Enantiopure 2-Thioxotetrahydro-1,3-*O,N*-heterocycles from Carbohydrates. 3. Enantiopure C-4 Chiral Oxazine- and Oxazolidine-2-thiones from 3-Deoxy-3-isothiocyanato Sugars†

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Received March 23, 1994®

The synthesis of 3-deoxy-3-isothiocyanato derivatives of D-glucose, D-allose, and D-galactose is reported. The intramolecular cyclization of partially or fully unprotected 3-deoxy-3-isothiocyanates has been found to proceed with total stereocontrol, the outcome of the reaction being governed by the sugar configuration. Bicyclic enantiopure C-4 (and C-5) chiral tetrahydrooxazine- and oxazolidine-2-thiones have been prepared in this way. An unexpected nucleophilic addition of the γ-oxo group to the NCS group has been observed in the case of the fully unprotected D-*gluco* derivative, leading to the formation of a 4-(trihydroxypropyl)tetrahydrooxazine-2-thione.

Introduction

The development of effective chiral auxiliaries for asymmetric chemical synthesis as well as for the resolution of racemates has become an important subject in chemistry. The main source for such enantiomerically pure chiral agents continues to be the chiral pool, i.e. the chemical modification of chiral compounds of natural origin.[1]

Among chiral natural products, carbohydrates offer many interesting advantages for organic synthesis. They are inexpensive, widespread natural compounds with numerous functional groups and stereogenic centers. Yet, they can undergo highly stereoselective reactions as a result of conformational bias. Their use as chiral auxiliaries is therefore very tempting.[2] A main difficulty, however, lies in organizing the chiral information they contain in order to be exploited in stereodifferentiating processes. A promising approach in this sense is the construction of a 2-oxooxazolidine or -tetrahydrooxazine ring on a conveniently functionalized monosaccharide template, thus combining the well-established features of enantiomerically pure 2-oxotetrahydro-1,3-*O,N*-heterocycles as effective chiral auxiliaries[3] and the complex-forming ability of carbohydrates. A few examples of enhanced asymmetric inductions on prochiral compounds using this new type of chiral auxiliaries have recently been reported.[2,4] In contrast, no attention has been directed to the synthesis of thioxo analogs, although their use as chiral auxiliaries may show some advantages as compared to their oxo counterparts.[5]

As a part of our studies on the synthesis and reactivity of sugar isothiocyanates,[6] we have shown that unprotected primary deoxyisothiocyanato sugars undergo spontaneous or based-induced cyclization to give enantiopure C-5 chiral oxazoline- or tetrahydrooxazine-2-thiones in a complete regioselective manner.[7] The isothiocyanate intermediates can be isolated provided that the anomeric position is blocked, and this fact has been further exploited for the selective functionalization of nonreducing oligosaccharides of biological and economical importance such as trehalose, sucrose, and cyclodextrines.[8]

In order to implement this strategy in the access of enantiomerically pure C-4 chiral 2-thioxotetrahydro-1,3-*O,N*-heterocycles, for comparative purposes in asymmetric induction studies, it was of interest to check the reactivity of an -NCS group on a secondary position in a sugar molecule as a function of the relative configuration of the different hydroxyl groups. There are no examples in the literature of unprotected deoxyisothiocyanato sugars bearing the -NCS group on a secondary carbon atom other than the anomeric one. Although some per-*O*-acylated 2-deoxy-2-isothiocyanato sugars have been reported,[9] the high reactivity of isothiocyanates toward bases prevents the *O*-deprotection step.[10] On the other hand, the -NCS functionality is compatible with the acidic conditions used for deprotection of acetal protecting groups, thus providing a convenient route to fully un-

† For part 2 see ref 7a. Part 1 is ref 7b. Presented, in part, at the Seventh European Carbohydrate Symposium, Cracow, Poland, August 22–27, 1993, Abstr. A 059.

® Abstract published in *Advance ACS Abstracts,* August 15, 1994.

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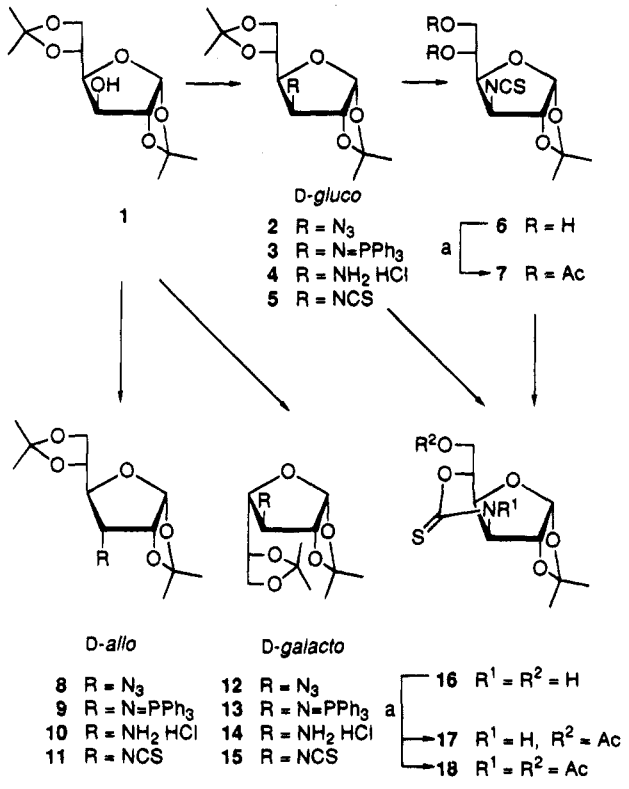
Scheme 1[a]



[a]Key: (a) Ac_2O/Py.

protected deoxyisothiocyanato sugars from selectively protected derivatives.[7]

Because isothiocyanates are obtained from the corresponding amines, the direct transformation of the amino sugar precursors into the target heterocyclic compounds has also been investigated. The synthesis of the key intermediates, the mechanisms of the reactions, and the scope and limitations of the methods are discussed. A conformational study is also included.

Results and Discussion

The 3-deoxy-1,2:5,6-di-*O*-isopropylidene-3-isothiocyanato-α-D-hexofuranoses **5**, **11**, and **15**, having respectively the D-*gluco*, D-*allo*, and D-*galacto* configurations, have been synthesized (Scheme 1). All three diastereomers were prepared from commercially available 1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose (**1**) using known procedures (see Experimental Section). Particularly interesting was the Staudinger reduction[11] of the 3-azidodeoxy derivatives **2**, **8**, **12** to give the corresponding amine hydrochlorides **4**, **10**, **14** *via* triphenylphosphinimines **3**, **9**, **13** (see supplementary material). To our knowledge, this reaction had never been before applied to the preparation of secondary amino deoxy sugars. In our hands, it was more convenient than the catalytic hydrogenation of the azides, although more strenuous conditions were generally needed for the base hydrolysis of the phosphinimine intermediates **3**, **9**, **13** as compared to derivatives at a primary position.[7a,12]

In principle, fully unprotected 3-deoxy-3-isothiocyanato hexoses may undergo intramolecular cyclization either through the furanose or pyranose tautomers or through the open chain form. Which of them, and which of the different functional groups of the molecule are involved depends dramatically on the configuration of the sugar template and on the reaction conditions. In order to get complete insight into the problem, three cases have been sequentially considered for each sugar configuration: selective deprotection of the 5,6-*O*-isopropylidene group in **5**, **11**, **15**, simultaneous deprotection of both acetal groups, and direct reaction of fully unprotected 3-amino-3-deoxy sugars with thiophosgene.

