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N-Germyl derivatives of sulfacetamide and *ortho*-(sulfonamido)phenylamines: characterization of *N*-[*o*-(*N′*,*N′*-dimethylsulfonamido)phenyl]-*N*-dimesitylgermaimine

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Triethylgermylation of sulfacetamide occurs on the sulfonamido nitrogen in competition with the 1,2 addition of the starting triethylgermyl dimethylamine on the carbonyl group. Thermal decomposition in the presence of dimethylamine yields *N*-triethylgermylsulfanilamide. Stable 1:1 sulfacetamide–DBU and 1:1 sulfacetamide–Et_3N complexes were isolated and fully characterized in the course of dehydrochlorination reactions. *o*-Sulfonamidophenylamine yields *N*,*N′*-bis-triethylgermylated derivatives, whereas *o*-(*N*,*N*-dimethylsulfonamido)phenylamine leads to monogermylated compounds. The *N*-dimethylaminodimesitylgermyl derivative is thermally stable. Dehydrohalogenation of the *N*-dimesitylfluorogermyl compound leads to the thermally stable but water sensitive *N*-[*o*-(*N′*,*N′*-dimethylsulfonamido)phenyl]-*N*-dimesitylgermaimine. Copyright © 2003 John Wiley & Sons, Ltd.

KEYWORDS: *N*-triethylgermyl sulfacetamide; *N*-germyl derivatives of *o*-sulfonamido phenylamine; *N*-germyl derivatives of *o*-*N*,*N*-(dimethylsulfonamido)phenylamine; germaimine; sulfacetamide–DBU complex; sulfacetamide–Et_3N complex

INTRODUCTION

Until recently, *N*-germyl sulfonamides have received little attention,[1–3] unlike silicon sulfonamides, which were highly studied during the 1970.[2,4–19]

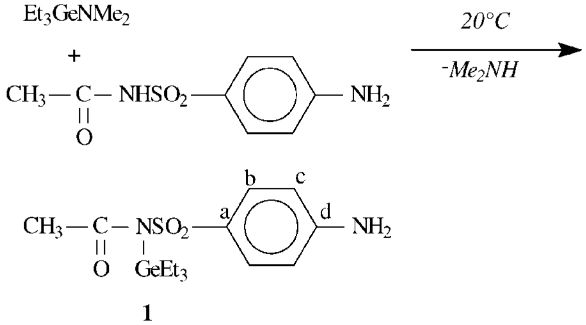
In our search for new inhibitors of carbonic anhydrase of the metal sulfonamides type,[20–24] we found that *p*-toluene dimesitylgermaimine was an active and selective inhibitor of the isoenzyme II of carbonic anhydrase.

Since it was previously established that electron-withdrawing aromatic groups on nitrogen stabilize Ge=N bonds,[25–29] we started from *para*- or *ortho*-sulfonamido phenylamines in the hope of obtaining a stable germaimine that might be an active enzyme inhibitor.

We present here our results for a series of sulfacetamido and *ortho*-sulfonamidophenyl aminogermanes.

RESULTS AND DISCUSSION

Taking into account the carbonyl group in sulfacetamide, transamination instead of transmetallation was used to prepare an *N*-germylsulfacetamide derivative. Although sulfacetamide could give two different aminogermanes, germylation occurs on the sulfonamido nitrogen (Eqn. (1)), as attested by the free NH_2 group in IR and ^1H NMR spectra and also by the shift to low field in ^{13}C NMR spectra observed for the C_a carbon.



(1)

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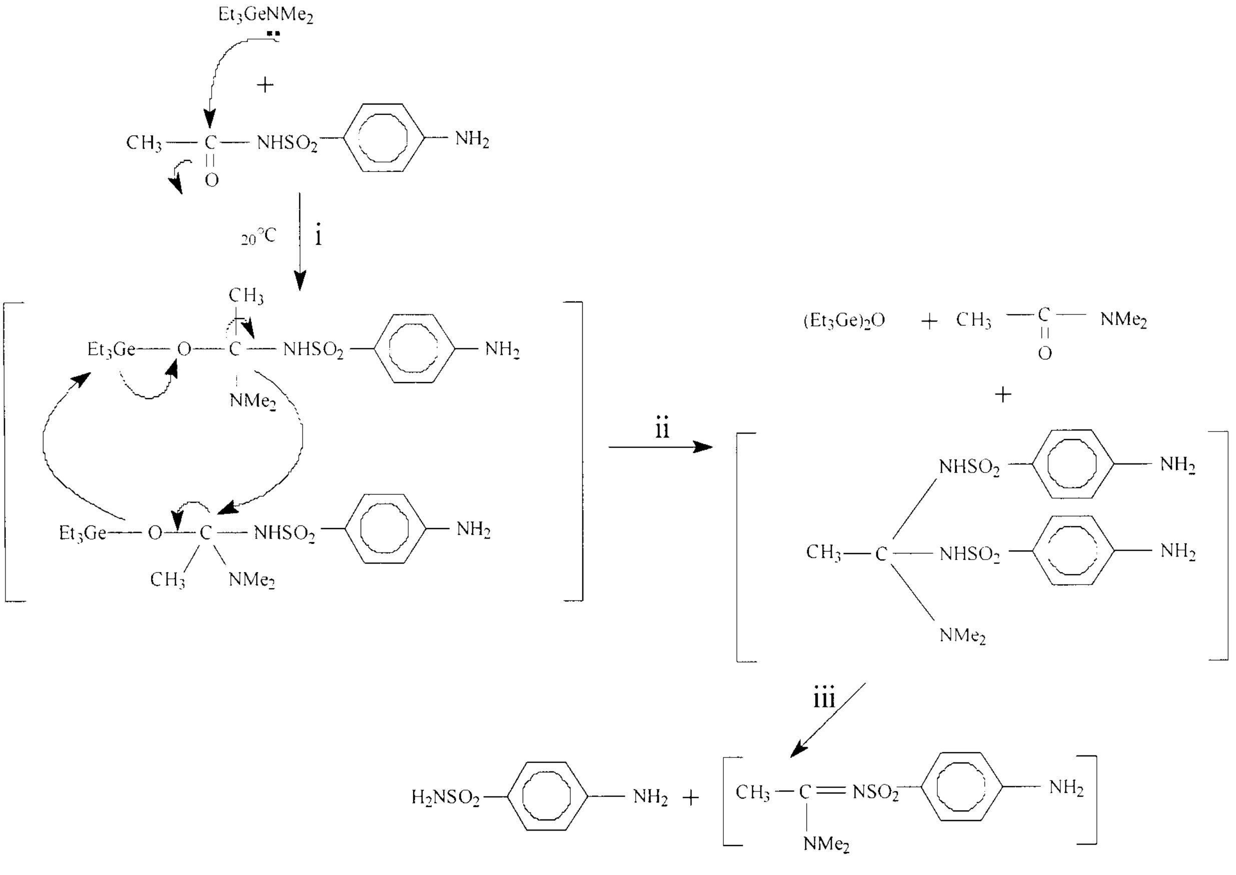
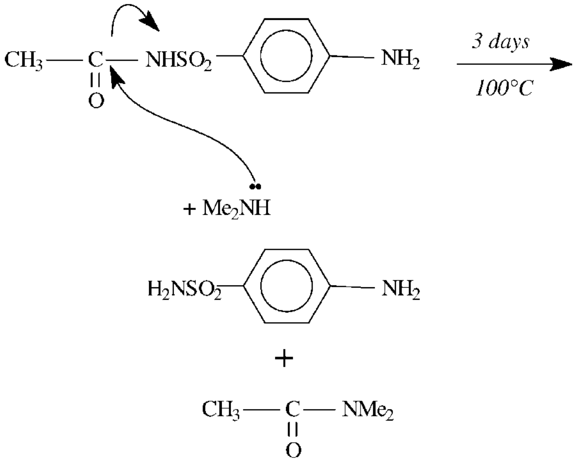


Scheme 1.

