THE ALCOHOLYSIS OF TRIALKYLALKOXYSILANES

PART II. THE PREPARATION AND CHEMISTRY OF METHYL 2,3,4-TRI-*O*-TRIMETHYLSILYL-α-D-GLUCOPYRANOSIDE[1]

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ABSTRACT

The trimethylsilyl group on the 6-position of methyl 2,3,4,6-tetra-*O*-trimethylsilyl-α-D-glucopyranoside is preferentially removed by methanolysis, using basic or acidic catalysts, giving methyl 2,3,4-tri-*O*-trimethylsilyl-α-D-glucopyranoside in high yield (>80%). Reaction of the latter with acetic anhydride, benzoyl chloride, or phenyl isocyanate produces the corresponding 6-substituted derivatives in quantitative yield. The trimethylsilyl residues from the latter compounds are hydrolyzed by 50% aqueous methanol with the concomitant formation of 6-*O*-acetyl, 6-*O*-benzoyl, or 6-carbanilate derivatives of methyl α-D-glucopyranoside in excellent yield. Chemical and proton magnetic resonance (p.m.r.) studies established the structure of methyl 2,3,4-tri-*O*-trimethylsilyl-α-D-glucopyranoside, and of subsequent derivatives prepared from this compound. Infrared and p.m.r. evidence is offered to support conclusions regarding the conformation of the groups or atoms attached to C_6 and C_5 of the glucoside residue in some of these compounds.

INTRODUCTION

Although general methods used for the preparation of trialkylalkoxysilanes (trialkylsilyl ethers), or trialkylaryloxysilanes, have been described by Eaborn in his excellent book (1*a*), it is only the trimethylsilyl residue which has been used extensively to protect hydroxyl (2) and amino groups (1*b*). These derivatives are easily prepared, are resistant to oxidation, and have more volatility and thermal stability than the parent compound (3). Moreover, they are readily hydrolyzed under neutral conditions by hot aqueous ethanol or methanol, and the hydrolysis is catalyzed by acids or bases (1*c*). Derivatives of this type, therefore, have been used for the separation and purification of compounds containing hydroxyl groups by fractional distillation (2), and in the gas–liquid partition chromatography (g.l.p.c.) of sugars (4). The physical properties of trimethylsilyl ethers are also utilized in mass spectrometry to prevent the elimination of water from alcohols on volatilization (5).

Recently the primary hydroxyl groups in sucrose have been selectively substituted with tricyclohexylsilyl groups (6). This work, however, also established that tricyclohexylsilyl and triphenylsilyl groups are only hydrolyzed by hot solutions of a strong acid or base. Consequently, one of the advantages in using trimethylsilyl residues as blocking groups, namely their ease of hydrolysis, is lost when a tricylcohexylsilyl residue is used. Nevertheless, a literature survey reveals no other case in which advantage was taken of the relative rates of substitution of different types of hydroxyl groups by trialkylsilyl residues. Moreover, it was not realized until the present work (7) that trialkylsilyl derivatives of primary, secondary, or tertiary alcohols might have different rates of alcoholysis (or hydrolysis) and that this property could be used for synthetic purposes.

The present communication describes a method for the preparation of methyl 2,3,4-tri-*O*-trimethylsilyl-α-D-glucopyranoside in high yield by the preferential methanolysis of the

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trimethylsilyl residue on the primary 6-position of the corresponding fully substituted trimethylsilyl derivative of methyl α-D-glucopyranoside. Further work has shown that this reaction can probably be applied to any polyhydroxyl compound since the trimethylsilyl groups of primary, secondary, and tertiary hydroxyl groups have significantly different rates of methanolysis under acidic, basic, and neutral conditions, and this work will be the subject of future publications. It would also be of interest to establish whether the corresponding derivatives of phenolic and carboxylic hydroxyl groups in different chemical environments also differ in their rates of methanolysis.

