ENAMINES DERIVED FROM 3,4,6-TRI-*O*-ACETYL-2-AMINO-2-DEOXY-α-D-GLUCOPYRANOSE AND β-DICARBONYL COMPOUNDS. A SYNTHESIS OF 3,4,6-TRI-*O*-ACETYL-2-AMINO-2-DEOXY-α-D-GLUCOPYRANOSE

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ABSTRACT

Reactions of 1,3,4,6-tetra-*O*-acetyl-2-amino-2-deoxy-β-D-glucopyranose with 2,4-pentanedione and 1-phenyl-1,3-butanedione yielded 1,3,4,6-tetra-*O*-acetyl-2-[(2-acetyl-1-methylvinyl)amino]-2-deoxy-β-D-glucopyranose (**4**) and 1,3,4,6-tetra-*O*-acetyl-2-[(2-benzoyl-1-methylvinyl)amino]-2-deoxy-β-D-glucopyranose (**5**), respectively. Similar reaction with benzoylacetaldehyde gave 1,3,4,6-tetra-*O*-acetyl-[(2-benzoylvinyl)amino]-2-deoxy-β-D-glucopyranose as a mixture of the two geometrical isomers (**6**) and (**9**), from which the chelated *cis*-isomer **6** was isolated.

When compounds **4–6**, and the related enamine 1,3,4,6-tetra-*O*-acetyl-2-deoxy-2-[(2,2-diethoxycarbonylvinyl)amino]-β-D-glucopyranose (**3**) were treated with catalytic amounts of barium methoxide in methanol at 0°, *O*-deacetylation at C-1 and inversion of this centre occurred; enamines **12–15** derived from 3,4,6-tri-*O*-acetyl-2-amino-2-deoxy-α-D-glucopyranose and β-dicarbonylic compounds were thus obtained. Hydrolysis of these tri-*O*-acetylated enamines with hydrochloric acid afforded 3,4,6-tri-*O*-acetyl-2-amino-2-deoxy-α-D-glucopyranose hydrochloride (**16**), which was further transformed into the corresponding free base by treatment with triethylamine or sodium acetate. Similarly, *O*-deacetylation, under the same conditions, of the α-D anomers (**7** and **8**) of the keto-enamine derivatives **4** and **5** occurred selectively at C-1 with retention of configuration, giving 3,4,6-tri-*O*-acetyl-2-[(2-acetyl-1-methylvinyl)-amino]-2-deoxy-α-D-glucopyranose (**12**) and 3,4,6-tri-*O*-acetyl-2-[(2-benzoyl-1-methylvinyl)amino]-2-deoxy-α-D-glucopyranose (**13**).

Treatment of the β-D anomer **4** with barium methoxide under more drastic conditions resulted in a complex reaction, the main products being 2-[(2-acetyl-1-methylvinyl)amino]-2-deoxy-α-D-glucopyranose (**1a**, $R^3 = R^5 = Me$, $R^4 = H$), and its cyclization product 3-acetyl-5-(D-*arabino*-tetrahydroxybutyl)-2-methylpyrrole (**17**).

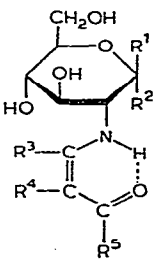
INTRODUCTION

The reactions of 2-amino-2-deoxy-D-glucose with β-dicarbonyl compounds[1–3] and with enol ethers of some β-dicarbonyl compounds (diethyl ethoxymethylene-

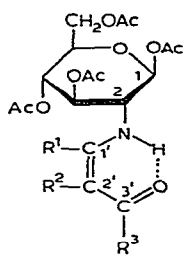
malonate[4] and ethyl ethoxymethylenecyanoacetate[5]) produce enamines (**1a**) having the α-D anomeric configuration. The corresponding β-D anomers (**1b**) have not been obtained even when 2-amino-2-deoxy-β-D-glucopyranose[3–5] was used as starting material. However, 1,3,4,6-tetra-*O*-acetyl derivatives of **1b** (for example, compounds **2** and **3**) were easily obtained by direct reaction of 1,3,4,6-tetra-*O*-acetyl-2-amino-2-deoxy-β-D-glucopyranose with acetoacetic esters[3] and with diethyl ethoxymethylenemalonate[4]. In continuation of these studies, other enamines (**4–6**) derived from 1,3,4,6-tetra-*O*-acetyl-2-amino-2-deoxy-β-D-glucopyranose and β-dicarbonyl compounds have been prepared. Tetra-*O*-acetylated enamines (**3–6**), when submitted to the Zemplén *O*-deacetylation conditions, gave unexpected results that are also the subject-matter of this paper.

