ELSEVIER

Journal of Fluorine Chemistry 78 (1996) 187–191

JOURNAL OF FLUORINE CHEMISTRY

Syntheses and molecular structures of 2-[1'-*N*-(alkyl)imino-2',2',2'-trifluoroethyl]phenols

Ralph-Matthias Schoth, Enno Lork, Gerd-Volker Röschenthaler *

Institute of Inorganic and Physical Chemistry, University of Bremen, Leobener Straße, D-28334 Bremen, Germany

Received 19 January 1996; accepted 18 February 1996

Abstract

N-(Alkyl)imino derivatives of trifluoroacetyl phenol of the general formula 1,2-$C_6H_4[C(=NR)CF_3][OH]$ (R = H, **3a**; Me, **3b**; ^nPr, **3c**; ^iPr, **3d**; $CH_2CH_2NH_2$, **3e**; $CH_2CH_2CH_2NH_2$, **3f**; $CH_2CH_2CH_2CH_2NH_2$, **3g**; CH_2CH_2OH, **3h**; $CH_2CH_2NMe_2$, **3i**) were synthesized from 2-trifluoroacetyl phenol and the corresponding primary amines RNH_2. The molecular structures of **3b** [monoclinic, $P2_1/n$, $a = 6.641(3)$, $b = 18.044(8)$, $c = 7.716(3)$ Å, $\beta = 99.95(4)°$], **3d** [orthorhombic, $P2_12_12_1$, $a = 7.784(2)$, $b = 9.291(2)$, $c = 15.942(4)$ Å] and **3i** [monoclinic, $P2_1/n$, $a = 8.660(2)$, $b = 18.135(2)$, $c = 13.300(2)$ Å, $\beta = 99.83(2)°$] were determined. In the solid state, **3b**, **3d** and **3i** exist exclusively as *E* isomers with *inter*molecular hydrogen bridges, whereas according to the *1*H and *19*F NMR spectra in chloroform solution, compounds **3b**, **3c** and **3d** isomerize to give a mixture of 66% *Z* and 34% *E* isomers.

Keywords: Syntheses; Crystal structures; [*N*-(Alkyl)imino trifluoroethyl]phenols; NMR spectroscopy; Mass spectrometry

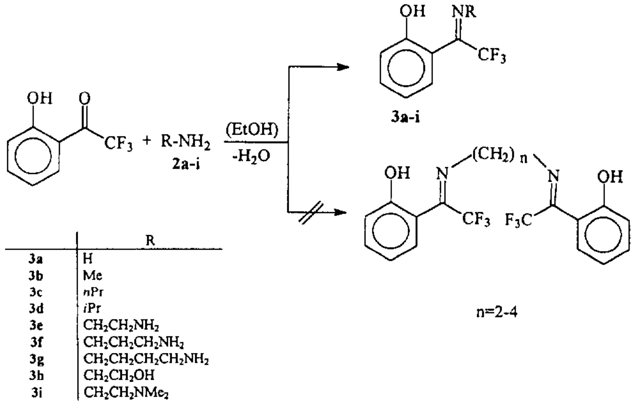
1. Introduction

For the synthesis of 2-trifluoroacetyl phenol (**1**), a copper(II) complex of the imino derivative, 2-(1'-imino-2',2',2'-trifluoromethyl)phenol [1] is required. Since the reactions of 2-trifluoroacetyl phenol and $\lambda^3\sigma^3P$ compounds turned out to yield mono, spiro and tricyclic phosphoranes [2–6], 2-[1'-*N*-(alkyl)imino-2',2',2'-trifluoromethyl]-phenols attracted our attention [7]. In addition, *E*/*Z* isomerism and hydrogen-bridging properties were of considerable interest.