Synthesis of Enantiopure C-4 Chiral 2-Thioxotetrahydro-1,3-oxazines from *gluco*-Isothiocyanates. Treatment of **5** with 90% TFA in water at 0 °C selectively removed the 5,6-*O*-isopropylidene group, keeping the furanose tautomer anchored by means of the remaining 1,2-*O*-acetal group. An IR spectrum of the reaction mixture showed an intense band at ~2100 cm^{-1} for **6** (ν_{NCS}) together with a sharp one at ~1560 cm^{-1} for the thiocarbamate group of **16** (δ_{NH}). Attempts to isolate **6** from the mixture failed, its spontaneous transformation into the cyclization product **16** being observed during column chromatography. Compound **6** could be trapped as the corresponding diacetate **7** after treatment of the crude reaction mixture with Ac_2O–pyridine. When the deprotection reaction of **5** was conducted at room temperature, a quantitative transformation into **16** was achieved (Scheme 1). The spontaneous annelation reaction of **6** involving the γ-located OH-5 deserves further comment. We have previously reported[7a] that 6-deoxy-6-isothiocyanato aldoses having the pyranose form anchored are stable compounds. Their cyclization into the corresponding 6,4-cyclic thiocarbamates occurred only in the presence of a basic catalyst, resulting in a *cis*- or *trans*-decalin type system. This difference of behavior is indicative of a lower activation energy for the furanoid isothiocyanate **6** as compared to pyranoid derivatives, which may be correlated to stereoelectronic prerequisites of the corresponding transition states. To enable an efficient charge stabilization, the forming oxazine ring must adopt a conformation with the C-6–O-1–C(=S)–N-3–C-4 region in the same plane. In the event that the 1,3-*O*,*N*-heterocycle is fused to a pyranose ring, this structural requirement can be fulfilled only after some distortion of the preexisting rigid chair conformation, an unfavorable arrangement. The higher flexibility of the furanose ring of **6** facilitates this planar disposition, thus resulting in a higher cyclization rate.

Acetylation of the NH group in the tetrahydrooxazine derivative **16** was significantly slower than acetylation at the hydroxymethyl substituent. Consequently, either the *O*-acetate **17** or the *O*,*N*-diacetate **18** could be selectively obtained using Ac_2O–pyridine by changing the reaction conditions (Scheme 1 and Experimental Section).

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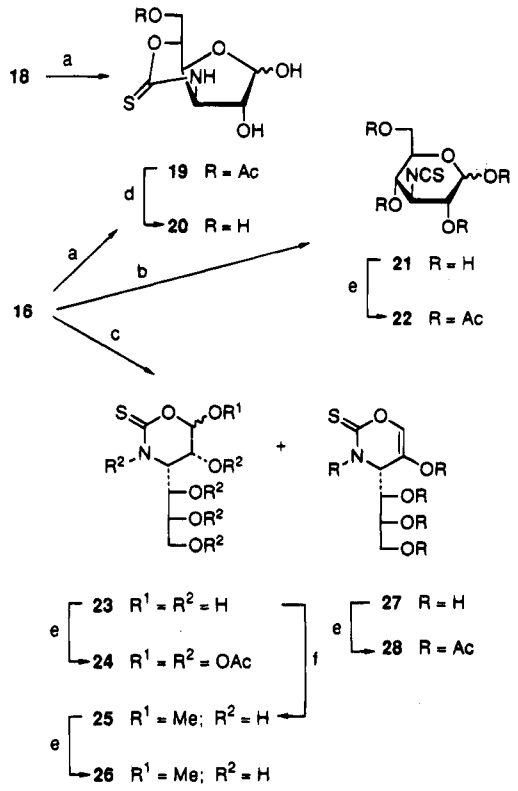
Scheme 2[a]



[a]Keys: (a) 90% TFA/H_2O, 40 °C, 8 h. (b) 50% TFA/H_2O, 50 °C, 4 h. (c) 50% TFA/H_2O, 50 °C, 12 h. A similar result was obtained starting from **5**. (d) MeONa. (e) Ac_2O/Py. (f) MeOH/H^+.

1,3-*O*,*N*-Heterocycles are compounds with a variety of synthetic and pharmacological applications.[13] It was thus of interest to contemplate the selective deprotection of the different functional groups in the tetrahydrooxazine derivative **18** as well as the preparation of water soluble derivatives. Removal of the 1,2-*O*-isopropylidene group in **5**, **16**, or **18** required more strenuous conditions than the 5,6-*O*-acetal group, and the outcome of the reaction was strongly dependent on the TFA–H_2O ratio, temperature, and reaction time. Treatment of **18** with 90% TFA in water at 40 °C for 8 h resulted in simultaneous hydrolysis of the isopropylidene group and *N*-deacetylation to give **19**. Catalytic *O*-deacetylation with sodium methoxide yielded the fully unprotected bicyclic tetrahydrooxazine-2-thione **20**. Compound **20** was obtained directly from **16** using the above acidic reaction conditions (Scheme 2).

When deprotection of **16** was performed at 50 °C using 50% TFA in water, the opening of the tetrahydrooxazine ring (→**21**) took place, as seen from an IR spectrum of the reaction mixture (ν_{NCS} at ~2100 cm^{-1}). Acetylation of the mixture after 4 h permitted isolation of the corresponding tetraacetate **22** as a pair of the α- and β-pyranoid anomers. Longer reaction times resulted in further rearrangement into the 5,6-dihydroxy-4-(D-*erythro*-triitol-1-yl)-2-thioxotetrahydro-1,3-oxazine **23**. Concomitant formation of a small proportion of the dihydrooxazine **27** was also observed under these reaction conditions (Scheme 2). A similar result was obtained when both acetal groups were simultaneously removed in the isothiocyanate derivative **5**.

The transformation of **5** and **16** into the open-chain D-*gluco* derivative **23** was an interesting although unexpected result. It can be explained assuming that the -NCS group of the fully unprotected intermediate **21** undergoes nucleophilic attack by the γ-located carbonyl group in the *aldehydo* form. The formation of analogous five-membered mesoionic heterocycles from β-oxo isothiocyanates has been previously reported.[14] No examples of intramolecular cyclization of 3-oxo isothiocyanates have been described so far, unless previous reduction of the carbonyl group was performed.[15]

Table 1. Selected ^1H NMR Spectral Parameters (δ) and *J* (hertz) of Tetraahydrooxazine-2-thione Derivatives (16–20)

	compound						
parameter[a]	**16**[b,f]	**17**[c,e]	**18**[c,e]	β-**19**[d,e,g]	α-**19**[d,e,g]	β-**20**[d,e,g]	α-**20**[d,e,g]
H-6a	3.64 dd	4.45 dd	4.43 dd	4.47 dd	4.43 dd	3.83 dd	3.82 dd
H-6b	3.60 dd	4.25 dd	4.22 dd	4.42 dd	4.27 dd	3.72 dd	3.75 dd
$J_{4,5}$	0	0	2.0	4.1	4.0	5.2	4.0

[a] See ref 16. [b] In Me_2SO-d_6. [c] In $CDCl_3$. [d] In CD_3OD. [e] At 300 MHz. [f] At 500 MHz. [g] The anomeric configuration (β or α) is referred to the L-series. See nomenclature in Experimental Section.

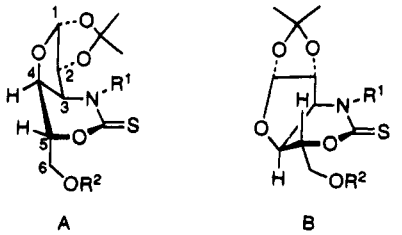


Figure 1. Flattened-chair conformers for tetrahydrooxazines **16–18**.

The six-membered cyclic thiocarbamate structure for compounds **16-18** was supported by both the proton (Table 1) and carbon-13 NMR spectra (see Experimental Section).[16] The ^{13}C chemical shifts of C-5 agreed with reported values[17] for structurally related α-D-glucofuranose derivatives having a 3,5-*O*-isopropylidene bridge, while the resonance of C-3 was comparatively strongly deshielded, indicative of the C-3–C(=S)NH–O-5 bridge. The signal at 184.2–186.9 ppm confirmed the presence of the thiocarbonyl group.[7,8] The strong deshielding effect observed for the resonances of H-6a,6b in **17**, **18**, or **19** as compared with the partially protected derivatives **16** or **20** was consistent with acetylation at the primary OH-6, ruling out an isomeric seven-membered cyclic thiocarbamate structure.

Heterocycles having a potential amidine group [NHC(=X)Y ↔ NH^+=C(X^-)Y] tend to adopt a near planar disposition[5a,18] which in the case of the six-membered derivatives **16-18** would correspond to the flattened-chair conformations A or B (Figure 1). The value of $J_{4,5}$ (0–

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(15) Jochims, J. C.; Abu-Taha, A. *Chem. Ber.* **1976**, *109*, 154.
(16) For clarity of presentation, the authors choose not to use the numbers resulting from the nomenclature of the heterocyclic compounds (see Experimental Section) in the notation of atoms for NMR data. Instead, the notation was kept consistent with the parent compounds.
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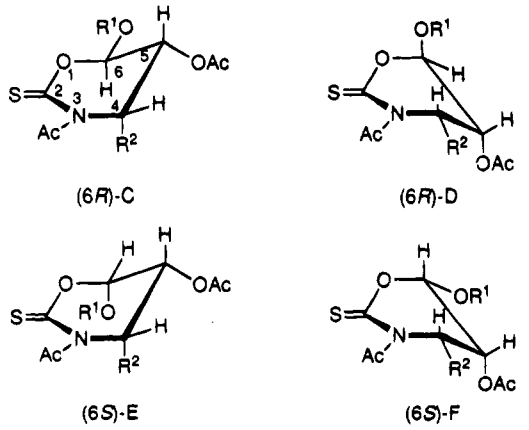


Figure 2. Flattened-chair conformers for tetrahydrooxazines **24** and **26**.

