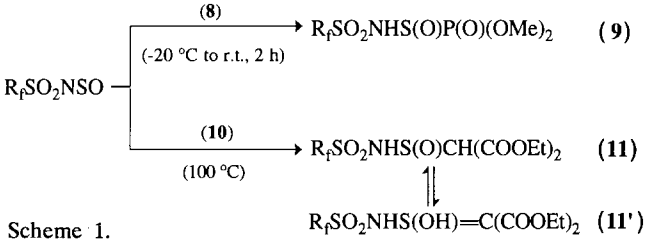
*Corresponding author.

SSDI 0022-1139(93)03060-Y

In all above reactions, attempts to isolate the unstable primary adduct $R_fSO_2NHS(O)OR$ were unsuccessful.

The addition reactions of dialkylphosphite to the N=C bond have been studied extensively. Compared with imines, compounds **1** containing the very polar N=S bond are more reactive towards the addition of $HP(O)(OMe)_2$ (**8**). The reaction temperature of imines with **8** was generally *c.* 100–140 °C. In some cases, Lewis acids have been used as catalysts [7–9]. The reactions of **1** with **8** occurred violently and exothermally at room temperature to generate in a 1:1 adduct $R_fSO_2NHS(O)P(O)(OMe)_2$ (**9**). The proton chemical shifts of the two methoxy groups in $P(O)(OMe)_2$ are different, occurring at δ 3.66 and 3.83 ppm, respectively, as doublets $^3J_{HP}=10$ Hz. It is reasonable to suggest that the two methoxy groups on the phosphorus atom in compound **9** are diastereotopic with respect to the asymmetric sulfur atom attached to the phosphorus atom. It is well known that $HP(O)(OR)_2$ has a tautomer, i.e. $HP(O)(OR)_2 \leftrightharpoons HOP(OR)_2$. However, in the above reaction, it seems that the P–H bond added concertedly to the N=S double bond to give **9**, which did not react fully with **8** to give the double addition product as in the alcoholysis of **1**.

Similarly, malonate reacts with **1** to form a 1:1 addition product. Stirring a mixture of **1** and diethyl malonate, $CH_2(COOEt)_2$ (**10**), for 8 h at 100 °C gives high yields of $R_fSO_2NHS(O)CH(COOEt)_2$ (**11**). The ^1H NMR spectrum of **11** has four peaks at δ 6.51, 3.20, 3.94, 1.05 ppm, corresponding to NH, CH, CH_2 and CH_3, respectively. When D_2O is added, the two peaks at δ 6.51 and 3.20 ppm disappear, which suggests that compound **11** exists as in the enol form **11'** (see Scheme 1).



Scheme 1.

The reactions of **1** with aniline proceed analogously to those with alcohol. The first-step reaction products, $R_fSO_2NHS(O)NHAr$, were not isolated. Intramolecular proton transfer leads to cleavage of the N–S bond yielding **3** and *N*-sulfinylaniline, thus:

$$\mathbf{1} + ArNH_2 \longrightarrow \quad (\mathbf{12})$$

$$[R_fSO_2NHS(O)NHAr] \longrightarrow R_fSO_2NH_2 + ArNSO \quad (\mathbf{13})$$

[Ar = C_6H_5 (**12a**), 4-FC_6H_4 (**12b**), C_6F_5 (**12c**)]

This reaction can be considered as an NSO group translation reaction [11].

All the results obtained are summarized in Table 1.

3. Experiment

^1H NMR and ^{19}F NMR spectra were recorded on a Varian 360L instrument using Me_4Si and CF_3COOH as internal and external standards, respectively [δ(TFA) = δ(F11) + 76.8 ppm] (upfield shifts are given positive signs). IR spectra were obtained with an IR-440 Shimadzu spectrophotometer. Low-resolution MS spectra were obtained on a Finnigan GC–MS 4021 instrument. Elemental analysis were performed by the Analysis Department of this Institute. All boiling points are uncorrected.

3.1. Reactions of 1 with alcohols

A typical process was as follows. Compound **2c** (2.0 ml, 22 mmol) was added dropwise to **1c** (2.5 g, 7.3 mmol) at −20 °C. After addition, the temperature was raised slowly to room temperature and the reaction mixture stirred for 1 h. After removing excess **2c**, vacuum distillation gave a colourless liquid containing **4c** (2.10 g) and **3c** (2.02 g). Similar treatment of **1** with **2a**, **2b** and **2d** gave **4a**, **4b** and **5d**, respectively.

