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Evaporation of the solvent gave garosamine hydrochloride identical with authentic material.

Acknowledgments. We thank our colleagues for helpful discussions and Messrs. J. Morton, J. McGlotten, and P. Bartner for spectral data.

Registry No.—4, 65483-48-9; 8, 65483-49-0; 9, 65483-50-3; 10, 65483-51-4; 13, 65483-52-5; 14, 65483-53-6; 15, 65483-54-7; 19, 65483-55-8; 21, 65483-56-9; 22, 65483-57-0; 24, 65483-58-1; 25, 65483-59-2; 26, 65483-60-5; 27, 65504-54-3; garosamine, 28914-71-4; N-acetyl-3-aminomethyl-3-deoxy-1,2,5,6-diisopropylidene-α-D-galactofuranosane, 19131-09-0.

References and Notes
(10) J. J. Wright, unpublished observations.

Poly(iminomethylenes). 6.1 Synthesis and Polymerization of α- and β-D-Glucopyranosyl Isocyanide
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Both anomers of 2,3,4,6-tetra-O-benzyl-D-glucopyranosyl isocyanide have been synthesized starting from 2,3,4,6-tetra-O-benzyl-α-D-glucopyranosyl bromide. This bromide was converted into the β-azide which after hydrogenation to the amine and formylation afforded N-formyl-2,3,4,6-tetra-O-benzoyl-a-D-glucopyranosylamine. Dehydration of the latter compound gave the isocyanides in an a to β ratio of 1:9. Polymerization of the isocyanides was performed with nickel chloride. From the optical rotations it was concluded that the helical polymers obtained from the anomeric monomers are opposites in a screw sense.

Poly(isocyanides), more systematically named poly(iminomethylenes), [RN=C]n, are rigid rod polymers with a helical configuration. In general, they are easily prepared from the monomeric isocyanides, RN=C, with nickel chloride or a nickel(II) complex as catalyst. Stereoselective formation of either a right-handed (P) or left-handed (M) helix can be expected when the monomeric isocyanide is one enantiomer of R*N=C, in which R* is chiral.

Because of their ready availability and optical purity natural compounds often are the starting materials of choice for stereoselective syntheses. Our first entry into this field was the synthesis of a poly(iminomethylene) derived from L-histidine. In the present paper we wish to report the synthesis of such polymers derived from glucose. An additional motive for the synthesis of these compounds is the fact that polymer-bounded sugars and especially sugar residues linked to amino acids may be interesting models in immunological studies.

Results and Discussion
Reaction of silver cyanide with benzyl protected glucopyranosyl halides (1) was recently reported to give formerly unknown isocyano sugars (2).

In our hands, however, this reaction afforded unseparable mixtures of α and β anomers and other unidentified products.

We have synthesized the α and β anomers of D-glucopyranosyl isocyanide, compounds 7 and 9, via amine 5 and N-substituted formamide 6 according to Scheme I.

A convenient route for the synthesis of per-O-acylglycosylamines is provided by the reduction of the corresponding O-acylglycosyl azides. Sproviero synthesized 2,3,4,6-tetra-O-benzyl-β-D-glucopyranosyl azide (4a) in 66% yield from 2,3,4,6-tetra-O-benzyl-α-D-glucopyranosyl bromide (3a) by a nucleophilic displacement reaction with sodium azide in boiling acetonitrile. We have carried out this reaction by using phase-transfer catalysis in a mixture of chloroform and water. Compound 4a was isolated in quantitative yield; its β-D-gluc configuration was confirmed by the 1H-NMR spectrum, in which the signal for the anomeric proton appeared as a doublet at 4.95 ppm (J1,2 = 8.7 Hz).