EXPERIMENTAL

Methyl 2,3,4,6-Tetra-O-trimethylsilyl-α-D-glucopyranoside (I) from Methyl α-D-Glucopyranoside

The procedure for the preparation and purification of I has been described previously by Hedgley and Overend (3). Methyl α-D-glucopyranoside (0.31 mole) was reacted with trimethylchlorosilane (1.8 moles) in pyridine (500 ml) at 0° to yield I (0.29 mole), b.p. 115–120° at 0.25 mm, $[\alpha]_D^{22}$ +86.7° (*c*, 0.67 in chloroform), η_D^{22} 1.4410. Reported physical constants for this compound (3) are b.p. 109–110° at 0.1 mm, η_D^{25} 1.4415, $[\alpha]_D^{20}$ +92.5° (*c*, 0.692 in chloroform).

Methyl 2,3,4-Tri-O-trimethylsilyl-α-D-glucopyranoside (II) from I

The methanolysis of I (0.105 mole) in anhydrous methanol (200 ml) at 0° using a solution of potassium carbonate (0.8 millimole in 25 ml methanol) as catalyst, with the concomitant formation of II, was followed by analyzing aliquots of the reaction mixture by g.l.p.c. (7). After 45 min the relative intensities of the peaks corresponding to I and II on the g.l.p.c. tracing indicated that the reaction was complete, so the catalyst was destroyed by the addition of an equivalent amount of acetic acid to the reaction solution. Distilled water was then added to the latter, with vigorous shaking, until the solution remained cloudy. This turbidity was carefully removed by the addition of a few drops of methanol, and the resulting solution was placed in a refrigerator at 5°. When crystallization of II (0.088 mole) was complete, the product was recrystallized from cold aqueous methanol to yield II (0.081 mole) as a white crystalline compound, m.p. 98.5–99.5°, $[\alpha]_D^{24}$ +91.48° (*c*, 5.0 in chloroform).

Anal. Calcd. for $C_{16}H_{38}O_6Si_3$: C, 46.83; H, 9.27. Found: C, 46.88; H, 9.53.

A similar yield of II was obtained when acetic acid was used instead of a base as catalyst for the methanolysis reaction. However, for a comparable reaction rate the concentration of acetic acid has to be approximately 15 times that of a basic catalyst (7).

Methyl 6-O-Acetyl-2,3,4-tri-O-trimethylsilyl-α-D-glucopyranoside (III) from II

A solution of II (10 millimoles) and acetic anhydride (11 millimoles) in anhydrous pyridine (20 ml) was heated on a steam bath for 1 h and was then taken to dryness under reduced pressure. The residue was distilled under reduced pressure to obtain III (9.3 millimoles) as a colorless oil, b.p. 145–147° at 0.34 mm, $[\alpha]_D^{23}$ +90.26° (*c*, 1.047 in chloroform), and η_D^{21} 1.4502.

Anal. Calcd. for $C_{18}H_{40}O_7Si_3$: C, 47.79; H, 8.85. Found: C, 47.51; H, 9.08.

Methyl 6-O-Acetyl-α-D-glucopyranoside (IV) from III

Distilled water was added to a solution of III (5 millimoles) in methanol (40 ml) until cloudy, and then the solution was refluxed for 4 h. Subsequently, the solution was taken to dryness under reduced pressure and the oily residue was dissolved in distilled water and filtered. The clear filtrate was taken to dryness and dried over phosphorus pentoxide *in vacuo* to yield IV (4.55 millimoles) as an oil $[\alpha]_D^{21}$ +150.1° (*c*, 1.12 in acetone).

Anal. Calcd. for $C_9H_{16}O_7$: C, 45.75; H, 6.83. Found: C, 46.10; H, 6.97.

Methyl 6-O-Acetyl-α-D-glucopyranoside 2,3,4-Tricarbanilate (V) from IV

A solution containing IV (5 millimoles) and phenyl isocyanate (17.25 millimoles) in anhydrous pyridine (10 ml) was heated on a steam bath for 1 h, and then the excess phenyl isocyanate was destroyed by the addition of ethanol (1 ml). The reaction solution was subsequently taken to dryness under reduced pressure, and the residue was crystallized several times from ethanol. Compound V (4.3 millimoles) was obtained as needles, m.p. 244–246° and $[\alpha]_D^{24}$ +73.4° (*c*, 0.105 in acetone).

Anal. Calcd. for $C_{30}H_{31}O_{10}N_3$: C, 60.70; H, 5.26; N, 7.08. Found: C, 60.73; H, 5.44; N, 7.05.

