Monatshefte für Chemie 133, 427–448 (2002)

Monatshefte für Chemie
Chemical Monthly

Rearrangements in the Course of Fluorination by Diethylaminosulfur Trifluoride at C-2 of Glycopyranosides: Some New Parameters

Karl Dax*, **Martin Albert, David Hammond, Carina Illaszewicz, Thomas Purkarthofer, Martin Tscherner,** and **Hansjörg Weber**

Institut für Organische Chemie, Technische Universität Graz, A-8010 Graz, Österreich

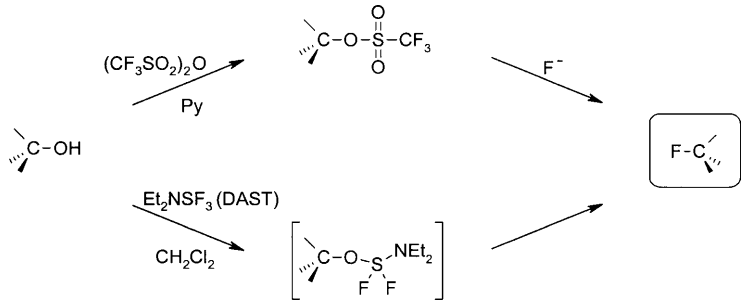
Summary. Reaction of a series of 21 glycosides unprotected at O-2 and featuring various configurations with *DAST* (diethylaminosulfur trifluoride) was monitored by ^{19}F NMR spectroscopy. By means of the diacritical set of data (shift values and coupling constants) thus obtained for each product, identification of the operative mechanisms was possible. By correlation of these findings with stereochemical details from the structure of the educts, new parameters governing the choice of the reaction paths could be deduced. This evaluation led to the result that ring contraction after attack at C-2 of the ring oxygen and entry of the fluoride at C-1 is strongly favoured over all other possibilities. Exceptions are all derivatives of the manno series as well as all members of the *trans*-decalin type structure as present after 4,6-O-benzylidene acetal formation with educts having their ring substituents at C-4 and C-5 in diequatorial (*trans*) orientation. From these, α-D-mannopyranosides generally and of the *trans*-decalin types those with an additional 1,2-*trans*-configuration are prone to 1,2-aglycon migration and, again, entry of the fluoride at C-1. Additional pathways like alkoxy group migration, substitution under retention of configuration, or orthoester formation, are possible by participation of a suitably located neighbouring group at C-3 inasmuch as an alkoxy group interferes from an antiperiplanar orientation to the leaving group at C-2 and an acyloxy functionality attacks in a diequatorial relationship to the latter. The generally intended nucleophilic substitution by fluoride under inversion of configuration is of minor importance.

Keywords. Glycosides; Nucleophilic substitution; Fluorination; Rearrangements; Neighbour group participation; ^{19}F NMR spectroscopy; *DAST*.

Introduction

Within the carbohydrates, the so-called deoxyfluoro analogues which contain fluorine instead of a hydroxyl group are of special importance in biological studies [1]. Thus far, they have served, for example, as mechanistic probes to investigate receptor-substrate interactions, attachment sites of antibodies, specifity of enzymes, or metabolism and transport phenomena. For the stereoselective

* Corresponding author. E-mail: dax@orgc.tu-graz.ac.at



Scheme 1

chemical synthesis of these species, most frequently the principle of a nucleophilic displacement reaction with concomitant inversion of configuration (S_N2) is employed. This consists, as generally depicted in Scheme 1, either of the treatment of a sulfonate (trifluoromethanesulfonate, triflate) with fluoride anion or of the direct reaction of an unprotected alcohol with diethylaminosulfur trifluoride (*DAST*).

However, side reactions, many of them caused by neighbouring group (NG) participation, are often involved in such intended transformations [2–4]. Own unsuccessful efforts towards the synthesis of certain 2-deoxy-2-fluoro sugars applying the S_N2-strategy initiated attempts to categorize the set of hitherto observed reaction pathways in such nucleophilic displacement reactions for all non-glycosidic positions in carbohydrates [5]. From these, the structural prerequisites for the individual types of side reactions seemed evident:

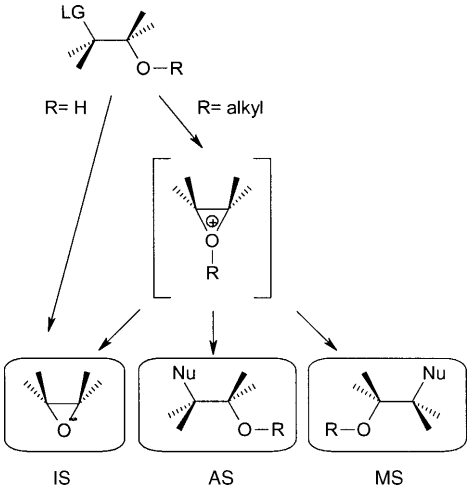
i) Any vicinal alkoxy group oriented antiperiplanar to the leaving group (LG) (including that containing the ring oxygen) may, under inversion of configuration at the reaction centre, cause formation of an intermediate oxiranium ion (anchimeric assistance of the 'simple' type, Scheme 2). The oxiranium ion is opened, again under inversion of configuration, by the nucleophile at one of the carbons involved.

ii) A vicinal acyloxy group is able to interfere, with inversion of configuration, by attack of its carbonyl oxygen under formation of a cyclic acyloxonium ion ('complex' type, Scheme 3). The steric requirement is the diequatorial arrangement of both partners. The reaction is completed by attack of the external nucleophile at one of the carbons involved.

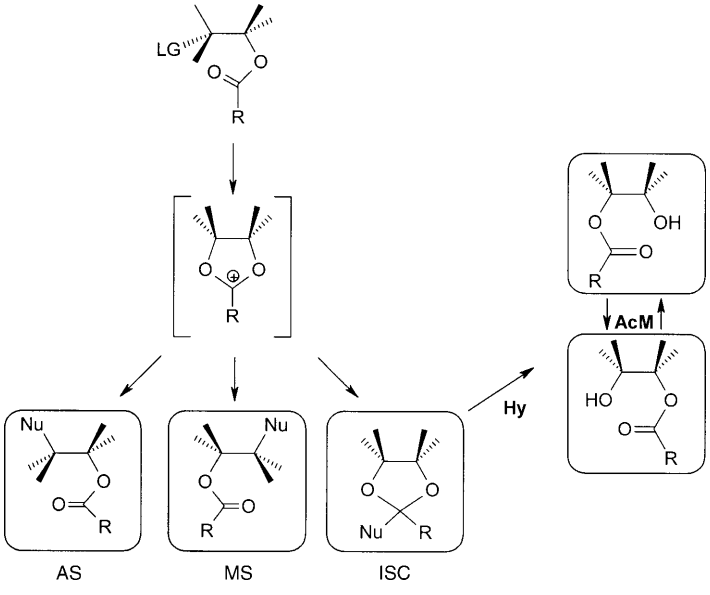
iii) Out of an antiperiplanar orientation relative to the LG, a hydrogen atom or an alkyl group (including parts of the sugar ring) may shift to the reaction centre with entry of the external nucleophile at the other end under inversion of configuration at both centres.

iv) As fluoride also may act as a base, in case of educts containing an axially oriented LG together with a vicinal *trans*-located hydrogen atom elimination (E) is often observed.

v) Fragmentation (F) may occur with the prerequisite that a well-stabilized (oxo)carbenium ion can be eliminated from the C-atom vicinal to that bearing the LG. This is usually the case with the anomeric centre in educts that contain the LG in equatorial position at C-3.



Scheme 2



Scheme 3. Hy = hydrolysis, AcM = acyl migration

Generally it should be noted that mechanistic concertedness in the course of these reactions manifests itself by the stereochemical homogeneity of the product, whereas formation of structures effected by epimerization at one single centre points to the existence of intermediates; this is especially the case when the stabilized oxocarbenium ion containing C-1 is involved.

