Terminal Aziridines by Addition of Grignard Reagents or Organoceriums to an (α-Chloro)sulfinylimine

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Abstract: Reaction of N-(2-chloroethylidene)-tert-butylsulfinylamide with Grignard reagents or organoceriums gives terminal N-tert-butylsulfinyl aziridines in good yields and (mainly with organoceriums) good diastereomeric ratios. Oxidation of terminal N-tert-butylsulfinyl aziridines provides synthetically useful terminal N-Bus (Bus = tert-butylsulfonyl) aziridines.

Key words: aziridines, chiral auxiliaries, imines, nucleophilic addition, organoceriums

Facilitating ways to introduce nitrogen-containing organic fragments into organic molecules is an important goal in synthetic chemistry. Aziridines, typically when bearing an electron-withdrawing/-activating group on nitrogen, are becoming increasingly important electrophiles.1 Terminal aziridines are probably the most useful aziridines of all, because of the ease, generality and predictable regioselectivity with which they undergo ring-opening reactions with nucleophiles.2 Five strategically different ways that have been used to access terminal aziridines are outlined in Scheme 1.1b,3 In the context of asymmetric synthesis, all of these strategies have been pursued with varying degrees of success, but it remains the case that there is currently no general and straightforward method to access highly enantioenriched 2-substituted (particularly 2-alkyl-substituted) aziridines in an efficient manner.4,5

![Scheme 1](image-url) Synthetic approaches to terminal aziridines

We became aware of current limitations for the asymmetric synthesis of terminal aziridines during our recent development of several new transformations of terminal aziridines proceeding by α-lithiation, including trapping of electrophiles, dimerisation, and intramolecular cyclopropanation of terminal N-Bus (Bus = tert-butylsulfonyl) aziridines 2 (Scheme 2).10 The Bus protecting group was originally introduced by Weinreb and co-workers as a base-stable (acid-labile) protecting group for nitrogen,11 and we have found the Bus group uniquely suited for the range of chemistry shown in Scheme 2.

![Scheme 2](image-url) Reactions of α-lithiated terminal N-Bus aziridines

Where we used enantioenriched terminal N-Bus aziridines 2 in the chemistry in Scheme 2, the aziridines were typically prepared using t-BuSO₂NH₂ in a three-step regioselective epoxide ring-opening/aziridine ring-closure sequence, with the starting enantiopure terminal epoxides being accessed by Jacobsen’s hydrolytic kinetic resolution protocol.10d With the aim of developing a more direct asymmetric synthesis of terminal N-Bus aziridines which avoided a resolution step, we were attracted to a report in 2006 by De Kimpe and co-workers concerning an asymmetric synthesis of 2,2,3-trisubstituted aziridines 4 by addition of Grignard reagents to nonenolisable a-chloroaldimines 3 (Scheme 3).12,13 Successful adaptation of this latter chemistry to make terminal N-Bus aziridines 2 would require: (i) straightforward access to the N-tert-butylsulfinyl imine of a-chloroacetaldehyde 3 (R¹ = H), (ii) development of conditions for the efficient and highly diastereoselective addition of organometallics to this imine (which avoid enolisation and/or chloride displacement) followed by ring-closure (ideally in situ), and (iii) sulfinyl to sulfonyl oxidation while preserving the terminal aziridine. The present article describes the realisation of these goals.14
De Kimpe and co-workers prepared their α-chloroaldimines 3 (R1 = alkyl) by condensation of commercially available t-BuSONH2 with the corresponding α-chloroaldehydes using Ti(OEt)4 in THF at reflux, where the Lewis acid also acts as a trap for the generated water. As α-chloroacetaldehyde (7) is supplied in aqueous solution, which only gives the hemiacetal on extraction with organic solvents, we first attempted to prepare our desired imine 8 from commercially available chloroacetaldehyde dimethyl acetal and t-BuSONH2; however, no reaction was seen in the presence of Ti(OEt)4, whereas decomposition was observed using TiCl4. Among the reported methods to access anhydrous α-chloroacetaldehyde (7),15,16 in our hands only Et3NHClicatalysed loss of CO2 from 4-chloro-1,3-dioxolan-2-one (6) proved viable (Scheme 4).16 Dioxolanone 6 is commercially available (but now expensive); however, it can be conveniently prepared by chlorination of cheap 1,3-dioxolan-2-one (5) in CCl4.17 Although reaction of t-BuSONH2 with anhydrous α-chloroacetaldehyde in the presence of Ti(OEt)4 led to decomposition, milder conditions using anhydrous CuSO418 did generate the desired imine 8; the latter reaction is essentially quantitative and requires no further purification following filtration and solvent removal.