Table 2. Selected ^{1}H NMR (300 MHz, $CDCl_3$) Spectral Parameters (δ) and J (hertz) of Tetrahydrooxazine- (24, 26) and Dihydrooxazine-2-thione (28) Derivatives

	compound			
parameter	**24**	(6*S*)-**26**	(6*R*)-**26**	**28**
H-1	6.87 d	5.88 d	4.78 d	7.41 s
$J_{4,5}$	1.8	2.7	1.8	–
$J_{5,6}$	3.4	2.7	3.7	–

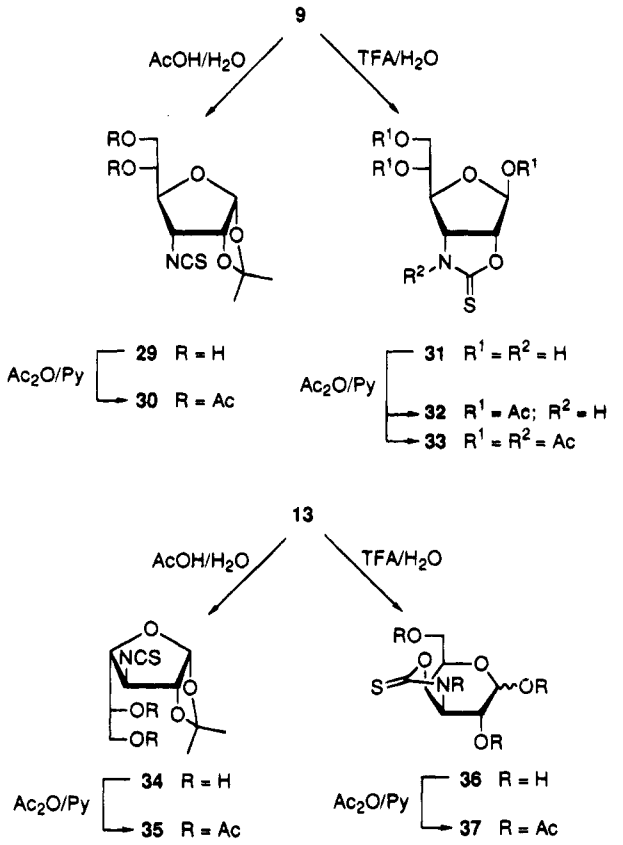
5.2 Hz), indicative[19] of a *gauche* arrangement between H-4 and H-5, is then in agreement with a preferred conformation close to A for the tetrahydrooxazine-2-thione derivatives **16-20** in DMSO, MeOH, or $CHCl_3$ solutions, precluding a significant contribution of conformer B in which H-4 and H-5 would be in *anti*-disposition.

Compounds **23** and **27** were isolated as the corresponding peracetates **24** and **28**. The open chain structure, regarding the sugar skeleton, was evident from the presence of six and five acetyl groups, respectively, in their ^{1}H NMR spectra. The involvement of the anomeric position in the tetrahydro- or dihydrooxazine ring was inferred from the values of the resonances of H-1 and C-1 in ^{1}H (Table 2) and ^{13}C NMR spectroscopies. No signals arising from an aldehyde group were present. The strong deshielding effect observed for the resonances of C-5 and C-6 of **28** as compared with those of **24** confirmed the dihydrooxazine structure of the latter.

It is noteworthy that only one of the two possible diastereomers at the hemiacetal center of **23** was detected on acetylation (→**24**). Assignment of the correct configuration on the basis of the $J_{4,5}$ and $J_{5,6}$ values (Table 2) was problematic. Each of the (6*R*)- and the (6*S*)-diastereomers can exist in two flattened-chair conformations (Figure 2, conformations C, D and E, F, respectively). Conformer C, having H-5 and H-6 in *anti*-disposition, can be ruled out in view of the low value of $J_{5,6}$. Of the remaining structures, only conformers (6*R*)-D and (6*S*)-E fit the anomeric effect, but an unfavorable 1,3-interaction would appear in the latter one. Therefore, the (6*R*)-configuration was tentatively assigned to compound **24**.

To get further support for this hypothesis, the corresponding (6*R*)- and (6*S*)-6-methoxy derivatives **25** were prepared by acid treatment of **23** in MeOH and isolated as a pair of diastereomers **26** after acetylation (Scheme 2). One of them displayed a ^{1}H NMR spectrum (Table 2) very similar to that for **24**. The shape of the signal for H-5 (dd) was particularly significant, showing different values for $J_{4,5}$ and $J_{5,6}$. The same signal appeared as a triplet in the case of its C-6 epimer, indicative of identical relative dispositions between H-4, H-5 and H-5, H-6. This result agrees with the (6*S*)-configuration for the latter in either E or F conformation and thus confirms the (6*R*)-configuration for **24** in conformation D. The absence of NOE[20] between H-4 and H-6 in the spectrum of (6*S*)-**26** accords with the major conformation E in $CHCl_3$ solution.

Scheme 3



Synthesis of Enantiopure C-4 Chiral Oxazolidine-2-thiones from *allo*- and *galacto*-Isothiocyanates. The above results on the reactivity of 3-isothiocyanato-glucose derivatives clearly show that reaction of the -NCS group with a β-located OH group in *trans*-relative disposition does not occur either in the furanose or in the pyranose tautomeric form of the sugar, while the *aldehydo* form is active only when the reaction involves the carbonyl group. Our next interest is to consider the cases of *cis*-relationships between neighboring NCS and OH groups in both cyclic stereostructures, in order to check this reaction pattern in the regioselective preparation of bicyclic enantiopure C-4 chiral oxazolidine-2-thiones.

Selective deprotection of the 5,6-*O*-isopropylidene group in the *allo*- and *galacto*-isothiocyanates **11** and **15** led to the stable γ,δ-dihydroxy isothiocyanates **29** and **34**, respectively. No intramolecular cyclization reaction was observed even in the presence of Et_3N in DMF solutions. Conventional acetylation with Ac_2O–pyridine quantitatively yielded the corresponding diacetates **30** and **35** (Scheme 3).

The difference of reactivity of the -NCS group in **29** and **34** toward the γ-located OH-5 as compared with the *gluco*-diastereomer **6** is obviously a consequence of the

(20) A ROESY (Rotation Frame Overhauser Effect Spectroscopy) experiment was performed at 500 MHz (Bruker AMX 500) in $CDCl_3$ solution. See: Bax, A.; Davis, D. G. *J. Magn. Reson.* **1985**, *63*, 207.

Table 3. Selected ^{1}H NMR Spectral Parameters (δ) and J (hertz) of Oxazolidine-2-thione Derivatives (31–33, 36, 37)

parameter[a]	compound						
	31[b,d]	**32**[c,d]	**33**[c,d]	α-**36**[b,e]	β-**36**[b,e]	α-**37**[c,e]	β-**37**[c,e]
H-5	3.75–3.58 m	5.09 ddd	5.25 ddd	4.32 ddd	3.99 ddd	4.45–4.30 m	4.45–4.30 m
$J_{1,2}$	0	0	0	3.6	7.6	4.0	3.8
$J_{2,3}$	7.7	7.7	7.6	6.7	7.6	8.0	2.8
$J_{3,4}$	0.8	1.0	1.0	7.7	7.6	8.6	7.5
$^4J_{1,3}$							0.6

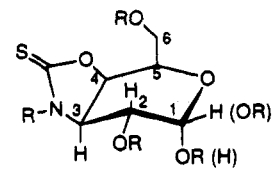
[a] See ref 16. [b] In CD_3OD. [c] In $CDCl_3$. [d] At 300 MHz. [e] At 500 MHz.

trans-arrangement between the C-3 and C-4 substituents in the furanose ring of **29** and **34**, which would bring about the formation of a tensioned *trans*-fused bicyclic system.