One possible explanation for the formation of **1** is the low nucleophile power of the NH_2 nitrogen due to conjugation of the lone pair with the aromatic ring. Such a difference of activity between the two nitrogen atoms was established in the sulfonamide $H_2NC_6H_5SO_2NH_2$ in which the first germylation also occurred on the sulfonamido nitrogen.[23] Although **1** is well characterized at 20 °C, it is never perfectly pure because of the competitive addition reaction on the carbonyl group which leads to unstable adducts whose decomposition[30] is given in Scheme 1.

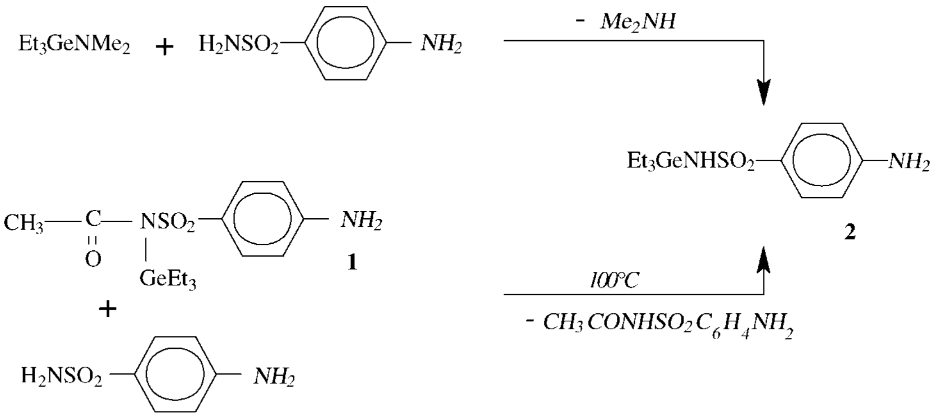


(2)

The products formed by this decomposition, i.e. *N,N*-dimethylacetamide, triethylgermanium oxide and sulfanilamide, were perfectly characterized by reference to authentic samples. At 20 °C, sulfacetamide does not react with dimethylamine formed by transamination (Eqn. (1)); but, at 100 °C, a transamination reaction (Eqn. (2)) between these two compounds led to *N,N*-dimethylacetamide and sulfanilamide.

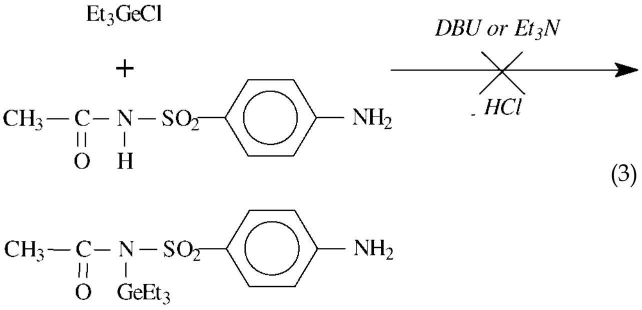
When the reaction between triethylgermyldimethylamine and sulfacetamide (Eqn. (1)) occurred with heating for 3 days in a sealed tube, *N*-triethylgermylsulfanilamide (**2**) was obtained. This compound was formed by the secondary reaction upon heating of compound **1** or triethylgermyldimethylamine, with sulfanilamide formed by reactions of Scheme 1 and Eqn. (2) (Scheme 2). Triethylgermylsulfanilamide (**2**) was identified by comparison with an authentic sample.[23]

After 3 days at 100 °C, **2** became the major compound (60%) and **1** could not be separated from the compounds derived from the secondary reactions of Schemes 1 and 2. To obtain **1** pure, intermolecular dehydrochlorination between



Scheme 2.

triethylgermanium chloride and sulfacetamide (Eqn. (3)), the method used with success for the preparation of **2**,[23] was attempted.



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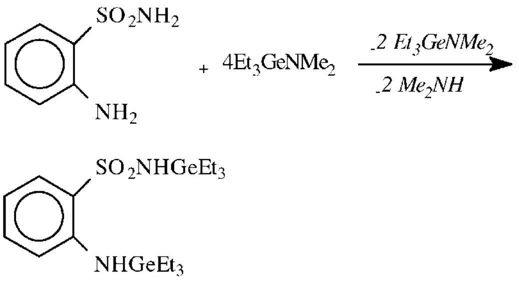
(3)

Two different amines were used as dehydrochlorinating agent: 1,8-diaza-bicyclo[5.4.0]undec-7-ene (DBU) and triethylamine. In the two cases, a complex between the amine and the sulfacetamide precipitated. There was no dehydrochlorination reaction. These complexes were isolated and perfectly characterized. Compared with the starting sulfacetamide, the chemical shift to low field of the carbonyl group favors a complexation of the amine on this carbon in a way similar to the initiation of the reaction observed with dimethylamine (Eqn. (2)).



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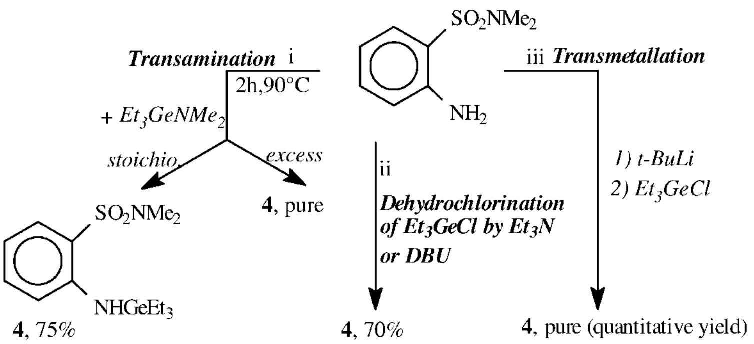
(4)

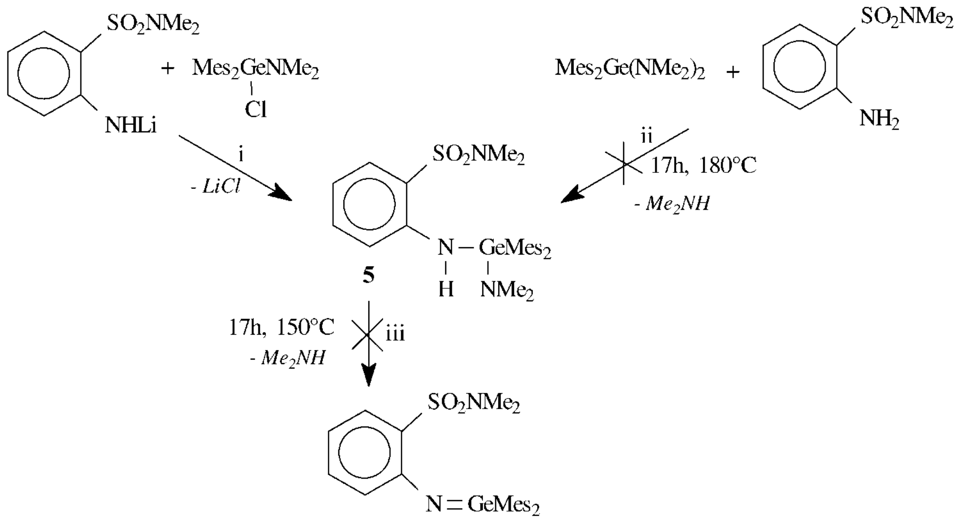
Because of these secondary reactions on the carbonyl group of sulfacetamide, we were unable to prepare any of the —C_6H_4—N(H)—Ge(X)Mes_2 compounds, as suitable starting material for a possible germaimine. Therefore, we concentrated on the series of *ortho*-sulfonamidophenyl-amines.

We first tried to form a Ge—N bond starting from the commercially available *o*-sulfonamidophenylamine. With an excess of triethylgermylamine, the transamination reaction (Eqn. (4)) easily gave the digermylated derivative **3**.