Initial application of De Kimpe’s conditions (CH2Cl2, –78 °C, 2 h)12 using BuMgCl (1.1 equiv) as a representative Grignard reagent led to complete consumption of imine 8 and cleanly gave chloroamine 9 (80%); however, virtually no diastereoselectivity was observed (53:47, by GC of crude reaction mixture). Diastereoselectivity was not significantly improved by switching to THF as sol-

Biographical Sketches

David M. Hodgson obtained his first degree in Chemistry at Bath University. After a Ph.D. at Southampton University in the field of natural product synthesis (with P. J. Parsons) and a research position at Schering, he was appointed in 1990 to a lectureship at Reading University. In 1995 he moved to the Chemistry Department at Oxford University, where he is now a Professor of Chemistry. His research interests are broadly in the development and application of synthetic methods.

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Brian Evans obtained his first degree in Chemistry at the University of Liverpool. After a research position at Allen & Hanburys, and a Ph.D. at Liverpool on porphyrins (with K. M. Smith), he joined Glaxo-Allenburys Research in 1977 and stayed with Glaxo under the various name changes. His research activities have encompassed histamine H2 blockers (zantac), serotonin receptors (sumatriptan, ondansetron), adenosine receptors, β-stimulants (ser-end), neurokinin receptors, combinatorial chemistry, and early-phase drug discovery.
vent, or by the use of additives such as dioxane (potentially driving the Schlenk equilibrium towards BuMgCl), LiCl (potential chelation of Li⁺ to N and Cl), or CeCl₃, whereas using BuLi simply resulted in decomposition of imine 8. Nevertheless, allowing a reaction under the original conditions to warm to room temperature did lead to ring-closure and isolation of terminal aziridine 10a in 78% yield and unchanged diastereomeric ratio (51:49) (Scheme 5).

In De Kimpe’s study, imine 3 (R¹ = Me) was reduced with i-PrMgCl,₁₂ whereas in the present work less-hindered imine 8 efficiently gave aziridine 10b [81%, only traces of the corresponding reduced imine, N-(2-chloroethyl)- tert-butylsulfonimide,₉ were detected], but the diastereoselectivity (57:43 dr) remained similar to that seen with BuMgCl. However, t-BuMgCl gave aziridine 10c (88%) with significant diasterecontrol (94:6 dr) and PhMgBr gave aziridine 10d (76%) with 83:17 dr.

**Scheme 5** Addition of Grignard reagents to imine 8

Repeating the reaction with t-BuMgCl, but using imine (Rᵡ)-8 [prepared as before, but using commercially available (Rᵡ)-t-BuSONH₂]₉ provided an opportunity to both study the viability of the desired subsequent sulfinyl to sulfonyl oxidation step, as well as establish the predominant sense of asymmetric induction [as the specific rotation of N-Bus aziridine (R)-2c is known].¹⁰ MCPBA has previously been reported to oxidise 2,3-disubstituted N- tert-butylsulfinyl aziridines to N-Bus aziridines, and in the present case efficient oxidation of the sulfinyl aziridine from t-BuMgCl and imine (Rᵡ)-8 gave N-Bus aziridine (R)-2c (84%, Scheme 6), which illustrates asymmetric access to synthetically valuable terminal N-Bus aziridine functionality. The sense of asymmetric induction found using imine 8 with t-BuMgCl is opposite to that observed with non-functionalised tert-butylsulfinyl aldimines, but parallels that observed in De Kimpe’s study (and in most other reports concerning N-sulfinyl imines containing a-coordinating groups).¹²,¹³ With non-functionalised aldimines, the sense of asymmetric induction has been rationalised by invoking a chair-like transition state involving chelation of the incoming nucleophile to the sulfinyl oxygen of the E-imine, with the sterically demanding t-Bu group residing equatorial (TS-A, Figure 1). To explain the reversal with a-coordinating groups, it has been proposed that such groups either override sulfinyl oxygen chelation (TS-B),₂¹ or additionally chelate (TS-C),₂² the latter only being possible following to E- to Z-imine isomerisation under the reaction conditions.