For the sake of clarity, within this account the following symbols [5] for the above cited mechanisms which involve neighbouring proup participation will be used:

AS: Anchimerically assisted substitution with retention of configuration at the position of the original activation

MS: Substitution by migration of the participating group and entry of the nucleophile (fluoride) at the position where the participating group departs with inversion of configuration at both centres

IS: Intramolecular nucleophilic substitution with inversion of configuration by a hetero atom of an NG under formation of a (small) heterocyclic ring ('simple' type)

ISC: Intramolecular substitution by the carbonyl oxygen of a vicinal acyl group under inversion of configuration at the position of the original activation and entry of the nucleophile at the carbon of the original carbonyl group to form an orthoester derivative ('complex' type)

In all instances, the position of activation in the sugar ring as well as the type of the participating group ('H' for hydrogen, 'NG' for any neighbouring group, 'rO' for ring oxygen) and its location in the educt are given in parentheses.

For the respective reactions at C-2 of glycopyranosides, the inventory of published data comprises the following reaction paths:

i) Straight S_N2-displacement is rather the exception than the rule; modest to good results are obtained with educts of β-D-manno- and β-D-gluco-configurations only. The disposition of the α-D-gluco-anomer to give this reaction is restricted to structures containing a 4,6-O-benzylidene protection (Table 1, entries 1–3).

ii) 2-Triflates of α-D-mannopyranosides are prone to elimination under formation of 2,3-unsaturated products upon treatment with fluoride anion (Table 1, entry 4).

iii) The corresponding *DAST*-reaction with the OH-2 unprotected α-D-mannopyranoside **1** causes 1,2-aglycon migration, MS(2,NG-1), with concomitant entry of the fluoride at C-1 under formation of the corresponding 2-O-methyl-D-glucopyranosyl fluorides **2** (Table 1, entry 5).

iv) Treatment of methyl 3-azido-4,6-O-benzylidene-3-deoxy-α-D-altropyranoside (**3**) with *DAST* (Table 1, entry 6) results in AS(2,NG-3 and/or NG-1) (substitution at C-2 with retention of configuration to form **4**) together with MS(2,NG-3) and MS(2,NG-1) which produce benzyl 2-azido-2,3-dideoxy-3-fluoro-α-D-glucopyranoside **5** and 3-azido-2-O-benzyl-3-deoxy-D-allopyranosyl fluorides **6**, respectively.

v) 2-Triflates of 6-deoxy-L-galactopyranosides (fucopyranosides, **7**), independent of the anomeric configuration, give ring contraction, MS(2,rO), to form 2,5-anhydro sugars **8** with inversion of configuration at C-2 and entry of fluorine at C-1 (Table 1, entry 7). This special type of side reaction is frequently observed with educts of galacto- and arabino-configurations when other nucleophiles than fluoride are applied.

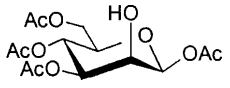
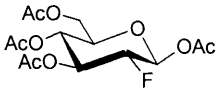
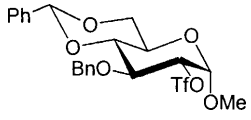
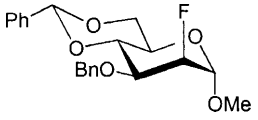
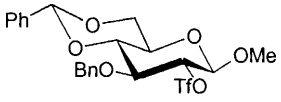
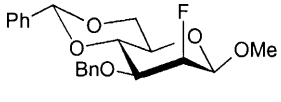
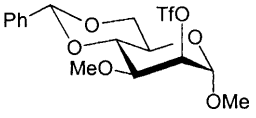
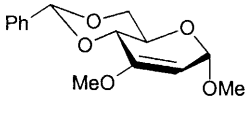
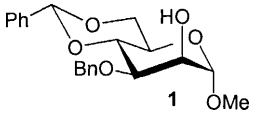
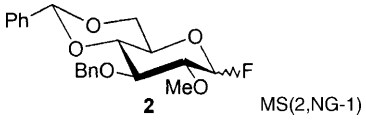
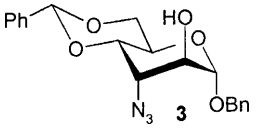
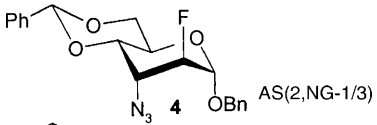
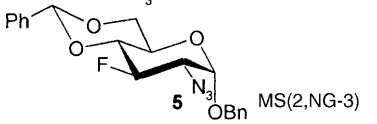
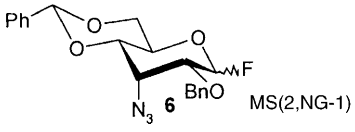
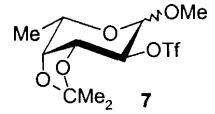
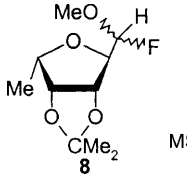
In reactions of carbohydrate 2-triflates with other nucleophiles and in (mechanistically closely related) nitrous acid deaminations of 2-amino-2-deoxy sugars the following additional pathways have been observed:

i) Hydride shift, MS(2,H-3), occurred in the course of a diazotation reaction of methyl α-D-mannosaminide under formation of a 2-deoxy-3-ulose (Table 2,

entry 1; this reaction formally corresponds to an elimination followed by *retro*-enolization). Additionally, aglycon migration took place.

ii) Alkyl shift, MS(2,C-4), was found with a nitrous acid deamination of methyl α- and β-D-glucosaminide to give a pentofuranose derivative with a formyl side

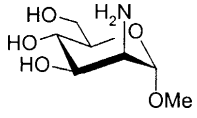
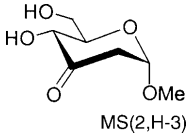
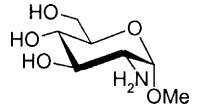
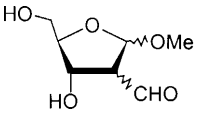
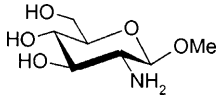
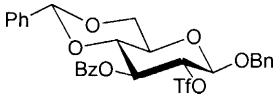
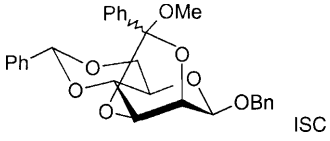
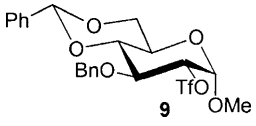
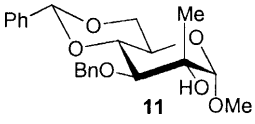
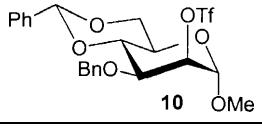
Table 1. Results from attempted fluorinations at C-2 of pyranosides (*TBAF* = tetrabutylammonium fluoride)

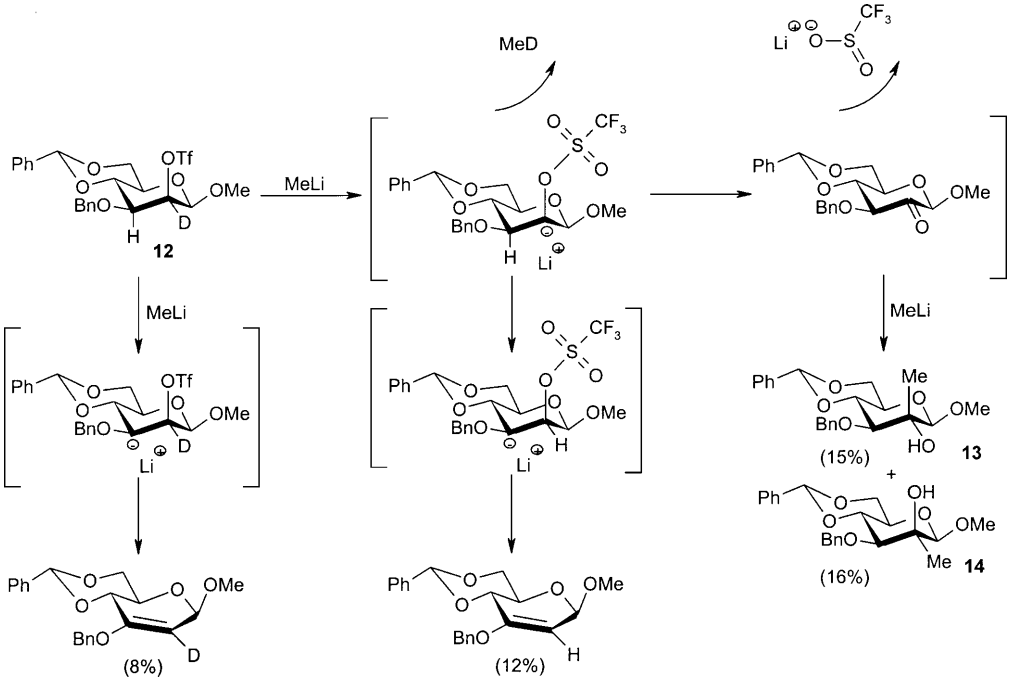
	Educt	Product(s)/Mechanism	Conditions	Yield/%	Ref.
1		 S_N2	*DAST* diglyme 100°C, 7 min	77	[6]
2		 S_N2	*TBAF*, MeCN reflux, 2.5 h	30	[7]
3		 S_N2	*TBAF*, MeCN reflux, 80 min	77	[7]
4		 E	*TBAF*, MeCN reflux, 30 min	82	[8]
5	 **1**	 **2** MS(2,NG-1)	*DAST* diglyme 100°C, 30 min	76	[9]
6	 **3**	 **4** AS(2,NG-1/3)  **5** MS(2,NG-3)  **6** MS(2,NG-1)	*DAST*, benzene reflux, 2 h	40 (AS) 40 (MS(2,NG-3)) 15 (MS(2,NG-1))	[10]
7	 **7**	 **8** MS(2,rO)	3HF · *TEA*, *TEA*, MeCN, room temperature, 16 h	60	[11]

