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NEW TYPES OF THE *TRANS*-GLYCOSYLATION REACTION

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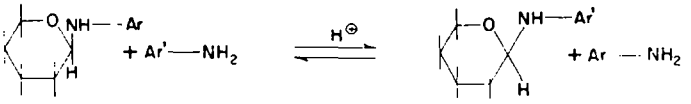
Abstract—Newer types of *trans*-glycosylation of N-arylglycosylamines have been realised in which N-arylglycosylamines and monosaccharides as well as two N-arylglycosylamines with different amine and sugar components took place. Results are summarized in Tables 1–4. *Trans*-glycosylation of acetylated N-arylglycosylamine with monosaccharide means a new method for the preparation of partly acetylated monosaccharides. Mechanisms of the reactions have been discussed.

IT was reported previously[1] that the scope of the *trans*-glycosylation reaction of N-arylglycosylamines may be extended, so that not only the arylamine, but also the glycosyl and acetylated glycosyl part of the molecule may be exchanged. We have now found that *trans*-glycosylations may be realised in almost any variation.

In previous papers[2] and in examples known until now, the following types of *trans*-glycosylation were described:



Type Ia

The N-arylglycosylamine is acted upon by another arylamine, forming the glycosylamine of the new arylamine and liberating the amine from the original arylglycosylamine.

$$\text{glycosyl-NH-aryl} + \text{H}_2\text{N-aryl'} \rightleftharpoons \text{glycosyl-NH-aryl'} + \text{H}_2\text{N-aryl}$$

Type Ib

Reaction of an N-arylglycosylamine acetate with an aromatic amine results in the combination of the O-acetylglycosyl part with the other amine forming a new N-arylglycosylamine acetate.

$$(\text{Ac})_n\text{-glycosyl-NH-aryl} + \text{H}_2\text{N-aryl'} \rightleftarrows (\text{Ac})_n\text{-glycosyl-NH-aryl'} + \text{H}_2\text{N-aryl}$$

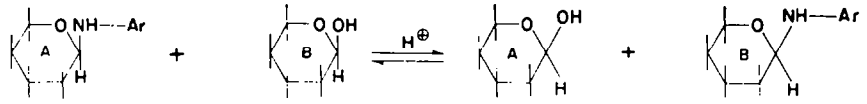
Trans-glycosylations of types Ia and Ib were carried out in alcoholic solutions, in the presence of acid catalysts. The conversions were shown to be equilibrium reactions, and could be made reversible under suitable conditions. The reactions were comparatively rapid in solutions of a molarity of 0·2–0·5; the product, as a component of the equilibrium system, separated from the mixture in crystalline form in good yield. When suitable solvents and concentrations are used the method may be applied for preparative purposes.

[1] R. Bognár and P. Nánási, *Acta Chim. Hung.* **12**, 115 (1957); unpublished results communicated at I.U.P.A.C. Congress, Paris 1957.

[2] R. Bognár and P. Nánási, *Nature, Lond.* **171**, 475 (1953); *J. Chem. Soc.* 189 (1955); *Magyar Kémiai Folyóirat* **62**, 88 (1956); R. Bognár, P. Nánási and E. Nemes-Nánási, *J. Chem. Soc.* 193 (1955); *Magyar Kémiai Folyóirat* **62**, 271 (1956).

In addition, it was shown that the reaction was true *trans*-glycosylation and not hydrolysis followed by reglycosylation. This was also true for more dilute solutions (0·04 M concentration), and when about 10 per cent water was present. (*J. Chem. Soc.* In press.)

We now report the feasibility of achieving the *trans*-glycosylation reaction in cases described below.



Type IIa

Reaction of N-arylglycosylamine with a monosaccharide leads to the formation of an N-arylglycosylamine containing the new sugar, and the original sugar moiety is released. The possibility of this type of reaction was demonstrated independently by Inoue *et al.*[3], by the technique of paper chromatography.

glycosyl-NH-aryl + glycosyl'-OH ⇄ glycosyl'-NH-aryl + glycosyl-OH

Respective experiments and their results are summarized in Table 1.

This type of *trans*-glycosylation gives best yields and the purest products in the presence of a small amount of water (5–10 per cent). In absolute alcohol prolonged refluxing is necessary for dissolving the starting materials, when the solutions become strongly coloured. Free sugars have, in general, very low solubilities in anhydrous alcohol. A fair yield is obtained if the solvent contains a small amount of water or pyridine. When the reaction is carried out in aqueous medium, the possibility of hydrolysis and subsequent reglycosylation must be taken into consideration. True *trans*-glycosylation and glycoside formation after previous hydrolysis may, in our opinion, take place as parallel reactions.

When either component is taken in 1 mole excess, yields of the crude product are increased; however, the purity of the product is not satisfactory, therefore no appreciable gain is found from the preparative point of view by employing 1 mole excess of one of the components.

Yield percentages given in the Table 1 for the crude product relate to materials containing less than 10 per cent impurity. In general they are about 95 per cent pure.

Type IIb

Reaction of an N-arylglycosylamine acetate with a free simple sugar, gives a new N-arylglycosylamine and a monosaccharide acetate with a free hydroxyl group on $C_{(1)}$

$(Ac)_n$-glycosyl-NH-aryl + glycosyl'-OH ⇄ glycosyl'-NH-aryl + $(Ac)_n$-glycosyl-OH

Experiments and results are shown in Table 2.

Aqueous alcohol was employed as the solvent, because in this type of reaction one component is again a free sugar. Ammonium chloride was found to be a better catalyst than hydrochloric acid, but best yields were obtained in the presence of pyridine with hydrochloric acid catalyst.

As the result of the reaction, the new, non-acetylated, free N-arylglycosylamine

[3] Y. Inoue, K. Onodera and S. Kitaoka, *J. Agric. Chem. Soc. Japan* 27, 5 (1953).

