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REACTIONS OF GLYCOSAN-ANNELATED OXOLACTAMS

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Dedicated with highest esteem to Prof. Dr. Ekkehard Winterfeldt on the occasion of his 75th anniversary.

Abstract - Starting with 4-imido-mannosan and 2-imido-galactosan derivatives Norrish-Yang cyclization led to saccharide-annelated azepanediones and azocanediones. Following *N*-protection these lactams could be opened to give higher branched-chain carbohydrate components of the 4-amino-3-dehydro type. In some cases concomitant rearrangement reactions were observed to give α,β-unsaturated hydroxy lactams as well as saccharides linked to substituted furans.

INTRODUCTION

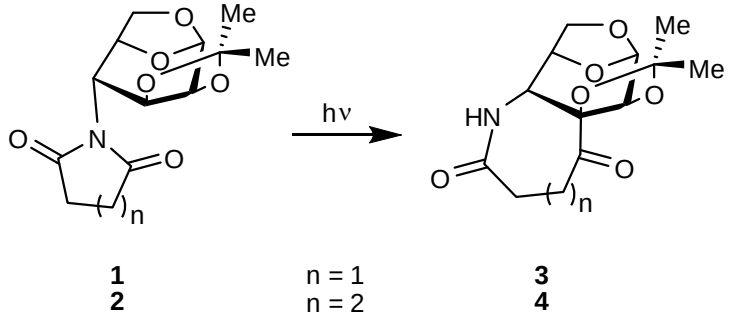
Previously we reported on photochemical methods to functionalize imido-substituted saccharide derivatives employing the Norrish-Yang cyclization[1] as predominantly elaborated by Kanaoka et al.[2-5] Studies on photoreactions of *N*-glycopyranosyl-succinimides[6] and their 2-deoxy analogues[7,8] revealed that the regiochemistry of the hydrogen abstraction and thus the cyclization was essentially controlled both by stereoelectronic as well as conformational factors. These in turn reflected the influence of the nature of the monosaccharide configuration and protecting groups.

Recently we could employ various imides of more rigid saccharide derivatives such as in 1,6-anhydro-β-D-hexopyranoses with completely fixed conformations. Thus cyclization studies with the 2-imido-galactosans and 4-imido-mannosans[9] as well as with 3-imido-glucosans[10] could be performed. These proved the preparative versatility of this approach to obtain the desired saccharide-annelated azepane or azocane derivatives with high regio- and stereoselectivity. We anticipated that such structures could be of particular interest as precursors to complex branched-chain sugars.[11] *N*-Protection, lactam opening and cleavage of the 1,6-anhydro-bridge should open a straightforward access to novel higher branched-chain

saccharides of the 3-dehydro type which could be incorporated into oligosaccharides or glycopeptides and mimic natural functionalities.

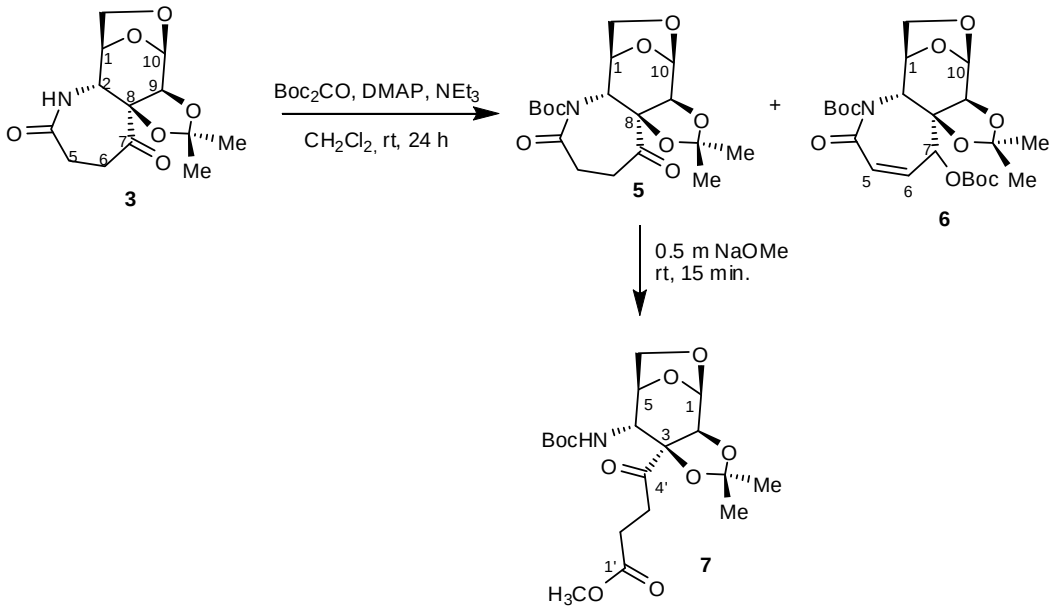
RESULTS AND DISCUSSION

As recently described the 4-azido mannosan could be prepared[12] and after reduction transformed into the 4-succinimide **1** or the 4-glutarimide **2**. Irradiation of compound **1** led in high yields to the corresponding component **3** with a mannosan-annelated azepanedione seven-membered ring. Accordingly the glutarimide **2** gave the derivative **4** which shows the mannosan annelated to the eight-membered azocanedione ring system (Scheme 1).[9]