**Scheme 6** Addition of Grignard reagents to imine (Rᵡ)-8

During the course of our initial studies discussed above, Crimmins and Shamszad reported in a synthesis of thiazolidine thione 11 an isolated example of an addition to imine (Rᵡ)-8, using mesitylmagnesium bromide (mesitylmgbr, 5 equiv) at –78 °C in toluene and which occurred with high/complete diastereoselectivity (Scheme 6).³,²⁴ While re-examination of the above three alkyl Grignard reagents (5 equiv) with imine 8 in toluene did not change the efficiency, or the magnitude (or sense) of stereoenoduction found for aziridine formation in CH₂Cl₂, we were intrigued that Crimmins and Shamszad had noted the opposite sense of asymmetric induction with mesitylmgbr to that which we had determined with t-BuMgCl. We confirmed the remarkable complete reversal of asymmetric induction between these two hindered Grignard reagents by X-ray crystallographic analysis of picrate 13.²⁵ Picrate 13 was derived from addition of mesitylmgbr to imine (Rᵡ)-8 with quenching at low temperature (the corresponding aziridine 10e was formed in 57% yield and >99:1 dr if the reaction was allowed to warm to room temperature), followed by counter-anion exchange from the hydrochloride salt 12 (Scheme 6). Perhaps the more sterically demanding mesityl group prevents coordination to the α-chloro group, resulting in reaction proceeding by way of TS-A (Figure 1).²⁶

The addition of Grignard reagents to imine 8 furnished the desired aziridines 10 in good yields. However, aside from the significant diastereocontrol observed with the bulky t-Bu and mesityl Grignard reagents, there was an obvious shortfall in diastereoselectivity seen for the simple alkyl-substituted aziridines and for which efficient asymmetric access was a principal goal of the current study. Ellman and co-workers, in their seminal studies on additions of organometallics to simple N-tert-butyldesulfinyl-substituted aldimines, noted in a single example (8, Me instead of Cl)
that MeCeCl₂ (THF, −78 °C) was inferior to MeMgBr (CH₂Cl₂, −48 °C) with respect to diastereoselectivity (78:22 compared with 97:3, respectively). However, encouraged by Denmark and co-workers’ earlier report on organocerium additions to SAMP-hydrazones, we examined BuCeCl₂ (1.2 equiv) with imine 8 in THF or Et₂O at −78 °C and were pleased to observe significant rises in diastereoselectivity (93:7 and 87:13, respectively); allowing these reactions to warm to room temperature led to ring-closure and isolation of terminal aziridine 10a in 82% and 77% yield, respectively, and unchanged diastereomeric ratio as reported by Ellman and co-workers. The reaction was less effective with essentially complete diastereocontrol, with the exception of MeCeCl₂ (entries 1–5). The reaction was less diastereoselective for alkenyl, aryl, heteroaryl, and alkyl cerium reagents (entries 6–10). Entries 5, 6, 8, and 10 illustrate the ability to carry additional functionality into the aziridine 10. Similarly to BuCeCl₂, the absence of 10% DMPU was shown to result in significantly lower diastereomeric ratios for methyl-, allyl- and phenylcerium additions [83% yield (63:37 dr), 91% yield (85:15 dr), and 90% (70:30 dr), respectively].