TABLE 1

Experiment Type	Experiment No	Reactants (Mole ratio of the reactants = 1:1 except given cases)	Solvent	Catalyst	Period of boiling	Product	Yield (%) Crude	Yield (%) Pure
IIa	1	N-*p*-tolyl-D-glucosylamine + D-mannose	94% EtOH	HCl	5	N-*p*-tolyl-D-mannosylamine	76·5	70
IIa	2	N-*p*-tolyl-D-glucosylamine + D-mannose	94% EtOH	HCl	1	N-*p*-tolyl-D-mannosylamine	63·5	56
IIa	3	N-*p*-tolyl-D-glucosylamine + D-mannose	75% MetOH	HCl	5	N-*p*-tolyl-D-mannosylamine	55	53·8
IIa	4	N-*p*-tolyl-D-glucosylamine + D-mannose	94% EtOH + Py	HCl	5	N-*p*-tolyl-D-mannosylamine	56·5	
IIa	5	N-*p*-tolyl-D-glucosylamine + D-mannose	94% EtOH + Py	HCl	5	N-*p*-tolyl-D-mannosylamine	73·2	69
IIa	6	N-*p*-tolyl-D-glucosylamine + D-mannose	94% EtOH	NH_4Cl	5	N-*p*-tolyl-D-mannosylamine	63	60
IIa	7	N-*p*-tolyl-D-glucosylamine + D-mannose	abs. EtOH	HCl	8	N-*p*-tolyl-D-mannosylamine	6·7	6·1
IIa	8	N-*p*-tolyl-D-glucosylamine + D-mannose	abs. EtOH + Py	HCl	15	N-*p*-tolyl-D-mannosylamine	67	64·5
IIa	9	N-*p*-tolyl-D-glucosylamine + D-mannose	abs. EtOH	NH_4Cl	5	N-*p*-tolyl-D-mannosylamine	33·3	32
IIa	10	N-*p*-tolyl-D-glucosylamine + D-mannose	abs. EtOH	—	5	N-*p*-tolyl-D-mannosylamine	20	17
IIa	11	N-*p*-tolyl-D-glucosylamine + D-mannose	abs. EtOH	—	120, 40°	N-*p*-tolyl-D-mannosylamine	35	
IIa	12	N-*p*-tolyl-D-glucosylamine + D-mannose	94·6% EtOH + Py	—	5 after 2 days		0 20	17
IIa	13	N-*p*-tolyl-D-glucosylamine + D-mannose	94·6% EtOH	—	5 after 2 days	N-*p*-tolyl-D-mannosylamine	7 40	
IIa	14	N-*p*-tolyl-D-glucosylamine + D-mannose 1:2	94% EtOH	HCl	5	N-*p*-tolyl-D-mannosylamine	93·5	75
IIa	15	N-*p*-tolyl-D-glucosylamine + D-mannose 1:2	75% EtOH	HCl	5	N-*p*-tolyl-D-mannosylamine	73	61·6
IIa	16	N-*p*-tolyl-D-glucosylamine + D-mannose 1:0·5	94% EtOH	HCl	5	N-*p*-tolyl-D-mannosylamine	80	72·2
IIa	17	N-*p*-tolyl-D-glucosylamine + D-mannose 1:2	94% EtOH + Py	HCl	5	N-*p*-tolyl-D-mannosylamine	80	62·7
IIa	18	N-*p*-tolyl-D-glucosylamine + D-mannose 1:2	94% EtOH	NH_4Cl	5	N-*p*-tolyl-D-mannosylamine	76·6	64·1
IIa	19	N-*p*-tolyl-D-glucosylamine + D-mannose 1:0·5	94% EtOH	NH_4Cl	5	N-*p*-tolyl-D-mannosylamine	80	73·6
IIa	20	N-*p*-tolyl-D-galactosylamine + D-mannose	abs. EtOH	HCl	30	N-*p*-tolyl-D-mannosylamine	27·5	
IIa	21	N-*p*-tolyl-D-galactosylamine + D-mannose	abs. EtOH	HCl	5	N-*p*-tolyl-D-mannosylamine	70	66·2
IIa	22	N-*p*-tolyl-D-glucosylamine + D-galactose	97% EtOH	HCl	10	N-*p*-tolyl-D-galactosylamine	65	
IIa	23	N-*p*-tolyl-D-glucosylamine + D-galactose	97% EtOH + Py	HCl	5	N-*p*-tolyl-D-galactosylamine	72·5	
IIa	24	N-*p*-tolyl-D-glucosylamine + D-galactose	abs. EtOH	HCl	40	N-*p*-tolyl-D-galactosylamine	25 and 28	
IIa	25	N-*p*-Br-phenyl-D-glucosylamine + D-galactose	90% MeOH + Py	HCl	5	N-*p*-Br-phenyl-D-galactosylamine	67·5	
IIa	26	N-*p*-Br-phenyl-D-glucosylamine + D-galactose 1:2	90% MeOH + Py	HCl	5	N-*p*-Br-phenyl-D-galactosylamine	77·5	
IIa	27	N-*p*-Br-phenyl-D-glucosylamine + D-galactose 1:1	90% EtOH	NH_4Cl	15	N-*p*-Br-phenyl-D-galactosylamine	21·5	
IIa	28	N-*p*-Br-phenyl-D-glucosylamine + D-galactose	90% EtOH	NH_4Cl	15	N-*p*-Br-phenyl-D-galactosylamine	29·5	
IIa	29	N-*p*-NO_2-phenyl-D-glucosylamine + D-galactose	90% EtOH	HCl	15	N-*p*-NO_2-phenyl-D-glucosylamine	35·5	15
IIa	30	N-*p*-NO_2-phenyl-D-glucosylamine + D-galactose	90% EtOH + Py	HCl	15	N-*p*-NO_2-phenyl-D-glucosylamine	50	34

TABLE 2

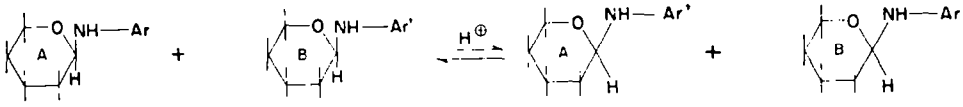
Experiment Type	Experiment No	Reactants (Mole ratio of the reactants = 1:1 except given cases)	Solvent	Catalyst	Period of boiling (min)	Product	Yield (%)
IIb	1	N-*p*-tolyl-D-glucosylamine tetraacetate + D-mannose	96% EtOH	HCl + Py	15	N-*p*-tolyl-D-mannosylamine	78
IIb	2	N-*p*-tolyl-D-glucosylamine tetraacetate + D-mannose	96% EtOH	NH_4Cl	30	N-*p*-tolyl-D-mannosylamine	64·5
IIb	3	N-*p*-tolyl-D-glucosylamine tetraacetate + D-mannose	96% EtOH	HCl + Py	10	N-*p*-tolyl-D-mannosylamine + D-glucosetetracetate	75 61
IIb	4	N-*p*-tolyl-D-glucosylamine tetraacetate + D-mannose	96% EtOH	HCl	10	0	0
IIb	5	N-*p*-tolyl-D-glucosylamine tetraacetate + D-mannose	96% EtOH	—	10	0	0
IIb	6	N^4-*p*-sulphamylphenyl-D-glucosylamine tetraacetate + D-glucose	abs. EtOH	HCl + Py	15	N^4-*p*-sulphamylphenyl-D-glucosylamine	17
IIb	7	N-*p*-tolyl-D-mannosylamine-tetraacetate + D-mannose	96% EtOH	HCl + Py	10	N-*p*-tolyl-D-mannosylamine + D-mannosetetraacetate	63·5 54·5
IIb	8	N-*p*-tolyl-D-galactosylamine-tetraacetate + D-mannose	96% EtOH	HCl + Py	10	N-*p*-tolyl-D-mannosylamine + D-galactose-tetraacetate	64·5 46·8

TABLE 3

Experiment Type	Experiment No	Reactants (Mole ratio of the reactants = 1:1 except given cases)	Solvent	Catalyst	Period of boiling (min)	Product	Yield (%)
IIIa	1	N-*p*-nitrophenyl-D-glucosylamine + N-*p*-tolyl-D-galactosylamine	abs. ethanol	HCl	10	N-*p*-nitrophenyl-D-galactosylamine	42
IIIa	2	N-*p*-nitrophenyl-D-glucosylamine + N-*p*-tolyl-D-galactosylamine	abs. ethanol	HCl + Py	5	N-*p*-nitrophenyl-D-galactosylamine	42
IIIa	3	2 moles N-*p*-nitrophenyl-D-glucosylamine + N-*p*-tolyl-D-galactosylamine	abs. ethanol	HCl	4	N-*p*-nitrophenyl-D-galactosylamine	55
IIIa	4	2 moles N-*p*-nitrophenyl-D-glucosylamine + N-*p*-tolyl-D-galactosylamine	abs. ethanol	—	10	N-*p*-nitrophenyl-D-galactosylamine	0
IIIa	5	N^4-*p*-sulphamylphenyl-D-galactosylamine + N-*p*-tolyl-D-glucosylamine	abs. methanol	HCl	5	N^4-*p*-sulphamylphenyl-D-glucosylamine	15·5
IIIa	6	N^4-*p*-sulphamylphenyl-D-galactosylamine + N-*p*-tolyl-D-glucosylamine	abs. methanol	HCl + Py	5	N^4-*p*-sulphamylphenyl-D-glucosylamine	24
IIIa	7	0·5 mole N^4-*p*-sulphamylphenyl-D-galactosylamine + N-*p*-tolyl-D-glucosylamine	abs. methanol	HCl + Py	5	N^4-*p*-sulphamylphenyl-D-glucosylamine	27·5
IIIa	8	2 moles N^4-*p*-sulphamylphenyl-D-galactosylamine + N-*p*-tolyl-D-glucosylamine	abs. methanol	HCl + Py	5	0	—
IIIa	9	N^4-*p*-sulphamylphenyl-D-galactosylamine + N-(4-carboxy-3-hydroxyphenyl)-D-glucosylamine	abs. methanol	NH_4Cl	30	N^4-*p*-sulphamylphenyl-D-glucosylamine	18·2
IIIa	10	N^4-*p*-sulphamylphenyl-D-galactosylamine + N-(4-carboxy-3-hydroxyphenyl)-D-glucosylamine	abs. methanol	HCl + Py	5	N^4-*p*-sulphamylphenyl-D-glucosylamine	20

