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# 2-Acetamido-2-deoxyaldonolactones from sugar formazans

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## ABSTRACT

A new approach towards simple aldonic acid derivatives starting from the corresponding aldoses via the 2-acetamido-2-deoxy formazans resulted in the synthesis of 2-acetamido-2-deoxy-D-galactono-1,4-lactone (**8**), and its 6-deoxy (**11**) and 6-azido-6-deoxy (**14**) analogues on treatment with trifluoroacetic acid. The five-membered ring structure of the lactones and that of the intermediate lactone phenylhydrazone (**7**) was proved by $^{1}H$ and $^{13}C$ NMR studies, including deuterium-induced differential isotope shift (DIS) measurements. With sodium borohydride, lactones **8** and **11** were converted into 2-acetamido-2-deoxy-D-galactitol (**15**) and its 6-deoxy analogue (**17**), respectively.

## INTRODUCTION

Synthetic[1] and biological[2,3] interest in 2-acetamido-2-deoxyaldonic acid derivatives has led to a variety of methods for their preparation. We now present a simple synthesis of the title compounds from 2-acetamido-2-deoxyaldose formazans[4] accessible by a regiospecific and stereoselective reaction of per-*O*-acetylated aldose formazans with ammonia.

The method for decomposition of aldose formazans into thioaldonic acid phenylhydrazides[5] and subsequent conversion into aldonic acids[6] was not successful when applied to 2-acetamido-2-deoxy derivatives. We later found[7] that trifluoroacetic acid converted the aldose formazans into aldonic acid phenylhydrazides, potential precursors of aldonic acids.

## RESULTS AND DISCUSSION

Recently, we observed that D-galactonic acid phenylhydrazide (**2**) prepared[7] from **1** by treatment with 3 mol of trifluoroacetic acid could be hydrolysed with a

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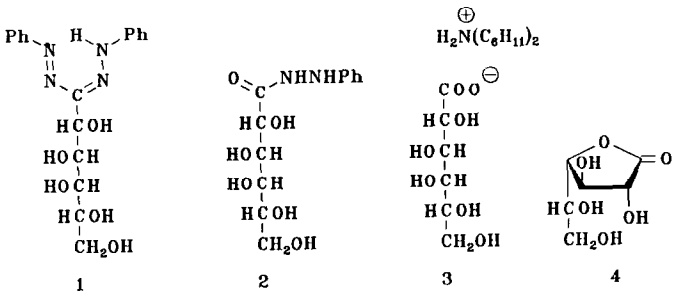
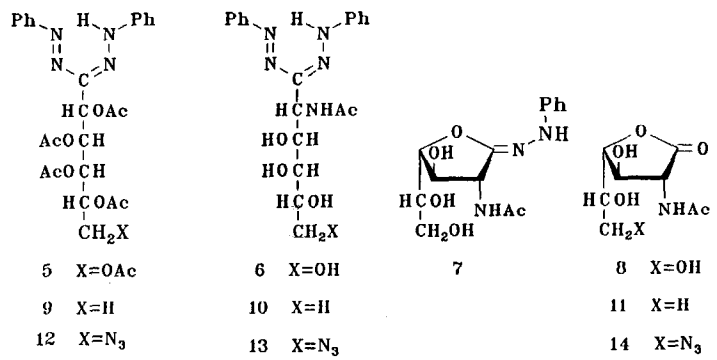


Scheme 1.

strongly acidic cation-exchange resin, giving D-galactonic acid, isolated as its crystalline dicyclohexylammonium salt[8] (**3**). When D-galactose *N,N'*-diphenylformazan (**1**) was allowed to stand with a large excess of trifluoroacetic acid (15 mol), crystalline D-galactono-1,4-lactone (**4**) was formed in 52% yield.