2. Results and discussion

Primary amines, RNH_2 **2** (**a**: R = H; **b**: R = Me; **c**: R = ^nPr; **d**: R = ^iPr; **e**: R = $CH_2CH_2NH_2$; **f**: R = $CH_2CH_2CH_2NH_2$; **g**: R = $CH_2(CH_2)_2CH_2NH_2$; **h**: R = CH_2CH_2OH; **i**: R = $CH_2CH_2NMe_2$) and 2-trifluoroacetyl phenol (**1**) in ethanol reacted to furnish the respective imines **3a–i** (Scheme 1). The water formed was removed completely together with ethanol by distillation. The new compounds were colourless solids but turned yellow in chloroform in the case of **3b**, **c** and **d**.

The reaction of $^tBuNH_2$ or $(CF_3)_2CHNH_2$ and **1** did not yield the expected products under the conditions applied.



	R
3a	H
3b	Me
3c	*n*Pr
3d	*i*Pr
3e	$CH_2CH_2NH_2$
3f	$CH_2CH_2CH_2NH_2$
3g	$CH_2CH_2CH_2CH_2NH_2$
3h	CH_2CH_2OH
3i	$CH_2CH_2NMe_2$

Scheme 1.

Surprisingly enough, the diamines **2e–g** gave the mono-substituted compound only in their *E* configuration. In solution, an inversion to furnish the *Z* isomer was not observed. The condensation of a second molecule of ketone **1** did not take place (Scheme 1). Probably there would be a too close steric interaction of the two neighbouring phenol groups in an *E* isomeric arrangement. The decreased reactivity of the second H_2N moiety due to *inter*molecular interactions with phenolic HO groups could also prevent the disubstitution.

X-Ray investigations revealed that the imines **3b**, **3d** and **3i** prefer an *E* configuration (Figs. 1-3, Scheme 2). Compounds **3b** and **3d** showed long *inter*molecular hydrogen-

---

* Corresponding author.

0022-1139/96/$15.00
PII S0022-1139(96)03441-0

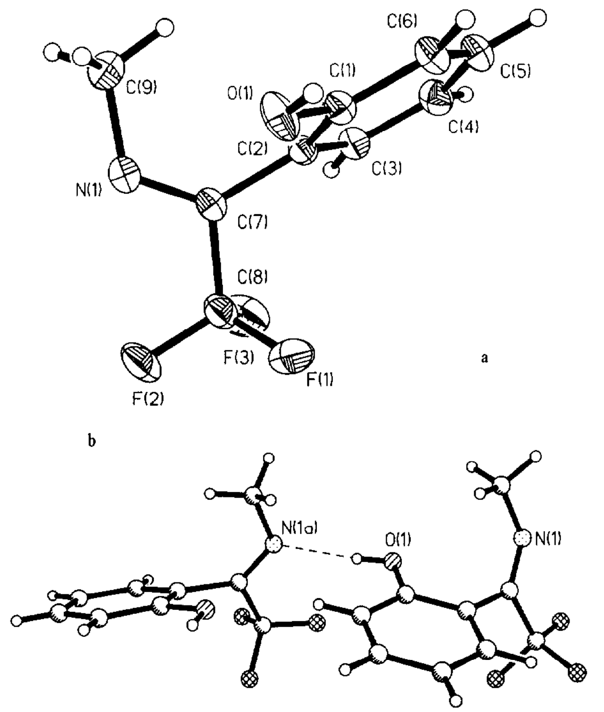


Fig. 1. (a) Molecular structure of **3b** and (b) two molecules with an *inter*-molecular hydrogen bridge.