Catalytic hydrogenation of the glycosyl azide 4a over palladium on carbon afforded 1,3,4,6-tetra-O-benzyl-β-D-glucopyranosylamine (5a) as a white foam. The latter amine was converted into its debenzoylated form (5b) by reaction with sodium methanolate in methanol. The infrared absorption spectrum of 5b showed that this compound was uncontaminated by N-benzoylglucopyranosylamine, proving that in the reduction step no O —► N benzoyl migration had oc-
The infrared absorption spectra of the solids showed characteristic isocyanide stretching vibrations at 2124 cm⁻¹. The polymers showed an intrinsic viscosity in the order of 0.025 dL/g (toluene, 30.0 °C). Applying the Mark–Houwink equation as determined for poly(1-phenylethyliminomethylene), a molecular weight of 6000 is calculated. Higher degrees of polymerization can be expected at higher isocyanide concentrations.

Table I. Optical Rotation Data of Poly(iminomethylenes) [RN=C<]ₙ, and Monomers, RN=C

<table>
<thead>
<tr>
<th>R</th>
<th>Monomer [α]₁₅₀⁺⁄₉₂⁺</th>
<th>Polymer [α]₁₅₀⁺⁄₉₂⁺</th>
<th>Contribution of helix to [α]</th>
<th>Screw sense of helix</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>+70.4⁺ b</td>
<td>+44.7⁺ d</td>
<td>0.0⁺ c</td>
<td>M</td>
</tr>
<tr>
<td>7a</td>
<td></td>
<td></td>
<td></td>
<td>P</td>
</tr>
<tr>
<td>9a</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a In chloroform; the rotation of the polymer is expressed per repeating unit. b c 1.47. c 0.42. d c 2.52. e 0.73.

Preliminary experiments, however, showed that neither triethylammonium chloride nor triethylamine could effect anomerization of 7a and 9a. Elevated temperatures and strong bases like 1,8-bis(dimethylamino)naphthalene (“proton sponge”) and 1,5-diazabicyclo[4.3.0]non-5-ene (DBN) were ineffective as well. Enhancement of the electron-withdrawing effect of the isocyan group through coordination of 7a and 9a to copper(II) tetrafluoroborate and subsequent treatment with strong base was not successful either. The results above suggest that anomerization is most likely to occur in some stage of the dehydration of the N-formylglucopyranosylamine by phosphorus oxychloride.

Both glycosyl isocyanides 7a and 9a were polymerized by 1 mol % nickel chloride in chloroform–methanol 1:1 (v/v). Under these conditions the rate of polymerization of 7a was very slow, probably as a result of steric hindrance; its isocyan group is in axial position. As judged by TLC, polymerization of 7a was accompanied by anomerization. The poly(iminomethylenes) were isolated as creamish brown solids. They were soluble in apolar solvents and insoluble in alcohols and water. Their infrared absorption spectra showed partly obscured N=C< stretching vibrations at approximately 1640 cm⁻¹. The polymers showed an intrinsic viscosity in the order of 0.025 dL/g (toluene, 30.0 °C). Applying the Mark–Houwink equation as determined for poly(1-phenylethyliminomethylene), a molecular weight of 6000 is calculated. Higher degrees of polymerization can be expected at higher isocyanide catalyst ratios.

Removal of the protecting groups in 10a and subsequent ultrafiltration and freeze drying of the resulting solution afforded poly(β-D-glucopyranosylimethylene), 10b, as a light-brown solid. In its infrared spectrum a distinct N=C< stretching vibration was visible at 1630 cm⁻¹. Compound 10b was soluble only in water.

In earlier papers we showed that poly(iminomethylenes) have a helical configuration. On polymerization of a chiral isocyanide an excess of one screw sense can be expected. The preferred screw sense can be predicted by application of our S–M–L rule which will be described in a forthcoming paper. S–M–L stands for small, medium, and large in isocyanide C(S) (M) (L)–N=C, respectively. The reverse direction of rotation S → M → L in 7 and 9 gives rise to an opposed screw sense of their polymers, viz., right handed (P) for 10a and left handed (M) for 8a. We know that a P screw gives rise to a (−) contribution to the optical rotation. Since the side chain in polymer 10a will probably have the same sign of optical rotation as in the monomer, the contributions by main chain and side chain are opposing. The total rotation can be expected to be small; in fact, it is not significantly different from zero (Table I). In polymer 8a the contributions by main chain and side chain are both predicted to be (+). The experimental value of 80° (Table I) is probably still somewhat too low for pure 8a. Because of the anomerization mentioned above, our sample of 8a will contain 10a or be a copolymer of 7a and 9a.
Experimental Section