2-Acetamido-2-deoxy-D-galactose *N,N'*-diphenylformazan[4] (**6**), prepared from the penta-*O*-acetyl derivative **5**, was similarly treated with trifluoroacetic acid (2.6 mol) in ethanolic suspension below 20°C. Gas evolution was observed and, after 2 h, yellow crystals of 2-acetamido-2-deoxy-D-galactono-1,4-lactone phenylhydrazone (**7**) were isolated in 60% yield. A second product, identified as 2-acetamido-2-deoxy-D-galactono-1,4-lactone[9–11] (**8**), was obtained from the mother liquor in the form of colourless crystals in 22% yield. Since the intermediate **7** spontaneously affords lactone **8** even in ethanolic solution, lactone **8** was the main product (76% yield) when ca. 10 mol of $CF_3CO_2H$ was used and the mixture was allowed to stand at room temperature for 2 days.

Evidence for the structures of **7** and **8** was obtained from NMR studies. Tables I–III contain the $^1H$ and $^{13}C$ spectral parameters (chemical shifts and spin–spin coupling constants).



Scheme 2.

TABLE I

$^1$H NMR chemical shifts (ppm) of compounds **2**, **7**, **8**, **11**, **14**, and **17**

| Compound | **2** | **7** | **8** | **11** | **14** | **17** |
|---|---|---|---|---|---|---|
| H-1a | | | | | | 3.728 **AB**d |
| H-1b | | | | | | 3.670 **AB**d |
| H-2 | 4.505 d | 4.872 d | 4.658 d | 4.595 d | 4.632 d | 4.242 ddd |
| H-3 | 3.985 dd | 4.225 t | 4.604 dd | 4.470 t | 4.572 t | 3.815 dd |
| H-4 | 3.669 dd | 4.258 dd | 4.417 dd | 4.211 dd | 4.379 dd | 3.226 dd |
| H-5 | 3.900 td | 3.803 ddd | 3.959 ddd | 4.025 dq | 4.069 dt | 4.054 qd |
| H-6a | 3.622 d | 3.718 **AB**d | 3.766 **AB**d | 1.305 d | 3.558 d | 1.228 d |
| H-6b | | 3.705 | 3.734 | | | |
| NAcMe | | 2.050 s | 2.102 s | 2.078 s | 2.086 s | 2.054 s |
| NH–NH | 9.095 d | | | | | |
| | 6.949 d | | | | | |
| Ar H-2′ | 6.862 dd | 6.974 dd | | | | |
| Ar H-3′ | 7.133 dd | 7.154 dd | | | | |
| Ar H-4′ | 6.753 tt | 6.710 tt | | | | |
| Temp. (K) | 323 | | 323 | 308 | 323 | 323 |
| Solvent | $CDCl_3$–$(CD_3)_2SO$ [4:1] | | $D_2O$ | $D_2O$ | $D_2O$ | $D_2O$ |
| Reference | Internal $Me_4Si$ | | Internal acetone at 2.225 ppm | | | |

TABLE II

Vicinal coupling constants [Hz] of **2**, **7**, **8**, **11**, **14**, and **17**. Torsion angles (degrees) are given in parentheses.

| Compound | **2** | **7** | **8** | **11** | **14** | **17** |
|---|---|---|---|---|---|---|
| $J_{1a,1b}$ | | | | | | −11.3 |
| $J_{1a,2}$ | | | | | | 6.2 |
| $J_{1b,2}$ | | | | | | 7.7 |
| $J_{2,3}$ | 1.6 | 7.4 | 9.1 | 8.8 | 9.1 | 1.7 (60) |
| $J_{3,4}$ | 9.3 | 7.2 | *8.1* | *8.0* | *7.8* | *9.3 (179)* |
| $J_{4,5}$ | 1.8 | 3.6 | 3.6 | 5.3 | 4.0 | 2.0 (−59) |
| $J_{5,6a}$ | 6.2 | 5.7 | 5.2 | 6.6 [a] | 5.9 [a] | 6.6 [a] |
| $J_{5,6b}$ | | 6.7 | 6.8 | | | |
| $J_{6a,6b}$ | | −11.7 | −11.9 | | | |
| $J_{NH,NH}$ | 3.4 | | | | | |
| $J_{2',3'}$ | 8.6 | 8.5 | | | | |
| $J_{2',4'}$ | 1.1 | 0.8 | | | | |
| $J_{3',4'}$ | 7.3 | 7.5 | | | | |
| Temp. (K) | 323 | | 323 | 308 | 323 | 323 |
| Solvent | $CDCl_3$–$(CD_3)_2SO$ [4:1] | | $D_2O$ | $D_2O$ | $D_2O$ | $D_2O$ |

[a] Protons at position 6 are equivalent.

