THE ABNORMAL CONFORMATIONS OF PYRIDINIUM α-GLYCOPYRANOSIDES

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ABSTRACT

The nuclear magnetic resonance spectra for *N*-(tetra-*O*-acetyl-α-D-glucopyranosyl)-pyridinium and 4-methylpyridinium bromides and *N*-(tri-*O*-acetyl-2-deoxy-2-iodo-α-*D*-mannopyranosyl)-pyridinium perchlorate (V) require these compounds to exist in the 1C-conformation wherein the pyridinium group is in equatorial orientation. The highly strained condition of V was evidenced by its high reactivity as compared to the β-D-*gluco* diastereoisomer (IV). It is suggested that the instability of the C1-conformation is partly attributable to the reverse of the anomeric effect, and the probable importance of this phenomenon is discussed. The optical rotatory dispersion properties of these and a number of other pyridinium glycosides are presented.

INTRODUCTION

In 1910, Fischer and Raske (1) reported the preparation of *N*-(tetra-*O*-acetyl-β-D-glucopyranosyl)-pyridinium bromide (I). Recently, Lemieux and Morgan (2) reported the preparation of the α-anomer as a syrup. Application of these synthetic methods has now yielded both the anomers for the 4-methylpyridine analogs in pure crystalline condition. The unique conformational properties of these compounds stimulated a study of related compounds, and the results obtained are the subject of this communication.

The 100 Mc.p.s. spectrum (Fig. 1) of the crystalline *O*-acetylated 4-methylpyridinium α-glucoside (III), for reasons of the expected change in the coupling constant for protons on neighboring carbons with change in the dihedral angle defined by the protons (3, 4), appeared to require that the compound has the pyranose ring strongly distorted from the C1-conformation. It is seen that the signals for the five ring protons are all well separated and, consequently, the spectrum is subject to first-order analysis. On this basis, the coupling constants $J_{1,2} = 2.8$, $J_{2,3} = 3.1$, $J_{3,4} = 3.2$, and $J_{4,5} = 5.7$ c.p.s. are indicated. In view of these coupling constants, the compound appears to have a conformation which is close to the 1C-conformation wherein the acetoxy groups at the 2-, 3-, and 4-positions are in axial orientation. In fact, the signals for three of the acetoxy groups are in the region *normally* found for axial acetoxy groups (3). Such a strong distortion of the pyranose ring from the C1-conformation, wherein the substituents at the 2 to 5 positions would be in the equatorial orientation, must arise from powerful non-bonding interactions arising from the 4-methylpyridinium group when in axial orientation at the anomeric center. Since the *A* value for the benzene ring is believed to be in the order of only 2–3 kcal/mole (5), the distortion noted in III could not have been expected on steric grounds. However, the N—C bond length in quaternary ammonium compounds is substantially shorter, 1.48 Å (maximum), than the C—C bond in a compound such as toluene, 1.52 ± 0.01 Å (6). It is to be noted, however, that the establishment of a positively charged atom in axial orientation at the anomeric center must be expected to meet a strongly destabilizing effect (relative to when the group is in equatorial orientation) arising from the electrostatic interaction between the C-1 to N and C-5 to O bonds, when the N and C-5 atoms are in