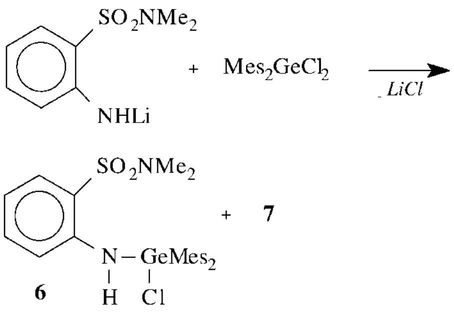
o-(*N*,*N*-Dimethylsulfonamido)phenylamine[31] was used to



Scheme 3.



Scheme 4.

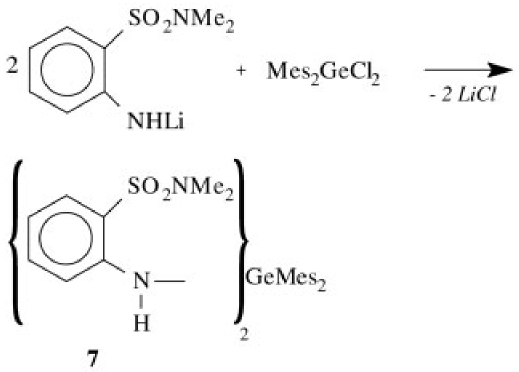


(5)

obtain a mono-germylated compound. Three different routes to Ge—N bonds were tried (Scheme 3). Transamination (Scheme 3, *i*) requires an excess of triethylgermylamine to yield **4** quantitatively; dehydrochlorination (Scheme 3, *ii*) in the presence of triethylamine or DBU, however, cannot be quantitative; this is in contrast to transmetallation (Scheme 3, *iii*), which is therefore the best route to the *N*-germylamines.

According to the method used for obtaining *p*-nitrophenyldimesitylgermaimine,[29] *N*-[*o*-(*N*′,*N*′-dimethylsulfonamido)phenyl]-*N*-dimethylaminodimesitylgermyl)-amine (**5**) (Scheme 4, *i*) was prepared. **5** could not be formed by transamination (Scheme 4, *ii*), the amino nitrogen of the starting material being a poor nucleophile. Unfortunately, **5** is thermally stable and, therefore, not a suitable starting material for the expected germaimine (Scheme 4, *iii*).

Since dimesitylhalogermyl secondary amines have previously been used as starting materials for germaimines,[24–28] the chlorogermyl derivative **6** was prepared according to Eqn. (5). However, **6** was always obtained in a mixture with diamine **7**, formed by reaction of the starting aminolithium derivative with the very reactive Ge—Cl bond in **6**. A pure sample of **7** was obtained according to Eqn. (6).

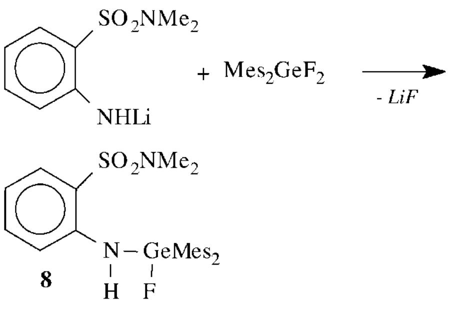


(6)

By contrast, the fluorogermyl amine **8** was easily obtained as a pure compound according to Eqn. (7).

Elimination of lithium fluoride from the lithium derivative of **8** (Scheme 5) allowed the characterization of germaimine **9**. Germaimine **9** was easily characterized by mass spectroscopy (MS; DCI/CH_4) by its peaks $M + 1 = 511$ and $M + 29 = 539$. **9** is very water sensitive; the corresponding germanol **10** was also characterized ($M + 1 = 529$).

Molecular modeling of **9** (Insight discover 2000, ESFF force field) shows that in the most stable conformer the distances



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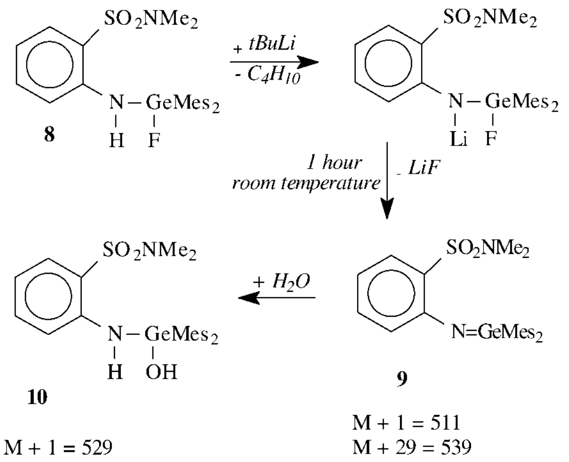


Scheme 5.

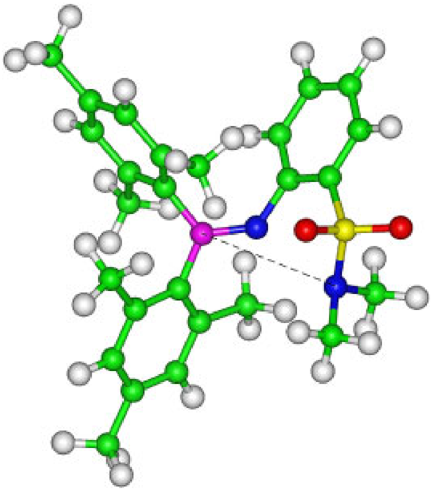


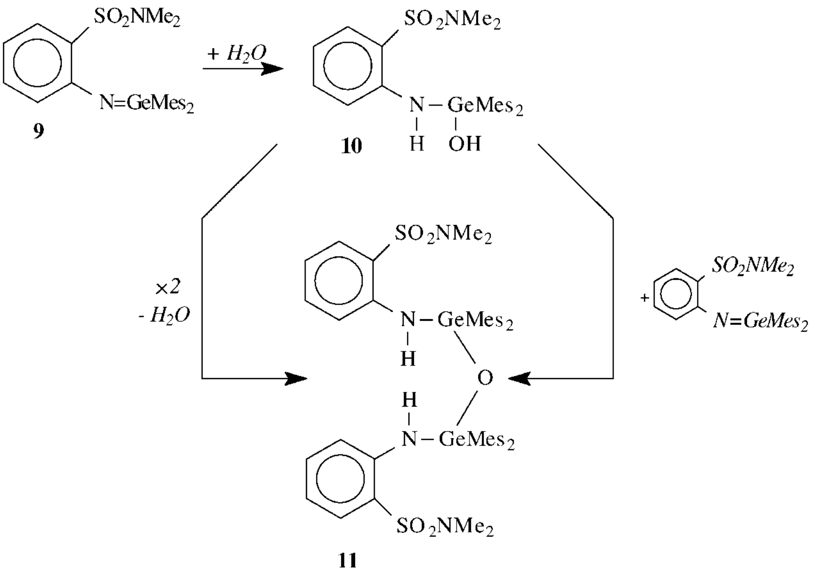
Figure 1. Molecular modeling of **9** (Insight Discover 2000, ESFF force field). The Ge—N distance (dotted line) is shorter than the van der Waals radii.

Ge—N (sulfonamide) and Ge—O are respectively 3.85 Å and 4.56 Å, and the van der Waals radii are respectively 4.12 Å (2.72 + 1.4 Å) for Ge—N and 4.07 Å (2.72 + 1.35 Å) for Ge—O. Therefore, germaimine **9** might be stabilized by both the electron-withdrawing effect of the *ortho*-sulfonamido group on phenyl and intramolecular coordination between germanium and nitrogen of the sulfonamido group (Fig. 1). Such a coordination explains the non-equivalence of the *N*-methyl groups observed in NMR spectra of **9**. All attempts to crystallize led to the oxide **11**, which was prepared according to previous hydrolyses of other germaimines[26,28] (Scheme 6).