TABLE III

$^{13}C$ NMR chemical shifts (ppm) of **2**, **7**, **8**, **11**, **14**, and **17**

| Compound | **2** | **7** | **8** | **11** | **14** | **17** |
|---|---|---|---|---|---|---|
| C-1 | 173.33 | 146.31 | 176.72 | 177.00 | 176.63 [a] | 64.50 |
| C-2 | 70.91 | 56.40 | 59.93 | 60.45 | 60.09 | 54.64 |
| C-3 | 71.12 | 74.59 | 73.71 | 74.23 | 73.87 | 72.13 |
| C-4 | 69.48 | 84.49 | 84.75 | 88.50 | 85.23 | 75.93 |
| C-5 | 69.78 | 70.70 | 72.32 | 69.16 | 71.34 | 68.79 |
| C-6 | 63.28 | 62.76 | 64.81 | 20.54 | 55.53 | 21.50 |
| AcMe | | 22.77 | 24.51 | 24.48 | 24.60 | 24.79 |
| C=O | | 171.26 | 177.16 | 177.25 | 177.27 [a] | |
| C-1′ | 148.39 | 146.91 | | | | |
| C-2′ | 112.74 | 112.50 | | | | |
| C-3′ | 128.37 | 128.82 | | | | |
| C-4′ | 119.08 | 118.49 | | | | |
| Temp. (K) | 323 | | 323 | 308 | 323 | 323 |
| Solvent | $CDCl_3$–$(CH_3)_2SO$ [4:1] | | $D_2O$ | $D_2O$ | $D_2O$ | $D_2O$ |
| Reference | Internal $Me_4Si$ | | Internal TSP-$d_4$ [b] at 0 ppm | | | |

[a] Assignments may be reversed. [b] TSP-$d_4$ = sodium 2,2,3,3-tetradeuterio-4,4-dimethyl-4-silapentanoate.

For **7**, a mixed solvent [$CDCl_3$–$(CD_3)_2SO$ 4:1] was used because in pure $(CD_3)_2SO$ most resonances were overlapping. The $^1H$ NMR spectrum was readily interpreted by first-order analysis and the parameters were refined by spin-simulation[12]. $^{13}C$ Assignments were obtained selectively by the FLOCK pulse sequence[13]. The high value of the chemical shift of C-4 (84.49 ppm) suggested a 1,4-lactone ring structure. As a comparison, the acyclic compound **2** can be considered where all $^{13}C$ shifts appear between 72 and 63 ppm in accordance with other aldonic acid derivatives[14].

A direct proof for the cyclic nature of **7** was found by the deuterium-induced differential isotope shift (DIS) experiment[15,16] where these shifts (Table IV) proved unambiguously that C-6 was linked to C-5 bearing an OH group ($\beta$- and $\gamma$-shifts observed at C-6: 114 and 39 ppb, respectively).

It is worth remarking that the observed high value for the chemical shift of C-4 seems to be a general diagnostic feature for all aldono-1,4-lactones[17] and their derivatives[18,19].

The assignment of **2** was obtained in the same way as that of **7**. Based on the observed $^3J_{HH}$ coupling values, the major conformer of **2** may be assumed to have a zigzag form, as was found for other acyclic galactonic acid derivatives[14].

Early studies of compound **8** already suggested a 1,4-lactone structure, based on derivatisation[9,11] and IR data[3]. In this work, we report complete $^1H$ and $^{13}C$ NMR assignments. The chemical shift of C-4 is 84.75 ppm, and DIS data (Table IV) again gave direct evidence for the five-membered ring of **8**. (In a six-membered lactone ring, C-4 would bear an OH group and consequently its DIS value would be higher than 100 ppb, being a $\beta$-shift.)

