Carbohydrates as Chiral Auxiliaries. [2+2] Cycloadditions of Ketenes to Enol Ethers

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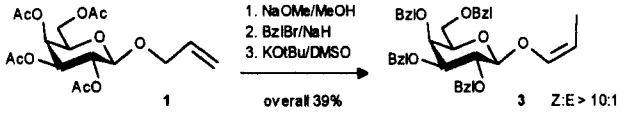
Enantiomerically pure cyclobutanols containing up to four chiral centers were synthesized applying a [2+2] cycloaddition between carbohydrate enol ethers and substituted ketenes. Acid-catalysed cleavage of the anomeric acetal linkage to the carbohydrate auxiliary gave (1R,2R,3S)-3-benzyloxy-2-methylcyclobutanol in high yield and under conservation of all generated chiral centers. The absolute configuration of the synthesized cyclobutanols was determined by single-crystal X-ray analysis.

Despite the large potential for [2+2] ketene cycloaddition reactions to achieve the synthesis of small carbocyclic compounds, only a few applications of this type of reaction to stereoselective synthesis using chiral auxiliaries have been reported to date[1]. Greene and Charbonnier[2,3] applied a dichloroketene cycloaddition with efficient diastereofacial differentiation in the synthesis of various natural products by using optically pure 2-phenylcyclohexanol as the chiral auxiliary. The synthesis of optically active cyclobutane nucleosides has been accomplished by Ahmad et al.[4] by addition of fluoroketene diethylacetal to (-)-dimenthyl fumarate. Chiral cyclobutanones were obtained by Ghosez et al.[5] starting from chiral keteneiminium salts. Redlich et al.[6] and Hanna et al.[7] used dichloroketene cycloadditions in the sense of ex-chiral pool syntheses and synthesized various carbohydrate derivatives. In recent years, carbohydrates have received increasing interest as chiral templates[8]. With regard to [2+2] cycloaddition reactions, carbohydrates were used as substrates or templates in β-lactam syntheses[9,10,11]. In this paper, we report on cycloadditions of ketenes to enol ethers using either anomeric enol ethers or enol ethers derived from glucofuranose. The anomeric enol ethers are particularly interesting because they provide the opportunity to release the synthesized cyclobutanol derivatives without destruction of any of the chiral centers.

Starting from allyl-2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranoside[12] **1**, replacement of the acetyl groups by benzyl ether protecting groups, *yielding the benzyl*-protected allyl galactoside **2**, followed by base-catalysed isomerisation[13] of the allylic moiety gave the enantiomerically pure crystalline enol ether **3**.

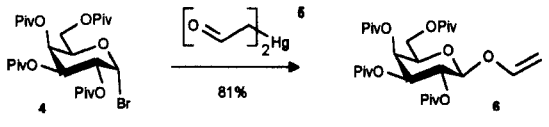


Scheme 1

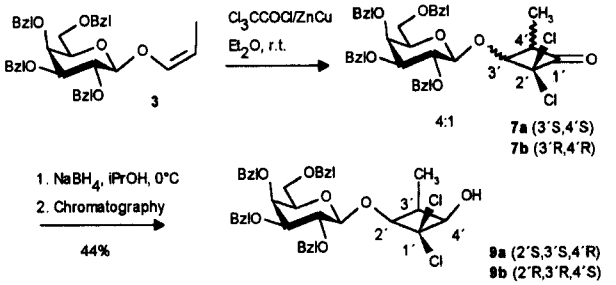
The isomerisation carried out with KOtBu/DMSO[13] gave a 10:1 mixture of *Z*- and *E*-enol ethers whereas application of "Wilkinsons catalyst" $[(PPh_3)_3Rh]Cl$ lead to a 3:2 Xmixture of the isomers which could not be separated by standard chromatographic procedures.

Surprisingly, the corresponding pivaloyl-protected derivative was completely inert to the base-catalysed isomerisation.

An alternative route to anomeric enol ethers consists of the reaction of organo-mercury compounds such as bisformylmethylmercury[14] **5** with glycosyl bromides. Following the procedure of Ferrier et al.[14], vinyl-2,3,4,6-tetra-*O*-pivaloyl-β-D-galactopyranoside **6** was obtained in high yield starting from 2,3,4,6-tetra-*O*-pivaloyl-α-D-galactopyranosyl bromide[15] **4**.