Reported physical constants for V (8) are m.p. 235–237° and $[\alpha]_D^{25}$ +71° (*c*, 0.1 in acetone). A satisfactory melting point for V could not be obtained on a hot stage micro melting point apparatus (the compound appeared to sublime) so the melting point was determined by the capillary method.

Methyl 6-O-Benzoyl-2,3,4-tri-O-trimethylsilyl-α-D-glucopyranoside (VI) from II

Compound II (10 millimoles) was reacted, overnight, with benzoyl chloride (11 millimoles) in pyridine (30 ml) at 0°, and the reaction mixture was worked up in the usual manner. However, when the chloroform solution of the reaction product was washed with acid, to remove traces of pyridine, care was taken to ensure

that the aqueous phase did not become strongly acidic. The latter condition could lead to the hydrolysis of the trimethylsilyl groups. Distillation of the residue obtained from the chloroform solution under reduced pressure yielded VI (8.8 millimoles), b.p. 208–212° at 0.47 mm, $[\alpha]_D^{23}$ +80.12° (*c*, 0.92 in chloroform) and η_D^{22} 1.4780.

Anal. Calcd. for $C_{16}H_{38}O_6Si_3$: C, 53.70; H, 8.30. Found: C, 53.52; H, 8.30.

Methyl 6-O-Benzoyl-α-D-glucopyranoside (VII) from VI

The trimethylsilyl groups of VI (5 millimoles) were hydrolyzed in aqueous methanol by the procedure described above for the preparation of IV. Removal of the solvent under reduced pressure left a solid residue. Crystallization of the latter from ethyl acetate yielded VII (4.1 millimoles) as prisms, m.p. 132–133° (reported m.p. 174–175° (9)), $[\alpha]_D^{24}$ +104° (*c*, 1.45 in chloroform).

Anal. Calcd. for $C_{14}H_{18}O_7$: C, 56.37; H, 6.08. Found: C, 56.33; H, 6.13.

Methyl α-D-Glucopyranoside 6-Carbanilate (IX) from II

Compound II (10 millimoles) was reacted with phenyl isocyanate (11 millimoles) in pyridine (10 ml) by the same procedure described for the preparation of V above. The residue (VIII) from the reaction mixture was immediately hydrolyzed in aqueous methanol (35 ml) to remove the trimethylsilyl groups, using 1 drop of glacial acetic acid as a catalyst (see procedure described for the preparation of IV and VII above). Removal of the solvent under reduced pressure left a solid residue which crystallized from water to yield IX (8.5 millimoles) as long needles, m.p. 141–143°, $[\alpha]_D^{23}$ +126.2° (*c*, 0.93 in pyridine).

Anal. Calcd. for $C_{14}H_{19}O_7N$: C, 53.67; H, 6.11; N, 4.47. Found: C, 53.62; H, 6.16; N, 4.43.

Precipitation of IX from ethyl acetate gave an amorphous white powder, m.p. 131–132.5°. Reported physical constants for IX (10) are m.p. 131–133° (from ethyl acetate), $[\alpha]_D^{25}$ +115° (*c*, 1.0 in pyridine).

Methyl 2,3,4-Tri-O-acetyl-α-D-glucopyranoside 6-Carbanilate (X) from IX

Acetylation of IX (3.2 millimoles) with acetic anhydride (3.92 millimoles) in pyridine (20 ml) in the usual manner gave a product which crystallized from methanol to yield X (3.01 millimoles) as prisms, m.p. 146–147°, $[\alpha]_D^{24}$ +1.43° (*c*, 1.1 in chloroform).

Anal. Calcd. for $C_{20}H_{25}O_{10}N$: C, 54.66; H, 5.73; N, 3.19. Found: C, 54.57; H, 5.72; N, 3.20.

Reported physical constants for X(10) are m.p. 147–148° (from methanol), $[\alpha]_D^{24}$ +145° (*c*, 1 in chloroform).