RESULTS AND DISCUSSION

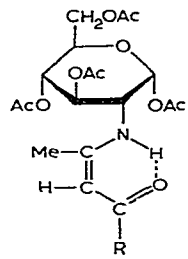
Enamines **3–6**, having the β-D configuration, and enamines **7** and **8**, with the α-D configuration, were used in this investigation. Compounds **3**, **7**, and **8** were prepared as previously described[1–4]. New compounds (**4–6**) were obtained in yields of 40–60% by reaction of 1,3,4,6-tetra-*O*-acetyl-2-amino-2-deoxy-β-D-glucopyranose with the appropriate β-dicarbonyl compound (2,4-pentanedione, 1-phenyl-1,3-butanedione, benzoylacetaldehyde) in *p*-dioxane. When reactions were performed with the hydrochloride of the amino sugar in *p*-dioxane containing triethylamine, the yields of enamines were lower.



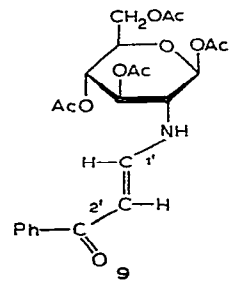
	R^1	R^2
1a	H	OH
1b	OH	H



	R^1	R^2	R^3
2	Me	H	OMe
3	H	CO_2Et	OEt
4	Me	H	Me
5	Me	H	Ph
6	H	H	Ph



7 R = Me
8 R = Ph



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The physical properties of the derivatives (**4** and **5**, respectively) of 2,4-pentanedione and 1-phenyl-1,3-butanedione were consistent with the proposed structures. The i.r. spectra in the 3500–1500 cm^{-1} region were very similar to those[1,2] of the corresponding α-D anomers (**7** and **8**) and showed the anticipated bathochromic displacements of the N-H and C=O bands due to the presence of the mesomeric, chelated, enamine system. The p.m.r. spectra (Table I) had the features typical of intramolecularly bonded ketoenamines[6], and were very similar to those[2] of com-

pounds **7** and **8**. The β-D anomeric configurations were confirmed by the $J_{1,2}$ values and by the positions of the H-1 signals at higher fields than those of the α-D anomers **7** and **8**. The optical rotations, although rather high, were significantly lower than those[1,2] corresponding to the α-D anomers **7** and **8**.

The reaction of 1,3,4,6-tetra-*O*-acetyl-2-amino-2-deoxy-β-D-glucopyranose with benzoylacetaldehyde gave a mixture of the chelated *cis*-isomer **6** and the *trans*-form **9**. The i.r. spectrum (Nujol) of this mixture showed bands at 3226 and 1658 cm^{-1}, assigned as the N-H and C=O vibrations of the *trans*-form **9**, and bands at 3165 and 1631 cm^{-1}, assigned as the same vibration modes of the chelated *cis*-form **6**. Similarly, the p.m.r. spectrum in chloroform-*d* showed two sets of signals. In the set of higher intensity, due to the *cis*-form **6**, the doublet ($J_{1',2'}$ 8.0 Hz) at δ 5.76 p.p.m. was assigned to H-2′, the quartet ($J_{1',2'}$, $J_{NH,1'}$ 11.5 Hz) at 6.85 to H-1′, and the triplet ($J_{NH,1'}$, $J_{NH,2}$ 10.0 Hz) at 10.02 to the N-H proton which is almost equally coupled with H-1′ and H-2. In the second set of signals, attributable to the *trans*-form **9**, the doublet ($J_{1',2'}$ ~13 Hz) at δ 6.01 p.p.m. was assigned to H-2′, and the very broad triplet ($J_{NH,1'} \simeq J_{NH,2} \simeq 10$ Hz) at 6.18 to the non-bonded N-H; the signal corresponding to H-1′, which was not apparent in the spectrum, was overlapped by the multiplet due to the phenyl group. The two isomers **6** and **9** differed also in the chemical shifts of H-1, H-2, H-3, and H-4, the signals coming from the *trans*-isomer **9** appearing at lower fields. The values of $J_{1,2}$ observed in both isomers confirmed the β-D anomeric configurations, and integration of the spectrum indicated that the *cis*- and *trans*-isomers were in the ratio *ca.* 5:2. The i.r. spectra of this mixture in chloroform solutions showed that the *cis–trans* ratio was dependent of the concentration, the equilibrium being shifted towards the *cis*-form in dilute solutions. Thus, the spectrum of a 1% solution showed a strong C=O band at 1636 cm^{-1} due to the *cis*-isomer **6**, and a weak shoulder at 1655 cm^{-1} corresponding to the same vibration of the *trans*-form **9**. Treatment of this solution with light petroleum afforded the *cis*-isomer **6**, as indicated by the p.m.r. spectrum which showed only the signals of the *cis*-form. Attempts to isolate the *trans*-isomer **9** were unsuccessful. It was observed that the relative proportion of this isomer was increased by recrystallization of the mixture from ethanol; however, the richest preparations of **9** still showed appreciable i.r. absorption due to the *cis* form **6**.

