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, 29914-71-4; N-acetyl-3-amino-3-deoxy-L,2:5,6-diisopropylidine-α-D-galactofuranose, 19131-09-0.

References and Notes

(1) W. Meyer zu Reckendorf and E. Bischof, Chem Ber., 105, 2546 (1972).

Poly(iminomethylene). 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-benzoyl-D-glucopyranosyl isocyanide have been synthesized starting from 2,3,4,6-tetra-O-benzoyl-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-D-glucopyranosylamine. Dehydration of the latter compound gave the isocyanides in an α 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(iminomethylene), [RN=C]n, are rigid rod polymers with a helical configuration.3,4 In general, they are easily prepared from the monomeric isocyanides, RN=C, with nickel chloride or a nickel(II) complex as catalyst.5,6 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.1 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 polymer-bounded amino acids may be interesting models in immunological studies.8

Results and Discussion

Reaction of silver cyanide with benzyl protected glucopyranosyl halides (1) was recently reported9 to give formerly unknown isocyanosugar (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-α-acylglycosylamines is provided by the reduction of the corresponding O-acylglycosyl azides.10 Sproviero11 synthesized 2,3,4,6-tetra-O-benzoyl-β-D-glucopyranosyl azide (4a) in 66% yield from 2,3,4,6-tetra-O-benzoyl-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-benzoyl-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,12 proving that in the reduction step no O → N benzoyl migration had oc-
**Table I. Optical Rotation Data of Poly(iminomethylene) [RN=C=]<sub>n</sub>, and Monomers, RN=C**

<table>
<thead>
<tr>
<th>R</th>
<th>Monomer [\alpha] \text{in a}</th>
<th>Polymer [\alpha] \text{in b}</th>
<th>Contribution of helix to [\alpha]</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\text{e} \text{b}</td>
<td>&gt;+80\text{c}</td>
<td>(+)</td>
<td>M</td>
</tr>
<tr>
<td></td>
<td>+44.7\text{d}</td>
<td>0.0\text{c}</td>
<td>(-)</td>
<td>P</td>
</tr>
</tbody>
</table>

* In chloroform; the rotation of the polymer is expressed per repeating unit.  
  \(b\) c 1.47.  
  \(c\) 0.42.  
  \(d\) c 2.52.  
  \(e\) c 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)napththalene ("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 isocyano 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-formylglucopyranosamine by phosphorus oxychloride.

Both glycosyl isocyanides 7a and 9a were polymerized by 1 mol % nickel chloride<sub>16</sub> in chloroform–methyl alcohol 1:1 (v/v). Under these conditions the rate of polymerization of 7a was very slow, probably as a result of steric hindrance; its isocyanate group is in axial position. As judged by TLC, polymerization of 7a was accompanied by anomerization. The poly(iminomethylene)s 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 \(\text{N=C=C}<\) stretching vibrations at approximately 1640 cm<sup>-1</sup>. 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<sup>2</sup> for poly(1-phenylethyliminomethylene), a molecular weight of 6000 is calculated. Higher degrees of polymerization can be expected at higher isocyanide catalyst ratios.<sup>16</sup>

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

In earlier papers<sup>3,4</sup> we showed that poly(iminomethylene)s 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.<sup>19</sup> S–M–L stands for small, medium, and large in isocyanide C(S) (M) (L). \(\text{N=C}<\), 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<sup>4</sup> 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 457 spectrophotometer. $^1$H-NMR and $^{13}$C-NMR spectra were obtained on Varian EM-390 and Varian CFT-20 instruments, respectively. Chemical shifts (δ) are given in ppm downfield from internal trimethylsilyl or sodium-2,2,3,3-tetradeutero-3-(trimethylsilyl)propionate. Abbreviations used are: s = singlet, d = doublet, t = triplet, m = multiplet, br = broad signal. Mass spectra were recorded on an 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. Bijs. TLC was performed on silica (Schleicher and Schüll 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 a few minutes. Column chromatography was performed on silica (Merck Kieselgel 60, 230–400 mesh).

2,4,6-Tetra-O-benzoyl-d-glucopyranosyl Bromide (3a). This compound was prepared as described in the literature. 20

To a solution of 15.2 g (20 mmol) of 3a in 100 mL of chloroform was added 26 g of sodium azide and stirring was continued until TLC (chloroform-methanol, 25:1) revealed the complete conversion of 3a. The reaction mixture was filtered and used directly for the synthesis of 4a.

2,4,6-Tetra-O-benzoyl-β-d-glucopyranosyl Azide (4a). To a solution of 15.2 g (20 mmol) of 3a in 100 mL of water and 300 mg of benzyltriethylammonium chloride was added and stirring was continued until TLC (benzene-isopropanol alcohol, 100:1) indicated complete conversion of 3a (6–15 h). The aqueous layer was separated and extracted twice with chloroform. The combined organic layers were washed, dried over sodium sulfate, and concentrated in vacuo to give 12.6 g of white solid 4a. Recrystallization from absolute ethanol afforded a purified sample: mp 113–114.4 °C; [α]$_D^{22}$ +0.54 (c 5.0, CHCl$_3$) [lit. [α]$_D^{22}$ +42.0° (c 1.0, CHCl$_3$)] 21 to us this value seems less reliable; IR (KBr) 2120 (N$_3$), 1725 cm$^{-1}$ (C=O) ; $^1$H NMR (CDCl$_3$) δ 7.90 and 7.40 (2 × m, 50, benzoyl), 6.00–6.40 (m, 3, H-2,3,4), 4.95 (d, J = 6.7 Hz, 1, H-1), 4.40–4.15 (m, 1, H-1). Anal. Calc for C$_{23}$H$_{23}$N$_3$O$_7$: C, 67.25; H, 4.83; N, 12.78. Found: C, 65.54; H, 4.23; N, 6.82; O, 23.19.

