dimethylindole). Recrystallization of this material proved troublesome, but rechromatography of the product gave a sample having an infrared spectrum identical with that of a commercial sample, mp 104° (lit.[30] mp 104–104.5°).

Benzene–ether (9:1) eluted a mixture (0.8 g) which was mainly 2,2-dimethylindolin-3-one but contained two other components. Rechromatography on alumina gave pure (tlc) **10** (0.40 g, 2.5 mmoles, 11%) as an oil. Crystallization from cyclohexane–hexane gave yellow needles: mp 87–88° (lit. mp 88°,[31] 89°[32]); ν_{NH} 3340 cm^{-1}; $\nu_{C=O}$ 1675 cm^{-1}; $\lambda\lambda_{max}$ 230 mμ (log ε 4.33), 253 (3.79), 391 (3.60); nmr peaks ($CDCl_3$) at δ 1.32 (singlet, 6 H), 4.78 (broad singlet, 1 H), and 6.6–7.75 (multiplet, 4 H).

The fractions containing the two contaminants were combined and chromatographed on alumina. Poor separation resulted, but recrystallization of the residue from the concentrated fractions gave 2,2,2′,2′-tetramethyl-3,3′-biindoline (**11**) as white crystals: mp 172–174°, ν_{NH} 3315 cm^{-1}.

Anal. Calcd for $C_{20}H_{24}N_2$: C, 82.14; H, 8.27. Found: C, 82.19; H, 8.43.

Deoxygenation of α-Methyl-2′-nitrostilbene (4).—A solution of **4** (3.1 g, 13 mmoles) in triethyl phosphite (12.9 g, 78 mmoles) was heated at 163 ± 2° for 6 hr and then subjected to the usual work-up. Chromatography on silicic acid gave 1-ethyl-2-methyl-3-phenylindole (0.658 g, 2.8 mmoles, 21%), a liquid eluted by hexane–benzene (9:1). The nmr and infrared spectra of this material were identical with those of an authentic sample described below.

Benzene–hexane (1:1) eluted 2-methyl-3-phenylindole (2.07 g, 10 mmoles, 77%), mp 60–61° (lit.[33] mp 58–60°) after recrystallization from benzene–hexane: ν_{NH} 3375 cm^{-1}; $\lambda\lambda_{max}$ (ethanol) 225 mμ (log ε 4.72), 275 mμ (log ε 4.29); nmr peaks at δ 2.37 (singlet, 3 H), and 6.9–7.8 (multiplet, 10 H). The infrared spectrum of the sample was identical with that of an authentic sample prepared as described by Ockenden and Schofield.[33]

1-Ethyl-2-methyl-3-phenylindole (13).—Sodium amide (0.39 g, 10 mmoles) was placed in a three-neck flask equipped with a Dry Ice–acetone condenser. Liquid ammonia (20 ml) was added, followed by dropwise addition of an ether solution of 2-methyl-3-phenylindole (1.35 g, 6.5 mmoles). After 5 min ethyl iodide (1.0 g, 6.5 mmoles) in ether (5 ml) was added. The reaction mixture was stirred for 30 min, and the ammonia was then allowed to evaporate. Water (100 ml) was added to the residue, and the mixture was extracted with ether. Chromatography of the crude product on silicic acid gave **13** (0.563 g, 2.3 mmoles, 47%) as well as unreacted **12** (0.327 g). An analytical sample was prepared by short-path distillation: bp 145–147° (0.36 mm); nmr peaks at δ 1.3 (triplet, 3 H), 2.4 (singlet, 3 H), 4.1 (quartet, 2 H), and 6.9–7.7 (multiplet, 4 H).

Anal. Calcd for $C_{17}H_{17}N$: C, 86.77; H, 7.28. Found: C, 86.60; H, 7.52.

Interrupted Deoxygenations of 4.—The usual temperature and reactant ratios were used, but in separate runs the reaction was stopped 0.5, 1, and 2 hr after heating began. The crude reaction product obtained after distillation of triethyl phosphite and triethyl phosphate was dissolved in ether and extracted with base to isolate any N-hydroxyindole. None was found. The neutral products from the 1- and 2-hr runs were subsequently chromatographed, giving unreacted **4** as well as **12** and **13**.

Attempted Oxidation of 5,6,7,8,9,10-Hexahydrocyclohept[*b*]-indole in the Presence of Triethyl Phosphite.—Air was passed for 24 hr through a solution of **5** (9.25 g, 50 mmoles) and triethyl phosphite (49.8 g, 300 mmoles) in ether (150 ml). The ether was evaporated, and the residue was filtered, giving unchanged **5** (7.1 g). The filtrate was diluted with hexane and refrigerated, giving additional **5** (1.7 g). The mother liquor was distilled, giving triethyl phosphate (1.1 g), and additional unreacted **5** (0.4 g) remained as the residue. Total recovery was 9.2 g, >99%. The recovered indole was homogeneous to thin layer chromatography.