The p.m.r. spectra of compounds **5**, **6**, and **9**, and their close similarities with the spectra of other derivatives of analogous structures obtained in the reactions of 2-amino-2-deoxy-D-glucose[2] and glycosylamines[7] with 1-phenyl-1,3-butanedione and with benzoylacetaldehyde allowed elimination of the alternative structures **10** and **11** which could also be considered for the reaction products of 1,3,4,6-tetra-*O*-acetyl-2-amino-2-deoxy-β-D-glucopyranose with these unsymmetrical β-dicarbonyl compounds.

When either the α-D or β-D anomeric forms (**7** and **4**, and **8** and **5**, respectively) of the *O*-acetylated enamines derived from 2,4-pentanedione and 1-phenyl-1,3-butanedione were treated with catalytic amounts of barium methoxide in methanol at 0°, *O*-deacetylation at C-1 occurred, accompanied by inversion of this centre when

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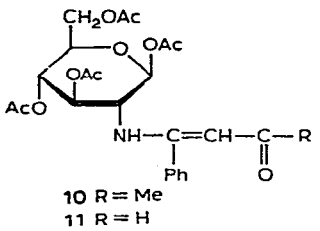
TABLE I

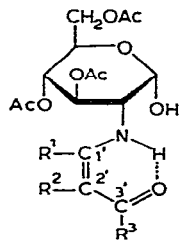
CHEMICAL SHIFTS (δ, P.P.M.) AND COUPLING CONSTANTS (Hz) OF COMPOUNDS **4–6**, AND **9** AT 100 MHz IN CHLOROFORM-*d*

Substance	*N-H*	*H-1'*	*H-2'*	*H-1*	*H-2*	*H-3*	*H-4*	*H-5*	*H-6a*	*H-6b*	*Me-1', Me-3', and OAc*
4	10.66d[a] $J_{NH,2}$ 11.0		4.99	5.64d $J_{1,2}$ 8.8	3.75q $J_{2,3}$ ~10	5.22t $J_{3,4}$ ~9.5	5.07t $J_{4,5}$ ~9.5	3.08m $J_{5,6a}$ 4.2 $J_{5,6b}$ 2.0	4.35q $J_{6a,6b}$ −12.4	4.08q	1.97, 1.98[b], 2.02, 2.08[b]
5[c]	11.31d $J_{NH,2}$ 11.0		5.70	5.70d $J_{1,2}$ 8.6	3.85q $J_{2,3}$ ~9	5.27t $J_{3,4}$ ~9	5.12t $J_{4,5}$ ~9	~3.9m $J_{5,6a}$ 4.0 $J_{5,6b}$ 2.3	4.38q $J_{6a,6b}$ −12.5	4.10q	1.98, 2.02, 2.08[b], 2.12
6[c]	10.02t $J_{NH,2}$ 10.0 $J_{NH,1'}$ 11.5	6.85q $J_{1',2'}$ 8.0	5.76d	5.78d $J_{1,2}$ 8.6	3.36q $J_{2,3}$ 9.6	5.35t $J_{3,4}$ 9.1	5.12t $J_{4,5}$ 9.3	3.89m $J_{5,6a}$ 4.6 $J_{5,6b}$ 2.2	4.34q $J_{6a,6b}$ −12.4	4.11q	2.04, 2.05, 2.10, 2.11
9[c]	6.18t $J_{NH,2}$ 10.0 $J_{NH,1'}$ ~10		6.01d $J_{1',2'}$ ~13	5.83d $J_{1,2}$ 8.6	3.61q $J_{2,3}$ ~9	5.38t $J_{3,4}$ ~9	5.16t $J_{4,5}$ ~10	~3.9m $J_{5,6a}$ 4.8 $J_{5,6b}$ 2.2	4.34q $J_{6a,6b}$ −12.4	4.11q	2.04, 2.05, 2.10, 2.11

[a]Peak multiplicities: d, doublet; m, multiplet; q, quartet; t, triplet. The absence of any indication implies that a singlet was observed. [b]Signal of intensity six. [c]This substance also showed multiplets at δ ~7.4 and ~7.85 p.p.m. due to the aromatic protons.



10 R = Me
11 R = H



	R¹	R²	R³
12	Me	H	Me
13	Me	H	Ph
14	H	CO_2Et	OEt
15	H	H	Ph

the β-D anomers were used. Enamines **12** and **13**, derived from 3,4,6-tri-*O*-acetyl-2-amino-2-deoxy-α-D-glucopyranose, were thus obtained in yields of *ca.* 50%. Similar reactions with the β-D anomers **3** and **6** produced compounds **14** and **15**, respectively, having the α-D configuration. Evidence for the structures **12–15** is as follows.