TABLE IV

Deuterium-induced secondary isotope shifts (DIS) observed in the $^{13}C$ NMR spectra of **7** and **8**. Values are given in ppb; $\gamma_{m,n}$ denotes the effect of OH-*n* observed at C-*m*.

| Compound | **7** [a,c] | **8** [b,c] | |
|---|---|---|---|
| C-1 | 69 | < 8 | $\gamma_{NH}$ |
| C-2 | 134, 85, 48 | 129 | $\beta_2 + \gamma_{32}$ |
| C-3 | 93, 32 | 134 | $\beta_3 + \gamma_{23}$ |
| C-4 | | 63 | $\gamma_{34} + \gamma_{54}$ |
| C-5 | 96 | 133 | $\beta_5 + \gamma_{65}$ |
| C-6 | 114, 39 | 182 | $\beta_6 + \gamma_{56}$ |
| Ac $CH_3$ | 44 | 114 | $\gamma_{NHCOCH_3}$ |
| C=O | 85 | 55 | $\beta_{NH}$ |
| Solvent | $(CH_3)_2SO$-$d_6$ | $D_2O$ | |
| Temp. (K) | 297 | 323 | |
| $f_0$ (MHz) | 75 | 100 | |

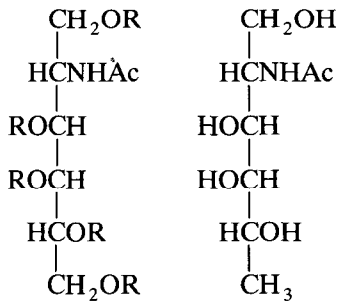
[a] The isotope multiplet method of Reuben[16] was used, resulting in separate $\beta$- and $\gamma$-effects. [b] Following Pfeffer et al.[15], solutions in $D_2O$ and $H_2O$ located in a coaxial sample tube were measured together ($\beta$- and $\gamma$-effects are added). [c] $\beta$-Shifts are induced on $^{13}C$ resonances by directly bonded hydroxyl or NH groups, and $\gamma$-shifts originate from hydroxyl or NH groups being at a vicinal position.

With regard to the biological importance of *N*-acetyl-D-fucosamine derivatives[20], the hitherto unknown 2-acetamido-2,6-dideoxy-D-galactono-1,4-lactone (*N*-acetyl-D-fucosamino-1,4-lactone, **11**) was similarly obtained from 2-acetamido-2-deoxy-D-fucose *N*,*N*′-diphenylformazan (**10**), prepared[21] from **9**. Furthermore, the analogous 2-acetamido-6-azido-2,6-dideoxy-D-galactono-1,4-lactone (**14**) was produced from the tetraacetate **12**[21] via the 2-acetamido-6-azido-2,6-dideoxyformazan **13**[4].

The five-membered ring nature of lactones **11** and **14** was investigated by IR and 1D- and 2D-NMR spectroscopy. Although the carbonyl stretching frequency in the IR spectrum of **11** appeared at lower value (1760 $cm^{-1}$) than that of **8** and **14** (1780 $cm^{-1}$), the chemical shift values of C-4 ($\delta$ 88.50 ppm for **11** and 85.23 ppm for **14**, respectively) provided evidence for the five-membered $\gamma$-lactone structure of both compounds (Table III). It is noteworthy that, in all three $\gamma$-lactones (**8**, **11**, and **14**) and also in the lactone phenylhydrazone **7**, C-3, which is a member of the ring, resonates at lower field than C-5.

Reduction of lactone **8** with sodium borohydride afforded 2-acetamido-2-deoxy-D-galactitol (**15**) in a good yield. The alditol **15** and its pentaacetate **16** proved to be identical with the compounds prepared[22] from *N*-acetyl-D-galactosamine. 2-Acetamido-2,6-dideoxy-D-galactono-1,4-lactone (**11**) was similarly reduced to give a new compound, 2-acetamido-2,6-dideoxy-D-galactitol (2-acetamido-2-deoxy-D-fucitol, **17**) in 82% yield.

In the case of **17**, the NMR spectra unequivocally prove its acyclic character. The conformation in solution was inferred from theoretical energy calculations[23]. The minimum energy conformation obtained by in vacuo calculation is shown in



**15** R = H
**16** R = Ac

**17**

Scheme 3.

