Selective Conversion of *N*-Trichloroethoxycarbonyl (Troc) Groups into *N*-Acetyl Groups in the Presence of *N*-*tert*-Butoxycarbonyl (Boc) Protecting Groups

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Abstract: Deprotection of *N*-trichloroethoxycarbonyl (Troc) groups with zinc in acetic anhydride cleaves also *N*-*tert*-butoxycarbonyl (Boc) groups, thus liberating the amino groups, which are immediately *N*-acetylated. When this reaction is performed in the presence of triethylamine only Troc groups are selectively cleaved as demonstrated for several examples.

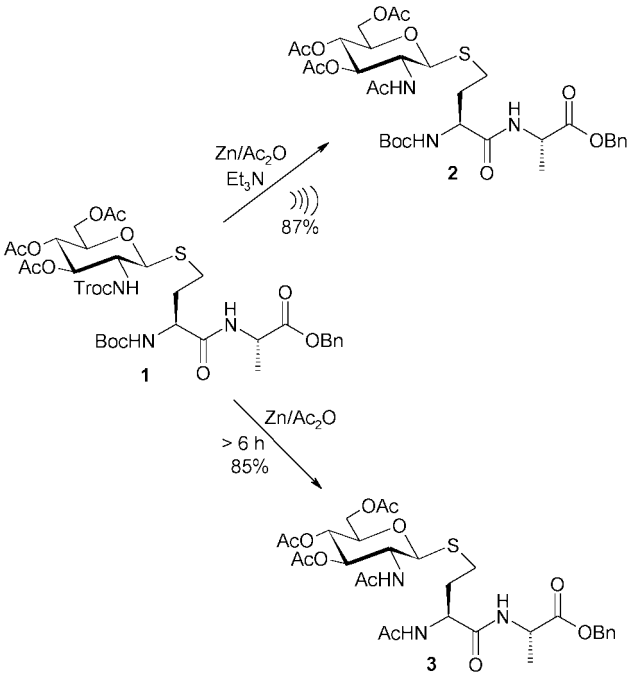
Key words: protecting groups, orthogonality, cleavage, zinc, amines

Protecting groups play a central role in modern organic synthesis,[1] and the selective removal or conversion of one protecting group in the presence of another is of critical importance in many synthetic sequences. The more selectively a protecting group can be removed, the more useful it becomes. We report herein an efficient procedure for the selective conversion of *N*-trichloroethoxycarbonyl (Troc) groups into *N*-acetyl groups in the presence of *N*-Boc protecting groups.

Among the various amine protecting groups, the Troc group is one which is frequently used in organic synthesis,[1a] especially in syntheses with amino sugar derivatives.[2] This is due to its stability under mild acidic and basic conditions and its ease of removal under specific conditions; thus, this group is orthogonal to other amino protecting groups which renders it ideal as a temporary protecting group.[3]

Removal of the *N*-Troc group can be carried out under a number of conditions, e.g. with Zn/HOAc,[4] Zn and acidic buffer,[5] Zn-Cu couple/HOAc,[2c] Cd-Pb/HOAc,[3] or other reduction methods. The only condition available for its one-pot conversion into an *N*-acetyl group is Zn/Ac_2O.[2a,b,6] The *N*-Boc group can be also selectively removed with trifluoroacetic acid in the presence of *N*-Troc groups.

In the course of our studies on the synthesis of glycopeptides, we required a mild and efficient method for the transformation of **1** into **2**, as shown in Scheme 1.



Scheme 1

Unexpectedly, when **1** was treated with Zn/Ac_2O, the side product **3** was produced in addition to the desired product **2**, i.e. the *N*-Boc group of **1** was removed and the amino group was converted into an *N*-acetyl group. Indeed, compound **2** could be isolated from the mixture, but in low yield, and compound **3** was obtained exclusively if the reaction time was extended (Scheme 1). In the literature,[2b,3,7] *N*-Troc groups have been used in combination with *N*-Boc groups, but no specific reaction conditions providing exclusive conversion of *N*-Troc into *N*-acetyl groups in one-pot has been described[3,7] or when Zn/Ac_2O was employed,[2b] the reaction mixture contained presumably already some Et_3N from the preceding reaction. We anticipated that not Zn dust but $ZnCl_2$, which was produced in situ after cleavage of *N*-Troc groups in this reaction, cleaved the *N*-Boc groups. To verify this hypothesis, compounds **4a** and **4b** were treated directly with $ZnCl_2$, as shown in Scheme 2. Expectedly, the *N*-Boc groups were indeed removed completely within 2 hours to give the corresponding free amine products. Analogous deprotection of *N*-Boc groups conducted with $ZnBr_2$ in CH_2Cl_2 has already been reported.[8]