Methyl 2,3,4-Tri-O-methyl-α-D-glucopyranoside 6-(N-Methyl)-carbanilate (XI) from IX

Compound IX (5 millimoles) was methylated (11) in anhydrous *N,N*-dimethylformamide (DMF) (20 ml) using methyl iodide (0.11 mole) and freshly prepared silver oxide (40 millimoles). The reaction was assisted by vigorous agitation of the reaction solution on a mechanical shaker for 30 h. At the end of the reaction period the solution was filtered and the clear filtrate was diluted with chloroform (250 ml) to precipitate silver iodide. The latter was removed by filtration and the chloroform/DMF solution was taken to dryness *in vacuo* on a rotary evaporator. Drying under reduced pressure over phosphorous pentoxide left an oily residue (1.29 g). The residue was further purified by distillation under reduced pressure, followed by chromatography on neutral Wöelm alumina using chloroform as the eluant. Removal of the chloroform under reduced pressure yielded XI (3.14 millimoles) as a colorless oil, $[\alpha]_D^{22}$ +89.8° (*c*, 1.314 in acetone), η_D^{21} 1.5006.

Anal. Calcd. for $C_{18}H_{27}O_7N$: C, 58.52; H, 7.37; N, 3.79. Found: C, 58.58; H, 7.63; N, 3.81.

Periodate Oxidation of IX

Compound IX (0.348 millimole) was oxidized with sodium metaperiodate (1.44 millimoles) in acetate buffer solution (100 ml; pH 4) as described by Guthrie (12). The periodate consumed by IX was determined periodically on aliquots of the reaction solution by the Fleury–Lange method (13). Aliquots of the solution (5 ml) were pipetted into a solution of saturated sodium bicarbonate (10 ml) and 0.01 *N* sodium arsenite (20 ml) and left standing in the dark for 15 min. Subsequently, a 20% solution of potassium iodide was added and the excess arsenite was titrated against 0.1 N iodine solution, using a 1% starch solution (1 ml) as indicator. The results are given in Fig. 2.

All p.m.r. spectra were taken on a Varian A60 spectrometer fitted with a variable temperature probe, and using tetramethylsilane (TMS) as an internal standard. The infrared spectra were recorded on a Perkin-Elmer model 521 spectrometer.

RESULTS AND DISCUSSION

The reaction scheme for the preparation and chemistry of II is depicted in Fig. 1.

The experimental procedures which were used to make a kinetic study of the controlled methanolysis of I to produce II have already been described in this issue (7). Essentially the same reaction conditions were used for the production of II on a preparative scale (see Experimental), apart from changes in the relative concentrations of reagents, and g.l.p.c. was again used to follow the course of the reaction. However, no g.l.p.c. internal standard (7) was present in the reaction solution since the course of the reaction could be estimated in a qualitative manner by observing the relative intensities of I and II on the g.l.p.c. tracing.