The loss of one acetyl group was deduced from the analytical data, and from the presence in the p.m.r. spectra (Table II) of three singlets at δ *ca.* 2.0 p.p.m., attributable to two equatorial acetoxyl groups and the primary acetoxyl group. The singlet at δ *ca.* 2.3 p.p.m., due to the anomeric, axial, acetoxyl group, shown[2] by starting compounds **7** and **8**, disappeared during the *O*-deacetylation reaction. The presence of one hydroxyl group, the acetyl groups, and the chelated ketoenamine, or enamino ester, structure was deduced from the i.r. spectra and the p.m.r. spectra (Table II). The location of the hydroxyl group on C-1 was deduced from the multiplicity of the H-1 signal; this proton appeared as a triplet or a quartet due to the couplings $J_{1,2}$ (3.0–3.6 Hz) and $J_{OH,1}$ (4.5–5.0 Hz). Treatment of the samples with deuterium oxide removed the OH doublet and caused the collapse of the H-1 multiplet to a doublet. Similar results were obtained by irradiation of the OH proton. When the H-2 sextuplet was irradiated, the H-1 signal became a doublet with the spacing $J_{OH,1}$. The couplings $J_{1,2}$ and the extremely high values of the optical rotations indicated the α-D configurations. In the reaction using derivative **3**, the ethoxycarbonyl groups remained unchanged during the transesterification process, as indicated by the analytical data and the p.m.r. spectrum of the product (**14**) which showed the signals of two non-equivalent CO_2Et groups.

Re-acetylation of compound **12** with acetic anhydride in pyridine at 0° gave the tetra-*O*-acetyl derivative **7** having the α-D configuration.

Hydrolysis of compounds **12**, **13**, and **15** with 5M hydrochloric acid in acetone afforded 3,4,6-tri-*O*-acetyl-2-amino-2-deoxy-α-D-glucopyranose hydrochloride (**16**) in high yields. The spectroscopic properties of this substance were in accordance with this structure. The anomeric configuration and the location of the hydroxyl group on C-1 were again derived from the couplings of H-1 ($J_{1,2}$ 3.3 Hz, $J_{OH,1}$ 4.4 Hz), and was confirmed by deuteration and double-resonance experiments, as indicated for the parent substances **12–15**. No mutarotation was observed for compounds **12–16**. Treatment of the hydrochloride **16** with triethylamine or sodium acetate afforded the corresponding free base also having the α-D anomeric configuration, as indicated by the $J_{1,2}$ (3.2 Hz) and $[\alpha]_{5461}$ (+163°) values.

The deacetylation reaction and subsequent hydrolysis described above using

TABLE II

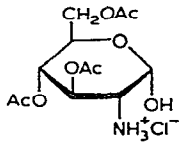
CHEMICAL SHIFTS (δ, P.P.M.) AND COUPLING CONSTANTS (Hz) OF COMPOUNDS **12–15** AT 100 MHz IN CHLOROFORM-*d*

Substance	*N-H*	*H-1'*	*H-2'*	*H-1*	*H-2*	*H-3*	*H-4*	*H-5 H-6a*	*H-6b*	*OH*	*Me-1', Me-3', and OAc*
12	10.96d[a] $J_{NH,2}$ 10.0		4.95	5.16q[b] $J_{1,2}$ 3.3 $J_{1,OH}$ 5.0	3.71sx $J_{2,3}$ 9.3	5.45t $J_{3,4}$ 9.3	5.02t $J_{4,5}$ 9.4	4.25–4.55m	~4.03m	7.86d[c]	1.96[d], 2.01, 2.07
13[e]	11.43d $J_{NH,2}$ 10.0		5.65	5.19t[b] $J_{1,2}$ 3.0 $J_{1,OH}$ ~4.5	3.79sx $J_{2,3}$ 10.0	5.54t $J_{3,4}$ 10.0	5.06 $J_{4,5}$ 10.0	4.25–4.60m	~4.07m	~7.3[f]	1.97, 2.03, 2.07[g]
14[h]	9.07q $J_{NH,2}$ 9.5 $J_{NH,1'}$ 14.0	7.94d		5.39t $J_{1,2}$ 3.6 $J_{1,OH}$ ~4.5	3.50sx $J_{2,3}$ 9.4	5.39t $J_{3,4}$ ~9.5	5.06t $J_{4,5}$ 9.5	4.0–4.4m		5.64d[c]	2.00, 2.03, 2.08
15[e]	10.25q $J_{NH,2}$ 10.0 $J_{NH,1'}$ 12.7	6.92q $J_{1',2'}$ 7.5	5.73d	5.33t $J_{1,2}$ 3.3 $J_{1,OH}$ 4.5	3.99sx $J_{2,3}$ 9.5	5.49t $J_{3,4}$ 9.5	5.05t $J_{4,5}$ 9.5	4.0–4.5m		7.18d[c]	2.00, 2.03, 2.05

