DOI: 10.1002/ejoc.200700709

Mild Electrochemical Deprotection of *N*-Phenylsulfonyl *N*-Substituted Amines Derived from (*R*)-Phenylglycinol

Vincent Coeffard,[a] Christine Thobie-Gautier,[b] Isabelle Beaudet,[a] Erwan Le Grognec,*[a] and Jean-Paul Quintard*[a]

Keywords: Sulfonamides / Protecting groups / Cleavage reactions / Electrolyses / Cyclic voltammetry

The electrochemical reduction of *N*-phenylsulfonyl *N*-substituted amines in a protic medium under constant cathodic potential was found to be a mild desulfonylation method, which is able to challenge the chemical ones. The influence of the nature of the *N*-substituents was considered in order to clarify the mechanistic aspects and to evaluate the scope of the method.

Introduction

Since its use by Fischer in 1915 for the protection of the amino functionality of α-amino acids,[1] arenesulfonyl groups (SO_2Ar) have emerged amongst the most useful in the activation and protection of alcohol and amine functional groups.[2,3] In particular, the toluenesulfonyl group (tosyl or Ts) has been widely used as an efficient protecting group for nitrogen because of its easy introduction and its propensity to lower the basicity of the nitrogen atom. In addition, the obtained sulfonamides, which are often crystalline, provide a strong chromophore and are stable to a wide variety of reaction conditions.

However, sulfonyl protection of amines involves problematic removal in the case of highly functionalized, sensitive substrates. Indeed, the early deprotection protocols for *N*-SO_2Ar derivatives involved reduction with Na/NH_3, parent reactions with anthracene or naphthalene–sodium or refluxing in CH_3CO_2H/HBr, conditions which often detract with their initial synthetic appeal.[2] Several other deprotection protocols including reduction by $LiEt_3BH$ in THF,[4] photolysis in the presence of $NaBH_4$,[5] reduction by $Bu_3SnH/AIBN$,[6] treatment with KF supported on Al_2O_3[7] or with NaI/TMSCl[8] were also shown to be sometimes effective. More recently, milder experimental conditions involving electron transfers were disclosed for desulfonylation such as magnesium in methanol under sonication,[9] SmI_2 in THF/DMPU[10] or in THF/HMPA.[11]

In parallel, to circumvent these harsh conditions, a number of sulfonyl protecting groups that are amenable to mild deprotection have been developed.[2,3] For instance, Fukuyama recently reviewed the versatility of *p*- and *o*-nitrobenzenesulfonyl group (nosyl or Ns) into both activation and protection of the amino group.[12] However, the nitrobenzenesulfonyl group strongly lowers the basicity of the nitrogen atom and presents the drawback of a possible displacement of the nitro group during the sulfonamide cleavage with thiolate.[13] Similarly, the pyridylsulfonyl group was described as a versatile protecting group.[14] Pyridylsulfonyl chloride is, however, still not commercially available and its preparation is not straightforward.[15] Other sulfonyl protecting groups that have also been reported are the (β-trimethylsilyl)ethanesulfonyl (SES)[16,17] and the 2-(1,3-dioxan-2-yl)ethylsulfonyl (Dios)[18] or heteroarenesulfonyl groups;[19,20] they are, however, not commercially available. Recently, a new sulfonamide analogue of the Boc group, the *tert*-butylsulfonyl group (Bus), which is stable to strong metallation conditions, was introduced.[21] However, the *tert*-butylsulfonyl moiety is not readily introduced because it requires two steps from the *tert*-butylsulfinyl chloride. Several other sulfonyl protecting groups have also been described, such as the methanesulfonyl (Ms)[22] or trifluoromethanesulfonyl (Tf) groups,[23] but they are often unable to satisfy the requirements for the synthesis of polyfunctional molecules owing to their harsh cleavage conditions.[2]

Besides the chemical removal of *N*-arenesulfonyl groups, several electrochemical studies related to the cathodic cleavage of protecting groups and notably sulfonamides have

[a] Université de Nantes, Nantes Atlantique Universités, CNRS, Faculté des Sciences et des Techniques, Laboratoire de Synthèse Organique (LSO), UMR 6513,
2 rue de la Houssinière, B. P. 92208, 44322 Nantes Cedex 3, France
Fax: +33-2-51125402
E-mail: erwan.legrognec@univ-nantes.fr
jean-paul.quintard@univ-nantes.fr
[b] Université de Nantes, Nantes Atlantique Universités, CNRS, Faculté des Sciences et des Techniques, Laboratoire d'Analyse Isotopique et Electrochimique des Métabolismes (LAIEM), UMR 6006,
2 rue de la Houssinière, B. P. 92208, 44322 Nantes Cedex 3, France

been reported in the last decades.[24] In a pioneering work, Horner and Neumann showed that the electrochemical reduction of simple sulfonamides at a mercury cathode in MeOH containing Me_4NCl as a supporting electrolyte led to the corresponding amines and sulfinic acid in good yields.[25] Later, the mechanism of the electrochemical cleavage of sulfonamides was rationalized according to Equation (1).[24,26,27] Moreover, further electrochemical investigations have underlined the milder reduction potential required for the cleavage of more labile sulfonamides like *N*-SO_2Pyr,[14] or *N*-Ns[28] relative to *N*-Ts[29–31] as a result of their lower LUMO.

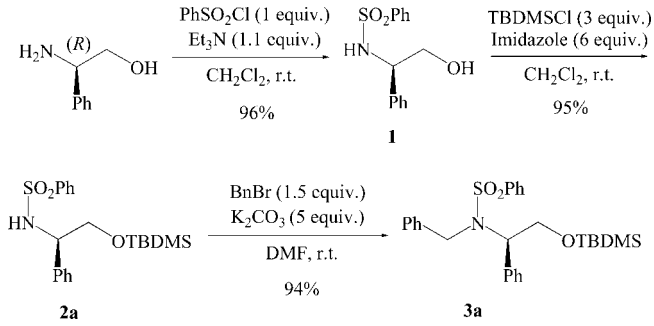
$$RR'NSO_2Ar + 2e^- + 2H^+ \rightarrow RR'NH + ArSO_2H \quad (1)$$

Nevertheless, to the best of our knowledge these studies were mostly limited to unfunctionalized sulfonamides,[24] even if desulfonylation by electrochemical reduction was used in some multistep syntheses.[32,33] In connection with some ongoing projects, we were interested in the smooth and selective removal of the arenesulfonyl group on β-amino alcohols that was compatible with functionalities, stereogenic centres and nitrogen substitution.[34] Because the usual chemical methods of *N*-SO_2Ph removal were not efficient to solve our problem, we then considered that such a cleavage could be performed electrochemically. Herein, we describe the electrochemical cleavage of the *N*-SO_2Ph bond of *N*-substituted β-amino alcohols as a simple, selective, reproducible and efficient method.

Results and Discussion

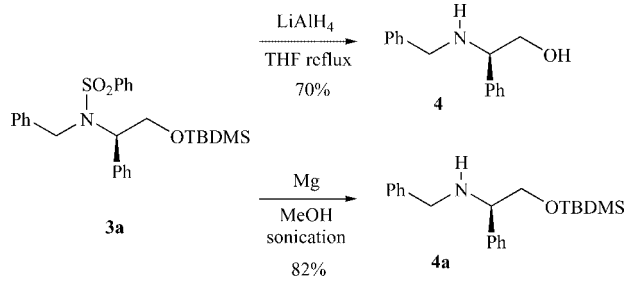
We first considered (*R*)-phenylglycinol derivative **3a** as a model compound in order to find a smooth and efficient method for removing the benzenesulfonyl group. This β-amino alcohol, commercially available as both (*R*) and (*S*) enantiomers, is widely used as a chiral auxiliary in organic synthesis, as we have recently reported in a study devoted to the preparation of enantioenriched α-aminoorganostannanes.[35,36] In addition, phenylglycinol contains an epimerizable hydrogen at the benzylic position, which was an additional criterion for our study. Treatment of (*R*)-phenylglycinol with benzenesulfonyl chloride in the presence of triethylamine in dichloromethane afforded benzenesulfonamide **1** in 96% yield (Scheme 1). Subsequent protection of the alcohol with *tert*-butyldimethylsilyl chloride in dichloromethane gave **2a** in 95% yield, which was in turn treated with benzyl bromide and an excess amount of K_2CO_3 to afford **3a** in 94% yield.