chain (the former C-3) at C-2; this product was subject to epimerization at C-2 (Table 2, entries 2 and 3). The 'conventional' ring contraction, MS(2,rO) (compare Table 1, entry 7) was the main reaction.

iii) Orthoester formation, ISC(2,NG-3), resulted from a *trans*-diequatorial arrangement between the triflate and an acyloxy group at C-3 (Scheme 2, entry 4); the intermediate acyloxonium ion was partly hydrolyzed to a mixture of the respective 2- and 3-benzoate with inverted configuration at C-2.

Table 2. Further side reactions upon attempted nucleophilic substitution at C-2 of pyranosides

	Educt	Product(s)/Mechanism	Conditions	Yield/%	Ref.
1		 MS(2,H-3)	$NaNO_2$, HOAc/H_2O room temperature, 2 h	50 (MS(2,H-3)) 30 (MS(2,NG-1))	[12]
2		 MS(2,C-4) + Hydrolysis	$NaNO_2$ (pH = 3.5) room temperature, 12 h	27 (MS(2,C-4)) 73 (MS(2,rO))	[13]
3				16 (MS(2,C-4)) 84 (MS(2,rO))	[13]
4		 ISC	MeOH, *sym*-collidine, toluene, reflux, 6 h	90	[14]
5	 **9**			91	[15]
		 **11**	MeLi, Et_2O, −50°C → room temperature, 1 h		
6	 **10**			77	[15]



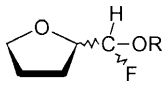
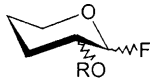
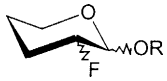
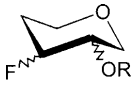
Scheme 4

iv) α-Hydrogen abstraction has recently been proven in experiments with deuterated educts by *El Nemr* and *Tsuchiya* [15] to be the initial step in the reaction of carbohydrate triflates with strong bases (alkyl lithium compounds). Thus, from the 2-triflates **9** and **10** of otherwise fully and identically protected α-D-gluco- and α-D-mannopyranoside, the same 2-C-alkyl derivative with D-gluco-configuration (**11**, Table 2, entries 5 and 6) was obtained. The whole set of products formed and the mechanisms involved for their formation is shown in Scheme 4 with the β-D-manno-educt **12**, where – besides unsaturated products – mixtures of 2-C-alkyl derivatives with D-gluco-(**13**) as well as D-manno-configuration (**14**) were formed due to the missing steric approach control in the final addition step.

Although this compilation sheds some light on the complex situation and even immediately allows the identification of a few seemingly contradictory results in the literature, a series of questions concerning the precise dependence on structural features has remained. Within this contribution we focus on the governing parameters for the most fascinating competitors, MS(2,rO) and MS(2,NG-1). Can these be made comprehensible when educts are used which – under the aspect of conformational flexibility – fulfill the stereochemical prerequisites for both possibilities?

As the collection of NMR data for all types of fluorinated reaction products obtained thus far in attempted syntheses by nucleophilic displacement reactions at C-2 had made available a set of diacritical ^{19}F NMR parameters (Table 3), the stage was set to conduct – under comparable conditions – a more

Table 3. Characteristic ^{19}F NMR data

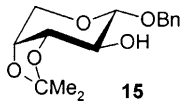
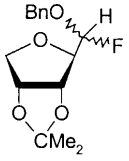
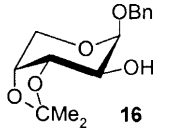
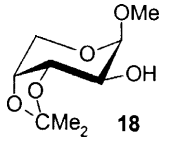
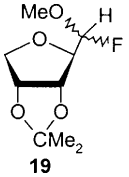
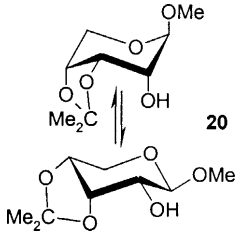
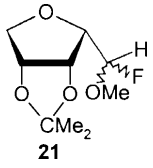
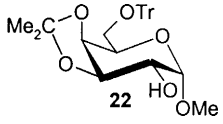
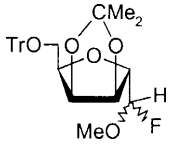
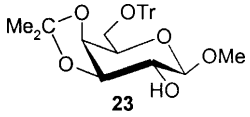
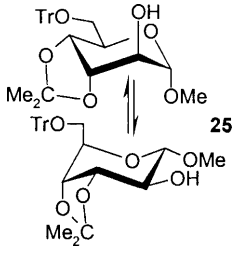
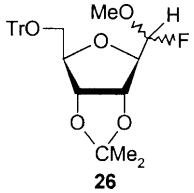
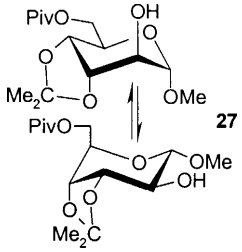
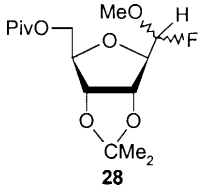
Operative mechanism	Type of structure	δ/ppm	$^{2}J_{F,H}$/Hz
MS(2,rO)		134–143	63–68
MS(2,NG-1)		135–150	48–54
S_N2 or AS(2,NG-1/3)		190–220	47–54
MS(2,NG-3)			

comprehensive study simply by monitoring the crude reaction mixtures by ^{19}F NMR spectroscopy.

