Synthesis of Ribosyl and Arabinosyl Cyanides by Reaction of 1-*O*-Acyl Sugars with Trimethylsilyl Cyanide

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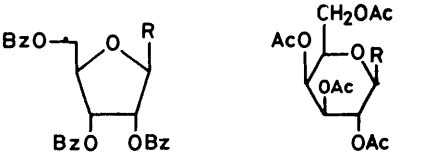
A new procedure is described for the synthesis of glycosyl cyanides by reaction of 1-*O*-acyl sugars with trimethylsilyl cyanide in a polar aprotic solvent and in the presence of a Lewis acid as catalyst. A variety of ribosyl and arabinosyl cyanides have been made in this way from sugar derivatives having acyl, chloro, or methoxy leaving groups at the anomeric position, furanose or pyranose rings, and acyl or benzyl protecting groups. The 1,2-*trans*-glycosyl cyanide was formed when the starting sugar had a participating 2-*O*-acyl substituent. A mixture of cyanide anomers was obtained when the starting sugar was protected with non-participating benzyl groups.

TRIMETHYLSILYL CYANIDE [1,2] reacts readily with aldehydes and ketones in the presence of Lewis acids to give trimethylsilyl cyanohydrin ethers.[3] In this and other reactions of Me_3SiCN, the cyano group, acting as an anion stabilized by the adjacent Si atom, reacts with electrophilic carbon atoms to form a new C–C bond.[4-6] Cyanosilylation of sp^2-hybridized carbonyl compounds is well known.[3-6] However, there are only two brief reports on similar reactions of Me_3SiCN with electrophilic sp^3-hybridized carbon atoms.[7,8] This prompted us to study the reactions of Me_3SiCN with electrophilic tetrahedral carbon atoms, in the hope of extending the range of applicability of this compound as a reagent for C–C bond formation.

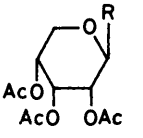
Formation of new C–C bonds is of particular importance in the synthesis of *C*-nucleoside antibiotics.[9-11] The most general and useful method for the preparation of *C*-nucleosides is the multi-step elaboration of the desired heterocycles from a *C*-glycosyl derivative functionalized at the anomeric position. One of the most important types of *C*-glycosyl intermediate is the glycosyl cyanide; these compounds have been used for the synthesis of most naturally occurring *C*-nucleoside antibiotics [9-11] and many analogues.[9-12] Glycosyl cyanides are obtained in variable yields by reaction of peracylated glycosyl halides with silver or mercury(II) cyanide.[9] This reaction may also yield other products such as isocyanides,[13] unsaturated sugars,[14] and 1,2-*O*-(cyanoalkylidene)glycosyl derivatives.[15] We report here a new procedure for the synthesis, under mild reaction conditions and in high yields, of glycosyl cyanides by reaction of acylated sugars with Me_3SiCN in a polar aprotic solvent and in the presence of a Lewis acid as catalyst.

We first attempted the synthesis of known glycosyl cyanides. Thus, 2,3,5-tri-*O*-benzoyl-β-D-ribofuranosyl cyanide (1) was prepared in 86% yield by reaction of 1-*O*-acetyl-2,3,5-tri-*O*-benzoyl-β-D-ribofuranose (2) with Me_3SiCN and $SnCl_4$ in acetonitrile at room temperature. Similarly, treatment of 1,2,3,4,6-penta-*O*-acetyl-β-D-galactopyranose (6) with Me_3SiCN and boron trifluoride–ether complex in nitromethane at room temperature gave the galactopyranosyl cyanide (5) in 82% yield. Both glycosyl cyanides (1) and (5) were identical, respectively, with authentic samples prepared by the previously described method.[16,17] Several experiments were also carried out using different combinations of polar aprotic solvent (nitromethane, acetonitrile, 1,2-dichloroethane) and Lewis acid (BF_3, $SnCl_4$, $AlCl_3$). Best yields were obtained with nitromethane and BF_3. Therefore, unless otherwise stated, the following experiments were all carried out using this solvent and Lewis acid.