[a]Peak multiplicities: d, doublet; m, multiplet; q, quartet; sx, sextuplet; t, triplet. The absence of any indication implies that a singlet was observed. [b]Became a doublet on deuteration. [c]Disappeared on deuteration. [d]Signal of intensity nine. [e]Also showed multiplets at ~7.4 and ~7.85 p.p.m. due to the aromatic protons. [f]Overlapped by the phenyl signals. [g]Signal of intensity six [h]Also showed the following signals due to the non-equivalent CO_2Et groups: 1.26t, 1.33t, and ~4.20m (J 6.9) .

the readily accessible[1] enamine **7** derived from 2,4-pentanedione provide a convenient way of preparing **16** and its corresponding free base, two simple, hitherto unknown, derivatives of 2-amino-2-deoxy-D-glucose.

Treatment of the β-D anomer **4** with barium methoxide in methanol under more drastic conditions (molar ratio of reactants, *ca.* 1:1; room temperature) resulted in a complex reaction, the main products being the fully *O*-deacetylated α-D-enamine (**1a**, $R^3 = R^5 = Me$, $R^4 = H$) (yield, 37%), and its cyclization product[1] 3-acetyl-5-(D-*arabino*-tetrahydroxybutyl)-2-methylpyrrole (**17**) (yield 7%).



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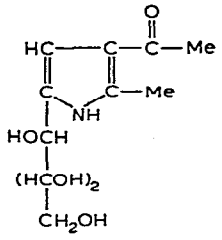

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EXPERIMENTAL

General methods. — Melting points are uncorrected. Solutions were evaporated under diminished pressure below 40°. Identification of products was based on mixed melting points, and comparison of i.r. spectra and chromatographic mobilities. Paper chromatography was performed on Whatman No. 1 paper by the horizontal technique, with butyl alcohol–ethanol–water–ammonia (40:10:49:1, organic phase) as the developer and indication with (*a*) alkaline silver nitrate, for polyhydroxylic compounds, (*b*) aniline hydrogen phthalate, for 2-amino-2-deoxy-D-glucose, or (*c*) *p*-dimethylaminobenzaldehyde–hydrochloric acid (Ehrlich reagent)[1] for enamines and pyrroles. Thin-layer chromatography (t.l.c.) was performed on silica gel (G, Merck), and detection was effected with 50% sulfuric acid and heating. Optical rotations at 5461 Å were determined with a Bendix–Ericsson Type 143C polarimeter. The u.v. spectra were obtained on a Beckman DU spectrophotometer, and the i.r. spectra on a Perkin–Elmer 621 instrument. The p.m.r. spectra were measured on a Varian HA-100 spectrometer, with tetramethylsilane ($\delta = 0$) as the internal standard, and the signal assignments were verified by spin decoupling. Deuteration was performed by adding a few drops of deuterium oxide to the prepared sample.

*1,3,4,6-Tetra-*O*-acetyl-2-[(2-acetyl-1-methylvinyl)amino]-2-deoxy-β-D-glucopyranose* (**4**). — (*a*) To a solution of 2,4-pentanedione (4.0 g, 40 mmoles) in *p*-dioxane (45 ml) was added 1,3,4,6-tetra-*O*-acetyl-2-amino-2-deoxy-β-D-glucopyranose (10.4 g, 30 mmoles). After being shaken until all the solid had dissolved, the reaction mixture was left for 24 h at room temperature. T.l.c. (ether) showed the presence of a single product (**4**, R_F 0.56). Evaporation left a syrup that crystallized upon treatment with a small volume of ethanol; after storage for several hours in the refrigerator, the solid (7.0 g), m.p. 122–128°, was filtered off. The filtrate was poured onto ice yielding a second crop (0.17 g), m.p. 128–130°. The combined solids were recrystallized from

ethanol to yield the title product (5.9 g, 45%), m.p. 143–144°, $[\alpha]_{5461}^{20}$ +166° (*c* 1.0, chloroform); ν_{max} (carbon tetrachloride) 3175 sh-w (chelated NH), 1757 s (OAc), 1618 s cm^{-1} (C=O); p.m.r. data: see Table I.

Anal. Calc. for $C_{19}H_{27}NO_{10}$: C, 53.14; H, 6.34; N, 3.26. Found: C, 53.07; H, 6.50; N, 3.11.