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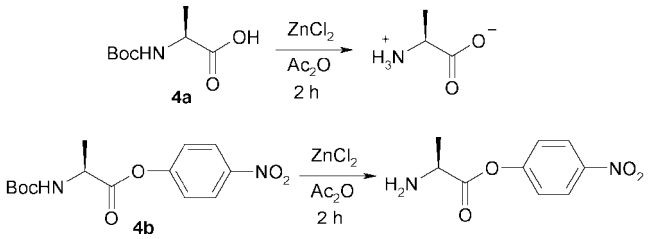


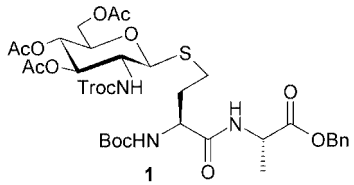
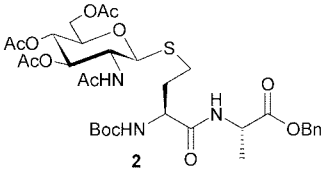
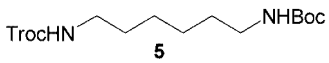
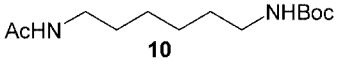
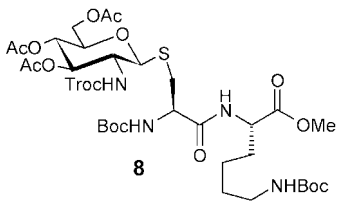
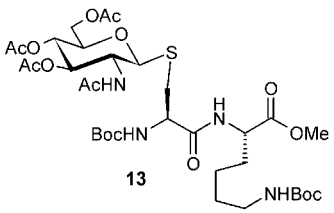
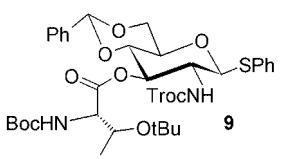
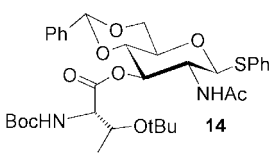
Scheme 2

In order to inhibit the formation of **3**, we considered that **1** might be converted only into **2** if additional base was present in the mixture to neutralize the $ZnCl_2$ produced during the course of the reaction . Thus, treatment of **1** with a large excess of Zn dust in Ac_2O in the presence of 2 equivalents of Et_3N for 8 hours did indeed give the desired glycopeptide **2** in much better yield as indicated on TLC. Subsequent optimization revealed that the reaction time could be reduced noticeably from 8 to 3 hours if a classic ultrasonic cleaning bath was applied instead of a normal stirrer and **2** was obtained in 87% yield after chromatographic purification.

To examine the scope of this procedure, some properly protected substrates for this purpose were prepared and subjected to the above sonication conditions (Table 1). Each substrate (1 mmol) was treated under the same conditions; it was dissolved in Ac_2O (5 mL) containing Et_3N (2 mmol). Freshly activated Zn dust (20 mmol) was added and the resulting mixture was sonicated in an ultrasonic cleaning bath below room temperature until TLC indicated complete consumption of the starting material.

