Carbohydrate Research, 62 (1978) 105–116

FORMATION OF 2,5-ANHYDRO DERIVATIVES IN THE ZEMPLÉN DEACETYLATION OF ACETYLATED SUGAR FORMAZANS

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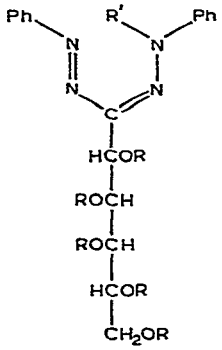
(Received April 29th, 1977; accepted for publication, September 12th, 1977)

ABSTRACT

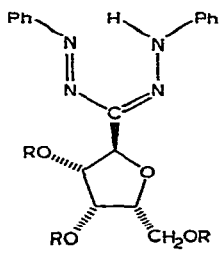
Deacetylation of acetylated D-galactose and 6-deoxy-D-galactose diphenylformazans under Zemplén conditions required much more (1.1 mol.) than the usual catalytic amount of sodium methoxide to complete the reaction, and 2,5-anhydro-D-talose diphenylformazans were obtained. The structure of the products was proved by ^{1}H- and ^{13}C-n.m.r. spectroscopy, and a mechanism for the reaction is suggested.

INTRODUCTION

Penta-*O*-acetyl-D-galactose *N*-acetyl-*N*,*N*′-diphenylformazan[1] (**1**), prepared by acetylating penta-*O*-acetyl-D-galactose *N*,*N*′-diphenylformazan[2] (**2**), could not be deacetylated with a catalytic amount of sodium methoxide according to the Zemplén method[3]. An excess (1.1 mol.) of base was required for completion of the reaction, and the product was a new anhydrohexose formazan (**4**) instead of the expected D-galactose *N*,*N*′-diphenylformazan[2] (**3**). We now report on the structure of **4** and on the mechanism of its formation.



1 R = R′ = Ac
2 R = Ac, R′ = H
3 R = R′ = H



4 R = H
5 R = Ac

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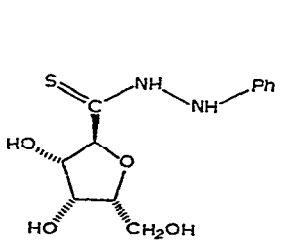
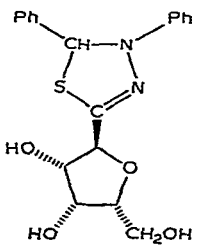
RESULTS AND DISCUSSION

Compound **4** was shown to be 2,5-anhydro-D-talose *N,N'*-diphenylformazan on the basis of the following data.

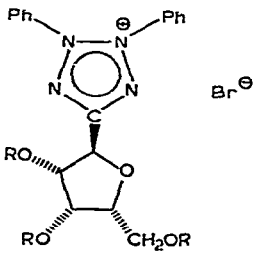
The formazan character of **4** and its triacetate **5** was supported by the spectroscopic data discussed earlier[1] and by reactions characteristic of sugar formazans[4,5]. Treatment of **4** with hydrogen sulphide afforded 2,5-anhydro-D-thiotalonic acid phenylhydrazide (**6**) in good yield. Condensation of **6** with benzaldehyde gave the crystalline thiadiazoline **7**.



6



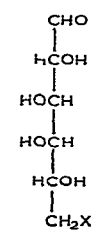
7



8 R = H
9 R = Ac

Reaction of **4** with *N*-bromosuccinimide yielded the tetrazolium bromide **8**; **8** gave a crystalline triacetate (**9**), showing that the anhydro ring remained intact. Treatment of **8** with periodate (under normal conditions) yielded no formic acid, indicating a five-membered ring, but there was substantial overoxidation.

Evidence for the five-membered ring structure of **4** was obtained by using data on Zemplén deacetylation of 2,3,4,5-tetra-*O*-acetyl-D-fucose *N*-acetyl-*N,N'*-diphenylformazan (**15**) and 2,3,4,5-tetra-*O*-acetyl-6-azido-6-deoxy-D-galactose *N*-acetyl-*N,N'*-diphenylformazan (**21**).



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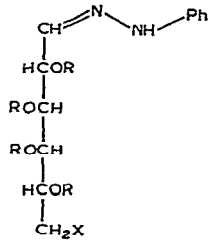
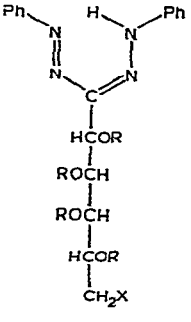
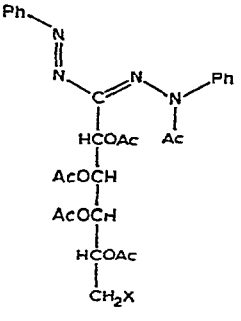
16 X = N_3



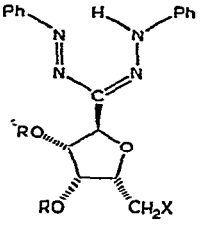
11 X = H, R = H
12 X = H, R = Ac
17 X = N_3, R = H
18 X = N_3, R = Ac



13 X = H, R = H
14 X = H, R = Ac
19 X = N_3, R = H
20 X = N_3, R = Ac



15 X = H
21 X = N_3



22 X = H, R = H
23 X = H, R = Ac
24 X = N_3, R = H
25 X = N_3, R = Ac

Treatment of the phenylhydrazone[6] (**11**) of D-fucose with benzenediazonium chloride afforded the diphenylformazan **13**, which was acetylated to give **14**. Similarly,

20 was obtained from 6-azido-6-deoxy-D-galactose[7] (**16**) *via* the phenylhydrazone **17** and the formazan **19**.