We then considered the usual methods used for chemical deprotection of the *N*-SO_2Ph group of derivative **3a** (vide supra).[2,3] Treatment of **3a** with metallic sodium in liquid ammonia induced complete degradation of the starting material. Similarly, heating of **3a** at 70 °C in an acetic acid solution containing HBr for 8 h resulted in complete decomposition of **3a**.[37] When **3a** was treated with $LiAlH_4$ in THF (reflux, 8 h),[38] N–S bond cleavage occurred, but the alkoxysilane functionality was also totally unmasked, which



Scheme 1.

led to β-amino alcohol **4** in 70% yield (Scheme 2). The spectroscopic data obtained for **4** were in complete agreement with those previously described in the literature.[39] Gratifyingly, treatment of **3a** with Mg (10 equiv.) in dry methanol under sonication was effective. Compound **3a** was sonicated at 50 °C until consumption of the starting material was complete, and after workup, desulfonylated compound **4a** was isolated in 82% yield (Scheme 2). Unfortunately, we found that this procedure was hardly reproducible on **3a** and that several decomposition products were observed when the conditions were applied to secondary amine **2a**.



Scheme 2.

Therefore, we concluded after numerous attempts that this method could not be considered as a versatile and general one. As SmI_2 in association with DMPU (or HMPA) was reported to be an efficient removal method for the *N*-SO_2Ph group, we then applied the described procedure to **3a**.[40] However, when **3a** was heated at reflux in THF in the presence of SmI_2 (6 equiv.) and DMPU (0.4 mL) no color change was observed and the characteristic purple color remained after 15 h. Finally, ^{1}H NMR spectroscopic and HPLC analyses of the crude material revealed that no cleavage of the sulfonamide group had occurred. The latter attempt revealed to us that the reducing power of SmI_2 when associated to DMPU was not sufficient to cleave the *N*-SO_2Ph bond. In order to determine the appropriate potential required to promote N–S bond cleavage, we embarked upon electrochemical studies. First, a cyclic voltammetry study of compound **3a** was performed to evaluate its reduction potential and to examine the feasibility of the selective removal of the *N*-benzenesulfonyl group of **3a** (Figure 1).

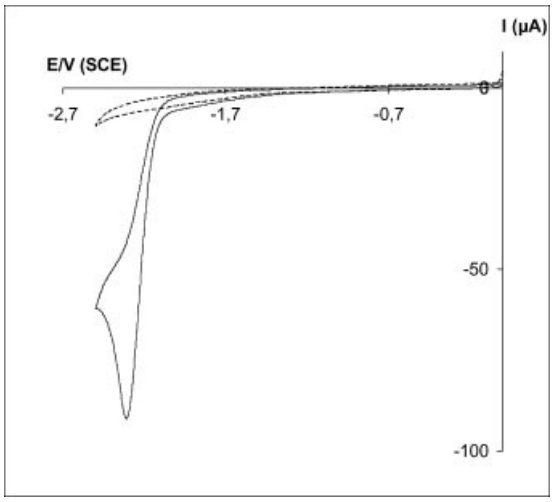
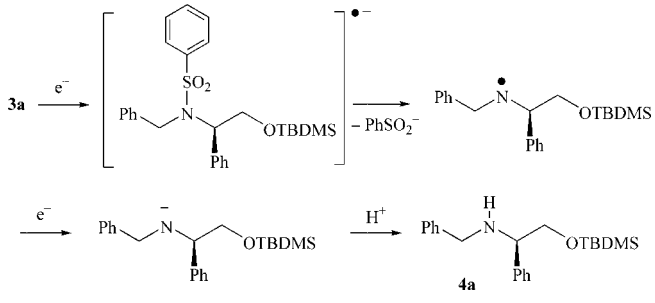


Figure 1. Cyclic voltammograms at a glassy carbon electrode in MeCN and Bu_4NHSO_4 (0.1 mol L^{-1}) (---) and in the presence of **3a** (−), c = 3.3.10^{-3} mol L^{-1}, v = 100 mV s^{-1}.

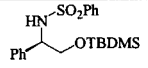
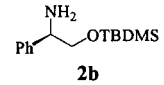
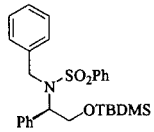
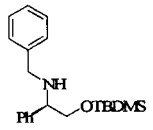
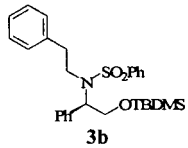
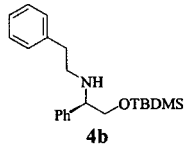
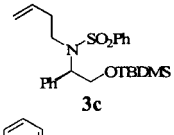
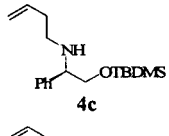
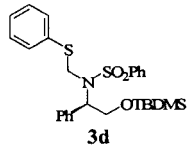
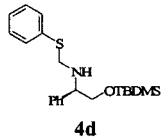
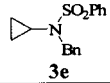
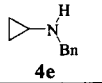
By considering the literature and after extensive investigation of solvents and supporting electrolytes, we found that the electrochemical experiments should be performed in MeCN by using Bu_4NHSO_4 as the supporting electrolyte at a glassy working electrode. Whereas no oxidation peak was observed for **3a** in the potential range from 0 to 1.5 V (vs. SCE), it displayed an irreversible reduction wave at –2.31 V (vs. SCE). This potential explains the lack of reproducibility of the deprotection method for **3a** by using Mg/MeOH, as this value is close to the normal potential of magnesium (–2.3 V vs. SCE).[41] By using a rotating electrode, we determined this reduction to be a two-electron process with respect to ferrocene. The observed reduction corresponds to the formation of a radical anion, which allows cleavage of the N–S bond into a sulfinate anion and a nitrogen-centred radical able to trap a second electron to give the corresponding amine after protonation by Bu_4NHSO_4 as proposed by Simonet (Scheme 3).[27] These results are in good agreement with previous work reporting the electrochemical reduction of arenesulfonamides.[26,42]



Scheme 3.

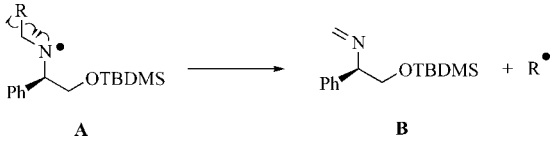
We then performed electrolysis of benzenesulfonamide **3a** at a controlled potential in order to assess the feasibility of preparative cathodic cleavage under the experimental conditions previously established. The electrolysis was conducted at –2.3 V and the number of electrons consumed was determined to be 2.05 F mol^{-1} (Table 1, Entry 2), which is a value that is in good agreement with the mechanism. At the end of the electrolysis, the analysis of the crude material by ^{1}H NMR spectroscopy indicated that the SO_2Ph moiety was completely removed. The amine was isolated in 85% yield after chromatography on silica gel. Similarly, extension of the electrolysis to sulfonamide **2a** resulted in complete removal of the protecting group to give desired β-amino alcohol **2b** in 96% yield, whereas chemical methods failed (vide supra). At this stage we checked by ^{1}H NMR spectroscopic analysis that no epimerization occurred during the electrolysis.[43]

Table 1. Electrochemical data for the removal of *N*-benzenesulfonyl group.

Entry	Sulfonamide	$E_{p,c}$ [V][a]	Product	Yield [%][b]	n [F mol^{-1}]
1	 **2a**	–2.26	 **2b**	96[c]	2.10
2	 **3a**	–2.31	 **4a**	85[d]	2.05
3	 **3b**	–2.27	 **4b**	85[c]	2.50
4	 **3c**	–2.31	 **4c**	89[c]	2.30
5	 **3d**	–2.20	 **4d**	57[d,e]	2.35
6	 **3e**	–2.27	 **4e**	56[d,e]	2.80

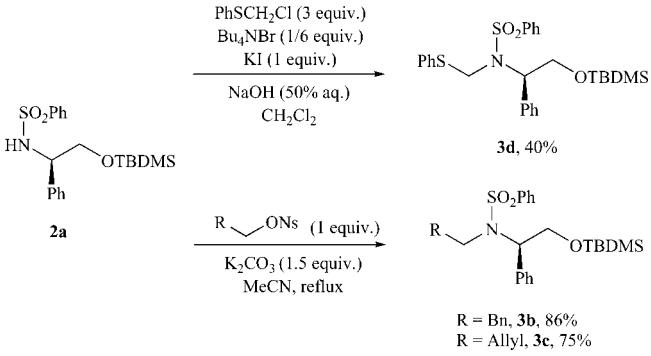
[a] Determined by cyclic voltammetry. [b] Isolated yields obtained after electrolysis, extraction with diethyl ether and chromatography on silica gel. [c] A Hg pool was used as cathode for the electrolysis. [d] A vitreous carbon electrode was used as cathode for the electrolysis. [e] In this case, we also observed **2b** in the crude (**4d/2b**, 71:29 by ^{1}H NMR spectroscopy). [f] In this case, we also observed **3e** and **4g** in the crude (**3e/4e/4g**, 17:65:18 by ^{1}H NMR spectroscopy).