$(CH_3O)_2S(O)$ (**4a**): ^1H NMR δ: 3.21 (s, OCH_3) ppm. MS (*m/z*, %): 110 (M^+, 6.87); 80 (SO_3^+, 19.6); 79 ($M^+ - OCH_3$, 100.00); 64 (SO_2^+, 15.8). IR (KBr, film) (ν, cm^{-1}): 2960 (w); 1195 (s); 700 (s).

$(Me_3CO)_2S(O)$ (**4b**): ^1H NMR δ: 1.01 (s, CH_3) ppm. MS (*m/z*, %): 196 ($M^+ + 2$, 42.39); 58 (Me_2CO^+, 100.00); 57 (Me_3C^+, 36.79); 43 ($C_3H_7^+$, 16.76). IR (ν, cm^{-1}): 2960 (w); 1460 (m); 1380 (m); 1255 (m); 1170 (s); 800 (s). Analysis: $C_8H_{18}O_3S$ requires: C, 49.48; H, 9.28%. Found: C, 49.30; H, 9.18%.

$(HCF_2CF_2CH_2O)_2S(O)$ (**4c**): ^1H NMR (CCl_4) δ: 5.62 (t–t, $^2J_{HCF}=54.0$ Hz, $^3J_{HCCF}=3.6$ Hz, HCF_2); 4.07 (t, $^2J_{HCCF}=13.2$ Hz, CH_2O) ppm. ^{19}F NMR δ: 46.7 (s, CF_2CH_2); 60.8 (d, HCF_2) ppm. MS (*m/z*, %): 310 (M^+, 7.25); 179 ($M^+ - OCH_2CF_2CF_2H$, 9.12); 131 ($HCF_2CF_2CH_2O^+$, 17.34); 119 ($CF_3CF_2^+$, 58.90); 115 ($HCF_2CF_2CH_2^+$, 9.11); 101 ($HCF_2CF_2^+$, 65.65); 100 ($CF_2CF_2^+$, 22.07); 80 (SO_3^+, 42.91); 51 (HCF_2^+, 3.35); 50 (CF_2^+, 100.00). IR (ν, cm^{-1}): 2970 (w); 1450 (m); 1400 (m); 1210 (s); 1110 (s); 1000 (s); 945 (m); 835 (m); 740 (s). Analysis: $C_6H_6F_8O_3S$ requires: C, 23.23; H, 1.95; F, 49.03%. Found: C, 22.96; H, 1.96; F, 49.79%.

$\overline{OCH_2CH_2O}S(O)$ (**5d**): ^1H NMR δ: 4.27 (m, 2H); 4.60 (m, 2H) ppm. MS (*m/z*, %): 108 (M^+, 30.11); 78 ($M^+ - CH_2O$, 92.37); 44 ($CH_2CH_2O^+$, 49.11); 29 ($C_2H_5^+$, 100.00). IR (ν, cm^{-1}): 2965 (w); 2900 (m); 1465 (m); 1200 (s); 1005 (s); 910 (s); 745 (s); 670 (s).

TABLE 1. Reactions of R_fSO_2NSO with NuH

Reactants 1+NuH	Conditions	Products[a]	Yield[b] (%)	B.p. (°C/mmHg)
	Temp., time, solvent			
1a+2a	−20 °C to 25 °C; 1h, –	**4a** **3a**	98	125/760
1a+2b	−20 °C to 25 °C, 1 h, –	**4b** **3a**	96	55–56/20
1c+2c	−20 °C to 25 °C, 1 h, –	**4c** **3c**	93	64–66/10
1a+2d	−20 °C to 25 °C, 1 h, –	**5d** **3a**	76	52–54/10
1a+6a	25 °C, 3 h, benzene	**7a** **3a**	86	52–53/1
1a+6b	25 °C, 3 h, benzene	**7b** **3a**	84	62–64/1
1a+8	−30 °C to 0 °C, 2 h, –	**9**	95	90–94/0.1
1a+10	100 °C, 6 h, –	**11**	96	95–98/0.1
1a+12a	25 °C, 8 h, –	**13a** **3a**	90	38/4
1a+12b	25 °C, 8 h, –	**13b** **3a**	90	40/4
1a+12c	25 °C, 8 h, –	**13c** **3a**	90	42/3

[a]Compounds **3a**, **3c**, **4a**, **13a** and **13c** are known [6, 10–13].
[b]Isolated yield based on **1**.

Analysis: $C_2H_4O_3S$ requires: C, 22.22; H, 3.70%. Found: C, 22.38; H, 3.92%.