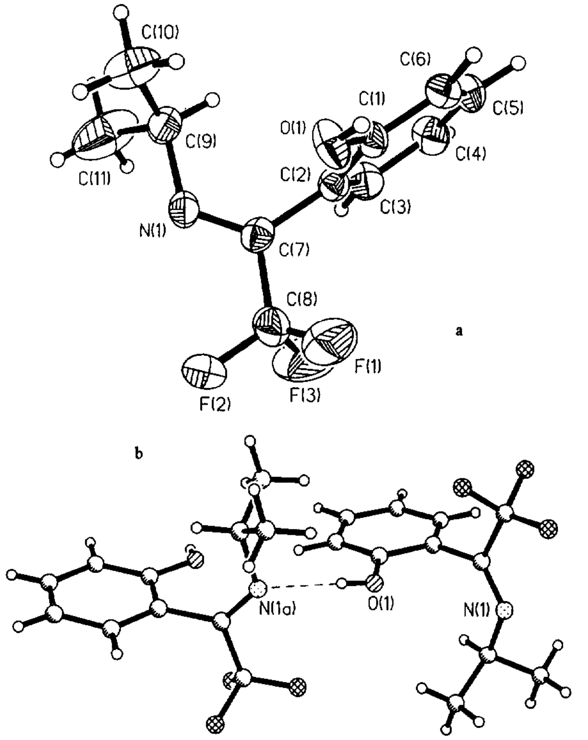


Fig. 2. (a) Molecular structure of **3d** and (b) two molecules with an *inter*-molecular hydrogen bridge.

bridge bonding, –O–H···N(R)=C–, of 198 pm. A much shorter distance, 185.3 pm, was found for the interaction –O–H···N(Me$_2$)CH$_2$– in compound **3i**. In all three compounds the aromatic ring plane is forced to be almost perpendicular with respect to the imine system. The dihedral angle C(1)–C(2)–C(7)–C(8) was found to be 114.8(0.1)° for **3b**, 97.2(0.3)° for **3d** and 93.0(0.5)° for **3i**. The C=N bond distances were averaged to be 126.1 pm with a maximum deviation of 0.8 pm (Table 1).

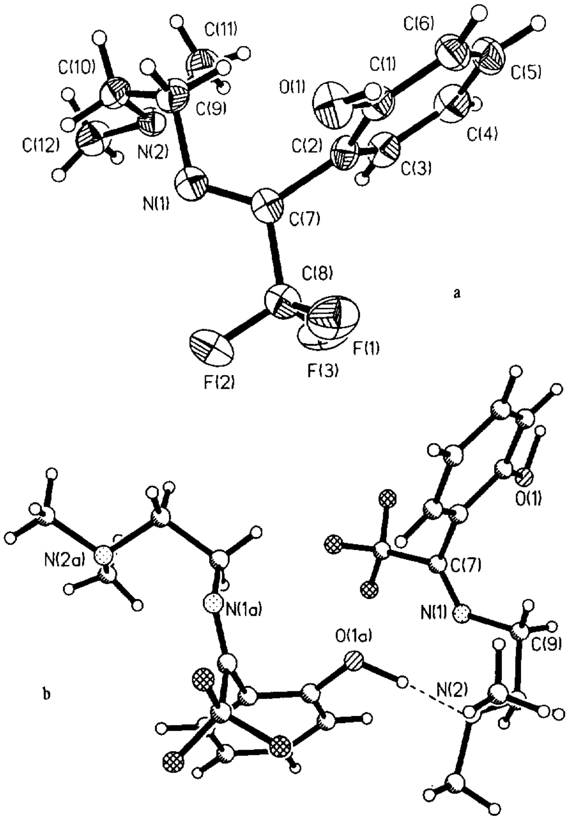
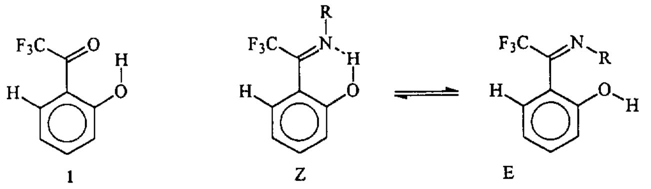


Fig. 3. (a) Molecular structure of **3i** and (b) two molecules with an *inter*-molecular hydrogen bridge.