We then decided to evaluate the scope of this electrochemical removal procedure with *N*-substituted sulfonamides. Indeed, we anticipated that aminyl radical **A** could be prone to give rise to imine **B** by β-fragmentation (Scheme 4) as already reported.[44–46]



Scheme 4.

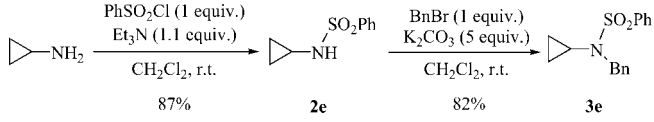
In this context, *N*-substituted benzenesulfonamides **3b**–**d** were conveniently prepared from **2a** according to Scheme 5. Tertiary amines **3b** (R = Bn) and **3c** (R = allyl) were efficiently obtained by using the corresponding *p*-nitrobenzenesulfonyl derivative according to a reported procedure.[47] In contrast, the preparation of phenylthiomethyl derivative **3d** required an aqueous/dichloromethane biphasic reaction and the use of Bu_4NBr as a phase-transfer agent. This procedure afforded **3d** in 40% yield from **2a** after purification by flash chromatography. The cyclic voltammetry of these benzenesulfonamides was investigated and indicated similar behaviour relative to that of **3a**. An irreversible reduction peak in the range of –2.2 to –2.3 V (vs. SCE) corresponding to a two-electron process was observed (Table 1). As with **3a**, no oxidation peak was observed for these derivatives in the potential range from 0 to 1.5 V (vs. SCE).



Scheme 5.

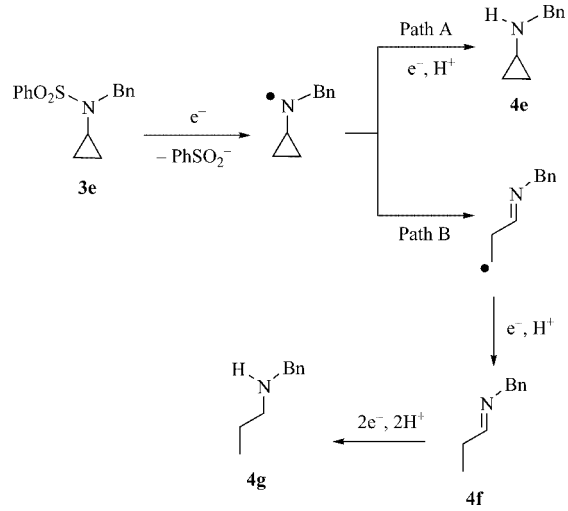
Whatever the nature of the substitution on nitrogen in **3a**–**d**, the cathodic potentials present low differences, which indicates the poor influence of the substituents. The electrolysis of sulfonamides **3b**–**d** was performed under similar conditions to those used for **3a** by using either a vitreous carbon or a Hg pool as the cathodic electrode.[48] Under these conditions, desired deprotected β-amino alcohols **4b**,**c** were isolated in good yields (85 and 89% yield, respectively). In contrast, the electrolysis conducted on **3d** afforded amine **4d** in moderate yield (57%) along with primary amine **2b** (**4d**/**2b**, 71:29 on the basis of ^{1}H NMR spectra recorded of the crude material). The formation of the latter compound could be explained by the hydrolysis of corresponding imine **B** during the workup procedure (Scheme 4). Within the detection limits of the NMR spectrometer, *N*-methylamine, which might be expected through reduction of the imine moiety, was not observed in the crude reaction mixture. For **3b**,**c**, β-fragmentation producing $PhCH_2^{\cdot}$ or $CH_2{=}CH{-}CH_2^{\cdot}$ did not occur, as no trace of **2b** was observed in those cases, although β-scissions expelling a benzyl radical have already been reported.[49] For **3d**, this radical decomposition, which releases PhS$^{\cdot}$, constitutes a competitive reaction to the formation of expected unmasked amine **4d**. This result is in good agreement with the easier β-elimination of the thiophenoxy radical from the intermediate aminyl radical.[50]

To evaluate the limits of the methodology and to support the above interpretation, we then turned our attention to the study of cyclopropyl derivative **3e**, as the cyclopropyl ring opening is highly favoured in the presence of radicals.[51–53] The preparation of **3e** was achieved through *N*-SO_2Ph protection of cyclopropylamine (87% yield), followed by benzylation with benzyl bromide under usual conditions that proceeded in 82% yield (Scheme 6).



Scheme 6.

The cyclic voltammetry of **3e** exhibits an irreversible reduction peak at –2.27 V. In this case, as a result of adsorption of **3e** on the vitreous carbon electrode, the preparative electrolysis was carried out on a Hg pool. Surprisingly, we observed a significantly larger amount of electrons consumed (2.8 F mol^{-1}) relative to those of compounds **3a**–**d** (Table 1). The reaction resulted in the production of *N*-benzylcyclopropylamine **4e** (56%) by path A along with *N*-benzylpropylamine **4g** (**4e**/**4g**, 78:22 from the ^{1}H NMR spectrum of the crude) by path B (Scheme 7).



Scheme 7.

The formation of **4g** can be explained by ring opening of the cyclopropyl aminyl radical, which leads to the imine intermediate that is subsequently reduced with two electrons. It is noteworthy that both electrochemical processes (paths A and B) are fortuitously overlapped. Indeed, the observed cyclic voltammogram of **3e** encompassed the formation of amine **4e** (path A) and the reduction of imine **4f**

(path B) (see Figure 2). This interpretation was confirmed by carrying out separate cyclic voltammetry on **4f**, prepared by condensation of benzylamine and propionaldehyde. These results confirmed that *N*-substituted amines are prone to give homolytic β-scission, which can seriously challenge the formation of the expected deprotected amine, such as **4d** and **4e**. In spite of these possible side reactions, it is noteworthy that the electrochemical reduction of sulfonamides is able to afford the corresponding deprotected amines in good yields and in a preparative fashion at the laboratory scale.

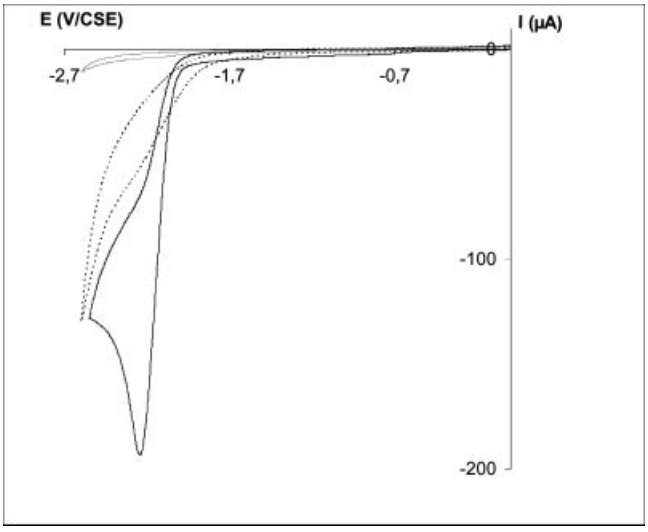


Figure 2. Cyclic voltammograms of **3e** (−), $c = 6.10^{-3}$ mol L^{-1}, in MeCN and Bu_4NHSO_4 (0.1 mol L^{-1}), $v = 100$ mV s^{-1} and **4f** (---), $c = 2.3.10^{-3}$ mol L^{-1}.

Conclusions

The above results complete previous reports on the mechanism of deprotection of *N*-arenesulfonylamines. The mechanism previously proposed is firmly established on the basis of the observed β-elimination of a thiophenoxy radical or on the basis of the rearrangement of a cyclopropylaminyl radical. This study points out the efficiency of the electrochemical method to deprotect *N*-phenylsulfonyl *N*-substituted amines under mild experimental conditions without alteration of the stereochemistry of the benzylic position of the phenylglycinol moiety.