In conclusion, although we showed that *N*-[*o*-(*N′*,*N′*-dimethylsulfonamido)phenyl]-*N*-dimesitylgermaimine (**9**) is thermally stable, its extreme sensitivity to hydrolysis prevents it from being used as a carbonic anhydrase inhibitor. Compounds **3, 4, 5** and **6** were tested as potential inhibitors of carbonic anhydrase, but they were ineffective; this fact can be attributed to the steric hindrance around the sulfonamido nitrogen.[32] The stable complexes of sulfacetamide with DBU or triethylamine are in the process of being tested for their activity towards carbonic anhydrase.

EXPERIMENTAL

The NMR numbering used in this paper is shown in Fig. 2.



Scheme 6.

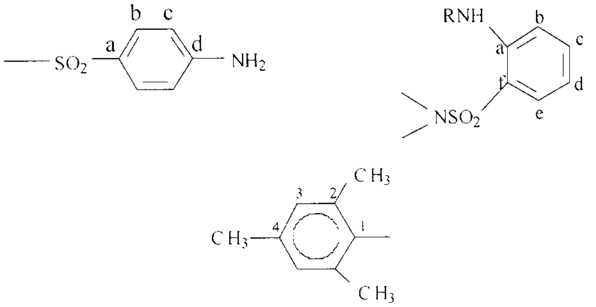


Figure 2. NMR numbering scheme.

Characterization of *N*-triethylgermylsulfacetamide (1)

To sulfacetamide (0.56 g; 2.62 mmol) in acetonitrile was added Et_3GeNMe_2 (0.57 g; 2.61 mmol). The mixture was left with stirring for one night at 20 °C, and the solvent evaporated. The ^1H NMR analysis of the sticky residue allowed the identification of **1** as the main compound (56%). ^1H NMR ($CDCl_3$) δ ppm: 1.02 (s, 15H, Et); 2.53 (s, 3H, CH_3CO); 7.54 (d, 2H, H_b, $^3J_{bc} = 9$ Hz); 6.48 (d, 2H, H_c, $^3J_{bc} = 9$ Hz); ^{13}C NMR ($CDCl_3$) δ ppm: 7.99 (CH_3); 6.33 (CH_2); 35.56 (CH_3CO); 170.40 (CO); 154.81 (C_d); 114.33 (C_c); 128.60 (C_b); 150.82 (C_a). IR (CH_3CN) ν cm^{-1}: 3374 and 3472 (NH_2). MS (EI): $M^{+\cdot} - Et = 345$ (5%); $M^{+\cdot} - Et - COCH_3 = 302$ (70%). Bis(triethylgermyl)oxide, $(Et_3Ge)_2O$ (16%), dimethylacetamide, CH_3CONMe_2 (8%), and sulfanilamide, H_2N-*p*-$C_6H_4SO_2NH_2$ (20%), were also identified by gel chromatography (GC), GC–MS, and ^1H and ^{13}C NMR by comparison with authentic samples.

Characterization of *N*-triethylgermylsulfanilamide (2)

To sulfacetamide (0.66 g; 3.08 mmol) in suspension in 8 ml tetrahydrafuran (THF) was added Et_3GeNMe_2 (0.68 g; 3.11 mmol). The mixture was transferred to a Schlenk tube and heated for 3 days at 100 °C. Evaporation of THF under vacuum led to a sticky orange residue. The ^1H NMR and gas chromatography (GC)–MS analyses showed *N*-triethylgermylsulfanilamide[23] (**2**, 53%), $(Et_3Ge)_2O$ (3%), CH_3CONMe_2 (27%) and sulfacetamide, H_2N-*p*-$C_6H_4SO_2NHCOCH_3$ (17%). These compounds were identified by comparison with authentic samples.

Tentative preparation of 1 by dehydrochlorination

Using DBU

To sulfacetamide (0.20 g; 0.93 mmol) and Et_3GeCl (0.18 g; 0.93 mmol) in THF was added DBU (0.14 g; 0.94 mmol). The white precipitate formed was filtered and washed with pentane. Evaporation of the solvent under vacuum yielded 0.30 g of a white powder of the complex $H_2NC_6H_4SO_2NHCOCH_3$–DBU, identified by comparison with starting materials and DBU–HCl (Table 1, 2D NMR attributions). Yield: 99%.

Using triethylamine

To sulfacetamide (0.51 g; 2.38 mmol) in 12 ml THF were added Et_3GeCl (0.47 g; 2.41 mmol) and 0.70 ml Et_3N. The white precipitate formed (0.76 g) was isolated by filtration and identified as the complex H_2N-*p*-$C_6H_4SO_2NHCOCH_3$–Et_3N. Yield: 65%.

Preparation of $CH_3C(O)NHSO_2C_6H_4$-*p*-NH_2–DBU

To sulfacetamide (0.76 g; 3.55 mmol) in 15 ml THF was added DBU (0.65 g; 4.26 mmol). The white precipitate was filtered, washed once with THF and twice with pentane, affording 1.25 g of 1:1 sulfacetamide–DBU complex. Yield: 97%. M.p.: 135 °C. ^1H NMR and ^{13}C NMR are given in Table 1. IR (DMSO) ν cm^{-1}: 3378 and 3207 (NH and NH_2); 1707 (C=O); 1468 and 1326 (SO_2). MS (DCI/NH_3) $C_{17}H_{26}N_4O_3S$: $M + 1 = 367$. Anal. Calc.: C, 55.70; H, 7.20; N, 15.30; S, 8.70. Found: C, 55.05; H, 7.26; N, 14.98; S, 8.61%.

Preparation of $CH_3C(O)NHSO_2C_6H_4$-*p*-NH_2–Et_3N

To sulfacetamide (0.78 g; 3.64 mmol) in 15 ml THF was added Et_3N (1.08 g; 10.69 mmol). The white precipitate was filtered and washed once with THF and twice with pentane, affording 0.97 g of 1:1 sulfacetamide–Et_3N complex. Yield: 84%. M.p.: 97 °C. ^1H NMR ($CDCl_3$) δ ppm: 1.14 (t, 9H, CH_3, $^3J_{HH} = 7$ Hz); 2.83 (q, 6H, CH_2, $^3J_{HH} = 7$ Hz); 2.00 (s, 3H, CH_3); 6.60 (d, 2H, H_c, $^3J_{bc} = 9$ Hz); 7.67 (d, 2H, H_b, $^3J_{bc} = 9$ Hz). ^{13}C NMR ($CDCl_3$) δ ppm: 10.59 (CH_3, Et_3N); 45.97 (CH_2, Et_3N); 25.54 (CH_3CO); 178.06 (CO); 134.00 (C_d); 113.91 (C_c); 128.48 (C_b); 149.19 (C_a). IR ($CDCl_3$) ν cm^{-1}: 3154 (NH and NH_2); 1793 (C=O); 1472 and 1384 (SO_2). MS (DCI/NH_3) $C_{14}H_{25}N_3O_3S$: $M + 1 - Et_3N = 316$. Anal. Calc.: C, 53.30; H, 8.00; N, 13.30; S, 10.20. Found: C, 52.81; H, 7.68; N, 12.89; S, 10.15%.

N-*o*-(*N′*-Triethylgermylsulfonamido)phenyl-*N*-triethylgermylamine (3)

By transamination in the presence of an excess of triethylgermylamine

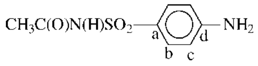
Et_3GeNMe_2 (0.98 g; 4.83 mmol) was added to *o*-sulfonamidophenylamine (0.21 g; 1.22 mmol) in 2 ml THF. The mixture was left with stirring at room temperature for 17 h. Evaporation of THF and excess Et_3GeNMe_2 under vacuum led to a sticky residue (0.60 g) identified as **3**. Yield: 98%. ^1H NMR (DMSO) δ ppm: 0.96 (s, 15H, $Et_3GeNHSO_2$); 1.06 (s, 15H, Et_3GeNH); 5.44 (s, 1H, NH); 6.64 (s, 1H, $NHSO_2$); 6.50–7.63 (m, 4H, C_6H_4). ^{13}C NMR (DMSO) δ ppm: 7.83 and 7.96 (CH_3); 5.84 and 6.13 (CH_2); 148.20 (C_a); 114.11 (C_b); 132.45 (C_c); 116.19 (C_d); 128.47 (C_e); 127.60 (C_f). IR (nujol) ν cm^{-1}: 3242 and 3344 (NH). MS (EI) $C_{18}H_{36}Ge_2N_2O_2S$: $M^{+\cdot} = 490$ (10%); $M^{+\cdot} - Et = 461$ (100%).