N-Acetylation of **14** and **20** to give **15** and **21**, respectively, was carried out with acetic anhydride–trifluoroacetic acid instead of acetic anhydride–fluoroboric acid[1], in order to avoid the formation of the tetrazolium fluoroborate. The *N*-acetyl structure of **15** and **21** was indicated by characteristic blue shifts, reported[1] also for **1**, in their u.v. spectra (Table I), in accordance with the Grammaticakis[8] rule.

Under the conditions of Zemplén deacetylation, **15** and **21** reacted as **1**; 1.1 mol. of sodium methoxide were required to complete the reactions which gave **22** and **24**, respectively. Diacetates (**23** and **25**, respectively) were formed by **22** and **24**, indicating an anhydro-ring structure, and the formazan structure of **22** and **24** was demonstrated by the λ_{max} values in Table I.

The mass spectra of **5**, **23**, and **25** reveal the most characteristic fragmentation to be elimination of the formazyl group by β-cleavage, which supports the participation of C-2 in anhydro-ring formation. The subsequent fragmentation does not permit determination of the ring size (*cf.* Ref. 9). The ring size was established by ^{1}H- and

TABLE I

MAXIMA OF U.V. SPECTRA OF 6-DEOXYHEXOSE DIPHENYLFORMAZANS

Compound	**13**	**14**	**15**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
λ_{max}^{EtOH}(nm)	428	460	350	425	460	350	440	458	456	456

TABLE II

N.M.R. DATA[a, b] FOR THE ACETYLATED 2,5-ANHYDRO-D-TALOSE DIPHENYLFORMAZANS **5**, **23**, AND **25**

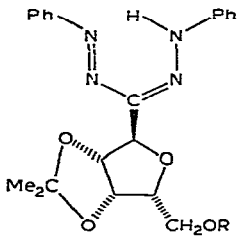
	5		**23**		**25**	
	δ	J_{HH} (Hz)	δ	J_{HH} (Hz)	δ	J_{HH} (Hz)
H-2[a]	5.30	6.1	5.25	6 9	5.28	6.0
H-3	5 95	4.6	5.98	4.9	5.96	4.6
H-4	5.82	4.6	5 64	3.7	5 81	4 8
H-5	4.67	3.4 8.8	4.60	6 4	4.58	
H-6a	4.36		1.30		3.54	
H-6b	4.29	−11.2			3.50	
C-2[b]	80.7		79.5		81.0	
C-3	74.5		74.8		74.6	
C-4	72 2		73.4		72.4	
C-5	76.8		75.1		77.8	
C-6	63.0		14.6		50.8	

[a]The parameters for protons were generally obtained by first-order approximation or spin–spin decoupling and, for **5**, by iterative calculations using a LAOCN3 program. [b]The assignment of carbon resonances in the ^{13}C-n.m.r. spectra was made by off-resonance and selective-decoupling techniques.

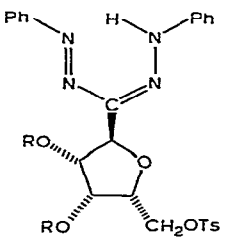
^{13}C-n.m.r. spectroscopy. The ^{13}C spin–lattice relaxation times, which also indicated a 2,5-anhydro structure for **5**, are published elsewhere[10].

The chemical shifts of the corresponding ring-protons (H-2,3,4,5) for **5**, **23**, and **25** (Table II) were similar. The signals for H-3 and H-4 appear at δ values that are higher than those of H-2 and H-5. These data are consistent with bonding of C-2 and C-5 to ether oxygen, and C-3 and C-4 to acetoxyl groups, and confirm the presence of a 2,5-anhydro ring in each compound. The same conclusion was obtained from the ^{13}C chemical-shift values of the corresponding carbon atoms (Table II).

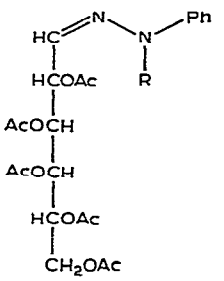
The $^3J_{HH}$ values (Table II) for H-2 and H-3 reveal an identical configuration at C-2 in **5**, **23**, and **25**, but could not be used for configurational assignments because of the mobility of the conformers[11]. Acetonation of **4**, to give **26** which was acetylated to give **27**, afforded a crystalline product containing a more rigid ring system. The ^{1}H-n.m.r. spectrum of **27** contained a singlet for H-2 at δ 5.48 ($J_{2,3}$ 0 Hz), proving the *trans* geometry of H-2 and H-3 and demonstrating that, in the conversion **1** → **4**, inversion at C-2 occurs, *i.e.*, **4** is 2,5-anhydro-D-talose diphenylformazan.