The results, summarized in Table 1, indicate that under the above reaction conditions, *N*-Troc groups can be selectively converted into *N*-acetyl groups in the presence of *N*-Boc protecting groups. Initially, experiments were run with 1-*N*-Troc-6-*N*-Boc-hexadiamine (**5**). A clean conversion occurred within 2 hours and the acetamide **10**[9] was obtained in almost quantitative yield without any effect on the *N*-Boc group. Excellent yields were also achieved for the selective conversion of *N*-Troc into *N*-acetyl groups in compounds **6** and **7**. Moreover, the stability of the *N*-Boc group under these conditions was confirmed when **7** was sonicated for 5 hours and the desired product **12** was still obtained in 87% yield. The reaction conditions were again so mild to inhibit the cleavage of the *N*-Boc group in **8**, even in the presence of two *N*-Boc groups, and the β-GlcNAc containing glycopeptide **13** was obtained in 81% yield. Notably, the Troc group of thioglycoside **9** was also selectively converted into **14** in 76% yield under sonication conditions and both the benzylidene and *tert*-butyl groups survived these conditions.

Table 1 Selective Conversion of *N*-Troc Groups into *N*-Ac Groups

Substrate	Time (h)	Product	Yield (%)
	3		87
	2		95
Troc-Lys(Boc)-OMe (**6**)	2	Ac-Lys(Boc)-OMe (**11**)[10]	quant
Troc-Lys(Boc)-Val-OMe (**7**)	2 5	Ac-Lys(Boc)-Val-OMe (**12**)	96 87
	3		81
	2		76

In summary, *N*-Troc groups have been selectively converted into *N*-acetyl groups in the presence of *N*-Boc groups in a one-pot reaction, using a very simple ultrasound treatment with Zn in an Ac_2O/Et_3N mixture. This procedure renders the Troc group a versatile temporary protecting group particularly in peptide and glycopeptide synthesis.

The solvents were purified according to the standard procedures. Petroleum ether used had a bp range 35–80 °C. TLC was performed on plastic plates coated with silica gel 60 F_{254}. Detection was achieved by treatment with a solution of ammonium molybdate (20 g) and cerium(IV) sulfate (0.4 g) in 10 or 15% H_2SO_4 (400 mL), and heating at 150 °C. Flash chromatography was carried out on silica gel (Baker 30–60 mm) at a pressure of 0.3–0.4 bar. Optical rotations were determined at 21 °C with a Perkin-Elmer 241/MC polarimeter (1 dm cell). NMR spectra were recorded with Bruker AC 250 (250 MHz) instrument by using tetramethylsilane as internal standard. MS spectra were recorded with a MALDI-compact (Kratos) instrument in the positive mode using 2,5-dihydroxybenzoic acid in dioxane as matrix. Elemental analyses were performed in the Microanalysis unit at the Fachbereich Chemie, Universität Konstanz.

N-*tert*-Butoxycarbonyl-*S*-[3,4,6-tri-*O*-acetyl-2-deoxy-2-(2,2,2-trichloroethoxycarbonylamino)- β-D-glucopyranosyl]-L-homocysteinyl-l-alanine Benzyl Ester (1); Typical Procedure

To a solution of Boc-Hcy-Ala-OBn (440 mg, 1.1 mmol) in 10% aq Na_2CO_3 (15 mL) was added a solution of 3,4,6-tri-*O*-acetyl-2-deoxy-2-(2,2,2-trichloroethoxycarbonylamino)-α-bromo-D-glucopyranose (1.1 g, 2.1 mmol) in EtOAc (15 mL). After the addition of Bu_4NHSO_4 (1.5 g, 4.4 mmol), the mixture was vigorously stirred at r.t. for 8 h. The mixture was diluted with EtOAc, washed successively with sat. aq $NaHCO_3$ and brine, dried ($MgSO_4$) and concentrated to give a crude product which was purified by flash column chromatography (petroleum ether–EtOAc, 2:1→1:1). Compound **1** was obtained as a white solid (850 mg, 90%); $[\alpha]_D$ –20.9 (*c* = 1.0 $CHCl_3$).