(*b*) To a suspension of 1,3,4,6-tetra-*O*-acetyl-2-amino-2-deoxy-β-D-glucopyranose hydrochloride (1.15 g, 3 mmoles) in *p*-dioxane (20 ml) were added 2,4-pentanedione (0.5 ml, *ca.* 5 mmoles) and triethylamine (0.5 ml). The mixture was shaken for 24 h and filtered, and the filtrate was evaporated. The residual syrup was worked up as indicated under (*a*), yielding compound **4** (0.4 g), m.p. 131–134°. After recrystallization from ethanol, the product (0.33 g, 26%) had m.p. 139–141°, and was identical with the preparation described under (*a*).

*1,3,4,6-Tetra-*O*-acetyl-2-[(2-benzoyl-1-methylvinyl)amino]-2-deoxy-β-D-glucopyranose* (**5**). — This substance was prepared from 1-phenyl-1,3-butanedione and 1,3,4,6-tetra-*O*-acetyl-2-amino-2-deoxy-β-D-glucopyranose, as described under (*a*) for compound **4**. After recrystallization from ethanol, the product (42%) had m.p. 147–148°, $[\alpha]_{5461}^{20}$ +228° (*c* 0.8, chloroform); ν_{max} (carbon tetrachloride) 3180 b-w (chelated NH), 1757 s (OAc), 1605 s cm^{-1} (C=O); p.m.r. data: see Table I.

Anal. Calc. for $C_{24}H_{29}NO_{10}$: C, 58.65; H, 5.95; N, 2.85. Found: C, 58.38; H, 6.05; N, 2.75.

*1,3,4,6-Tetra-*O*-acetyl-2-[(benzoylvinyl)amino]-2-deoxy-β-D-glucopyranose.*—To a solution of benzoylacetaldehyde (6.7 g, 45 mmoles) in *p*-dioxane (50 ml) was added 1,3,4,6-tetra-*O*-acetyl-2-amino-2-deoxy-β-D-glucopyranose (13.5 g, 40 mmoles), and the mixture was shaken until dissolution occurred. After storage for 24 h, the solution was evaporated to yield a crystalline solid that was triturated with a small volume of ethanol and filtered off; yield, 14.5 g; m.p. 182–183°. The filtrate was poured onto ice, affording a second fraction (1.6 g), m.p. 174–175°. The combined products were recrystallized from ethanol to yield 12.1 g (64%) of a mixture of **6** and **9**, m.p. 179–181°, ν_{max} (Nujol) 3225 m and 3165 b-w (NH), 1763 s and 1745 s (OAc), 1658 m and 1631 s cm^{-1} (C=O). The p.m.r. spectrum (chloroform-*d*) showed the signals indicated in Table I for **6** and **9**; the integral value of the spectrum showed that these isomers were in a ratio of *ca.* 5:2.

Anal. Calc. for $C_{23}H_{27}NO_{10}$: C, 57.85; H, 5.70; N, 2.93. Found: C, 58.07; H, 5.61; N, 3.14.

A 1% solution of the above mixture in chloroform was treated with light petroleum (b.p. 50–70°) to yield the cis-isomer **6**, m.p. 192–193°, $[\alpha]_{5461}^{23}$ +164° (*c* 0.4, chloroform); ν_{max} (Nujol) 3168 b-w (chelated NH), 1748 s (OAc), 1660 sh-w (C=O, *trans*-isomer **9**), and 1643 s cm^{-1} (C=O); the p.m.r. data (Table I) showed the signals corresponding to the *cis*-form **6** only.

Anal. Calc. for $C_{23}H_{27}NO_{10}$: C, 57.85; H, 5.70; N, 2.93. Found: C, 57.91; H, 5.90; N, 3.00.

Enamines **12–15***: general procedure.* — A solution of the appropiate tetra-*O*-acetylated enamine (**3–9**) (12 mmoles) in warm, dry, methanol (100 ml) was cooled

in an ice–salt bath. The solute partly crystallized, and to the suspension was added 0.5M methanolic barium methoxide (0.3 ml). Upon shaking, all the solid quickly dissolved, and, in some cases, the product crystallized spontaneously. The reaction mixture was kept at 0° until t.l.c. (ether) of a sample, neutralized with acetic acid, showed that all of the starting material had disappeared (*ca.* 0.5 h). The product was collected, and the mother liquor, after neutralization with Amberlite IR-120 (H^+) resin, was concentrated and refrigerated to afford a second crop. Dilution of the mother liquor with water, followed by refrigeration, afforded an additional crop. The combined fractions were recrystallized from the solvent indicated below for each case. The following compounds were thus obtained:

3,4,6-Tri-*O*-acetyl-2-[(2-acetyl-1-methylvinyl)amino]-2-deoxy-α-D-glucopyranose (**12**), 52% from **7**, 50% from **4**, m.p. 157–158° (dec.) (from ethanol), $[\alpha]_{5461}^{20}$ +478° (*c* 0.5, chloroform); ν_{max} (Nujol) 3190 b-m (OH, NH), 1744 s and 1730 s (OAc), and 1610 s cm^{-1} (C=O); p.m.r. data see Table II.