Table 1
The main geometrical parameters of **3b**, **3d** and **3i**

	3b (R=Me)	**3d** (R=^{i}Pr)	**3i** (R=CH$_2$CH$_2$NMe$_2$)
Bond lengths (Å)			
C(1)–O(1)	135.3(2)	135.5(5)	135.9(4)
C(1)–C(2)	139.9(2)	140.0(6)	140.0(4)
C(2)–C(7)	149.3(2)	151.6(6)	149.7(4)
C(7)–C(8)	152.3(2)	149.6(7)	152.1(4)
C(7)–N(1)	126.9(2)	125.9(6)	125.6(4)
N(1)–C(9)	145.7(2)	146.7(6)	146.2(3)
C(8)–F(1)	133.2(2)	133.9(6)	133.7(4)
C(8)–F(2)	132.5(2)	129.9(6)	131.9(4)
C(8)–F(3)	133.8(2)	133.6(7)	133.4(3)
Bond angles (°)			
C(2)–C(7)–N(1)	128.6(1)	127.3(4)	128.6(2)
C(2)–C(7)–C(8)	115.2(1)	115.6(4)	115.1(2)
C(8)–C(7)–N(1)	116.1(1)	117.0(4)	116.3(2)
C(1)–C(2)–C(3)	119.8(3)	121.0(4)	119.8(1)
C(1)–C(2)–C(7)	118.3(1)	115.9(4)	118.9(2)
C(7)–N(1)–C(9)	118.7(1)	121.8(4)	119.5(2)
Torsion angles (°)			
C(1)–C(2)–C(7)–C(8)	114.8(1)	93.0(5)	97.2(3)

Fresh solutions of **3b**, **3c** and **3d** at ambient temperature showed *one* signal in the ^{19}F NMR spectrum attributed to the *E* isomer (Table 2). After a few minutes the solution turned yellow and a second signal appeared at lower field probably due to a conversion into the *Z* isomer (Scheme 2). After 20 min a constant ratio $Z/E = 66:34$ was obtained. In the Z isomers, intramolecular hydrogen bridges should be present as in the starting compound **1**, which was also yellow and showed a J_{FCCCCH} coupling of 2.2 Hz with a considerable 'through-space' contribution [4]. For this rearrangement, the aromatic ring should be in the same plane (dihedral angle ~0°) as the imine system, so that the 'through-space' coupling contributions for J_{FCCCCH} could be larger. The same argument may apply for the increase in the value of J_{FCCNCH}. The conversion of the *E* isomers of **3e–i** was not observed, probably because of steric reasons or strong *inter*molecular hydrogen bridges $-O-H\cdots N(R_2)CH_2-$ (R = H, Me) or $-O-H\cdots O(H)CH_2-$(**3h**).



Scheme 2.

3. Experimental details

The appropriate precautions in handling moisture and oxygen-sensitive compounds were observed throughout this work. Elemental analysis: Mikroanalytische Laboratorium Beller, Göttingen. MS: MAT 8222 spectrometer (EI, electron energy 70 eV). NMR: AC 80, operating at 80.13 MHz (H, internal standard TMS) and 75.39 MHz (^{19}F, internal standard CCl_3F). Compound **1** was synthesized using a literature procedure [1].

3.1. General method (see Table 3)

Compound **1** was dissolved in 20 ml of ethanol and the appropriate amount of ammonia or amine added. After removing all volatiles in vacuo, the imines were recrystallized from n-hexane.

Table 2
^{1}H and ^{19}F NMR data for compounds **3a-i** (*J*-values are given in Hz)

Compound		^{1}H chemical shifts [a] (ppm)			^{19}F chemical shifts [a] (ppm)
		CH_3 ($^3J_{HH}$)	CH_2	C_6H_4	CF_3 ($^nJ_{HNCCF}$; $^5J_{HCCCCF}$)
3a (R = H) [b]		–	–	6.7–7.6	−73.4 (2.3, $n = 4$; 1.5)
3b (R = Me) [c]	(*Z*)	3.6	–	6.6–7.6	−63.1 (4.0, $n = 5$; 2.6)
	(*E*)	3.2	–	6.6–7.6	−75.7 (1.9, $n = 5$; 0.8)
3c (R = ^{n}Pr) [c]	(*Z*)	1.1 [d] (7.2)	1.8, 3.9 [d]	6.6–7.6	−63.0 (3.0, $n = 5$; –)
	(*E*)	1.1 [d] (7.2)	1.8, 3.9 [d]	6.6–7.6	−75.1 (1.8, $n = 5$; 0.6)
3d (R = ^{i}Pr) [c,e]	(*Z*)	1.1 (5.2)	–	6.5–7.5	−63.1 (2.3, $n = 6$; –)
	(*E*)	1.3 (6.2)	–	6.5–7.5	−75.9 (–)
3e [R = $(CH_2)_2NH_2$] [f]		–	3.1	6.5–7.5	−84.0
3f [R = $(CH_2)_3NH_2$] [g]		–	1.2, 2.0, 3.0 [h]	6.8–7.4	−87.9
3g [R = $(CH_2)_4NH_2$]		–	1.6, 2.9	6.7–7.6	−83.5
3h [R = $(CH_2)_2OH$] [i]		–	3.3 [j], 4.0 [j]	6.7–7.5	−85.0
3i [R = $(CH_2)_2Me_2$] [k]		2.2	3.5	6.7–7.4	−76.2