^{1}H NMR ($CDCl_3$, 250 MHz): δ = 7.40 (m, 5 H), 6.80 (d, *J* = 7.0 Hz, 1 H), 5.96 (d, *J* = 10.0 Hz, 1 H), 5.29 (t, *J* = 9.9 Hz, 1 H), 5.23 (s, 2 H), 5.14 (d, *J* = 10.0 Hz, 1 H), 5.09 (t, *J* = 9.5 Hz, 1 H), 4.90 (d, *J* = 12.0 Hz, 1 H), 4.68 (m, 3 H), 4.40 (m, 1 H), 4.25 (dd, *J* = 12.2, 4.6 Hz, 1 H), 4.11 (dd-like, *J* = 12.4, 2.1 Hz, 1 H), 3.79 (m, 1 H), 3.64 (m, 1 H), 2.90 (m, 1 H), 2.72 (m, 1 H), 2.09, 2.04, 2.02 (3 s, 9 H), 1.90 (m, 1 H), 1.75 (m, 1 H), 1.45 (d, *J* = 7.8 Hz, 3 H), 1.43 (s, 9 H).

^{13}C NMR ($CDCl_3$, 62.8 MHz): δ = 172.7, 171.3, 170.6, 170.3, 169.2, 155.4, 154.1, 135.1, 128.4, 128.2, 127.9, 95.4, 84.5, 79.9, 75.6, 74.2, 73.2, 68.5, 67.1, 62.0, 54.9, 52.5, 48.0, 32.5, 28.1, 26.7, 20.5, 20.4, 17.5.

MALDI-MS: *m*/*z* = 897.5 [MK^+].

Preparation of 5, 6 and 7; General Procedure

To a stirred solution of the appropriate free amine (1.0 mmol) in anhyd CH_2Cl_2 (15 mL) was added TrocCl (0.2 mL) followed by *N*,*N*-diisopropylethylamine (0.35 mL). The mixture was stirred for 2 h at r.t., and then the solvent was evaporated. The residue was purified by flash column chromatography (petroleum ether–EtOAc) to give the corresponding *N*-Troc protected compound.

N-(*tert*-Butoxycarbonyl)-*N*′-(2,2,2-trichloroethoxycarbonyl)hexane-1,6-diamine (5)

^{1}H NMR ($CDCl_3$, 250 MHz): δ = 5.15 (br s, 1 H), 4.73 (s, 2 H), 4.57 (br s, 1 H), 3.23 (q, *J* = 6.6 Hz, 2 H), 3.10 (m, 2 H), 1.60–1.33 (m, 8 H), 1.44 (s, 9 H).

^{13}C NMR ($CDCl_3$, 62.8 MHz): δ = 156.0, 154.6, 95.7, 79.1, 74.4, 41.0, 40.2, 30.0, 29.6, 28.4, 26.14, 26.10.

MALDI-MS: *m*/*z* = 413.5 [MNa^+], 429.6 [MK^+].

Anal. Calcd for $C_{14}H_{25}Cl_3N_2O_4$ (391.7): C, 42.93; H, 6.43; N, 7.24. Found: C, 42.91; H, 6.35; N, 7.24.

Troc-Lys(Boc)-OMe (6)

$[\alpha]_D$ +3.0 (*c* = 1.0 $CHCl_3$).

^{1}H NMR ($CDCl_3$, 250 MHz): δ = 5.70 (d, *J* = 7.7 Hz, 1 H), 4.74 (AB peak, *J* = 12.0 Hz, 2 H), 4.58 (br s, 1 H), 4.38 (m, 1 H), 3.77 (s, 3 H), 3.12 (m, 2 H), 1.92–1.69 (m, 2 H), 1.45 (m, 4 H), 1.44 (s, 9 H).

^{13}C NMR ($CDCl_3$, 62.8 MHz): δ = 172.3, 156.0, 154.2, 95.2, 78.9, 74.3, 53.8, 52.2, 39.7, 31.5, 29.3, 28.2, 22.1.

MALDI-MS: *m*/*z* = 472.4 [MK^+].

Troc-Lys(Boc)-Val-OMe (7)

$[\alpha]_D$ –5.0 (*c* = 1.0 $CHCl_3$).

