A New Method of N-Benzhydryl Deprotection in 2-Azetidinone Series

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Abstract: A mild and efficient procedure for the selective cleavage of N-benzhydryl protecting group of β-lactams is described. The protected 2-azetidinones 4, precursors of carbapenems, were treated with a stoichiometric amount of N-bromosuccinimide and a catalytic amount of bromine under sun light irradiation in CH2Cl2–H2O mixture at 20 °C for 3 hours. The N-benzhydryl intermediates 6, which could be isolated, were then hydrolyzed with p-TsOH in aqueous aceton to furnish β-lactams 7 and benzophenone quantitatively.

Key words: antibiotics, halogenation, protecting groups, benzhydryl derivatives, stable hemiaminals

The importance of 2-azetidinones (β-lactams) is widely recognized as key intermediates for the synthesis of antibiotics, as well as versatile synthons for the preparation of β-amino acid derivatives. Enantiomerically pure 2-azetidinones are now accessible via different routes based on cyclization, [2+2] cycloaddition, or cyclocondensation strategies. Because of their excellent stability towards β-lactamases and enhanced activity, carbapenems, a new class of β-lactam antibiotics, have attracted much attention over the last twenty years. Recently, we revisited the synthesis of 3-[1′-(R)-hydroxyethyl]azetidin-2-one intermediates of carbapenems, by applying the C-3/C-4 ring-closure method from (2R,3R)-epoxybutyramide precursors. We were interested in the replacement of the habitual p-anisyl N-1 protecting group with the benzhydryl group. Indeed, the cleavage of p-anisyl substituent requires supra-stoichiometric amount of ceric ammonium nitrate (CAN) as selective oxidant, a method which uses a toxic reagent, and is not really compatible with large scale synthesis. The other useful N-1 protecting groups of 2-azetidinones are trialkylsilyl residues, 2,4-dimethoxybenzyl and di(p-methoxyphenyl)methyl substituents, the last ones being removable also by CAN oxidation or under strongly acidic treatments.

In this paper, we describe the incorporation of N-1 benzhydryl group into β-lactams using the commercially available benzhydrylamine for the preparation of synths 1 [Scheme 1, (1)], and the further N-1 deprotection of β-lactams 4 resulting from the coupling of 1 with chiral epoxide 2, followed by basic cyclization [Scheme 1, equation (2)] (Table 1). Our method relies upon the ease with which photobromination of the diphenylmethyl moiety can be performed.

![Scheme 1](image)

**Scheme 1** Synthesis of β-lactams. Reagents and conditions: (i) benzhydrylamine (2 equiv), MeOH, r.t., overnight; (ii) benzhydrylamine (1 equiv), K2CO3 (1.1 equiv), Kl (1.1 equiv), DMF, reflux, 5 h; (iii) a) 2 (1.2 equiv), (COCl)2 (1.3 equiv), THF, –5 °C, 2 h; b) pyridine (2 equiv), LAH, THF, –5 °C, 2 h; (iv) LiHMDS (1.1 equiv), THF, 0 °C, 3 h.

**Table 1** Yields of Isolated Compounds (%)

<table>
<thead>
<tr>
<th>Product</th>
<th>EWG</th>
<th>1 (Method)</th>
<th>3</th>
<th>4</th>
<th>trans: cis</th>
</tr>
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<tbody>
<tr>
<td>a</td>
<td>COt-Bu</td>
<td>88 (i)</td>
<td>46 90*</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>b</td>
<td>COPh</td>
<td>86 (i)</td>
<td>55 57</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>c</td>
<td>COt-Bu</td>
<td>95 (ii)</td>
<td>67 69</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>d</td>
<td>CN</td>
<td>90 (ii)</td>
<td>41 47</td>
<td>52:48</td>
<td></td>
</tr>
</tbody>
</table>