General. Melting points were determined on a Mettler FP5/FP51 photoelectric melting point apparatus. Rotations were measured on a Perkin-Elmer 141 polarimeter. Infrared (IR) spectra were recorded on a Perkin-Elmer 145 spectrophotometer. 1H-NMR and 13C-NMR spectra were obtained on Varian EM-390 and Varian CP-20 instruments, respectively. Chemical shifts (δ) are given in ppm downfield from internal tetradeutero-methylene oxide (0.40 ppm, 1H) or deuterated chloroform (7.26 ppm, 13C) as references. Elemental analyses were carried out by the Element Analytical Section of the Institute for Organic Chemistry TNO, Utrecht, The Netherlands, under supervision of W. J. Buis. TLC was performed on silica (Schleicher and Schuell TLC Ready Plastic Foil FR-1500) and detection was effected by UV and/or spraying with 20% sulfuric acid in methanol and heating at 120 °C for 1 min. Column chromatography was performed on silica (Merck Kieselgel 60, 230-400 mesh).

2,4,6-Tetra-O-benzoyl-a-D-glucopyranosyl Bromide (3a).

This compound was prepared as described in the literature.20

2,4,6-Tetra-O-benzoyl-a-D-glucopyranosyl Azide (4a).

To a solution of 15.2 g (20 mmol) of 3a in 100 mL of chloroform was added 26 g of sodium azide and 300 mg of benzyltriethylammonium chloride. The mixture was vigorously stirred for 2 h at 70 °C. Hereafter another 26 g of sodium azide and 300 mg of benzyltriethylammonium chloride were added and stirring was continued until TLC (benzene-isopropyl alcohol, 5:1) indicated complete conversion of 3a (6-15 h). The aqueous layer was separated and extracted twice with chloroform. The combined organic layers afforded a purified sample: mp 113-114 °C; [α]22d +42.0° (c 0.7, CHCl3); IR (KBr) 3400 (NH), 1720 (C==O benzoyl), 1690 cm⁻¹ (C=O formyl); 1H NMR (CDCl3) δ 7.50, 8.15 (s, 1, CHO), 7.95 and 7.30 (2 X m, 21, benzoyl and NH), 7.60-7.45 (m, 3, H-2,3,4), 5.60 (d, J1 = 8.4 Hz, 1, H-1’), 4.80-4.40 (m, 2, H-2,3,4), 4.45-4.15 (m, 1, H-5). Anal. Calcd for C36H27NO11: C, 67.41; H, 4.69; N, 2.25; O, 24.06. Found: C, 67.06; H, 4.83; N, 2.13; O, 25.89.

2,4,6-Tetra-O-benzoyl-α-D-glucopyranosyl Bromide (3a).

To a solution of 0.34 g (1 mmol) of 2,4,6-tri-O-benzoyl-α-D-glucopyranosyl azide (4a) in 10 mL of chloroform was added 1.58 g (2.63 mmol) of phosphorus oxychloride. After heating at 70 °C for 6 h at 70 °C. Hereafter another 26 g of sodium azide and 300 mg of benzyltriethylammonium chloride were added and stirring was continued until TLC (benzene-isopropyl alcohol, 5:1) revealed the complete conversion of 6a.