Table 1. NMR data for sulfacetamide, DBU and related complexes

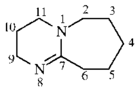
^{1}H NMR (δ ppm)						
Sulfacetamide[a]			Sulfacetamide–DBU complex			
			DBU		Sulfacetamide	
CDCl$_3$	DMSO	DBU[b] (CDCl$_3$)	DMSO	CDCl$_3$	DMSO	CDCl$_3$
7.78 (d, 2H, H$_b$, $^3J_{bc}$ = 7 Hz) 6.66 (d, 2H, H$_c$, $^3J_{bc}$ = 7 Hz) 2.03 (s, 3H, CH$_3$) 4.09 (s, 2H, NH$_2$)	7.54 (d, 2H, H$_b$, $^3J_{bc}$ = 7 Hz) 6.61 (d, 2H, H$_c$, $^3J_{bc}$ = 7 Hz) 1.87 (s, 3H, CH$_3$) 6.06 (s, 2H, NH$_2$) 10.04 (s, 1H, NH)	4.31 (m, 6H, CH$_2$ (2,9,11)) 3.45 (m, 2H, CH$_2$ (6)) 2.70 (m, 8H, CH$_2$ (3,4,5,10))	3.50 (m, 6H, CH$_2$ (2,9,11)) 2.80 (m, 2H, CH$_2$ (6)) 1.60–2.20 (m, 8H, CH$_2$ (3,4,5,10))	3.44 (m, 6H, CH$_2$ (2,9,11)) 2.90 (m, 2H, CH$_2$ (6)) 1.90 (m, 8H, CH$_2$ (3,4,5,10))	7.41 (d, 2H, H$_b$, $^3J_{bc}$ = 8 Hz) 6.59 (d, 2H, H$_c$, $^3J_{bc}$ = 8 Hz) 1.65 (s, 3H, CH$_3$)	7.72 (d, 2H, H$_b$, $^3J_{bc}$ = 8 Hz) 6.59 (d, 2H, H$_c$, $^3J_{bc}$ = 8 Hz) 1.97 (s, 3H, CH$_3$)

^{13}C NMR (δ ppm)					
		Sulfacetamide–DBU complex			
		DBU		Sulfacetamide	
Sulfacetamide[a] (DMSO)	DBU[b] (CDCl$_3$)	DMSO	CDCl$_3$	DMSO	CDCl$_3$
153.54 (C$_a$)	23.81 (C$_{10}$)	18.82 (C$_{10}$)	21.52 (C$_{10}$)	150.33 (C$_a$)	153.30 (C$_a$)
112.15 (C$_c$)	27.32 (C$_5$)	23.33 (C$_5$)	25.92 (C$_5$)	111.72 (C$_c$)	117.49 (C$_c$)
129.68 (C$_b$)	29.79 (C$_3$)	25.87 (C$_3$)	28.46 (C$_3$)	128.17 (C$_b$)	130.87 (C$_b$)
123.67 (C$_d$)	30.96 (C$_4$)	28.17 (C$_4$)	31.04 (C$_4$)	132.38 (C$_d$)	133.21 (C$_d$)
168.28 (CO)	38.30 (C$_6$)	31.44 (C$_6$)	35.40 (C$_6$)	174.05 (CO)	183.59 (CO)
23.07 (CH$_3$)	45.31 (C$_9$)	37.55 (C$_9$)	40.57 (C$_9$)	26.35 (CH$_3$)	27.79 (CH$_3$)
	49.48 (C$_{11}$)	47.76 (C$_{11}$)	50.79 (C$_{11}$)		
	53.89 (C$_2$)	53.24 (C$_2$)	56.74 (C$_2$)		
	161.92 (C$_7$)	165.24 (C$_7$)	168.53 (C$_7$)		

[a] Very low solubility in CDCl$_3$.



[b] 1,8-diazobicyclo[5,4,0] undec-7-ene = DBU



Without an excess of triethylgermylamine

Et_3GeNMe_2 (0.48 g; 2.36 mmol) was added to *o*-sulfonamidophenylamine (0.19 g; 1.13 mmol) in 2 ml THF and left with stirring at room temperature for 17 h. Evaporation of THF under vacuum led to a sticky residue containing (GC/MS, ^1H and ^{13}C NMR analysis): 60% of **3** and 40% of the monogermylated derivative, *N*-(*o*-sulfonamido)phenyl-*N*-triethylgermylamine. ^1H NMR (DMSO) δ ppm: 0.96 (s, 15H, $Et_3GeNHSO_2$); 5.80 (s, 2H, NH_2); 6.55 (s, 1H, $NHSO_2$); 6.50–7.63 (m, 4H, C_6H_4). ^{13}C NMR (DMSO) δ ppm: 7.58 (CH_3); 6.00 (CH_2); 145.27 (C_a); 114.52 (C_b); 132.14 (C_c); 116.39 (C_d); 127.37 (C_e); 125.47 (C_f). MS (EI) $C_{12}H_{22}GeN_2O_2S$: $M^{+\cdot} = 332$ (17%); $M^{+\cdot} - Et = 303$ (100%).

(*N,N*-Dimethylsulfonamido)phenylamine

This was obtained according to Ref. 31. M.p.: 89 °C. ^1H NMR ($CDCl_3$) δ ppm: 2.74 (s, 6H, CH_3); 5.03 (s, 2H, NH_2); 6.70 (dd, 1H, H_b, $^3J_{bc} = 8$ Hz and $^4J_{bd} = 2$ Hz); 6.71 (td, 1H, H_d, $^3J_{cd} = {}^3J_{de} = 8$ Hz and $^4J_{bd} = 2$ Hz); 7.27 (td, 1H, H_c, $^3J_{cb} = {}^3J_{cd} = 8$ Hz and $^4J_{ce} = 2$ Hz); 7.55 (dd, 1H, H_e, $^3J_{de} = 8$ Hz and $^4J_{ce} = 2$ Hz). ^1H NMR (C_6D_6) δ ppm: 2.34 (s, 6H, CH_3); 4.80 (s, 2H, NH_2); 6.23 (dd, 1H, H_b, $^3J_{bc} = 8$ Hz and $^4J_{bd} = 2$ Hz); 6.44 (td, 1H, H_d, $^3J_{cd} = {}^3J_{de} = 8$ Hz and $^4J_{bd} = 2$ Hz); 6.94 (td, 1H, H_c, $^3J_{cb} = {}^3J_{cd} = 8$ Hz and $^4J_{ce} = 2$ Hz); 7.60 (dd, 1H, H_e, $^3J_{de} = 8$ Hz and $^4J_{ce} = 2$ Hz). ^{13}C NMR ($CDCl_3$) δ ppm: 37.94 (CH_3); 146.56 (C_a); 117.75 (C_b); 134.26 (C_c); 117.10 (C_d); 130.42 (C_e); 117.00 (C_f). ^{13}C NMR (C_6D_6) δ ppm: 37.59 (CH_3); 147.22 (C_a); 116.85 (C_b); 134.02 (C_c); 117.78 (C_d); 130.77 (C_e); 109.11 (C_f). IR (nujol) ν cm^{-1}: 3392 and 3490 (NH_2). MS (EI) $C_8H_{12}N_2O_2S$: $M^{+\cdot} = 200$ (23%); $M^{+\cdot} - C_6H_4NH_2 = 108$ (17%).