Scheme 1. Norrish-Yang cyclization of 4-succinimido (**1**) or 4-glutarimido mannosan (**2**) to azepanedione **3** and azocanedione **4**.[9]

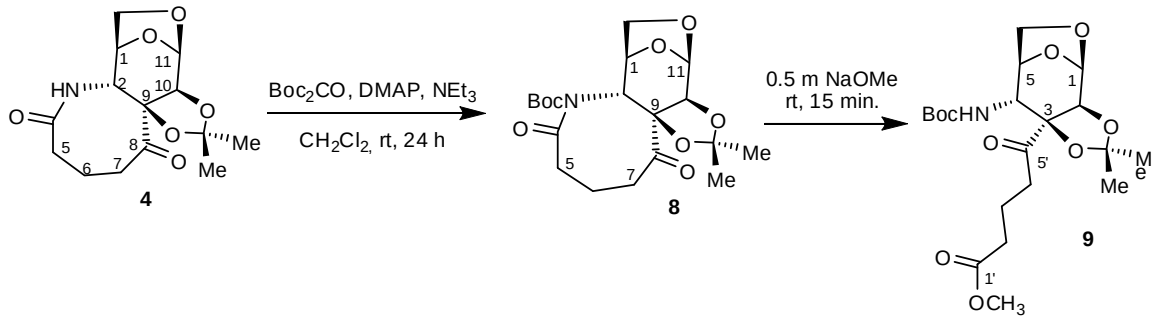
In previous experiments we observed that prior to nucleophilic lactam cleavage protection of the NH-function would be required. Particularly suited was the *tert*-butoxycarbonyl (Boc) group and thus introduced employing Boc-anhydride with 4,4-dimethylamino pyridine (DMAP) and triethylamine at room temperature.[13] In contrast to the expectation reaction of azepandione **3** under these conditions, workup and separation revealed the formation of the normal *N-tert*-butyloxycarbonylated material **5** in only 39 % yield accompanied by another component in 56 % yield. This proved to be a bis-Boc-protected α,ß-unsaturated hydroxy lactam **6** (Scheme 2). Evidence was provided by ^{13}C-NMR spectra showing a new C-7 signal δ 76.26 ppm of a tertiary alcohol as well as two olefin carbons (C-5, C-6) at δ 143.93 and 126.51 ppm. The original saturated C-5 and C-6 methylene and the C-7 ketogroup signals in **3** were missing. Support of these assignments were by ^{1}H-NMR showing olefin protons H-5 and H-6 at δ 6.30 and 6.04 ppm and correlation of ^{13}C- and ^{1}H-NMR by HMBC experiments. NMR could not provide information concerning the configuration at the new stereogenic center at C-7, and since compound **6** could be only obtained as amorphous material an X-ray structure could not be provided. Due to expected minimum interactions of the OBoc-group and the 8,9-O-isopropylidene group the (7R)-configuration should be most likely. This is also in keeping with the anticipated mechanism which will be outlined for formation of the corresponding compound **14** in the galactosan series (see below and Scheme 5).



Scheme 2. *N*-Acylation of azepanedione **3** to give **5** and rearrangement product **6** as well as alkaline cleavage of **5** to branched-chain component **7**.

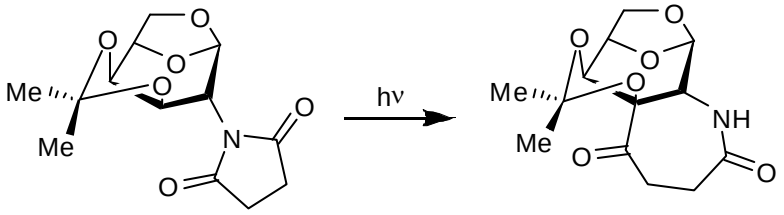
Repeated experiments proved it feasible to enhance the yield of the *N*-protected compound **5** to 77 % under similar conditions using particularly purified and dried solvents. In this case the formation of **6** was negligible. On the other hand, a selective formation of the unsaturated rearrangement product **6** could not be realized. Alkaline ring opening of the lactam function[14] of compound **5** was facile and fast employing 0.5 M sodium methoxide solution in methanol to give the 3-dehydro branched-chain decose derivative **7** almost quantitatively.

The azocanedione **4** was treated with Boc-anhydride under corresponding conditions to give the *N*-protected ketolactam **8** in moderate 46 % yield. By tlc the formation of another product was observed, however, during column chronotographic purification this proved to be labile and could not be isolated. Alkaline cleavage of the eight-membered ketolactam ring of **8** with 0.5 M NaOMe required longer reaction times which also increased degradation. A compromise of 90 min gave the 3-dehydro branched-chain undecose derivative **9** in 74 % yield (Scheme 3).



Scheme 3. *N*-Acylation of azocanedione **4** and cleavage to **9**.