separates from the reaction mixture, and the 2,3,4,6-tetra-O-acetyl-hexoses could readily be isolated from the solution. This is a new method for preparing, e.g. partly acetylated monosaccharides. Though yields are only around 40–50 per cent, this new method appears to be simpler than the classic synthesis.

A preparative method for the *trans*-glycosylation of N-arylglycosylamines by means of partly acetylated sugars has not yet been realized.



Type IIIa

When two different N-arylglycosylamines having different sugar and amine parts react with one another, total or double *trans*-glycosylation can occur. In this case, both possible new N-arylglycosylamines are obtained.

glycosyl-NH-aryl + glycosyl'-NH-aryl' ⇄ glycosyl-NH-aryl' + glycosyl'-NH-aryl

Experiments and results are summarized in Table 3.

These reactions were carried out in anhydrous methanol or ethanol using absolutely dry reagents. Hydrogen chloride in the presence of pyridine proved to be the best catalyst; no *trans*-glycosylation occured in the absence of an acid catalyst. Only one of the two possible new N-arylglycosylamines have been isolated so far in crystalline form from the equilibrium reaction mixture, under conditions depending upon the solubilities, with special regard to the nature and quantity of the solvent.

Type IIIb

A variation of double *trans*-glycosylation, when an N-arylglycosylamine acetylated in its sugar moiety is acted upon by a free, non-acetylated N-arylglycosylamine, may be regarded as a new class of *trans*-glycosylation. In this case, the acetyl–glycosyl part becomes attached to the other amine.

$(Ac)_n$-glycosyl-NH-aryl + glycosyl-NH-aryl' ⇄ $(Ac)_n$-glycosyl-NH-aryl' + glycosyl-NH-aryl

Only one example of this reaction has been realized so far, however, in an excellent yield. Data are given in Table 4.

It appears that this type of reaction also gives best results, and is carried out most readily in the presence of hydrogen chloride and pyridine, and in anhydrous solvents.

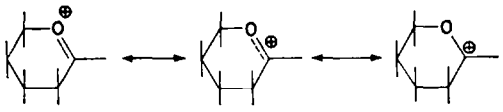
The above experimental results lead to the conclusion that N-arylglycosylamines or their acetates form an equilibrium system with the other amine, sugar, or new N-arylglycosylamine present; this reaction which takes place under the action of proton-catalysis in alcoholic solution, is comparatively rapid. The resulting mixture contains the possible new N-arylglycosylamine, which may separate from the reaction mixture as a consequence of its slight solubility, and may thus shift the equilibrium of the reaction, and can under proper conditions be obtained in crystalline form, in yields often useful for preparative purposes. It is assumed that the reactions should be regarded

TABLE 4

Experiment		Reactants (Mole ratio of the reactants = 1:1 except given cases	Solvent	Catalyst	Period of boiling (min)	Product	Yield (%)
Type	No						
IIIb	1	N^4-*p*-sulphamylphenyl-D-glucosylamine tetraacetate + N-*p*-tolyl-D-glucosylamine. 2 moles.	96% ethanol	HCl	15	N^4-*p*-sulphamylphenyl-D-glucosylamine	90

as true *trans*-glycosylations in all cases when the reactions were carried out in anhydrous medium (types IIIa and IIIb), by analogy with the proved real *trans*-glycosylations of types Ia and Ib (*J. Chem. Soc.* In press). When the reactions were carried out in the presence of water a small amount of which improves the yields, and is necessary for dissolving the sugar, hydrolysis and subsequent reglycosylation must also be taken into consideration. (Types IIa and IIb.)

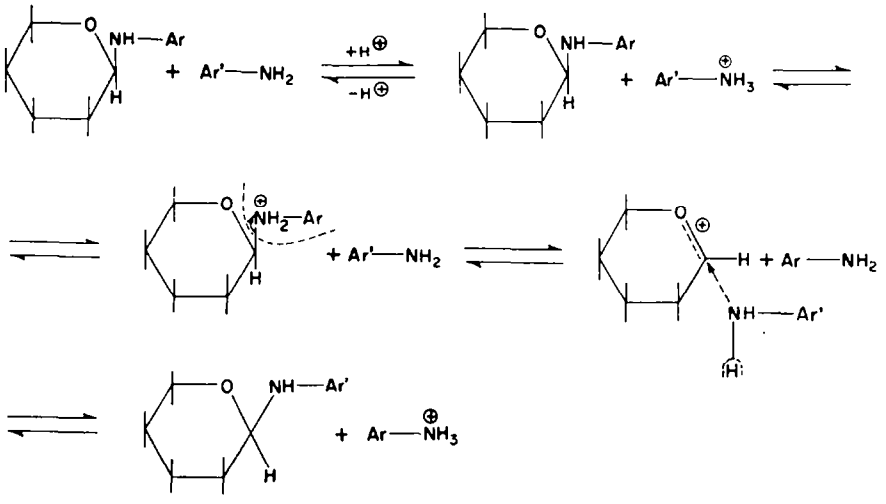
In our opinion, *trans*-glycosylation reactions as special cases of *trans*-acetalization are comparable with proton-catalysed *trans*-esterification reactions, in which latter type an acyl–oxygen bond is split, (*cf.*[4]), and the formation of a transient acylium ion is assumed. Formation of a transient glycosylium ion or to be more exact the



mesomerie cyclic cation may be considered in the cases of *trans*-glycosylations, which offers a satisfactory explanation for the mechanism of the individual types of *trans*-glycosylations, as suggested in our previous papers. The *trans*-glycosylation mechanism presented by Isbell and Frush[5], involving an intermediate imonium ion /R—$\overset{\ominus}{C}$=NH—R'/ and transient complexes derived therefrom, could be applied to *trans*-glycosylations of types IIIa and IIIb only with difficulty; this mechanism, together with the possibility of the formation of the acyclic oxonium cation (R—CH=$\overset{\oplus}{O}$H) should be taken into account in the case of *trans*-glycosylations of types IIa and IIb.