β-D-Glucopyranosyl Isocyanide (9b). Debenzylation of 9a as described for 6a afforded 9b in quantitative yield. The product was isolated by freeze drying: IR (KBr) 3400 (OH), 2150 cm⁻¹ (C=O), no C=O or CH stretching vibrations in liquid. The solution was stirred for 2 days at room temperature. The solvent was removed under diminished pressure and the resulting red-brown solid was dissolved in 15 mL of chloroform. This solution was added dropwise, with vigorous stirring, to 500 mL of methanol-water 4:1. The precipitate was filtered off and dried in vacuo yielding 1.56 g (98%) of pale yellow 10a: [α]22d +44.7° (c 2.5, CHCl3); IR (KBr) 1730 (C=O), 1640 cm⁻¹ (N=O); 1H NMR (CDCl3) δ 7.9 (Δ½=45 Hz) and 7.4 (Δ½=45 Hz) (2 X br, benzoyl), 5.8 (Δ½=105 Hz, br, 4, tentative assignment H-1,2,3,4), 4.6 (Δ½=90 Hz, br, 3, tentative assignment H-5,6,6'). Anal. Calcd for C35H32NO11: C, 68.63; H, 4.64; N, 2.67; O, 24.06. Found: C, 68.79; H, 4.83; N, 2.78; O, 24.03.

N-Formyl-2,3,4,6-tetra-O-benzoyl-a-D-glucopyranosyl Isocyanide (7a).

A solution of 1.59 g (2.63 mmol) of 9a in 4 mL of chloroform was added to a solution of 6.1 ml (0.026 mmol) of nickel chloride hexahydrate in 4 mL of methanol. The mixture was stirred for 2 days at room temperature. The solvent was removed under diminished pressure and the resulting red-brown solid was dissolved in 15 mL of chloroform. This solution was added dropwise, with vigorous stirring, to 500 mL of methanol-water 4:1. The precipitate was filtered off and dried in vacuo yielding 1.54 g (35%) of polymer: [α]22d +80° (c 2.5, CHCl3); IR (KBr) 1724 ± 42.0° (c 1.5, CHCl3); 1H NMR (CDCl3) δ 8.15 (s, 1, CHO), 7.95 and 7.30 (2 X m, 21, benzoyl and NH), 7.60-7.45 (m, 3, H-2,3,4), 5.60 (d, J1 = 8.4 Hz, 1, H-1’), 4.80-4.40 (m, 2, H-2,3,4), 4.45-4.15 (m, 1, H-5). Anal. Calcd for C36H27NO11: C, 69.42; H, 4.49; N, 2.31; O, 24.05. Found: C, 68.79; H, 4.64; N, 2.78; O, 24.03.

β-D-Glucopyranosyl Isocyanide (9a). A procedure analogous to that described for the polymerization of 9a was followed, except that the temperature of the reaction mixture was kept at 45 °C. After a reaction time of 7 days 50% yield of polymer was obtained: [α]22d +80° (c 0.45, CHCl3).

Black poly(β-D-glucopyranosyliminomethylene) (10a). To a solution of 162 mg (0.07 mmol) of 10a in 40 mL of dry THF was added sodium methanolate in methanol until the reaction mixture had pH 7. Then stirring was stopped for 2 h at room temperature, TLC revealed complete removal of the benzoyl groups. The solution was washed with 20% sulfuric acid in methanol and the residue was stirred overnight at room temperature. A solution of 200 mg of sodium hydroxide in 10 mL of methanol-water 4:1 was added dropwise with stirring at 0 °C. The mixture was stirred overnight at room temperature. Subsequently, 25 mL of methanol chloride was added and the mixture was poured into an ice-cold saturated solution of sodium bicarbonate in water. The layers were separated and the aqueous layer was extracted three times with 25 mL of methylene chloride. The combined organic layers were washed with water, dried over sodium sulfate, and evaporated to dryness in vacuo, yielding a crude mixture of 7a and 9a. After separation by chromatography on a column of silicagel (30 cm long, 4 cm i.d.) with chloroform as eluent. In this way 0.12 g of 7a, 0.17 g of a mixture of 7a and 9a, and 1.78 g of 9a were obtained. Total yield 86%.