MCPBA oxidation of sulfinyl aziridine 10f, formed from addition of C₆H₅CeCl₂ to imine (Rₛ)-8 (Table 1, entry 3), gave known N-Bus aziridine (Rₛ)-2 (R = C₆H₅) 30 (87%, 96:4 er by chiral HPLC); this result indicates the sense of asymmetric induction for reaction of C₆H₅CeCl₂ with imine (Rₛ)-8 is the same as that seen earlier for i-BuMgCl. The same predominant sense of asymmetric induction was also observed for phenylcerium and 4-chlorophenylnercium (Table 1, entry 8). For phenylcerium, the absolute sense of asymmetric induction was established using imine (Rₛ)-8 by chemical correlation of sign of specific rotation following MCPBA oxidation to the corresponding N-Bus phenyl aziridine (Rₛ)-2d, with the latter being also derived from (R)-phenylglycine methyl ester hydrochloride (14) (Scheme 7). For 4-chlorophenylnercium, the relative stereochemistry of the major diastereomer of sulfanylaziridine 10j was determined to be Rₛ⁺,R*- by X-ray crystallographic analysis. As phenylcerium was observed to give the same predominant sense of asymmetric induction with imine 8 as was found earlier with PhMgBr (Scheme 5), then [now knowing both the absolute sense of asymmetric induction with phenylcerium and with mesitylMgBr (Scheme 6)] this establishes that PhMgBr gives the opposite sense of asymmetric induction to mesitylMgBr.

The above chemistry was exemplified in the preparation of highly enantioenriched unsaturated N-Bus terminal aziridine (Rₛ)-2m (Scheme 8). Aziridine 2m has previously been shown to undergo the range of chemistry outlined in Scheme 2, with (S)-2m being obtained by the epoxide resolution strategy discussed earlier. Reaction of homoallylcerium with imine (Rₛ)-8 gave sulfanylaziridine (Rₛ,R)-10m (64%, 99:1 dr). While oxidation of sulfanylaziridine (Rₛ,R)-10m using MCPBA was complicated by concomitant epoxidation, chemoselective oxidation at

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### Table 1 Aziridines 10 from α-Chloroimine 8 Using Organoceriums

<table>
<thead>
<tr>
<th>Entry</th>
<th>Organocerium reagent</th>
<th>Aziridine</th>
<th>Yield (%)</th>
<th>dr</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>t-BuCeCl₂</td>
<td>10a</td>
<td>86</td>
<td>99:1</td>
</tr>
<tr>
<td>2</td>
<td>CeCl₂</td>
<td>10b</td>
<td>76</td>
<td>99:1</td>
</tr>
<tr>
<td>3</td>
<td>MeCeCl₂</td>
<td>10c</td>
<td>81</td>
<td>91:9</td>
</tr>
<tr>
<td>4</td>
<td>CeCl₂</td>
<td>10d</td>
<td>83</td>
<td>99:1</td>
</tr>
<tr>
<td>5</td>
<td>PhCeCl₂</td>
<td>10e</td>
<td>75</td>
<td>86:14</td>
</tr>
<tr>
<td>6</td>
<td>PhCeCl₂</td>
<td>10f</td>
<td>92</td>
<td>92:8</td>
</tr>
<tr>
<td>7</td>
<td>PhCeCl₂</td>
<td>10g</td>
<td>84</td>
<td>85:15</td>
</tr>
<tr>
<td>8</td>
<td>PhCeCl₂</td>
<td>10h</td>
<td>92</td>
<td>92:8</td>
</tr>
<tr>
<td>9</td>
<td>PhCeCl₂</td>
<td>10i</td>
<td>82</td>
<td>92:8</td>
</tr>
</tbody>
</table>

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* By GC of crude reaction mixture.
* Using (Rₛ)-8.
* Isolated as the corresponding N-Bus aziridine following oxidation.
* Using HMPA instead of DMPU gave 10d in 93% yield, 92:8 dr.

The scope of this reaction was then examined with a range of organocerium reagents (Table 1). The organocerium reagents were prepared from the corresponding organolithiums and CeCl₃. Alkyl- and allylcerium reagents added with essentially complete diastereocontrol, with the exception of MeCeCl₂ (entries 1–5). The reaction was less diastereoselective for alkenyl, aryl, heteroaryl, and sulfanyl cerium reagents (entries 6–10). Entries 5, 6, 8, and 10 illustrate the ability to carry additional functionality into the aziridine 10. Similarly to BuCeCl₂, the absence of 10% DMPU was shown to result in significantly lower diastereomeric ratios for methyl-, allyl- and phenylcerium additions [83% yield (63:37 dr), 91% yield (85:15 dr), and 90% (70:30 dr), respectively].