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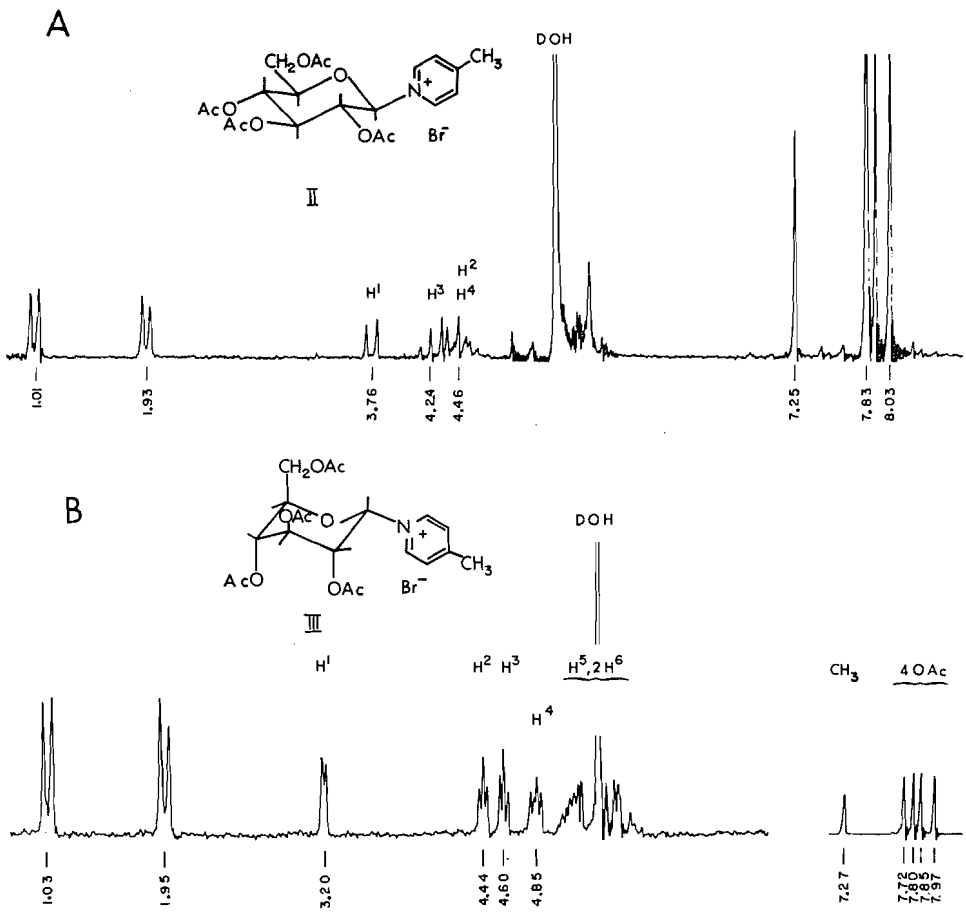
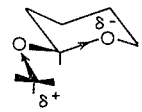


FIG. 1. N.m.r. spectra measured at 100 Mc.p.s. with deuterium oxide as solvent. A, *N*-(Tetra-*O*-acetyl-β-D-glucopyranosyl)-4-methylpyridinium bromide (II). B, *N*-(Tetra-*O*-acetyl-α-D-glucopyranosyl)-4-methylpyridinium bromide (III).

gauche relationship. This interaction amounts to the *reverse* of the anomeric effect (7, 8). Since, for example, the anomeric effect for the tetra-*O*-acetyl-D-glucopyranosyl chlorides amounts to about 3 kcal/mole in favor of the α-anomer wherein the chlorine is in axial orientation (9), it can be anticipated that the *reverse* anomeric effect may well amount to an even stronger destabilizing interaction for the 4-methylpyridinium α-glucoside (III) in the C1-conformation than that arising from the space requirements of the 4-methylpyridinium group. Thus, the fact that the n.m.r. spectrum of III requires the compound to exist in a conformation approaching the 1C-conformation in order to have the aglycone in equatorial orientation may arise from both steric and dipolar interactions, both of which destabilize the α-anomer. The n.m.r. spectrum of the syrupy preparation of the pyridinium α-glucoside (2) was virtually identical with that of III.

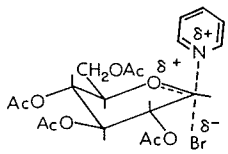
The above-mentioned evidence that a quaternized nitrogen at the anomeric position of a lactol ring structure is strongly demanding for an equatorial orientation could be of great importance for a number of reasons. First of all, the phenomenon would have an important bearing on the conformation and conformational rigidity of such important

biological compounds as the pyridine nucleosides. Secondly, it is evident that the protonation of an axial aglycon at the atom bonded to the anomeric center will cause strong destabilization of the conformation of the sugar ring relative to that wherein the aglycon is in equatorial orientation. Thus, it can be speculated that for α-glucosides, the preferred point of protonation in the course of acid-catalyzed hydrolysis would be at the ring-oxygen atom. On the other hand, for β-glucosides, the reverse anomeric effect would tend to lead to protonation at the oxygen of the aglycon since, in this case, protonation of the ring-oxygen would have to disturb the orientation of the aglycon from the sterically and electronically most favorable position wherein the first carbon of the aglycon is *gauche* to the ring-oxygen as depicted in structure VII (10).