N-o-(*N′,N′*-Dimethylsulfonamido)phenyl-*N*-triethylgermylamine (4)

By transamination

With a 1:1 stoichiometry. Et_3GeNMe_2 (1.78 g; 8.74 mmol) and *o*-(*N,N*-dimethylsulfonamido)phenylamine (1.67 g; 8.37 mmol) were heated for 2 h at 90 °C in a sealed tube. The liquid residue obtained after evaporation of excess Et_3GeNMe_2 under reduced pressure contained a mixture of **4** (75%) and unreacted starting sulfonamide (25%).

With a 1:2 stoichiometry. Et_3GeNMe_2 (1.97 g; 9.70 mmol) and *o*-(*N,N*-dimethylsulfonamido)phenylamine (0.97 g; 4.85 mmol) in a sealed tube were heated for 2 h at 90 °C. The liquid obtained (1.67 g) was identified as **4**. Yield: 96%. An attempt to distill led to decomposition. ^1H NMR ($CDCl_3$) δ ppm: 1.03 (s, 15H, Et); 2.66 (s, 6H, NMe_2); 6.77 (s, 1H, NH); 6.52 (dt, 1H, H_d, $^3J_{de} = {}^3J_{cd} = 8$ Hz and $^4J_{bd} = 2$ Hz); 6.57 (dd, 1H, H_b, $^3J_{bc} = 8$ Hz and $^4J_{bd} = 2$ Hz); 7.18 (dt, 1H, H_c, $^3J_{cd} = {}^3J_{bc} = 8$ Hz and $^4J_{ce} = 2$ Hz); 7.50 (dd, 1H, H_e, $^3J_{de} = 8$ Hz and $^4J_{ce} = 2$ Hz). ^{13}C NMR (DMSO) δ ppm: 8.25 (CH_3); 6.51 (CH_2); 151.01 (C_a); 114.62 (C_b); 134.03 (C_c); 117.10 (C_d); 131.05 (C_e); 117.66 (C_f); 37.76 (NMe_2). MS (EI) $C_{14}H_{26}GeN_2O_2S$: $M^{+\cdot} = 360$ (8%); $M^{+\cdot} - Et = 331$ (100%).

By dehydrochlorination

Et_3GeCl (1.12 g; 5.74 mmol) and *o*-(*N,N*-dimethylsulfonamido)phenylamine (1.12 g; 5.60 mmol) were heated in a sealed tube with an excess (200%) of triethylamine. After 3 h at 90 °C, an NMR sample showed 70% of **4** and 30% of unreacted starting materials. The mixture was left for three more hours at 90 °C without further change. The use of DBU as a dehydrochlorinating agent gave the same result.

By transmetallation

To *o*-(*N,N*-dimethylsulfonamido)phenylamine (0.58 g; 2.89 mmol) in 2 ml THF at − 78 °C was added *t*-BuLi (2.89 mmol; 1.6 M in hexane). After 1 h with stirring at room temperature, Et_3GeCl (0.56 g; 2.89 mmol) was added. THF was partially evaporated and LiCl centrifuged. The residue was treated twice with diethyl ether. After evaporation of the remaining solvents under vacuum, the viscous liquid (1.02 g) was identified as **4**. Yield: 99%. An attempt to distill led to decomposition.

Chlorodimethylaminodimesitylgermane, *$Mes_2GeCl(NMe_2)$*

Mes_2GeCl_2 (4.03 g; 10.56 mmol) in 30 ml benzene was added to Me_2NLi (10.50 mmol) in 5 ml THF at − 60 °C. THF was removed and replaced by toluene. LiCl was then centrifuged. Evaporation of toluene under reduced pressure led to $Mes_2GeCl(NMe_2)$ (3.09 g) as a viscous liquid, which could not be distilled because of symmetrization leading to Mes_2GeCl_2 and $Mes_2Ge(NMe_2)_2$. Yield: 75%. ^1H NMR ($CDCl_3$) δ ppm: 2.29 (s, 6H, *p*-CH_3); 2.47 (s, 12H, *o*-CH_3); 2.69 (s, 6H, NMe_2); 6.88 (s, 4H, C_6H_2). ^{13}C NMR ($CDCl_3$) δ ppm: 21.10 (*p*-CH_3); 23.23 (*o*-CH_3); 39.96 (NMe_2); 133.82 (C_1); 143.19 (C_2); 129.78 (C_3); 139.84 (C_4). MS (EI) $C_{20}H_{28}ClGeN$: $M^{+\cdot} = 391$ (13%); $M^{+\cdot} - NMe_2 = 347$ (52%); $M^{+\cdot} - Cl = 356$ (52%).

Bis(dimethylamino)dimesitylgermane, *$Mes_2Ge(NMe_2)_2$*

This was prepared as described in Ref. 29.

N-[*o*-(*N′,N′*-Dimethylsulfonamido)phenyl]-*N*-(dimethylaminodimesitylgermyl)amine (5)

By transmetallation

To *o*-(*N,N*-dimethylsulfonamido)phenylamine (0.50 g; 2.50 mmol) in 3 ml THF at − 60 °C was added *t*-BuLi (2.55 mmol). After 1 h under stirring at room temperature, $Mes_2Ge(Cl)NMe_2$ (1.00 g; 2.55 mmol) in 3 ml THF was added. The mixture was placed into a sealed tube and heated for 17 h at 150 °C. THF was replaced by toluene and LiCl centrifuged. Evaporation of toluene under reduced pressure led to 1.22 g of **5** as a sticky powder. Yield: 88%. ^1H NMR ($CDCl_3$) δ ppm: 2.24 (s, 6H, *p*-CH_3); 2.39 (s, 12H, *o*-CH_3); 2.51 (s, 6H, $GeNMe_2$); 2.56 (s, 6H, SO_2NMe_2); 6.81 (s, 4H, C_6H_2); 6.01–7.80 (m, 4H, C_6H_4). ^{13}C NMR ($CDCl_3$)

δ ppm: 20.98 (*p*-CH_3); 22.22 (*o*-CH_3); 39.66 ($GeNMe_2$); 37.26 (SO_2NMe_2); 149.14 (C_a); 115.27 (C_b); 133.68 (C_c); 118.85 (C_d); 130.81 (C_e); 119.04 (C_f); 133.21 (C_1); 143.02 (C_2); 129.56 (C_3); 139.16 (C_4). IR (THF) $\nu\, cm^{-1}$: 3356 (NH). MS (EI) $C_{28}H_{39}GeN_3O_2S$: $M^{+\cdot} - NMe_2 = 511$ (73%); $M^{+\cdot} - NHC_6H_4$-*o*-$SO_2NMe_2 = 356$ (100%).

Thermal stability of 5

A sample of **5** heated for 17 h at 150 °C in a sealed tube gave an ^1H NMR spectrum that still showed NMe_2 protons, indicating that thermal elimination of dimethylamine in **5** had not occurred under these conditions.

Attempt by transamination

o-(*N*,*N*-Dimethylsulfonamido)phenylamine (0.20 g; 1.01 mmol) in 1 ml THF and $Mes_2Ge(NMe_2)_2$ (0.50 g; 1.01 mmol) when heated in a sealed tube for 48 h at 180 °C did not react. An ^1H NMR spectrum showed unchanged starting materials.