Experimental Section

General Method: ^{1}H and ^{13}C NMR spectra were recorded with Bruker Avance 300 or Bruker ARX 400 spectrometers. Chemical shifts are given in ppm as δ values relative to tetramethylsilane (^{1}H, ^{13}C) and coupling constants are given in Hz. Mass spectra were obtained in EI (70 eV) and CI modes with a HP apparatus (Engine 5989A) in direct introduction mode. HRMS were recorded at the CRMPO in Rennes (Centre Régional de Mesures Physiques de l'Ouest) or at the Université Claude Bernard Lyon 1. IR spectra were recorded with a Bruker IFS Vector 22 apparatus. Cyclic voltammetry experiments and controlled potential electrolyses were performed by using a potentiostat-galvanostat E66 PARC Model 273 controlled by the Echem software. CH_3CN and CH_2Cl_2 were dried with CaH_2 prior to use and THF was distilled from sodium–benzophenone. MeOH was dried with magnesium methoxide and distilled before use. DMF was dried with 4 Å molecular sieves prior to distillation. TLC analyses were achieved on silica-coated plates (Merck Kieselgel 60F_{254}).

***N*-[(1*R*)-2-Hydroxy-1-phenylethyl]benzenesulfonamide (1):** To a solution of (*R*)-phenylglycinol (5 g, 36.45 mmol) and Et_3N (5.6 mL, 40.09 mmol) in CH_2Cl_2 (50 mL) was added dropwise benzenesulfonyl chloride (4.65 mL, 36.45 mmol) diluted in CH_2Cl_2 (50 mL) at 0 °C. The reaction mixture was stirred at room temperature overnight, and then quenched by the addition of aqueous H_2SO_4 (2 N, 50 mL). The organic layer was further washed with aqueous H_2SO_4 (2 N, 2 × 50 mL) and dried with $MgSO_4$. Concentration of the filtered organics under reduced pressure gave **1** as a white solid (9.7 g, 96%), which was used without further purification.[54] M.p. 117–120 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.75–7.65 (br. d, J = 7.4 Hz, 2 H), 7.50–7.41 (tt, J = 7.4, 1.4 Hz, 1 H), 7.40–7.30 (br. t, J = 7.4 Hz, 2 H), 7.21–7.13 (m, 3 H), 7.11–7.03 (m, 2 H), 5.77 (d, J = 7.2 Hz, 1 H, N*H*), 4.37 (ddd, J = 7.2, 6.3, 4.6 Hz, 1 H, C*H*Ph), 3.71 (dd, J = 11.4, 4.6 Hz, 1 H, CH_2O), 3.67 (dd, J = 11.4, 6.3 Hz, 1 H, CH_2O), 2.20 (br. s, 1 H, O*H*) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 140.2, 137.4, 132.4, 128.8 (2 C), 128.5 (2 C), 127.8, 127.0 (2 C), 126.9 (2 C), 66.1 (*C*H$_2$O), 59.8 (*C*HPh) ppm. IR (KBr): $\tilde{\nu}$ = 3543, 3497, 3324, 1603, 1495, 1452, 1309, 1162, 1149, 1074, 753, 692, 594, 554 cm^{-1}. MS (EI): *m*/*z* (%) = 246 (33), 141 (30), 91 (8), 77 (100), 51 (18). MS (CI): *m*/*z* = 295 [M + NH_4]$^+$.

***N*-[(1*R*)-2-{[*tert*-Butyl(dimethyl)silyl]oxy}-1-phenylethyl]benzenesulfonamide (2a):** To a solution of **1** (3 g, 10.82 mmol) in CH_2Cl_2 (125 mL) were added imidazole (4.42 g, 64.92 mmol) and TBDMSCl (4.89 g, 32.46 mmol). The mixture was stirred overnight and then hydrolyzed with water (100 mL). The aqueous layer was extracted with CH_2Cl_2 (2 × 100 mL), dried with $MgSO_4$, filtered and concentrated under reduced pressure. Purification by flash chromatography (hexanes/Et_2O, 70:30) afforded **2a** as a white solid (4.03 g, 95%). R_f = 0.25 (hexanes/Et_2O, 75:25). M.p. 60–62 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.69 (br. d, J = 8.3 Hz, 2 H), 7.5–7.1 (m, 8 H), 5.33 (d, J = 4.7 Hz, 1 H, N*H*), 4.33 (ddd, J = 6.6, 4.7, 4.5 Hz, 1 H, C*H*Ph), 3.69 (dd, J = 10.2, 4.5 Hz, 1 H, CH_2O), 3.58 (dd, J = 10.2, 6.6 Hz, 1 H, CH_2O), 0.81 (s, 9 H), 0.08 (s, 3 H, CH_3Si), –0.09 (s, 3 H, CH_3Si) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 140.3, 138.0, 132.4, 128.7 (2 C), 128.2 (2 C), 127.9, 127.2 (4 C), 66.6 (*C*H$_2$O), 59.3 (*C*HPh), 25.7 (3 C), 18.2, –5.6 (2 C) ppm. IR (KBr): $\tilde{\nu}$ = 3224, 2957, 2857, 1469, 1461, 1327, 1161, 1116, 1076, 837, 778, 546 cm^{-1}. MS (EI): *m*/*z* (%) = 334 (6), 246 (36), 214 (100), 141 (17), 77 (52), 51 (6). MS (CI): *m*/*z* = 409 [M + NH_4]$^+$, 392 [M + H]$^+$. HRMS (CI): calcd. for $C_{20}H_{30}NO_3SSi$ [M + Na]$^+$ 392.1716; found 392.1717.

***N*-Benzyl-*N*-[(1*R*)-2-{[*tert*-butyl(dimethyl)silyl]oxy}-1-phenylethyl]-benzenesulfonamide (3a):** To a solution of **2a** (500 mg, 1.28 mmol) in DMF (12 mL) were added K_2CO_3 (885 mg, 6.40 mmol) and BnBr (230 μL, 1.92 mmol) in sequence. The reaction mixture was stirred until complete consumption of the starting material as monitored by TLC analysis. Then, the mixture was diluted with H_2O and extracted with Et_2O. The combined organic layer was washed with brine, dried with $MgSO_4$, filtered and concentrated under reduced pressure. Column chromatography on silica gel (hexanes/Et_2O, 95:5) gave rise to pure **3a** (578 mg, 94%) as a viscous oil. R_f = 0.54 (hexanes/Et_2O, 75:25). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.8 (br. d, J = 8.3 Hz, 2 H), 7.6–6.85 (m, 13 H), 5.02 (dd, J = 8.3, 6.0 Hz, 1 H, NC*H*Ph), 4.57 (d, J = 16 Hz, 1 H, CH_2Ph), 3.98 (d,

J = 16 Hz, 1 H, CH_2Ph), 3.91 (dd, J = 10.4, 6.0 Hz, 1 H, CH_2O), 3.78 (dd, J = 10.4, 8.3 Hz, 1 H, CH_2O), 0.75 (s, 9 H), –0.06 (s, 6 H, CH_3Si) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 141.1, 137.6, 136.1, 132.2, 128.8–127.1 (14 C), 63.3 (*C*H_2O), 62.5 (N*C*HPh), 48.8 (*C*H_2Ph), 25.7 (3 C), 18.0, –5.5, –5.6 ppm. IR (neat): $\tilde{\nu}$ = 3064, 3031, 2928, 2856, 1680, 1496, 1471, 1447, 1343, 1258, 1164, 1092, 861, 814, 729, 599 cm^{-1}. MS (EI): *m*/*z* (%) = 424 (3), 336 (7), 177 (7), 91 (100), 77 (6). MS (CI): *m*/*z* = 499 [M + NH_4]$^+$, 482 [M + H]$^+$. HRMS (ESI): calcd. for $C_{27}H_{35}NNaO_3SSi$ [M + Na]$^+$ 504.2004; found 504.1995.

Reaction of 3a with Na/NH_3: In a three-necked flask equipped with a dry acetone cooled Dewar condenser, small pieces of sodium were added to liquid ammonia (ca. 35 mL) until a permanent dark blue colour was obtained. Substrate **3a** (200 mg, 0.42 mmol) in freshly distilled THF was added, and the resulting solution was left to stir at –78 °C for 1 h under an atmosphere of argon before quenching with 2-propanol, then water and warming to room temperature. Once the ammonia had evaporated, the mixture was extracted twice with CH_2Cl_2, and the combined organic phase was washed with brine, dried with $MgSO_4$ and concentrated under vacuum to provide decomposition products.