Acknowledgment.—Acknowledgment is made to the donors of the Petroleum Research Fund, administered by the American Chemical Society, for partial support of this research through a Type G Grant. This work was also supported in part by National Science Foundation Grant GP-5292.

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Reversal of the Hudson Rules of Rotation. Effect of Solvent and Temperature on the Rotations of the Anomeric 1,3,4,6-Tetra-*O*-acetyl-2-deoxy-2-(2,4-dinitroanilino)-D-glucopyranoses[1]

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The specific rotations of 1,3,4,6-tetra-*O*-acetyl-2-deoxy-2-(2,4-dinitroanilino)-α-D-glucopyranose (**1**) and its β-D anomer (**2**) have been determined over the temperature range 20–60° in the solvents chloroform, benzene, pyridine, acetone, and methanol, and ORD spectra of **1** and **2** in chloroform have been measured over the wavelength range 300–500 mμ. In all cases the β-D anomer **2** is more dextrorotatory than the α-D anomer **1**, contrary to expectations based on Hudson's rule. The rotatory anomaly is related to the nitro group at the *ortho* position of the aryl moiety.

1,3,4,6-Tetra-*O*-acetyl-2-deoxy-2-(2,4-dinitroanilino)-α-D-glucopyranose (**1**) and its β-D anomer (**2**) have been synthesized[1,4] by several definitive routes, and their anomeric configurations have also been verified by nmr.[1] This pair of anomers is unusual in that β-D anomer **2** is considerably more dextrorotatory than α-D anomer **1**, for rotations measured in chloroform solution at room temperature. This constitutes a complete reversal of the Hudson rule[5] that α-D anomers should be more dextrorotatory than the corresponding β-D anomers, and is the first recorded example of such a reversal for a pair of anomers having a simple aglycon. In the present work it is shown that this reversal of the normal rotatory relationships by the anomeric pair **1** and **2** is observed with a variety of different solvents, at various temperatures; in most cases the rotations show marked changes as the temperature is varied.

The specific rotations of **1** and **2**, measured at various temperatures between 20 and 60° for the solvents chloroform, benzene, pyridine, acetone, and methanol,

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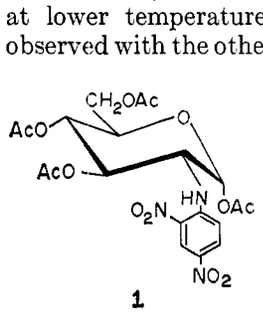
TABLE I

SPECIFIC ROTATIONS OF 1 AND 2 IN VARIOUS SOLVENTS OVER A RANGE OF TEMPERATURE

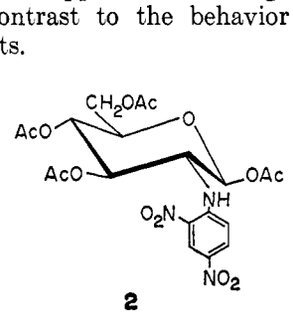
Substance	Solvent	Concn, g/100 ml	Specific rotation, deg (temp, deg)
1	Chloroform	1.1	11 ± 2 (23), 10 ± 3 (29), 11 ± 2 (34), 13 ± 3 (40), 14 ± 3 (45)
2	Chloroform	1.1	52 ± 3 (23), 47 ± 3 (29), 44 ± 3 (36), 38 ± 2 (42)
1	Benzene	0.35	4 ± 4 (25), −5 ± 4 (31), −13 ± 6 (39), −18 ± 3 (46), −24 ± 7 (53)
2	Benzene	1.1	63 ± 4 (27), 58 ± 3 (34), 51 ± 4 (41), 47 ± 4 (47), 41 ± 4 (53)
1	Pyridine	0.95	−11 ± 2 (24), −9 ± 3 (31), −11 ± 3 (39), −11 ± 2 (46) −11 ± 2 (54), −10 ± 3 (60)
2	Pyridine	1.1	71 ± 2 (23), 65 ± 2 (30.5), 60 ± 3 (37), 53 ± 2 (47) 50 ± 3 (54), 48 ± 3 (58)
1	Acetone	1.1	61 ± 2 (21), 56 ± 2 (29), 53 ± 3 (35), 50 ± 4 (41)
2	Acetone	1.1	72 ± 2 (25), 64 ± 2 (30), 64 ± 2 (34), 61 ± 3 (39), 55 ± 3 (45) 49 ± 3 (50)
1	Methanol	0.65	59 ± 3 (24), 54 ± 4 (29), 48 ± 3 (35), 48 ± 3 (40), 46 ± 3 (45) 37 ± 6 (52), 38 ±, 3 (58)
2	Methanol	0.23	37 ± 5 (39), 37 ±, 10 (45), 23 ± 5 (50), 5 ± 10 (55)