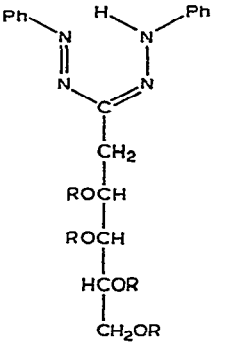
26 R = H
27 R = Ac
30 R = Ts



28 R = H
29 R = Ac



31 R = H
32 R = Ac
33 R = Me



34 R = Ac
35 R = H

Previously, a 2,6-anhydro structure was reported[1] for **4**, because tritylation or tosylation did not occur under the usual conditions. Reinvestigation of the tosylation of **4** showed that, under more vigorous conditions, with 2.6 mol. of toluene-*p*-sulphonyl chloride, the expected 6-*O*-tosyl (**28**), 3,4-di-*O*-acetyl-6-*O*-tosyl (**29**), and 3,4-*O*-isopropylidene-6-*O*-tosyl (**30**) derivatives were obtained.

The unusual behaviour of **1** under Zemplén deacetylation conditions is also shown by penta-*O*-acetyl-D-galactose diphenylformazan (**2**), which affords **4** as the main product; this behaviour is attributed to the ability of the phenylhydrazone moiety of the formazyl group to interact with the carbohydrate chain. Support for this view is provided by the behaviour of acetylated galactose phenylhydrazones, the precursors of formazans, under Zemplén deacetylation conditions. Thus, penta-*O*-acetyl-D-galactose phenylhydrazone[12] (**31**) and its *N*-acetyl derivative[13] (**32**) required more than one mol. of reagent, but no definite product was isolated.

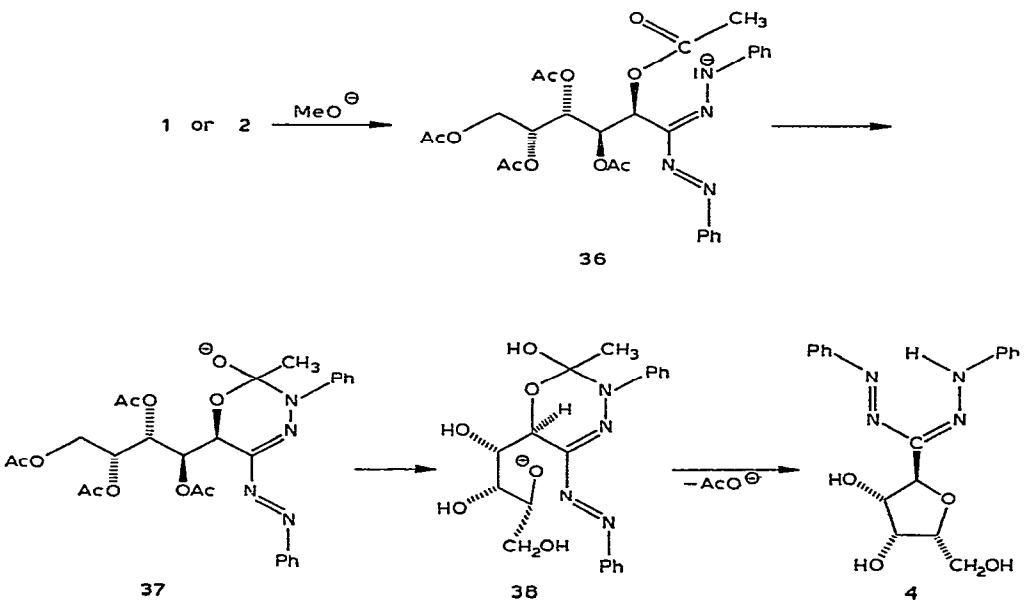
On the other hand, penta-*O*-acetyl-D-galactose *N*-methylphenylhydrazone[12] (**33**) can be deacetylated with a catalytic amount of sodium methoxide, to give D-

galactose *N*-methylphenylhydrazone in very good yield. Similar experiments with formazans cannot be performed, because methylation of penta-*O*-acetyl-D-galactose diphenylformazan (**2**) gives a verdazyl derivative[14].

Monitoring of the deacetylation of the penta- and hexa-acetates **1** and **2** by t.l.c. revealed that no D-galactose formazan (**3**) was formed, and the formation of **2** from **1** was not detected. The importance of the role of AcO-2 is shown by the fact that Zemplén deacetylation of **5**, **23**, and **25**, each of which contains an ether group at position 2, proceeds normally to give **4**, **22**, and **24**, respectively. Likewise, Zemplén deacetylation of tetra-*O*-acetyl-2-deoxy-D-*lyxo*-hexose diphenylformazan (**34**), prepared from tetra-*O*-acetyl-2-deoxy-*aldehydo*-D-*lyxo*-hexose[15] by the method of Mester and Major[16], yielded **35** which, on reacetylation, afforded **34**.

On the basis of the foregoing data, the following mechanism can be proposed for the behaviour of acetylated galactose formazans under the conditions of Zemplén deacetylation.