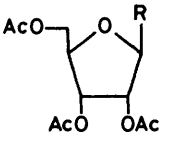


(1) R = CN
(2) R = OAc
(3) R = Cl
(4) R = OMe

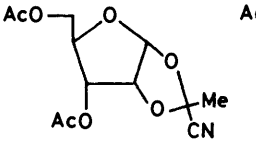
(5) R = CN
(6) R = OAc



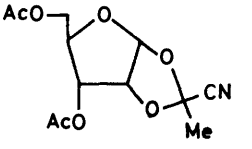
(7) R = CN
(8) R = OAc



(9) R = CN
(10) R = OAc



(11a)



(11b)

In order to discover the influence of the anomeric substituent (*i.e.* the leaving group), on the reaction, three 2,3,5-tri-*O*-benzoyl-β-D-ribofuranosyl derivatives having 1-*O*-acetyl- (2), 1-chloro- (3), and 1-*O*-methyl- (4) groups were treated with Me_3SiCN and boron trifluoride–ether in nitromethane; each reaction gave the same ribosyl cyanide (1), in yields of 87, 85, and 7%, respectively. The production of the cyanide (1) from the 1-*O*-acetyl

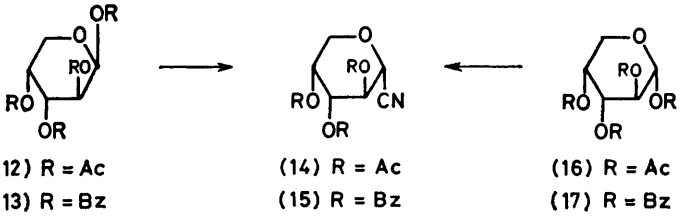
derivative (2) in good yield, even better than that from the 1-chloro derivative (3), represents an advantage over the previous method,[16] which uses as starting material the ribosyl chloride (3), usually obtained from (2).[18]

The influence of ring size did not seem to be important, since the furanosyl and pyranosyl cyanides (1) and (5), respectively, were obtained in similar good yields under mild conditions. Moreover, tetra-acetyl-β-D-ribofuranose (10) and -ribopyranose (8) reacted with Me_3-SiCN to give the ribosyl cyanides (9) and (7) in 59 and 78% yield, respectively. From the reaction of (10), a 1 : 1 mixture, chromatographically homogeneous in several solvent systems, of the *endo*- and *exo*-3,5-di-*O*-acetyl-1,2-*O*-(1-cyanoethylidene)-α-D-ribofuranose (11) was also obtained in 10% yield.

The β-anomeric configuration of the ribopyranosyl cyanide (7) was determined from the ^{1}H n.m.r. coupling constant $J_{1,2}$ 9.2 Hz. This constant and the high value of $J_{4,5\text{-}ax}$ (9.1 Hz) indicated the existence of the ribopyranose in the $^4C_1$ conformation. The anomeric configuration of the ribofuranosyl cyanide (9) could not be determined from the ^{1}H n.m.r. spectrum since $J_{1,2}$ was 5 Hz.[19] Therefore, (9) was treated with methanolic ammonia and the resulting ribofuranosyl cyanide was benzoylated with benzoyl chloride and pyridine to give the β-ribofuranosyl cyanide (1).[16]

The formation of a 1 : 1 mixture of *endo*- and *exo*-1,2-*O*-cyanoethylidene derivatives (11a and b) was confirmed by ^{1}H n.m.r. spectroscopy.[15,20-22] The assignment was based on the different chemical shifts of the anomeric protons[15,21] [δ($CDCl_3$) 5.98 and 6.05 for (11) and 4.70 for (9)] and the differences between the chemical shifts of the CH_3–C groups of (11) and the CH_3–CO groups.[20,22] The structure of (11) was further confirmed by ^{13}C n.m.r.; the signals corresponding to C-1 of (11) appeared at much lower chemical shift (104.95 and 105.97 p.p.m.) than that for (9). The mixture (11) showed only four CO bands (169.74—170.42 p.p.m.) in that region, and two bands at much higher field (100.82, 102.28 p.p.m.) which were assigned to the tetrahedral dioxolan 2-carbon atom. Finally, the resonances of the dioxolan 2-methyl carbon atoms appeared at 24.46 and 27.33 p.p.m., clearly downfield from the narrow range 20.38—20.67 p.p.m. in which the acetyl methyl resonances occur. The ^{13}C chemical shift assignments (see Experimental) were made from off-resonance-decoupled spectra.