Anal. Calc. for $C_{17}H_{25}NO_9$: C, 52.71; H, 6.51; N, 3.62. Found: C, 53.00; H, 6.55; N, 3.72.

3,4,6-Tri-*O*-acetyl-2-[(2-benzoyl-1-methylvinyl)amino]-2-deoxy-α-D-glucopyranose (**13**), 50% from **8**, 52% from **5**, m.p. 186–187° (dec.) (from ethanol), $[\alpha]_{5461}^{21}$ +494° (*c* 0.5, chloroform); ν_{max} (Nujol) 3180 b-m (OH, NH), 1743 s (OAc), and 1600 s cm^{-1} (C=O); p.m.r. data: see Table II.

Anal. Calc. for $C_{22}H_{27}NO_9$: C, 58.79; H, 6.06; N, 3.12. Found: C, 58.87; H, 6.01; N, 3.17.

3,4,6-Tri-*O*-acetyl-2-deoxy-2-[(2,2-diethoxycarbonylvinyl)amino]-α-D-glucopyranose (**14**); in the preparation of this substance from **3**, evaporation of the neutralized methanol solution left a syrup that was dissolved in ethanol. Dilution of the filtered solution with 4 volumes of water afforded crystalline **14**. After recrystallization from ethanol–water, the product (49%) had m.p. 124–125°, $[\alpha]_{5461}^{21}$ +191° (*c* 0.5, chloroform); ν_{max} (Nujol) 3340 b-m (OH, NH), 1745 s (OAc), 1698 s and 1686 s (CO_2Et), and 1655 s cm^{-1} (intramolecularly bonded CO_2Et); p.m.r. data: see Table II.

Anal. Calc. for $C_{20}H_{29}NO_{12}$: C, 50.52; H, 6.15; N, 2.95. Found: C, 50.34; H, 6.24; N, 2.78.

3,4,6-Tri-*O*-acetyl-2-[(2-benzoylvinyl)amino]-2-deoxy-α-D-glucopyranose (**15**), 30% from **6**, m.p. 158–163° (dec.) (from methanol), $[\alpha]_{5461}^{23}$ +452° (*c* 0.5, chloroform); ν_{max} (Nujol) 3455 b-m and 3230 b-m (OH, NH), 1740 s (OAc), and 1628 s cm^{-1} (C=O); p.m.r. data: see Table II.

Anal. Calc. for $C_{21}H_{25}NO_9$: C, 57.92; H, 5.79; N, 3.22. Found: C, 57.92; H, 5.84; N, 3.22.

*Acetylation of 3,4,6-tri-*O*-acetyl-2-[(2-acetyl-1-methylvinyl)amino]-2-deoxy-α-D-glucopyranose* (**12**.) — Compound (**12**) (0.15 g) in pyridine (8 ml) was treated with acetic anhydride (4 ml) at 0°. After storage in the refrigerator for 48 h, the mixture was poured onto ice, and the crystalline solid was collected and recrystallized from ethanol. The product (**7**) (0.13 g, 84%), m.p. 172–174°, R_F 0.58 (t.l.c., ether), was identified by comparison with an authentic sample.

Acid hydrolysis of enamines **12**, **13**, *and* **15**: *3,4,6-tri-*O*-acetyl-2-amino-2-deoxy-α-*D*-glucopyranose hydrochloride* (**16**). — A boiling solution of enamine (**12**, **13**, or **15**) (2 mmoles) in acetone (60 ml) was treated with 5M hydrochloric acid (0.5 ml, 2.4 mmoles). Crystallization of the product (**16**) began upon cooling of the reaction mixture, and was completed by dilution with ether (30 ml) and storage in the refrigerator for 0.5 h. The product (**16**), m.p. *ca.* 197° (dec.), was purified by dissolution in the smallest volume of cold methanol and slow addition of ether to the filtered solution. The crystals obtained had m.p. 193–196° (dec.), $[\alpha]_{5461}^{20}$ +144° (*c* 1, water); ν_{max} (Nujol) 3210 b-m (OH), 2735–2532 m (NH_3^+), 1746 s (OAc), 1597–1568 m and 1508 m cm^{-1} (NH_3^+); p.m.r. data (methyl sulfoxide-d_6): δ 1.97 (3-proton singlet, OAc), 2.00 (3-proton singlet, OAc), 2.01 (3-proton singlet, OAc), 7.82 (1-proton doublet, the signal disappeared in the presence of deuterium oxide, $J_{OH,1}$ 4.4 Hz, OH), 8.65 (3-proton singlet, the signal disappeared in the presence of deuterium oxide, NH_3^+), 5.45 (1-proton triplet, becoming a doublet in the presence of deuterium oxide, $J_{1,2}$ 3.3 Hz, H-1), 3.41 (1-proton quartet, $J_{2,3}$ 10.3 Hz, H-2), 5.26 (1-proton triplet, $J_{3,4}$ 8.7 Hz, H-3), 4.89 (1-proton triplet, $J_{4,5}$ 9.4 Hz, H-4), 3.9–4.25 (3-proton multiplet, H-5 and 2 H-6) p.p.m.