Release of the proton or acetyl group from the nitrogen atom of the formazyl group of **2** and **1**, respectively, yields the anion **36**, from which the oxadiazine **37** is formed by participation of AcO-2. Loss of the remaining acetyl groups from **37** by catalytic deacetylation yields **38**. Intramolecular nucleophilic attack by O-5 on C-2 then yields **4** with inversion of configuration. The acetic acid simultaneously produced is responsible for the neutralization of the sodium methoxide.



The conversion of **1** → **4** by methanolic sodium methoxide provides a new method for the preparation of 2,5-anhydrotalose derivatives from galactose.

EXPERIMENTAL

General methods. — Optical rotations were measured with an Opton Polarimeter. T.l.c. was performed on Silica Gel G (Merck), unless otherwise stated. I.r. spectra were recorded with Perkin–Elmer 457 and Unicam SP 200 spectrometers, and u.v. spectra with a Unicam SP 800 spectrometer. P.m.r. spectra (internal Me_4Si) were recorded with Varian XL-100 and A-60 instruments. ^{13}C-N.m.r. spectra were recorded at 25.16 MHz with a Varian XL-100-15 Fourier-transform spectrometer and an internal deuterium lock. Mass spectra (70 eV) were recorded with an AEI MS-902 instrument. Microanalyses were performed in the Microanalytical Laboratory of the Institute.

*Penta-*O*-acetyl-*D*-galactose* N*-acetyl*-N,N′*-diphenylformazan* (**1**). — Penta-*O*-acetyl-D-galactose *N,N′*-diphenylformazan (**2**; 14.5 g, 25 mmol) was added to a mixture of trifluoroacetic acid (20 ml) and acetic anhydride (230 ml). After storage for 5 h at room temperature, the mixture was poured into ice–water (2 l). The amorphous precipitate was treated repeatedly with water to give reddish-brown, crude **1** (13.5 g, 87%), m.p. 156–158°. Recrystallization from ethanol (160 ml) yielded brick-red needles (11.1 g, 71%), m.p. 171°; lit.[1] m.p. 170°.

*2,5-Anhydro-*D*-talose* N,N′*-diphenylformazan* (**4**). — (*a*) To a solution of **1** (11 g, 17.6 mmol) in dry chloroform (40 ml) and dry methanol (40 ml) was added dry, methanolic 2M sodium methoxide (10 ml, 20 mmol) in 3 portions during 3 h. The mixture was stored for 12 h, made neutral with dry Amberlite IR-120(H^+) resin, and filtered, and the solvents were evaporated *in vacuo*. The residue was dissolved in boiling ethanol and water (9:1, 50 ml), and then mixed with water (25 ml) to afford red needles of **4** (3.2 g, 50.4%), m.p. 162–163°. Recrystallization from ethanol and water (2:1, 45 ml) yielded the pure product (2.5 g, 40.5%), m.p. 172–173°; lit.[1] m.p. 173°.

(*b*) A solution of 3,4,6-tri-*O*-acetyl-2,5-anhydro-D-talose *N,N′*-diphenylformazan (**5**; 0.24 g, 0.5 mmol) in dry methanol (3 ml) and chloroform (3 ml) was treated with methanolic M sodium methoxide (0.08 ml, 0.08 mmol) for 2 h. T.l.c. (carbon tetrachloride–ethyl acetate, 6:4) then revealed no starting material. A few drops of acetic acid were added to the mixture, the solvent was evaporated *in vacuo*, and the residue was recrystallized from an ethanol–water mixture, as in (*a*), to give red needles of **4** (0.15 g, 85%), m.p. 171° alone or in admixture with the product from (*a*).

*3,4,6-Tri-*O*-acetyl-2,5-anhydro-*D*-talose* N,N′*-diphenylformazan* (**5**). — (*a*) A solution of **2** (1.75 g, 3 mmol) in dry methanol–chloroform was treated overnight with an excess of sodium methoxide (3.6 mmol) as described above. T.l.c. (ether–ethyl acetate–carbon tetrachloride–1,4-dioxane, 3:3:2:2) then showed only **4** to be present.

The mixture was made neutral with Amberlite IR-120(H^+) resin and then filtered, and the solvents were evaporated. The red residue was treated with acetic anhydride (3 ml) in pyridine (5 ml) for 2 days at ~5°. The mixture was worked-up in the usual manner, and the crude product was eluted from acidic alumina (Woelm)

with benzene–ethyl acetate (8:2) to afford red crystals of **5** (0.29 g, 20%), m.p. 151–152°; lit.[1] m.p. 152–154°.

(*b*) To a solution of toluene-*p*-sulphonyl chloride (0.22 g, 1.1 mmol) in dry pyridine (2 ml) was added a solution of **4** (0.36 g, 1 mmol). The mixture was kept for 2 h at 0° and then for 24 h at room temperature. T.l.c. (carbon tetrachloride–ethyl acetate–1,4-dioxane, 6:2:2) then showed only **4**. After the addition of acetic anhydride (4 ml) and pyridine (3 ml), the mixture was stored for 2 days at 0°, and then worked-up as described above; the product was recrystallized from ethanol to give **5** (0.4 g, 83%) as red needles, m.p. 152° alone or in admixture with an authentic sample.