Results and Discussion

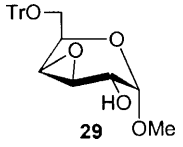
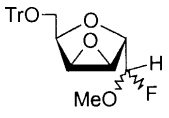
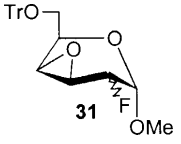
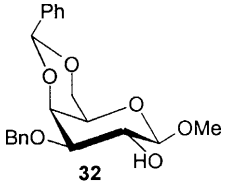
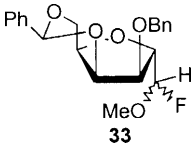
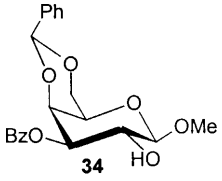
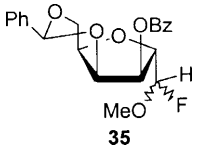
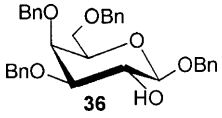
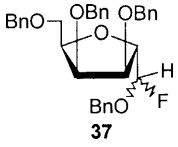
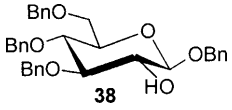
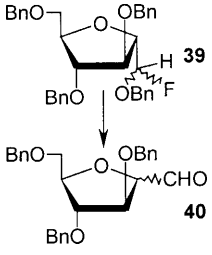
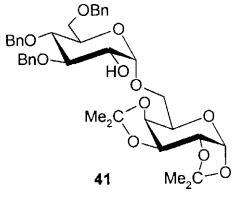
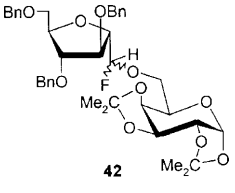
The first aim in these studies was to reexamine the reported (but by no means substantiated) 1,2-aglycon shifts, MS(2,NG-1), from *DAST*-treatment of 2-OH-unprotected educts of α-L-arabino- and β-D-galacto-configuration, respectively, containing a 3,4-O-isopropylidene group [16]. In contrast to this (and completely provable), the 2-sulfonates of similar compounds from the α-L- (Table 1, entry 7 [11]) as well as the β-D-galacto-series [17, 18] had been found to give ring contraction, MS(2,rO), on attempted nucleophilic displacements. When taking into account some conformational flexibility of these educt structures, the given 1,2-*trans*-orientation allows an antiperiplanar arrangement of LG and the respective migrating NG as the stereochemical prerequisite for both types of reactions. However, as can be seen from Table 4, entries 1 and 6, the *DAST*-treatment, under identical conditions as described [16] (in dichloromethane, 3 equivalents of *DAST*, room temperature), of benzyl 3,4-O-isopropylidene-α-D-arabinopyranoside (**15**, the enantiomer of the original educt [16]) as well as methyl 3,4-O-isopropylidene-6-O-trityl-β-D-galactopyranoside (**23**) caused MS(2,rO) only. In full agreement with previous findings [11, 17, 18] with sulfonate displacement reactions, the same pairs of ring-contracted products (but in differing individual ratios) were formed when the respective anomer (**16** or **22**; Table 4, entries 2 and 5) was reacted. MS(2,rO) was also exclusively observed when methyl 3,4-O-isopropylidene-β-D-arabinopyranoside (**18**, Table 4, entry 3) or its 2-triflate were treated with *DAST* and tetrabutylammonium fluoride, respectively. To elucidate any conformational barrier in the obviously clear-cut preference for MS(2,rO) over MS(2,NG-1), we turned to the (1,2-*trans*-configured) educts **20** (β-D-ribo) as well as **25** and **27** (α-D-altro) which – in comparison to the structures **15** and **23** – show inverted configurations

Table 4. Reactions with *DAST*

	Educt	Proposed structure of products	^{19}F NMR δ/ppm J/Hz	^{1}H NMR δ/ppm J/Hz	^{13}C NMR δ/ppm J/Hz	Operative mechanism
1	 **15**	 **17**	−140.0 67/26	H-1: 5.39 66.9/2.0	C-1: 111.2 219.8	MS(2,rO)
2	 **16**		−134.2 63/5	H-1: 5.37 63.4/2.6	C-1: 109.3 220.7	
3	 **18**	 **19**	−141.3 67/24 −135.5 64/9	H-1: 5.23 67.4/2.1 H-1: 5.18 63.6/2.7	C-1: 114.2 222.9 C-1: 112.6 223.4	MS(2,rO)
4	 **20** **21**		−138.6 67/6 −138.0 64/5	H-1: 5.34 68.8/6.9 H-1: 5.42 62.8/7.0	C-1: 112.8 220.6 C-1: 111.7 214.3	MS(2,rO)
5	 **22**		−140.8 67/24	H-1: 5.25 67.8/1.8	C-1: 113.4 220.5	MS(2,rO)
6	 **23**	**24**	−135.4 64/6	H-1: 5.19 63.3/2.6	C-1: 111.7 220.4	
7	 **25**	 **26**	−142.7 67/15 −136.9 64/6	H-1: 5.24 66.4/3.3 H-1: 5.19 64.6/4.1	C-1: 111.8 220.7 C-1: 111.9 219.7	MS(2,rO)
8	 **27**	 **28**	−143.3 67/18 −137.5 64/9	H-1: 5.18 66.8/2.2 H-1: 5.13 64.2/3.1	C-1: 111.6 220.9 C-1: 111.4 219.8	MS(2,rO)

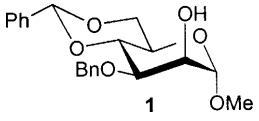
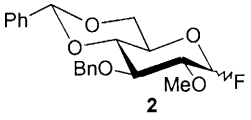
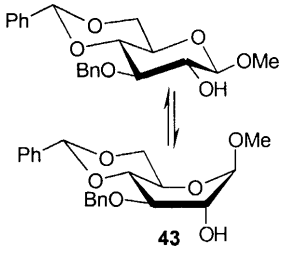
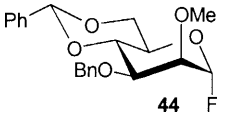
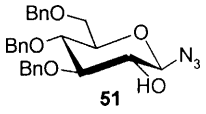
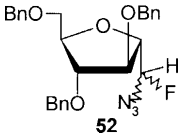
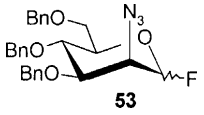
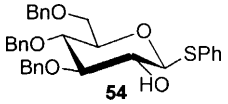
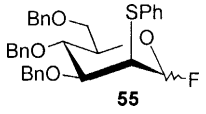
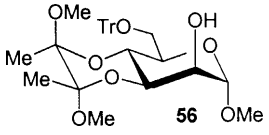
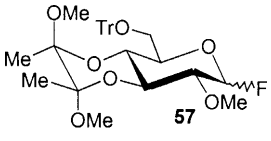
(*continued*)

Table 4 (*continued*)

	Educt	Proposed structure of products	^{19}F NMR δ/ppm J/Hz	^{1}H NMR δ/ppm J/Hz	^{13}C NMR δ/ppm J/Hz	Operative mechanism
9	 **29**	 **30**	−142.4 67/21	H-1: 5.18 66.8/2.6	C-1: 112.4 222.1	MS(2,rO)
			−136.8 64/5	H-1: 5.16 63.7/3.1	not resolved	
		 **31**	−196.5 47/12/7	H-1: 4.62 13.6 H-2: 4.60 45/3	C-1: 97.3 34.7 C-2: 85.2 176.8	S_N2 or AS(2,rO)
10	 **32**	 **33**	−142.3 66/14	H-1: 5.27 67/2	C-1: 112.3 219.2	MS(2,rO)
			−143.2 64/13	H-1: 5.26 63.7/1.8	C-1: 111.4 219.3	
11	 **34**	 **35**	−141.9 66/16	H-1: 5.41 66.0/2.1	C-1: 112.5 221.5	MS(2,rO)
			−140.2 64/not resolved	H-1: 5.39 63.8/2.8	C-1: 111.5 220.3	
12	 **36**	 **37**	−141.9 67/18	H-1: 5.44 66.8/1.8	C-1: 110.2 221.7	MS(2,rO)
			−136.9 64/6	H-1: 5.41 63.7/2.4	C-1: 109.7 219.4	
13	 **38**	 **39** **40**	−138.5 67/15	aldehyde, after hydrolysis at C-1		
			−134.7 67/9	H-1: 9.77	C-1: 202.9	MS(2,rO)
14	 **41**	 **42**	−135.9 67/15	H-1: 5.45 65.5/3.5	C-1: 111.6 221.7	MS(2,rO)
			−132.4 67/9	H-1: 5.41 66.4/6.2	C-1: 111.6 222	