[a] Highfield shifts allocated negative signs (TMS and CCl_3F used as standards).
[b] $\delta_H = 10.3$ (OH); 13.8 (NH) ppm; only *one* set of signals found.
[c] No resonance for the phenolic OH group found.
[d] Signals for *E* and *Z* isomer overlapping.
[e] $\delta_H = 3.5$ (CH) ppm for *E* and *Z* isomer.
[f] $\delta_H = 2.5$ (NH_2), 11.4 (OH) ppm.
[g] $\delta_H = 11.4$ (OH) ppm.
[h] 4H, CH_2 and NH_2.
[i] No signal found for OH.
[j] Multiplets, centred at value given.
[k] $\delta_H = 10.1$ (OH) ppm.

Table 3
Experimental details for the preparation of compounds *3a-i*

Compound	Reactants	[g (mmol)]	M.p. (°C)	Yield [g (%)]
3a [a]	**1**	3.3 (17.4)	25	2.8 (86)
	NH_3	0.5 (23.5)		
3b	**1**	2.5 (13.2)	88	1.9 (73)
	H_2NCH_3	0.4 (15.0)		
3c	**1**	2.2 (11.5)	125	1.8 (68)
	$H_2N(CH_2)_2CH_3$	0.7 (12)		
3d	**1**	1.9 (10)	128	2.0 (86)
	$H_2NCH(CH_3)_2$	0.6 (11)		
3e	**1**	1.9 (10)	85	1.9 (81)
	$H_2N(CH_2)_2NH_2$	0.6 (10)		
3f	**1**	2.8 (15)	91	2.6 (70)
	$H_2N(CH_2)_3NH_2$	1.0 (15)		
3g	**1**	1.9 (10)	121	2.4 (90)
	$H_2N(CH_2)_4NH_2$	0.9 (10)		
3h	**1**	1.9 (10)	87	1.8 (77)
	$H_2N(CH_2)_2OH$	0.6 (10)		
3i	**1**	3.0 (16)	114	3.8 (91)
	$H_2N(CH_2)_2NMe_2$	1.5 (16)		

[a] B.p. 81/12 mmHg, orange solid.

3.2. Crystal structure analysis of 3b, 3d and 3i (see Table 4)

The main crystallographic data are listed in Table 5.

3.3. Analytical data

2-[1'-Imino-2',2',2'-trifluoroethyl]phenol (**3a**): MS (30 °C) *m/e* (%): 189 (M^+, 100); 120 (M^+-CF_3, 97); 102 ($C_7H_4N^+$, 38); 92 ($C_7H_8^+$, 25) and other fragments. Analysis: $C_8H_6F_3NO$ (189.14): found C, 50.68; H, 3.30; F, 30.0%. Calc.: C, 50.80; H, 3.20; F, 30.13%.

2-[1'-*N*-Methylimino-2',2',2'-trifluoroethyl]phenol (**3b**): MS (60 °C) *m/e* (%): 203 (M^+, 36); 134 (M^+-CF_3, 100); 119 ($C_7H_5NO^+$, 10), 77 ($C_6H_5^+$, 6); 69 (CF_3^+, 5); 42 ($CH_2{=}N{=}CH_2$), 20) and other fragments. Analysis: $C_9H_8F_3NO$ (203.23): Found: C, 53.26; H, 4.11; F, 28.2%. Calc.: C, 53.19; H, 3.97; F, 28.04%.