Pure 7a had mp 54–56 °C; [α]22d +70.4° (c 1.5, CHCl3); IR (KBr) 2124 ± 1 (NC, CO was used for calibration), 1725 cm⁻¹ (C=O); 1H NMR (CDCl3) δ 6.80 and 7.35 (2 X m, 20, benzoyl), 6.25 (d, d, 1, 5.85 (d, d, 1), 6.00-6.40 (m, 3, H-2,3,4), 4.95 (d, J1 = 8.4 Hz, 1, H-1’), 4.80-4.40 (m, 2, H-2,3,4), 4.45-4.15 (m, 1, H-5). Column chromatography on a AEI MS-902 mass spectrometer. Elemental analyses were carried out by the Element Analytical Section of the Institute for Organic Chemistry TNO, Utrecht, The Netherlands, under supervision of W. J. Buis. TLC was performed on silica (Schleicher and Schuell TLC Ready Plastic Foil FR-1500) and detection was effected by UV and/or spraying with 20% sulfuric acid in methanol and heating at 120 °C for 1 min. Column chromatography was performed on silica (Merck Kieselgel 60, 230-400 mesh).

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Synthesis of Substituted Coumarins

RegISTRY NO.—3a, 1428-11-2; 4a, 39639-93-9; 5a, 39639-91-7; 6a, 65292-31-4; 6b, 65292-32-5; 7a, 65375-78-2; 8a, 65292-96-8; 9a, 65375-79-3; 9b, 65292-94-6; 10a, 65292-93-5; 10b, 65292-95-7; sodium azide, 26628-22-8; formic acetic anhydride, 2258-42-6.

**References and Notes**


**Substituted Coumarins and Azacoumarins. Synthesis and Fluorescent Properties**

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Received August 30, 1977

A number of new substituted 7-amino- and 8-aza-7-amino coumarins have been synthesized. Substituent effects on fluorescence properties (maxima and quantum yields) are reported. Substitution by fluorine in the 4-methyl position and by nitrogen in the benzo ring has been found to reduce fluorescence quantum yields. Nitrogen substitution in the benzo ring provides a blue shift in the fluorescence while fluorine substitution at the 4-methyl position gives pronounced red shifts.

Recent synthesis programs in this laboratory have resulted in the preparation of a large number of substituted coumarins and azacoumarins for use as emission sources for dye laser applications. The effects of substituents on the lasing characteristics of these compounds have been reported.1-4 This report describes the synthesis of several new laser dyes and the effects of substituents on their fluorescence maxima and fluorescence quantum yields.

The new coumarin dyes prepared in the present work are shown below. Results are summarized in Table I. The syntheses led to several new results of chemical interest.

**Synthesis.** The preparation of 8-aza-7-hydroxy-4-methylcoumarin (3e) by the method of von Pechmann5,6 from 2,6-dihydroxyxpyridine (4) and ethyl acetoacetate gave in addition to the desired product small amounts of the bis addition product 10-aza-2,8-dioxo-4,6-dimethyl-2H,8H-benzo[1,2-b:5,4-b]dipyran (5) (detected by mass spectroscopy; M+ ion at m/e 243). Merchant and co-workers7 also noted the formation of trace amounts of a similar bis addition product in the reaction of ethyl acetoacetate with resorcinol. When the condensation of 2,6-dihydroxyxpyridine (4) with resorcinol is carried out in ZnCl2-EtOH, a second product (3c) is formed, which is reported in this paper.

![Chemical structures](image-url)

References and Notes


(7) Polystyrene bounded sugars have been described in: (a) B. Helferich and H. J. Hofmann, Chem. Ber., 85, 175 (1952); (b) B. Helferich and K.-H. Jung, Hoppe-Seyler's Z. Physiol. Chem., 311, 54 (1958).


(9) P. Boullanger and G. Descotes, Tetrahedron Lett., 3427 (1976); the 13C-NMR resonance of the isocyano carbon in compound 2, reported in this paper, is probably incorrect; see ref 22.