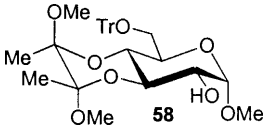
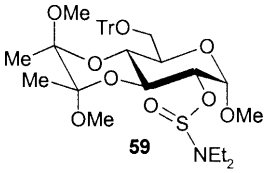
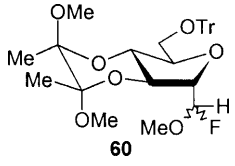
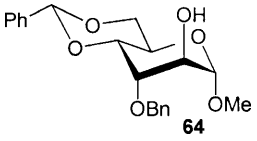
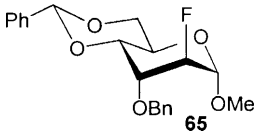
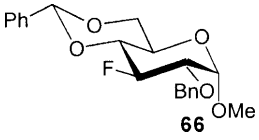
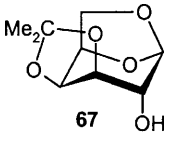
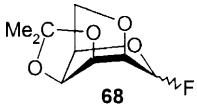
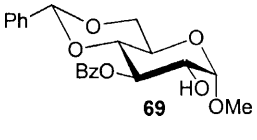
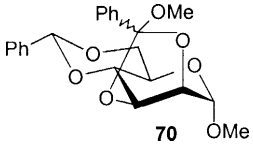
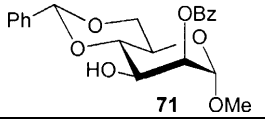
(*continued*)

Table 4 (*continued*)

	Educt	Proposed structure of products	^{19}F NMR δ/ppm J/Hz	^{1}H NMR δ/ppm J/Hz	^{13}C NMR δ/ppm J/Hz	Operative mechanism
15		 Ref. [9]	α-anomer −148.1 52/27 β-anomer −135.6 55/12	α-anomer 5.70 52.0/2.9 β-anomer 5.29 53.5/6.2	α-anomer 105.6 229.7 β-anomer 109.5 218.2	MS(2,NG-1)
16			−139.2 49/not resolved	H-1: 5.50 49.5/1.8 H-2: 3.62 1.8/1.5	C-1: 106.7 224.7	MS(2,NG-1)
17		 	−148.4 56/11 −147.4 57/12	H-1: 5.54 55.8/5.6 H-1: 5.55 57/4	C-1: 99.9 217.4 C-1: 99.5 220	MS(2,rO)
			−135.7 50	not detected	not detected	MS(2,NG-1)
18			−126.0 52	H-1: 5.78 52.3/1.7	C-1: 108.4 225.7 C-2: 52.3 28.0	MS(2,NG-1)
19			−147.8 53/23 −138.0 53/12	not detected	not detected	MS(2,NG-1)

(*continued*)

Table 4 (*continued*)

	Educt	Proposed structure of products	^{19}F NMR δ/ppm J/Hz	^{1}H NMR δ/ppm J/Hz	^{13}C NMR δ/ppm J/Hz	Operative mechanism
20		 **59**	–	H-1: 4.91 3.6 H-1: 4.90 3.6	C-1: 98.8 C-1: 99.5	
		 **60**	−142.5 66/10 −136.2 67/not resolved	not detected	not detected	MS(2,rO)
		61 unknown	−139.0 49/14	not detected	not detected	unknown
21		 **65**	−192.5 43/10/10	not detected	C-1: 99.2 34.5	AS(2,NG-3/1)
		 **66**	−199.0 54/10/10	not detected	C-1: 99.6 9.6	MS(2,NG-3)
22		 **68**	−122.1 67/6 −127.8 61/–	H-1: 5.85 65.9/1.5/1.5 H-1: 5.58 62.5 H-2: 4.00 (s)	C-1: 105.6 225.5 C-1: 106.3 227.8	MS(2,NG-1)
23		 **70**	–	H-1: 5.06 (s) H-1: 5.02 (s)	C-1: 98.7 C-1: 98.9	ISC(2,NG-3)
		 **71**	–	H-1: 4.85 (s)	C-1: 99.9	ISC(2,NG-3) +Hydrolysis

at C-1 as well as C-2. However, MS(2,rO) was found to be the sole reaction in all three cases (Table 4, entries 4, 7, and 8).

So far, in this series all educts contained a 3,4-*cis*-configuration and were, in this part of the molecule, also uniformly protected by the isopropylidene group. To test the influence of the latter, the conformationally more rigid methyl 3,4-anhydro-6-O-trityl-α-D-galactopyranoside (**29**) was studied; in this case (Table 4, entry 9), besides the ^{19}F NMR signals for the products **30** of the MS(2,rO)-reaction, that of **31** stemming from S_N2 or AS(2,rO) appeared (-196.4 ppm, 47/12/7 Hz). Subsequently, turning to the 3-O-protected derivatives of methyl 4,6-O-benzylidene-β-D-galactopyranoside, both benzyl ether **32** and benzoate **34** (Table 4, entries 10 and 11) were found to be subjects of MS(2,rO) exclusively. From the treatment of the 2-triflate of **34** with aliphatic alcohols in the presence of an organic base, formation of (the pair of) 2,3-orthoesters under inversion of configuration at C-2 has been claimed [14]. However, this reaction only had been proven with the β-D-gluco-analogue (see Table 2, entry 4). Thorough NMR measurements (private communication of the original authors) recently showed that the products are – as had been anticipated [5] – structural analogues of compounds **35** (Table 4, entry 11). Thus, even under these conditions, MS(2,rO) is preferred over ISC(2,NG-3).

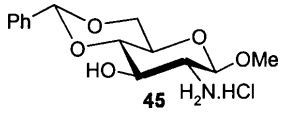
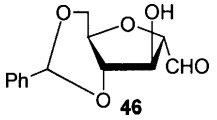
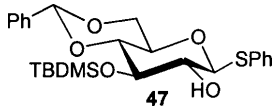
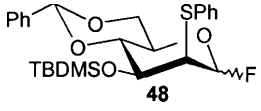
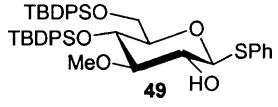
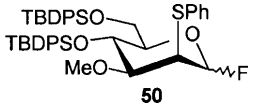
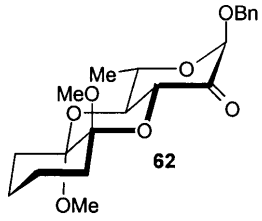
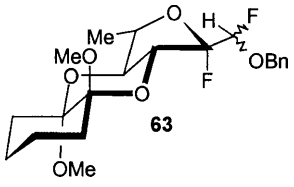
To complete these extensive arabino/ribo- as well as galacto/altro-series and to start in the gluco/manno-range, a few not dioxolane ring protected derivatives of both were treated with *DAST*. Again (Table 4, entries 12 and 13), benzyl 3,4,6-tri-O-benzyl-β-D-galacto- (**36**) as well as the identically protected β-D-glucopyranoside (**38**) were subject to MS(2,rO). In the crude reaction mixture of **38** and *DAST*, a small proportion of benzyl fluoride (triplet at -206.6 ppm, 49 Hz) was also detected. During the standard isolation of the primary products, obviously hydrolysis at C-1 occurred under liberation of the aldehydo-2,5-anhydro-D-hexose derivative **40**. The disaccharidic educt **41**, consisting of an α-D-glucopyranosyl moiety with an unprotected OH-group at C-2 as donor and a 1,2:3,4-di-O-isopropylidene-α-D-galactopyranose as acceptor, was subject to this dominant type of side-reaction (Table 4, entry 14).

This MS(2,rO)-side reaction was also observed with 2-triflates of alkyl 3,4,6-tri-O-benzyl-α- and β-D-glucopyranosides under hydrolytic conditions (water/pyridine in *DMF*, 160°C, 5 min) and was used [19] for glycoside cleavage in the synthesis of chiral cyclopropylmethanol derivatives. Nevertheless, a parallel S_N2-reaction by fluoride was also observed upon treatment of the triflate of **38** with *TBAF* in *THF* [20].

In contrast to the findings described above, where MS(2,rO) was the generally dominating option, treatment of the corresponding derivatives from the α-D-manno-series containing an unprotected OH-2 with *DAST* is known [2, 3] to induce aglycon migration, MS(2,NG-1). This tendency is not restricted to 4,6-O-benzylidene protected educts (see Table 1, entry 5 [9]), but also dominates in cases where a cyclic acetal protection group is absent [16, 21, 22].

To validate our approach, methyl 3-O-benzyl-4,6-O-benzylidene-α-D-manno-pyranoside (**1**) was subjected to reaction with *DAST* under our standard conditions, and the results ((MS(2,NG-1) as well as NMR data of product **2** (Table 4, entry 15)) were found to be in full agreement with the published ones from the *DAST*-reaction in diglyme at 100°C [9].