We have previously reported the preparation of epoxide intermediates 3a and 3b, and their transformation into 2-azetidinones 4a and 4b, respectively, equipped with piv-aloyl- and benzoyl-EWG (electron-withdrawing) groups at position C-4; side products (six- and seven-membered ring derivatives) of the S_Ni reaction were also isolated. According to the same strategy, based on the seminal work of Hanessian, we have now synthesized β-lactams 4c and 4d with tert-butyloxy carbonyl and cyano substitu-
ents, respectively, at this position (Table 1). Reaction of benzhydrylamine with tert-butyl bromoacetate and bromoacetonitrile, respectively, gave secondary amines 1c,13 and 1d,14 purified by recrystallization from methanol. Activation of sodium (2R,3R)-cis-2,3-epoxypentanate (2)10 with oxaly chloride in THF at low temperature, followed by addition of pyridine and 1c,d led to the isolation of 3c,d in 40–70% yield, after chromatography on silica gel. Compound 3e showed the presence of two rotamers in the NMR spectra (CDCl3), splitting practically all the signals, as a result of restricted rotation around the C(0)–N amide bond. In contrast, compound 3d showed broad signals characteristic of rotamers in rapid equilibrium; recording the NMR spectra at –55 °C allowed the detection of the signals of both the rotamers (see experimental). The best conditions of cyclization, previously determined, were applied. Thus, epoxymides 3c,d were treated with lithium hexamethyldisilazide (LiHMDS) in THF at 0 °C to furnish β-lactams 4c,d in 50–70% yield after purification. The cyclization of 3c into 4c occurred similarly to that of 3a,b,5 giving only the trans-diastereoisomer 4c. This most probably results from the steric control due to a bulky EWG-substituent when the third asymmetric center (C-4) is induced. Accordingly, in the case of 3d, the cyclization into 4d (EWG = CN) was no longer stereoselective: an equimolar mixture of trans and cis β-lactams was recovered, as revealed by the typical 1H NMR coupling constants of H-3 and H-4 (Jtrans = 2.4 Hz and Jcis = 5.4 Hz). Such loss of stereoselectivity has been previously mentioned for small EWG groups at position C-4.15

Traditionally, the removal of a benzhydryl protecting group from O- or N-functionalities has been achieved via hydrogenation or under vigorous acidic conditions;9 ether and esters derivatives being more easily cleaved than the corresponding amines and amides. Thus, we first applied various conditions of catalytic hydrogenation to compound 4a [Pd/C, Pd(OH)2/C, Pd/BaSO4, Pd/CaCO3 or Raney Ni, in EtOAc, EtOH, HOAc or DMF, under 50 psi H2, during several hours], but without success: the N-benzhydryl azetidinone was recovered unchanged. In the case of compound 4b, prolonged hydrogenation provoked the reduction of the benzoyl moiety (into hydroxybenzyl and benzyl groups), without any N-deprotection. Disappointing results were also obtained when submitting 4a to acidic conditions (HCO2H or CF3CO2H, neat or in the presence of anisole; HBr–HOAc), the benzhydryl group was never removed, and under prolonged reaction times, modifications of the hydroxy function of the C-3 sidechain appeared (such as formylation and trifluoroacetylation). Therefore, we turned to a totally different strategy making use of the sensitivity of benzyl derivatives towards free radical bromination.11 Our plan was to selectively produce bromobenzhydryl intermediates 5 (Scheme 2) and to further hydrolyze them into benzhydrol derivatives 6, the acid-catalyzed decomposition of which would lead to N-deprotected azetidinones 7 and benzophenone.

### Table 2 Deprotection Conditions of 4a

<table>
<thead>
<tr>
<th>Entry</th>
<th>Conditions</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NBS, AIBN (catal.), PhCl, 120 °C, 3 h</td>
<td>degradation^b</td>
</tr>
<tr>
<td>2</td>
<td>NBS, AIBN (catal.), CCL4, 70 °C, 3 h</td>
<td>degradation^b</td>
</tr>
<tr>
<td>3</td>
<td>NBS, AIBN (catal.), PhCl, 20 °C, dark, 24 h</td>
<td>4a (no reaction)</td>
</tr>
<tr>
<td>4</td>
<td>NBS, PhCl, white light (120 W), 20 °C, 30–90 min</td>
<td>4a + 5a + degradation^b</td>
</tr>
<tr>
<td>5</td>
<td>NBS, PhCl, fume hood lamp, 20 °C, 24 h</td>
<td>degradation^b</td>
</tr>
<tr>
<td>6</td>
<td>NBS, PhCl–H2O (10:1), fume hood lamp, 20 °C, 24 h</td>
<td>6a (&gt;95%)</td>
</tr>
<tr>
<td>7</td>
<td>NBS, CH3Cl–H2O (10:1), fume hood lamp, 20 °C, 24 h</td>
<td>6a (&gt;95%)</td>
</tr>
<tr>
<td>8</td>
<td>NBS, Br2 (catal.), CH3Cl2–H2O (5:1), hv, 20 °C, 3 h</td>
<td>6a (&gt;95%)</td>
</tr>
<tr>
<td>9</td>
<td>NBS, Br2 (catal.), CH3Cl2–H2O (5:1), dark, 20 °C, 3 h</td>
<td>4a (no reaction)</td>
</tr>
<tr>
<td>10</td>
<td>Br2, CH3Cl2–H2O (5:1), hv, 20 °C, 3 h</td>
<td>6a (ca. 85%) + degradation</td>
</tr>
</tbody>
</table>

^a 1H NMR analysis of the crude mixtures.