3.2. Reaction of 1 with phenol

A solution of **6a** (1.33 g, 14 mmol) in benzene (10 ml) was added dropwise into **1a** (3.3 g, 7.0 mmol) at room temperature. After stirring for 3 h, the solvent and excess **6a** were removed. Distillation under reduced pressure afforded compound **7a** as a yellowish liquid. Compound **7b** was obtained similarly.

$(C_6H_5O)_2S(O)$ (**7a**): ^1H NMR δ: 6.75 (s, C_6H_5) ppm. MS (*m/z*, %): 236 ($M^+ + 2$, 2.07); 235 ($M^+ + 1$, 5.33); 234 (M^+, 40.57); 141 ($M^+ - OC_6H_5$, 78.55); 77 ($C_6H_5^+$, 100.00). IR (ν, cm^{-1}): 3040 (w); 1600 (m); 1580 (m); 1480 (s); 1220 (s); 1130 (s); 1015 (m); 900 (w); 820 (s); 780 (m). Analysis: $C_{12}H_{10}O_3S$ requires: C, 61.54; H, 4.27%. Found: C, 61.45; H, 4.15%.

$(C_6F_5O)_2S(O)$ (**7b**); ^{19}F NMR δ: 76.2 (d, 2F); 79.7 (t, 1F); 87.5 (t, 2F) ppm. MS (*m/z*, %): 414 (M^+, 37.53); 231 ($M^+ - OC_6F_5$, 75.17); 167 ($C_6F_5^+$, 100.00). Analysis: $C_{12}F_{10}O_3S$ requires: C, 34.78; F, 45.89%. Found: C, 34.70; F, 45.93%.

3.3. Reaction of 1 with dimethylphosphite

Compound **8** (1.0 ml, 10.7 mmol) was injected slowly into a flask (10 ml capacity) containing **1a** (2.1 g, 4.5 mmol). The reaction mixture was stirred for 2 h at room temperature when the colour disappeared. After removing excess **8**, vacuum distillation gave **9** (2.61 g) as a thick liquid.

$I(CF_2)_2O(CF_2)_2SO_2NHS(O)P(O)(OCH_3)_2$ (**9**): ^1H NMR δ: 6.86 (s, NH); 3.83 (d, 3H); 3.66 (d, 3H, $^3J_{HP} = 10$ Hz) ppm. ^{19}F NMR δ: −12.4 (s, ICF_2); 3.7 (m, OCF_2); 7.7 (m, CF_2O); 39.3 (s, CF_2S) ppm. MS (*m/z*, %): 563 ($M^+ - O$, 0.52); 561 ($M^+ + 1 - F$, 6.28); 546 ($M^+ + 1 - F - CH_3$, 3.07); 545 ($M^+ + 1 - F - O$, 36.91); 531 ($M^+ - F - O - CH_3$, 11.20); 295 ($CF_2CF_2OCF_2$-$CF_2SO_2NH^+$, 16.19); 252 ($M^+ - ICF_2CF_2$, 15.70); 251 ($M^+ - 1 - ICF_2CF_2$, 98.20); 236 ($M^+ - ICF_2CF_2$-OCF_2, 2.61); 188 ($M^+ - ICF_2CF_2 - SO_2$, 9.31); 187 ($M^+ - ICF_2CF_2 - 1$, 48.48); 172 ($^+NHS(O)P(O)$-$(OCH_3)_2$, 4.10); 157 ($^+S(O)P(O)(OCH_3)_2$, 37.74); 127 (I^+, 100.00); 119 ($CF_3CF_2^+$, 13.30); 109 ($^+P(O)(OCH_3)_2$, 32.13); 64 (SO_2^+, 73.13). IR (ν, cm^{-1}): 3210 (w); 2970 (w); 1400 (m); 1340 (m); 1300 (s); 1150–1210 (vs); 1050 (vs); 920 (m); 860 (w). Analysis: $C_6H_7F_8INO_7PS_2$ requires: C, 12.44; H, 1.22; N, 2.42%. Found: C, 12.40; H, 1.20; N, 2.45%.

3.4. Reaction of 1 with diethyl malonate

Compound **10** (2.0 ml, 13.0 mmol) was mixed with **1a** (2.1 g, 4.5 mmol) in a flask (10 ml capacity). After stirring the mixture for 6 h at 100 °C, excess **10** was distilled out. The remaining liquid was purified by TLC to give compound **11** as a thick yellowish liquid (2.7 g).