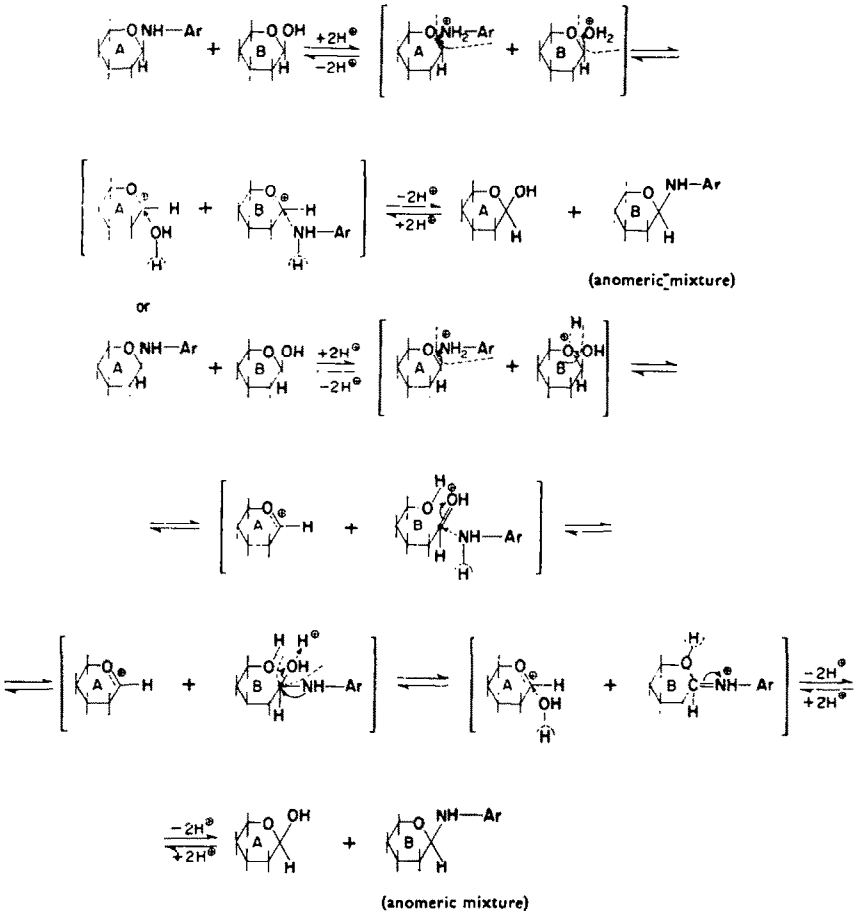
Suggested mechanisms

(1) Trans-*glycosylations of types* Ia *and* Ib.

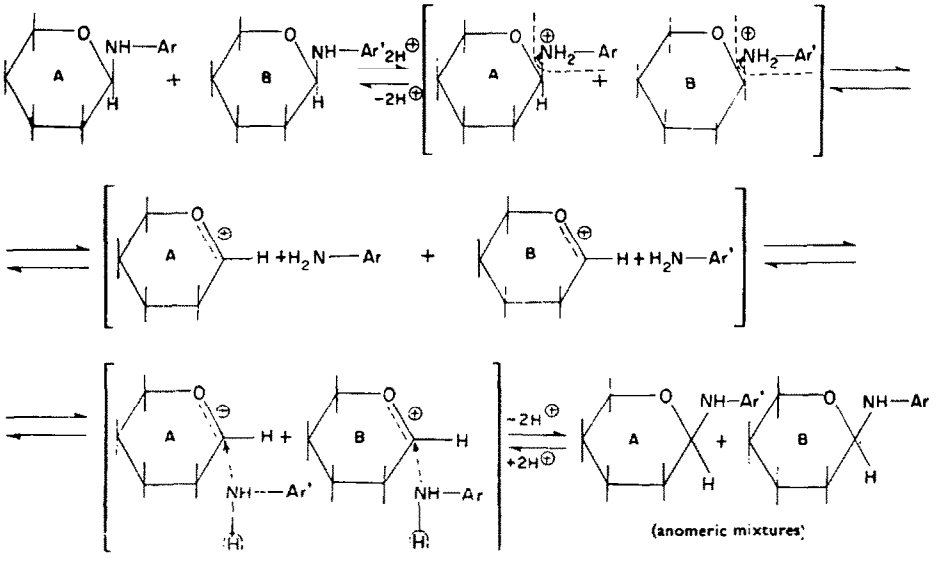


[4] C. H. Ingold, *Structure and Mechanism* p. 767. G. Bell, London (1953).
[5] H. S. Isbell and H. L. Frush, *J. Org. Chem.* **23**, 1309 (1958).

(2) Trans-*glycosylations of types* IIa *and* IIb.



(3) Trans-*glycosylations of types* IIIa *and* IIIb.



Further work is in progress to extend the scope of *trans*-glycosylation reactions, and to investigate the reaction mechanism.

EXPERIMENTAL

Melting points are uncorrected. Mixed melting points were determined with materials of standard purity. Optical activities were always measured in pyridine.

Trans-*glycosylation Reactions belonging to Type* IIa

Trans-glycosylation of N-arylglycosylamines and free sugars.

N-p-*Tolyl*-D-*mannosylamine by* trans-*glycosylation from* N-p-*tolyl*-D-*glucosylamine and* D-*mannose*

(IIa; 1). N-*p*-Tolyl-D-glucosylamine (3·0 g, 1 mole) m.p. 112–113°; $[\alpha]_D = -96°$ and D-mannose (2·2 g, 1 mole) were dissolved in 96% ethanol (30 ml) containing hydrochloric acid (0·5 ml). Dissolution of the starting materials took place in about 1 1/2 min, and the reaction solution was refluxed for 5 min. The mixture was allowed to stand at room temperature, when deposition of a crystalline precipitate shortly occurred. Next day, the crude product was filtered (2·15 g), m.p. 175° (decomp.), $[\alpha]_D^{20} = -162°$ (*c*, 1). The mother liquor gave another crop (0·15 g) on the next day. Yield of total crude product was 76·5%.

The purity of the N-*p*-tolyl-D-mannosylamine crude product was checked by paper chromatography in several experiments (for a description of the technique, *cf. J. Chem. Soc.* In press). In general, a purity of about 94–95% was found, the product containing about 2–3% of N-*p*-tolyl-D-glucosylamine and 2–3% of mannose.

The crude product (1·0 g) was recrystallized from 75% aqueous methanol to give 0·72 g of m.p. 183° $[\alpha]_D^{21} = -179°$ (*c*, 1). (Found: N, 5·2%).

The crude product can very readily be purified by the following method which was applied also in the other experiments: The material (1·5 g) was thoroughly digested at room temperature with 75% aqueous methanol (20 ml), and filtered by suction. This purification, accompanied by a loss of 8%, gave a product (1·28 g), $[\alpha]_D^{22} = -178°$ (*c*, 1), m.p. 184° (decomp.), undepressed after admixture with pure N-*p*-tolyl-D-mannosylamine, m.p. 183–184°;[6] 184°; $[\alpha]_D^{20} = -181°$.[5] (Found: C, 57·0; H, 7·05; N, 5·17. Calc. for $C_{13}H_{19}O_5N$ (269·2) C, 58·0; H, 7·1; N, 5·2%).

Other experiments (preparation, purification and checking of purity), in connexion with the *trans*-glycosylation of N-*p*-tolyl-D-glucosylamine and D-mannose, were carried out in the manner described above, with some modifications concerning the solvent, catalyst, ratio of reagents or time of refluxing, as described below.

(IIa, 2). This was done as in "IIa, 1" except that the reaction mixture was boiled for 60 min. After standing for 1 day, a precipitate (1·4 g) was obtained, m.p. 174°, $[\alpha]_D^{21} = -168°$. After the mother liquor had been stored for 5 days additional product (0·4 g, total yield 63·5%), m.p. 177° (decomp.) was obtained.

(IIa, 3). This was the same as "IIa, 1," except that a solvent mixture of methanol (30 ml) and water (7 ml) was employed instead of ethanol. The first crop (1·3 g) obtained after 1 day had m.p. 176° (decomp.), $(\alpha)_D^{22} = -171°$ (*c*, 0·6). This with the second crop (0·35 g collected 1 day later) gave a yield of 55%. Purification with cold aqueous methanol resulted in 2% loss, and gave a completely pure product, m.p. 184° (decomp.), $[\alpha]_D^{21} = -177°$ (*c*, 1). (Found: C, 57·6; H, 6·9; N, 5·17%).