*2,5-Anhydro-*D*-thiotalonic acid phenylhydrazide* (**6**). — Hydrogen sulphide was passed through a solution of **4** (10 g, 27.5 mmol) in warm ethanol (1 litre) for 1 h. The mixture was kept for 4 days at room temperature and then concentrated to dryness, and the residue was treated with cold ethanol (5 ml) to give crude **6**. Crystallization from ethanol (150 ml) gave yellowish-white crystals (4.65 g, 60%), m.p. 164–165°. Recrystallization from ethanol (110 ml) afforded **6** (3.7 g, 48%), m.p. 167–168°, $[\alpha]_D$ +57° (*c* 0.6, pyridine).

Anal. Calc. for $C_{12}H_{16}N_2O_4S$: C, 50.69; H, 5.66; N, 9.85; S, 11.28. Found: C, 50.25; H, 5.84; N, 10.04; S, 11.21.

*5-α-*D*-Lyxofuranosyl-2,3-diphenyl-1,3,4-thiadiazoline* (**7**). — A solution of freshly distilled benzaldehyde (0.24 g, 2.3 mmol) and **6** (0.6 g, 2.1 mmol) in 0.25% ethanolic hydrogen chloride (0.6 ml) was heated on a water bath for 1 min, cooled, and then mixed with ethanol (3 ml) to afford white needles of **7** (0.1 g, 12.7%), m.p. 146–147°, $[\alpha]_D$ −298 → +136.5° (*c* 0.6, ethanol–water, 24:1).

Anal. Calc. for $C_{19}H_{20}N_2O_4S$: C, 61.27; H, 5.41; N, 7.52; S, 8.61. Found: C, 61.00; H, 5.30; N, 7.26; S, 8.65.

*5-α-*D*-Lyxofuranosyl-2,3-diphenyltetrazolium bromide* (**8**). — To a solution of **4** (3 g, 8.2 mmol) in ethyl acetate (350 ml) was added a solution of *N*-bromosuccinimide (3.6 g, 20 mmol) in ethyl acetate (90 ml). The red colour of the solution disappeared in 30 min, and a light-yellow product precipitated. After 3 h, the crystals were collected, washed with ethyl acetate, and recrystallized from ethanol (170 ml) to give **8** as white crystals (2.6 g, 71%), m.p. 226°, $[\alpha]_D$ +47° (*c* 0.54, ethanol).

Anal. Calc. for $C_{18}H_{19}BrN_4O_4$: C, 49.67; H, 4.40; N, 12.87; Br, 18.36. Found: C, 49.51; H, 4.58; N, 13.14; Br, 17.70.

Conventional treatment of **8** with pyridine–acetic anhydride gave the triacetate **9** (95%), m.p. 209–210° (from ethyl acetate), $[\alpha]_D$ +51° (*c* 0.47, ethanol).

Anal. Calc. for $C_{24}H_{25}BrN_4O_7$: C, 51.35; H, 4.49; N, 9.98; Br, 14.22; Ac, 23.00. Found: C, 51.20; H, 4.56; N, 9.41; Br, 13.72; Ac, 23.18.

*2,3,4,5-Tetra-*O*-acetyl-*D*-fucose phenylhydrazone* (**12**). — Conventional treatment of D-fucose phenylhydrazone[5] (**11**; 0.8 g, 3.15 mmol) with acetic anhydride (3 ml) and pyridine (5 ml) at 0° for 2 days, with recrystallization of the crude product (1.25 g, 94%) from ethanol, gave white crystals of **12** (0.85 g, 64%), m.p. 142–144°, $[\alpha]_D$ +32° (*c* 1, ethanol–water, 24:1); ν_{max}^{KBr} 3285 (NH), 1750, and 1720 cm^{-1} (AcO).

Anal. Calc. for $C_{20}H_{26}N_2O_8$: C, 56.86; H, 6.20; N, 6.64; Ac, 40.76. Found: C, 56.35; H, 6.21; N, 6.69; Ac, 40.89.

D-*Fucose* N,N'-*diphenylformazan* (**13**). — A solution of D-fucose phenylhydrazone[5] (**11**; 9.84 g, 39 mmol) in pyridine (100 ml), ethanol (40 ml), and water (40 ml) was stirred at 0° with a solution of benzenediazonium chloride [prepared from aniline (4.65 g, 50 mmol) and dilute hydrochloric acid (1 : 1, 25 ml) in the usual manner] for 30 min and then at room temperature for 30 min. Treatment of the red solution with ice–water then afforded a red mass (10.5 g, 76%). Recrystallization of a sample (2 g) from propan-2-ol gave **13** (0.9 g), m.p. 163°.

Anal. Calc. for $C_{18}H_{22}N_4O_4$: C, 60.32; H, 6.19; N, 15.63. Found: C, 60.74; H, 6.28; N, 16.33.

Conventional treatment of **13** with pyridine–acetic anhydride gave the tetraacetate **14** (72%) as red crystals, m.p. 172–174° (from ethanol), ν_{max}^{KBr} 1730 cm^{-1} (AcO).