Fig. 1. It is in agreement with the observed proton–proton coupling constants (torsion angles are included in Table II).

Our method offers an efficient route for the preparation of 2-acetamido-2-deoxygalactonolactones and the corresponding 2-acetamido-2-deoxygalactitols. It uses easily available aldoses instead of the corresponding expensive 2-amino-2-deoxyhexoses, simple reagents, and gives good or reasonable overall yields.

2-Acetamido-2-deoxyaldono-1,5-lactones are known as powerful inhibitors of *N*-acetyl-β-D-hexosaminidase enzymes[3]. Recent investigations[24] on lactones **8**, **11**, and **14** have shown that these 1,4-lactones too are effective inhibitors of the *N*-acetyl-β-D-hexosaminidase isolated from germinating *Lupinus luteus* L. seeds.

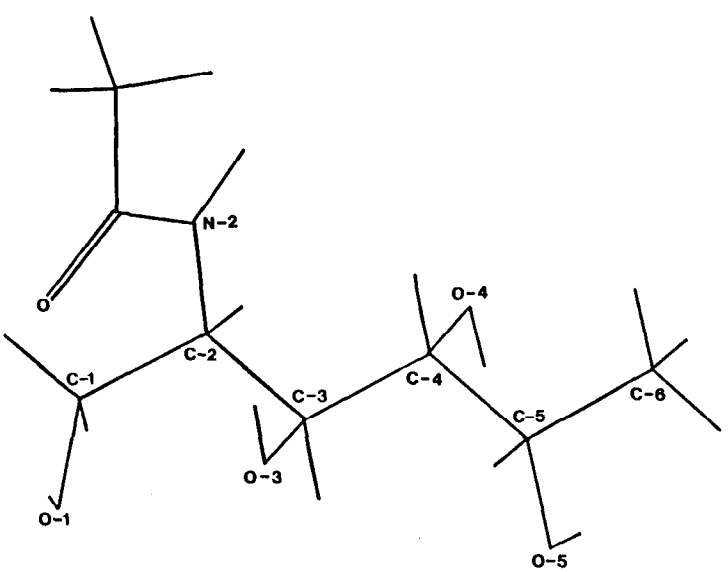



Fig. 1. Minimum energy conformation of **17**.

## EXPERIMENTAL

*General methods.*—TLC was performed on Silica Gel $F_{254}$ (Merck) with *A*, 3:1 $CHCl_3$–MeOH; *B*, 19:1 $CHCl_3$–MeOH; *C*, 19:1 $CHCl_3$–EtOAc; *D*, 5:5:0.06 EtOAc–1,4-dioxane–AcOH. Detection was effected by UV light at 254 nm or by heating or by charring with $H_2SO_4$. Optical rotations were measured with a Zeiss Polamat A polarimeter at 25°C. IR spectra were recorded with a Nicolet 205 FT spectrometer.

*NMR studies.*—Table V shows the various NMR experiments used for structure elucidation. Experimental conditions are given in Tables I–IV. Bruker AC/E-300 and Varian XL400 spectrometers were used. Multiplets of the $^1H$ spectra were analysed by spin-simulation: the LAOCOON III program[12] of Bothner-By was revised and modified by one of the authors (A.N.). For 2D spectra, the standard microprograms in the manufacturer's library were used.

D-*Galactonic acid dicyclohexylammonium salt* (**3**).—To a stirred suspension of D-galactonic acid phenylhydrazide[7] (**2**; 240 mg, 0.84 mmol) in EtOH (6 mL) and water (6 mL) was added Amberlite IR-120 ($H^+$) ion-exchange resin (1 mL) and stirring was continued at 70°C for 5 h, while TLC (solvent *A*) indicated consumption of **2**. After concentration, the brownish residue was dissolved in water, and dicyclohexylamine (0.84 mmol) and a few drops of EtOH were added. The mixture was stirred until homogeneous, then allowed to stand in a refrigerator overnight. The solid was filtered and recrystallised from 9:1 EtOH–water, giving white crystals; mp 154–155°C; $[\alpha]_D$ +2° (*c* 1, $H_2O$); lit.[8] mp 156°C; $[\alpha]_D$ +1.8° ($H_2O$).