(IIa, 4). As experiment "IIa, 1," but pyridine (3 ml) was added. The crude product precipitated after 2 days (1·7 g, 56·5%), had m.p. 170° (decomp.).

(IIa, 5). As experiments "IIa, 1" and "IIa, 4," but in the presence of less pyridine (1 ml). Crude product (2·2 g; 73·2%) had m.p. 170° (decomp.). Yield of the pure compound was 69%.

(IIa, 6). As experiment "IIa, 1," but in the presence of less ethanol (20 ml), and with ammonium chloride (0·2 g) catalyst. The crude product (1·9 g; 63%) had m.p. 174° (decomp). Washing with aqueous methanol gave 60% m.p. 184°, $[\alpha]_D^{21} = -179°$ (*c*, 1).

(IIa, 7). As experiment "IIa, 1," but under absolutely anhydrous conditions, in ethanol (20 ml) containing dry hydrogen (0·035 g). Time of reflux: 8 min. The reaction mixture was quite dark.

[6] G. P. Ellis and J. Honeyman: *J. Chem. Soc.* 1496 (1952); F. Weygand, *Ber. Dtsch. Chem. Ges.* **72**, 1667 (1939).

Total precipitation under cooling in ice 0·2 g (6·7%), m.p. 170° (decomp.); $[\alpha]_D^{20} = -166°$ (*c*, 1). Yield after washing with aqueous methanol 6·1%, m.p. 184° (decomp.), $[\alpha]_D^{20} = -176°$ (*c*, 1). (Found: N, 5·12%).

(IIa, 8). The experiment was the same as "IIa, 7," but pyridine (0·5 ml) was added. The mixture did not turn so dark as in experiment "IIa, 7." The product (2·02 g, 67%), precipitated directly, was of high purity, m.p. 183°; $[\alpha]_D = -168°$ (*c*, 1). Yield of purified product 64·5%. (Found: N, 5·15%).

(IIa, 9). As "IIa, 1," but the experiment was carried out in anhydrous alcohol (20 ml), and ammonium chloride (0·2 g) was used instead of hydrochloric acid catalyst, with a reflux time of 15 min. The crude product (1·0 g, 33·3%) had m.p. 172° (decomp.). Washing with aqueous methanol gave a product (32%) of m.p. 183° (decomp.), $[\alpha]_D^{20} = -177°$ (c, 1). (Found: N, 5·22%).

(IIa, 10). The experiment was carried out as "IIa, 1," but in anhydrous ethanol (20 ml) and without a catalyst. Complete dissolution required 50 min. The material (0·5 g), collected at room temperature on the second day, had m.p. 160° (decomp.). Purification of the crude product (20% yield) with aqueous methanol resulted in 15% loss, giving a substance decomposing at 184°.

(IIa, 11). The experiment was the same as "IIa, 10," but the mixture was heated only to 40°. Complete dissolution required shaking for 2 hr. The crude product (1·05 g, 35%) had m.p. 163° (decomp.), $[\alpha]_D^{21} = -165°$ (*c*, 1). (Found: N, 5·15%).

(IIa, 12). As experiment "IIa, 1," but without hydrochloric acid catalyst, and in the presence of pyridine (3 ml). The crude product (0·6 g, 20%) separated after 2 days, m.p. 170° (decomp.).

(IIa, 13). As experiment "IIa, 12," but in the absence of pyridine. Standing for 1 day gave a small amount of precipitate [0·2 g, m.p. 170° (decomp.)]. Additional 2 days resulted in a second crop (1·0 g), m.p. 170° (decomp.), $[\alpha]_D^{20} = -163°$ (*c*, 1). (Found: N, 5·07%). Yield of crude product was 40%.

(IIa, 14). As experiment "IIa, 1," but with a double amount of mannose (4·4 g, 2 moles). A rich crystalline precipitate (2·3 g, m.p. 175° with decomp.) was obtained on cooling, an additional crop (0·55 g, m.p. 162°, decomp.) being obtained on the second day at room temperature. An analysis by paper chromatography showed the product to contain free mannose (10–12%) and *p*-tolyl-D-glucosylamine (8–10%). The crude product (yield 93·5%) was purified by means of 75% aqueous methanol with a loss of 20%, to give very pure *p*-tolyl-D-mannosylamine, homogenous also according to control by paper chromatography; m.p. 184° $[\alpha]_D^{21} = -179°$ (*c*, 1·2). (Found: N, 5·09%).

(IIa, 15). The experiment was the same as "IIa, 14," but water (7 ml) was added. The material collected after 2 days was 2·1 g, m.p. 178° (decomp.), $[\alpha]_D^{20} = -168°$ (*c*, 1). A small amount was obtained the next day (0·1 g), of m.p. 165° (decomp.). Yield of crude product (calculated on basis of *p*-tolyl-D-glucosylamine used) was 73%. Yield of purified product was 61·6%.

(IIa, 16). As experiment "IIa, 1," but only half of the amount of mannose (1·1 g, 0·5 mole) was used. Standing for 2 days resulted 1·2 g product (80%, based on mannose), m.p. 173–174° (decomp.), $[\alpha]_D^{20} = -160°$ (*c*, 1).

(IIa, 17). As experiment "IIa, 14," but pyridine (1 ml) was added. The first crop (2·1 g) obtained after 1 day, had m.p. 168° with decomp., $[\alpha]_D^{20} = -165°$ (*c*, 1). Standing for several days gave an additional 0·31 g of less pure product, m.p. 162° (decomp.). Yield of crude product 80%.

(IIa, 18). As experiment "IIa, 1," but with a double amount of mannose (4·4 g, 2 moles), in less ethanol (20 ml) and with ammonium chloride (0·2 g) instead of hydrogen chloride catalyst. The crude product (2·3 g, 76·6%, m.p. 174° with decomp.) gave on washing with aqueous methanol pure *p*-tolyl-D-mannosyl-amine, with a loss of 16·3%; m.p. 184°, $[\alpha]_D^{21} = -178°$ (*c*, 1).

(IIa, 19). As experiment "IIa, 18," but less mannose (1·1 g, 0·5 mole) was employed. The crude product (1·2 g, 80%, based on mannose) had m.p. 160° (decomp.), $[\alpha]_D^{23} = -180°$ (*c*, 1). (Found: N, 5·22%). Yield of pure product was 73·6%.

N-p-*Tolyl*-D-*mannosylamine by* trans-*glycosylation from* N-p-*tolyl*-D-*galactosylamine and* D-*mannose*

(IIa, 20). N-*p*-Tolyl-D-galactosylamine (4·0 g, 1 mole) (m.p. 161–162°, $[\alpha]_D = -101°$) and anhydrous mannose (2·8 g, 1 mole) were refluxed in dry ethanol (120 ml) containing hydrogen chloride (0·028 g). Dissolution of the reagents occurred in 30 min. The crude product obtained on cooling was 1·1 g (27·5%), m.p. 180–181° (decomp.), $[\alpha]_D^{22} = -170°$ (*c*, 1). (Found: N, 5·25%).

(IIa, 21). As experiment "IIa, 20," but pyridine (4·0 ml) was added. After boiling for 5 min, crystallization set in on cooling (2·8 g, 70%); m.p. 180–181° (decomp.), $[\alpha]_D^{20} = -172°$ (*c*, 1) (c.f. 6). Yield of purified product was 66·2%. (Found: C, 57·4; H, 7·0; N, 5·1%).