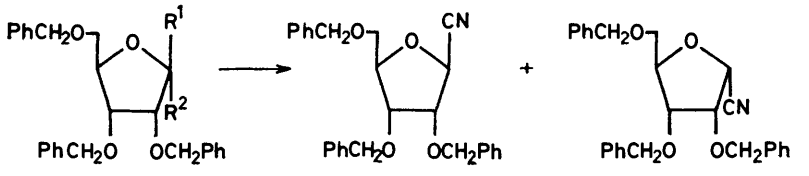
In order to investigate the occurrence of participation by a 2-*O*-acyl group, we carried out the reaction of 1,2,3,4-tetra-*O*-benzoyl-α- and β-D-arabinopyranoses [(17) and (13)], having 1,2-*trans*- and 1,2-*cis*-stereochemistry, respectively, with Me_3SiCN. Both anomers gave the same 2,3,4-tri-*O*-benzoyl-α-D-arabinopyranosyl cyanide (15), in 82 and 84% yield, respectively. Similarly, the tetra-acetyl-α- and β-D-arabinopyranoses (16) and (12) gave the α-arabino pyranosyl cyanide (14) in 67 and 63% yield, respectively. These results and the production of the dioxolan (11) indicated the participation of the neighbour 2-*O*-acyl group, possibly through acyloxonium ions such as (22) and (23).[23-25] The assistance by the 2-*O*-acyl group was further demonstrated as follows. 1-*O*-*p*-Nitrobenzoyl-2,3,5-tri-*O*-benzyl-β-D-ribofuranose (18) reacted with Me_3SiCN to



(12) R = Ac
(13) R = Bz

(14) R = Ac
(15) R = Bz

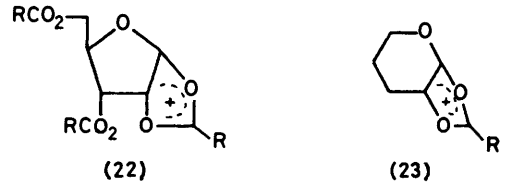
(16) R = Ac
(17) R = Bz



(18) $R^1 = p\text{-}NO_2\text{—}C_6H_4\text{—}CO_2$, R^2=H
(19) R^1=H, $R^2 = p\text{-}NO_2\text{—}C_6H_4\text{—}CO_2$

(20)

(21)



(22)

(23)

give a mixture of 2,3,5-tri-*O*-benzyl-β- and α-D-ribofuranosyl cyanides (20) and (21), in which the α-anomer (21) slightly predominated. A similar mixture of ribosyl cyanide anomers (20) and (21) was obtained from the reaction of the α-*p*-nitrobenzoate (19) with Me_3SiCN. Thus, the use of starting sugars protected by non-participating benzyl groups led to the formation of a mixture of 1,2-*trans*- and 1,2-*cis*-ribosyl cyanides, whereas sugars protected with participating acyl groups gave only 1,2-*trans*-glycosyl cyanides.