TABLE V

Methods used for structure elucidation of **2**, **7**, **8**, **11**, **14**, and **17**

| Compound | **2** | **7** | **8** | **11** | **14** | **17** |
|---|---|---|---|---|---|---|
| $^1H$ Assignment | $^3J_{HH}$ [a] | $^3J_{HH}$ [a] | $^3J_{HH}$ [a] | $^3J_{HH}$ [a] | $^3J_{HH}$ [a] | COSY [b] |
| $^1H$ Spin-analysis [c] | + | + | + | + | + | + |
| APT [d] | | + | + | + | + | |
| INAPT [e] | + | + | | + | | |
| $^{13}C$–$^1H$ correlation | | | + | + | + | + |
| Carbonyl carbons | | | $^3J_{CH}$ [f] | INAPT [e] | | |
| DIS [g] | | + | + | | | |
| Computer-aided modeling [h] | + | + | + | + | | + |

[a] Proton resonances were assigned by vicinal coupling relations. [b] $^1H$–$^1H$ correlation. [c] Exact values of $^3J_{HH}$ were obtained by spin-simulation[12]. [d] Partial assignment by attached proton test (APT)[27]. [e] The INAPT method[28] was used to obtain two- and three-bond connectivity information. [f] Assignment of the neighboring C-1 and *N*-acetyl carbonyl resonances was possible through the observation of the multiplets caused by $^3J_{CH}$ interaction with the acetyl methyl group. [g] Deuterium-induced secondary isotope shift (DIS) determination[15,16] was used for establishing the five-membered ring structure. [h] The most stable conformation of the molecules was calculated by the program Alchemy-III[23].

D-*Galactono-1,4-lactone* (**4**).—D-Galactose *N,N'*-diphenylformazan[25] (**1**; 2.0 g, 5.3 mmol) was suspended in a mixture of MeOH (20 mL) and acetone (15 mL), then $CF_3CO_2H$ (6 mL, 77.8 mmol) was added dropwise at 0°C with stirring. The mixture became homogeneous in a few minutes. After standing at room temperature for 5 days, the dark solution was concentrated to a syrup which was triturated with EtOAc and allowed to stand at room temperature for 2 days. White crystals of **4** separated (0.5 g, 52%); mp 133–135°C, $[\alpha]_D$ −75° (*c* 1.7, $H_2O$); $\nu_{max}^{KBr}$ 1780 $cm^{-1}$ (lactone CO); $R_f$ 0.28 (solvent *A*), identical with an authentic sample; lit.[26] mp 134–135°C; $[\alpha]_D$ −77.5° (*c* 4.2, $H_2O$).

*2-Acetamido-2-deoxy-*D*-galactono-1,4-lactone phenylhydrazone* (**7**).—To a stirred suspension of 2-acetamido-2-deoxy-D-galactose *N,N'*-diphenylformazan[4] (**6**; 2.52 g, 6 mmol) in dry EtOH (30 mL) was added dropwise $CF_3CO_2H$ (1.2 mL, 15.6 mmol), and the mixture was stirred at 0°C for 1 h and between 15–18°C for 2 h. The red colour of the suspension changed to yellow. The mixture was cooled below −10°C; the solid (1.12 g, 60%), mp 184–189°C, was filtered off and washed with cold EtOH. Recrystallisation from nitromethane or EtOH gave yellow needles of **7** (0.51 g), mp 201–202°C; $[\alpha]_D$ −7.4° (*c* 1, pyridine); $R_f$ 0.56 (solvent *A*). Anal. Calcd for $C_{14}H_{13}N_3O_5$: C, 54.36; H, 6.19; N, 13.58. Found: C, 54.35; H, 6.40; N, 13.69.