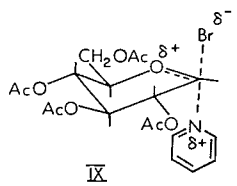


VII

Thirdly, an attack by a molecule at the anomeric center which leads to development of positive charge on the entering group must be expected to be much more favorable when the entering group leads to the equatorial product. For example, it would be expected on the basis of the reverse anomeric effect that the transition state VIII would be considerably more favorable than that represented by IX.



VIII



IX

In view of the above mentioned probable importance of the *reverse anomeric effect*, it was desirable to further examine the phenomenon. First of all, it was necessary to gain better evidence that compound III actually possesses the unusual conformation indicated by its n.m.r. spectrum. Although it seemed very unlikely, there was the possibility that the Karplus relationship for coupling constants broke down completely for this kind of structure. To test this possibility, it was of interest to determine the n.m.r. spectrum of a compound such as *N*-(tetra-*O*-acetyl-α-D-mannopyranosyl)-pyridinium bromide. Should, for the reasons outlined above, this compound exist in the 1C-conformation, then H-1 and H-2 would define a dihedral angle of about 180° and, under these circumstances, the protons should be coupled to an extent of about 9 c.p.s. However, reaction of tetra-*O*-acetyl-α-D-mannopyranosyl bromide with pyridine, with or without the addition of tetra-*n*-butylammonium bromide,* gave only the pyridinium β-mannoside. It was possible, however, to obtain pyridinium glycosides with the α-*manno* configuration by reacting D-glucal triacetate with halonium dipyridine perchlorates (11). One of these compounds, *N*-(tri-*O*-acetyl-2-deoxy-2-iodo-α-D-mannopyranosyl)-pyridinium perchlorate (V) was obtained in a pure crystalline condition. The n.m.r. spectrum of this compound is shown in Fig. 2. It is seen that, indeed, the spectrum corresponds closely with that expected for