are recorded in Table I and Figure 1. In each of the solvents, and at each temperature of measurement, β-D anomer **2** has a higher specific rotation than α-D anomer **1**, indicating that the reversal of Hudson's rule observed[1] with chloroform is not an isolated phenomenon for that particular solvent. The magnitude of the difference in specific rotation between **1** and **2** decreases for the solvents in this order: pyridine, benzene, chloroform, acetone, and methanol.

The specific rotation of β-D anomer **2** exhibits a large, negative temperature coefficient in each of the solvents. The specific rotation of α-D anomer **1** in acetone has a negative temperature coefficient of smaller magnitude than that of **2**. In pyridine the temperature coefficient for **1** is approximately zero, and in chloroform it is positive. It is probable that the specific rotation of **1** may exceed that of **2** at temperatures considerably above the normal boiling point, in acetone, pyridine, and chloroform. In benzene solution, the two anomers show large, almost equal, negative temperature coefficients of rotation, with no apparent convergence at higher temperatures. The low solubility of the anomers, particularly **1**, in methanol precluded accurate observations, but the rotations appear to converge at lower temperatures, in contrast to the behavior observed with the other solvents.



1



2

The anomalous rotatory behavior of **1** and **2** appears to be related to the presence of a nitro group at the *ortho* position in the aryl group. A range of analogs of **1** and **2**, having various acylamido, arylamino, and arylsulfonamido groups at C-2, but no *o*-nitroaryl groups, has been found[6] to exhibit "normal" rotatory relationships. It has long been known[7] that the *o*-nitrophenyl D-glucopyranoside tetraacetates are abnormal in that the β-D anomer exhibits positive rotation at room temperature, but a complete reversal of

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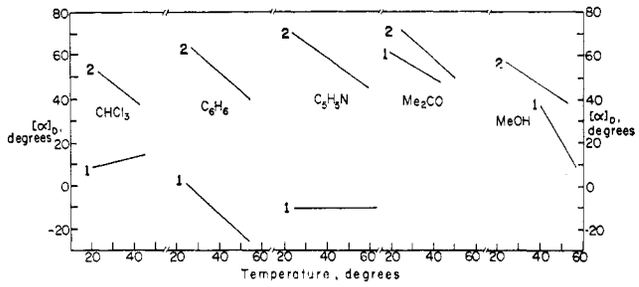

Figure 1.—The variation of specific rotation of **1** and **2** with temperature in various solvents.

the normal rotatory relationships is not observed. The abnormal, positive rotations of various *o*-nitroaryl β-D-glucopyranoside tetraacetates become negative, and quantitatively "normal" at higher temperatures.[7,8] Studies on various *ortho*-substituted aryl D-glucopyranosides have indicated[9] that the abnormal rotations are specifically associated with the *o*-nitro group. Other groups at this position do not give rise to abnormal rotations, indicating that steric hindrance to rotation of the aryl group is probably not the cause of the effect. It has recently been noted[10] that the anomeric *o*-nitrophenyl 2-acetamido-3,4,6-tri-*O*-acetyl-2-deoxy-D-glucopyranoses, in chloroform at room temperature, exhibit complete reversal of the normal rotatory relationships; this reversal is not observed with the *O*-deacetylated products in water solution.

It appears from the data given herein that the rotatory anomaly with **1** and **2** is greatest in solvents of low polarity. The available evidence suggests that there exists a specific, intramolecular, dipole interaction, between the *o*-nitro group and certain other groups in the molecule, which constrains the aryl group in such a way that a dissymmetric chromophore of high rotational strength is generated, whose conformational rotatory contribution[11] is of the same order of magnitude as the rotatory contribution of C-1. A similar factor would appear to be operative with the *o*-nitroaryl glycosides. In solvents of high polarity the rotatory anomaly will be diminished because of competing, intermolecular interaction of the dipoles in the