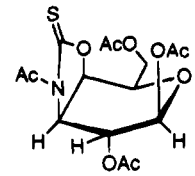
Simultaneous removal of both isopropylidene groups in **11** and **15** resulted in subsequent *cis*-annelation reactions to give the bicyclic oxazolidine-2-thiones **31** and **36** in high yield (Scheme 3). In the case of the *allo*-configuration, the reaction proceeds exclusively via the furanose tautomer, although a *cis*-disposition between the NCS and OH-2 groups would also occur in the pyranose form. When the sugar template has the *galacto*-configuration, a *cis*-relationship between the NCS and OH-4 groups is possible only in the pyranose form, which therefore becomes active. These results demonstrate the definitive importance of the sugar configuration in the outcome of the reaction as well as its control effect in the regioselectivity of the 1,3-*O*,*N*-heterocyclic ring formation.

A difference of reactivity between the OH and the NH groups toward acetylation was observed in the case of the *allo*-oxazolidine **31**, which allowed preparation of either the tri-*O*-acetate **32** or the peracetate **33**. No satisfactory conditions could be found for the selective *O*-acetylation in the case of the *galacto*-derivative **36**. The peracetate was obtained in this case as a mixture of the α and β anomers **37** (Scheme 3).

The respective ring sizes and anomeric configurations of the sugar moieties in *allo*- (**31-33**) and *galacto*- (**36**, **37**) derivatives were confirmed by comparison of the ^{13}C resonances of the furanose or pyranose carbon atoms with those for the parent sugars.[21] Further support for these assignments was obtained from the comparison of the H-5 chemical shifts[16] (Table 3) of the unprotected heterocyclic derivatives **31** and **36** with those for their acetylated derivatives (**32**, **33**, and **37**, respectively). A strong deshielding effect was observed in the case of the *allo*-derivatives (~1.5 ppm) but not in the case of their *galacto*-counterparts, which is in accord with the involvement of O-5 in the pyranose ring of the latter. The value of $J_{2,3}$ in **31-33** or $J_{3,4}$ in **36-37** (Table 3) is consistent with a ~0° dihedral angle for the respective protons, in agreement with near-planar oxazolidine rings. In the case of pyranose-fused derivatives (**36** and **37**) this arrangement corresponds to a conformation for the six-membered ring which must be close to a boat. The coupling constants values around the pyranose ring in α-**36**, β-**36**, and α-**37** would then agree with a $^{2,5}B$(D) conformation (Figure 3, conformation G), with H-2 and H-3 in *anti*-disposition ($J_{2,3}$ = 6.7–8.0 Hz), as well as H-1 and H-2 for the β-anomer of **36** ($J_{1,2}$ = 7.6 Hz). In contrast, the peracetylated derivative β-**37** showed low $J_{1,2}$ and $J_{2,3}$ values for respective *gauche* relationships. Furthermore, the $^4J_{1,3}$ value (0.6 Hz) was indicative of a W arrangement between H-1 and H-3, supporting a



G



H

Figure 3. Boat conformers for bicyclic oxazolidines **36** and **37**.

conformation close to $B_{2,5}$(D) (Figure 3, conformation H) in $CHCl_3$ solution, in agreement with the anomeric effect.

Reactions of Fully Unprotected 3-Amino-3-Deoxy Sugars with $CSCl_2$. Cyclization reactions of unprotected aminosugars into oxazolidine-2-thione derivatives upon action of $CSCl_2$ have previously been reported[7a] to occur *via* transient chlorothioformamide intermediates. Treatment of 3-amino-3-deoxy-D-glucose (kanosamine), 3-amino-3-deoxy-D-allose, and 3-amino-3-deoxy-D-galactose with $CSCl_2$ in acetone–water resulted in a very fast reaction leading to the formation of the 1,3-*O*,*N*-heterocycle derivatives **23**, **31**, and **36**, respectively, as the main reaction product. However, in each case the formation of minor byproducts was observed which is indicative of loss of regioselectivity as compared with cyclization of deoxyisothiocyanato derivatives, probably as a result of the higher reactivity of chlorothioformamides toward nucleophiles. Hence, although one more step is required, the conversion of the amino group into isothiocyanate seems advantageous for the preparation of sugar-derived enantiopure C-4 chiral oxazine- or oxazolidine-2-thiones.

Conclusions

3-Deoxy-3-isothiocyanato sugars undergo intramolecular cyclization to enantiomerically pure 2-thioxotetrahydro-1,3-*O*,*N*-heterocycles bearing chirality at C-4. The regioselectivity of the reaction, regarding both the tautomeric form of the sugar and the functional group involved in the annelation process, is self-controlled by the configuration of the sugar template. In the case of *gluco*-configuration the reaction proceeds through the OH-5 when the furanose tautomer is anchored, while the carbonyl group of the *aldehydo* form is involved when the fully unprotected isothiocyanate is generated. The presence of β-OH groups in *cis*-disposition with the -NCS group results in the formation of bicyclic oxazolidine-2-thiones, a fused oxazolidine–furanose system being favored to a fused oxazolidine-pyranose arrangement.

Similar results were obtained by reaction of 3-amino-3-deoxy sugars with thiophosgene, although a loss of selectivity was observed as a consequence of the higher reactivity of the chlorothioformamide intermediates involved in these reactions.

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Experimental Section

General Methods. The methods described in ref 7a were followed.

Materials. 3-Azido-3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose[22] (**2**) was prepared from commercial-grade 1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose (**1**) *via* 3-deoxy-3-iodo-1,2:5,6-di-*O*-isopropylidene-α-D-allofuranose.[23] 3-Azido-3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-allofuranose[24] (**8**) was obtained by nucleophilic displacement by NaN_3 on the 3-*O*-(trifluoromethanesulfonyl) derivative[25] of **1**. 3-Azido-3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-galactofuranose[26] (**12**) was prepared from **1** *via* 1,2:5,6-di-*O*-isopropylidene-α-D-gulofuranose[27] and S_N2 displacement on the 3-*O*-(trifluoromethanesulfonyl) derivative of the latter[28] by NaN_3. The overall yields on **2**, **8**, and **12** from **1** were 70, 60, and 45%, respectively. Staudinger reduction[11] of **2**, **8**, and **12** and hydrolysis of the resulting phosphinimines (**3**, **9**, and **13**) afforded the corresponding amino deoxy derivatives **4** (ref 29), **10** (ref 30), and **14** (ref 26) in excellent yields (see supplementary material). 3-Amino-3-deoxy-D-glucose (kanosamine),[31] 3-amino-3-deoxy-D-allose,[29] and 3-amino-3-deoxy-D-galactose[32] hydrochlorides were prepared in virtually quantitative yields from the corresponding 1,2:5,6-di-*O*-isopropylidene derivatives **4**, **10**, and **14** by treatment with diluted HCl.

Solvents were commercial grade and were used as supplied, with the exceptions indicated in ref 7a.

General Procedure for the Preparation of 3-Deoxy-1,2:5,6-di-*O*-isopropylidene-3-isothiocyanato-α-D-glycofuranoses. To a heterogeneous mixture of the corresponding 3-amino-3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-glycofuranose hydrochloride (1.5 g, 5.07 mmol) in $CHCl_3$ (15 mL), water (15 mL), and $CaCO_3$ (1.52 g, 15.2 mmol) was added thiophosgene (0.87 g, 0.58 mL, 7.6 mmol). The mixture was vigorously stirred for 3 h and then filtered. The organic layer was separated, washed with water, dried over Na_2SO_4, and concentrated. The crude product was purified by flash chromatography using hexanes–AcOEt (5:1) as eluent.

3-Deoxy-1,2:5,6-di-*O*-isopropylidene-3-isothiocyanato-α-D-glucofuranose (5): mp 64–65 °C (from *n*-hexane–ether); 1.31 g, 86%; R_f 0.4; $[\alpha]_D$-75.0° (*c* 1, $CHCl_3$); EIMS *m/z* 286 (M^+ − Me•); IR (KBr) 2101 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) supplementary material (Table 5); ^{13}C NMR (75.5 MHz, $CDCl_3$) δ 137.0 (NCS), 112.6, 109.7 (2 *C*Me_2) 104.8 (C-1), 84.2 (C-2), 80.2 (C-4), 72.9 (C-5), 67.3 (C-6), 62.5 (C-3), 26.7, 26.4, 26.1, 24.9 (4 Me). Anal. Calcd for $C_{13}H_{19}NO_5S$: C, 51.81; H, 6.36; N, 4.65; S, 10.64. Found: C, 51.81; H, 6.28; N, 4.62; S,10.50.