**These experiments were conducted by Mr. M. Ponpipom.*

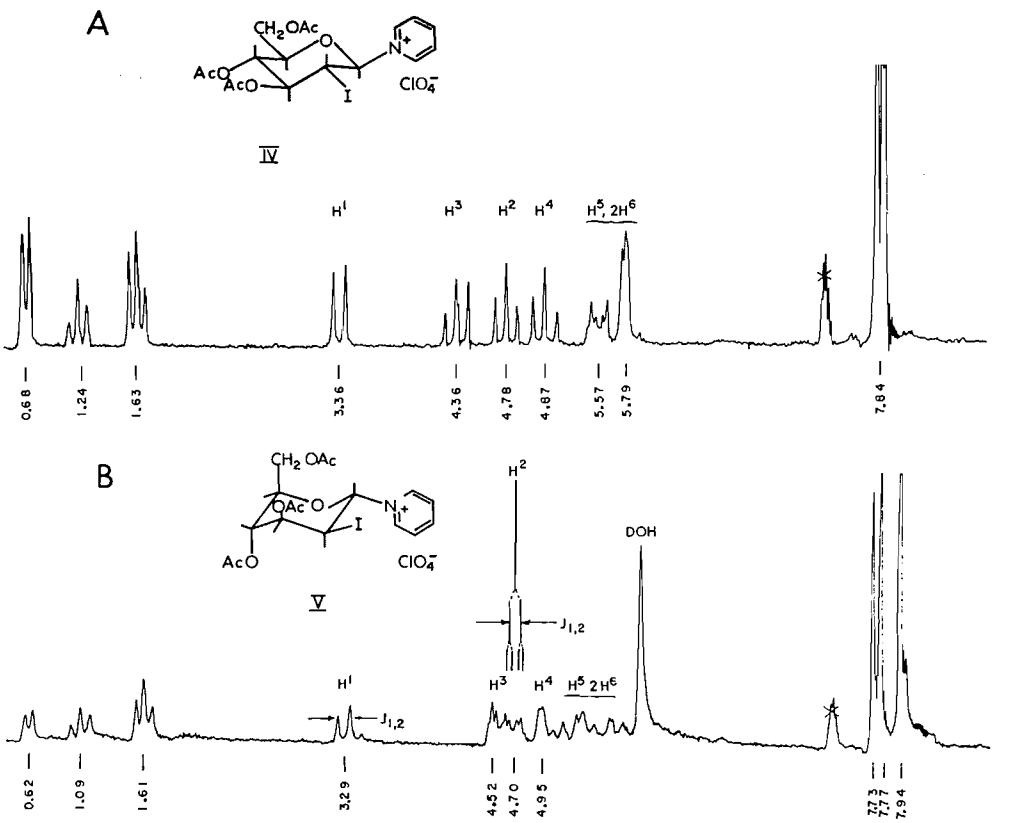


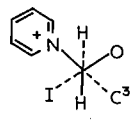
FIG. 2. N.m.r. spectra at 100 Mc.p.s. A, *N*-(Tri-*O*-acetyl-2-deoxy-2-iodo-β-D-glucopyranosyl)-pyridinium perchlorate (IV) dissolved in deuterated dimethylsulfoxide. B, *N*-(Tri-*O*-acetyl-2-deoxy-2-iodo-α-D-manno-pyranosyl)-pyridinium perchlorate (V) dissolved in deuterated dimethylsulfoxide containing a drop of deuterium oxide.

the compound in the 1C-conformation. Since there was a chemical shift of only τ 0.18 for H-2 and H-3, the structure of the doublet signal for the anomeric proton at τ 3.29 was undoubtedly affected by virtual long-range coupling (12). Nevertheless, the spacing of 9.0 c.p.s. clearly indicates that both these protons are in axial orientation. The signal for H-4 appeared at τ 4.95 as a rough singlet with a half-band width of 7 c.p.s. Therefore, the coupling of H-4 with both H-3 and H-5 must be in the range, about 3 c.p.s., expected for hydrogens in *gauche* relationship. Furthermore, the presence of signals for two acetyl groups at τ 7.73 and τ 7.77 lends support to the presence of two axial acetoxy groups as required by the 1C-conformation. The two acetyl groups gave their signals at 10–15 c.p.s. to lower field than did the other acetyl group in a variety of solvents, namely, dimethylsulfoxide, methylene chloride, acetone, pyridine, and methanol. Also, the β-D-*gluco* isomer (IV) of the above compound was prepared and the signal for the anomeric proton was found to be in almost the same position, τ = 3.36, as observed for that of the α-D-manno compound, τ = 3.29, in dimethylsulfoxide as the solvent. Also, as seen in Fig. 2, the n.m.r. spectrum of the β-D-*gluco* isomer (IV) corresponds well with that expected for the compound in the all equatorial C1-conformation. That is, the coupling constants agree well in magnitude to those normally observed in derivatives of β-D-glucopyranose (13). Therefore,

there can be no doubt that the Karplus relationship applies well enough to these compounds to allow the conclusion that definitely compounds III and V exist in conformations closely approaching the 1C-conformation. The coupling constants are not compatible with boat conformations.

In view of their highly strained conformations, compounds III and V would be expected to display somewhat abnormal properties. This was in fact the case. Compound IV was readily deacetylated in methanol using triethylamine as catalyst. On the other hand, the *α-manno* isomer (V) decomposed too readily to allow deacetylation. Although IV showed no reaction with aqueous potassium iodide solution, V rapidly decomposed to iodine and D-glucal triacetate. Furthermore, V readily isomerized to IV when dissolved in pyridine at room temperature.

Reaction of D-glucal triacetate with bromonium dipyridine perchlorate readily gave crystalline *N*-(tri-*O*-acetyl-2-bromo-2-deoxy-*β*-D-glucopyranosyl)-pyridinium perchlorate (VI). The *α-manno* isomer in the residual syrup could not be induced to cyrstallize. However, it was evident from the n.m.r. spectrum that the compound had formed and possessed the 1C-conformation of the 2-iodo analog (V). On standing in pyridine solution, the *α-manno* compound isomerized to VI.



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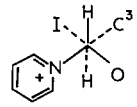