N-[*o*-(*N*′,*N*′-Dimethylsulfonamido)phenyl]-*N*-(dimesitylchlorogermyl)amine (6)

To *o*-(*N*,*N*-dimethylsulfonamido)phenylamine (0.57 g; 2.85 mmol) in 2 ml THF at − 70 °C was added *t*-BuLi (2.85 mmol). After 1 h stirring at room temperature, Mes_2GeCl_2 (1.10 g; 2.87 mmol) in 5 ml THF was added at − 40 °C. The mixture was heated for 17 h at 80 °C in a sealed tube. THF was replaced by toluene and LiCl centrifuged. Evaporation of toluene under reduced pressure led to a sticky residue containing 48% of **6** [^1H NMR ($CDCl_3$) δ ppm: 2.26 (s, 12H, *o*-CH_3); 2.47 (s, 6H, *p*-CH_3); 2.69 (s, 6H, NMe_2); 6.85 (s, 4H, C_6H_2); 6.40–7.80 (m, 4H, C_6H_4). ^{13}C NMR ($CDCl_3$) δ ppm: 21.18 (*p*-CH_3); 22.64 (*o*-CH_3); 37.66 (NMe_2); 147.39 (C_a); 115.46 (C_b); 134.40 (C_c); 118.52 (C_d); 129.09 (C_e); 119.16 (C_f); 149.33 (C_1); 143.53 (C_2); 129.66 (C_3); 141.09 (C_4). MS (EI) $C_{26}H_{33}GeClN_2O_2S$: $M^{+\cdot} = 546$ (19%); $M^{+\cdot} - Cl = 511$ (50%); $M^{+\cdot} - NHC_6H_4$-*o*-$SO_2NMe_2 = 347$ (100%)] and *N*,*N*-bis [*o*-(*N*′,*N*′-dimethylsulfonamido)phenyl]-*N*-dimesitylgermylamine (**7**, 52%), identified by comparison with an authentic sample prepared as follows.

N,*N*-Bis[(*o*-(*N*′,*N*′-dimethylsulfonamido)phenyl]-*N*-dimesitylgermylamine (7)

To *o*-(*N*,*N*-dimethylsulfonamido)phenylamine (0.61 g; 3.03 mmol) in 3 ml THF at − 60 °C was added *t*-BuLi (3.03 mmol). After 1 h with stirring at room temperature, Mes_2GeCl_2 (0.58 g; 1.52 mmol) in 5 ml THF at − 40 °C was added. After 2 h of further stirring, THF was replaced by toluene and LiCl centrifuged. Evaporation of toluene under reduced pressure led to a yellow powder, which was washed twice with diethyl ether, yielding 1.02 g of pure **7**. Yield: 95%. M.p.: 183 °C. ^1H NMR ($CDCl_3$) δ ppm: 2.25 (s, 6H, *p*-CH_3); 2.44 (s, 12H, *o*-CH_3); 2.64 (s, 6H, NMe_2); 6.45 (s, 1H, NH); 6.84 (s, 4H, C_6H_2); 6.55 (ddd, 1H, H_d, $^3J_{cd} = 7$ Hz, $^3J_{de} = 8$ Hz and $^4J_{bd} = 2$ Hz); 6.68 (dd, 1H, H_b, $^3J_{bc} = 8$ Hz and $^4J_{bd} = 2$ Hz); 7.01 (ddd, 1H, H_c, $^3J_{cd} = 7$ Hz, $^3J_{cb} = 8$ Hz and $^4J_{ce} = 2$ Hz); 7.52 (dd, 1H, H_e, $^3J_{de} = 8$ Hz, $^4J_{ce} = 2$ Hz). ^{13}C NMR ($CDCl_3$) δ ppm: 21.05 (*p*-CH_3); 22.51 (*o*-CH_3); 37.41 (NMe_2); 147.75 (C_a); 116.33 (C_b); 133.89 (C_c); 118.02 (C_d); 130.62 (C_e); 118.75 (C_f); 131.37 (C_1); 143.08 (C_2); 130.13 (C_3); 140.22 (C_4). IR ($CDCl_3$) $\nu\, cm^{-1}$: 3341 (NH). MS (EI) $C_{34}H_{44}GeN_4O_4S_2$: $M^{+\cdot} - NHC_6H_4$-*o*-$SO_2NMe_2 = 511$ (100%). Anal. Calc.: C, 57.56; H, 6.25; N, 7.90; S, 9.04. Found: C, 57.01; H, 6.27; N, 7.65; S, 8.92%.

N-[*o*-(*N*′,*N*′-Dimethylsulfonamidophenyl]-*N*-(dimesitylfluorogermyl)amine (8)

To *o*-(*N*,*N*-dimethylsulfonamido)phenylamine (0.32 g; 1.59 mmol) in 5 ml benzene at 0 °C was added *t*-BuLi (1.60 mmol). After 30 min, the aminolithium compound formed was transferred to Mes_2GeF_2 (0.55 g; 1.59 mmol) in 10 ml benzene. After 1 h with stirring at room temperature, LiF was centrifuged. Evaporation of benzene under reduced pressure led to a sticky residue, which was treated several times with diethyl ether, leading to 0.78 g of **8**. Yield: 92%. M.p.: 129 °C. ^1H NMR ($CDCl_3$) δ ppm: 2.27 (s, 6H, *p*-CH_3); 2.37 and 2.39 (s, 6H, *o*-CH_3); 2.69 (s, 6H, NMe_2); 6.85 (s, 4H, C_6H_2); 6.60–7.40 (m, 4H, H_b, H_c, H_d and NH); 7.62 (dd, 1H, H_e, $^3J_{de} = 8$ Hz and $^4J_{ce} = 2$ Hz). ^1H NMR (C_6D_6) δ ppm: 2.01 (s, 6H, *p*-CH_3); 2.48 and 2.51 (s, 6H, *o*-CH_3); 2.31 (s, 6H, NMe_2); 6.15 (d, 4H, C_6H_2, $^5J_{HF} = 0.18$ Hz); 6.50–7.30 (m, 4H, H_b, H_c, H_d and NH); 7.75 (dd, 1H, H_e, $^3J_{de} = 8$ Hz and $^4J_{ce} = 2$ Hz). ^{13}C NMR ($CDCl_3$) δ ppm; 21.20 (*p*-CH_3); 22.68 (*o*-CH_3); 37.67 (NMe_2); 147.44 (C_a); 118.51 (C_b); 134.41 (C_c); 117.47 (C_d); 130.64 (C_e); 119.10 (C_f); 143.54 (C_2); 129.67 (C_3); 141.10 (C_4). ^{13}C NMR (C_6D_6) δ ppm: 21.40 (*p*-CH_3); 22.93 (*o*-CH_3); 37.25 (NMe_2); 149.04 (C_a); 117.74 (C_b); 134.32 (C_c); 119.08 (C_d); 131.07 (C_e); 109.10 (C_f); 143.86 (C_2); 130.07 (C_3); 141.13 (C_4). ^{19}F NMR ($CDCl_3$) δ ppm: −83.54. IR ($CDCl_3$) $\nu\, cm^{-1}$: 3158 (NH). MS (EI) $C_{26}H_{33}FGeN_2O_2S$: $M^{+\cdot} = 530$ (63%); $M^{+\cdot} - F = 511$ (17%); $M^{+\cdot} - NHC_6H_4$-*o*-$SO_2NMe_2 = 331$ (100%). Anal. Calc.: C, 59.01; H, 6.29; N, 5.29; S, 6.06. Found: C, 58.79; H, 6.48; N, 4.79; S, 5.75%.