^{1}H NMR ($CDCl_3$, 250 MHz): δ = 6.66 (d, *J* = 8.5 Hz, 1 H), 5.95 (d, *J* = 7.7 Hz, 1 H), 4.72 (m, 3 H), 4.50 (dd, *J* = 8.8, 4.9 Hz, 1 H), 4.22 (m, 1 H), 3.71 (s, 3 H), 3.09 (m, 2 H), 2.15 (m, 1 H), 1.91–1.62 (m, 2 H), 1.42 (m, 4 H), 1.40 (s, 9 H), 0.88 (t, *J* = 7.3 Hz, 6 H).

^{13}C NMR ($CDCl_3$, 62.8 MHz): δ = 172.1, 171.5, 156.0, 154.4, 95.3, 78.9, 74.4, 57.1, 54.8, 52.0, 39.6, 32.0, 30.8, 29.3, 28.3, 22.2, 18.8, 17.6.

MALDI-MS: *m*/*z* = 557.0 [MNa^+], 572.9 [MK^+].

N^{α}-{*N*-*tert*-Butoxycarbonyl-*S*-[3,4,6-tri-*O*-acetyl-2-deoxy-2-(2,2,2-trichloroethoxycarbonylamino)-β-D-glucopyranosyl]-l-cysteinyl}-N^{ε}-*tert*-butoxycarbonyl-L-lysine Methyl Ester (8)

This compound was prepared following the typical procedure given for compound **1** in 92% yield; $[\alpha]_D$ –14.1 (*c* = 1.0 $CHCl_3$).

^{1}H NMR ($CDCl_3$, 250 MHz): δ = 7.05 (d, *J* = 6.7 Hz, 1 H), 5.96 (d, *J* = 6.1 Hz, 1 H), 5.69 (d, *J* = 7.0 Hz, 1 H), 5.25 (t, *J* = 9.9 Hz, 1 H), 5.09 (t, *J* = 9.8 Hz, 1 H), 4.75 (m, 4 H), 4.52 (m, 1 H), 4.41 (m, 1 H), 4.23 (m, 2 H), 3.80 (m, 2 H), 3.78 (s, 3 H), 3.06 (m, 4 H), 2.10, 2.04, 2.02 (3 s, 9 H), 1.80 (m, 2 H), 1.46, 1.44 (2 s, 18 H), 1.42 (m, 4 H).

^{13}C NMR ($CDCl_3$, 62.8 MHz): δ = 172.3, 170.6, 170.4, 170.3, 169.3, 156.0, 155.2, 154.3, 95.4, 84.8, 80.3, 79.1, 76.0, 74.4, 73.2, 68.5, 62.3, 54.8, 54.3, 52.5, 52.2, 40.1, 32.5, 31.6, 29.3, 28.4, 28.2, 20.6, 20.5.

MALDI-MS: *m*/*z* = 947.9 [MNa^+].

Anal. Calcd for $C_{35}H_{55}Cl_3N_4O_{16}S$ (926.2): C, 45.39; H, 5.98; N, 6.05. Found: C, 45.58; H, 5.99; N, 5.99.

Phenyl 4,6-*O*-Benzylidene-3-*O*-(*N*-*tert*-butoxycarbonyl-*O*-*tert*-butyl-L-threonyl)-2-deoxy-2-(2,2,2-trichloroethoxycarbonylamino)-1-thio-β-D-glucopyranoside (9)

Prepared by coupling Boc-Thr(*t*-Bu)-OH with the corresponding sugar under the known DCC/HOBt condition in 71% yield; $[\alpha]_D$ –31.1 (*c* = 1.0 $CHCl_3$).

^{1}H NMR ($CDCl_3$, 250 MHz): δ = 7.53–7.30 (m, 10 H), 6.10 (d, *J* = 6.8 Hz, 1 H), 5.72 (t, *J* = 9.3 Hz, 1 H), 5.65 (d, *J* = 10.4 Hz, 1 H), 5.50 (s, 1 H), 5.29 (d, *J* = 8.3 Hz, 1 H), 4.83, 4.65 (AB peak, *J* = 12.0 Hz, 2 H), 4.38 (m, 1 H), 4.10 (m, 2 H), 3.81 (t, *J* = 9.7 Hz, 1 H), 3.70 (m, 2 H), 3.11 (m, 1 H), 1.44 (d, *J* = 4.7 Hz, 9 H), 1.16 (d, *J* = 6.3 Hz, 3 H), 0.87 (s, 9 H).