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sulfur was achieved using catalytic TPAP/NMO in MeCN\textsuperscript{31} to give unsaturated N-Bus aziridine (R)-2m, (72\%). Similar conditions were found to be required for oxidation of vinyl aziridine \textsuperscript{10i} (Table 1, entry 6).

Although deprotection of several tert-butylsulfinyl aziridines has been reported, typically using HCl in dioxane, in our hands these methods did not prove viable with terminal aziridines.\textsuperscript{32–36} In particular, we sought deprotection conditions for alkyl-substituted terminal aziridines without degradation of enantiopurity.\textsuperscript{37} With decylaziridine (R\textsubscript{8}-R)-10f as a representative substrate, other methods previously reported for the deprotection of t-BuSO\textsubscript{2}Bus. Bus, and tosyl amines/aziridines were also examined, but without success;\textsuperscript{11,38} our attempts either resulted in no reaction or decomposition of the starting aziridine. Finally, we considered the use of HI, anticipating it to be both capable of initiating deprotection by protonation on nitrogen\textsuperscript{59} and S\textsubscript{8}2 ring-opening by iodoide of any putative transient aziridinium ion(s), thus leading to an intermediate SN\textsubscript{2} ring-opening by iodide of any putative transient aziridine can be achieved (and without erosion of enantiopurity).

Reactions were performed in flame-dried glassware under an atmosphere of dry argon. MeCN and CH\textsubscript{2}Cl\textsubscript{2} were degassed and dried over activated alumina under N\textsubscript{2}. THF was distilled from sodium benzenophenone ketyl in a continuous still under N\textsubscript{2}. DMPU and HMPA were distilled from CaH\textsubscript{2} and stored over CaH\textsubscript{2} and 3 Å molecular sieves; all other reagents were used as received, unless indicated otherwise. Flash column chromatography was performed with silica gel (BDH, 0.040–0.063 mm or Machery-Nagel Kieselgel 60M). Petroleum ether (PE) refers to the range of petrol boiling in the range of 30–40 °C. Melting points were obtained in capillary tubes using a Griffin melting point apparatus and are uncorrected. Specific rotations [\alpha]D\textsubscript{2} were measured with a cell of path length 10.0 cm at T °C and are given in 10\textsuperscript{1} deg cm\textsuperscript{2} g\textsuperscript{-1} with concentrations c given in g/100 mL. Gas chromatographic analysis was performed using a Phenomenex Zebron ZB-5 high performance 5% polydimethylsiloxane column with He as carrier gas.

Further details about instrumentation, techniques and experimental details/characterisation data for aziridines not described below can be found in the supporting information of ref. 14.

4-Chloro-1,3-dioxolan-2-one (6)\textsuperscript{17} A solution of 1,3-dioxolan-2-one 5 (Huntsman Ultrapure\textsuperscript{6} 700 g, 2.27 mol) in CCl\textsubscript{4} (300 mL) was irradiated with a sun-lamp (Osram Ultra-Vitalux\textsuperscript{8}, 300 W) and Cl\textsubscript{2} gas was passed into the solution at a rate slow enough for the reaction mixture to remain colourless. After 5 h, \textsuperscript{1}H NMR analysis indicated a mixture comprising 4-chloro-1,3-dioxolan-2-one (80%), 1,3-dioxolan-2-one (10%), and 4,5-dichloro-1,3-dioxolan-2-one (10%). The solvent was removed under reduced pressure and distillation of the residue (N\textsubscript{2}-bleed inlet) gave the title compound [bp 96–98 °C/9 mbar (Lit.\textsuperscript{17} bp 130–139 °C/39 Torr)] as a clear colourless liquid (203 g, 73%) in >95% purity by \textsuperscript{1}H NMR spectrum.

\textsuperscript{1}H NMR (400 MHz, CDCl\textsubscript{3}): \(\delta = 6.45\) (dd, \(J = 5.7, 1.8\) Hz, 1 H, CHCl), 4.84 (dd, \(J = 10.3, 5.7\) Hz, 1 H, CH\textsubscript{2}H\textsubscript{2}), 4.63–4.60 (m, 1 H, CH\textsubscript{2}F).