2-[1'-*N*-Propylimino-2',2',2'-trifluoroethyl]phenol (**3c**): MS (80 °C) *m/e* (%): 231 (M^+, 61); 202 ($M^+-C_2H_5$, 15); 162, (M^+-CF_3, 32); 120 ($HOC_6H_4CNH^+$, 100) and other fragments. Analysis: $C_{11}H_{12}F_3NO$ (231.22): Found: C, 57.31; H, 5.34; F, 24.7%. Calc.: C, 57.14; H, 5.23; F, 24.65%.

2-[1'-*N*-Isopropylimino-2',2',2'-trifluoroethyl]-phenol (**3d**): MS (50 °C) *m/e* (%): 231 (M^+, 42); 189 ($M^+-C_3H_6$, 13); 162 (M^+-CF_3, 10); 120 ($HOC_6H_4CNH^+$, 100); 102 ($C_6H_5CN^+$, 8); 42 ($C_3H_6^+$, 7) and other fragments. Analysis: $C_{11}H_{12}F_3NO$ (231.22): Found: C, 57.34; H, 5.34; F, 24.7%. Calc.: C, 57.14; H, 5.23; F, 24.65%.

2-[1'-*N*-(2''-Aminoethyl)imino-2',2',2'-trifluoroethyl]-phenol (**3e**): MS (50 °C) *m/e* (%): 232 (M^+, 62); 203

Table 4
Crystal and data reduction parameters for compounds **3b**, **3d** and **3i**

	3b	**3d**	**3i**
Formula	$C_9H_8F_3NO$	$C_{11}H_{12}F_3NO$	$C_{12}H_{15}F_3N_2O$
Formula weight	203.2	231.2	260.3
Crystal size (mm)	1.0×0.8×0.7	0.3×0.4×0.2	0.6×0.5×0.5
F(000)	416	480	544
Crystal system	monoclinic	orthorhombic	monoclinic
Space group	$P2_1/n$	$P2_12_12_1$	$P2_1/n$
a (Å)	6.641(3)	7.784(2)	8.660(2)
b (Å)	18.044(8)	9.291(2)	11.135(2)
c (Å)	7.716(3)	15.942(4)	13.300(2)
β (°)	99.95(4)	-	99.83(2)
V (Å^3)	910.6(7)	1153.1(5)	1263.6(3)
Z	4	4	4
D_{calc} (g cm^{-3})	1.482	1.332	1.368
μ (cm^{-1})	1.38	1.18	1.18
Index ranges	$-8\leq h\leq 8$	$0\leq h\leq 9$	$-5\leq h\leq 11$
	$-14\leq k\leq 23$	$0\leq k\leq 11$	$-14\leq k\leq 14$
	$-10\leq l\leq 9$	$0\leq l\leq 18$	$-17\leq l\leq 17$
Temperature (K)	153	153	153
θ_{max} (°) for data	55	50	55
Reflections collected	4774	1246	3284
Independent reflections	2099 ($R_{int}=1.77\%$)	1203 ($R_{int}=0.89\%$)	2890 ($R_{int}=1.98\%$)
Observed reflections	1918 [F>4.0σ(F)]	958 [F>4.0σ(F)]	1503 [F>4.0σ(F)]
Diffractometer used	Siemens P4 m/V		
Radiation	Mo Kα (λ = 0.710 73 Å)		
Monochromator	Highly oriented graphite crystal		
Background measurement	Stationary crystal and stationary counter at beginning and end of scan, each for 25% total scan time		
Standard reflections	3 measured every 197 reflections		
Hydrogen atoms	Riding model, fixed isotopic U		

Table 5

Coordinates ($\times 10^4$) for non-hydrogen atoms and their equivalent isotopic temperature factors B_{eq} ($\text{Å}^2 \times 10^{-1}$)