XI

The optical rotatory dispersion curves for the *O*-acetylated pyridinium glycosides IV and V support the conformations assigned above on the basis of the n.m.r. spectral data. Following Brewster's rules (14) for predicting rotation on the basis of conformational asymmetry, it would be expected that the screw pattern described by the conformational unit X for compound IV in the C1 conformation would make an important contribution to rotation. Since the pyridinium group absorbs in the 260 mμ region and is present in this unit, the exhaltation of the rotation with decreasing wavelength toward the region of absorption should render the contributions to rotation by other portions of the molecule negligible as compared to contribution by the conformational unit X. On this basis, therefore, compound IV can be expected to display a Cotton effect characteristic of the conformational unit X. From Fig. 3, it is seen that IV in water provided a plain positive curve. The strong absorption prevented a measurement of the full Cotton effect. For the above mentioned reasons, the *α-manno* isomer (V) in the 1C conformation, wherein the conformational unit XI is the mirror image of that in X, would be expected to display a plain negative o.r.d. curve. Indeed, as seen in Fig. 3, this was the case. Of course, this o.r.d. data provides only circumstantial evidence for the 1C conformation of V since it is not possible to predict the rotational properties of V in the C1 conformation. The *N*-(tri-*O*-acetyl-2-bromo-2-deoxy-*β*-D-glucopyranosyl)-pyridinium perchlorate (VI) also gave a plain positive curve. The o.r.d. curves for the *α*- and *β*-anomers of the *N*-D-glucopyranosides derived from pyridine and 4-methylpyridine were very similar to those previously reported (15) for the corresponding glucosides derived from nicotinamide. For the free glucosides, both the anomers gave plain positive curves.

The addition of iodonium dipyridine perchlorate to D-glucal triacetate in chloroform gave an immediate precipitation of *N*-(tri-*O*-acetyl-2-deoxy-2-iodo-*β*-D-glucopyranosyl)-pyridinium perchlorate in 70% yield. Since the isomerization of the *α-manno* isomer did

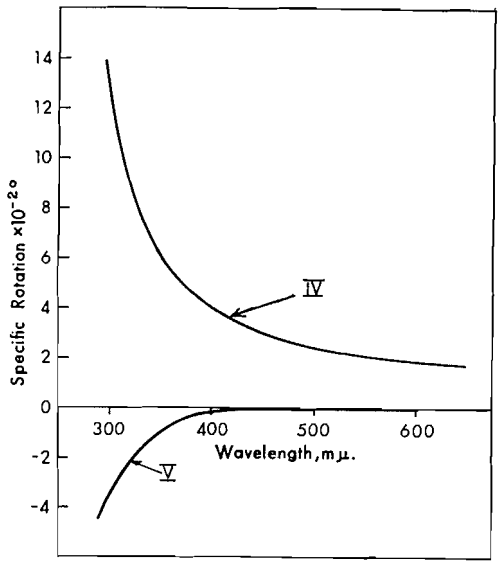

FIG. 3. The optical rotatory dispersion curves for *N*-(tri-*O*-acetyl-2-deoxy-2-iodo-D-glycopyranosyl)-pyridinium perchlorates with the *β-gluco* (IV) and *α-manno* (V) configurations.

not take place in chloroform solution, the reaction gave the product with the *β*-D-*gluco* configuration in preference to that with the *α*-D-*manno* configuration. This route of reaction is opposite to that observed in the reaction of D-glucal triacetate with alcohols in the presence of iodonium di-*sym*-collidine perchlorate (16, 17). These results support the contention (16) that the rate-controlling step in these reactions is not the formation of a 1,2-cyclic iodonium complex. Therefore, the transition state must be related to the nucleophilic attack. The reverse anomeric effect can be expected to influence the relative stabilities of these transition states. Since the reverse anomeric effect must be strong in an axial attack by pyridine and since the change in the yield of the *α-manno* product was only from about 70% for alcohols to about 30% for pyridine, it seems probable that the oxygen of the alcohol is positively charged in the transition states leading to the *O*-glycosides (18).

Although iodonium di-(2,4,6-trimethylpyridine) perchlorate did not form an isolable product when reacted with D-glucal triacetate (11), iodonium di-(2-methylpyridine) perchlorate readily formed the expected *N*-(tri-*O*-acetyl-2-deoxy-2-iodo-*β*-D-glucopyranosyl)-2-methylpyridinium perchlorate. The bromine analog was also prepared.

Reduction of IV with sodium dithionite gave a very unstable 1,4-dihydro derivative.

EXPERIMENTAL

The physical and chemical methods of analysis were described previously (15).

N-(Tetra-O-acetyl-β-D-glucopyranosyl)-pyridinium Bromide (I)

The compound, m.p. 170°, $[\alpha]_D$ −5.9° (*c*, 10 in water) was prepared following the directions of Fischer and Raske (1). The n.m.r. spectrum and o.r.d. curve of solutions in deuterium oxide were very similar to those published for the 3-carboxamido derivative (15). The signal for the anomeric proton was at τ 3.63, spacing 8.0 c.p.s.