N-[*o*-(*N*′,*N*′-Dimethylsulfonamido)phenyl]-*N*-dimesitylgermaimine (9)

To **8** (0.48 g; 0.91 mmol) in 15 ml benzene was added *t*-BuLi (1.02 mmol) at − 40 °C. After 3 h with stirring at room temperature, LiF was centrifuged and the solvent evaporated under reduced pressure. The residue obtained was identified as a mixture of **8** (30%) and **9** (70%). Another attempt by heating the starting materials in a sealed tube led to a similar result (15% **8** and 85% **9**); two other attempts with longer stirring under nitrogen in Schlenk tubes also gave the same results in addition to the hydrolysis products. ^1H NMR (C_6D_6) δ ppm: 2.07 (s, 6H, *p*-CH_3); 2.48 (s, 6H, *o*-CH_3); 2.52 (s, 6H, *o*-CH_3); 2.15 (s, 3H, NMe); 2.21 (s, 3H, NMe); 6.75 (s, 2H, C_6H_2); 6.85 (s, 2H, C_6H_2); 6.45 (m, 1H, H_b); 6.90–7.40 (m, 2H, H_c and H_d); 7.70 (m, 1H, H_e). ^{13}C NMR (C_6D_6) δ ppm: 21.06 (*p*-CH_3); 23.15 and 23.16 (*o*-CH_3); 37.29 and 37.31 (NMe_2);

149.80 (C_a); 109.07 (C_b); 131.28 (C_c); 125.34 (C_d); 129.50 (C_e); 108.73 (C_f); 134.85 (C_1); 143.28 (C_2); 130.57 (C_3); 139.40 (C_4). MS (DCI/CH_4) $C_{26}H_{32}GeN_2O_2S$: M + 1 = 511; M + 29 = 539 and germanol $Mes_2Ge(OH)$—NH—C_6H_4-*o*-SO_2NMe_2 (**10**) M + 1 = 529. Some signals of a transient compound observed in the ^{13}C NMR spectrum of germaimine **9** partially hydrolyzed were attributed to germanol **10**. An attempt to crystallize **9** from diethyl ether at −20 °C led to a mixture of **9** and its hydrolysis products.

Bis[*o*-(*N′*,*N′*-dimethylsulfonamido) phenylamino]dimesitylgermyloxide (11)

To **8** (0.52 g; 0.99 mmol) in 10 ml benzene was added *t*-BuLi (1.02 mmol; 1.7 M in hexane). After 3 h stirring at room temperature were added 30 ml of wet benzene (9 μl of H_2O ($\cong$0.5 mmol) added to 30 ml of benzene with a GC syringe). After 48 h further stirring at room temperature in a Schlenk tube, LiF was centrifuged and benzene was evaporated under vacuum, yielding 0.48 g of a sticky residue of **11**. Yield: 93%. The crude compound was dissolved in the minimum of diethyl ether and the minimum of pentane was added. After 24 h at − 20 °C, a sticky oily compound was obtained at the bottom of the flask and identified as **11**. ^{1}H NMR (C_6D_6) δ ppm: 2.06 (s, 12H, *p*-CH_3); 2.50 (s, 24H, *o*-CH_3); 6.63 (s, 8H, C_6H_2); 6.15 (dd, 2H, H_b, $^3J_{cb} = 8$ Hz and $^4J_{bd} = 2$ Hz); 6.90 (m, 2H, H_c); 6.48 (m, 2H, H_d); 7.60 (dd, 2H, H_e, $^3J_{de} = 8$ Hz and $^4J_{ce} = 2$ Hz); 4.63 (1s, 2H, NH); 2.32 (s, 12H, NMe_2). ^{13}C NMR (C_6D_6) δ ppm: 21.06 (*p*-CH_3); 23.15 (*o*-CH_3); 37.51 (NMe_2); 150.10 (C_a); 116.89 (C_b); 133.80 (C_c); 117.60 (C_d); 130.85 (C_e); 135.27 (C_1); 143.28 (C_2); 129.47 (C_3); 139.41 (C_4). IR ($CDCl_3$) ν cm^{-1}: 3232 (NH); 1128 and 1414 (SO_2). MS (DCI/CH_4) $C_{52}H_{66}Ge_2N_4O_5S_2$: M + 1 = 1037 and M + 29 = 1065, with traces of **9** (M + 1 = 511) and (Mes_2-GeO)*n*; *n* = 1 (M + 1 = 329), *n* = 2 (M + 1 = 655) and *n* = 3 (M + 1 = 981).

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REFERENCES

1. Blaschette A, Hamann T, Michalides A and Jones PG. *J. Organomet. Chem.* 1993; **456**: 49.
2. Gordetsov AS, Latyaeva VN, Zimin SV, Leshchukova LI, Skobeleva SE and Kulagina NV. *Zh. Obshch. Khim.* 1993; **63**: 1596.
3. Kuplennik ZI and Pinchuk AM. *Zh. Obshch. Khim.* 1979; **49**: 155.
4. Becke-Goehring M and Wunsch G. *Liebigs Ann. Chem.* 1958; **618**: 43.
5. Derkach NYa and Smetankina NP. *Zh. Obshch. Khim.* 1964; **34**: 3615.
6. Gordetsov AS, Vostokov IA, Dergunov YuI and Mushkin YuI. *Zh. Obshch. Khim.* 1974; **44**: 2456.
7. Dergunov YuI, Musin NI and Mushkin YuI. *Zh. Obshch. Khim.* 1975; **45**: 2240.
8. Vostokov IA and Dergunov YuI. *Tr. Khim. Khim. Tekhnol.* 1975; 31.
9. Appel R and Montenarh M. *Chem. Ber.* 1975; **108**: 1442.
10. Bartroli J and Marin Moga A. *Chem. Abstr.* 1987; **109**: 73651s; Spanish patat ES 556 322.
11. Appel R and Montenarh M. *Chem. Ber.* 1975; **108**: 2340.
12. Piekos R, Kobylczyk K and Osmialowski K. *Sci. Pharm.* 1977; **45**: 234.
13. Piekos R, Osmialowski K and Kobylczyk K. *Sci. Pharm.* 1977; **45**: 301.
14. Piekos R and Osmialowski K. *Sci. Pharm.* 1980; **48**: 54.
15. Roesky HW, Raubold J, Noltemeyer M, Witt M and Bohra R. *Z. Naturforsch.* 1992; **47**: 171.
16. Palomo A and Cabre J. *Afinidad* 1987; **44**: 234.
17. Appel R and Montenarh M. *Chem. Ber.* 1978; **111**: 759.
18. Montenarh M and Appel R. *Z. Naturforsch. Teil B* 1976; **31**: 902.
19. Appel R and Montenarh M. *Z. Naturforsch. Teil B* 1976; **31**: 993.
20. Ben Maarouf Z, Chazalette C, Rivière-Baudet M and Rivière P. *Main Group Met. Chem.* 1999; **22**: 405.
21. Chazalette C, Rivière-Baudet M, Scozzafava A, Abbate F, Ben Maarouf Z and Supuran CT. *J. Enz. Inhib.* 2001; **16**: 125.
22. Chazalette C, Rivière-Baudet M, Supuran CT and Scozzafava A. *J. Enz. Inhib.* 2001; **16**: 475.
23. Rivière-Baudet M, El Baz F, Satgé J, Khallaayoun A and Ahra M. *Phosphorus Sulfur Silicon Relat. Elem.* 1996; **112**: 203.
24. Rivière-Baudet M, Supuran CT, Scozzafava A, Briganti F, El Baz F, Ben Maarouf Z and Rivière P. *Main Group Met. Chem.* 1997; **20**: 641.
25. Rivière-Baudet M, Khallaayoun A and Satgé J. *J. Organomet. Chem.* 1993; **462**: 89.
26. Rivière-Baudet M, Khallaayoun A and Satgé J. *Organometallics* 1993; **12**: 1003.
27. El Baz F, Ahra M and Rivière-Baudet M. *Phosphorus Sulfur Silicon Relat. Elem.* 1996; **117**: 21.
28. Rivière-Baudet M and Morère A. *J. Organomet. Chem.* 1992; **431**: 17.
29. El Baz F, Rivière-Baudet M, Chazalette C and Gornitzka H. *Phosphorus Sulfur Silicon Relat. Elem.* 2000; **163**: 121.
30. Rivière-Baudet M. *Main Group Met. Chem.* 1995; **18**: 353.
31. Zhurawlewa LP and Kirsanov AV. *J. Gen. Chem. USSR* 1962; **32**: 3679 (English translation).
32. Chazalette C. *Thesis of European Doctorate*, Toulouse, 1 March 2002.