N-Formyl-2,3,4,6-tetra-O-benzoyl-d-glucopyranosylamine (5a). An amount of 15.8 g (25.4 mmol) of 4a in 350 mL of ethyl acetate was hydrolyzed over a stream of hydrogen. When TLC (chloroform-methanol, 25:1) showed that starting material was no longer present, the reaction mixture was filtered and used directly for the synthesis of 6a.

β-d-Glucopyranosyl Isocyanide (6a). To a solution of 15.9 g (2.63 mmol) of 9a in 4 mL of methanol was added 0.61 g (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 1.56 g (98%) of pale yellow 10a: [α]$_D^{22}$ +0.0° (c 0.7, CHCl$_3$); IR (KBr) 1730 (C=O), 1640 cm$^{-1}$ (N=O); $^1$H NMR (CDCl$_3$) δ 7.9 (Δ$
u_{1/2}$ 45 Hz) and 7.4 (Δ$
u_{1/2}$ 45 Hz) (2 × br, 50, benzoyl), 5.8 (Δ$
u_{1/2}$ 105 Hz), 4, tentative assignment H-1,2,3,4). 4.6 (Δ$
u_{1/2}$ 90 Hz), 3, tentative assignment H-5,6,6). Anal. Calc for C$_{20}$H$_{16}$N$_3$O$_7$: C, 69.42; H, 4.49; N, 12.71. Found: C, 69.32; H, 4.57; N, 12.74.

Polymerization of 2,3,4,6-Tetra-O-benzoyl-d-glucopyranosyl Isocyanide (7a). To a solution of 1.59 g (2.63 mmol) of 9a in 4 mL of chloroform was added a solution of 6.1 mg (0.026 mmol) of nickel chloride hexaheptadecane 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 1.56 g (98%) of pale yellow 10a: [α]$_D^{22}$ +0.0° (c 0.7, CHCl$_3$); IR (KBr) 1730 (C=O), 1640 cm$^{-1}$ (N=O); $^1$H NMR (CDCl$_3$) δ 7.9 (Δ$
u_{1/2}$ 45 Hz) and 7.4 (Δ$
u_{1/2}$ 45 Hz) (2 × br, 50, benzoyl), 5.8 (Δ$
u_{1/2}$ 105 Hz), 4, tentative assignment H-1,2,3,4). 4.6 (Δ$
u_{1/2}$ 90 Hz), 3, tentative assignment H-5,6,6). Anal. Calc for C$_{20}$H$_{16}$N$_3$O$_7$: C, 69.42; H, 4.49; N, 12.71. Found: C, 69.32; H, 4.57; N, 12.74.

Poly(β-d-glucopyranosyliminomethylene) (10b). To a solution of 162 mg (0.27 mmol) of 10a in 40 mL of dry THF was added sodium methanolate in methanol until the reaction mixture had pH 8. After being stirred for 2 h at room temperature, TLC revealed complete removal of the benzoyl groups. Diluted hydrochloric acid was added dropwise, with vigorous stirring, until the residual dissolved in water was 4. The precipitate was filtered off and dried in vacuo yielding 1.2 g (77%) of the polymer. After removal of the benzoyl groups, the polymer was dissolved in 15 mL of methanol-water 4:1. The precipitate was filtered off and dried in vacuo yielding 1.2 g (77%) of the polymer. After removal of the benzoyl groups, the polymer was dissolved in 15 mL of methanol-water 4:1. The precipitate was filtered off and dried in vacuo yielding 1.2 g (77%) of the polymer. After removal of the benzoyl groups, the polymer was dissolved in 15 mL of methanol-water 4:1. The precipitate was filtered off and dried in vacuo yielding 1.2 g (77%) of the polymer. After removal of the benzoyl groups, the polymer was dissolved in 15 mL of methanol-water 4:1. The precipitate was filtered off and dried in vacuo yielding 1.2 g (77%) of the polymer. After removal of the benzoyl groups, the polymer was dissolved in 15 mL of methanol-water 4:1.

Acknowledgments. The authors thank Professor W. Drenth and Dr. J. F. G. Vliegenthart for their helpful discussions and interest in the present work. The assistance of Dr. J. Haverkamp and Dr. J. P. Kamlering in the interpretation of $^{13}$C-NMR and mass spectra is gratefully acknowledged.
Synthesis of Substituted Coumarins

Registry No.—3a, 142-11-2; 4a, 39639-93-9; 5a, 39639-91-7; 6a, 65293-31-4; 6b, 65293-32-5; 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.

Synthesis of Substituted Coumarins

5'6-dihydroxypridine 6:5,4-6-dipyran (5) (detected by mass spectroscopy; M+ ion (m/e 243). Merchant and co-workers also noted the formation of trace amounts of a similar bis addition product in the reaction of ethyl acetocetate with resorcinol. When the condensation of 2,6-dihydroxypryidine (4) is carried out in

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. This report describes the synthesis of several new laser dyes and the effects of substituents on their fluorescence properties (maxima and quantum yields) are reported. Substitution by fluorine in the 4-methyl position on fluorescence properties (maxima and quantum yields) is carried out in

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 provides a blue shift in the fluorescence while fluorine substitution at the 4-methyl position gives pronounced red shifts.

Properties

Substantiated Coumarins and Azacoumarins. Synthesis and Fluorescent Properties

Ronald L. Atkins* and Dan E. Bliss

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. 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 Pechmann from 2,6-dihydroxypryidine (4) and ethyl acetocetate 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-workers also noted the formation of trace amounts of a similar bis addition product in the reaction of ethyl acetocetate with resorcinol. When the condensation of 2,6-dihydroxypryidine (4) is carried out in

**References and Notes**

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.