Compound I, 3.2 g, was set aside in 320 ml of 3% hydrobromic acid for 15 h at 40° (19). Evaporation left a syrup which was crystallized from ethanol. After two recrystallizations from ethanol and water mixtures, the compound, *N*-(*β*-D-glucopyranosyl)-pyridinium bromide, melted at 176–177°, $[\alpha]_D$ +45.5° (*c*, 1.2 in water). The signal for the anomeric proton in the n.m.r. spectrum using deuterium oxide as solvent was at τ 4.10, spacing 8 c.p.s.

Anal. Calcd. for $C_{11}H_{16}NO_5Br$: C, 41.01; H, 5.01; N, 4.35. Found: C, 40.98; H, 4.87; N, 4.27.

N-(Tetra-O-acetyl-β-D-glucopyranosyl)-4-methylpyridinium Bromide (II) and the α-Anomer (III)

Tetra-*O*-acetyl-α-D-glucopyranosyl bromide, 3.78 g, was dissolved in 5 ml of 4-methylpyridine, and after 2 d the solution became filled with crystals. Ethyl acetate was added and the crystals were removed by filtration. Recrystallization from 95% ethanol – ethyl acetate gave crystals, m.p. 202–203°. The n.m.r. spectrum showed that 0.5 of a molecule of each of ethanol, ethyl acetate and water per molecule of II was present in the crystals. After drying at high vacuum the crystals melted at 207–208.5°, $[\alpha]_D$ −10.2° (*c*, 1 in water). The n.m.r. spectrum of II is shown in Fig. 1. The o.r.d. curve was similar to that found for compound I and showed a plain negative curve. The specific rotations at 300, 350, 400, 450, and 500 mμ were −128, −61, −35, −22, and −17°, respectively.

Anal. Calcd. for $C_{20}H_{26}NO_9Br.0.5H_2O$: C, 46.80; H, 5.30; N, 2.73. Found: C, 46.95; H, 5.30; N, 2.62.

On standing, the filtrate from the isolation of II deposited crystals which were recrystallized from 95% ethanol – ethyl acetate. The material, m.p. 175°, $[\alpha]_D$ +43° (*c*, 1 in water), provided the n.m.r. spectrum reproduced in Fig. 1, and assigned to *N*-(tetra-*O*-acetyl-α-D-glucopyranosyl)-4-methylpyridinium bromide (III). The assignments of signals shown in Fig. 1 are based on spin-decoupling experiments and are unequivocal. The o.r.d. gave a plain positive curve with specific rotations of 138, 121, 90, 66, and 51° at 300, 350, 400, 450, and 500 mμ, respectively.

Anal. Calcd. for $C_{20}H_{26}NO_9Br.H_2O$: C, 45.98; H, 5.40. Found: C, 46.20; H, 5.14.

N-(β-D-Glucopyranosyl)-4-methylpyridinium Bromide

Compound II, 0.65 g, was kept at 40° for 12 h in 65 ml of 3% hydrobromic acid. Evaporation left a syrup which crystallized from ethanol – ethyl acetate, m.p. 162–162.5°, $[\alpha]_D$ +38.3° (*c*, 1.2 in methanol). The n.m.r spectrum was in complete agreement with the assigned structure. A plain positive o.r.d. curve was obtained with specific rotations of 127, 92, 70, and 55° at 350, 400, 450, and 500 mμ, respectively, in methanol.

N-(α-D-Glucopyranosyl)-4-methylpyridinium Bromide

Deacetylation of III under the conditions described above for the β-anomer gave a syrup which could not be induced to crystallize. The n.m.r. spectrum required the assigned structure. The o.r.d. was a plain positive curve with specific rotations of 267, 175, 125, 94, 73, and 59° at 300, 350, 400, 450, 500, and 550 mμ, respectively.

Iodonium Di-(2-methylpyridine) Perchlorate

2-Methylpyridine, 10 ml, and sodium perchlorate, 12.2 g, in 125 ml of water were added with stirring to 5.7 g of silver nitrate dissolved in 25 ml of water. The precipitate, 13.1 g, was washed with water and dried under high vacuum over phosphorus pentoxide. The silver di-(4-methylpyridine) perchlorate thus produced, 39 g, was dissolved in the minimum amount of dry dimethylformamide, and 25.4 g of iodine and 5 ml of 2-methylpyridine were added. After being briefly stirred, the precipitated silver iodide was removed by filtration. Crystals of the iodonium salt soon began to form in the filtrate. Ether was added to provide a 21.2 g yield. The content of positive iodine as determined by iodometric titration was quantitative on the basis of the formula $(C_6H_7N)_2IClO_4$.