On standing, white crystals of **8** (0.29 g, 22%) separated from the mother liquor of the mixture; mp 174–177°C; $[\alpha]_D$ −15° (*c* 0.8, $H_2O$). During recrystallisation or standing in solution, compound **7** was partly transformed into lactone **8**. The reaction could be completed by heating or by addition of acid (see below).

*2-Acetamido-2-deoxy-*D*-galactono-1,4-lactone* (**8**).—2-Acetamido-2-deoxy-D-galactose *N,N'*-diphenylformazan (**6**; 13.4 g, 32.3 mmol) was suspended in MeOH or EtOH (120 mL), and $CF_3CO_2H$ (27 mL, 350.5 mmol) added dropwise at 0°C with stirring. The mixture was stirred at room temperature for 6–8 h and then allowed to stand overnight. After cooling to 0°C, the pink solid (2.3 g) was filtered off and washed with ice-cold EtOH and then with EtOAc; mp 174–177°C. The mother liquor was concentrated to half volume and refrigerated, giving a second crop of product (2.0 g). The solution was concentrated and co-distilled several times with EtOAc, leaving a white solid (1.1 g, total yield 76%). A solution of the product in MeOH was concentrated to give **8** as white crystals (4.6 g, 65%); mp 173–175°C; $[\alpha]_D$ −16° (*c* 1.7, $H_2O$), $R_f$ 0.27 (solvent *A*); $\nu_{max}^{KBr}$ 1780 (lactone CO), 1630 and 1540 $cm^{-1}$ (NAc). Anal. Calcd for $C_8H_{13}NO_6$: C, 43.81; H, 5.98; N, 6.40. Found: C, 44.00; H, 6.05; N, 6.34.

Further recrystallisation from MeOH or EtOH decreased the mp to 162–165°C without detectable change in TLC or in spectroscopic data; lit.[8,11] mp 173.5–174°C or 162–166°C; $[\alpha]_D$ −15.9° ($H_2O$) or −21.6° ($H_2O$).

*2-Acetamido-2,6-dideoxy-*D*-galactose* N,N'*-diphenylformazan* (**10**).—2,3,4,5-Tetra-*O*-acetyl-6-deoxy-D-galactose *N,N'*-diphenylformazan[21] (**9**; 10 g, 19 mmol) was dissolved in a mixture of EtOH (80 mL) and 25% ammonium hydroxide (80 mL). The mixture was allowed to stand at room temperature for 2 days and at 0°C for

an additional 2 days, when TLC (solvent *D*) indicated the reaction to be complete. The precipitate was filtered off and washed with cold 1:1 EtOH–water to give red needles (5.6 g); mp 173–175°C. Concentration of the mother liquor (bath temperature below 30°C) resulted in a second crop of crystals (1.0 g, total yield 87%). Recrystallisation was effected by dissolving the solid in hot 4:1 2-propanol–water and dropping in water till turbidity; on cooling, red crystals (5.93 g, 78%) separated; mp 179–180°C; $R_f$ 0.53 (solvent *B*); $\nu_{max}^{KBr}$ 1625 and 1525 $cm^{-1}$ (NHAc). Anal. Calcd for $C_{20}H_{25}N_5O_4$: N, 17.53. Found: N, 17.11.

*2-Acetamido-2,6-dideoxy-D-galactono-1,4-lactone* (**11**).—To a stirred solution of 2-acetamido-2,6-dideoxy-D-galactose *N,N'*-diphenylformazan (**10**; 5.07 g, 12.7 mmol) in EtOH (140 mL) was added $CF_3CO_2H$ (12 mL, 155.8 mmol) dropwise at 0°C. The mixture was stirred at room temperature for 6 h and allowed to stand at room temperature overnight. TLC (solvents *A* and *D*) revealed no starting material. To the brown solution were added water (140 mL) and Amberlite IR-120($H^+$) ion-exchange resin (14 mL), and the mixture was stirred for 1 h. After filtration, the solution was concentrated and co-distilled several times with EtOAc. The residue was triturated with EtOAc and with a few drops of diethyl ether to give a white solid (1.72 g, 67%); mp 170–173°C. Recrystallisation from MeOH–EtOAc gave **11** as colourless prisms; mp 167–170°C; $[\alpha]_D$ −2° (*c* 1.76, $H_2O$); $R_f$ 0.54 (solvent *A*); $\nu_{max}^{KBr}$ 1760 (CO lactone), 1650 and 1540 $cm^{-1}$ (NHAc). Anal. Calcd for $C_8H_{13}NO_5$: C, 47.29; H, 6.45; N, 6.89. Found: C, 46.82; H, 6.53; N, 6.92.