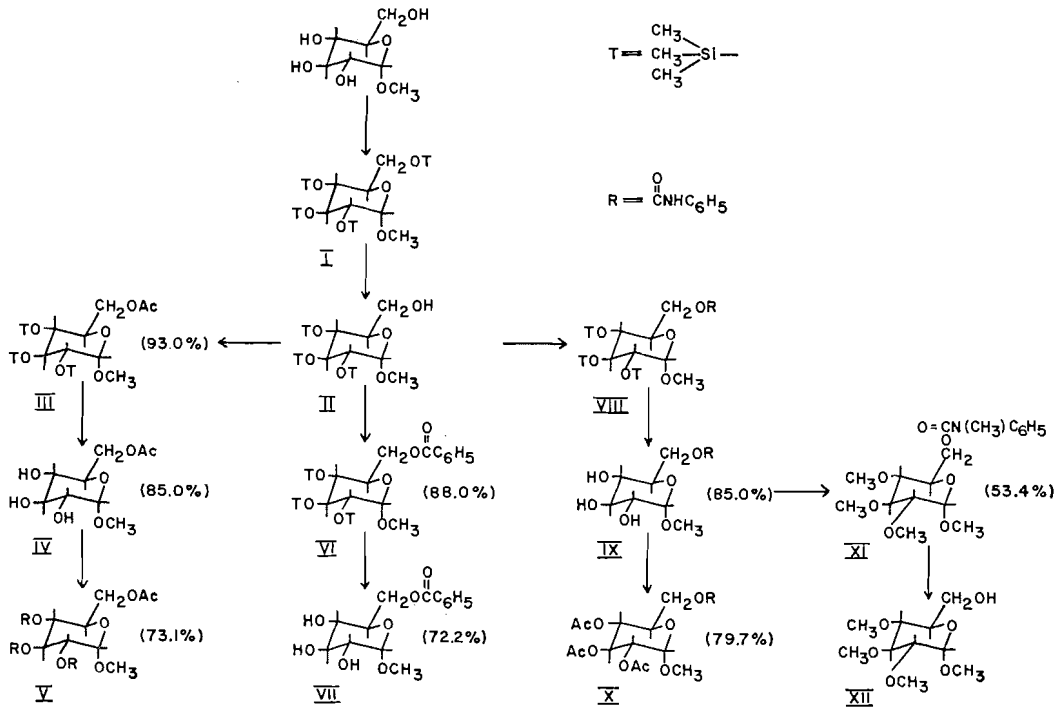


FIG. 1. The preparation and chemistry of methyl 2,3,4-tri-*O*-trimethylsilyl-α-D-glucopyranoside (II).

When the reaction was complete, II crystallized from the methanolic reaction solution on addition of water. This simple experimental procedure enabled II to be isolated in greater than 70% yield based on methyl α-D-glucopyranoside, or over 80% yield based on I. Moreover, studies in this laboratory have shown that the reaction of trimethylchlorosilane with polyhydroxy compounds in pyridine is virtually instantaneous at room temperature. Consequently, a supply of II for synthetic purposes can be obtained quickly provided it is prepared from crude (undistilled) I. The latter may be obtained sufficiently pure for this purpose by removing the pyridine under reduced pressure and dissolving I in petroleum ether, in which pyridinium hydrochloride is insoluble.

Compound II reacted with phenyl isocyanate in pyridine to form the corresponding monocarbanilate derivative VIII, which was subsequently hydrolyzed in aqueous methanol to give compound IX. The position of the carbanilate residue in IX could be determined by periodate oxidation studies. If the substituent was at carbon-6 of the glucose moiety of this compound it would consume 2 moles of periodate due to the presence of three secondary hydroxyl groups on contiguous carbon atoms, whereas the corresponding 2- and 4-derivatives, with only two secondary hydroxyl groups on adjacent carbon atoms, would require only 1 mole of the reagent. The remaining derivative with the substituent on the 3-position, and containing no secondary hydroxyl groups on adjacent carbon atoms, would not be oxidized by periodate. From Fig. 2 it can be seen that compound IX consumed 2 moles of periodate and consequently must have the substituent at carbon-6. This result requires that compounds VIII and II have the structures shown in Fig. 1, since the carbanilate residue of IX occupies the same position as the original hydroxyl group in II.

It was not possible to deduce the structure of IX by comparing its physical constants with those reported in the literature (10). Although the melting point of the latter agreed

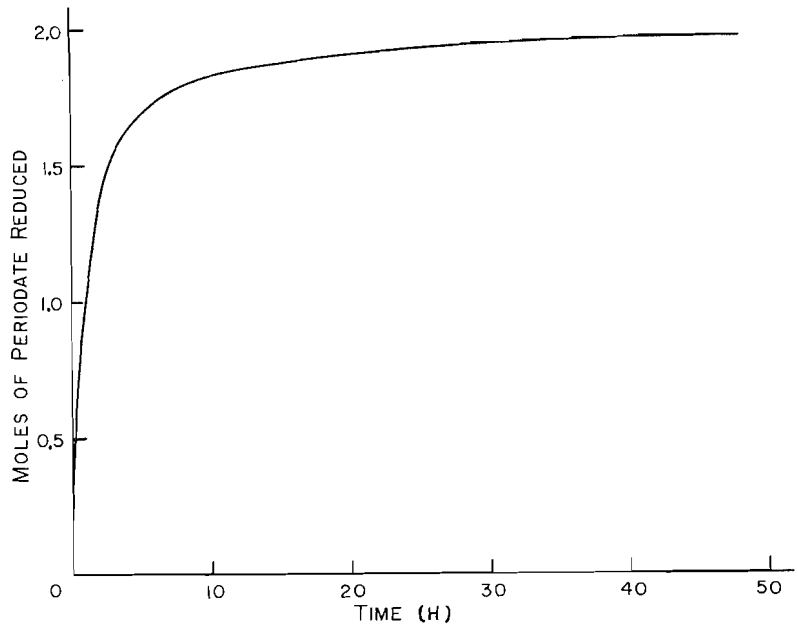


FIG. 2. A plot of the number of moles of periodate consumed by methyl α-D-glucopyranoside 6-carbanilate (IX) against time.