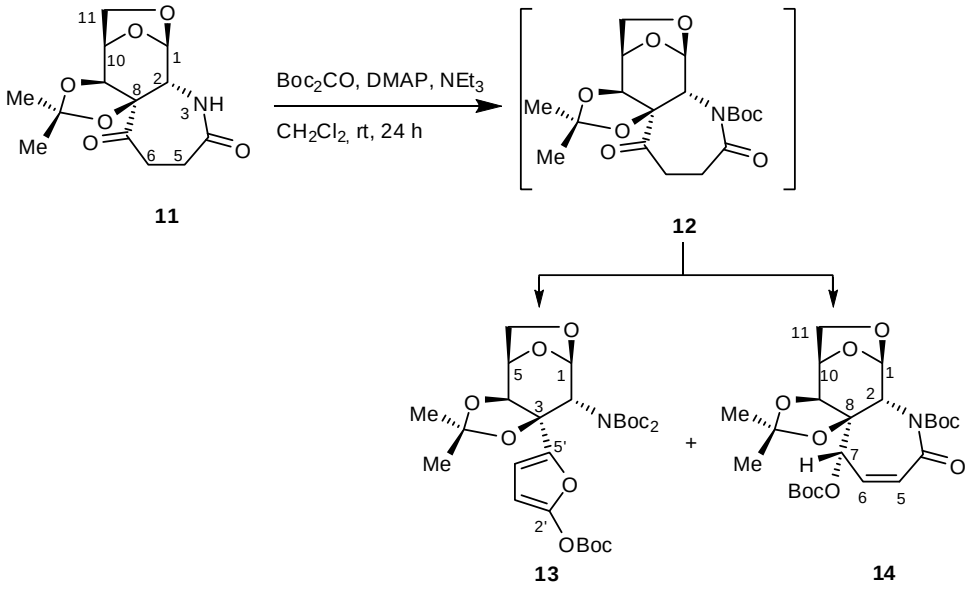
Starting with 2-azido galactosan[12] the 2-succinimido derivative **10** could be obtained and by Norrish-Yang cyclization transformed into the azepandione **11** (Scheme 4).[9]



10 **11**

Scheme 4. Norrish-Yang cyclization of 2-succinimido galactosan (**10**) to azepanedione **11**.[9]

As above it was of interest to open the ketolactam ring system *en route* to branched-chain galactose-derived higher dehydro saccharide components. Thus, treatment of **11** under mild conditions with Boc-anhydride and bases at room temperature surprisingly did not give the anticipated *N*-protected compound **12**, but rather two components, **13** (42 %) and **14** (45 %). Whereas **12** could never be isolated optimization studies revealed that the unsaturated lactam **14** could be obtained in 69 % yield. The assignment of its structure by ^{13}C- and ^{1}H-NMR spectra was as for compound **6**.



11 **13** **14**

Scheme 5. *N*-Acylation of galactosan-derived azepanedione **11** and subsequent rearrangement reactions to furan structure **13** and α,β-unsaturated lactam **14**.

In addition to the NMR the material could be crystallized and structurally elucidated. The tetracyclic system comprised of the 1,6-anhydro-ß-D-galactose (numbering in **14**: 1,11-anhydro-galactose substructure) shows an *endo*-bound unsaturated seven-membered azepenonol system in boat conformation (Figure 1). Evidence for the configuration of the newly-formed stereogenic center is (7S).

This result also sheds light on the likely assignment given for the non-crystalline sister compound in the mannosan series **6** (see above).