Table 5. Related reactions

	Educt	Product	NMR data δ/ppm, J/Hz	Yield/%	Ref.
1	 **45**	 **46**	no data	50	[23]
2	 **47**	 **48**	no data	88	[16]
3	 **49**	 **50**	α-anomer: H-1: 5.34 (53.2/5.9) β-anomer: H-1: 5.54 (51.5/2.3) F-1: −144.3 (62.4/6.0) F-2: −118.9 (m)	86	[16]
4	 **62**	 **63**	H-1: 5.32 (62.4/1.2) C-1: 106.2 (224.2/46.2) C-2: 110.3 (223.3/25.8)	19	[27]

The corresponding β-D-gluco-derivative **43** contains, in its $^4C_1$-conformation, an antiperiplaner orientation of the LG to the ring oxygen (rO) and a diequatorial one to the aglycon (NG-1). Due to 4,6-O-benzylidene protection it constitutes a rigid *trans*-decalin system. Thus far, for the displacement reactions of the corresponding triflates, S_N2 had been the choice [7]; the possible MS(2,rO), observed with educts devoid of this 'paralyzing' dioxane protection [19, 20], had never come into play[1]. However, there is a single report in the literature dealing with the nitrous acid deamination with methyl 2-amino-4,6-O-benzylidene-2-deoxy-β-D-glucopyranoside (**45**) of this *trans*-decalin type (Table 5, entry 1) [23] where from the elucidation of the product structure (that time by chemical means only) this MS(2,rO) had to be anticipated. In later experiments [24], isolation of the same product, 2,5-anhydro-4,6-O-benzylidene-D-mannose (**46**), from the corresponding benzyl glycoside could not be achieved (but its formation was not explicitly excluded).

In our case, against all expectations, the treatment of **43** with *DAST* caused aglycon migration, MS(2,NG-1), under formation of 3-O-benzyl-4,6-O-benzylidene-2-O-methyl-α-D-mannopyranosyl fluoride (**44**). For an explanation it can be argued that the centres involved in this rearrangement are located at the more flexible

[1] See Note Added in Proof at the end of this contribution

part of the *trans*-decalin system, thus possibly allowing *quasi*-diaxial arrangement of LG and NG-1 (as depicted in Table 4, entry 16). Furthermore it has been reported in the literature [16] that thioglycosides in the β-D-gluco- and β-D-galactopyranose series (as well β-D-galactopyranosyl azides) with unprotected OH-2, on treatment with *DAST*, give this MS(2,NG-1) in excellent yields (*e.g.* the phenyl thioglycosides **47** and **49** of the β-D-gluco-series shown in Table 5, entries 2 and 3).

To prove this exceptional migratory aptitude of the alkyl/arylthio as well as the azido group as compared to the aglycon of normal O-glycosides (*e.g.* **38**), azide **51** and thioglycoside **54** were treated with *DAST* under standard conditions. The results shown in Table 4, entries 17 and 18, give the impression that this report for the phenylthio group may be valid[1] (however, the given $J_{1,2}$ value of 5.9 Hz for the α-anomer of 2-phenylthio-mannopyranosyl fluoride **50** [16] cannot be imagined to be possible), whereas those from the azido-analogue could not be reproduced since a 10:1-preference for the MS(2,rO)-product **52** over that of the MS(2,NG-1)-reaction (**53**) was observed. As is evident from the literature [25], the geminal ^{19}F, ^{1}H couplings for derivatives containing an azido or arylthio substituent are by approximately 8–10 Hz smaller than the corresponding values in case of O-substitution.

The incorporation of the hexopyranose moiety into a *trans*-decalin ring system as in the 4,6-O-benzylidene protected educt **43** of the gluco-series obviously causes the exceptional reactivity order that the otherwise generally preferred MS(2,rO)[1] is 'prohibited', whereas (due to 1,2-*trans*-configuration) MS(2,NG-1) is 'allowed', even when a diequatorial orientation of LG and NG predominates. With the intention to bring the bridgeheads of the *trans*-annellation closer to the reaction centre, we chose the butane 2,3-*bis*-acetal (*BBA*) strategy [26] to simultaneously protect the diequatorial arranged OH-groups at C-3 and 4 in methyl α-D-manno- and -glucopyranoside. The corresponding educts, **56** and **58**, behaved as follows (Table 4, entries 19 and 20): The α-D-manno-isomer **56** solely gave the expected MS(2,NG-1)-products **57** (an identical result has very recently been published [27] with the corresponding cyclohexane diacetal (*CDA*) from the α-L-manno-series). However, the α-D-gluco-analogue **58**, under standard reaction conditions, led to at least eleven fluorinated products, most of them showing the characteristic ^{19}F NMR features of ring-contracted structures. Only when the reaction rate was drastically reduced (by conducting the treatment with *DAST* at $-20^{\circ}C$ in the presence of an excess of pyridine), formation of one single product could be observed by TLC monitoring. After isolation, it did not contain fluorine but a diethylamino moiety. From the similarity of the NMR spectra to those of the starting material **58** (except chemical shift values for H-2 and H-3), its structure was anticipated to be that of the two (diastereomeric) 2-O-diethylaminosulfinyl derivatives **59** (formed by hydrolysis of both S–F-bonds in the intermediate of the *DAST*-reaction, see Scheme 1). The distinct results presented in Table 4, entry 20, were then obtained after prolonged reaction time under these conditions. MS(2,rO) to give **60** clearly dominated (compare results from the *DAST*-treatment of a structurally related 2-ulose **62** bearing a 3,4-*CDA* protection [27], where ring contraction was observed; Table 5, entry 4). For the additionally observed signal ($\delta = -139.0$ ppm, $J = 49$ and 14 Hz), which corresponds to a glycosyl fluoride, presently no structure can be suggested (**61**). However, it proved, by the admixture of the reaction products **57**, not to be identical with the β-anomer of 2-O-methyl-glucopyranosyl fluoride **57** ($\delta = -138.0$ ppm, $J = 53$ and 12 Hz). The latter was

formed in the *DAST*-reaction of **56** (Table 4, entry 19), but its generation from **58** would have also been conceivable [24] as the opening of the intermediate oxiranium ion in the MS(2,rO)-mechanism by the neighbouring methoxy group from C-1 under overall retention of configuration.

Furthermore, two other educts were investigated, which both have a relatively rigid conformation as well as an axial OH-group at C-2. In the first case, with methyl 3-O-benzyl-4,6-O-benzylidene-α-D-altropyranoside (**64**), two antiperiplanar oriented alkoxy groups are present in vicinal positions to the LG, whereas in the second example, with 1,6-anhydro-3,4-O-isopropylidene-β-D-galactopyranose (**67**), the oxygen atom of the 1,6-anhydro ring occupies the antiperiplanar position. The results obtained with **64** (Table 4, entry 21) parallel those from the corresponding 3-azido-3-deoxy analogue **3** depicted in Table 1, entry 6, except that aglycon migration (MS(2,NG-1)) having led to compound **6** was not observed in this case. In comparison to the MS(2,rO) reactions found with the educts **25** and **27**, both of α-D-altro-configuration as well, the diacritical role of the protecting group with respect to the necessary conformational interconversion becomes evident. As expected, the *DAST*-treatment of **67** resulted in migrative substitution at C-2 by the oxygen of the 1,6-anhydro ring with inversion of configuration and entry of fluoride at C-1 (MS(2,NG-1)) to yield 2,6-anhydro-D-talopyranosyl fluorides **68**. Noteworthy, the ^{19}F NMR resonances are located at higher fields and show the same magnitude of geminal couplings as characteristic for MS(2,rO)-products. These results are in good agreement with those reported from the *DAST* reaction of the unprotected 1,6-anhydro-β-D-galactopyranose [28].

Finally, to test the S_N2- *vs*. the ISC(2,NG-3)-option, methyl 3-O-benzoyl-4,6-O-benzylidene-α-D-glucopyranoside (**69**) was reacted with *DAST* (Table 4, entry 23). Although TLC monitoring showed product formation, no discrete resonance signal could be observed by ^{19}F NMR. After work-up, the products were found to be those of ISC (**70**) and subsequent hydrolysis (**71**) as well as (not shown in entry 23) the 2-O-diethylaminosulfinyl derivative of educt **69**.