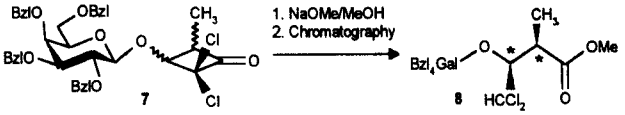


The [2+2] ketene cycloadditions were carried out by reacting the glycosyl enol ether with trichloroacetyl chloride and Zn-Cu couple in anhydrous diethyl ether. Dichloroketene generated by dehydrohalogenation of dichloroacetyl chloride with triethylamine did not react with the enol ethers. It is likely that activation of the ketene by a Lewis acid is necessary for the addition to anomeric enol ethers because such glycosyl enol ethers are less nucleophilic than their common aliphatic analogues.



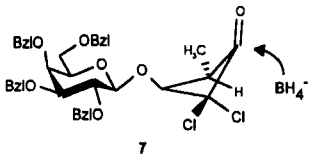
Scheme 3

The resulting dichlorocyclobutanone 7 is very reactive because of its ring strain and cannot be isolated in a pure form. For instance, in the presence of catalytic amounts of sodium methoxide in methanol ring opening occurs leading to the open-chain methyl ester **8**. This conversion parallels mechanistically the final step of the haloform reaction.



Scheme 4

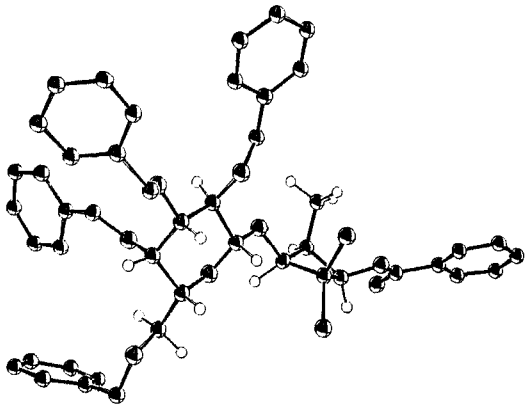
To determine the diastereomeric excess (by HPLC) achieved in the cycloaddition, the cyclobutanone 7 was reduced to give the cyclobutanoles **9a** (2'S,3'S,4'R) and **9b** (2'R,3'R,4'S) using $NaBH_4$ in 2-propanol[16]. The separation of the two diastereoisomers was achieved by silica gel chromatography. The reduction step proceeded stereoselectively, yielding exclusively the *cis*-configured cyclobutanols **9**. The proposed mechanism of this reduction is depicted in Scheme 5.



Scheme 5

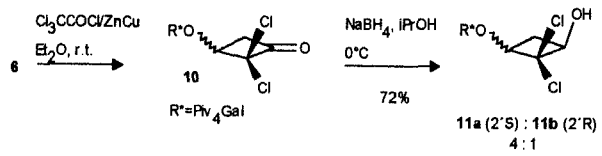
In the conformation of the cyclobutanone 7 shown, the *trans-annular* interaction of the chlorine atom in position 2' with the methyl group in position 4' is minimized. Moreover, it has also been shown[1] by X-ray crystallography of cyclobutanones that the carbonyl function is slightly inclined towards the *endo* face of the ring ("concorde nose"). We obtained single crystals of the benzoyl ester of alcohol **9a** suitable

offers further evidence for the proposed reduction pathway. However, more surprisingly, it revealed that the absolute stereochemistry of the major diastereomer of cyclobutanol **9** arises from attack of the ketene on the *Si*-face (C-2′) of the enol ether **3**.



Scheme 6. Pseudo ORTEP plot of **9a′** (benzoyl ester of **9a**)[17]