Reaction of 3a with HBr/AcOH and Phenol: To sulfonamide **3a** (150 mg, 0.31 mmol) in a sealed tube was added phenol (105 mg, 1.12 mmol) and hydrogen bromide (33% in acetic acid, 5 mL), and the resulting mixture was stirred and heated at 70 °C for 8 h. After cooling to 0 °C, saturated aqueous $NaHCO_3$ solution was added until pH was ca. 7. Then, the mixture was extracted with Et_2O (2 × 25 mL), and the combined organic extract was washed with water, dried with $MgSO_4$ and the solvent removed to provide decomposition products.

Reaction of 3a with $LiAlH_4$: To a solution of sulfonamide **3a** (153 mg, 0.32 mmol) in THF (2 mL) was added a solution of $LiAlH_4$ (0.5 M in DME, 1.3 mL, 0.64 mmol), and the reaction mixture was heated at reflux for 8 h. After cooling, the mixture was quenched with H_2O (10 mL) and extracted with Et_2O (3 × 10 mL). The combined organic layer was washed with brine (20 mL), dried with $MgSO_4$, filtered and concentrated under reduced pressure. Column chromatography on silica gel (hexanes/Et_2O, 30:70) gave pure **4** (50 mg, 70%) as white crystals.[39]

General Procedure for Mg/MeOH Reduction Under Sonication: In a Schlenk flask, anhydrous methanol (3.5 mL) was added to sulfonamides **3a** or **2a** (0.20 mmol) and Mg (48 mg, 2 mmol) under an atmosphere of argon. The resulting suspension was degassed (three freeze–pump–thaw cycles), placed under an argon atmosphere and sonicated at 50 °C until complete consumption of the starting material. The reaction was then diluted with brine (10 mL) and filtered through a pad of Celite by using Et_2O as eluent. The phases were separated, and the aqueous phase was extracted with Et_2O (2 × 10 mL). The combined organic layer was dried with $MgSO_4$ and concentrated in vacuo to afford **4a** as an oil (67 mg, 82%), which was not purified. No reduction occurred with **2a**.

Reaction of 3a with SmI_2/DMPU: In a Schlenk flask, THF (1 mL) and DMPU (0.4 mL) were added to sulfonamide **3a** (50 mg, 0.10 mmol), and the solution was degassed (three freeze–pump–thaw cycles) and placed under an atmosphere of argon. SmI_2 (0.60 mmol, 6 mL of a 0.1 M solution in THF prepared from 1,2-diiodoethane and metallic Sm)[55] was added by syringe, and the dark-purple solution was heated at reflux until all the SmI_2 was consumed (as judged by the solution colour, which turned yellow). The mixture was hydrolyzed with brine and extracted three times with CH_2Cl_2. The combined organic extract was dried with $MgSO_4$, filtered off and concentrated under vacuum to give a solution of starting sulfonamide **3a** in DMPU.

***N*-[(1*R*)-2-{[*tert*-Butyl(dimethyl)silyl]oxy}-1-phenylethyl]-*N*-(2-phenylethyl)benzenesulfonamide (3b):** 2-Phenethyl-4-nitrobenzenesulfonate[56] (785 mg, 2.55 mmol) was added to a stirred mixture of sulfonamide **2a** (1 g, 2.55 mmol) and K_2CO_3 (530 mg, 3.83 mmol) in dry acetonitrile (10 mL), and the reaction mixture was heated at reflux whilst the reaction progress was evaluated by TLC. After the reaction was complete, the mixture was diluted with ethyl acetate (25 mL) and washed with water (2 × 20 mL) followed by brine (20 mL) solution. After drying over $MgSO_4$, evaporation of the solvent under reduced pressure afforded the crude compound, which was purified on column chromatography (hexanes/AcOEt, 95:5) to afford product **3b** (1.09 g, 86%) as a viscous oil that crystallized on long standing. R_f = 0.35 (hexanes/Et_2O, 90:10). M.p. 49–50 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.91–7.80 (m, 2 H), 7.60–7.42 (m, 3 H), 7.30–7.10 (m, 8 H), 7.00–6.93 (m, 2 H), 5.07 (dd, J = 7.4, 5.8 Hz, 1 H, NC*H*Ph), 4.07 (dd, J = 10.7, 7.4 Hz, 1 H CH_2O), 3.96 (dd, J = 10.7, 5.8 Hz, 1 H, CH_2O), 3.37 (ddd, J = 15.0, 11.9, 5.3 Hz, 1 H, CH_2N), 3.25 (ddd, J = 15.0, 11.9, 5.7 Hz, 1 H, CH_2N), 2.83 (dt, J = 11.9, 5.7 Hz, 1 H, CH_2Ph), 2.47 (dt, J = 11.9, 5.3 Hz, 1 H, CH_2Ph), 0.80 (s, 9 H), 0.01 (s, 6 H, CH_3Si) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 141.1, 138.8, 137.1, 132.3, 128.9–126.3 (14 C), 63.2 (*C*H_2O), 61.7 (N*C*HPh), 47.4 (*C*H_2N), 37.5 (*C*H_2Ph), 25.7 (3 C), 18.1, –5.5 (2 C) ppm. IR (KBr): $\tilde{\nu}$ = 3063, 3029, 2954, 2929, 2857, 1603, 1585, 1497, 1447, 1344, 1257, 1163, 1094, 837, 778, 751, 698, 581 cm^{-1}. MS (EI): *m*/*z* (%) = 438 (2), 362 (17), 274 (100), 242 (40), 177 (29), 141 (38), 105 (39), 91 (27), 77 (87), 73 (86), 59 (26). MS (CI): *m*/*z* = 513 [M + NH_4]$^+$, 496 [M + H]$^+$. HRMS (ESI): calcd. for $C_{28}H_{37}NNaO_3SSi$ [M + Na]$^+$ 518.2161; found 518.2165.

***N*-(But-3-en-1-yl)-*N*-[(1*R*)-2-{[*tert*-butyl(dimethyl)silyl]oxy}-1-phenylethyl]benzenesulfonamide (3c):** Compound **3c** was prepared from **2a** and homoallyl nosylate[47] according to the procedure outlined for **3b**. Yield: 75%. R_f = 0.34 (hexanes/Et_2O, 90:10). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.88–7.80 (m, 2 H), 7.59–7.42 (m, 3 H), 7.28–7.15 (m, 5 H), 5.55 (ddt, J = 17, 10.2, 6.8 Hz, 1 H, =C*H*), 5.03 (dd, J = 7.2, 5.8 Hz, 1 H, NC*H*Ph), 4.93 (br. d, J = 10.2 Hz, 1 H, =CH_2), 4.88 (dq, J = 17.0, 1.5 Hz, 1 H, =CH_2), 4.10 (dd, J = 10.6, 7.2 Hz, 1 H, CH_2O), 3.98 (dd, J = 10.6, 5.8 Hz, 1 H, CH_2O), 3.26 (ddd, J = 14.7, 10.6, 5.5 Hz, 1 H, NCH_2), 3.13 (ddd, J = 14.7, 10.6, 5.5 Hz, 1 H, NCH_2), 2.35–2.15 (m, 1 H, CH_2CH=), 2.10–1.92 (m, 1 H, CH_2CH=), 0.81 (s, 9 H), 0.01 (s, 3 H, CH_3Si), 0 (s, 3 H, CH_3Si) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 141.1, 137.1, 134.7 (=*C*H), 132.1, 128.7 (2 C), 128.2 (2 C), 128.1 (2 C), 127.5, 127.0 (2 C), 116.4 (=*C*H_2), 63.2 (*C*H_2O), 61.8 (N*C*HPh), 45.0 (*C*H_2N), 35.0 (*C*H_2CH=), 25.7 (3 C), 18.0, –5.6 (2 C) ppm. IR (neat): $\tilde{\nu}$ = 3065, 3031, 2953, 2928, 2856, 1641, 1603, 1548, 1447, 1344, 1255, 1164, 1090, 918, 836, 777, 751, 690, 587 cm^{-1}. MS (EI): *m*/*z* (%) = 388 (14), 300 (20), 268 (20), 235 (16), 177 (25), 131 (100), 77 (89), 59 (32). MS (CI): *m*/*z* = 463 [M + NH_4]$^+$, 446 [M + H]$^+$. HRMS (ESI): calcd. for $C_{24}H_{35}NNaO_3SSi$ [M + Na]$^+$ 468.2004; found 468.2007.