The α-anomeric configuration of the arabinopyranosyl cyanides (14) and (15) was determined from their ^1H n.m.r. spectra [solutions in $(CD_3)_2SO$]. The anomeric protons of (14) and (15) showed $J_{1,2}$ 9 and 8.5 Hz, respectively, which indicated the α-anomeric configuration of the sugars and their existence in the $^1C_4$ conformation. The ^1H n.m.r. spectra of (20) and (21) were not immediately revealing since $J_{1,2}$ was 4.5 Hz for (20) and 6.0 Hz for (21).[19] However, one of the three methylene groups of (21) (assigned as the sterically hindered 2-O-CH_2-C_6H_5) appeared as a AB system. This, and the fact that (21) is more dextrorotatory than (20),[26] suggested the α-anomeric configuration for (21), which was confirmed by ^{13}C n.m.r. It has been shown both in *C*-glycosides [27] and in *C*-nucleosides [28] that the ^{13}C chemical shifts of the carbon atom attached to the anomeric position is at higher field when this atom has a *cis*-relationship with the C(2)–OR group than when there is a *trans*-relationship. The observed ^{13}C chemical shift of the CN carbon atom of (21) was at higher field than the CN signal of (20), thus confirming the 1,2-*cis*- and 1,2-*trans*-stereochemistry (*i.e.* α- and β-anomeric configurations), respectively.

The ^{13}C n.m.r. spectra of some glycosyl cyanides were studied by Coxon,[29] who suggested characteristic CN ^{13}C chemical shift intervals for the assignment of structures to glycosyl cyanides (114.5—115.0 p.p.m.) and cyanoethylidene dioxolan derivatives (117.0—117.1 p.p.m.) in the pyranose series. The CN bands of the present ribofuranose dioxolan derivatives (11) also appeared at lower field (116.67, 117.49 p.p.m.) than the CN bands of the corresponding ribofuranosyl cyanides (9) (115.84 p.p.m.). This criterion seems to be valid for a particular pair of isomeric cyanoethylidene and glycosyl cyanide derivatives such as (11) and (9), but no general CN chemical shift intervals can be given for the unequivocal assignment of one structure or the other in the furanose series. The CN bands of the ribofuranosyl cyanides (1), (9), (20), (21) appeared in almost the same range (115.64—117.50 p.p.m.) as those of the cyanoethylidene derivatives (11) (116.67, 117.49). The CN bands of the above furanosyl cyanides also occurred at lower field (115.64—117.50 p.p.m.) than those of the pyranosyl cyanides (114.5—115.70 p.p.m.) described in Coxon's and the present paper.

EXPERIMENTAL

M.p.s were measured with a Kofler hot-stage apparatus. ^1H N.m.r. spectra were recorded with a Varian XL-100 or a Varian EM-390 spectrometer operating at 100 or 90 MHz, respectively, with Me_4Si as internal standard. ^{13}C N.m.r. spectra were obtained with a Varian XL-100 or a Bruker HX-90-E spectrometer, with Me_4Si as internal standard. I.r. spectra were recorded with a Perkin-Elmer 257 spectrophotometer. Optical rotations were determined with a Perkin-Elmer 141 polarimeter. Analytical t.l.c. was performed on aluminium sheets coated with a 0.2 mm layer of silica gel 60 F_{254} (Merck), and preparative layer chromatography was performed on 20 × 20 cm glass plates coated with a 2 mm layer of silica gel PF_{254} (Merck). Compounds were detected with u.v. light (254 nm) or by spraying the plate with ethanol–sulphuric acid (3 : 1) and heating.

2,3,5-*Tri*-O-*benzoyl*-β-D-*ribofuranosyl Cyanide* (1).—To a solution of the 1-acetate (2) (1 g, 2 mmol) and Me_3SiCN (1 ml, 7.9 mmol) in dry acetonitrile (20 ml), $SnCl_4$ (3 drops) was added, and the mixture was stirred at room temperature for 10 min. Then the solution was treated with saturated aqueous $NaHCO_3$, washed with water, dried (Na_2SO_4), and concentrated *in vacuo*. The residue was chromatographed on preparative t.l.c. plates using benzene–ether (20 : 1) as eluant to give the cyanide (1) (0.8 g, 86%), m.p. 78—80 °C; $[\alpha]_D^{25}$ +24° (*c* 1, $CHCl_3$) {lit.,[17] m.p. 77—80 °C, $[\alpha]_D^{25}$ +23.8° (*c* 0.5, $CHCl_3$)}.

Use of the chloride (3) (1 g, 2.08 mmol) as starting material gave the cyanide (1) (0.83 g, 85%). Use of the 1-methyl ether (4) (1 g, 2.10 mmol) gave (1) (0.069 g, 7%).