with the literature value it was obtained as an amorphous powder from ethyl acetate and not crystalline as reported by Hearon *et al.* Compound IX, however, could be obtained as long crystalline needles from water. Moreover, the specific rotation of our compound was 11° higher than the reported value. However, the physical constants for X, prepared by the reaction of IX with acetic anhydride in pyridine, were in excellent agreement with those reported (10). Since Hearon and co-workers prepared IX by the deacetylation of X with boiling methanolic hydrogen chloride, it seems probable that any differences in the two sets of physical constants for IX may be due to the presence of some of the corresponding β-isomer in their product which must be present after this treatment. It is of interest that Hearon *et al.* obtained IX in 15% yield using a standard five step synthesis (i.e. tritylation, acetylation, carbanilation, etc.) whereas by the present method this compound can be obtained in >60% yield based on the methyl glucoside, and without the possibility of side reactions occurring. Compound XI was prepared from IX by the Kuhn procedure (11), and the former was converted to XII when treated with ethanolic barium hydroxide. The latter (XII) was identified (14) and isolated by g.l.p.c., and the physical constants of this compound agreed with those reported in the literature for methyl 2,3,4-tri-*O*-methyl-α-D-glucopyranoside (15). Consequently, the carbanilate residues of IX and XI, and the hydroxyl group of II, must have been attached to carbon-6 of the glucose moieties of these compounds. Moreover, the differences in the infrared spectra of IX and XI were consistent with those expected for *N*-methylation as well as *O*-methylation of IX by the Kuhn procedure. *N*-Alkylation of carbanilate groups under similar experimental conditions has been reported previously by Bouveng (16). This behavior is also observed in urethans and is in contrast to that exhibited by thiourethans which apparently can undergo *S*-alkylation (17), to produce dialkyl esters of ortho-thiocarbonic anil, RN=C(OR′)(SR″), or *N*-alkylation (18) depending on the basic catalyst.

The structure of XI was also confirmed by p.m.r. studies (see Fig. 3). At low field the five aromatic protons of the phenyl group appear as a broad singlet at 2.79, and the equatorial anomeric hydrogen occurs at 5.38 with the spacing of 3.3 c.p.s. (19) characteristic of protons in the *cis* orientation at carbon-1 and -2. The geminal hydrogens on carbon-6, which are not magnetically equivalent because of the presence of the asymmetric center at carbon-5, constitute the AB part of the ABX system shown in Fig. 4, R = —CH_3; R′ = —$OCN(CH_3)C_6H_5$, and are consequently present as two characteristic overlapping quartets centered at 5.83. Analysis of the AB multiplet gave values of 17.9 c.p.s. for the