Iodonium Dipyridine Perchlorate

Silver dipyridine perchlorate was prepared as described above and 46.5 g was dissolved in the minimum amount of pyridine. Finely powdered iodine, 27.8 g, was added with stirring and silver iodide precipitated at once. The precipitate was removed by filtration and, on the addition of chloroform, a white crystalline product was deposited in the filtrate. The positive iodine content was 97.5% of the theoretical for $(C_5H_5N)_2IClO_4$.

Bromonium Complexes

Procedures very similar to those described above for the preparation of the iodonium complexes were used to prepare bromonium dipyridine perchlorate, $(C_5H_5N)_2BrClO_4$, and bromonium di-(2-methylpyridine) perchlorate, $(C_6H_7N)_2BrClO_4$. In each case the content of positive bromine was that expected from the formula given.

N-(Tri-O-acetyl-2-deoxy-2-iodo-β-D-glucopyranosyl)-pyridinium Perchlorate (IV) and the Corresponding α-D-manno-Stereoisomer (V)

D-Glucal triacetate, 22.2 g (81.7 mmoles), and the iodonium dipyridine perchlorate, 31.4 g (81.7 mmoles), reacted rapidly in 200 ml of chloroform. As the latter dissolved a fine precipitate of the pyridinium glucoside (IV) appeared. The reaction mixture was shaken for 1 h and the product was isolated by filtration. Fine, needle-like crystals of the pyridinium mannoside (V) were obtained from the filtrate on standing at 0°.

Compound IV, 33 g (70% yield), was recrystallized from methanol to constant physical properties, m.p. 163–164°, $[\alpha]_D$ +109.8° (*c*, 1.1 in methanol), $[\alpha]_D$ +133° (*c*, 0.4 in acetone). The n.m.r. spectrum is shown in Fig. 2 and the o.r.d. curve in Fig. 3.

Anal. Calcd. for $C_{17}H_{21}NO_{11}ClI$: C, 35.34; H, 3.66; N, 2.43; I, 22.0. Found: C, 35.55; H, 3.56; N, 2.59; I, 21.1.

The pyridinium glucoside (IV), 4.0 g, was dissolved in 100 ml of methanol and 1 ml of triethylamine. After 1 d, the solvents were evaporated and the crystalline residue was recrystallized from water. A 72% yield,

2.25 g, was obtained. Further recrystallization from methanol with a little water gave an analytical sample, m.p. 155–157° (decomposition of the liquid phase to a black tar), $[\alpha]_D$ +132.5° (*c*, 1 in water). The n.m.r. spectrum agreed throughout with the assigned structure. The compound dissolved in water gave a plain positive o.r.d. curve with specific rotations of 1 610, 595, 301, 239, 214, and 194° at 300, 350, 400, 450, 500, and 550 mμ, respectively.

Anal. Calcd. for $C_{11}H_{15}NO_8ClI$: C, 29.25; H, 3.35; N, 3.10. Found: C, 29.01; H, 3.23; N, 3.02.

A 5.08 g sample of IV was dissolved on warming in 100 ml of water and 40 ml of methanol. Addition of anhydrous sodium bicarbonate, 5.02 g, and sodium dithionite, 5.5 g, in 40 ml of water immediately produced a yellow coloration. The solution then became turbid and a gummy precipitate was deposited. After 1 h, the gum was washed with water. It dissolved on gently warming in ethanol and, on cooling, crystals were obtained, m.p. 68.5–69.5°. The n.m.r. spectrum in chloroform initially gave a spectrum similar to that for the compound obtained on the dithionite reduction of *N*-(tetra-*O*-acetyl-β-D-glucopyranosyl)-pyridinium bromide (I). However, the solution soon liberated iodine and the signal at about τ 7.0 disappeared in 10 min.

Recrystallization of the crude mannoside (V), m.p. 97–102°, 14 g (30% yield), from chloroform was accomplished with difficulty as there was a tendency to obtain an oil, but seeding gave crystals, m.p. 103–104°, $[\alpha]_D$ −22.6° (*c*, 1 in methanol), $[\alpha]_D$ −15.5° (*c*, 2 in acetone). The n.m.r. spectrum is given in Fig. 2 and the o.r.d. curve in Fig. 3. The iodine content, 19%, agreed well with the theoretical amount for V, 22%. The assignments of the signals shown in Fig. 2 are based on spin-decoupling experiments and are unequivocal.