MALDI-MS: *m*/*z* = 813.6 [MNa^+], 829.6 [MK^+].

Anal. Calcd for $C_{35}H_{45}Cl_3N_2O_{10}S$ (792.2): C, 53.07; H, 5.73; N, 3.54. Found: C, 53.24; H, 6.07; N, 3.86.

_N_-Acetyl-_S_-(3,4,6-tri-_O_-acetyl-2-acetamido-2-deoxy-β-D-glucopyranosyl)-L-homocysteinyl-L-alanine Benzyl Ester (3)

Glycoside **1** (1.2 g, 1.4 mmol) was dissolved in Ac_2O (17 mL), freshly activated Zinc dust (0.4 g) was added, and the suspension was stirred for 8 h. The mixture was filtered through Celite and the filtrate was concentrated under vacuo to give the crude product. Purification by flash column chromatography (EtOAc–MeOH, 15:1) afforded **3** (793 mg, 85%) as a white amorphous solid; $[\alpha]_D$ –39.5 (*c* = 1.0 $CHCl_3$–MeOH, 1:1).

^{1}H NMR ($CDCl_3$/CD_3OD, 250 MHz): δ = 8.10 (d, *J* = 6.8 Hz, 1 H), 7.76 (d, *J* = 8.9 Hz, 1 H), 7.61 (d, *J* = 8.0 Hz, 1 H), 7.35 (m, 5 H), 5.25 (t, *J* = 9.7 Hz, 1 H), 5.19 (m, 2 H), 5.08 (t, *J* = 9.6 Hz, 1 H), 4.82 (d, *J* = 10.5 Hz, 1 H), 4.53 (m, 2 H), 4.25 (dd, *J* = 12.4, 4.4 Hz, 1 H), 4.13 (m, 1 H), 3.93 (t, *J* = 10.3 Hz, 1 H), 3.77 (m, 1 H), 2.72 (m, 2 H), 2.08, 2.04, 2.01, 1.95 (4 s, 15 H), 1.95 (m, 2 H), 1.46 (d, *J* = 7.3 Hz, 3 H).

^{13}C NMR ($CDCl_3$, 62.8 MHz): δ = 172.4, 171.6, 171.5, 171.3, 171.0, 170.7, 169.6, 135.1, 128.3, 128.1, 127.8, 83.6, 75.3, 73.6, 68.4, 66.9, 62.0, 53.0, 51.3, 48.0, 31.9, 26.0, 22.3, 22.2, 20.3, 20.2, 16.7.

MALDI-MS: *m*/*z* = 689.8 [MNa^+], 705.9 [MK^+].

Anal. Calcd for $C_{30}H_{41}N_3O_{12}S\cdot 3H_2O$ (721.8): C, 49.92; H, 5.73; N, 5.82. Found: C, 49.77; H, 5.86; N, 6.05.

Selective Conversion of _N_-Troc Groups into _N_-Ac Groups; General Procedure

Freshly activated Zn dust (0.65 g) was added to a solution of the appropriate *N*-Troc derivative (0.5 mmol) in Ac_2O (6 mL) containing Et_3N (0.14 mL). The reaction vessel was then sonicated in a classic ultrasonic cleaning bath below r.t. until the disappearance of starting material, as determined by TLC (typically 2–3 h). At this time the mixture was filtered through Celite, the filtrate was evaporated and the residue was chromatographed (petroleum ether–EtOAc) to give the corresponding *N*-Ac compound.

_N_-_tert_-Butoxycarbonyl-_S_-(3,4,6-tri-_O_-acetyl-2-acetamido-2-deoxy-β-D-glucopyranosyl)-L-homocysteinyl-L-alanine Benzyl Ester (2)

$[\alpha]_D$ –26.5 (*c* = 1.0 $CHCl_3$).