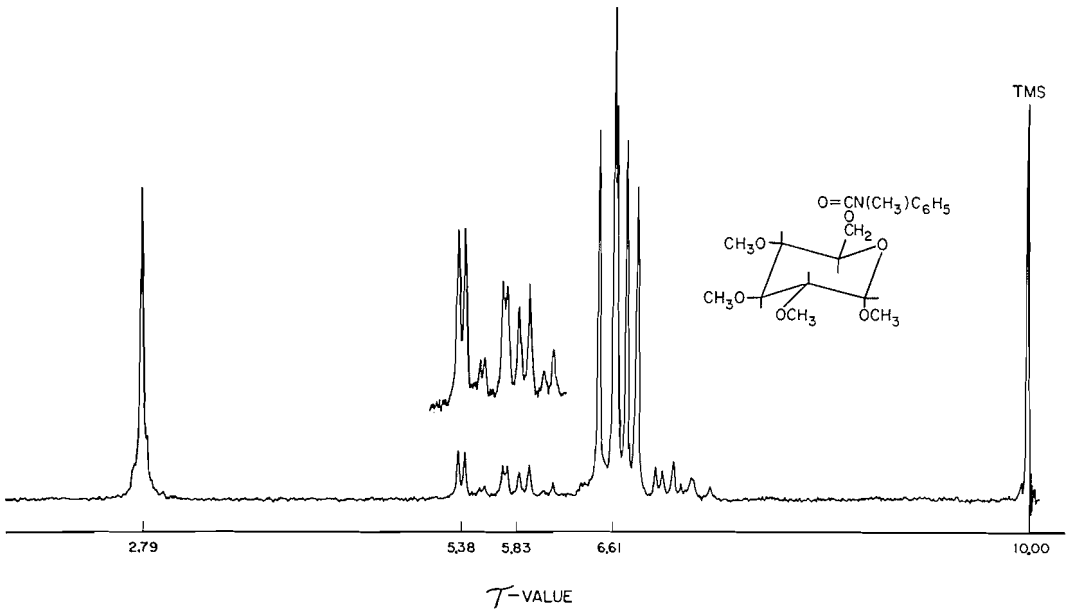
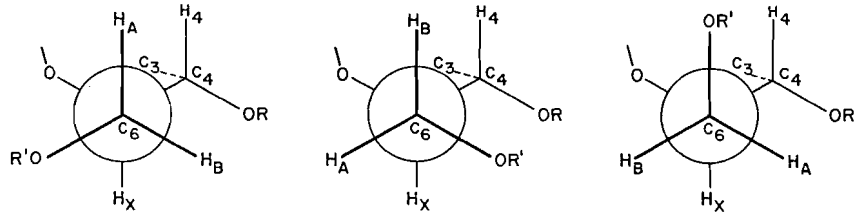


FIG. 3. The p.m.r. spectra of methyl 2,3,4-tri-*O*-methyl-α-D-glucopyranoside 6-(*N*-methyl)-carbanilate (XI) in CCl_4 using TMS as an internal standard.

chemical shift δ_{AB}, −11.7 c.p.s. for J_{AB}, 5.4 c.p.s. for J_{AX}, and 2.0 c.p.s. for J_{BX}. Although no information can be obtained about the absolute or relative signs of these coupling constants from the p.m.r. signals for the two geminal protons, it is known that geminal coupling constants (i.e. J_{AB}) are negative (20, 21), and of opposite sign to vicinal coupling constants (i.e. J_{AX} and J_{BX}) in substituted alkanes. Consequently, the above coupling constants were arbitrarily given appropriate signs. Calculation of the theoretical line positions and intensities for the AB multiplet, using the values for the chemical shift and coupling constants given above, gave results in excellent agreement with those obtained experimentally. Furthermore, the protons of the *N*-methyl and four methoxyl groups of XI appear as singlets at 6.5, 6.61, 6.63, 6.74, and 6.83. The remaining protons of the pyranose ring are partly hidden under the latter peaks or appear on the high-field side of the singlet at 6.83.

If compound XI exists solely in conformation 1*a* (R′ = —$OCN(CH_3)C_6H_5$; R = —CH_3) (see Fig. 4) in carbon tetrachloride solution the protons H_A and H_X, which are in a *trans* relationship to one another, would be expected to have a value of from 8 to 12 c.p.s. for J_{AX} (22, 23). The low experimental value of 5.4 c.p.s. for this coupling constant therefore suggests that there is free rotation about the C_5—C_6 bond resulting in a rapid interconversion of the three possible conformations (see Fig. 4; 1*a*, 1*b*, and 1*c*) with a concomitant



1a 1b 1c

FIG. 4. The three possible conformations of the groups or atoms attached to the fifth and sixth carbon atoms in the glucose moiety of compounds XI and II.