3-Deoxy-1,2:5,6-di-*O*-isopropylidene-3-isothiocyanato-α-D-allofuranose (11): mp 58–59 °C (from *n*-hexane–ether); 1.34 g, 88%; R_f 0.35; $[\alpha]_D$ +151.1° (*c* 1.4, $CHCl_3$); EIMS *m/z* 301 ($M^{+\cdot}$); IR (KBr) 2110 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) supplementary material (Table 7); ^{13}C NMR (75.5 MHz, $CDCl_3$) δ 136.8 (NCS), 115.3, 112.1 (2 *C*Me_2), 107.0 (C-1), 82.4, 82.1 (C-2,4), 78.5 (C-5), 69.1 (C-6), 61.6 (C-3), 28.7, 28.6, 28.5, 27.1 (4 Me). Anal. Calcd for $C_{13}H_{19}NO_5S$: C, 51.81; H, 6.36; N, 4.65; S, 10.64. Found: C, 51.60; H, 6.13; N, 4.46; S,10.36.

3-Deoxy-1,2:5,6-di-*O*-isopropylidene-3-isothiocyanato-α-D-galactofuranose (15): oil; 1.35 g, 89%; R_f 0.55; $[\alpha]_D$ −75.0° (*c* 1, $CHCl_3$); EIMS, *m/z* 286 (M^+ − Me•); IR (KBr) 2101 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) supplementary material (Table 8); ^{13}C NMR (75.5 MHz, $CDCl_3$) δ 136.0 (NCS), 114.9, 110.1 (2 *C*Me_2), 104.5 (C-1), 86.3 (C-2), 82.6 (C-4), 73.9 (C-5), 65.3 (C-6), 61.1 (C-3), 26.7, 26.4, 26.1, 24.9 (4 Me). Anal. Calcd for $C_{13}H_{19}NO_5S$: C, 51.81; H, 6.36; N, 4.65; S, 10.64. Found: C, 51.70; H, 6.12; N, 4.54; S,10.40.

Reactions of 3-Deoxy-1,2:5,6-di-*O*-isopropylidene-3-isothiocyanato-α-D-glucofuranose (5) with 90% TFA–H_2O. (a) Compound **5** (0.42 g, 0.69 mmol) was treated with 90% TFA–H_2O (10 mL) at 0 °C for 30 min. The reaction was quenched by pouring into cold saturated aqueous $NaHCO_3$ (100 mL) and the solution was extracted with AcOEt (3 × 25 mL) and then concentrated. TLC (hexanes–AcOEt (2:1)) of the syrupy residue showed total transformation of the starting material into two compounds, while its IR spectrum displayed bands at 2100 (ν_{NCS}) and 1560 cm^{-1} (δ_{NH}) fo the partially protected isothiocyanate **6** and the cyclic thionocarbamate **16**. Column chromatography using the above eluent yielded pure **16** (R_f 0.5, 0.24 g, 65%) and a mixture (91 mg, 25%) of **6** (R_f 0.75) and **16**. A complete conversion of **6** into **16** was observed in AcOEt solution after 2 h at room temperature.

(b) In an identical experiment, the reaction mixture arising from the action of 90% TFA–H_2O on **5**, after workup, was acetylated (Ac_2O–pyridine (1:1), 4 mL, 8 h). The acetylation product, which showed three spots on TLC (hexanes–EtOAc (1:1)) was subjected to column chromatography with the above eluent to give succesively the diacetylated isothiocyanate **7** (0.144 g, 30%) and the *O*- (**17**, 93 mg, 22%) and di-*O*,*N*-acetyl (**18**, 0.144 g, 30%) derivatives of **16**.

(c) Treatment of **5** (0.37 g, 1.22 mmol) with 90% TFA–H_2O (5 mL) at 20 °C for 10 min and evaporation of the solvents under vacuum at <40 °C gave **16** (0.31 g, 97%) as the sole reaction product.

5,6-Di-*O*-acetyl-3-deoxy-1,2-*O*-isopropylidene-3-isothiocyanato-α-D-glucofuranose (7): amorphous solid; R_f 0.86; $[\alpha]_D$ −60.0° (*c* 1.1, $CHCl_3$); EIMS *m/z* 345 ($M^{+\cdot}$); IR (KBr) 2068 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) supplementary material (Table 5); ^{13}C NMR (50.3 MHz, $CDCl_3$) δ 170.7, 169.5 (2 CO), 113.2 (*C*Me_2), 125.7 (NCS), 104.9 (C-1), 84.5 (C-2), 77.9 (C-4), 69.4 (C-5), 62.8 (C-6), 62.6 (C-3), 26.8, 26.6 (2 Me), 21.1, 21.0 (2 CO*C*H_3). Anal. Calcd for $C_{14}H_{19}NO_7S$: C, 48.69; H, 4.55; N, 4.06; S, 9.28. Found: C, 48.59; H, 5.38; N, 4.00; S, 9.04.

(5*S*,6*R*)-(6-(Hydroxymethyl)-3-deoxy-1,2-*O*-isopropylidene-β-L-threofuranoso)[3,4-*d*]tetrahydro-1,3-oxazine-2-thione (16): mp 206–208 °C (dec, from AcOEt); $[\alpha]_D$ +4.0° (*c* 0.9, DMSO); UV (DMF) 265 nm (ϵ_{mM} 2.9); EIMS *m/z* 261 ($M^{+\cdot}$); IR (KBr) 3325, 1562 cm^{-1}; ^1H NMR (500 MHz, Me_2SO-d_6) Table 1 and supplementary material (Table 5); ^{13}C NMR (125.5 MHz, Me_2SO-d_6) δ 184.2 (C=S), 111.2 (*C*Me_2), 103.5 (C-1), 83.4 (C-2), 78.4 (C-4), 70.4 (C-5), 60.6 (C-6), 56.2 (C-3), 26.4, 26.1 (2 Me). Anal. Calcd for $C_{10}H_{15}NO_5S$: C, 45.97; H, 5.79; N, 5.36; S, 12.27. Found: C, 45.91; H, 5.74; N, 5.36; S, 12.29.

(5*S*,6*R*)-(6-(Acetoxymethyl)-3-deoxy-1,2-*O*-isopropylidene-β-L-threofuranoso)[3,4-*d*]tetrahydro-1,3-oxazine-2-thione (17): foam; R_f 0.27; $[\alpha]_D$ -9.3° (*c* 0.75, $CHCl_3$); UV ($CHCl_3$) 256 nm (ϵ_{mM} 14.2); EIMS *m/z* 303 ($M^{+\cdot}$); IR (film) 3314, 1746, 1562 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) Table 1 and supplementary material (Table 5); ^{13}C NMR (50.3 MHz, $CDCl_3$) δ 185.2 (C=S), 169.9 (CO), 112.7 (*C*Me_2), 104.1 (C-1), 83.7 (C-2), 75.7 (C-4), 70.4 (C-5), 62.5 (C-6), 57.0 (C-3), 26.5, 26.0 (2 Me), 20.6 (CO*C*H_3). Anal. Calcd for $C_{12}H_{17}NO_6S$: C, 47.51; H, 5.65; N, 4.62; S, 10.57. Found: C, 47.43; H, 5.41; N, 4.54; S, 10.28.

Compound **17** was also prepared in 65% yield from alcohol **16** (0.2 g, 0.76 mmol) by treatment with Ac_2O–pyridine (1:2, 1 mL) at 10 °C for 3 h.

***N*-Acetyl-(5*S*,6*R*)-(6-(acetoxymethyl)-3-deoxy-1,2-*O*-isopropylidene-β-L-threofuranoso)[3,4-*d*]tetrahydro-1,3-oxazine-2-thione (18)**: amorphous solid; R_f 0.73; $[\alpha]_D$ −140° (*c* 0.8, $CHCl_3$); UV ($CHCl_3$) 279 nm (ϵ_{mM} 8.8); EIMS *m/z* 345 ($M^{+\cdot}$); IR (film) 1746, 1701, 1211 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$)

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Table 1 and supplementary material (Table 5); ^{13}C NMR (125.5 MHz, $CDCl_3$) δ 186.9 (CS), 173.3 (CO amide), 169.9 (CO ester), 112.8 (CMe_2) 104.3 (C-1), 85.3 (C-2), 77.4 (C-4), 73.6 (C-5), 61.9 (C-6), 60.9 (C-3), 26.9, 26.3 (2 Me), 25.9 ($NCOCH_3$), 20.4 ($OCOCH_3$). Anal. Calcd for $C_{14}H_{19}NO_7S$: C, 48.69; H, 5.55; N, 4.06; S, 9.28. Found: C, 48.51; H, 5.44; N, 3.83; S, 8.97.