***N*-[(1*R*)-2-{[*tert*-Butyl(dimethyl)silyl]oxy}-1-phenylethyl]-*N*-[(phenylthio)methyl]benzenesulfonamide (3d):** Sulfonamide **2a** (600 mg, 1.53 mmol) dissolved in CH_2Cl_2 (5 mL) was treated with chloromethyl phenyl sulfide (592 μL, 4.59 mmol), KI (252 mg, 1.53 mmol) and then with tetrabutylammonium bromide (35 mg, 0.17 mmol). To the resulting mixture was added aqueous NaOH (50%, 1.0 mL) at 0 °C. After stirring at room temperature for 12 h, the mixture was poured into saturated aqueous NH_4Cl solution and extracted with ethyl acetate. The organic phase was washed with water, dried with $MgSO_4$, filtered, and concentrated in vacuo. The residue was purified by column chromatography on silica gel

(hexanes/AcOEt, 95:5) to afford **3d** (315 mg, 40%) as a colourless oil. R_f = 0.41 (hexanes/Et_2O, 90:10). ^1H NMR (300 MHz, $CDCl_3$): δ = 7.69 (br. d, J = 7.8 Hz, 2 H), 7.51–7.02 (m, 13 H), 5.03 (d, J = 14.5 Hz, 1 H, CH_2S), 4.88 (dd, J = 7.9, 5.2 Hz, 1 H, NC*H*Ph), 4.39 (d, J = 14.5 Hz, 1 H, CH_2S), 4.14 (dd, J = 10.3, 7.9 Hz, 1 H, CH_2O), 3.91 (dd, J = 10.3, 5.2 Hz, 1 H, CH_2O), 0.71 (s, 9 H), –0.09 (s, 6 H, CH_3Si) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 140.7, 135.8, 134.6, 132.6–127.5 (15 C), 63.4 (*C*H_2O), 62.2 (N*C*HPh), 52.3 (*C*H_2S), 25.8 (3 C), 18.1, –5.5 (2 C) ppm. IR (neat): $\tilde{\nu}$ = 3061, 3032, 2954, 2928, 2856, 1584, 1480, 1471, 1463, 1447, 1347, 1258, 1163, 1090, 837, 776, 689, 612, 586 cm^{-1}. MS (EI): *m*/*z* (%) = 404 (2), 235 (40), 179 (23), 115 (11), 91 (12), 77 (12), 73 (100), 59 (24). MS (CI): *m*/*z* = 531 $[M + NH_4]^+$. HRMS (ESI): calcd. for $C_{27}H_{35}NNaO_3S_2Si$ $[M + Na]^+$ 536.1725; found 536.1724.

***N*-Cyclopropylbenzenesulfonamide (2e):** This compound was prepared from cyclopropylamine according to the procedure outlined for **1**. Sulfonamide **2e** was obtained as a white solid after purification by chromatography on silica gel (hexanes/Et_2O, 50:50). Yield: 87%. R_f = 0.18 (hexanes/Et_2O, 70:30). M.p. 54–57 °C. ^1H NMR (300 MHz, $CDCl_3$): δ = 7.95–7.87 (m, 2 H), 7.64–7.48 (m, 3 H), 5.11 (br. s, 1 H, N*H*), 2.27–2.20 (m, 1 H), 0.64–0.54 (m, 4 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 139.6, 132.8, 129.1 (2 C), 127.4 (2 C), 24.3 (*C*HN), 6.1 (2 C) ppm. IR (KBr): $\tilde{\nu}$ = 3236, 3014, 1447, 1478, 1324, 1167, 1161, 1094, 734, 687, 575 cm^{-1}. MS (EI): *m*/*z* (%) = 141 (9), 77 (100), 56 (61), 51 (47), 39 (8).

***N*-Benzyl-*N*-cyclopropylbenzenesulfonamide (3e):** This compound was prepared from **2e** according to the procedure outlined for **3a**. *N*-Benzyl sulfonamide **3e** was obtained as a white solid after purification by chromatography on silica gel (hexanes/Et_2O, 70:30). Yield: 82%. R_f = 0.37 (hexanes/Et_2O, 70:30). M.p. 100–102 °C. ^1H NMR (300 MHz, $CDCl_3$): δ = 7.90–7.80 (m, 2 H), 7.64–7.47 (m, 3 H), 7.37–7.21 (m, 5 H), 4.36 (s, 2 H), 2.06–1.97 (m, 1 H), 0.69–0.52 (m, 4 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 138.6, 136.9, 132.6, 128.9–127.8 (9 C), 54.7 (*C*H_2N), 30.8 (*C*HN), 7.1 (2 C) ppm. IR (KBr): $\tilde{\nu}$ = 3067, 2966, 1485, 1446, 1356, 1349, 1173, 1168, 730, 576 cm^{-1}. MS (EI): *m*/*z* (%) = 146 (72), 91 (100), 77 (13), 65 (13), 51 (7). MS (CI): *m*/*z* = 305 $[M + NH_4]^+$, 288 $[M + H]^+$. HRMS (ESI): calcd. for $C_{16}H_{17}NNaO_2S$ $[M + Na]^+$ 310.0877; found 310.0880.

General Procedure for Cyclic Voltammetry Studies: Cyclic voltammetry experiments were performed with 2.10^{-3} to 6.10^{-3} mol L^{-1} of sample in MeCN and Bu_4NHSO_4 (0.1 mol L^{-1}). A conventional three-electrode system was used with a glassy carbon working electrode (diameter 2 mm), saturated calomel reference electrode (SCE) and a platinum wire counter electrode.

General Procedure for the Preparative Electrochemical Deprotection of *N*-Benzenesulfonyl Derivatives: Bulk electrolyses were carried out under constant cathodic potential in a concentric cylindrical cell with two compartments separated by a glass frit diaphragm. A mercury pool electrode (diameter 4.7 cm) or reticulated vitreous carbon electrode (HF 2077-BAS) was used as the cathode, calomel saturated electrode as reference and a platinum plate as the anode. Bu_4NHSO_4 (100 mL) in acetonitrile (0.1 mol L^{-1}) was added into the anode and the cathode compartments. The solution was stirred, purged of oxygen by bubbling argon through the solution for 10 min, and then, pre-electrolysis was carried out at the appropriate potential for 10 min (Table 1). Sample (0.4–0.8 mmol) was added to the cathode compartment and electrolysis was performed at the appropriate potential. The reaction was monitored by cyclic voltammetry analysis and by TLC. When all starting material had disappeared, the content of the cathodic compartment was concentrated under reduced pressure and the residue was partitioned between Et_2O (100 mL) and water (100 mL). After neutralization with saturated aqueous $NaHCO_3$ solution to pH ca. 7 and extraction with Et_2O (2 × 100 mL), the combined organic phase was dried with $MgSO_4$, filtered and concentrated under vacuum.

(1*R*)-2-{[*tert*-Butyl(dimethyl)silyl]oxy}-1-phenylethanamine (2b): Amine **2b** was obtained from **2a** (279 mg, 0.71 mmol) as a white solid in pure form in a 96% yield (171 mg) without further purification. All the physical and spectroscopic data were in complete agreement with the reported ones.[57]

(1*R*)-*N*-Benzyl-2-{[*tert*-butyl(dimethyl)silyl]oxy}-1-phenylethanamine (4a): Amine **4a** was obtained from **3a** (310 mg, 0.64 mmol) and purified by flash chromatography (hexanes/Et_2O, 95:5) to provide **4a** as an oil (186 mg, 85%). R_f = 0.83 (hexanes/Et_2O, 70:30). ^1H NMR (300 MHz, $CDCl_3$): δ = 7.4–7.1 (m, 10 H), 3.77–3.50 (m, 5 H), 2.39 (br. s, 1 H, N*H*), 0.88 (s, 9 H), 0.01 (s, 3 H, CH_3Si), –0.01 (s, 3 H, CH_3Si) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 140.8, 128.9–125.6 (11 C), 68.5 (*C*H_2O), 64.1 (N*C*HPh), 51.3 (*C*H_2Ph), 25.9 (3 C), 18.3, –5.3, –5.4 ppm. IR (neat): $\tilde{\nu}$ = 3333, 3063, 3027, 2954, 2928, 2856, 1604, 1495, 1453, 1257, 1085, 836, 777, 700, 616 cm^{-1}. MS (EI): *m*/*z* (%) = 284 (2), 196 (87), 91 (100), 73 (10), 65 (9). MS (CI): *m*/*z* = 342 $[M + H]^+$. HRMS (ESI): calcd. for $C_{21}H_{32}NOSi$ $[M + H]^+$ 342.2253; found 342.2246.