2,3,4,6-*Tetra*-O-*acetyl*-β-D-*galactopyranosyl Cyanide* (5).—To a solution of compound (6) (1 g, 2.5 mmol) and Me_3SiCN (1 ml) in anhydrous nitromethane (20 ml), four drops of boron trifluoride–ether complex were added, and the resulting mixture was stirred at room temperature for 1 h. Then the mixture was evaporated to dryness and the solid residue was crystallized from methanol to give the cyanide (5) (0.65 g, 71%), m.p. 168—169 °C; $[\alpha]_D^{25}$ +35° (*c* 1, $CHCl_3$) {lit.,[18] m.p. 169 °C; $[\alpha]_D^{20}$ +36.4° (*c* 1.95, $CHCl_3$)}.

2,3,4-*Tri*-O-*acetyl*-β-D-*ribopyranosyl Cyanide* (7).—A mixture of compound (8) (1 g, 3.14 mmol), Me_3SiCN (1 ml), anhydrous nitromethane (20 ml), and boron trifluoride–ether (4 drops) was stirred at room temperature for 5 min and then concentrated *in vacuo*. The residue was chromatographed on preparative t.l.c. plates using benzene–EtOAc (3 : 1) as solvent, to give the *cyanide* (7) (0.70 g, 78%) as a syrup, $[\alpha]_D^{25}$ −18° (*c* 1, $CHCl_3$) (Found: C, 50.7; H, 5.65; N, 4.9. $C_{12}H_{15}NO_7$ requires C, 50.5; H, 5.3; N, 4.9%); δ_H ($CDCl_3$) 3.73 (dd, 1 H, H-5-*ax*, $J_{4.5\text{-}ax}$ 9.5, $J_{5\text{-}eq.5\text{-}ax}$ 12.2 Hz), 4.01 (dd, 1 H, H-5-*eq*, $J_{4.5\text{-}eq}$ 5 Hz), 4.60 (d, 1 H, H-1, $J_{1.2}$ 9 Hz), 4.99—5.24 (m, 2 H, H-2, H-4), and 5.66 (t, 1 H, H-3, $J_{2.3} = J_{3.4} = 3$ Hz); δ_C ($CDCl_3$) 20.36, 20.52, 20.79 (CH_3), 64.24 (C-5), 64.06, 65.48, 66.55, 67.52 (C-1, C-2, C-3, C-4), 114.85 (CN), 168.52, 169.07, and 169.19 (CO).

2,3,5-*Tri*-O-*acetyl*-β-D-*ribofuranosyl Cyanide* (9) *and* 3,5-*Di*-O-*acetyl*-1,2-O-(1-endo- *and* -exo-*cyanoethylidene*)-α-D-*ribofuranose* (11a *and* b).—To a solution of compound (10) (1 g, 3.14 mmol) and Me_3SiCN (1 ml) in anhydrous nitromethane (20 ml), boron trifluoride–ether (4 drops) was added. The resulting solution was stirred at room temperature for 15 min, and then concentrated *in vacuo*. The residue was chromatographed on preparative t.l.c. plates using benzene–EtOAc (5 : 1) as solvent. Two major bands were observed. From the slower moving band the *cyanide* (9) (0.53 g, 59%) was obtained as a syrup; $[\alpha]_D^{25}$ +6° (*c* 1, $CHCl_3$) (Found: C, 50.5; H, 5.7; N, 4.7. $C_{12}H_{15}NO_7$ requires C, 50.5; H, 5.3; N, 4.9%); δ_H ($CDCl_3$)

2.11, 2.14, 2.16 (3s, 9 H, OAc), 4.10—4.53 (m, 3 H, H-4, H-5), 4.71 (d, 1 H, H-1, $J_{1,2}$ 5 Hz), and 5.43 and 5.63 (2 t, 2 H, H-2, H-3, J 5 Hz); δ_C ($CDCl_3$) 20.38, 20.76 (CH_3), 62.41 (C-5), 69.13, 71.12, 73.84, 80.89 (C-1, C-2, C-3, C-4), 115.84 (CN), 169.21, 169.50, and 170.42 (CO).