Anal. Calc. for $C_{26}H_{30}N_4O_8$: C, 59.30; H, 5.74; N, 10.64; Ac, 32.70. Found: C, 58.90; H, 5.32; N, 10.53; Ac, 31.80.

2,3,4,5-Tetra-O-*acetyl*-D-*fucose* N-*acetyl*-N,N'-*diphenylformazan* (**15**). — Compound **14** (8.2 g, 15.6 mmol) was treated with acetic anhydride (150 ml) and trifluoroacetic acid (13 ml) for 7 h at room temperature. The mixture was poured into ice–water, and the brick-red, crude product (8.5 g, 96%), m.p. 172–174°, was crystallized from 90% ethanol (130 ml) to afford **15** (6.8 g, 76.7%), m.p. 178–180°; ν_{max}^{KBr} 1750, 1735 (OAc), and 1704 cm^{-1} (NAc).

Anal. Calc. for $C_{28}H_{32}N_4O_9$: C, 59.15; H, 5.68; N, 9.85; Ac, 37.85. Found: C, 59.55; H, 5.78; N, 9.77; Ac, 36.50.

2,5-Anhydro-6-deoxy-D-*talose* N,N'-*diphenylformazan* (**22**). — (*a*) To a solution of **15** (3.42 g, 6 mmol) in dry methanol (8 ml) and chloroform (7 ml) was added methanolic M sodium methoxide (7 ml). The solution was kept for 7 h, made neutral with Amberlite IR-120(H^+) resin, and filtered. The solvents were evaporated, and the residue was treated with boiling 90% ethanol (10 ml) and water (2 ml) to give red crystals of **22** (0.67 g, 32.7%), m.p. 175–176°.

Anal. Calc. for $C_{18}H_{20}N_4O_3$: C, 63.51; H, 5.92; N, 16.46. Found: C, 63.14; H, 6.03; N, 16.12.

Conventional treatment of **22** with pyridine–acetic anhydride afforded red needles of the diacetate **23** (56%), m.p. 155–156° (from methanol–water), ν_{max}^{KBr} 1735 cm^{-1} (AcO).

Anal. Calc. for $C_{22}H_{24}N_4O_5$: C, 62.25; H, 5.70; N, 13.20; Ac, 20.28. Found: C, 62.18; H, 5.85; N, 13.09; Ac, 20.09.

(*b*) Compound **23** (0.21 g, 0.5 mmol) was deacetylated with a catalytic amount of sodium methoxide in dry methanol–chloroform (1 : 1, 6 ml) to afford, after recrystallization as in (*a*), **22** (0.14 g, 84%), m.p. 177° alone or in admixture with the product from (*a*). T.l.c. (carbon tetrachloride–ethyl acetate, 6 : 4) showed the products from (*a*) and (*b*) to be homogeneous.

6-Azido-6-deoxy-D-*galactose phenylhydrazone* (**17**). — A solution of phenylhydrazine hydrochloride (3.6 g, 25 mmol) and sodium acetate (4 g) in water (40 ml)

was added to a solution of 6-azido-6-deoxy-D-galactose[6] (**16**; 4.1 g, 20 mmol) in water (50 ml). The white crystals (5.35 g, 91%; m.p. 157–159°) that separated after a few minutes were collected, and recrystallized from ethanol (210 ml) to give **17** (4.0 g, 68%), m.p. 162–164°, $[\alpha]_D$ +5° (*c* 1, pyridine), ν_{max}^{KBr} 2100 cm^{-1} (N_3).

Anal. Calc. for $C_{12}H_{17}N_5O_4$: C, 48.81; H, 5.79; N, 23.72. Found: C, 48.99; H, 6.00; N, 23.32.

Conventional treatment of **17** with pyridine–acetic anhydride gave the tetra-acetate **18** (57%), m.p. 129–130° (from ethanol), $[\alpha]_D$ +50° (*c* 1, ethanol–water, 24:1); ν_{max}^{KBr} 3320 (NH), 2115 (N_3), and 1735 cm^{-1} (AcO).

Anal. Calc. for $C_{20}H_{25}N_5O_8$: C, 51.83; H, 5.43; N, 15.11. Found: C, 51.40; H, 5.48; N, 14.90.

*6-Azido-6-deoxy-*D*-galactose* N,N'-*diphenylformazan* (**19**). — A solution of benzenediazonium chloride [prepared from aniline (2.3 g, 25 mmol), conc. hydrochloric acid (6.5 ml), and sodium nitrite (1.75 g) in water (10 ml)] was stirred into a solution of **17** (6 g, 20 mmol) in pyridine (30 ml), ethanol (15 ml), and water (15 ml) at 0°. The mixture was stirred for 30 min at 0° and 30 min at room temperature, and then saturated with ice–water to precipitate a red solid (7.7 g, 95%), m.p. 145–148°. Recrystallization from acetonitrile (1.5 l) gave red crystals of **19** (4.7 g, 58%), m.p. 176°, ν_{max}^{KBr} 2110 cm^{-1} (N_3).