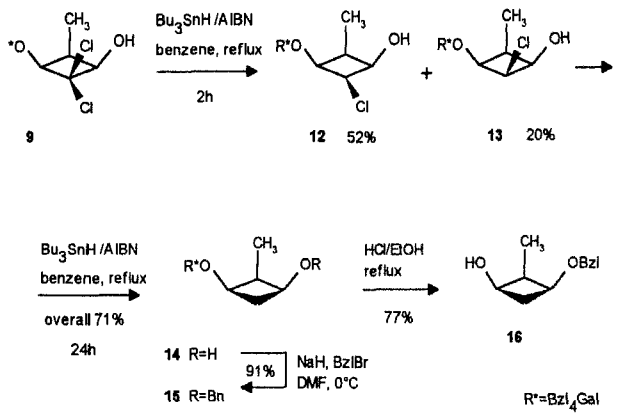
During the design of the chiral auxiliary we expected the protecting group at C-2 of the pyranose to provide an effective shielding of the *Si*-face (C-2′) of the double bond. For Diels–Alder additions of carbohydrate-linked dienes Stoodley[18a] et al. and Lubineau et al.[18b] discussed the repulsive effect of a 1,3-diaxial interaction between the C1-O5 bond of the sugar ring and the approaching dienophile. This effect would favor an attack from the *Si*-face. However, in the cycloadditions investigated by these workers, the carbohydrate compounds of interest carried exclusively O-acetyl protecting groups or no protection at all. It is not clear whether the O-benzyl protection used in our compounds will exhibit a different influence and/or whether the effect of a repulsive 1,3-diaxial interaction will be similar for attack by a rod-like ketene in comparison to dienophiles.
The cycloaddition of the pivaloyl protected auxiliary **6** carrying the vinyl moiety and subsequent reduction gave a 4:1 mixture of the cyclobutanols **11** in an overall yield of 72%.



Scheme 7

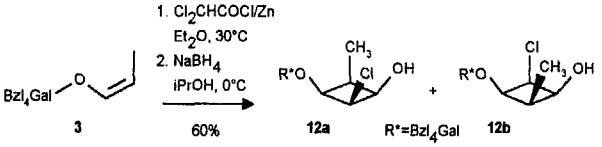
As in the case discussed above, the reduction resulted in the formation of only two diastereomers, although the intermediate cyclobutanone **10** should not strongly prefer a conformation analogous to 7 (scheme 5) due to the absence of a substituent at C-4′. The absolute stereochemistry of **11** has been assigned in analogy to the structure of **9a′**.
The ability of carbohydrate-derived auxiliaries to lock into distinct conformations by chelation of metal ions[8], often results in high stereoselectivities, e. g. in enolate alkylations or Lewis acid catalysed Diels–Alder reactions[8]. Anomeric enol ethers cannot be fixed in a favorable conformation via chelation, and as the reaction temperature required is relatively high, the diastereomeric excess in the addition of ketenes is only moderate.

Attempts to cleave the anomeric bond of **9a**, after benzylation of the hydroxyl function, were unsuccessful. It appeared, that prior to cleavage of the glycoside the chlorine substituents have to be removed from **9**. This was achieved using Bu_3SnH/AIBN. The intermediate monochlorocyclobutanols **12+13**, could also be isolated and separated in an overall yield of 72%. They represent interesting chiral building blocks containing four chiral centers.



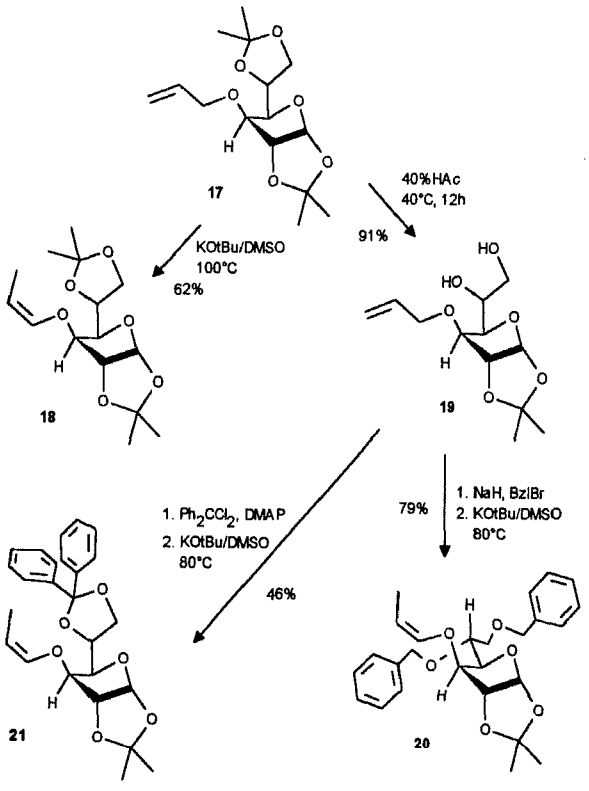
Scheme 8

After complete dehalogenation and benzylation of **14**, the substrate **15** was heated with conc. HCl in ethanol to yield the mono protected diol **16** with conservation of all three generated chiral centers.
Addition of monochloroketene, generated from dichloroacetyl chloride and Zn, to **3** required higher temperatures and proceeded with lower selectivity. After reduction of the monochlorocyclobutanones with $NaBH_4$ the monochlorocyclobutanols **12a** (2′S) and **12b** (2′R) are obtained in 60% overall yield as a mixture of diastereomers (**12a**:**12b**=71:29).