Compound **17** was also prepared in 93% yield from the (hydroxymethyl)oxazine **16** (0.1 g, 0.38 mmol) by treatment with Ac_2O–pyridine (1:1, 2 mL) at 40 °C for 12 h.

(5*S*,6*R*)-(6-(Acetoxymethyl)-3-deoxy-L-threofuranoso)-[3,4-*d*]tetrahydro-1,3-oxazine-2-thione (19). Compound **18** (0.38 g, 0.96 mmol) was treated with 90% TFA–H_2O (10 mL) at 40 °C for 8 h. The solvent was eliminated under reduced pressure (0.1 Torr) and the resulting residue was chromatographed (CH_2Cl_2–MeOH (9:1)) to give syrupy **19** (82 mg, 65%): R_f 0.4; β:α ratio 1:1 (H-1 integration); $[\alpha]_D$ +13.5° (*c* 0.9, MeOH); UV (MeOH) 251 nm (ϵ_{mM} 15.7); FABMS *m/z* 286 [(M + Na)$^+$]; IR (film) 3390, 1734, 1543 cm^{-1}; ^1H NMR (300 MHz, CD_3OD) Table 1 and supplementary material (Table 5); ^{13}C NMR (125.5 MHz, CD_3OD) β anomer δ 188.2 (C=S), 172.1 (CO), 97.4 (C-1), 78.2 (C-5), 77.4 (C-2), 69.1 (C-4), 63.4 (C-6), 59.5 (C-3), 20.6 ($COCH_3$); α anomer δ 188.0 (C=S), 172.1 (CO), 104.7 (C-1), 81.8 (C-2), 78.6 (C-5), 73.1 (C-4), 63.6 (C-6), 59.8 (C-3), 20.7 ($COCH_3$). Anal. Calcd for $C_9H_{13}NO_6S$: C, 41.07; H, 4.97; N, 5.32; S, 12.16. Found: C, 41.02; H, 5.11; N, 5.41; S, 11.91.

(5*S*,6*R*)-(6-(Hydroxymethyl)-3-deoxy-L-threofuranoso)-[3,4-*d*]tetrahydro-1,3-oxazine-2-thione (20). Compound **19** (0.1 g, 0.38 mmol) was stirred with 1 M methanolic sodium methoxide (0.04 mL) at room temperature, monitoring by TLC (CH_2Cl_2–MeOH (9:1)). After 1 h the reaction mixture was neutralized by shaking with Amberlite IRA 120 H^+ cation-exchange resin, the suspension filtered, and the filtrate concentrated to give the fully unprotected derivative **20**: syrup; 75 mg, 90%; R_f 0.2; β:α ratio 1:1.2 (H-1 integration); $[\alpha]_D$ +7.0° (*c* 0.9, MeOH); UV (MeOH) 251 nm (ϵ_{mM} 7.4); FABMS *m/z* 286 [(M + Na)$^+$]; IR (film) 3280, 1540 cm^{-1}; ^1H NMR (300 MHz, CD_3OD) Table 1 and supplementary material (Table 5); ^{13}C NMR (125.5 MHz, CD_3OD) β anomer δ 188.5 (C=S), 97.4 (C-1), 81.9 (C-5), 77.4 (C-2), 69.2 (C-4), 61.6 (C-6), 59.6 (C-3); α anomer 188.2 (C=S), 104.7 (C-1), 81.8 (C-5), 81.4 (C-2), 73.0 (C-4), 61.9 (C-6), 59.7 (C-3). Anal. Calcd for $C_7H_{11}NO_5S$: C, 38.00; H, 5.01; N, 6.33; S, 14.49. Found: C, 38.28; H, 5.13; N, 6.24; S, 14.69.

Compound **20** was also prepared in 70% yield from (5*S*,6*R*)-(6-(hydroxymethyl)-3-deoxy-1,2-*O*-isopropylidene-β-L-threofuranoso)[3,4-*d*]tetrahydro-1,3-oxazine-2-thione (**16**, 0.2 g, 0.76 mmol) by treatment with TFA–H_2O as described above for the preparation of **19** from **18**.

1,2,4,6-Tetra-*O*-acetyl-3-deoxy-3-isothiocyanato-α- and β-D-glucopyranose (22). Compound **16** (0.16 g, 16 mmol) was treated with 50% TFA–H_2O (6 mL) at 50 °C. An IR spectrum of the reaction mixture after 4 h showed an intense band at ~2100 cm^{-1} (ν_{NCS} of **21**). The solvent was evaporated under reduced pressure (0.1 Torr) and the syrupy residue was acetylated. Column chromatography of the peracetylated product (hexanes–AcOEt (1:2)) yielded a mixture of the α- and β pyranoid isothiocyanates **22** (R_f 0.8, 0.11 g, 50%). Both anomeric diastereomers showed identical R_f chromatographic values for different eluent systems: oil; α:β ratio 7:1 (H-1 integration); $[\alpha]_D$ +55.0° (*c* 1, $CHCl_3$); EIMS *m/z* 389 (M$^{\bullet+}$); IR (film) 2041, 1750 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) supplementary material (Table 5); ^{13}C NMR (75.5 MHz, $CDCl_3$) α anomer δ 171.0–166.0 (4 CO), 142.5 (NCS), 88.2 (C-1), 69.7 (C-5), 69.2 (C-2), 67.4 (C-4), 61.1 (C-6), 57.5 (C-3), 21.0–20.0 (4 $COCH_3$); β anomer δ 171.0–166.0 (4 CO), 142.5 (NCS), 91.4 (C-1), 73.1 (C-5), 69.7 (C-2), 67.5 (C-4), 60.7 (C-6), 57.5 (C-3), 21.0–20.0 (4 $COCH_3$). Anal. Calcd for $C_{15}H_{19}NO_9S$: C, 46.27; H, 4.91; N, 3.60; S, 8.23. Found: C, 46.41; H 4.94,; N, 3.91; S, 8.11.

***N*-Acetyl-(4*S*,5*R*,6*S*)-5,6-di-*O*-acetyl-4-(1′,2′,3′-tri-*O*-acetyl-D-*erythro*-triitol-1-yl)tetrahydro-1,3-oxazine-2-thione and *N*-Acetyl-5-*O*-acetyl-4-(1′,2′,3′-tri-*O*-acetyl-D-*erythro*-triitol-1-yl)-5,6-dihydro-4*H*-1,3-oxazine-2-thione (24 and 28).** Compound **16** (0.4 g, 1.52 mmol) was treated with 50% TFA–H_2O (5 mL) at 50 °C for 12 h. Evaporation of the solvent, conventional acetylation of the syrupy residue, and column chromatography of the peracetylated product (hexanes–AcOEt (2:1)) gave, successively, the dihydrooxazine **28** and the tetrahydrooxazine derivative **24**.

Compound **24**: syrup; 0.41 g, 55%; R_f 0.35; $[\alpha]_D$ +28.8° (*c* 0.9, CH_2Cl_2); UV (CH_2Cl_2) 253 nm (ϵ_{mM} 5.9); EIMS *m/z* 491 (M$^{\bullet+}$); IR (film) 1753, 1711, 1223 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) Table 2 and supplementary material (Table 6); ^{13}C NMR (75.5 MHz, $CDCl_3$) δ 185.3 (C=S), 170.5, 170.3, 169.5, 169.4, 167.8, 167.7 (6 CO), 86.1 (C-6), 78.7 (C-5), 69.7 (C-1′), 69.6 (C-2′), 60.8 (C-3′), 57.6 (C-4), 25.3 ($NCOCH_3$), 20.8, 20.5, 20.4, 20.3, 20.2 (5 $COCH_3$). Anal. Calcd for $C_{19}H_{25}NO_{12}S$: C, 46.44; H, 5.13; N, 2.85; S, 6.51. Found: C, 46.42; H, 5.13; N, 2.71; S, 6.62.

Compound **24** was also prepared in 40% yield by treatment of 3-amino-3-deoxy-D-glucose (kanosamine) hydrochloride (0.2 g, 0.9 mmol) with thiophosgene (0.15 g, 0.1 mL, 1.35 mmol) and $CaCO_3$ (0.27 g, 2.7 mmol) in a mixture of H_2O-acetone (1:1, 5 mL) at room temperature for 30 min and conventional acetylation of the reaction mixture after evaporation of solvents.