^b The β-lactam ring was broken.

### Scheme 2 Benzhydryl group deprotection (unprotected substrates). **Reagents and conditions:** (i) NBS (1.2 equiv), CH3Cl–H2O 5:1; Br2 (0.1 equiv), r.t., hv, 3 h; (ii) pTsOH (1 equiv), CH3CN–H2O 1:1; r.t., dark, overnight

Treatment of 4a with N-bromosuccinimide16 (NBS) was thus considered under various conditions (Table 2). We first used azobis(isobutyro)nitrile (AIBN) as free radical initiator. Reaction took place at higher temperatures (entries 1,2), and after aqueous workup, we could identify the presence of benzophenone in the crude mixtures, indicating that the sequence of reactions outlined in Scheme 2 could occur, at least partially! But the reaction further
Benzhydryl group deprotection (O-protected substrate). Reagents and conditions: (i) TBDMSCl (5 equiv), imidazole (10 equiv), DMF, r.t., 2 d; (ii) NBS (1.2 equiv), CH₂Cl₂–H₂O 5:1, Br₂ (0.1 equiv), r.t., hv, 3 h; (iii) pTsOH (1 equiv), CH₃CN–H₂O or acetone–H₂O 1:1; r.t.; dark, overnight; (iv) TBDMSCl (2 equiv), imidazole (5 equiv), DMF, r.t., 16 h.

Scheme 3 Benzhydryl group deprotection (O-protected substrate).
500 MHz for proton and 125 MHz for carbon); the chemical shifts are reported in ppm downfield from tetramethylsilane (internal standard). Mass spectra were obtained on a Finnigan-MAT TSQ-70 instrument at 70 eV (chemical ionization mode). Microanalyses were performed at the Christopher Ingold Laboratories of the University College London, UK. HRMS were recorded at the University of Mons, Belgium (Prof. R. Flanang).

TLC was carried out on silica gel 60 plates F254 (Merck, 0.2 mm thick); visualization was effected with UV light. Column chromatography (under medium pressure) was carried out with Merck silica gel 60 of 230–240 mesh ASTM. Compounds 1a, 1b, 3a, 3b, 4a and 4b were fully described in Ref. 6.

tert-Butyl[diphenylmethylamino]ethanoate (1c)13

To a solution of benzhydrylamine (7.6 mL, 44.1 mmol, 1 equiv) in anhyd DMF (160 mL) were added K2CO3 (6.70 g, 48.5 mmol, 1.1 equiv) and KI (8.16 g, 49.1 mmol, 1.1 equiv). The suspension was stirred and brought to reflux. tert-Butyl bromoacetate (8.63 g, 44.3 mmol, 1 equiv) was then added dropwise during 15 min. A white precipitate appeared. After 5 h, the precipitate was filtered off and the organic solution was diluted with EtOAc (200 mL), washed with brine (3 × 100 mL), dried (MgSO4), and concentrated under reduced pressure. The solid obtained was then purified by chromatography on silica gel (hygroscopic compounds).

tert-Butyl (2′R, 3′R)-2-[N-(Diphenylmethyl)-N-(2′,3′-epoxybutanoyl)amino]ethanoate (3c)

Starting from 1c (1.14 g, 3.8 mmol) and following the general procedure, a white foam (0.98 g, 67%) was obtained after chromatography (eluent: cyclohexane-EtOAc, 5:1); Rf 0.18; mp 90–92 °C; [α]D20 +57.2 (c = 0.458, CHCl3).

IR (neat): 3321 (OH), 1723 (C=O ester), 1660 (C=O amide) cm⁻¹.