From the faster moving band a 1 : 1 mixture of cyanoethylidene derivatives (11a and b) (0.090 g, 10%) was obtained as a chromatographically homogeneous syrup (Found: C, 50.45; H, 5.7; N, 4.95. Calc. for $C_{12}H_{15}NO_7$: C, 50.5; H, 5.3; N, 4.9%); δ_H ($CDCl_3$ solution of the mixture) 1.79 [s, 3 H, C–CH_3 of (11a)], 1.87 [s, 3 H, C–CH_3 of (11b)], 2.09, 2.14, 2.17 (3s, 12 H, OAc), 4.04—4.51 (m, 6 H, H-4, H-5), 4.57—5.10 (m, 4 H, H-2, H-3), and 6.00 and 6.04 (2d, 2 H, H-1, $J_{1\ 2}$ 3.9 Hz); δ_C ($CDCl_3$ solution of the mixture) 20.38, 20.68 (Ac), 24.46, 27.33 (dioxolan CH_3), 61.50, 62.66 (C-5), 71.36 71.51, 75.98, 77.97, 78.95, 79.58 (C-2, C-3, C-4), 100.82, 102.28 (dioxolan C), 104.95, 105.97 (C-1), 116.67, 117.49 (CN), 169.74, 170.18, and 170.42 (four CO).

2,3,4-*Tri*-O-*acetyl*-α-D-*arabinopyranosyl Cyanide* (14).—To a mixture of compound (12) (1 g, 3.14 mmol), Me_3SiCN (1 ml) and anhydrous nitromethane (15 ml), boron trifluoride–ether (4 drops) was added. The mixture was stirred for 30 min at room temperature, and then evaporated to dryness. The residue crystallized from ethanol to give the *cyanide* (14) (0.60 g, 67%), m.p. 137—139 °C, $[\alpha]_D^{25}$ −5° (*c* 1, $CHCl_3$) (Found: C, 50.75; H, 5.55; N, 5.0. $C_{12}H_{15}NO_7$ requires C, 50.5; H, 5.3; N, 4.9%); δ_H[$(CD_3)_2$-SO] 3.95 (m, 2 H, H-5), 4.97 (d, 1 H, H-1, $J_{1,2}$ 9 Hz), and 5.23 (m, 3 H, H-2, H-3, H-4); δ_H($CDCl_3$) 3.77 (dd, 1 H, H-5-*eq*, $J_{4,5\text{-}eq}$ 3.8, $J_{5\text{-}eq,5\text{-}ax}$ 12.5 Hz), 4.10 (dd, 1 H, H-5-*ax*, $J_{4,5\text{-}ax}$ 5.8 Hz), 4.46 (d, 1 H, H-1, $J_{1,2}$ 6 Hz), and 5.10—5.40 (m, 3 H, H-2, H-3, H-4); δ_C($CDCl_3$) 20.57 (Ac), 65.14 (C-5), 65.39, 66.07, 67.33, 68.50 (C-1, C-2, C-3, C-4), 114.58 (CN), 168.87, 169.60, and 169.84 (CO).

Use of compound (16) (1 g, 3.14 mmol) as starting material gave the same cyanide (14) (0.56 g, 63%).