(1*R*)-2-{[*tert*-Butyl(dimethyl)silyl]oxy}-1-phenyl-*N*-(2-phenylethyl)-ethanamine (4b): Electrolysis of **3b** (305 mg, 0.62 mmol) afforded **4b** as an oil in pure form (186 mg, 85%) without further purification. R_f = 0.34 (hexanes/Et_2O, 90:10). ^1H NMR (300 MHz, $CDCl_3$): δ = 7.37–7.10 (m, 10 H), 3.76 (dd, J = 9.0, 3.8 Hz, 1 H, NC*H*Ph), 3.63 (dd, J = 9.6, 3.8 Hz, 1 H, CH_2O), 3.50 (dd, J = 9.6, 9.0 Hz, 1 H, CH_2O), 2.85–2.67 (m, 5 H, NCH_2CH_2Ph + NH), 0.82 (s, 9 H), –0.03 (s, 3 H, CH_3Si), –0.04 (s, 3 H, CH_3Si) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 141.0, 140.2, 128.8 (2 C), 128.5 (2 C), 128.4 (2 C), 127.8 (2 C), 127.4, 126.1, 68.5 (*C*H_2O), 65.2 (N*C*HPh), 48.8 (*C*H_2N), 36.5 (CH_2Ph), 26.0 (3 C), 18.3, –3.4 (2 C) ppm. IR (neat): $\tilde{\nu}$ = 3326, 3085, 3063, 3027, 2954, 2927, 2856, 1603, 1494, 1471, 1453, 1257, 1129, 1087, 837, 777, 700 cm^{-1}. MS (EI): *m*/*z* (%) = 298 (2), 264 (4), 210 (100), 179 (7), 105 (44), 91 (10), 73 (37). MS (CI): *m*/*z* = 356 $[M + H]^+$. HRMS (ESI): calcd. for $C_{22}H_{34}NOSi$ $[M + H]^+$ 356.2409; found 356.2409.

***N*-[(1*R*)-2-{[*tert*-Butyl(dimethyl)silyl]oxy}-1-phenylethyl]but-3-en-1-amine (4c):** Electrolysis of **3c** (356 mg, 0.80 mmol) afforded **4c** as an oil in pure form (218 mg, 89%) without further purification. R_f = 0.35 (hexanes/Et_2O, 90:10). ^1H NMR (300 MHz, $CDCl_3$): δ = 7.40–7.20 (m, 5 H), 5.55 (ddt, J = 17.1, 10.4, 6.8 Hz, 1 H, =C*H*), 5.09 (dq, J = 17.1, 1.7 Hz, 1 H, =CH_2), 5.02 (ddt, J = 10.4, 1.7, 1.1 Hz, 1 H, =CH_2), 3.76 (dd, J = 9.0, 4.0 Hz, 1 H, NC*H*Ph), 3.65 (dd, J = 9.8, 4.0 Hz, 1 H, CH_2O), 3.53 (dd, J = 9.8, 9.0 Hz, 1 H, CH_2O), 2.63–2.43 (m, 2 H, NCH_2), 2.30–2.15 (m, 2 H, CH_2CH=), 1.95 (br. s, 1 H, N*H*), 0.89 (s, 9 H), 0.02 (s, 6 H, CH_3Si) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 141.2, 136.8 (=*C*H), 128.4 (2 C), 127.9 (2 C), 127.4, 116.4 (=*C*H_2), 68.6 (*C*H_2O), 65.3 (N*C*HPh), 46.7 (*C*H_2N), 34.4 (*C*H_2CH=), 26.0 (3 C), 18.4, –5.3 (2 C) ppm. IR (neat): $\tilde{\nu}$ = 3330, 3063, 3026, 2955, 2929, 2857, 1640, 1603, 1493, 1457, 1257, 1087, 837, 778, 701 cm^{-1}. MS (EI): *m*/*z* (%) = 248 (2), 160 (100), 131 (37), 91 (11), 73 (33), 55 (11), 41 (5). HRMS (ESI): calcd. for $C_{18}H_{32}NOSi$ $[M + H]^+$ 306.2253; found 306.2272.

(1*R*)-2-{[*tert*-Butyl(dimethyl)silyl]oxy}-1-phenyl-*N*-[(phenylthio)-methyl]ethanamine (4d): Electrolysis of **3d** (240 mg, 0.47 mmol) provided **4d** as an oil (100 mg, 57%) after careful column chromatography on silica gel (hexanes/Et_2O, 95:5). R_f = 0.70 (hexanes/Et_2O, 90:10). ^1H NMR (300 MHz, $CDCl_3$): δ = 7.44–7.11 (m, 10 H), 4.40 (d, J = 13.4 Hz, 1 H, CH_2S), 4.30 (dd, J = 9.8, 4.0 Hz, 1 H, NC*H*Ph), 3.82 (d, J = 13.4 Hz, 1 H, CH_2S), 3.57 (dd, J = 9.8,

4.0 Hz, 1 H, CH_2O), 3.45 (t, J = 9.8 Hz, 1 H, CH_2O), 2.67 (br. s, 1 H, NH), 0.75 (s, 9 H), –0.84 (s, 6 H, CH_3Si) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 139.2, 137.0, 132.1, 129.0–125.5 (9 C), 68.1 (*C*H_2O), 60.4 (N*C*HPh), 54.8 (*C*H_2S), 25.9 (3 C), 18.3, –5.5, –5.4 ppm. IR (neat): $\tilde{\nu}$ = 3341, 3060, 3029, 2954, 2927, 2856, 1582, 1447, 1438, 1257, 1135, 1081, 837, 777, 739, 700 cm^{-1}. MS (EI): *m*/*z* (%) = 264 (12), 206 (64), 179 (37), 118 (29), 110 (49), 91 (37), 73 (100), 73 (100), 59 (48). MS (CI): *m*/*z* = 374 [M + H]$^+$.

***N*-Benzylcyclopropylamine (4e):** Electrolysis of **3e** (175 mg, 0.61 mmol) afforded **4e** as an oil in pure form (50 mg, 56%) without further purification. All the physical and spectroscopic data were in complete agreement with the reported ones.[58]

***N*-Benzylpropylamine (4g):** All the physical and spectroscopic data were in complete agreement with the reported ones.[59]

***N*-Benzylpropylideneimine (4f):** A mixture of propionaldehyde (270 mg, 4.65 mmol), benzylamine (500 mg, 4.65 mmol) and anhydrous $MgSO_4$ (1.7 g) in CH_2Cl_2 (3.5 mL) was stirred at room temperature for 1.5 h. The solid was removed by filtration, and the solvent was evaporated under reduced pressure. Then, imine **4f** was analyzed without further purification by cyclic voltammetry. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.80 (t, J = 4.7 Hz, 1 H, CH=N), 7.40–7.20 (m, 5 H), 4.57 (s, 2 H, CH_2Ph), 2.29 (dq, J = 7.5, 4.7 Hz, 2 H, CH_3CH_2), 1.13 (t, J = 7.5 Hz, 3 H, CH_3CH_2) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 166.9 (=*C*H), 139.4, 130.0–125.0 (5 C), 65.1 (*C*H_2Ph), 29.2, 10.6 ppm.

Acknowledgments

We are grateful to CNRS and to MENRT for financial support and for a doctoral fellowship (V. C.).