Anal. Calc. for $C_{18}H_{21}N_7O_4$: C, 54.13; H, 5.30; N, 24.55. Found: C, 53.80; H, 5.54, N, 23.72.

Conventional treatment of **19** with pyridine–acetic anhydride gave red crystals of the tetra-acetate **20** (78%), m.p. 141–142° (from 90% ethanol), ν_{max}^{KBr} 2110 (N_3) and 1735 cm^{-1} (AcO).

Anal. Calc. for $C_{26}H_{29}N_7O_8$: C, 55.02; H, 5.16; N, 17.28. Found: C, 55.09; H, 5.40; N, 16.57.

*2,3,4,5-Tetra-*O*-acetyl-6-azido-6-deoxy-*D*-galactose* N-*acetyl*-N,N'-*diphenylformazan* (**21**). — Treatment of **20** with acetic anhydride and trifluoroacetic acid, as described above for **15**, yielded brick-red crystals of **21** (1.44 g, 79%), m.p. 172–173° (from 85% ethanol); ν_{max}^{KBr} 2120 (N_3), 1740 (AcO), and 1695 cm^{-1} (AcN).

Anal. Calc. for $C_{28}H_{31}N_7O_9$: C, 55.17; H, 5.13; N, 16.08; Ac, 35.31. Found: C, 55.49; H, 5.51; N, 16.31; Ac, 35.00.

*2,5-Anhydro-6-azido-6-deoxy-*D*-talose* N,N'-*diphenylformazan* (**24**). — (*a*) To a solution of **21** (1.22 g, 2 mmol) in dry methanol (8 ml) and chloroform (7 ml) was added methanolic M sodium methoxide (2.1 ml, 2.1 mmol) during 2 h. After storage of the mixture for 5 h at room temperature, red crystals (0.3 g) separated. Treatment of the mother liquor with Amberlite IR-120(H^+) resin gave an additional crop (0.1 g) of the product. Recrystallisation from methanol gave **24** (0.32 g, 42%), m.p. 201°, ν_{max}^{KBr} 2100 cm^{-1} (N_3).

Anal. Calc. for $C_{18}H_{19}N_7O_3$: C, 56.68; H, 5.02; N, 25.71. Found: C, 56.79; H, 5.12; N, 24.98.

Conventional treatment of **24** with pyridine–acetic anhydride gave the diacetate **25** (74%), m.p. 116–117° (from 80% ethanol), ν_{max}^{KBr} 2100 (N_3) and 1738 cm^{-1} (OAc).

Anal. Calc. for $C_{22}H_{23}N_7O_5$: C, 56.77; H, 4.98; N, 21.06; Ac, 18.50. Found: C, 56.75; H, 5.50; N, 21.16; Ac, 18.90.

(*b*) A solution of **20** (0.28 g, 0.5 mmol) in dry methanol (5 ml) and chloroform (3 ml) was treated with methanolic M sodium methoxide (0.7 ml, 0.7 mmol) in several portions during 2 h, and the mixture was stored overnight at ~0°. The resulting red needles (40 mg, 21%), m.p. 194–196°, were recrystallized from 80% methanol (4 ml) to give **24** (35 mg, 19%), m.p. 201°, which was identical with the product from (*a*).

(*c*) Zemplén deacetylation of **25** (0.23 g, 0.5 mmol) gave red needles of **24** (0.18 g, 90%), m.p. 199°. Recrystallization from 80% methanol (10 ml) afforded material (0.16 g, 84%), m.p. 201° alone or in admixture with the product from (*a*).

*2,5-Anhydro-3,4-*O*-isopropylidene-*D*-talose* N,N′*-diphenylformazan* (**26**).—Compound **4** (1.1 g, 3.1 mmol) was added to a solution of freshly prepared, dry zinc chloride (0.9 g) in acetone (15 ml). Conc. sulphuric acid (2 drops) was added and the suspension was shaken for 3 h. T.l.c. (carbon tetrachloride–1,4-dioxane–ethyl acetate, 6:2:2) then showed that no **4** remained. The acid was neutralized with aqueous sodium carbonate (0.8 g), and the filtered solution was treated with water to yield red crystals of the crude product (1.1 g, 88%), m.p. 165°. Recrystallization from 90% ethanol yielded **26** (0.83 g, 68%), m.p. 166–167°, λ_{max}^{EtOH} 459 nm.

Anal. Calc. for $C_{21}H_{24}N_4O_4$: C, 63.62; H, 6.10; N, 14.13. Found: C, 63.28; H, 6.31; N, 14.35.

Conventional treatment of **26** with pyridine–acetic anhydride gave red needles of the acetate **27** (90%), m.p. 178–180° (from ethanol), ν_{max}^{KBr} 1740 cm^{-1} (AcO).

Anal. Calc. for $C_{23}H_{26}N_4O_5$: C, 63.00; H, 5.98; N, 12.78; Ac, 9.82. Found: C, 62.91; H, 5.87; N, 12.16; Ac, 9.65.