2,3,4-*Tri*-O-*benzoyl*-α-D-*arabinopyranosyl Cyanide* (15).—A solution of compound (13) (1 g, 1.7 mmol) and Me_3SiCN (1 ml) in anhydrous nitromethane (20 ml) was treated as indicated before with boron trifluoride–ether (4 drops) for 5 min. Then the mixture was evaporated to dryness and the residue chromatographed on preparative t.l.c. plates with benzene–ethyl ether (20 : 1) as eluant. The resulting compound crystallized from methanol to give the *cyanide* (15) (0.7 g, 84%); m.p. 184—185 °C; $[\alpha]_D^{25}$ −159° (*c* 1, $CHCl_3$) (Found: C, 68.45; H, 4.6; N, 3.15. $C_{27}H_{21}NO_7$ requires C, 68.8; H, 4.5; N, 2.95%); δ_H [$(CD_3)_2SO$] 4.30 (m, 2 H, H-5), 5.41 (dd, 1 H, H-1, $J_{1,2}$ 9 Hz), 5.72—5.94 (m, 3 H, H-2, H-3, H-4); δ_H($CDCl_3$) 4.08 (dd, 1 H, H-5-*eq*, $J_{4,5\text{-}eq}$ 3.6, $J_{5\text{-}eq,5\text{-}ax}$ 12.3 Hz), 4.34 (dd, 1 H, H-5-*ax*, $J_{4,5\text{-}ax}$ 6.6 Hz), 4.82 (dd, 1 H, H-1, $J_{1,2}$ 5.7 Hz), and 5.8 (m, 3 H, H-2, H-3, H-4); δ_C($CDCl_3$) 65.39, 67.85, 68.38, 70.04 (C-1, C-2, C-3, C-4), 66.83, (C-5), and 115.70 (CN).

The same procedure with compound (17) (1 g, 1.7 mmol) gave the same cyanide (15) (0.68 g, 82%).

2,3,5-*Tri*-O-*benzyl*-β- *and* α-D-*ribofuranosyl Cyanide* (20) *and* (21).—A solution of compound (18) (2 g, 3.5 mmol) and Me_3SiCN (1 ml) in anhydrous nitromethane (15 ml) was treated as usual with boron trifluoride–ether (4 drops). The reaction was very fast; within 1 min the starting material had disappeared. Then the mixture was concentrated *in vacuo* and the residue was chromatographed on preparative t.l.c. plates with benzene–diethyl ether (20 : 1) as eluant. Two major bands were observed. From the faster moving band was obtained the *cyanide* (20) (0.60 g, 40%) as a syrup; $[\alpha]_D^{25}$ +12° (*c* 1, $CHCl_3$) (Found: C, 75.65; H, 6.4; N, 3.35. $C_{27}H_{27}NO_4$ requires C, 75.5; H, 6.35; N, 3.25%); δ_H [$(CD_3)_2SO$] 3.54 (m, 2 H, H-5) 4.15 (m, 2 H, H-3, H-4), 4.46 (dd, 1 H, H-2), 4.49, 4.54, 4.63 (3s, 6 H, $CH_2C_6H_5$), and 4.93 (d, 1 H, H-1, $J_{1,2}$ 4.5 Hz); δ_C($CDCl_3$) 68.72, 77.52, 80.86, 82.96 (C-1, C-2, C-3, C-4), 69.30, 72.40, 72.83, 73.41 (C-5 and $CH_2C_6H_5$), and 117.50 (CN).

From the slower moving band was obtained the *cyanide* (21) (0.67 g, 45%) as a syrup; $[\alpha]_D^{25}$ +70° (*c* 1, $CHCl_3$) (Found: C, 75.55; H, 6.45; N, 3.1. $C_{27}H_{27}NO_4$ requires C, 75.5; H, 6.35; N, 3.25%); δ_H[$(CD_3)_2SO$] 3.48 (m, 2 H, H-5), 3.96—4.40 (m, 3 H, H-2, H-3, H-4), 4.43, 4.65 (2s, 4 H, $CH_2C_6H_5$), 4.52, 4.62 (AB system, 2 H, $CH_2C_6H_5$, J_{gem} 13 Hz), δ_H($CDCl_3$) 3.43 (m, 2 H, H-5), 3.92—4.36 (m, 3 H, H-2, H-3, H-4), 4.44, 4.68 (2 s, 4 H, $CH_2C_6H_5$), 4.51, and 4.69 (AB system, 2 H, $CH_2C_6H_5$, J_{gem} 12 Hz); δ_C($CDCl_3$) 68.49, 76.92, 77.74, 82.91 (C-1, C-2, C-3, C-4), 69.12, 72.35, 73.15, 73.26 (C-5, $CH_2C_6H_5$), and 115.64 (CN).