In conclusion, the following 'rules', additional to those mentioned in the introduction, can be derived from the results described herein on the treatment of alkyl hexopyranosides containing an unprotected OH-group at C-2 with *DAST* in dichloromethane at room temperature:

i) MS(2,rO), the ring contraction under attack of the ring oxygen, is generally preferred over all other possibilities, even when the predominating conformation does not contain OH-2 in the (*quasi*-essential) equatorial position. This is especially valid in the class of pento- and hexopyranosides which contain a (*cis*)-3,4-O-isopropylidene protecting group. Exceptions from this type of reaction are all educts of the manno-series as well as those 4,6-O-benzylidenated hexopyranosides which are members of the *trans*-decalin family (derivatives of the gluco-, allo-, and altro-series as they contain their ring substituents at C-4 and C-5 in (*trans*)-diequatorial orientation)[1].

ii) MS(2,NG-1), the so-called aglycon migration, seems to be the 'opposite' alternative to MS(2,rO) as they, with O-glycosidic educts, have never been observed together in the same reaction. Independently of the protecting groups present, MS(2,NG-1) finds its stage set for single action in all derivatives of α-D-mannopyranoside.

Table 6. ^{13}C NMR data (δ/ppm, J/Hz); assignments marked with an asterisk may be interchanged

	C-1	C-2	C-3	C-4	C-5	C-6	Others
17a	111.2 219.8	84.8 21.0	80.9 3.6	81.5	74.7	–	71.7 (*Bn*), 112.5/26.6/25.0 (CMe_2)
17b	109.3 220.7	84.3 29.4	80.8	81.4	74.7	–	71.3 (*Bn*), 112.5/26.6/25.0 (CMe_2)
19a	114.2 222.9	85.3 21.5	81.4 3.5	82.1	75.2	–	57.7 (OMe), 113.4/26.8/25.1 (CMe_2)
19b	112.6 223.4	84.9 29.5	81.3	82.0	75.2	–	57.8 (OMe), 113.6/26.8/25.1 (CMe_2)
21a	112.8 220.6	82.7 22.2	81.3 6.2	81.5	74.1	–	57.9 (OMe), 113.5/26.2/24.9 (CMe_2)
21b	111.7 214.3	82.2 35.8	80.8	81.5	74.2	–	57.8 (OMe), 113.5/26.3/25.0 (CMe_2)
26a	111.8 220.0	84.7 24.9	80.8 3.5	82.4	84.8	64.4	57.5 (OMe), 114.1/27.6/25.7 (CMe_2), 87.0 (CPh_3)
26b	111.9 219.7	84.9 26.6	81.1 2.3	82.8	85.2	64.8	57.5 (OMe), 113.8/27.6/25.7 (CMe_2), 87.0 (CPh_3)
28a	111.6 220.9	84.5 24.0	80.5 3.8	81.9	83.3	63.9	57.6 (OMe), 114.4/27.5/25.6 (CMe_2), 178.4/39.0/27.4 (*Piv*)
28b	111.4 220.7	85.1 29.4	80.7 1.5	82.3	83.7	64.3	57.6 (OMe), 114.1/27.5/25.6 (CMe_2), 178.4/39.0/27.4 (*Piv*)
31	97.3 34.7	85.2 176.8	51.0 24.4	48.6	65.3	63.3	55.4 (OMe), 87.0 (CPh_3)
33a	111.4 219.3	80.6 25.0	79.2 [n.r.]	74.3*	73.3*	67.6*	57.5 (OMe), 72.2* (*Bn*), 99.0 (CHPh)
33b	112.3 219.2	80.7 22.0	79.2 [n.r.]	74.5*	73.3*	67.5*	57.4 (OMe), 72.2* (*Bn*), 99.1 (CHPh)
35a	111.2 221.3	79.8 23.3	74.4 4.0	74.8*	73.6*	67.3*	57.5 (OMe), 166.2 (*Bz*), 98.7 (CHPh)
35b	111.5 220.3	79.7 27.7	74.1 1.3	74.7*	73.6*	67.3*	57.6 (OMe), 166.2 (*Bz*), 98.7 (CHPh)
2α	105.6 229.7	81.5 24.1	78.2	81.2	64.7 3.8	68.8	60.2 (OMe), 75.4 (*Bn*), 101.6 (CHPh)
2β	109.5 218.2	83.3 24.1	79.6 8.8	80.7	65.6	68.8	60.5 (OMe), 74.7 (*Bn*), 101.5 (CHPh)
44	106.7 224.7	78.3 35.6	75.6 2.7	78.5	66.3 2.7	68.6	60.9 (OMe), 73.7 (*Bn*), 101.9 (CHPh)
55	108.4 225.7	52.3 28.0	77.8* 2.7	75.3	74.2* 3.7	68.6	74.2/73.5/71.9 (*Bn*)
58	99.9	69.5*	70.2*	71.0*	66.4	62.0	55.3 (OMe), 99.7/48.4/48.2/18.0/17.8 (*BBA*), 86.6 (CPh_3)
59a	98.8	69.9	68.2	68.7	66.8	61.9	54.9 (OMe), 99.6/48.1/48.0/17.6/17.5 (*BBA*), 86.3 (CPh_3), 36.7/36.6/14.0/13.9 (NEt_2)
59b	99.5	71.9	68.1	66.7	68.7	61.7	

(*continued*)

Table 6 (*continued*)

	C-1	C-2	C-3	C-4	C-5	C-6	Others
65	99.2 34.5	88.2 174.2	72.2 27.2	71.1 1.9	58.7	69.5	56.1 (OMe), 73.6 (*Bn*), 102.6 (CHPh)
66	99.6 9.6	80.0 16.9	91.4 187.2	77.2 ∼15	61.8 ∼5	69.1	55.7 (OMe), 73.8 (*Bn*), 101.9 (CHPh)
68a	105.6 225.5	65.3 21.4	70.5 4.2	69.9	69.3 1.5	60.8	110.9/26.2/24.5 (CMe_2)
68b	106.3 227.8	68.4 19.5	73.5 9.2	70.5 6.8	68.7 2.0	63.0	113.0/26.2/25.1 (CMe_2)
70a	98.7	76.7	75.9	79.7	60.2	69.1	55.6 (OMe), 102.0 (CHPh), 121.0/51.2 (orthoester)
70b	98.9	77.0	75.2	79.5	60.5	69.1	55.6 (OMe), 102.2 (CHPh), 122.1/51.6 (orthoester)
71	99.9	72.8	67.7	79.4	63.6	69.0	55.4 (OMe), 102.5 (CHPh), 166.4 (*Bz*)

iii) MS(2,NG-1) is also operative in pyranoid educts with a 4,6-O-benzylidene protection as soon as a 1,2-*trans*- as well as 4,5-*trans*-orientation of their ring substituents is given (α-D-altro and β-D-gluco[1]; β-D-allo was not probed). In the case of 4,6-O-benzylidene-α-D-altropyranosides, MS(2,NG-3), the migrative substitution ('simple' case) by the NG from C-3, as well as AS(2,NG-1 and/or 3), the anchimerically assisted substitution under retention of configuration, become significant as well.

iv) ISC(2,NG-3), the participation of the 'complex' type (out of a diequatorial arrangement to the LG) by a neighbouring acyloxy group, ranks behind a possible MS(2,rO) but before S_N2.

v) S_N2, the usually intended nucleophilic substitution under inversion of configuration, is the reaction of choice with β-D-mannopyranosides only.

vi) E, elimination, was never observed, although many educts fulfilled the stereochemical prerequisite of an antiperiplanar orientation between the LG and a vicinal hydrogen atom at C-3 or C-1.

Synthesis of Educts

Many of the educts used in this study were taken either directly or in form of essential precursors from the carbohydrate reference collection of this institute or were gifts of Chemprosa Company, Lannach (Austria). The eventually necessary final transformations on donated precursors as well as the syntheses of the remaining educts were conducted according to literature procedures. The regioselective introduction of the butane *bis*-acetal protection in educt **58** was achieved starting from the known methyl 2-benzoyl-α-D-glucopyranoside. All compounds gave satisfactory ^1H and ^{13}C NMR spectra, but were not further characterized.