N-p-*Tolyl*-D-*galactosylamine by* trans-*glycosylation from* N-p-*tolyl*-D-*glucosylamine and* D-*galactose*

(IIa, 22). The reaction mixture consisted of D-galactose (2·8 g, 1 mole), water (1 ml), methanol (40 ml) containing conc. hydrochloric acid [0·1 ml, and N-*p*-tolyl-D-glucosylamine (m.p. 112–113°, $[\alpha]_D^{25} = -96°$ (*c*, 1)]. The mixture was boiled for 10 min. When chilled in an ice-bath, the solution gave a crystalline precipitate (2·6 g, 65%), of m.p. 160–162°, $[\alpha]_D = -99·5°$ (*c*, 1·2). (Found: N, 5·05%). (Literature records:[9] m.p. 161–162°; $[\alpha]_D^{19} = -80°$ (in methanol). $[\alpha]_D^{20} = -101°$ (*c*, 1, in pryidine, own measurement). Mixed melting point determination gave no depression.

(IIa, 23). The experiment was the same as "IIa, 22," but pyridine (3 ml) was added and with 5 min reflux. The crystalline product (2·9 g, 72·5%) was very pure, m.p. 161°, $[\alpha]_D^{21} = -100°$ (*c*, 1). (Found: C, 57·1; H, 6·95; N, 5·11%).

The product gave homogenous galactosazone.

(IIa, 24). As experiment "IIa, 22," but without the addition of water, in the presence of dry hydrogen chloride catalyst (0·028 g). Dissolution required 40 min at the boiling point. The product (yields 25% and 28%, resp.) had m.p. 162°, $[\alpha]_D^{23} = -100°$ (*c*, 1·2).

N-p-*Bromophenyl*-D-*galactosylamine by* trans-*glycosylation from* N-p-*bromophenyl*-D-*glucosylamine and* D-*galactose*

(IIa, 25). The reaction mixture consisted of D-galactose (2·14 g, 1 mole), water (2 ml), pyridine (1 ml), methanol (20 ml), 3% hydrochloric acid (0·5 ml) and N-*p*-bromophenyl-D-glucosylamine (4·0 g, 1 mole) (m.p. 153°, $[\alpha]_D = -111°$ (*c*, 0·5, in pyridine); own measurements (see below). The mixture was refluxed for 5 min. The crystalline product (2·5 g), separated after 1 day, had m.p. 175° (decomp.); standing for several days gave but little additional precipitate (0·2 g) of m.p. 181° (decomp.). Yield 67·5%. $[\alpha]_D^{21} = -115°$ (*c*, 1). (Found: N, 4·07. $C_{18}H_{16}O_5NBr$ (334·1) requires N,4·2 0%). The glycoside gave a pure galactosazone.

Data of pure N-*p*-bromophenyl-D-galactosylamine are: m.p. 183–184°, $[\alpha]_D^{23} = -116·5°$ (*c*, 1). Own measurements (see below).

(IIa, 26). As experiment "IIa, 25," but with double amount of galactose (4·28 g, 2 moles). The yield of the crude product (3·1 g) was 77·5%, m.p. 173°, $[\alpha]_D^{20} = -114°$ (*c*, 1). (Found: N, 4·1%).

The product gave a pure galactosazone.

(IIa, 27). As experiment "IIa, 25," but without pyridine and with ammonium chloride (0·4 g) instead of hydrogen chloride catalyst. The mixture was refluxed for 15 min. Yield of the crude product (0·50 g, m.p. 177–178° and 0·36 g, m.p. 162–173°; $[\alpha]_D = -112°$ (*c*, 1), was 21·5%. (Found: N, 4·14; Br, 24·0, requires: N, 4·20; Br, 24·2%).

The product gave a pure galactosazone.

(IIa, 28). As experiment "IIa, 27," but pyridine (0·8 ml) was added. First crop (1·04 g) had m.p. 179° (decomp.), second crop (0·14 g), m.p. 168–172° (decomp.). $[\alpha]_D^{23} = -116°$ (*c*,1). Yield of crude product was 29·5%.

The product gave a pure galactosazone.

N-p-*Bromophenyl*-D-*glucosylamine*

p-Bromoaniline (6·0 g), and D-glucose (4·0 g) were refluxed for 30 min in methanol (50 ml), in the presence of concentrated hydrochloric acid catalyst (0·1 ml). On cooling, the crude product (5·2 g, 70%, m.p. 150°) separated, which was recrystallized from methanol (20 ml/5 g of product). The pure substance (3·3 g) had m.p. 153°, $[\alpha]_D = -111°$ (*c*, 0·5).

N-p-*Bromophenyl*-D-*galactosylamine*

p-Bromoaniline (2·0 g) and D-galactose (2·0 g) in 10% aqueous methanol (22 ml) was refluxed for 30 min in the presence of concentrated hydrochloric acid (1 drop). The crude product (2·85 g, 74%), separated on cooling, had m.p. 183–184°. It was recrystallized from 95% methanol; m.p. 184°, $[\alpha]_D^{23} = -116·5°$ (*c*, 1).

N-p-*Nitrophenyl*-D-*galactosylamine by* trans-*glycosylation from* N-p-*nitrophenyl*-D-*glucosylamine and* D-*galactose*

(IIa, 29). The reaction mixture consisted of N-*p*-nitrophenyl-D-glucosylamine (4·5 g, 1 mole)

[m.p. 184° $[\alpha]_D^{22} = -193°$ (*c*, 1·4)],[7] D-galactose (3·0 g, 1 mole), 96% ethanol (200 ml), and concentrated hydrochloric acid (0·2 ml). The mixture was refluxed for 15 min, complete dissolution occurred in the first 3 min. The solution was cooled, and the crude product (1·6 g, 35·5%) recrystallized from 75% aqueous methanol (30 ml) (0·67 g, 15%); m.p. 215° (decomp.), $[\alpha]_D = -185° \rightarrow 232°$ (*c*, 1·2) (Found: N, 9·51. Calc.: N, 9·34%). The product gave galactosazone. Literature[8] records for N-*p*-nitrophenyl-galactosylamine: m.p. 219°, $[\alpha]_D^{21} = -187 \rightarrow 248°$ (in anhydrous pyridine).

(IIa, 30). As experiment "IIa, 29," but pyridine (5 ml) was added. The time of refluxing was 5 min. The crude product [2·35 g, 50%, m.p. 170° (decomp.)] was recrystallized from 75% methanol to give a product of m.p. 210°, $[\alpha]_D^{20} = -183 \rightarrow 235°$ (*c*, 1). Yield of the purified substance was 34%. (Found, C, 47·92; H, 5·41; N, 9·39. Calc. for $C_{12}H_{16}O_7N_2$ (300·3): C, 48·07; H, 5·37; N, 9·34%).

Trans-*glycosylation Reactions belonging to Type* IIb

Trans-glycosylation of N-aryl-acetylglycosylamines and free aldoses.

N-p-*Tolyl*-D-*mannosylamine*

(IIb, 1). N-*p*-Tolyl-D-mannosylamine tetraacetate (4·5 g, 1 mole) and D-mannose (2·0 g, 1 mole) were refluxed in a mixture of 96% ethanol (20 ml), pyridine (1 ml), and concentrated hydrochloric acid (0·1 ml). Dissolution of the reagents took place in 10 min, and the mixture was boiled for an additional 5 min. After cooling and seeding, the solution solidified. On washing with aqueous methanol, pure N-*p*-tolyl-D-mannosylamine (78%) was obtained, m.p. 184°, $[\alpha]_D^{22} = -170°$ (*c*, 1). (Found: N, 5·28. Calc. 5·2%).