The same procedure repeated for (19) (2 g, 3.5 mmol) gave (20) (0.55 g, 37%) and (21) (0.66 g, 44%), both as syrups.

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REFERENCES

[1] D. A. Evans, G. L. Carroll, and L. K. Truesdale, *J. Org. Chem.*, 1974, **39**, 914.
[2] W. Kantlehner, E. Hang, and W. W. Mergen, *Synthesis*, 1980, 460.
[3] W. C. Groutas and D. Felker, *Synthesis*, 1980, 861.
[4] I. Fleming, *Chem. Ind.* (*London*), 1975, 449.
[5] L. Birkofer and O. Stuhl, *Fortschr. Chem. Forsch.*, 1980, **88**, 33.
[6] I. Fleming in 'Comprehensive Organic Chemistry,' eds. D. H. R. Barton and W. D. Ollis, Pergamon, Oxford, 1979, vol. 3, pp. 541—686.
[7] W. Lidy and W. Sundermeyer, *Tetrahedron Lett.*, 1973, 1449.
[8] F. Becsi and E. Zbiral, *Monatsh. Chem.*, 1979, **110**, 955.
[9] S. Hanessian and A. G. Pernet, *Adv. Carbohydr. Chem. Biochem.*, 1976, **33**, 111.
[10] R. J. Suhadolnik in 'Nucleoside Antibiotics,' Wiley–Interscience, New York, 1970.
[11] G. D. Daves and C. C. Cheng, *Prog. Med. Chem.*, 1976, **13**, 303.
[12] M. S. Poonian and E. F. Nowoswiat, *J. Org. Chem.*, 1980, **45**, 203.
[13] M. Martin-Lomas and M. E. Chacon Fuertes, *Carbohydr. Res.*, 1977, **59**, 604.
[14] B. Coxon, *Tetrahedron*, 1966, **22**, 2281.
[15] B. Coxon and H. G. Fletcher, *J. Am. Chem. Soc.*, 1963, **85**, 2637.
[16] M. Bobek and J. Farkas, *Collect. Czech. Chem. Commun.*, 1969, **34**, 247.
[17] B. Coxon and H. G. Fletcher, *J. Am. Chem. Soc.*, 1964, **86**, 922.
[18] N. Yung and J. J. Fox, *Methods Carbohydr. Chem.*, 1963, **2**, 109.
[19] L. B. Townsend in 'Synthetic Procedures in Nucleic Acid Chemistry,' eds. W. W. Zorbach and R. S. Tipson, Wiley–Interscience, New York, 1973, vol. 2, p. 323.
[20] V. I. Betaneli, M. V. Ovchinnikov, L. V. Backinowsky, and N. K. Kochetkov, *Carbohydr. Res.*, 1979, **68**, C11.

[21] G. Barnathan, T. Huynh Dinh, A. Kolb, and J. Igolen, *Eur. J. Med. Chem.*, 1976, **11**, 67.
[22] M. Martin-Lomas, M. Bernabé, and M. E. Chacon-Fuertes, *An. Quim.*, 1979, **75**, 718.
[23] W. G. Overend in ' The Carbohydrates,' eds. W. Pigman and D. Horton, Academic Press, New York, 1972, vol. 1A, pp. 297—304.
[24] H. Paulsen, H. Behre, and C. P. Herold, *Fortschr. Chem. Forsch.*, 1970, **14**, 472.
[25] K. A. Watanabe, D. H. Hollenberg, and J. J. Fox, *J. Carbohydr., Nucleosides, Nucleotides*, 1974, **1**, 1.
[26] C. S. Hudson, *J. Am. Chem. Soc.*, 1909, **31**, 66.
[27] H. Ohrui, G. H. Jones, J. G. Moffatt, M. L. Maddox, A. T. Christensen, and S. K. Byram, *J. Am. Chem. Soc.*, 1975, **97**, 4602.
[28] E. Wenkert, E. W. Hagamen, and G. E. Gutowski, *Biochem. Biophys. Res. Commun.*, 1973, **51**, 318.
[29] B. Coxon, *Ann. N.Y. Acad. Sci.*, 1973, **222**, 952.