Compound **28**: syrup; 65 mg, 10%; R_f 0.45; $[\alpha]_D$ +9.1° (*c* 0.7, CH_2Cl_2); UV (CH_2Cl_2) 266 nm (ϵ_{mM} 11.6); EIMS *m/z* 431 (M$^{\bullet+}$); IR (film) 3098, 1755, 1713, 1209 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) Table 2 and supplementary material (Table 6); ^{13}C NMR (75.5 MHz, $CDCl_3$) δ 183.7 (C=S), 170.2 (CO amide), 169.2 (2 C), 166.0 (2 C) (4 CO ester), 128.6 (C-5,6), 78.6 (C-1′), 70.1 (C-2′), 61.1 (C-3′), 59.7 (C-4), 25.9 ($NCOCH_3$), 20.5, 20.2 (2 C), 20.0 (4 $COCH_3$). Anal. Calcd for $C_{17}H_{21}NO_{10}S$: C, 47.33; H, 4.91; N, 3.25; S, 7.42. Found: C, 47.51; H, 5.00; N, 3.54; S, 7.59.

***N*-Acetyl-(4*S*,5*R*,6*S* and 6*R*)-5-*O*-acetyl-6-methoxy-4-(1′,2′,3′-tri-*O*-acetyl-D-*erythro*-triitol-1-yl)tetrahydro-1,3-oxazine-2-thione (26).** The reaction mixture arising fron the action of thiophosgene on 3-amino-3-deoxy-D-glucose hydrochloride (0.2 g, 0.9 mmol) after evaporation of solvents, as described above for the preparation of **24**, was treated with dry MeOH (5 mL). The resulting solution, which contained traces of acid, was kept at room temperature for 2 h and then concentrated. Conventional acetylation of the resulting syrupy residue and column chromatography of the peracetylated product (CCl_4–acetone (6:1)) gave the 6-methoxytetrahydrooxazine-2-thione derivative **26** as an inseparable mixture (TLC) of the (6*S*)- and (6*R*)-diastereomers: syrup; 0.146 g, 35%; R_f 0.5; 6*S*:6*R* ratio 1:1 (H-1 integration); $[\alpha]_D$ +38.8° (*c* 0.9, CH_2Cl_2); UV (CH_2Cl_2) 265 nm (ϵ_{mM} 17.6); EIMS *m/z* (M$^{\bullet+}$); IR (film) 1748, 1713, 1217 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) Table 2 and supplementary material (Table 6); ^{13}C NMR (125.5 MHz, $CDCl_3$) δ 185.9, 185.8 (2 C=S), 170.6, 170.5, 170.3, 169.8, 169.7, 169.5 (3C), 169.4, 169.3 (10 CO), 94.8 (C-6, 6*R*), 94.5 (C-6, 6*S*), 79.5 (C-5, 6*R*), 79.2 (C-5, 6*S*), 69.8, 69.7 (C-1′, 6*S*,*R*), 69.6, 69.5 (C-2′, 6*S*,*R*), 60.9, 60.8 (C-3′, 6*S*,*R*), 58.3 (C-4, 6*R*) 57.9 (C-4, 6*S*), 57.6, 57.4 (2 OMe), 25.5, 25.4 (2 $NCOCH_3$), 20.7, 20.6, 20.5, 20.2 (each 2 C, 8 $COCH_3$). Anal. Calcd for $C_{18}H_{25}NO_{11}S$: C, 46.62; H, 5.43; N, 3.02; S, 6.90. Found: C, 46.69; H, 5.45; N, 2.94; S, 7.04.

3-Deoxy-1,2-*O*-isopropylidene-3-isothiocyanato-α-D-allofuranose (29). A solution of 3-deoxy-1,2:5,6-di-*O*-isopropylidene-3-isothiocyanato-α-D-allofuranose (**11**, 0.78 g, 2.32 mmol) in 50% aqueous AcOH (70 mL) was heated at 60 °C for 2 h, cooled at room temperature and poured into ice-cooled saturated aqueous $NaHCO_3$ (500 mL). Extraction with AcOEt (3 × 50 mL) and evaporation gave **29**: 0.47 g, 78%; mp 60–62 °C (from AcOEt); R_f 0.2 (hexanes–AcOEt (1:1)); $[\alpha]_D$ +151.0° (*c* 0.6, CH_2Cl_2); EIMS *m/z* 261 (M$^{\bullet+}$); IR (KBr) 3333, 2128 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) supplementary material (Table 7); ^{13}C NMR (125.5 MHz, $CDCl_3$) δ 136.0 (NCS), 113.3 (CMe_2), 103.9 (C-1), 79.6, 79.4 (C-2,4), 71.2 (C-5), 62.7 (C-6), 56.7 (C-3), 26.5, 26.4 (2 Me). Anal. Calcd for $C_{10}H_{15}NO_5S$: C, 45.96; H, 5.78; N, 5.36; S, 12.27. Found: C, 45.96; H, 5.88; N, 5.42; S, 12.35.

5,6-Di-*O*-acetyl-3-deoxy-1,2-*O*-isopropylidene-3-isothiocyanato-α-D-allofuranose (30). Conventional acetylation of **29** (0.1 g, 0.38 mmol) yielded **30** as a syrup which crystallized on standing: 0.13 g, 97%; R_f 0.55 (hexanes–AcOEt (2:1)); $[\alpha]_D$ +183.0° (*c* 0.9, CH_2Cl_2); EIMS *m/z* 330 (M$^+$ – Me$^{\bullet}$); IR (KBr)

2079, 1746 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) supplementary material (Table 7); ^{13}C NMR (75.5 MHz, $CDCl_3$) δ 170.4, 170.1 (2 CO), 113.5 (CMe_2), 136.9 (NCS), 104.7 (C-1), 85.8 (C-2), 81.8 (C-4), 69.1 (C-5), 62.3 (C-6), 60.8 (C-3), 26.9, 26.3 (2 Me), 20.6, and 20.4 (2 $COCH_3$). Anal. Calcd for $C_{14}H_{19}NO_7S$: C, 48.69; H, 5.55; N, 4.06; S, 9.28. Found: C, 48.71; H, 5.42; N, 4.00; S, 9.27.

(2,3-Dideoxy-β-D-allofuranoso)[3,2-*d*]oxazolidine-2-thione (31). To the diisopropylidene derivative **11** (0.6 g, 1.99 mmol) was added TFA–H_2O (9:1, 8 mL) and the reaction mixture was kept at 25 °C for 20 min under reduced pressure (water pump). Evaporation of the solvent at 40 °C and column chromatography ($CHCl_3$–MeOH (3:1)) of the residue yielded **31**: syrup; 0.405 g, 82%; R_f 0.65; $[\alpha]_D$ +12° (*c* 0.8, MeOH); UV ($CHCl_3$) 244 nm (ϵ_{mM} 12.5); FABMS *m/z* 244 [(M + Na)$^+$]; IR (film) 3405, 1528 cm^{-1}; ^1H NMR (300 MHz, CD_3OD) supplementary material (Table 7); ^{13}C NMR (75.5 MHz, CD_3OD) δ 188.1 (C=S), 103.2 (C-1), 92.5 (C-2), 88.5 (C-4), 73.4 (C-5), 63.9 (C-6), 49.8 (C-3). Anal. Calcd for $C_7H_{11}NO_5S$: C, 38.00; H, 5.01; N, 6.33; S, 14.49. Found: C, 37.79; H, 5.10; N, 6.28; S, 14.28.

Compound **31** was also obtained in 63% yield by treatment of 3-amino-3-deoxy-D-allose hydrochloride (0.2 g, 0.9 mmol) with thiophosgene (0.15 g, 0.1 mL, 1.35 mmol) and $CaCO_3$ (0.27 g, 2.7 mmol) in a mixture of H_2O–acetone (1:1, 5 mL) at room temperature for 30 min.