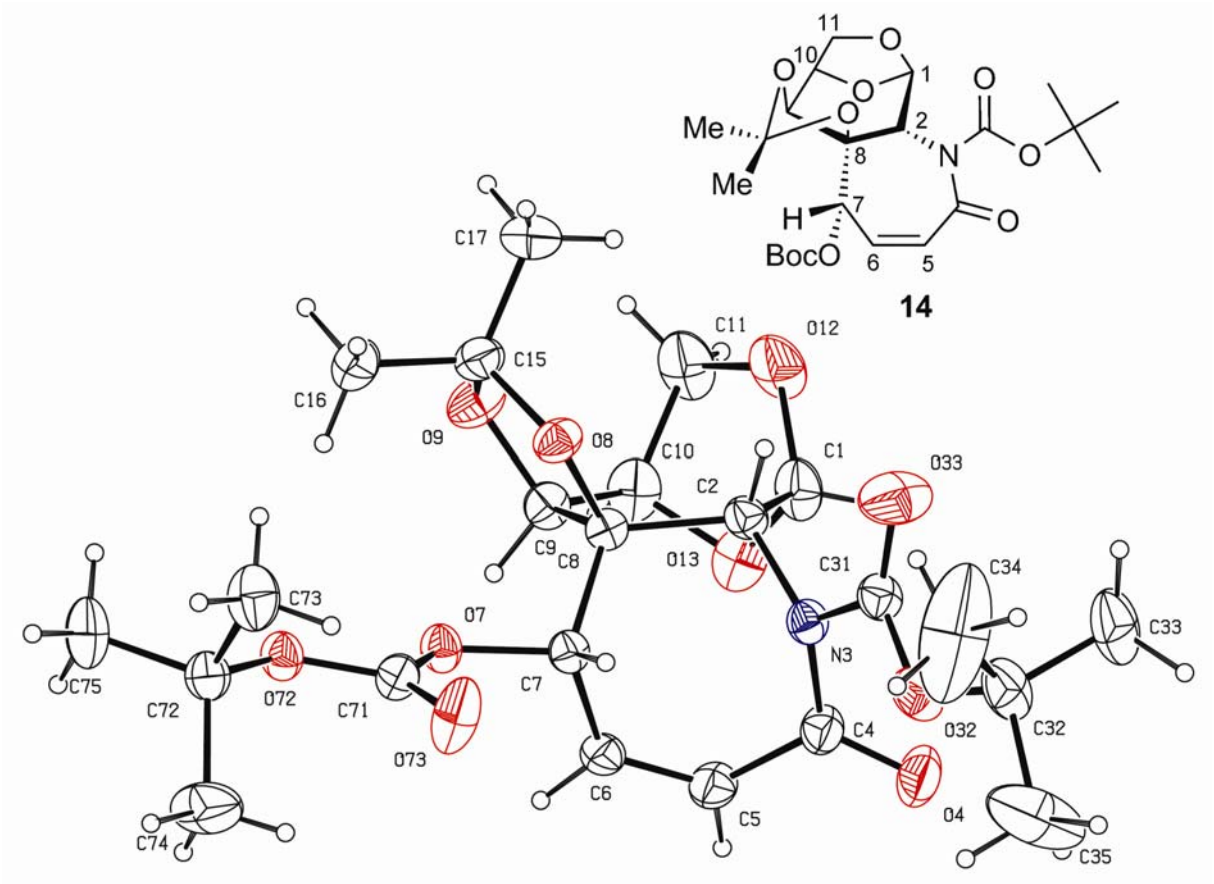
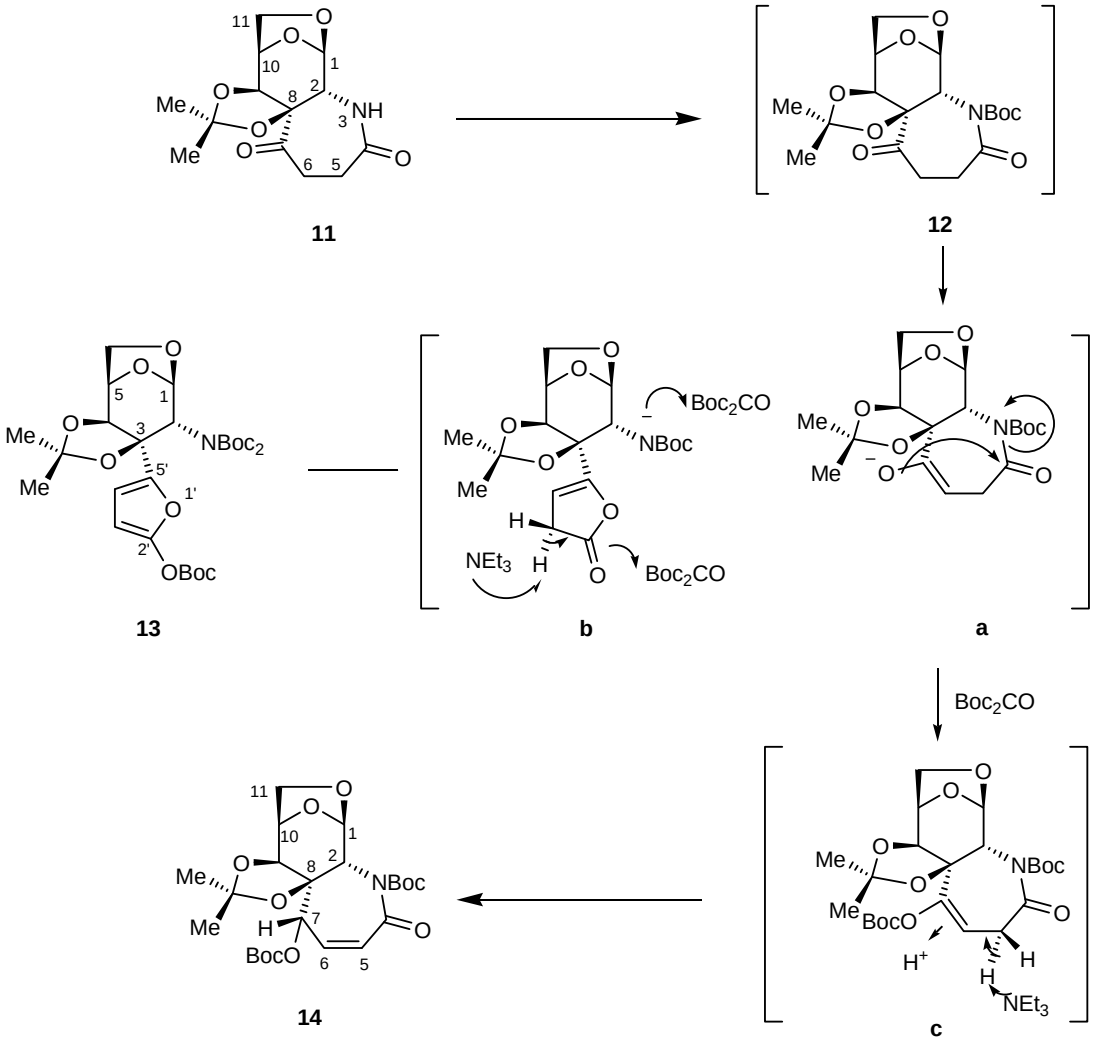


Figure 1. X-Ray structure of α,β-unsaturated lactam **14**.