Table 7. ^{1}H NMR data (δ/ppm, J/Hz)

	H-1	H-2	H-3	H-4	H-5a	H-5b/6a	H-6b	Others
17a	5.39 66.9/2.0	4.13 25.7/2.0/1.5	4.81 not resolved	4.96 6.4/1.5/1.5	3.98–4.03 not resolved		–	4.92 (12.0)/4.67 (12.0/1.5) (*Bn*), 1.50/1.34 (CMe_2)
17b	5.37 63.4/2.6	4.20 not resolved	4.81 not resolved	4.96 6.4/1.5/1.5	3.98–4.03 not resolved		–	4.92 (12.0)/4.65 (12.0/1.5) (*Bn*), 1.50/1.34 (CMe_2)
19a	5.24 67.4/2.0	4.09 25.0/2.0/1.5	4.92 5.7/1.5	4.81 5.7/2.8/2.8	4.02 2.8/2.8		–	3.57 (1.2) (OMe), 1.52/1.33 (CMe_2)
19b	5.18 63.6/2.6	4.15 7.0/2.6/1.0	4.92 6.2/1.0	4.81 6.2/2.7/2.7	3.99 2.7/2.7		–	3.55 (1.3) (OMe), 1.52/1.33 (CMe_2)
24a	5.25 67.8/1.8	4.05 24.4/not resolved	4.93 6.2/not resolved	4.76 5.7/4.4	4.2 not resolved	3.40 9.2/5.7	3.32 9.2/6.6	3.55 (OMe), 1.43/1.32 (CMe_2)
28a	5.18 66.8/2.2	4.1 not resolved	4.78 6.6/3.5	4.3 5.7/3.5	4.0–4.25 not resolved			3.56 (OMe), 1.51/1.32 (CMe_2), 1.19 (*Piv*)
35a	5.41 66.0/2.1	4.63 16/9/2	5.59 8.3/4.3	4.84 not resolved	4.09 not resolved	4.43 12.2	4.12 12.2/1.5	3.61 (OMe), 5.50 (CHPh)
35b	5.39 63.8/2.8	4.68 7.8/2.8	5.64 7.8/4.2	4.84 not resolved	4.09 not resolved	4.43 12.2	4.12 12.2/1.5	3.59 (OMe), 5.50 (CHPh)
58	4.91 3.6	3.5–3.95 not resolved				3.40 11.4	3.14 11.4/5	3.49 (OMe), 3.29/3.02/1.33/1.15 (*BBA*)
59a	4.91 3.6	4.29 10.3/3.6	4.09 10.3/9.8	3.76 10.3/9.8	3.9 not resolved	3.1–3.4 not resolved		3.47 (OMe), 3.29/3.02/1.33/1.15 (*BBA*)
59b	4.90 3.6	4.18 10.3/3.6	4.06 10.3/9.8	3.83 10.3/9.8	3.9 not resolved	3.1–3.4 not resolved		3.45 (OMe), 3.29/3.02/1.33/1.15 (*BBA*)
68a	5.85 65.9/1.5/1.5	4.15 not resolved	4.47 7.8	4.44 7.8	4.14 not resolved	4.07 9.5/6.4	3.68 9.5/1.5	1.58/1.38 (CMe_2)
68b	5.58 62.5	4.00 –	4.22 7.8	4.39 7.8/4.4	4.14–4.20 not resolved			1.58/1.39 (CMe_2)

Characterization of products

As in most cases the formed mixtures of diastereomers were found to be hardly separable, unequivocal identification of individual ^{1}H and ^{13}C NMR signals was not possible in all instances; this was especially the case with proton resonance spectra. Data essential for the structure assignments are included in Table 4; further data are collected in Tables 6 and 7 (signals corresponding to aromatic moieties of protecting groups are omitted). The configuration at C-1 within a pair of diastereomers formed by MS(2,rO) can be deduced from the set of couplings observed with the nuclei F, H-1, and H-2 [11], but this was not done with the products obtained here. They are designated simply as isomers 'a' or 'b'; this holds also for the pair of diastereoisomers in compound **59**.

Experimental

General

NMR spectra were recorded at 300.13 or 200 MHz (^{1}H), 75.47 or 50.29 MHz (^{13}C), and 282.4 MHz (^{19}F) using a Bruker MSL 300 and a Varian Gemini 200 apparatus, respectively, except for the elucidation of **59** where a Varian Inova 500 spectrometer was employed. As reference standards, tetramethylsilane (^{1}H and ^{13}C NMR) and trichlorofluoromethane (^{19}F NMR) were used. TLC was performed on silica gel 60 F_{254} precoated aluminum plates (Merck 5554) with detection by charring after spraying with vanillin/H_2SO_4 (1%). For column chromatography, silica gel 60, 230–400 mesh (Merck 9385), was employed.

General procedure for the DAST-reaction

Analytical Scale: To a cold (0°C) solution of 0.1 mmol educt in 1 cm^3 absolute CH_2Cl_2, 0.04–0.05 cm^3 *DAST* (0.30–0.38 mmol) were added under stirring. After 10 min the cooling bath was removed, and the mixture was stirred at room temperature for 5 h under monitoring by TLC (generally, the reaction products are faster moving than the educt). For the ^{19}F NMR measurements, 0.4 cm^3 of the reaction mixture were transferred into the NMR tube and diluted with $CDCl_3$.

Preparative Scale: The reaction conditions were the same as used in the analytical scale. The amount of educt, solvent, and reagent was ten- to fifteen-fold. The reaction time was extended to 15–24 h. Work-up started with dilution of the reaction mixture with CH_2Cl_2 and quenching of the excess reagent by addition of an excess of MeOH. After 15 to 20 min the mixture was then extracted with H_2O, followed by aqueous $NaHCO_3$ and again H_2O. After drying with Na_2SO_4 the solvent was evaporated, and the residue was chromatographically purified on silica gel.

Note Added in Proof

After having submitted the manuscript we became aware of a recent paper dealing with the *DAST* reaction of glycosides and thioglycosides of 3-deoxy-3-C-methyl-3-nitro-*D*/*L*-gluco- as well as -mannopyranoses [29]. These educt structures, in the same way as ours, are subject to either ring contraction (MS(2,rO)) or aglycon migration (AS(2,NG-1)) and show, as is to be expected, a higher degree of reactivity in displacement reactions at C-2. As the presented generalizations concerning the diacritic structural parameters in the choice of the side reaction were in contrast to those we had deduced from our findings, a thorough inspection of the reported ^{1}H and ^{13}C NMR data was carried out in order to re-examine the elucidation of product structures. From the value of the geminal ^{19}F,

^{1}H couplings ($^2J_{F,H}$) and other diacritical data (*e.g.* chemical shifts of H-2 and C-2, respectively) it has to be concluded that the structure appointments are wrong in 8 cases. According to our interpretation of the data, the methyl α-L-manno derivative as well as all thioglycosides (α- and β-anomers from the D/L-gluco series) were subject to AS(2,NG-1), whereas all O-glycosides with α- or β-D/L-gluco configuration, including those containing a 4,6-O-benzylidene protection, gave MS(2,rO) only. This is in full agreement with parameters we have deduced herein from our results, except that in the (more reactive) 3-deoxy-3-C-methyl-3-nitro-glucopyranose case, a 4,6-O-benzylidene protection does no more cause prevention of the ring contractive MS(2,rO)-reaction.

Acknowledgements

We appreciate financial support by the *Fonds zur Förderung der wissenschaftlichen Forschung*, Vienna (P-11021 OECH) and thank Chemprosa, Lannach (Austria) for the gift of educts for this investigation. Student coworkers in the synthesis of educts as well as their treatment with *DAST* have been: *R. Peinsipp*, *J. Wolfgang*, *G. Koller*, *B. J. Paul*, *F. Burghart*, *C. Gruber*, *W. Haas*, *M. Grininger*, *R. Harrer*, *W. Kroutil*, *S. Leitgeb*, *M. Waldhuber*, *D. Kober*, *T. Sovic*, and *J. Steinreiber*. They are all thanked for their valuable help in these laborious studies.

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Received November 26, 2001. Accepted November 28, 2001