^{1}H NMR ($CDCl_3$, 250 MHz): δ = 7.37 (m, 5 H), 7.23 (d, *J* = 7.2 Hz, 1 H), 6.24 (d, *J* = 8.5 Hz, 1 H), 5.34 (t, *J* = 9.7 Hz, 1 H), 5.29 (d, *J* = 8.1 Hz, 1 H), 5.20 (AB peak, *J* = 12.3 Hz, 2 H), 5.08 (t, *J* = 9.6 Hz, 1 H), 4.92 (d, *J* = 10.3 Hz, 1 H), 4.61 (m, 1 H), 4.39 (m, 1 H), 4.25 (dd, *J* = 12.3, 4.7 Hz, 1 H), 4.12 (dd, *J* = 12.3, 2.1 Hz, 1 H), 3.82 (m, 1 H), 3.70 (m, 1 H), 2.79 (m, 2 H), 2.08, 2.04, 2.03, 1.96 (4 s, 12 H), 1.95 (m, 2 H), 1.45 (d, *J* = 7.4 Hz, 3 H), 1.43 (s, 9 H).

^{13}C NMR ($CDCl_3$, 62.8 MHz): δ = 172.6, 171.7, 170.8, 170.63, 170.56, 169.3, 155.6, 135.3, 128.5, 128.3, 127.9, 83.4, 79.8, 75.7, 73.4, 68.6, 67.0, 62.1, 53.8, 52.4, 48.1, 32.5, 28.2, 26.2, 23.1, 20.61, 20.56, 20.5, 17.5.

MALDI-MS: *m*/*z* = 764.8 [MK^+].

_N_-Acetyl-_N′_-(_tert_-butoxycarbonyl)hexane-1,6-diamine (10)[9]

^{1}H NMR ($CDCl_3$, 250 MHz): δ = 5.90 (br s, 1 H), 4.62 (br s, 1 H), 3.23 (q, *J* = 6.6 Hz, 2 H), 3.11 (m, 2 H), 1.99 (s, 3 H), 1.44 (s, 9 H), 1.42 (m, 8 H).

^{13}C NMR ($CDCl_3$, 62.8 MHz): δ = 170.1, 156.1, 78.8, 40.1, 39.2, 29.9, 29.4, 28.4, 26.1, 26.0, 23.3.

MALDI-MS: *m*/*z* = 296.9 [MK^+].

Ac-Lys(Boc)-OMe (11)[10]

$[\alpha]_D$ +12.0 (*c* = 1.0 $CHCl_3$).

^{1}H NMR ($CDCl_3$, 250 MHz): δ = 6.28 (d, *J* = 7.2 Hz, 1 H), 4.60 (m, 2 H), 3.75 (s, 3 H), 3.10 (q like, 2 H), 2.04 (s, 3 H), 1.91–1.65 (m, 2 H), 1.44 (s, 9 H), 1.40 (m, 4 H).

^{13}C NMR ($CDCl_3$, 62.8 MHz): δ = 172.9, 170.2, 156.0, 78.7, 52.0, 51.8, 39.7, 31.4, 29.3, 28.1, 22.6, 22.2.

MALDI-MS: *m*/*z* = 324.8 [MNa^+], 340.8 [MK^+].

Ac-Lys(Boc)-Val-OMe (12)

$[\alpha]_D$ –22.1 (*c* = 1.0 $CHCl_3$).

^{1}H NMR ($CDCl_3$, 250 MHz): δ = 6.66 (d, *J* = 8.3 Hz, 1 H), 6.35 (d, *J* = 7.5 Hz, 1 H), 4.74 (br s, 1 H), 4.49 (m, 2 H), 3.75 (s, 3 H), 3.12 (m, 2 H), 2.20 (m, 1 H), 2.03 (s, 3 H), 1.80 (m, 2 H), 1.45 (m, 4 H), 1.44 (s, 9 H), 0.92 (t, *J* = 6.8 Hz, 6 H).

^{13}C NMR ($CDCl_3$, 62.8 MHz): δ = 172.4, 171.9, 170.3, 156.0, 78.7, 57.4, 52.7, 51.9, 39.8, 31.9, 30.4, 29.3, 28.2, 22.7, 22.2, 18.8, 17.6.

MALDI-MS: *m*/*z* = 424.0 [MNa^+], 440.1 [MK^+].