The other component **13** showed a remarkable UV-activity indicating to contain a conjugated or aromatic system. By ^{13}C-NMR spectra two quaternary signals for C-2' (δ 152.08 ppm) and C-5' (δ 142.60 ppm) together with two tertiary signals for C-3' (δ 116.37 ppm) and C-4' (δ 101.69 ppm) clearly refer to the 2,5-disubstituted furan moiety. The ^{13}C- and ^{1}H-NMR data could be correlated by HMBC spectra, and are well in accord with literature data of 2,5-disubstitued furan derivatives.[15,16]

Attempts to understand a mechanism behind these unusual transformations are of interest. Starting with deprotonation of the intermediate *N*-protected compound **12** at C-6 leads to the enolate **a**. Its intramolecular nucleophilic attack at the amide function results in formation of the five-membered ring structure **b**. Further deprotonation facily will form the furan system which is stabilized by reaction with Boc-anhydride to give the furan-linked compound **13**.



Scheme 6. Anticipated mechanism for formation of rearrangement products **13** and **14**.

Alternatively, the enolate **a** will react with Boc-anhydride to give **c**, which in turn will isomerize to the thermodynamically more stabile conjugated component **14**. These considerations cannot account for the stereochemistry at C-7. Further, at this stage the dubious fact is under study, why the galactosan-based lactam **11** would yield the rearrangement products, whereas the isomeric mannosan-based compound **3** does not.

In summarising a number of glycosan-annelated and thus conformationally restricted azepanediones as well as azocanediones could be studied. In addition to normal protection and lactam ring opening reactions leading to larger dehydro-type branched-chain sugars several unusual rearrangements were observed. Assignments by NMR and X-ray spectroscopy revealed the structures, and suggestions for their formation could be proposed. Further work focused on synthetic and photochemical transformation in less rigid hexopyranose derivatives will be reported in due course.

EXPERIMENTAL

General Methods

Procedure A: Reaction with tert-butyloxycarbonyl (Boc) anhydride

The unprotected lactam (1.0 mmol) was dissolved in dry CH_2Cl_2 (50 mL) and treated with 4-dimethylaminopyridine (123.7 mg, 1.0 mmol), triehtylamine (0.14 mL, 1.0 mmol) and di-*tert*-butyl dicarbonate (877.2 mg, 4.0 mmol). The reaction mixture was stirred at rt until no further conversion could be detected by tlc. After removal of the solvent under reduced pressure, separation and purification of the product(s) was performed by column chromatography.

Procedure B: Lactam ring opening

The protected lactam (0.25 mmol) was stirred in a 0.5 M solution of sodium methanolate (5 mL) for the quoted time. Subsequent neutralisation by addition of Dowex 50Wx8 (H^+), filtration from the ion exchange resin and removal of the solvent under reduced pressure gave the crude product which was purified by column chromatography.

(1*R*,2*R*,8*S*,9*S*,10*R*)-*N*-*tert*-Butyloxycarbonyl-8,9-isopropylidenedioxy-11,13-dioxa-3-azatricyclo-[8.2.1.0^{2,8}]tridecan-4,7-dione (5) and (1*R*,2*R*,7*S* or *R*,8*R*,9*S*,10*R*)-*N*-*tert*-Butyloxycarbonyl-7-*tert*-butyloxycarbonyloxy-8,9-isopropylidenedioxy-11,13-dioxa-3-aza-tricyclo[8.2.1.0^{2,8}]tridec-5-en-4-one (6)

The oxolactam **3** (250.0 mg, 0.88 mmol) was reacted according to Procedure A, and the products were separated by column chromatography using petroleum ether/EtOAc (6:1).

Compound **5** (129.4 mg, 0.34 mmol, 39%) was obtained as a white solid: mp 148-150 °C, $[\alpha]^{20}_D$ -113.6 ° (*c* 1.0, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 500.13 MHz): δ 5.59 (d, 1H, $J_{9,10}$ 3.56 Hz, H-10), 4.82 (d, 1H, $J_{1,12b}$ 5.60 Hz, H-1), 4.63 (d, 1H, H-9), 4.44 (s, 1H, H-2), 4.03 (dd, 1H, $J_{12a,12b}$ 7.63 Hz, $J_{1,12a}$ 1.02 Hz, H-12a), 3.88 (dd, 1H, H-12b), 3.47 (m, 1H, H-5a), 2.96 (m, 1H, H-6a), 2.85-2.73 (m, 2H, H-5b, H-6b), 1.61 (s, 3 H, CH_3, isopropylidene), 1.46 (S, 9H, C(CH_3)$_3$, Boc) 1.29 ppm (s, 3H, CH_3, isopropylidene). ^{13}C-NMR ($CDCl_3$, 100.62 MHz): δ 204.53 (C=O), 173.79 (NH-C=O), 154.29 (C=O, Boc), 113.18 (isopropylidene), 98.98 (C-10), 85.88 (C-8), 84.94 (*C*(CH$_3$)$_3$, Boc), 75.70 (C-1), 73.82 (C-9), 67.63 (C-12), 62.04 (C-2), 36.73 (C-6), 31.65 (C-5), 28.55 (*C*H$_3$, isopropylidene), 28.04 (*C*(*C*H$_3$)$_3$, Boc), 27.30 ppm (*C*H$_3$, isopropylidene). Anal. Calcd for $C_{18}H_{25}NO_8$: C, 56.39; H, 6.57; N, 3.65. Found: C, 56.70; H, 6.74; N, 3.49.