1H NMR (CDCl3, 200 MHz, two rotamers in a 55:45 ratio): δ (major rotamer) = 7.1–7.4 (m, 10 Hm), 6.61 (s, 1 H, PhCH2), 4.07 (d, 1 H, J = 16.9 Hz, NHCH2CO), 3.93 (d, 1 H, J = 16.9 Hz, NCH2CO), 3.60 (d, 1 H, J = 4.4 Hz, H-2′), 3.29 (dq, 1 H, J = 4.5, 3.5 Hz, H-3′), 1.38 (d, 3 H, J = 6.4 Hz, t-Ch2), 1.25 (s, 9 H, t-Ch3). δ (minor rotamer) = 7.1–7.4 (m, 11 H arom and Ph2C=CH2), 4.47 (d, 1 H, J = 18.4 Hz, NHCH2CO), 3.94 (d, 1 H, J = 18.4 Hz, NCH2CO), 3.67 (d, 1 H, J = 4.4 Hz, H-2′), 3.29 (dq, 1 H, J = 4.5, 3.5 Hz, H-3′), 1.35 (d, 3 H, J = 5.5 Hz, CH3), 1.21 (s, 9 H, t-Ch2H6).

13C NMR (CDCl3, 75 MHz): δ = 168.4, 168.0, 167.1, 138.9, 138.8, 127.9–129.6, 64.6, 61.4, 55.7, 55.1, 54.3, 47.3, 47.2, 28.3, 15.1, 14.5.

MS (Cl, CH2—N=O): m/z (%) = 464.3 (14), 382.1 (1 [M + H]+), 298.1 ([Ph2CHN(CH3)2CO2H]+), 183.0 (100), 166.9 (Ph2CH+), 83.


(2′R,3′R)-N-(Diphenylmethyl)-N-cyanomethyl-2,3-epoxybutanamide (3d)

Starting from 1d (1.21 g, 5.4 mmol) and following the general procedure, a white foam (0.69 g, 41%) was obtained after trituration with acetone; Rf 0.22 (EtOAc–CH2Cl2, 10:1); mp 146.5–148.0 °C; [α]D20 +51.7 (c = 0.750, CHCl3).

IR (neat): 3312 (NH), 2240 (C=O ester), 1669 (C=O amide) cm⁻¹.

1H NMR (CDCl3, 300 MHz, two rotamers in nearly rapid exchange at 25 °C): δ = 7.3–7.6 (m, 10 Hm), 6.63 (br s, 1 H, PhCH2), 4.34 (br m, 2 H, NCH2CN), 3.81 (br s, 1 H, H-2′), 3.46 (br s, 1 H, H-3′), 1.49 (br d, 3 H, J = 4.8 Hz, CH3).

1H NMR (CDCl3, 200 MHz, two rotamers in slow exchange at −55 °C in a 73:27 ratio): δ = 4.43 (d, 1 H, J = 16.9 Hz, NCH2CN), 4.05 (d, 1 H, J = 16.9 Hz, NCH2CN), 3.72 (d, 1 H, major, J = 4.1 Hz, H-2′), 3.62 (d, 1 H minor, J = 4.8 Hz, H-2′), 3.41 (d, 1 H, J = 4.8 Hz, H-3′).

13C NMR (CDCl3, 50 MHz): δ = 167.3, 137.1, 136.9, 126.9–128.9, 114.8, 64.4, 53.9, 53.7, 32.1, 13.7.

MS (Cl, CH2—N=O): m/z (%) = 268.0 ([M – CH2CN]+), 18, 182.9 ([Ph2CHN(CH3)2]+), 92, 166.9 ([Ph2CH]+), 100.

Anal. Calcd for C20H19NO2: C, 74.49; H, 6.10; N, 8.92.

Azetidinones 4: General Procedure

To a stirred solution of 3 (1 equiv) in anhyd THF (10 mL/mmol of 3) at 0 °C under argon was added LiHMDS (1.1 equiv). The solution was stirred for 2 h at 0 °C. The reaction was quenched with aq 0.1 N HCl. The mixture was diluted with EtOAc, washed with sat. aq NaHCO3, and concentrated under reduced pressure. The solid obtained was then purified by chromatography on silica gel (hygroscopic compounds).
(3,4S,5R)-N-Diphenylmethyl-3-(1'-hydroxyethyl)-4-(tett-butyl-oxoxyomethyl)azetidin-2-one (4c)

Starting from 3c (1.29 g, 3.4 mmol, 1 equiv) and following the general procedure, a white foam (0.89 g, 69%) was obtained after chromatography (gradient of elution from cyclohexane–EtOAc 5:1 to cyclohexane–EtOAc 1:1); Rf 0.18 (cyclohexane–EtOAc, 5:2); mp 113.5–115 °C; [α]D20 +2.3 (c = 0.259, CHCl3).