(IIb, 2). As experiment "IIb, 1," but without pyridine and with ammonium chloride (0·3 g, 0·5 mole) instead of hydrochloric acid catalyst. The time of refluxing was 30 min. On standing in a refrigerator, the crude product separated. It was washed with 75% aqueous methanol to give a product (64·5%), m.p. 184°, $[\alpha]_D = -171°$ (*c*, 1). (Found: N, 5·12%).

N-p-*Tolyl*-D-*mannosylamine and* 2:3:4:6-*Tetra-acetyl*-D-*glucose*

(IIb, 3). The experiment was carried out in the same way as "IIb, 1," except that a double amount of pyridine and four times as much hydrochloric acid were used. Yield of separated and purified *p*-tolyl-mannosylamine was 75% and 76%, respectively, as a result of two parallel experiments.

The mother liquor of this experiment was worked up for isolating the tetraacetyl glucose by evaporation under reduced pressure, and the residue was extracted with acetone; the acetone was distilled, the remaining material dissolved with water, and the aqueous solution extracted with chloroform. The solid residue from the chloroform solution was recrystallized from a small amount of a mixture of acetone and ethyl acetate: 61% and 42%, resp., yields of β-tetraacetyl glucose were obtained in two experiments; m.p. 118–120°, $[\alpha]_D^{22} = +29·2° \rightarrow +78·4°$ (*c*, 1, in alcohol). Literature[9] records, m.p. 118–120°, $[\alpha]_D^{22} = +2·19° \rightarrow +82·7°$ (in ethanol). The product contained no nitrogen. (Found: acetyl, 47·8%. Calc. 49·4%).

(IIb, 4). When experiment "IIb, 1," was repeated in the absence of pyridine, no *trans*-glycosylation reaction occurred.

(IIb, 5). When experiments "IIb, 1" or "IIb, 3" were tried without employing pyridine and hydrochloric acid catalyst, 89% of unreacted *p*-tolyl-D-glucosylamine tetraacetate was recovered after 20 min boiling, i.e. no *trans*-glycosylation reaction took place.

N^4-p-*Sulphamylphenyl*-D-*glucosylamine*

(IIb, 6). N^4-*p*-Sulphamylphenyl-D-glucosylamine tetraacetate (5·0 g, 1 mole) and D-glucose (3·0 g, 1 mole) were boiled for 15 min in ethanol (80 ml) containing water (2 ml) and hydrogen chloride (0·06 g). On standing in a refrigerator, the solution gave N^4-*p*-sulphamylphenyl-D-glucosylamine, in a small amount (0·5 g, 15%), but in high purity; m.p. 204°, $[\alpha]_D^{22} = -116°$ (*c*, 1). (Found: N, 8·27; S, 9·4. Calc. N, 8·4; S, 9·6%) (cf.[10]).

[7] R. Bognár and P. Nánási, *J. Chem. Soc.* 191 (1955); *Magyar Kémiai Folyóirat* **62**, 90 (1956).
[8] F. Weygand, W. Perkow and P. Kuhner, *Ber. Dtsch. Chem. Ges.* **84**, 194 (1951).
[9] E. Fischer and K. Delbrück, *Ber. Dtsch. Chem. Ges.* **42**, 2776 (1909)
[10] R. Bognár and P. Nánási, *J. Chem. Soc.* 1703 (1953); *Magyar Kémiai Folyóirat* **59**, 178 (1955).

N-p-*Tolyl*-D-*mannosylamine and tetraacetyl*-D-*mannose*

(IIb, 7). N-*p*-Tolyl-mannosyl tetraacetate (4·5 g, 1 mole), and D-mannose (2·0 g, 1 mole) were refluxed in 96% alcohol (20 ml), in the presence of pyridine (1 ml) and concentrated hydrochloric acid (0·1 ml). Complete dissolution occured in 5 min, and after an additional 5 min of boiling the mixture was allowed to stand at room temperature, then in a refrigerator for 2 hr, when N-*p*-tolyl-mannosylamine crystallized. (Experiment I: 1·26 g, 45·5%, m.p. 184°, $[\alpha]_D^{21} = -178°$ (*c*, 1·2); Found: N, 5·32. Calc.: N, 5·2. Experiment II: 63·5%, m.p. 183°, $[\alpha]_D = -175°$ (*c*, 1). Found: N, 5·16%).

The reddish-brown mother liquor was evaporated under reduced pressure until almost dry. The residue was extracted four times with 12 ml portions of ether, the ether solution was filtered, and mixed with light gasoline until the mixture became turbid. Inoculation at room temperature started crystallization.

Experiment I gave 36·6% tetraacetyl mannose of m.p. 95–96°, experiment II resulted in a yield of 54·5%, m.p. 96°, $[\alpha]_D^{21} = +27·5°$ (*c*, 1), $[\alpha]_D^{21} = +28·8$ (*c*, 1, in $CHCl_3$). The products contained no nitrogen. (Found: acetyl, 48·8%. Calc.: 49·4%). Literature[11] records m.p. 94° and 93°, $[\alpha]_D = +25·5$ and $+26·3°$ (both in chloroform).

N-p-*Tolyl*-D-*mannosylamine and tetraacetyl*-D-*galactose*

(IIb, 8). N-*p*-Tolyl-D-galactosylamine tetraacetate (2·25 g, 1 mole) and D-mannose (1·0 g, 1 mole) were boiled for 10 min in ethanol (8 ml), in the presence of pyridine (0·2 ml) and concentrated hydrochloric acid (0·1 ml). Crystallization of N-*p*-tolyl-mannosylamine started on cooling. The product (0·9 g, 65%) was filtered off, m.p. 182° (decomp.), $[\alpha]_D^{21} = -173°$ (*c*, 1). (Found: N, 5·12%).

The mother liquor was concentrated and the residue extracted with chloroform (20 ml). The chloroform solution, after treatment with activated carbon, was again concentrated under reduced pressure, and the remaining solid extracted with cold water. This water solution was shaken again with chloroform, the extract dried on Na_2SO_4, evaporated, and the residue recrystallized from a mixture of ether and light gasoline, to give a product (0·69 g, 38·5%) of m.p. 114°.

A repetition of the above purification and crystallization process gave tetraacetyl galactose (26%) of m.p. 118·5°, $[\alpha]_D = +52·1° \rightarrow 71°$ (in 4 hr; *c*, 1·2 in water). (Found: acetyl, 48·5%. Calc. for $C_{14}O_{20}O_{10}$ (348·3): 49·4%).

A second experiment gave the following results: Yield of N-*p*-tolyl-mannosylamine 64·5%; m.p. 182°. Yield of tetraacetyl-D-galactose 46·8%; m.p. 114°.

Literature[12] records for β-tetraacetyl galactose, m.p. 112–128°, $[\alpha]_D^{24} = +25° \rightarrow +76°$ (in H_2O).

Trans-*glycosylation Reactions belonging to Type* IIIa

Trans-glycosylation of two N-arylglycosylamines containing different arylamine and glycosyl parts.

N-p-*Nitrophenyl*-D-*galactosylamine by* trans-*glycosylation from* N-p-*nitrophenyl*-D-*glucosylamine and* N-p-*tolyl*-D-*galactosylamine*

(IIIa, 1). Dry N-*p*-tolyl-D-galactosylamine (2·7 g, 1 mole) (m.p. 154–155°; 161–162°; $[\alpha]_D = -101°$) and dry N-*p*-nitrophenyl-D-glucosylamine (3·0 g, 1 mole) (m.p. 183–184°, $[\alpha]_D = -202°$) were boiled in absolute ethanol (28 ml) containing dry hydrogen chloride (0·025 g). Complete dissolution was obtained in about 2 min, and a further 3 min of refluxing resulted in the beginning of crystallization. On cooling, 1·8 g crystalline material (60%) was obtained, m.p. 185–195°.