$ICF_2CF_2OCF_2CF_2SO_2NHS(O)CH(COOC_2H_5)_2$ (**11**): ^1H NMR δ: 6.49 (s, NH); 3.94 (q, 4H); 3.18 (s, 1H); 1.02 (t, 6H) ppm. ^{19}F NMR δ: −10.7 (s, ICF_2); 4.7 (m, OCF_2); 8.8 (m, CF_2O); 39.9 (s, CF_2S) ppm. MS (*m/z*, %): 592 ($M^+ - F - O$, 2.94); 546 ($M^+ - F - SO_2$, 5.88); 296 ($^+CF_2CF_2OCF_2CF_2SO_2NH_2$, 10.86); 227 ($ICF_2CF_2^+$, 21.22); 159 ($M^+ - IC_2F_4OC_2F_4SO_2NHS$-(O), 2.15); 143 ($M^+ - IC_2F_4OC_2F_4SO_2NHS(O)O$, 17.03); 100 ($CF_2CF_2^+$, 29.45); 64 ($SO_2^+$, 100.00). IR ($\nu$, cm^{-1}): 3230 (m); 2990 (m); 1740 (vs); 1450 (w); 1400 (s); 1340 (s); 1300 (s); 1150–1210 (vs); 1100 (m); 1040 (m); 920 (m). Analysis: $C_{11}H_{12}F_8NIO_8S_2$ requires: C, 21.00; H, 1.91; N, 2.23%. Found: C, 21.42; H, 1.75; N, 2.39%.

3.5. Reaction of 1 with anilines

Compound **12b** (0.52 ml, 5.43 mmol) was injected into a flask (10 ml capacity) containing a solution of **1a** (2.55 g, 5.43 mmol) and benzene (5 ml). After refluxing for 2 h, the precipitate was filtered off to give **3a** (2.07 g). Distillation of the filtrate under reduced pressure gave **13b** (0.77 g). Compounds **13a** and **13c** were obtained by similar treatment of **1** with $C_6H_5NH_2$ and $C_6F_5NH_2$.

4-FC_6H_4NSO (**13b**): ^1H NMR δ: 7.37 (d, 2H); 6.55 (t, 2H) ppm. ^{19}F NMR δ: 29.3 (s, 1F) ppm. MS (*m/z*, %): 157 (M^+, 14.56); 141 ($M^+ - O$, 100.00); 138 ($M^+ - F$, 14.15); 109 (4-$FC_6H_4N^+$, 31.37); 95 (4-$FC_6H_5^+$, 55.97). Analysis: C_6H_4FNOS requires: C, 45.85; H, 2.55; N, 8.92; F, 12.10%. Found: C, 46.01; H, 2.43; N, 8.72; F, 11.98%.

Acknowledgement

The authors wish to thank the Shanghai Natural Science and Technology Foundation for financial support.

References

1 R. Bussas, G. Kresze, H. Munsterer and A. Schwobel, *Sulfur Rep., 2* (1983) 215.
2 G. Kresze, A. Maschke, K. Albrecht, K. Bederke, H.P. Patzschke, H. Smalla and A. Trede, *Angew. Chem., Int. Ed. Engl., 1* (1962) 89.
3 G. Kresze and W. Wucherpfennig, *Angew. Chem., Int. Ed. Engl., 6* (1967) 149.
4 H.W. Roesky, G. Holtschneide and H.H. Giere, *Z. Naturforsch., 256* (1970) 252.
5 S.Z. Zhu and Q.Y. Chen, *J. Chem. Soc., Chem. Commun.* (1991) 732.
6 S.Z. Zhu, *J. Fluorine Chem., 60* (1992) 283.
7 E.K. Fields, *J. Am. Chem. Soc., 79* (1974) 1528.
8 A.N. Pudovik, *Dokl. Akad. Nauk SSSR, 83* (1952) 865; [*Chem. Abs., 47* (1952) 4300g].
9 C.Y. Yuan and S.H. Cui, *Phosphorus, Sulfur and Silicon, 55* (1991) 159.
10 *Beilstein, 1, 282,* Springer, Berlin, 1918.
11 G. Kresze, A. Maschke, R. Albrecht, K. Bederke, H.P. Patschke, H. Smalla and D.A. Trede, *Angew. Chem., Int. Ed. Engl., 1* (1962) 89.
12 G. Butt, M. Davis, Y.T. Pang, R.D. Topsom and A.R. Katritzky, *J. Chem. Soc., Perkin Trans. 2* (1974) 260.
13 O. Glemser, S.P.V. Halasz and U. Biermann, *Inorg. Chem. Nucl. Lett., 4* (1968) 591.