\textsuperscript{13}C NMR (100 MHz, CDCl\textsubscript{3}): \(\delta = 152.4\) (C=O), 85.3 (CHCl), 73.8 (CH\textsubscript{2}F).

MS (CI): m/z (%) = 140.0 (100, [M + NH\textsubscript{4}]\textsuperscript{+}).

HRMS-Cl: m/z [M + NH\textsubscript{4}]\textsuperscript{+} calcd for C\textsubscript{4}H\textsubscript{7}ClNO\textsubscript{3}: 140.0112; found: 140.0116.

2-Chloroacetaldehyde (7)\textsuperscript{16} Et\textsubscript{2}N (one drop) was added to 4-chloro-1,3-dioxolan-2-one (6; 7.35 g, 60 mmol) in a 25 mL round-bottomed flask equipped with a short path distillation kit. After heating the reaction to 180 °C (oil-bath temperature), distillation commenced and collection of the fraction boiling between 87–89 °C (Lit.\textsuperscript{16} bp 84–86 °C/760 Torr) furnished the title compound as a pale yellow-green liquid of acrid odor (3.67 g, 78%). The material thus obtained was analytically pure by \textsuperscript{1}H NMR and \textsuperscript{13}C NMR analyses and was used without further purification.

IR (neat): 2967, 2360, 2341, 1826, 1430, 1348, 1061, 1017, 763 cm\textsuperscript{-1}.

\textsuperscript{1}H NMR (250 MHz, CD\textsubscript{2}D\textsubscript{2}O): \(\delta = 8.92\) (br t, 1 H, CHO), 3.38 (br d, 2 H, CH\textsubscript{2}Cl).

\textsuperscript{13}C NMR (100 MHz, CDCl\textsubscript{3}): \(\delta = 193.3\) (CHO), 48.6 (CH\textsubscript{2}Cl).

MS (FI): m/z (%) = 77.9 (100, [M\textsuperscript{+}]\textsuperscript{+}).
HRMS-FI: m/z [M]+ calcd for C4H7Cl: 77.9872; found: 77.9874.

N-(2-Chloroethylidene)-2-methylpropane-2-sulfonamide (8)\textsuperscript{23}
To a solution of t-BuSO\textsubscript{3}H (3.64 g, 20 mmol) and anhyd CuSO\textsubscript{4} (9.58 g, 60 mmol) in CH\textsubscript{2}Cl\textsubscript{2} (300 mL) was added dropwise anhyd 2-chloroacetalddehyde (7; 1.88 g, 24 mmol). After complete consumption of the t-BuSO\textsubscript{3}H (8 h, TLC monitoring), the reaction mixture was filtered through a pad of Celite\textsuperscript{e} and the filter cake washed with CH\textsubscript{2}Cl\textsubscript{2} (4 × 20 mL). Evaporation of the solvent in vacuo afforded the title compound (3.57 g, 98%) as a pale yellow oil. The material thus obtained, pure by H\textsuperscript{1} and \textsuperscript{13}C NMR analyses, was used without further purification; R\textsubscript{f} = 0.28 (PE–Et\textsubscript{2}O, 2:1).

IR (neat): 2963, 1831, 1623, 1475, 1253, 1125, 1091, 720, 657, 582 cm\textsuperscript{-1}.

\textsuperscript{1}H NMR (200 MHz, CDCl\textsubscript{3}); δ = 8.02 (s, 1 H, CHN), 4.32 (d, J = 4.6 Hz, 2 H, CHCl), 1.21 (s, 9 H, t-C\textsubscript{4}H\textsubscript{8}).

\textsuperscript{13}C NMR (100 MHz, CDCl\textsubscript{3}); δ = 142.8 (CH\textsubscript{2}Cl), 126.3 (C(CH\textsubscript{3})\textsubscript{3}), 124.2 (CH\textsubscript{2}Cl), 22.4 (C\textsubscript{4}CH\textsubscript{3}).

MS (Cl): m/z (%): 199.1 (100, [M + NH\textsubscript{4}]\textsuperscript{+}), 182.3 (60, [M + H\textsuperscript{+}]\textsuperscript{+}).

HRMS-FI: m/z [M + Na\textsuperscript{+}] calcd for C\textsubscript{4}H\textsubscript{7}Cl\textsubscript{2}N\textsubscript{O}\textsubscript{3}S: 204.1421; found: 204.1421.