Compound **6** (238.1 mg, 0.49 mmol, 56%) was obtained as white foam: $[\alpha]^{20}_D$ -115.7 ° (*c* 1.0, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 500.13 MHz): δ 6.30 (dd, 1H, $J_{5,6}$ 11.70 Hz, $J_{6,7}$ 4.07 Hz, H-6), 6.04 (dd, 1H, $J_{5,7}$ 2.54 Hz, H-5), 5.84 (dd, 1H, H-7), 5.50 (d, 1H, $J_{9,10}$ 4.57 Hz, H-10), 4.77 (d, 1H, $J_{1,2}$ 1.02 Hz, H-2) 4.38 (d, 1 H, H-9), 4.23 (dd. 1H, $J_{1,12b}$ 4.58 Hz, H-1) 3.91 (d, 1H, $J_{12a,\ 12b}$ 7.63 Hz, H-12a), 3.72 (dd, 1H, H-12b),

1.53 (s, 9H, C(C*H*$_3$)$_3$, Boc), 1.51 (s, 3H, C*H*$_3$ isopropylidene), 1.49 (s, 9H, C(C*H*$_3$)$_3$, Boc), 1.44 ppm (s, 3H, C*H*$_3$, isopropylidene). ^{13}C-NMR ($CDCl_3$ 100.62 MHz): δ 168.14 (N-C=O), 154.52, 153.00 (C=O, Boc), 143.93 (C-6), 126.51 (C-5), 113.51 (isopropylidene), 97.27 (C-10), 90.21 (C-8), 84.61, 83.80 (*C*(CH$_3$)$_3$, Boc), 77.00 (C-1), 76.33 76.26 (C-7, C-9), 70.93 (C-12), 65.11 (C-2), 28.51 (*C*H$_3$, isopropylidene), 28.32, 28.13 (C(*C*H$_3$)$_3$, Boc), 28.02 ppm (*C*H$_3$, isopropylidene). Anal. Calcd for $C_{23}H_{33}NO_{10}$: C, 57.13; H, 6.88; N, 2.90. Found: C, 56.58; H, 6.90; N, 2.82.

1,6-Anhydro-4-(*N*-*tert*-butyloxycarbonyl)amino-2,3-*O*-isopropylidene-3-*C*-(4'-oxo-methylbutanoat-4'-yl)-ß-D-mannopyranose (7)

The protected lactam **5** (90.0 mg, 0.23 mmol) was reacted according to Procedure B for 15 min. Column chromatography using petroleum ether/EtOAc (6:1) yielded **7** (92.4 mg, 0.22 mmol, 95%) as a white solid: mp 152-154 °C, $[\alpha]^{20}_D$ -49.9 ° (*c* 1.0, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 500.13 MHz): δ 5.43 (d, 1H, $J_{1',2'}$ 3.56 Hz, H-1'), 4.78 (d, 1H, $J_{4',NH}$ 11.19 Hz, NH), 4.68 (d, 1H, H-2'), 4.37 (m$_c$, 2H, H-4', H-5'), 4.12 (dd, 1H, $J_{5',6a'}$ 1.02 Hz, $J_{6a',6b'}$ 7.63 Hz, H-6a'), 3.75 (t, 1H, $J_{5',6b'}$ 7.12 Hz, H-6b'), 3.18 (m$_c$, 1H, H-3a), 2.87 (dt, 1H, *J* 6.10 Hz, *J* 12.20 Hz, H-3b), 2.53 (m$_c$, 1H, H-2a), 2.36 (dt, 1H, *J* 6.11 Hz, *J* 12.21 Hz, H-2b), 1.59 (s, 3H, C*H*$_3$, isopropylidene), 1.40 (s, 9H, C(C*H*$_3$)$_3$, Boc), 1.24 ppm (s, 3 H, C*H*$_3$, isopropylidene). ^{13}C-NMR ($CDCl_3$, 100.62 MHz): δ 208.28 (C=O), 173.26 (MeO-C=O), 155.22 (C=O, Boc), 112.92 (isopropylidene), 99.44 (C-1'), 86.90 (C-3'), 81.34 (*C*(CH$_3$)$_3$, Boc), 76.85 (C-5'), 72.05 (C-2'), 65.25 (C-6'), 52.63 (C-4'), 52.18 (O*C*H$_3$), 31.99 (C-3), 28.56 (C(*C*H$_3$)$_3$, Boc), 28.53 (*C*H$_3$, isopropylidene), 28.03 (C-2), 26.87 ppm (*C*H$_3$, isopropylidene). Anal. Calcd for $C_{19}H_{29}NO_9$: C, 54.93; H, 7.04; N, 3.37. Found: C, 54.53; H, 7.12; N, 3.22.