When pure pyridinium mannoside (V) was dissolved in pyridine, crystals were obtained after 1 week in about 80% yield. The melting point, mixed melting point and the n.m.r. spectrum of the product were identical with those of IV. Treatment of V with aqueous potassium iodide gave a rapid liberation of iodine. The iodine was destroyed by the addition of sodium thiosulfate. Extraction with chloroform gave D-glucal triacetate, m.p. 53–54° in 94% yield. The pyridinium glucoside (IV) did not liberate iodine under similar conditions even after 1 d. Iodine was liberated when the solution was heated to the boiling point. Compound V decomposed to dark-brown products when an attempt was made to deacetylate the compound under the conditions which proved useful to deacetylate the diastereoisomer IV.

N-(Tri-O-acetyl-2-bromo-2-deoxy-β-D-glucopyranosyl)-pyridinium Perchlorate (VI)

Bromonium dipyridine perchlorate, 19.5 g, reacted rapidly with D-glucal triacetate, 15.7 g (58 mmoles), dissolved in pure chloroform to yield a fine crystalline precipitate. Recrystallization from ethanol, with a little methanol to facilitate solution, gave a product of m.p. 117–119°, $[\alpha]_D$ +78.8° (*c*, 1.2 in methanol). Cooling of the mother liquors resulted in a further crop of crystals which, when crystallized from methanol, melted at 152.5–155°. After drying *in vacuo* both lots of crystals had the same n.m.r. spectrum. Those with melting point 117–119°, on dissolving in methanol and seeding with the crystals melting at 152.5–155°, yielded crystals with the latter melting point. The n.m.r. spectrum was in agreement with the assigned structure and the specific rotation in water was 690, 377, 253, 140, 68, and 45° at 300, 350, 400, 450, 500, and 550 mμ, respectively.

Anal. Calcd. for $C_{17}H_{21}NO_{11}ClBr$: C, 38.47; H, 3.17; N, 2.64. Found: C, 38.24; H, 3.99; N, 2.81.

On adding ether to the filtrate, a syrup separated which could not be induced to crystallize. The n.m.r. spectrum of the syrup in methylene chloride was very similar to that shown in Fig. 2 for *N*-(tri-*O*-acetyl-2-deoxy-2-iodo-α-D-mannopyranosyl)-pyridinium perchlorate (IV). When the syrup was dissolved in pyridine, crystals of VI were deposited after the solution had been kept at room temperature for several days.

N-(3,4,6-Tri-*O*-acetyl-2-bromo-2-deoxy-β-D-glucopyranosyl)-pyridinium bromide, m.p. 130–133°, $[\alpha]_D$ +79.2° (*c*, 1.2 in methanol), was prepared by dissolving the syrupy mixture of tri-*O*-acetyl-2-bromo-2-deoxy-D-glucopyranosyl bromides (20) in pyridine.

The n.m.r. spectrum was very similar to that of the perchlorate VI.

Anal. Calcd. for $C_{17}H_{21}NO_7Br_2.H_2O$: C, 38.58; H, 4.38; N, 2.63. Found: C, 38.50; H, 4.30; N, 2.52.

N-(Tri-O-acetyl-2-bromo-2-deoxy-β-D-glucopyranosyl)-2-methylpyridinium Perchlorate

The compound, m.p. 223–224° (decomp.), $[\alpha]_D$ +100° (*c*, 0.5 in methanol), was prepared in a manner similar to that described above for the preparation of VI. The n.m.r. spectrum agreed with the assigned structure.

Anal. Calcd. for $C_{18}H_{23}NO_{11}ClBr$: C, 39.69; H, 4.26; N, 2.57. Found: C, 39.69; H, 4.36; N, 2.68.

N-(Tri-O-acetyl-2-iodo-2-deoxy-β-D-glucopyranosyl)-2-methylpyridinium Perchlorate

Reaction of D-glucal triacetate with iodonium di-(2-methylpyridine) perchlorate in chloroform solution gave a syrup which was extracted with hot water. On cooling, the extract deposited crystals, m.p. 186–187°. The n.m.r. spectrum was very similar, except for the signals from the 2-methylpyridine residue, to that for compound IV and left no doubt as to its identity.

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