\textsuperscript{3}13C NMR (CDCl\textsubscript{3}); δ (R\textsubscript{S},R\textsubscript{R}) = 56.9 (C(CH\textsubscript{3})\textsubscript{3}), 33.5 (CHN), 110.5 (CH\textsubscript{2}CH\textsubscript{2}CH\textsubscript{2}), 25.0 (CH\textsubscript{2}CH\textsubscript{2}CH\textsubscript{2}), 12.7 (CH\textsubscript{2}CH\textsubscript{2}CH\textsubscript{2}), 12.2 (CH\textsubscript{2}CH\textsubscript{2}CH\textsubscript{2}), 25.8 (C\textsubscript{4}H\textsubscript{3}), 24.3 (CH\textsubscript{2}CH\textsubscript{2}CH\textsubscript{2}), 14.1 (CH\textsubscript{3}).

MS (ESI): m/z (%): 203.9 (100, [M + H\textsuperscript{+}]\textsuperscript{+}).

HRMS-FI: m/z [M + Na\textsuperscript{+}] calcd for C\textsubscript{4}H\textsubscript{7}N\textsubscript{O}\textsubscript{3}S: 204.1421; found: 204.1421.

HRMS-FI: m/z [M + H\textsuperscript{+}] calcd for C\textsubscript{4}H\textsubscript{7}N\textsubscript{O}\textsubscript{3}S: 204.1421; found: 204.1421.
ine (R$_2$)8, 0.29 g, 1.0 mmol) in CH$_2$Cl$_2$ (10 mL). After 3 h, sat. aq NaHSO$_4$ (10 mL) was added and the reaction mixture stirred for 15 min; the layers were separated and the aqueous phase extracted with CH$_2$Cl$_2$ (3 × 10 mL). The combined organic layers were washed with H$_2$O (10 mL), sat. aq NaHCO$_3$ (10 mL) and brine (10 mL), dried (MgSO$_4$), and concentrated in vacuo. Purification of the residue by column chromatography (PE–Et$_2$O, 5:1) gave N-But aziridine (R)–2e (0.19 g, 84%) as a clear, colourless oil: [d]$^25$ = +81.0 (c 1.00, CHCl$_3$); [Lit.10 for pure (R):[d]$^25$ = –87.5 (c 1.00, CHCl$_3$)]; $R_f$ = 0.3 (SiO$_2$, PE–Et$_2$O, 5:1).

1H NMR (500 MHz, CDCl$_3$): $\delta$ = 8.90 (br, s, 3 H, NH$_a$), 6.89 (s, 2 H$_{H_2}$), 4.93 (dd, $J = 6.3, 2.7$ Hz, 1 H, CH$_N$), 4.24 (dd, $J = 11.9, 2.9$ Hz, 1 H, CH$_{HP}$), 3.82 (dd, $J = 11.9, 5.7$ Hz, 1 H, CH$_{HP'}$), 2.44 (s, 6 H, o-CH$_3$), 2.26 (s, 3 H, p-CH$_3$), 1.06 (s, 9 H, C(CH$_3$)$_3$).

13C NMR (126 MHz, CDCl$_3$): $\delta_c$ = 139.2 (quat), 136.6 [br, o-CH$_C$] (130.1 [br, o-CH$_C$]), 126.8 (CH$_3$), 53.2 (CH$_N$), 43.2 (CH$_{CH_C}$), 21.4 (br, o-CH$_C$), 20.8 (p-CH$_C$).

(S)-2-Chloro-1-mesitylthioanilinium Chloride (12)

To a solution of imine (R$_2$)8 (0.55 g, 3 mmol) in toluene (15 mL) at –78 °C was added mesitylene magnesium bromide (1.0 M in Et$_2$O, 15 mL, 15 mmol), and the reaction mixture slowly warmed to r.t. overnight. After quenching with MeOH (5 mL), then aq HCl (1 M, 5 mL), and partitioning, the aqueous layer was extracted with EtO$_2$O (2 × 20 mL) and brine (20 mL), dried (MgSO$_4$), and concentrated in vacuo. Column chromatography (SiO$_2$, PE–Et$_2$O, 6:1) of the residue gave the title compound as a pale yellow oil (0.45 g, 57%); $[d]$$_{25}$+74.1 (c 1.00, CHCl$_3$); $R_f$ = 0.6 (PE–Et$_2$O, 6:1).