IR (neat): 3239 (OH), 1732 (two C=O) cm–1.

1H NMR (CDCl3, 300 MHz): δ = 7.2–7.4 (m, 10 H arom), 5.90 (s, 1 H, Ph2CO), 4.26 (dq, 1 H, J = 3.6, 6.3 Hz, MeCHOH), 4.04 (d, 1 H, J = 2.4 Hz, H-4), 3.14 (dd, 1 H, J = 2.4, 3.6 Hz, H-3), 1.30 (s, 9 H, t-C6H13), 1.23 (3, 3 H, J = 6.3 Hz, CH3).

13C NMR (CDCl3, 75 MHz): δ = 170.3, 168.0, 138.9, 138.8, 128.9, 128.7, 128.0, 82.5, 62.7, 54.2, 28.3, 21.7.

MS (CL, CH–N–O); m/z (%) = 382.2 ([M + H]+ , 9), 253.0 (20), 182.9 ([Ph2CHNH]–, 16), 166.9 ([PH2CH]–, 100).


(3,4S,5R)-N-Diphenylhydroxymethyl-3-(1'-hydroxyethyl)-4-cyanoazetidin-2-one (trans-4d) and (3,4S,5R)-N-Diphenyl-3-(1'-hydroxyethyl)-4-cyanooazetidin-2-one (cis-4d)

Starting from 3d (0.22 g, 0.72 mmol) and following the general procedure, after chromatography (gradient of elution from cyclohexane–EtOAc 5:1 to cyclohexane–EtOAc 1:1) trans-4d (0.053 g, 24%) and cis-4d (0.051g, 23%) were obtained as yellow solids.

trans-4d

Rf 0.13 (cyclohexane–EtOAc, 5:2); mp 101–103.0 °C; [α]D20 +18.0 (c = 0.183, CHCl3).

IR (neat): 3308 (OH), 2193 (C≡N), 1772 (C=O) cm–1.

1H NMR (acetone-d6, 300 MHz): δ = 7.3–7.45 (m, 10 H arom), 6.08 (s, 1 H, Ph2CO), 4.52 (br d, 1 H, J = 4.2 Hz, OH), 4.36 (d, 1 H, J = 2.4 Hz, H-4), 4.20 (ddq, 1 H, J = 4.2, 4.5, 6.7 Hz, MeCHOH), 3.66 (dd, 1 H, J = 2.4, 4.5 Hz, H-3), 1.27 (3, 3 H, J = 6.7 Hz, CH3).

13C NMR (CDCl3, 75 MHz): δ = 166.3, 137.5, 137.3, 128.4–129.4, 117.4, 63.9, 63.8, 62.0, 40.1, 21.9.

MS (CL, CH–N–O); m/z (%) = 307.1 ([M + H]+ , 7), 289.1 ([M + H – H2O]+, 4), 182.9 ([Ph2CHNH]–, 100), 166.9 ([Ph2CH]–, 60), 83.8 (83), 73.0 (78), 60.8 (68).

Anal. Caled for C34H29NO5; C, 74.49; H, 5.92; N, 9.14. Found: C, 73.77; H, 6.08; N, 8.93.

cis-4d

Rf 0.09 (cyclohexane–EtOAc, 5:2); mp 93.5–94.5 °C; [α]D20 +4.62 (c = 0.325, CHCl3).

IR (neat): 3459 (OH), 2246 (C≡N), 1763 (C=O) cm–1.

1H NMR (CDCl3, 300 MHz): δ = 7.3–7.4 (m, 8 H arom), 7.23 (dd, 2 H arom, J = 7.0, 2.0 Hz, para H), 6.10 (s, 1 H, Ph2CO), 4.43 (dq, 1 H, J = 8.1, 6.3 Hz, MeCHOH), 4.07 (d, 1 H, J = 5.4 Hz, H-4), 3.44 (dd, 1 H, J = 5.4, 8.1 Hz, H-3), 1.46 (d, 3, 3 H, J = 6.3 Hz, CH3).

13C NMR (CDCl3, 75 MHz): δ = 165.5, 137.1, 129.5, 129.2, 128.6, 116.6, 65.7, 61.8, 60.9, 42.7, 22.1.