Recrystallization from 75% methanol and repeated washing gave a final yield of 42%, m.p. 217° (decomp.), $[\alpha]_D^{22} = -186°$ (*c*, 1·1, immediately after dissolution). (Found: C, 47·7; H, 5·42; N, 9·26. Calc. for $C_{12}H_{16}O_7N_2$ (300·3): C, 48·04; H, 5·37; N, 9·3%).

Pure galactosazone was obtained from the product.

(IIIa, 2). The experiment was carried out in the same way as "IIa, 1," but in the presence of pyridine.

[11] A. M. Gachokidze, *Z. Org. Chem.* **22**, 139 (1952); P. A. Levene and R. S. Tipson, *J. Biol. Chem.* **90**, 89 (1931).

[12] J. Compton and M. L. Wolfrom, *J. Amer. Chem. Soc.* **56**, 1157 (1934).

The reaction mixture consisted of N-*p*-tolyl-D-galactosylamine (4·0 g, 1 mole), N-*p*-nitrophenyl-D-glucosylamine (4·4 g, 1 mole), pyridine (1 ml) and anhydrous ethanol (50 ml) containing hydrogen chloride (0·05 g). The mixture was refluxed for 5 min. The separated crude product was recrystallized from 75% methanol to give a yield of 2·97 g (67·5%), m.p. 213° (decomp.), $[\alpha]_D^{21} = -189°$ (*c*, 1 immediately after dissolution). (Found: N, 9·2. Calc.: N, 9·3%).

The product gave a pure galactosazone.

(IIIa, 3). As experiment "IIIa, 1," but 2 moles of *p*-nitrophenyl-D-glucosylamine and a more dilute solution were employed.

The reaction mixture consisted of N-*p*-tolyl-D-galactosylamine (2·0 g, 1 mole) and N-*p*-nitrophenyl-D-glucosylamine (4·4 g, 2 moles) in anhydrous ethanol (60 ml) containing dry hydrogen chloride (0·03 g). The mixture was refluxed 3 min. The crude precipitates were recrystallized from 30 volumes of 75% methanol. Yield 55%, m.p. 210–213°, $[\alpha]_D^{24} = -188° \rightarrow -225°$ (*c*, 0·8 in 48 hr). (cf.[8]).

The product gave a pure galactosazone.

(IIIa, 4). As experiment "IIIa, 1," but without employing hydrogen chloride catalyst. In this case no *trans*-glycosylation could be detected, and the original glycosides were recovered by fractionated crystallization.

N[4]-p-*Sulphamylphenyl*-D-*glucosylamine*

(a) *By* trans-*glycosylation from* N[4]-p-*sulphamylphenyl*-D-*galactosylamine and* N-p-*tolyl*-D-*glucosylamine*. (IIIa, 5). The reaction mixture consisted of N[4]-*p*-sulphamylphenyl-D-galactosylamine (3·4 g, 1 mole) (m.p. 171–175°, $[\alpha]_D = -110°$)[9] and N-*p*-tolyl-D-glucosylamine (2·6 g, 1 mole) in anhydrous methanol (60 ml) containing dry hydrogen chloride (0·038 g). The mixture was boiled for 5 min. After separating a small amount (0·1 g, m.p. 201°) direct precipitation, the mother liquor gave a second crop (0·43 g) on the addition of ether. The combined crude products were recrystallized from dry methanol. Total yield of pure product was 15·5%, m.p. 198°, $[\alpha]_D^{20} = -112°$ (*c*, 0·8). (Found: N, 8·3; S, 9·7. Calc. for $C_{12}H_{18}O_7N_3S$ (334·34): N, 8·4; S, 9·6%). (cf.[10]).

The osazone test gave pure glucosazone.

Literature[7] records, for N[4]-*p*-sulphamylphenyl-D-glucosylamine, m.p. 202–204°, $[\alpha]_D^{22} = -115°$.

(IIIa, 6). As experiment "IIIa, 5," but in the presence of pyridine (0·7 ml). Yield 24%; m.p. 196° (decomp.), $[\alpha]_D = -113°$ (*c*, 1).

The product gave a pure glucosazone.

(IIIa, 7). As experiment "IIIa, 6," but 2 moles, of N-*p*-tolyl-D-glucosylamine were employed. Yield 27·5%; m.p. 198° (decomp,), $[\alpha]_D^{20} = -112°$ (*c*, 1).

The product gave pure glucosazone.

(IIIa, 8). As experiment "IIIa, 6," but 2 moles of N[4]-*p*-sulphamylphenyl-D-galactosylamine were employed. Excess N[4]-*p*-sulphamylphenyl-D-galactosylamine crystallized from the reaction mixture.

(b) *By* trans-*glycosylation from* N[4]-p-*sulphamylphenyl*-D-*galactosylamine and* N-(4-*carboxy*-3-*hydroxyphenyl*-D-*glucosylamine*. (IIIa, 9). The reaction mixture consisted of dry N[4]-*p*-sulphamylphenyl-D-galactosylamine (5·0 g, 1 mole) (m.p. 171–174°) dry N-(4-carboxy-3-hydroxyphenyl)-D-glucosylamine (5·0 g, 1·05 moles) (m.p. 142°, $[\alpha]_D = -134°$ [10]), ammonium chloride (0·2 g, 0·3 mole), and anhydrous methanol (50 ml). The reaction mixture was boiled for 30 min. Ether was admixed to the cooled solution until it became turbid, and the precipitated material was recrystallized from methanol to give 0·91 g product (18·2%); m.p. 201° (decomp,), $[\alpha]_D^{22} = -115°$ (*c*, 1). (Found: N, 8·27; S, 9·7. Calcd.: N, 8·4; S, 9·6%).

(IIIa, 10). As experiment "IIIa, 9," but in the presence of pyridine (1·5 ml), and with hydrogen chloride (0·05 g) instead of ammonium chloride catalyst. Cooling in an ice-bath gave a direct separated crop (20%); m.p. 190° (decomp.), $[\alpha]_D^{20} = -113°$ (*c*, 1).

The product gave a pure glucosazone.

Trans-*glycosylation belonging to Type* IIIb

Reaction of aryl-acetylglycosylamine with non-acetylated arylglycosylamine.

N[4]-p-*Sulphamylphenyl*-D-*glucosylamine*

Trans-*glycosylation of* N[4]-p-*sulphamylphenyl*-D-*glucosylamine tetraacetate and* N-p-*tolyl*-D-*glucosylamine*

(IIIb 1). N^4-*p*-sulphamylphenyl-D-glucosylamine tetraacetate (5·0 g, 1 mole) and N-*p*-tolyl-D-glucosylamine (5·4 g, 2 moles) were refluxed for 15 min in 96% ethanol (100 ml) in the presence of 3% hydrochloric acid (1 ml). Scratching started crystallization in about 2 hr. The mixture was then gently warmed (40°–50°) in order to prevent precipitation of N^4-*p*-sulphamylphenyl-D-glucosylamine tetraacetate. The product (3·0 g, 90%), separated at room temperature, consisted of pure N^4-*p*-sulphamylphenyl-D-glucosylamine; m.p. 202°, $[\alpha]_D^{23} = -121°$ (*c*, 1, in water). (Found: N, 8·32; S, 9·42. Calc. for $C_{12}H_{18}O_7N_2S$ (334·34): N, 8·4; S, 9·6%). (cf.[10]).

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