(1,5,6-Tri-*O*-acetyl-2,3-dideoxy-β-D-allofuranoso)[3,2-*d*]-oxazolidine-2-thione (32). Acetylation of **31** (0.2 g, 0.9 mmol) with Ac_2O–pyridine (1:2, 1 mL) at 10 °C for 1 h and column chromatography (hexanes–AcOEt (3:2)) of the acetylated product afforded the tri-*O*-acetate **32** as the main reaction product: syrup; 0.18 g, 57%; R_f 0.25; $[\alpha]_D$ +11° (*c* 1, $CHCl_3$); UV ($CHCl_3$) 249 nm (ϵ_{mM} 15.8); EIMS *m/z* 347 (M$^{\bullet+}$); IR (film) 3308, 1748, 1507 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) supplementary material (Table 7); ^{13}C NMR (75.5 MHz, $CDCl_3$) δ 187.9 (C=S), 170.4, 169.8, 168.6 (3 CO ester), 100.4 (C-1), 89.8, 85.9 (C-4,2), 70.5 (C-5), 62.2 (C-6), 61.9 (C-3), 20.7, 20.5, 20.4 (3 $OCOCH_3$). Anal. Calcd for $C_{13}H_{17}NO_8S$: C, 44.95; H, 4.93; N, 4.03; S, 9.23. Found: C, 44.97; H, 4.78; N, 4.04; S, 9.00.

***N*-Acetyl-(1,5,6-tri-*O*-acetyl-2,3-dideoxy-β-D-allofuranoso)[3,2-*d*]oxazolidine-2-thione (33).** Acetylation of **31** (0.2 g, 0.9 mmol) with Ac_2O–pyridine (1:1, 2 mL) at 40 °C for 12 h and column chromatography (hexanes–AcOEt (3:2)) of the peracetylated product yielded the tetraacetate **32** as the sole reaction product: syrup; 0.33 g, 95%; R_f 0.5; $[\alpha]_D$ −62° (*c* 1.1, $CHCl_3$); UV ($CHCl_3$) 266 nm (ϵ_{mM} 14.6); EIMS *m/z* 389 (M$^{\bullet+}$); IR (film) 1746, 1715 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) supplementary material (Table 7); ^{13}C NMR (75.5 MHz, $CDCl_3$) δ 183.1 (C=S), 170.8, 170.7, 170.2, 168.4 (4 CO), 99.9 (C-1), 86.2, 84.8 (C-4,2), 70.2 (C-5), 64.0 (C-6), 62.5 (C-3), 25.9 ($NCOCH_3$), 20.9, 20.7, 20.5 (3 $OCOCH_3$). Anal. Calcd for $C_{15}H_{19}NO_9S$: C, 46.27; H, 4.92; N, 3.60; S, 8.23. Found: C, 46.07; H, 5.04; N, 3.44; S, 8.13.

3-Deoxy-1,2-*O*-isopropylidene-3-isothiocyanato-α-D-galactofuranose (34). Treatment of 3-deoxy-1,2:5,6-di-*O*-isopropylidene-3-isothiocyanato-α-D-galactofuranose (**15**, 0.3 g, 0.99 mmol) with 50% aqueous acetic acid (30 mL), as above described for the preparation of **29**, gave **34**: syrup; 0.18 g, 72%; R_f 0.5 (hexanes–AcOEt (1:1)); $[\alpha]_D$ +31.3° (*c* 1, CH_2Cl_2); EIMS *m/z* 246 (M$^{\bullet+}$); IR (film) 3434, 2093 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) supplementary material (Table 8); ^{13}C NMR (125.5 MHz, $CDCl_3$) δ 135.7 (NCS), 114.2 (CMe_2), 104.8 (C-1), 85.9 (C-2), 84.8 (C-4), 69.7 (C-5), 63.3 (C-6), 61.1 (C-3), 26.9, 26.4 (2 Me). Anal. Calcd for $C_{10}H_{15}NO_5S$: C, 45.96; H, 5.78; N, 5.36; S, 12.27. Found: C, 46.02; H, 5.79; N, 5.13; S, 12.04.

5,6-Di-*O*-acetyl-3-deoxy-1,2-*O*-isopropylidene-3-isothiocyanato-α-D-galactofuranose (35). Conventional acetylation of **34** (0.1 g, 0.38 mmol) yielded **35**: syrup; 0.1 g, 80%; R_f 0.5 (hexanes–AcOEt (2:3)); $[\alpha]_D$ +10.0° (*c* 1, CH_2Cl_2); EIMS *m/z* 330 (M$^{\bullet+}$); IR (film) 2058, 1746 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) supplementary material (Table 8); ^{13}C NMR (75.5 MHz, $CDCl_3$) δ 170.2, 169.8 (CO), 136.9 (NCS), 114.7 (CMe_2), 104.7 (C-1), 85.8 (C-2), 81.8 (C-4), 69.1 (C-5), 62.3 (C-6), 60.8 (C-3), 26.9, 26.3 (2 Me), 20.6, 20.4 (2 $COCH_3$). Anal. Calcd for $C_{14}H_{19}NO_7S$: C, 48.69; H, 5.55; N, 4.06; S, 9.28. Found: C, 48.69; H, 5.44; N, 3.97; S, 9.17.

(3,4-Dideoxy-D-galactopyranoso)[3,4-*d*]oxazolidine-2-thione (36). Treatment of the diisopropylidene derivative **15** (0.5 g, 1.66 mmol) with TFA–H_2O (9:1, 7 mL), as above described for the preparation of **31**, and column chromatography (CH_2Cl_2-MeOH (4:1)) of the reaction mixture yielded **36**: syrup; 0.27 g, 74%; R_f 0.4; α:β ratio 1.6:1 (H-1 integration); $[\alpha]_D$ +6.6° (*c* 0.9, MeOH); UV (MeOH) 246 nm (ϵ_{mM} 16.5); FABMS *m/z* 244 [(M + Na)$^+$]; IR (film) 3362, 1678, 1512 cm^{-1}; ^1H NMR (500 MHz, CD_3OD) Table 3 and supplementary material (Table 8); ^{13}C NMR (125.5 MHz, CD_3OD) α anomer δ 188.1 (C=S), 92.2 (C-1), 81.7 (C-4), 70.4 (C-2), 68.4 (C-5), 61.9 (C-6), 58.7 (C-3); β anomer δ 188.1 (C=S), 97.3 (C-1), 82.1 (C-4), 75.5 (C-5), 74.9 (C-2), 62.0 (C-3), 61.9 (C-6). Anal. Calcd for $C_7H_{11}NO_5S$: C, 38.00; H, 5.01; N, 6.33; S, 14.49. Found: C, 38.10; H, 5.01; N, 6.51; S, 14.44.

***N*-Acetyl-(1,2,6-tri-*O*-acetyl-3,4-dideoxy-α- and β-D-galactopyranoso)[3,4-*d*]oxazolidine-2-thione (37).** Conventional acetylation of **36** (0.2 g, 0.98 mmol) and column chromatography (hexanes–AcOEt (1:1)) of the peracetylated product yielded **37** as an inseparable mixture of the α and β anomers: syrup; 0.34 g, 89%; R_f 0.45; α:β ratio 1.2:1 (H-1 integration); $[\alpha]_D$ −55.0° (*c* 1, CH_2Cl_2); EIMS *m/z* (M$^{\bullet+}$); IR (film) 1759, 1711 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) Table 3 and supplementary material (Table 8); ^{13}C NMR (75.5 MHz, $CDCl_3$) α anomer δ 184.7 (C=S), 170.6–168.2 (4 CO), 88.2 (C-1), 75.8 (C-4), 67.0 (C-2), 66.0 (C-5), 61.9 (C-6), 56.7 (C-3), 25.8 ($NCOCH_3$), 20.6–20.4 (3 $OCOCH_3$); β anomer δ 185.6 (C=S), 170.6–168.2 (4 CO), 89.1 (C-1), 74.6 (C-4), 68.3 (C-2), 65.9 (C-5), 62.4 (C-3), 56.8 (C-6), 26.0 ($NCOCH_3$), 20.6–20.4 (3 $OCOCH_3$). Anal. Calcd for $C_{15}H_{19}NO_9S$: C, 46.27; H, 4.92; N, 3.60; S, 8.23. Found: C, 46.10; H, 4.95; N, 3.51; S, 8.38.

Acknowledgment. We thank the Dirección General de Investigación Científica y Técnica for fiancial support (grant no. PB 91/0617), the Junta de Andalucía for a doctoral fellowship to J.L.J.B., and the Ministerio de Educación y Ciencia of Spain for a postdoctoral fellowship to J.M.G.F.

Supplementary Material Available: General procedures for **3**, **9**, **13**, **4**, **10**, and **14**. Tables of ^1H NMR data of **3**, **5**, **7**, **9**, **11**, **13**, **15-20**, **22**, **24**, **26**, and **28-37** (7 pages). This material is contained in libraries on microfiche, immediately follows the article in the microfilm version of the journal, and can be ordered from the ACS; see any current masthead page for ordering information.