MS (CL, CH–N–O); m/z (%) = 307.1 ([M + H]+ , 2), 182.9 ([Ph2CHNH]–, 8), 166.7 ([Ph2CH]–, 8), 165.0 (17), 102.8 (25), 100.8 (37), 82.8 (100), 64.8 (23).

Anal. Caled for C34H29NO5; C, 74.49; H, 5.92; N, 9.14. Found: C, 73.46; H, 5.91; N, 8.77.

Deprotection of 4; General Procedure

To a solution of 4 (1 equiv) in a biphasic mixture of CH2Cl2 and H2O (5:1, 15 mL CH2Cl2/mmol 4), were added N-bromosuccinimi-
Starting from cis-4d (0.24 g, 0.77 mmol) and following the general procedure for the first step of the deprotection, crude cis-6d (0.22 g, 92%) was obtained.

IR (neat): 3345 (NH, OH), 2250 (C≡N), 1765 (C=O), 1735 (C=O) cm⁻¹.


Starting from cis-6d (0.19 g) was allowed to stand in air for 24 h to give a brown oil, which give after purification by chromatography on RP-18 gel (eluent: MeCN:H₂O, 1:1) a yellow oil (0.077 g, 65% from cis-4d; Rₜ: 0.61; [α]D²⁵ +17.5 (c = 0.332, H₂O).

IR (neat): 3351 (NH, OH), 2248 (C≡N), 1767 (C=O) cm⁻¹.


Starting from trans-4d (0.13 g, 0.42 mmol) and following the general procedure for the first step of the deprotection, crude trans-6d (0.15 g, crude yield: quantitative) was obtained.

IR (neat): 3334 (NH, OH), 1765 (C=O), 1744 (C=O) cm⁻¹.


Starting from trans-6d (0.10 g) was allowed to stand in air for 24 h to give a brown oil, which gave after purification by chromatography on RP-18 gel (eluent: MeCN:H₂O, 1:1) a yellow oil (0.040 g, 95% from trans-4d; Rₜ: 0.93 (RP-18, MeCN:H₂O 1:1); [α]D²⁵ -324 (c = 0.36, H₂O).

IR (neat): 3332 (NH, OH), 2250 (C≡N), 1767 (C=O) cm⁻¹.

1 H NMR (CDCl₃, 200 MHz): δ = 7.1–7.6 (m, 10 H arom.), 5.18 (br s, 1 H, OH), 4.72 (d, 1 H, J = 2.2 Hz, H-4), 4.30 (dq, 1 H, J = 6.0, 6.3 Hz, MeCHOH), 2.78 (dd, 1 H, J = 6.0, 2.2 Hz, H-3), 1.33 (d, 3 H, J = 6.3 Hz, CH₃), 0.96 (s, 9 H, t-C₆H₃), 0.80 (s, 9 H, Si(CH₃)₃), 0.16, 0.15 (2 s, 6 H, Si(CH₃)₄).

13C NMR (CDCl₃, 75 MHz): δ = 216.2, 166.8, 142.1, 141.5, 126.2–129.9, 87.4, 66.6, 62.0, 56.6, 43.8, 26.2, 25.7, 25.3, 18.1, -3.6, -4.5.

1H NMR (CDCl₃, 200 MHz): δ = 5.96 (br s, 1 H, NH), 4.59 (d, 1 H, J = 2.1 Hz, H-4), 4.27 (dq, 1 H, J = 6.3, 4.5 Hz, MeCHOH), 3.17 (m, 1 H, H-3), 1.26 (d, 3 H, J = 6.3 Hz, CH₃), 1.22 (s, 9 H, t-C₆H₃), 0.89 (s, 9 H, Si(CH₃)₃), 0.10, 0.09 (2 s, 6 H, Si(CH₃)₄).

13C NMR (CDCl₃, 75 MHz): δ = 212.8, 168.6, 65.6, 64.5, 51.3, 44.1, 26.4, 25.8, 23.0, 18.0, -4.4, -4.7.

MS (CI, CH₄–N₂O) – : 44.1, 26.4, 25.8, 23.0, 18.0, -4.4, -4.7.

Anal. Calcd for C₁₆H₃₁NO₃Si: C, 61.30; H, 9.97; N, 4.47. Found: C, 57.6; H, 10.10; N, 4.41.

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