Anal. Calcd for $C_{19}H_{35}N_3O_6$ (401.5): C, 56.84; H, 8.79; N, 10.47. Found: C, 56.61; H, 8.79; N, 10.41.

N^{α}-[_N_-_tert_-Butoxycarbonyl-_S_-(3,4,6-tri-_O_-acetyl-2-acetamido-2-deoxy-β-D-glucopyranosyl)-L-cysteinyl]-N^{ε}-_tert_-butoxycarbonyl-L-lysine Methyl Ester (13)

$[\alpha]_D$ –31.1 (*c* = 1.0 $CHCl_3$).

^{1}H NMR ($CDCl_3$, 250 MHz): δ = 7.11 (d, *J* = 7.2 Hz, 1 H), 6.12 (d, *J* = 8.3 Hz, 1 H), 5.69 (d, *J* = 7.3 Hz, 1 H), 5.13 (m, 2 H), 4.74 (m, 1 H), 4.70 (d, *J* = 10.5 Hz, 1 H), 4.53 (m, 1 H), 4.42 (m, 1 H), 4.23–4.12 (m, 3 H), 3.78 (s, 3 H), 3.77 (m, 1 H), 3.05 (m, 4 H), 2.09, 2.04, 2.03, 1.96 (4 s, 12 H), 1.80 (m, 2 H), 1.46, 1.44 (2 s, 18 H), 1.42 (m, 4 H).

^{13}C NMR ($CDCl_3$, 62.8 MHz): δ = 172.4, 170.9, 170.7, 170.5, 170.3, 169.3, 156.1, 155.2, 85.0, 80.4, 79.2, 76.2, 73.7, 68.3, 62.3, 54.4, 52.9, 52.5, 52.3, 42.8, 40.2, 32.4, 31.7, 29.4, 28.4, 28.3, 23.2, 22.4, 20.6.

MALDI-MS: *m*/*z* = 814.8 [MNa^+], 830.7 [MK^+].

Anal. Calcd for $C_{34}H_{56}N_4O_{15}S$ (792.9): C, 51.50; H, 7.12; N, 7.07. Found: C, 51.97; H, 7.19; N, 6.78.

Phenyl 2-Acetamido-4,6-_O_-benzylidene-3-_O_-(_N_-_tert_-butoxycarbonyl-_O_-_tert_-butyl-L-threonyl)-2-deoxy-1-thio-β-D-glucopyranoside (14)

$[\alpha]_D$ –47.2 (*c* = 1.0 $CHCl_3$).

^{1}H NMR ($CDCl_3$, 250 MHz): δ = 7.50 (m, 2 H), 7.38 (m, 2 H), 7.29 (m, 6 H), 6.55 (d, *J* = 6.5 Hz, 1 H), 6.00 (d, *J* = 10.3 Hz, 1 H), 5.86 (t like, *J* = 9.2 Hz, 1 H), 5.48 (s, 1 H), 5.36 (d, *J* = 8.4 Hz, 1 H), 4.36 (d like, *J* = 8.6 Hz, 1 H), 4.15 (m, 1 H), 4.00 (dd, *J* = 8.3, 1.9 Hz, 1 H), 3.82–3.68 (m, 3 H), 2.97 (m, 1 H), 1.96 (s, 3 H), 1.46 (s, 9 H), 1.18 (d, *J* = 6.2 Hz, 3 H), 0.81 (s, 9 H).

^{13}C NMR ($CDCl_3$, 62.8 MHz): δ = 171.4, 171.3, 157.1, 136.9, 132.6, 132.5, 129.2, 129.0, 128.0, 127.8, 126.7, 102.2, 85.4, 80.2, 78.9, 74.2, 72.2, 70.4, 68.7, 66.5, 60.5, 57.6, 28.4, 28.0, 23.4, 21.0.

MALDI-MS: *m*/*z* = 680.0 [MNa^+], 695.9 [MK^+].

Anal. Calcd for $C_{34}H_{46}N_2O_9S$ (658.8): C, 61.99; H, 7.04; N, 4.25. Found: C, 62.16; H, 7.33; N, 4.05.

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