Compound	Atom	*x*	*y*	*z*	B_{eq} (Å^2)
3b	C(1)	2381(2)	3306(1)	6516(2)	20(1)
	C(2)	1696(2)	3876(1)	5329(2)	18(1)
	C(3)	2481(2)	4590(1)	5637(2)	22(1)
	C(4)	3916(2)	4742(1)	7131(2)	26(1)
	C(5)	4585(2)	4176(1)	8298(2)	27(1)
	C(6)	3848(2)	3462(1)	8004(2)	24(1)
	C(7)	203(2)	3688(1)	3712(2)	19(1)
	C(8)	991(2)	3787(1)	1986(2)	27(1)
	C(9)	−2513(2)	3360(1)	5169(2)	27(1)
	O(1)	1589(2)	2622(1)	6140(1)	28(1)
	N(1)	−1595(2)	3432(1)	3593(1)	21(1)
	F(1)	2840(1)	3487(1)	2074(1)	45(1)
	F(2)	−212(2)	3486(1)	619(1)	45(1)
	F(3)	1193(2)	4506(1)	1627(1)	48(1)
3d	C(1)	−919(6)	3404(5)	3324(3)	30(1)
	C(2)	−1620(6)	4419(5)	3876(3)	30(1)
	C(3)	−2654(7)	4003(5)	4529(3)	41(2)
	C(4)	−3031(7)	2537(5)	4632(3)	43(2)
	C(5)	−2322(6)	1549(5)	4103(3)	37(2)
	C(6)	−1300(6)	1964(5)	3445(3)	33(2)
	C(7)	−1145(6)	5975(5)	3708(3)	32(1)
	C(8)	384(8)	6526(6)	4177(3)	48(2)
	C(9)	−3446(6)	6434(5)	2764(3)	39(1)
	C(10)	−3101(7)	6207(7)	1845(3)	62(2)
	C(11)	−4709(9)	7622(9)	2908(4)	95(3)
	O(1)	59(5)	3938(3)	2694(2)	39(1)
	N(1)	−1863(5)	6831(4)	3206(2)	32(1)
	F(1)	83(6)	6489(5)	5004(2)	98(2)
	F(2)	871(5)	7823(3)	3988(2)	89(2)
	F(3)	1754(4)	5675(4)	4082(3)	85(1)
3i	C(1)	1072(3)	3476(3)	2966(2)	27(1)
	C(2)	1600(3)	2297(2)	2886(2)	24(1)
	C(3)	1538(3)	1487(3)	3672(2)	31(1)
	C(4)	929(3)	1837(3)	4521(2)	37(1)
	C(5)	390(3)	3000(3)	4592(2)	38(1)
	C(6)	476(3)	3816(3)	3825(2)	33(1)
	C(7)	2228(3)	1937(2)	1949(2)	24(1)
	C(8)	1063(3)	1303(3)	1137(2)	31(1)
	C(9)	4763(3)	2700(3)	2493(2)	32(1)
	C(10)	6288(3)	2014(3)	2638(2)	31(1)
	C(11)	6194(4)	979(3)	4233(2)	41(1)
	C(12)	7493(3)	76(3)	2976(3)	39(1)
	O(1)	1166(3)	4243(2)	2184(2)	36(1)
	N(1)	3584(3)	2084(2)	1754(2)	28(1)
	N(2)	6182(3)	845(2)	3133(2)	28(1)
	F(1)	573(2)	271(2)	1488(1)	52(1)
	F(2)	1629(2)	1049(2)	302(1)	53(1)
	F(3)	−216(2)	1973(2)	858(1)	49(1)

($M^+ - H_2C{=}NH_2$, 32); 163 ($M^+ - CF_3$, 100); 134 [$HOC_6H_4CN(CH_3)^+$, 68]; 120 ($HOC_6H_4CNH^+$, 20); 44 ($H_2C{=}NH - CH_3^+$, 48); 30 ($H_2C{=}NH_2^+$, 60) and other fragments. Analysis: $C_{10}H_{11}F_3N_2O$ (232.20): Found C, 51.78; H, 4.77; F, 24.70%. Calc.: C, 51.73; H, 4.77; F, 24.54%.