Anal. Calc. for $C_{12}H_{20}ClNO_8$: C, 42.17; H, 5.90; N, 4.10. Found: C, 42.38; H, 5.98; N, 3.95.

Yields of **16** obtained from compounds **12**, **13**, and **15** were 88, 90, and 48%, respectively.

*3,4,6-Tri-*O*-acetyl-2-amino-2-deoxy-α-*D*-glucopyranose.* — (*a*) To a suspension of the ground hydrochloride **16** (1.2 g, 3.5 mmoles) in ethanol (5 ml) was added triethylamine (0.7 ml, 7 mmoles). Shaking of this mixture gave a thick mass of crystals that were filtered off and recrystallized from ethanol. The product (0.76 g, 71%) had m.p. 100–101° (dec.), $[\alpha]_{5461}^{21}$ +163° (*c* 1, chloroform); ν_{max} (chloroform) 3390 b-m (OH, NH_2), 1745 s (OAc), and 1580 w cm^{-1} (NH_2); p.m.r. data (chloroform-*d*): δ 2.02 (3-proton singlet, OAc), 2.07 (6-proton singlet, 2 OAc), 4.55 (broad, 3-proton singlet, OH and NH_2), 5.29 (1-proton doublet, $J_{1,2}$ 3.2 Hz, H-1), 3.04 (1-proton quartet, $J_{2,3}$ 9.7 Hz, H-2), 5.22 (1-proton triplet, $J_{3,4}$ 9.7 Hz, H-3), 4.96 (1-proton triplet, $J_{4,5}$ 9.5 Hz, H-4), 3.95–4.5 (3-proton multiplet, H-5 and 2 H-6) p.p.m.

Anal. Calc. for $C_{12}H_{19}NO_8$: C, 47.21; H, 6.27; N, 4.59. Found: C, 47.12; H, 6.35; N, 4.39.

(*b*) To a solution of hydrochloride **16** (1.9 g, 5.6 mmoles) in water (5 ml) was added sodium acetate trihydrate (1.5 g, 11.2 mmoles). The solution was extracted with chloroform (4 × 10 ml), and the combined extracts were dried ($MgSO_4$) for 0.25 h, and filtered. Evaporation of the filtrate gave a syrup that crystallized upon treatment with ether. The product (0.55 g), m.p. 86–90° (dec.), was recrystallized from ethanol to give the title compound (0.44 g, 26%), m.p. 97–99° (dec.), identical with the preparation described under (*a*).

This substance was unstable and became a dark syrup on standing.

O-*Deacetylation of compound* **4**. — A solution of enamine **4** (5.8 g, 15 mmoles)

in warm, dry, methanol (250 ml) was cooled in an ice–salt bath. The solute partly crystallized, and to the suspension was added 0.5M methanolic barium methoxide (20 ml). After being shaken until the solid had dissolved, the reaction mixture was kept for 24 h in the refrigerator. An additional volume of 0.25M methanolic barium methoxide (4 ml) was added, and the mixture was left for 3 h at room temperature. T.l.c. (ether) then showed the absence of *O*-acetylated substances ($R_F > 0.05$). The reaction mixture was neutralized [Amberlite IR-120 (H^+) resin], and then evaporated affording a syrup that crystallized upon treatment with ether. The solid was filtered off, and extracted with boiling ethanol (4 × 30 ml). The residual solid melted above 300° and was discarded. Concentration of the combined ethanol extracts yielded enamine **7** (1.5 g), m.p. 91–98°; recrystallization from ethanol gave the pure product (1.0 g, 25%), m.p. 103–105°, R_F (on paper) 0.68, identical with an authentic specimen. Paper chromatography of the mother liquor showed the presence of **7**, 3-acetyl-2-methylpyrrole (R_F 0.94), 3-acetyl-5-(D-*arabino*-tetrahydroxybutyl)-2-methylpyrrole (**17**) (R_F 0.61), 2-amino-2-deoxy-D-glucose (R_F 0.26), and weak spots of R_F 0.75 [reagent (*c*)], 0.40 and 0.31 [reagent (*a*)]. Evaporation of this liquor left a syrup that crystallized from warm water, yielding (tetrahydroxybutyl)pyrrole (**17**) (0.28 g, 7%), m.p. 106–107°, identical with an authentic sample.

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