(1*R*,2*R*,9*S*,10*S*,11*R*)-*N*-*tert*-Butyloxycarbonyl-9,10-isopropylidenedioxy-12,14-dioxa-3-azatricyclo-[9.2.1.0^{2,9}]tetradecan-4,8-dione (8)

The oxolactam **4** (140 mg, 0.47 mmol) was protected according to Procedure A. Column chromatography using petroleum ether/EtOAc (8:1) as eluent afforded **8** (86.1 mg, 0.22 mmol, 46%) as a white solid: mp 161-164 °C, $[\alpha]^{20}_D$ -51.1 ° (*c* 0.5, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 500.13 MHz): δ 5.47 (d, 1H, $J_{10,11}$ 3.05 Hz, H-11), 4.92 (d, 1H, $J_{1,13b}$ 6.1 Hz, H-1), 4.81 (d, 1H, H-10), 4.50 (s, 1H, H-2), 4.12 (d, 1H, $J_{13a,13b}$ 7.63 Hz, H-13a), 3.83 (dd, 1H, H-13b), 3.19 (dt, 1H, *J* 2.03 Hz, *J* 13.73 Hz, H-7a), 3.27 (m, 1 H, H-5a), 2.56 (m, 1 H, H-5b), 2.20 (ddd, 1H, *J* 2.54 Hz, *J* 7.12 Hz, *J* 13.22 Hz, H-7b), 2.10 (m, 1H, H-6a), 2.02 (m, 1H, H-6b), 1.60 (s, 3H, C*H*$_3$, isopropylidene), 1.56 (s, 9H, C(C*H*$_3$)$_3$, Boc), 1.17 ppm (s, 3H, C*H*$_3$, isopropylidene). ^{13}C-NMR ($CDCl_3$, 100.62 MHz): δ 207.23 (C=O), 174.59 (NH-C=O), 152.92 (C=O, Boc), 112.14 (isopropylidene), 99.72 (C-11), 88.17 (C-9), 85.16 (*C*(CH$_3$)$_3$, Boc), 75.88 (C-1), 72.09 (C-10), 66.83 (C-13), 59.34 (C-2), 36.85 (C-7), 36.32 (C-5), 28.28 (-*C*H$_3$, isopropylidene), 27.85 (C(*C*H$_3$)$_3$,

Boc) 26.79 (*C*H_3, isopropylidene), 23.70 ppm (C-6). Anal. Calcd for $C_{19}H_{27}NO_8$: C, 57.42; H, 6.85; N, 3.52. Found: C, 57.45; H, 7.06; N, 3.35.

1,6-Anhydro-4-(*N*-*tert*-butyloxycarbonyl)amino-2,3-*O*-isopropylidene-3-*C*-(5'-oxomethylbutanoat-5'-yl)-ß-D-mannopyranose (9)

Reaction of protected lactam **8** (55 mg, 0.14 mmol) following Procedure B for 90 min. and column chromatography petroleum ether/EtOAc (6:1) as eluent gave **9** (44.6 mg, 0.10 mmol, 74%) as a white foam: $[\alpha]^{20}_D$ -27.9 ° (*c* 0.5, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 500.13 MHz): δ 5.43 (d, 1H, $J_{1',2'}$ 3.56 Hz, H-1'), 4.77 (d, 1H, $J_{4',NH}$ 11.19 Hz, NH), 4.70 (d, 1H, H-2'), 4.35 (m_c, 2H, H-4', H-5'), 4.11 (dd, 1H, $J_{5',6a'}$ 1.02 Hz, $J_{6a',6b'}$ 7.63 Hz, H-6a'), 3.74 (t, 1H, $J_{5',6b'}$ 7.12 Hz, H-6b'), 2.85 (ddd, 1H, *J* 6.11 Hz, *J* 8.65 Hz, *J* 19.33 Hz, H-4a), 2.58 (ddd, 1H, *J* 6.10 Hz, *J* 8.64 Hz, *J* 19.32 Hz, H-4b), 2.40-2.24 (m, 2H, H-2a, H-2b), 1.96-1.71 (m, 2H, H-3a, H-3b), 1.58 (s, 3H, C*H*$_3$, isopropylidene), 1.40 (s, 9H, C(C*H*$_3$)$_3$, Boc), 1.17 ppm (s, 3H, C*H*$_3$, isopropylidene). ^{13}C-NMR ($CDCl_3$, 100.62 MHz): δ 209.16 (C=O), 173.81 (MeO-C=O), 155.21 (C=O, Boc), 112.62 (isopropylidene), 99.47 (C-1'), 86.95 (C-3'), 81.29 (*C*(CH$_3$)$_3$, Boc), 76.86 (C-5'), 71.96 (C-2'), 65.22 (C-6'), 52.57 (C-4'), 51.92 (O*C*H$_3$), 35.55 (C-4), 33.54 (C-2), 28.55 (*C*H$_3$, isopropylidene, C(C*H*$_3$)$_3$, Boc), 26.83 (*C*H$_3$, isopropylidene), 18.77 ppm (C-3). Anal. Calcd for $C_{20}H_{31}NO_9$: C, 55.93; H, 7.28; N, 3.26. Found: C, 56.02; H, 7.39; N, 3.17.