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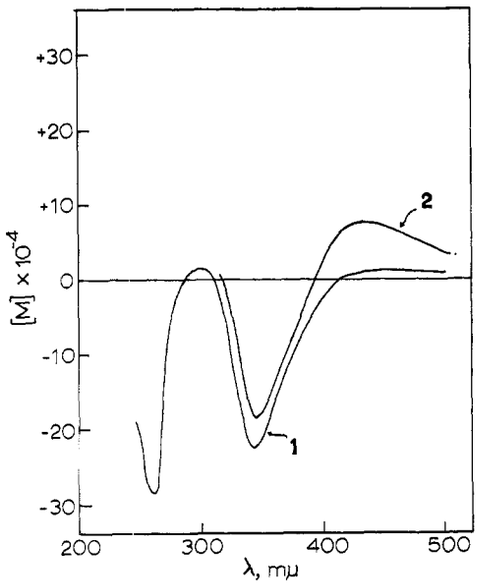

Figure 2.—The optical rotatory dispersion spectra of 1 and 2 in chloroform solution at 25°.

molecule with solvent dipoles. Elevation of the temperature would also tend to diminish the anomaly, by facilitating interconversion of rotomers. The exact nature of the proposed dipole interaction is speculative, but determination of the favored conformation of the aryl group, by X-ray crystallographic analysis, would provide useful evidence on this point.

It has already been shown[1] that the reversal of Hudson's rule for **1** and **2** in chloroform solution holds true over the wavelength range 500–700 mμ; observations at shorter wavelengths were prevented by the strong absorptions of the 2,4-dinitrophenyl chromophore. With the use of a more sensitive spectropolarimeter, measurements over the range 300–500 mμ have been made (Figure 2). It is seen that β-D anomer **2** remains more dextrorotatory than α-D anomer **1** over this whole spectral range. Both anomers show an optically active absorption, of the same sign, in the region 345–360 mμ, and in the case of **1** a second optically active absorption at 260 mμ is observed.

The feasibility of ORD measurements with 2,4-dinitrophenyl derivatives suggests that it might be possible to assign the configuration of amino groups attached to asymmetrically substituted carbon atoms, by means of ORD data on the *N*-(2,4-dinitrophenyl) derivatives.

Experimental Section

1,3,4,6-Tetra-*O*-acetyl-2-deoxy-2-(2,4-dinitroanilino)-α- (and β-) D-glucopyranose (1 and 2).—The anomers were prepared by the procedure previously described,[1] and each product was recrystallized several times. The compounds were chromatographically homogeneous, anomerically pure by nmr, and had melting points and specific rotations in exact agreement with the given values.[1]

Rotation Measurements.—The specific rotations of **1** and **2** were measured in the solvents chloroform, benzene, pyridine, acetone, and methanol. A jacketed, center-filling, 1-dm polarimeter tube was used; the jacket was connected to water circulating from a thermostatically controlled water bath, and measurements were made at various temperatures between 20 and 60°. The polarimeter tube was closed with a plastic stopper fitted with an open capillary tube, to allow for thermal expansion while preventing evaporation, and the specific rotations at room temperature were redetermined after the measurements at higher temperatures had been made. Solute concentrations used were approximately 1%, except for the case of **1** in benzene, and **1** and **2** in methanol, where solubility limitations necessitated the use of lower concentrations. The results are given in Table I and Figure 1.

Optical rotatory dispersion measurements were made with chloroform solutions and a Bendix Model 460 C recording spectropolarimeter (Bendix Corp., Cincinnati, Ohio).

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Use of *p*-Nitrophenyl Chloroformate in Blocking Hydroxyl Groups in Nucleosides[1,2]

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p-Nitrophenyl chloroformate reacts with hydroxyl groups in nucleosides and nucleoside derivatives at room temperature to give two useful types of O-blocked derivatives. Compounds with "isolated" hydroxyl groups are converted into the *p*-nitrophenyl carbonate esters; those with adjacent *cis*-hydroxyl groups (ribonucleosides) are converted into cyclic carbonates. Specific examples include the formation of *p*-nitrophenyl 5′-O-trityl-thymidine 3′-carbonate from 5′-O-tritylthymidine, *p*-nitrophenyl thymidine 5′-carbonate from thymidine, and uridine 2′,3′ cyclic carbonate from uridine. The O-blocking groups are stable to conditions used for phosphorylation reactions and may be removed in weakly basic solutions (*e.g.*, imidazole in aqueous organic solvents for the nitrophenyl esters and dilute sodium hydroxide or hot aqueous pyridine for the cyclic carbonates).

For the synthesis of oligonucleotides and other complex substances from nucleosides, a variety of selective blocking agents for hydroxyl groups are desirable. Acetyl,[3,4] benzoyl,[4,5] triarylmethyl (triphenylmethyl and mono-, di-, and trimethoxytriphenylmethyl),[4-6] and alkylidene[4,7] groups have been widely used. The acyl groups are removed by alkaline hydrolysis and the triarylmethyl and alkylidene groups by acid hydrolysis. Recently, 2,4-dinitrobenzenesulfenyl chlo-

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