*2-Acetamido-6-azido-2,6-dideoxy-D-galactono-1,4-lactone* (**14**).—2-Acetamido-6-azido-2,6-dideoxy-D-galactose *N,N'*-diphenylformazan[4] (**13**; 1 g, 2.3 mmol) was suspended in EtOH (13 mL), then $CF_3CO_2H$ (1.6 mL, 20.8 mmol) was added to the stirred mixture at 0°C. Stirring was continued at room temperature for 6 h, and the resulting brown solution was allowed to stand overnight. After concentration, the brown oil was triturated with EtOAc to give light crystals of **14** (0.35 g, 63%); mp 154–156°C. Recrystallisation from a mixture of EtOAc (20 mL) and 2-propanol (5 mL) gave a pure product (0.31 g, 56%); mp 156–157°C; $[\alpha]_D$ −17° (*c* 1.86, $H_2O$); $R_f$ 0.63 (solvent *A*); $\nu_{max}^{KBr}$ 2100 ($N_3$), 1780 (CO lactone), 1630 and 1540 $cm^{-1}$ (NHAc). Anal. Calcd for $C_8H_{12}N_4O_5$: C, 39.35; H, 4.95; N, 22.94. Found: C, 39.30; H, 5.08; N, 22.57.

*2-Acetamido-2-deoxy-D-galactitol* (**15**).—To a stirred mixture of 2-acetamido-2-deoxy-D-galactono-1,4-lactone (**8**; 219 mg, 1 mmol) in 0.4 M aq $H_3BO_3$ (5 mL) was added 0.3 M $NaBH_4$ (10 mL) at 0°C during 30 min. Stirring was continued for 30 min, and the solution was then adjusted to pH 9 with 10 M NaOH, stored in a refrigerator overnight, and de-ionised by passing through a column (10 mL) of Amberlite IR-120 ($H^+$) ion-exchange resin. The solvent was evaporated and the residue was co-distilled several times with MeOH to give a syrup which was triturated with EtOH. The resulting white crystals (200 mg, 90%) had mp 168–170°C. Recrystallisation from MeOH gave pure **15** (160 mg, 72%); mp 173–174°C; $[\alpha]_D$ −41° (*c* 1.4, $H_2O$); lit[22] mp 174–176°C; $[\alpha]_D$ −42° ($H_2O$).

Acetylation of **15** (200 mg, 0.9 mmol) with NaOAc (129 mg) and $Ac_2O$ (0.8 mL)

by heating on a water bath for 2 h resulted in a homogeneous solution. It was poured into crushed ice and triturated to give a white solid (292 mg, 75%). Recrystallisation from MeOH gave colourless crystals of **16** (225 mg, 58%); mp 176–177°C; $[\alpha]_D$ +16° (*c* 1.25, $CHCl_3$); lit[22] mp 176–178°C; $[\alpha]_D$ +15° (*c* 0.53, $CHCl_3$).

*2-Acetamido-2,6-dideoxy-*D*-galactitol* (**17**).—2-Acetamido-2,6-dideoxy-D-galactono-1,4-lactone (**11**; 406 mg, 2 mmol) was reduced as described for **15**. The crude oily product was refluxed with aq 90% EtOH, and the solution was filtered and evaporated to give a colourless solid (340 mg, 82%); mp 168–170°C. Recrystallisation from MeOH gave pure **17** (220 mg, 53%); mp 170–171°C; $[\alpha]_D$ −44° (*c* 1, $H_2O$); $R_f$ 0.32 (solvent *A*). Anal. Calcd for $C_8H_{17}NO_5$: C, 46.37; H, 8.27; N, 6.76. Found: C, 45.73; H, 8.33; N, 6.72.

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