[1] E. Fischer, W. Lifschitz, *Ber. Dtsch. Chem. Ges.* **1915**, *48*, 360–378.
[2] T. W. Greene, P. G. M. Wuts, *Protective Groups in Organic Synthesis*, 3rd ed., Wiley Interscience, New York, **1999**.
[3] P. J. Kocienski, *Protecting Groups*, 3rd ed., Georg Thieme, New York, **2005**.
[4] A. W. Kubiak, G. G. Sledeski, M. K. O'Brien, M. R. Powers, T. H. Powner, L. K. Truesdale, *J. Org. Chem.* **2000**, *65*, 8114–8818.
[5] T. Hamada, A. Nishida, O. Yonemitsu, *J. Am. Chem. Soc.* **1986**, *108*, 140–145.
[6] H. S. Knowles, A. F. Parsons, R. M. Pettifer, S. Rickling, *Tetrahedron* **2000**, *56*, 979–988.
[7] G. Sabitha, S. Abraham, B. V. S. Reddy, J. S. Yadav, *Synlett* **1999**, *11*, 1745–1746.
[8] G. Sabitha, B. V. S. Reddy, S. Abraham, J. V. Yadav, *Tetrahedron Lett.* **1999**, *40*, 1569–1570.
[9] B. Nyasse, L. Grehn, U. Ragnarsson, *Chem. Commun.* **1997**, 1017–1018.
[10] E. Vedejs, S. Lin, *J. Org. Chem.* **1994**, *59*, 1602–1603.
[11] Additives such as NMP and HMPA are sometimes used to increase the reducing power of SmI_2, see M. Shabangi, J. M. Sealy, J. R. Fuchs, R. A. Flowers II, *Tetrahedron Lett.* **1998**, *39*, 4429–4432.
[12] T. Kan, T. Fukuyama, *Chem. Commun.* **2004**, 353–359.
[13] P. G. M. Wuts, J. M. Northuis, *Tetrahedron Lett.* **1998**, *39*, 3889–3890.
[14] C. Goulaouic-Dubois, A. Guggisberg, M. Hesse, *J. Org. Chem.* **1995**, *60*, 5969–5972.
[15] S. Hanessian, M. Kagotani, K. Komaglou, *Heterocycles* **1989**, *28*, 1115–1120.
[16] S. M. Weinreb, D. M. Demko, T. A. Lessen, *Tetrahedron Lett.* **1986**, *27*, 2099–2102.
[17] L. L. Parker, N. D. Gowans, S. W. Jones, D. J. Robins, *Tetrahedron* **2003**, *59*, 10165–10171.
[18] I. Sakamoto, N. Izumi, T. Yamada, T. Tsunoda, *Org. Lett.* **2006**, *8*, 71–74.
[19] E. Vedejs, S. Lin, A. Klapars, J. Wang, *J. Am. Chem. Soc.* **1996**, *118*, 9796–9797.
[20] S. W. Wright, K. N. Hallstrom, *J. Org. Chem.* **2006**, *71*, 1080–1084.
[21] P. Sun, S. M. Weinreb, *J. Org. Chem.* **1997**, *62*, 8604–8608.
[22] P. Merlin, J. C. Braekman, D. Daloze, *Tetrahedron Lett.* **1988**, *29*, 1691–1694.
[23] A.-M. Bálint, A. Bodor, A. Gömöry, K. Vékey, D. Szabó, J. Rábai, *J. Fluorine Chem.* **2005**, *126*, 1524–1530.
[24] H. Lund, O. Hammerich, *Organic Electrochemistry*, 4th ed., Marcel Dekker, New York, **2001**.
[25] L. Horner, H. Neumann, *Chem. Ber.* **1965**, *98*, 3462–3469.
[26] V. G. Mairanovsky, *Angew. Chem. Int. Ed. Engl.* **1976**, *15*, 281–291 and references cited herein.
[27] A. Lebouc, P. Martigny, R. Carlier, J. Simonet, *Tetrahedron* **1985**, *41*, 1251–1258.
[28] M. V. B. Z. Zanoni, C. H. M. Sartorello, N. R. Stradiotto, *J. Electroanal. Chem.* **1993**, *361*, 103–108.
[29] P. T. Cottrell, C. K. Mann, *J. Am. Chem. Soc.* **1971**, *93*, 3579–3583.
[30] R. C. Roemmele, H. Rapoport, *J. Org. Chem.* **1988**, *53*, 2367–2371.
[31] L. Benedetti, M. Borsari, C. Fontanesi, G. Grandi, R. Andreoli, G. B. Gavioli, *Electrochim. Acta* **1989**, *34*, 1581–1586.
[32] T. Harder, T. Löhl, M. Bolte, K. Wagner, D. Hoppe, *Tetrahedron Lett.* **1994**, *35*, 7365–7368.
[33] M. R. Paleo, N. Aurrecoechea, K.-Y. Jung, H. Rapoport, *J. Org. Chem.* **2003**, *68*, 130–138.
[34] J.-C. Cintrat, V. Léat-Crest, J.-L. Parrain, E. Le Grognec, I. Beaudet, J.-P. Quintard, *Eur. J. Org. Chem.* **2004**, 4251–4267.
[35] V. Coeffard, J.-C. Cintrat, E. Le Grognec, I. Beaudet, J.-P. Quintard, *J. Organomet. Chem.* **2006**, *691*, 1488–1497.
[36] V. Coeffard, E. Le Grognec, I. Beaudet, M. Lepeltier, V. Léat-Crest, J.-P. Quintard, *Synthesis* **2006**, 4151–4158.
[37] B. E. Haskell, S. B. Bowlus, *J. Org. Chem.* **1976**, *41*, 159–160.
[38] M. Ousmer, N. A. Braun, C. Bavoux, M. Perrin, M. A. Ciufolini, *J. Am. Chem. Soc.* **2001**, *123*, 7534–7538.
[39] F. Roussi, A. Chaveau, M. Bonin, L. Micouin, H.-P. Husson, *Synthesis* **2000**, 1170–1179.
[40] T. L. Fevig, R. L. Elliott, D. P. Curran, *J. Am. Chem. Soc.* **1988**, *110*, 5064–5067.
[41] B. Nyasse, L. Grehn, H. L. S. Maia, L. S. Monteiro, U. Ragnarson, *J. Org. Chem.* **1999**, *64*, 7135–7139.
[42] R. Kossai, B. Emir, J. Simonet, G. Mousset, *J. Electroanal. Chem.* **1989**, *270*, 253–260.
[43] The ^{1}H NMR spectrum was recorded of a $CDCl_3$ solution of **2b** obtained by electrolysis after addition of $Eu(hfc)_3$. The comparison was realized from a spectrum recorded of a solution of (*R*)- and (*S*)-**2b** in a 70:30 ratio ($\Delta\delta$ = 0.2 ppm).
[44] S. Kim, K. H. Kim, J. R. Cho, *Tetrahedron Lett.* **1997**, *38*, 3915–3918.
[45] S. Kim, J. H. Cheong, *Chem. Commun.* **1998**, 1143–1144.
[46] M. Bonifačić, D. A. Armstrong, I. Carmichael, K.-D. Asmus, *J. Phys. Chem. B* **2000**, *104*, 643–649.
[47] S. Raghavan, A. Rajender, *Tetrahedron* **2004**, *60*, 5059–5067.
[48] The electrolyses were carried out on a Hg pool when adsorption phenomena occurred on vitreous carbon.
[49] Y. Uenoyama, T. Fukuyama, I. Ryu, *Org. Lett.* **2007**, *9*, 935–937.
[50] T. E. Boothe, J. L. Greene Jr, P. B. Shevlin, M. R. Willcott III, R. R. Inners, A. Cornelis, *J. Am. Chem. Soc.* **1978**, *100*, 3874–3879.
[51] B. Maillard, D. Forrest, K. U. Ingold, *J. Am. Chem. Soc.* **1976**, *98*, 7024–7026.
[52] G. S. Foray, A. B. Peñéñory, R. A. Rossi, *Can. J. Chem.* **1999**, *77*, 676–680.

[53] O. M. Musa, J. H. Horner, H. Shahin, M. Newcomb, *J. Am. Chem. Soc.* **1996**, *118*, 3862–3868.
[54] Compound **1** was recently described in a racemic form: D. J. Michaelis, C. J. Shaffer, T. P. Yoon, *J. Am. Chem. Soc.* **2007**, *129*, 1866–1867.
[55] J. M. Concellón, H. Rodríguez-Solla, E. Bardales, M. Huerta, *Eur. J. Org. Chem.* **2003**, 1775–1778.
[56] D. J. Pasta, F. Cottard, L. Jumelle, *J. Am. Chem. Soc.* **1994**, *116*, 8978–8994.
[57] A. S. Y. Yim, M. Wills, *Tetrahedron* **2005**, *61*, 7994–8004.
[58] R. N. Loeppky, S. Elomari, *J. Org. Chem.* **2000**, *65*, 96–103.
[59] S. Sato, T. Sakamoto, E. Miyazawa, Y. Kikugawa, *Tetrahedron* **2004**, *60*, 7899–7906.

Received: July 28, 2007
Published Online: October 16, 2007