1,6-Anhydro-3-*C*-(2'-*tert*-butyloxycarbonyloxyfuran-5'-yl)-2-*N*,*N*-bis(*tert*-butyloxycarbonyl)amino-2-deoxy-3,4-*O*-isopropylidene-ß-D-galactopyranose (13) and (1*R*,2*R*,7*S*,8*R*,9*S*,10*R*)-*N*-*tert*-Butyloxycarbonyl-7-butyloxycarbonyloxy-8,9-isopropylidenedioxy-12,13-dioxa-3-azatricyclo-[8.2.1.0^{2,8}]tridecan-4,7-dione (14)

The oxolactam **11** (270 mg, 0.95 mmol) was reacted following Procedure A. Separation and purification of the products was performed by column chromatography using petroleum ether/EtOAc (8:1) as eluent. Compound **13** (236.9 mg, 0.40 mmol, 42%) was obtained as a white foam: $[\alpha]^{20}_D$ -7.3 ° (*c* 1.0, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 500.13 MHz): δ 5.80 (d, 1H, $J_{3',4'}$ 8.19 Hz, H-3', furan), 5.68 (d, 1H, $J_{1,2}$ 1.00 Hz, H-1), 5.43 (d, 1H, H-4', furan), 4.85 (dt, 1H, $J_{4,5}$ 1.58 Hz, $J_{5,6a}$ 1.58 Hz, $J_{5,6b}$ 5.99 Hz, H-5), 4.79 (m_c, 2H, H-2, H-4), 4.31 (d, 1H, $J_{6a,6b}$ 7.56 Hz, H-6a), 3.64 (dd, 1H, H-6b), 1.55 (s, 3H, C*H*$_3$, isopropylidene), 1.52, 1.49, 1.47 (each s, each 9 H, C(C*H*$_3$)$_3$, Boc), 1.42 ppm (s, 3H, C*H*$_3$, isopropylidene). ^{13}C-NMR ($CDCl_3$, 100.62 MHz): δ 152.08 (C-2', furan), 151.82, 150,30, 148.12 (C=O, Boc), 142.60 (C-5', furan), 116.37 (C-3', furan), 112.27 (isopropylidene), 101.69 (C-4', furan), 100.80 (C-1), 84.32, 83.74, 83.47, 82.89 (C-3, *C*(CH$_3$)$_3$, Boc), 74.88 (C-5), 72.01 (C-4), 68.65 (C-2), 61.20 (C-6), 28.42, 28.11, 28.07 (*C*H$_3$, isopropylidene, -C(*C*H$_3$)$_3$, Boc), 26.92 ppm (*C*H$_3$, isopropylidene). Anal. Calcd for $C_{28}H_{41}NO_{12}$: C, 57.62; H, 7.08; N, 2.40. Found: C, 57.25; H, 7.25; N, 2.12.

Compound **14** (206.7 mg, 0.43 mmol, 45%), was obtained as a white solid, which crystallises from the eluent as colourless crystals: mp 161-163 °C, $[\alpha]^{20}_{D}$ +18.4 ° (*c* 0.3, $CHCl_3$). ^{1}H-NMR ($CDCl_3$, 500.13 MHz): δ 6.26 (dd, 1H, $J_{5,6}$ 11.60 Hz, $J_{6,7}$ 4.10 Hz, H-6), 6.00 (dd, 1H, $J_{5,7}$ 2.52 Hz, H-5), 5.83 (dd, 1H, H-7), 5.13 (s, 1H, H-1), 4.81 (d, 1H, $J_{9,10}$ 7.88 Hz, H-9), 4.72 (s, 1H, H-2), 4.67 (m_c, 1H, H-10), 4.34 (d, 1H, $J_{11a,11b}$ 7.88 Hz, H-11a), 3.57 (dd, 1H, $J_{10,11b}$ 5.36 Hz, H-11b), 1.55 (CH_3, isopropylidene), 1.53, 1.52 (each s, each 9H, C(CH_3)$_3$, Boc), 1.41 ppm (CH_3, isopropylidene). ^{13}C-NMR ($CDCI_3$, 100.62 MHz): δ 167.43 (N-C=O), 153.36 (C=O, N-Boc), 143.25 (C-6), 143.23 (C=O, O-Boc), 126.56 (C-5), 112.04 (isopropylidene), 102.80 (C-1), 90.59 (C-8), 84.42, 83.77 (*C*$(CH_3)_3$, Boc), 75.58 (C-7), 71.79 (C-9), 70.95 (C-10), 65.74 (C-2), 62.42 (C-11), 28.31 (-C(*C*H_3)$_3$, Boc), 28.17 (-*C*H_3, isopropylidene), 28.13 (C(*C*H_3)$_3$, Boc), 27.52 ppm (*C*H_3, isopropylidene). Anal. Calcd for $C_{23}H_{33}NO_{10}$: C, 57.13; H, 6.88; N, 2.90. Found: C, 56.98; H, 7.01; N, 2.85.

SUPPLEMENTARY MATERIAL

Complete crystallographic data for the structural analysis have been deposited with the Cambridge Crystallographic Data Centre, CCDC 657194 (**14**). Copies of this information may be obtained free of charge from The Director, CCDC, 12 Union Road, Cambridge CB21EZ, UK (fax: +44-1223-336033, e-mail: *deposit@ccdc.cam.ac.uk* or www: *http://www.ccdc.cam.ac.uk*).

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