IR (neat): 2958, 2930, 2962, 1458, 1350, 1250, 965, 752, 628 cm$^{-1}$.

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Azidirines 10 from Organoceriums; 2-Butyl-1-(1-tert-butyssulfinyl)aziridine (10a); Typical Procedure B

n-BuLi (1.6 M in hexanes, 0.75 mL, 1.2 mmol) in THF (5 mL) was added dropwise to a stirred slurry of anhyd CeCl$_3$ (0.30 g, 1.2 mmol, prepared as described above) in THF (7 mL) at –78 °C under argon. After addition of anhyd THF (7 mL), the suspension was vigorously stirred for 2 h and employed in Typical Procedure B, described below.
1.22 [m, 15 H, C(CH3)3], and CH2CH2CH2CH3], 0.92 (br t, 3 H, CH2CH3CH2CH3].

13C NMR (63 MHz, CDC13): δ = 57.0 [C(CH3)3], 33.6 (CHN), 31.6 (CHN), 28.8 (CH2CH2CH2CH3), 25.1 (CH2CH2CH2CH3), 22.8 [C(CH3)3], 22.3 [C(CH3)3], 14.0 (CH2CH2CH3CH3].

HRMS-ESI: m/z (%) = 203.9 (100, [M + H]+).

HRMS-EI: m/z (%) = 203.9 (100, [M + H]+).

HRMS-ESI: m/z (%) = 190.1 (100, [M + H]+) calcd for C6H10NO2S: 190.0902; found: 190.0899.

1-tet-Butylsulfinyl)-2-methylaziridine (2; R = Me)

MeLi (1.6 M in Et2O, 0.75 mL, 1.2 mmol) was used following Typical Procedure B. GC-MS analysis indicated the formation of 1-tet-Butylsulfinyl)-2-methylaziridine (10g) in 91:9 dr, which was immediately oxidised to 2 (R = Me) as follows. Crude sulfinyl aziridine 10g was dissolved in CH2Cl2 (5 mL), cooled to 0 °C and MCPBA (0.46 g, 3 mmol) was added. After warming to r.t., and stirring for 4 h, the reaction was quenched with sat. aq NaHCO3, (20 mL), H2O (20 mL) and brine (20 mL), dried (MgSO4), and concentrated in vacuo. Purification of the residue in CH2Cl2 (50 mL) was added MCPBA (3.45 g, 20 mmol). The combined organic layers were washed with sat. aq NaHCO3 (20 mL), H2O (20 mL) and brine (20 mL), dried (MgSO4), and concentrated in vacuo. Column chromatography (SiO2, PE–Et2O, 3:1) provided the title compound as a clear, colourless oil (0.14 g, 81%); Rf = 0.3 (PE–Et2O, 3:1).

IR (neat): 2973, 1657, 1559, 1475, 1442, 1394, 1161, 1091, 1033, 958 cm–1.

HRMS-ESI: m/z (%) = 190.1 (100, [M + H]+).
IR (KBr): 3410, 2980, 2913, 1709, 1308, 1216, 1130, 1051, 950, 893, 865, 709 cm⁻¹.

¹H NMR (400 MHz, CDCl₃); δ = 7.38–7.35 (m, 5 H, CH₃), 5.28 (d, J = 8.8 Hz, 1 H, NH), 5.22 (d, J = 8.8 Hz, 1 H, CH), 2.75 (s, 3 H, CH₃), 1.30 [s, 9 H, C(CH₃)₃].

¹³C NMR (100 MHz, CDCl₃); δ = 171.6 (CO₂CH₃), 136.6 (quat), 129.0 (p-CH), 128.7 (CH), 127.1 (CH), 60.0 [C(CH₃)₃], 53.1 (CO₂CH₃), 24.9 [C(CH₃)₃].

MS (CI); m/z (%) = 303.1 (100, [M + NH₄⁺]), 286.1 (20, [M + H⁺]).


**References**


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