*2,5-Anhydro-6-*O*-toluene-*p*-sulphonyl-*D*-talose* N,N′*-diphenylformazan* (**28**).—To a solution of **4** (0.72 g, 2 mmol) in dry pyridine (5 ml) was added a solution of toluene-*p*-sulphonyl chloride (1 g, 5.2 mmol) in dry pyridine (10 ml) at 0°. The mixture was stored for 2 h at 0°, and then poured into ice–water to precipitate a red solid (0.75 g) that was shown by t.l.c. (carbon tetrachloride–1,4-dioxane–ethyl acetate, 6:2:2) to contain **4**, **28**, and two other formazans. The crude product was treated with cold ethyl acetate to separate the main product **28** (0.35 g, 34%) from impurities. Pure **28** has m.p. 156–158°, but is not definitely crystalline; λ_{max}^{EtOH} 453 nm; ν_{max}^{KBr} 1360 and 1170 cm^{-1} (SO_2).

Anal. Calc. for $C_{25}H_{26}N_4O_6S$: C, 58.81; H, 5.13; N, 10.97; S, 6.28. Found: C, 59.60; H, 5.21; N, 10.42; S, 6.94.

Conventional treatment of **28** with pyridine–acetic anhydride gave **29** (92%) as red, amorphous material that was homogeneous by t.l.c. (carbon tetrachloride–ethyl acetate–1,4-dioxane, 6:2:2); λ_{max}^{EtOH} 456 nm; ν_{max}^{KBr} 1738 (AcO), 1370, and 1170 cm^{-1} (SO_2).

Anal. Calc. for $C_{29}H_{30}N_4O_8S$: C, 58.57; H, 5.08; N, 9.42; S, 5.39; Ac, 14.48. Found: C, 59.16; H, 5.52; N, 9.13; S, 5.79; Ac, 15.39.

*2,5-Anhydro-3,4-*O*-isopropylidene-6-*O*-toluene-*p*-sulphonyl-*D*-talose* N,N′*-di-*

phenylformazan (**30**). — To a solution of **26** (0.4 g, 1 mmol) in pyridine (5 ml) was added a solution of toluene-*p*-sulphonyl chloride (0.5 g, 2.6 mmol) in pyridine (5 ml). The mixture was kept at 60° for 2 h and then poured into ice–water. The red precipitate (0.4 g, 72%), m.p. 185–187°, was recrystallized from propan-2-ol to give red needles of **30** (0.25 g, 45%), m.p. 189–190°, λ_{max}^{EtOH} 460 nm, ν_{max}^{KBr} 1360 and 1170 cm^{-1} (SO_2).

Anal. Calc. for $C_{28}H_{30}N_4O_6S$: C, 61.07; H, 5.49; N, 10.18; S, 5.82. Found: C, 61.00; H, 5.71; N, 10.37; S, 5.83.

*3,4,5,6-Tetra-O-acetyl-2-deoxy-*D-lyxo-*hexose* N,N′-*diphenylformazan* (**34**). — (*a*) A solution of 3,4,5,6-tetra-*O*-acetyl-2-deoxy-D-*lyxo*-hexose (1.3 g, 3.7 mmol) and phenylhydrazine (0.6 g, 5.5 mmol) in ethanol (15 ml) and water (15 ml) was kept at 60° for 4 h and then at room temperature for 20 h. Pyridine (20 ml) was added, and the solution was treated at −5° with a solution of benzenediazonium chloride prepared from aniline (1.86 g), hydrochloric acid (1:1, 10 ml), and sodium nitrite (1.5 g). The red mixture was stirred at 0° for 30 min and at room temperature for 30 min, poured into ice–water, and extracted with several portions of dichloromethane. The combined extracts were washed successively with dilute hydrochloric acid, aqueous sodium hydrogen carbonate, and water, dried ($MgSO_4$), and concentrated to give a red syrup. P.l.c. (acidic alumina; benzene–ethyl acetate, 96:4) afforded pure **34** as a red syrup, λ_{max}^{EtOH} 422 nm. Mass spectrum: *m/e* 526 (M^+, $C_{26}H_{30}N_4O_8$).

(*b*) A solution of **34** (0.51 g, 1 mmol) in dry methanol (5 ml) was treated with methanolic M sodium methoxide (0.1 ml, 0.1 mmol) at room temperature for 30 min. T.l.c. (ether–ethyl acetate, 1:1) then showed that no **34** remained; the mixture was still alkaline. The solution was made neutral with Amberlite IR-120(H^+) resin and filtered, and the solvents were evaporated. Repeated p.l.c. (ether–ethyl acetate, 1:1) of the residue afforded a sample of pure 2-deoxy-D-*lyxo*-hexose *N,N′*-diphenylformazan (**35**; 0.1 g, 29%) as a red syrup.

Treatment of **35** (0.1 g) with acetic anhydride (1 ml) and pyridine (1 ml) at 0° for 2 days, with conventional work-up of the mixture, gave a red syrup (0.1 g, 67%) that was identical with **34** according to t.l.c. (benzene-ethyl acetate, 9:1), u.v., and m.s. data.

ACKNOWLEDGMENTS

We thank Dr. J. Tamas for the mass spectra, and Dr. Eva Boromissza for the microanalyses.

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