2-[1′-*N*-(3″-Aminopropyl)imino-2′,2′,2′-trifluoroethyl]phenol (**3f**): MS (50 °C) *m/e* (%): 246 (M^+, 58); 216 ($M^+ - H_2C{=}NH_2$, 32); 177 ($M^+ - CF_3$, 100); 134 [$HOC_6H_4CN(CH_3)$, 40]; 120 ($HOC_6H_4CNH^+$, 42); 30 ($H_2C{=}NH_2$, 48) and other fragments. Analysis: $C_{11}H_{13}F_3N_2O$ (246.23): Found: C, 53.79; H, 5.25; F, 23.0%. Calc.: C, 53.66; H, 5.32; F, 24.15%.

2-[1′-*N*-(3″-Aminobutyl)imino-2′,2′,2′-trifluoroethyl]-phenol (**3g**); MS (80 °C) *m/e* (%): 260 (M^+, 30); 191 ($M^+ - CF_3$, 20); 120 ($HOC_6H_4CNH^+$, 20); 70 ($C_4H_8N^+$, 70); 43 ($C_2H_5N^+$, 38); 30 (CH_4N^+, 100) and other fragments. Analysis: $C_{12}H_{15}F_3N_2O$ (260.26): Found: C, 55.43; H, 5.81; F, 22.00%. Calc.: C, 55.38; H, 5.81; F, 21.90%.

2-[1′-*N*-(Ethyl-2″-ol)imino-2′,2′,2′-trifluoroethyl]-phenol (**3h**): MS (50 °C) *m/e* (%): 233 (M^+, 70); 202 ($M^+ - CH_2OH$, 30); 164 ($M^+ - CF_3$, 100); 121 ($HOC_6H_4N{=}CH_2$, 70); 44 ($H_2C{=}CHOH^+$, 60) and other fragments. Analysis: $C_{10}H_{10}F_3NO_2$ (233.12): Found C, 51.15; H, 4.32; F, 24.5%. Calc.: C, 51.51; H, 4.32; F, 24.44%.

2-[1′-*N*-(2″-Dimethylamino)ethyl)imino-2′,2′,2′-trifluoroethyl]phenol (**3i**): MS (60 °C) *m/e* (%): 260 (M^+, 95); 120 ($HOC_6H_4CNH^+$, 42); 102 [$M^+ - H_2N{=}N(CH_3)_2$, 25]; 77 ($C_6H_5^+$, 30); 71 [$H_3CCH{=}N(CH_3)_2$, 68]; 58 [$H_2N{=}N(CH_3)_2$, 100]; 42 ($H_2C{=}N{=}CH_2$, 98); 30 ($H_2C{=}NH_2$, 90) and other fragments. Analysis: $C_{12}H_{15}F_3N_2O$ (260.26): Found C, 55.30; H, 5.86; F, 21.80%. Calc.: C, 55.38; H, 5.81; F, 21.90%.

Acknowledgements

We are grateful for financial support by Fonds der Chemischen Industrie.

References

[1] S. Matsumoto, H. Kobayashi and K. Ueno, *Bull. Chem. Soc. Jpn., 42* (1969) 960.

[2] R.D. Hund and G.-V. Röschenthaler, *Phosphorus, Sulfur, Silicon, 62* (1991) 65.

[3] R.D. Hund and G.-V. Röschenthaler, *Phosphorus, Sulfur, Silicon, 66* (1992) 301.

[4] R.D. Hund, U. Behrens and G.V. Röschenthaler, *Phosphorus, Sulfur, Silicon, 69* (1992) 119.

[5] R.D. Hund and G.-V. Röschenthaler, *Phosphorus, Sulfur, Silicon, 73* (1992) 99.

[6] F.U. Seifert and G.-V. Röschenthaler, *Z. Naturforsch., Teil b, 48* (1993) 169.

[7] R.-M. Schoth and G.-V. Röschenthaler, *Phosphorus, Sulfur, Silicon, 103* (1995) 235.