decrease in the value of J_{AX} (22). However, the coupling constants J_{AX} and J_{BX} remained unchanged when the spectrum of XI was recorded over a temperature range of 60° to −60°, and when a solvent of high dielectric constant such as acetone-d_6 was used as a solvent instead of carbon tetrachloride. Since changes in coupling constants resulting from a changing equilibrium between conformations of different dipole moments on varying the polarity of the solvent have already been found by Sheppard (24), and since similar changes can occur by varying the temperature of the solution (25), the results only seem to be compatible with the presence of a single conformer. Consideration of the *gauche* interactions of the substituents on carbon-5 and carbon-6, together with the 1,3-interactions between the substituents on the latter and on carbon-4, leaves little doubt that 1*a* is the most stable and 1*b* the least stable conformation (see Fig. 4). Indeed the differences in non-bonded interactions in the three conformations make it unlikely that they would be equally populated in solution under all of the experimental conditions described above. Consequently, compound XI probably exists almost entirely in conformation 1*a*. The low value obtained for J_{AX} may be due to the fact that the 1,3-interactions in 1*a* would tend to repel H_A and H_4 thereby reducing the dihedral angle subtended by the C_6—H_A and C_5—O bonds. This would result in a reduction in the angle subtended by the C_5—H_X and C_6—H_A bonds, which would result in a decrease in the value of J_{AX} (23). It should also be remembered that the electronegativity of the R′ group (see Fig. 4) could also have a profound effect on the value of J_{AX} (23).

The infrared spectrum of a 5×10^{-3} *M* solution of II in carbon tetrachloride gave a single absorption band in the O—H stretching region in the infrared at 3 609 cm^{-1}. Since free primary hydroxyl groups under similar experimental conditions give absorption bands with little variation at 3 636 – 3 641 cm^{-1} (26, 27) it would appear that the primary hydroxyl group of II is involved in a *weak* intramolecular hydrogen bond corresponding to a shift to lower frequency of approximately 30 cm^{-1}. The only conformations in which the primary hydroxyl group could form a hydrogen bond are 1*a* and 1*b*, see Fig. 4; R′ = —H; R = —Si(CH$_3$)$_3$, and the single absorption band at 3 609 cm^{-1} implies that there is only one conformer present, or that the hydrogen bonds formed in the two conformations are of equal energy. It is unlikely, however, that II exists in conformation 1*b* since the short O—O distance (≈2.4 Å) (28) and the high electron density at the oxygen atom attached to carbon-4, due to the ionic character of the Si—O bond (1*d*), would require the presence of a much stronger hydrogen bond. Indeed, the experimental results can be explained if II exists in the same conformation as XI, namely 1*a*. In this case if the angle between the C_6—O and C_5—O bonds was increased because of the 1,3-interactions discussed above, the O—O distance in this conformation could easily be about 3 Å, and this

large distance would of course result in a weak hydrogen bond (28) between the hydroxyl group and the oxygen atom in the pyranose ring. It is possible, however, that 3 609 cm^{-1} is the normal O—H stretching frequency for the free primary hydroxyl group in compounds such as II, although there is no evidence in the literature to support such a contention.

In conclusion compounds III and VI were prepared by the reaction of II with acetic anhydride or benzoyl chloride in pyridine, and hydrolysis of these compounds with boiling aqueous methanol gave IV, and VII, in excellent yield. The former has not been synthesized previously, and the physical constants of the latter reported in the literature (7) are in error (see Experimental). Inspection of the p.m.r. spectra of III and VI in $CDCl_3$ reveals that the signals for the two geminal protons on carbon-6 are present as two overlapping quartets centered at τ values of 5.74 and 5.50. Calculation as in the case of compound XI gave values for III of 18.5 c.p.s. for δ_{AB}, −12.2 c.p.s. for J_{AB}, 4.7 c.p.s. for J_{AX}, and 1.5 c.p.s. for J_{BX} and corresponding values for VI of 20.0 c.p.s. for δ_{AB}, −12.4 c.p.s. for J_{AB}, 5.4 c.p.s. for J_{AX}, and 1.6 c.p.s. for J_{BX}. Although V was prepared by the reaction of IV with phenyl isocyanate in pyridine, it was not possible to confirm the identity of the latter by preparing this derivative because the melting point and $[\alpha]_D$ reported for this compound (8) were lower than the values obtained in this laboratory (see Experimental). Proton magnetic resonance temperature studies on III and IV also indicate that the atoms and groups attached to carbon-5 and -6 have the same conformation as described above for XI and II.

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