Scheme 9

Prompted by the results published by Greene et al. concerning [2+2] cycloadditions using chiral alcohols as auxiliaries[19], we were also interested in the application of enol ethers derived from 3-*O*-allyl-glucofuranose.



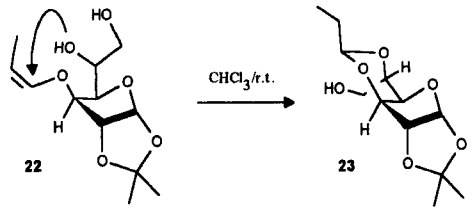
Scheme 10

3-*O*-Enol ethers of 1,2;5,6-di-*O*-isopropylidene-α-D-glucofuranose have been used as auxiliaries in the syntheses of β-lactams by isocyanate addition[11] and in hetero Diels–Alder reactions yielding oxazines[20].

3-*O*-Allyl-1,2;5,6-di-*O*-isopropylidene-α-D-glucofuranose **17** was readily transformed into the corresponding *Z*-3-*O*-propenyl ether **18**[13] via base-catalyzed isomerisation. Moreover, selective cleavage of the 5,6-*O*-isopropylidene protecting group allows the introduction of various protecting groups and, thus, the optimization of the chiral auxiliary.

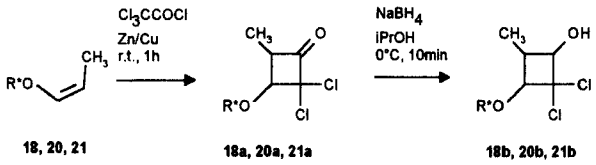
Thus the 5,6-ketal function was cleaved using acetic acid at 40°C to give **19** in almost quantitative yield[21]. Benzyl ether protecting groups were introduced using standard procedures. Compound **19** was also reacted with dichlorodiphenylmethane in order to obtain an alternative acetal protecting group.

As a consequence of the instability of ester type protecting groups such as pivaloyl or benzoyl to the basic conditions required for allyl isomerisation, we attempted to introduce such protecting groups only following rearrangement of the double bond in **19**. Unfortunately, *Z*-3-*O*-propenyl-1,2-*O*-isopropylidene-α-D-glucofuranose **22** was found to undergo easily an intramolecular addition of the 5-OH function to the enol double bond and hence this approach was not successful.



Scheme 11

The cycloadditions and subsequent reductions were carried out in an analogous fashion to the corresponding reactions of the anomeric enol ethers.



Scheme 12

Table I. Dichloroketene cycloaddition to 3-*O*-enol ethers of glucofuranose-derived auxiliaries.

Cyclobutanol	5,6 protection	Yield[1)]	Selectivity
18b	$C(CH_3)_2$	44%	75:25[2)]
20b	2x Bzl	35%	83:17[3)]
21b	$C(Ph)_2$	53%	66:34[3)]

1) of the major diastereomer after chromatography;
2) determined by NMR measurement of the crude reaction mixture;
3) determined by analytical HPLC of the crude reaction mixture.

The conformationally more rigid derivative **21** is obviously ineffective in shielding one of the diastereotopic faces of the double bond. In contrast the more flexible compound **20** carrying benzyl groups in the 5- and 6-positions obviously can adopt a conformation more favorable for diastereofacial differentiation at the enol ether.

In conclusion, diastereodifferentiation in [2+2] cycloadditions of ketenes to enol ethers linked to chiral auxiliaries is much more difficult to achieve than in analogous ex-chiral pool processes in which a chiral enol ether[6] is used as the substrate. As a consequence, only a few examples of stereoselective formations of auxiliary-bound cyclobutanone derivatives, starting from enol ethers, have been reported until now[2,3]. Furthermore, the detachment of the synthezised carbocycle from the auxiliary had previously only been achieved by elimination processes destroying one chiral center[2,3]. In this sense, carbohydrate auxiliaries offer interesting opportunities. They provide the possibility to perform [2+2] cycloadditions of ketenes to enol ethers with a satisfying stereodifferentiation. After reduction of the cyclobutanone formed, cyclobutanol derivatives which contain three (**9**, **14**, **15**) or even four chiral centers in the ring (**12**, **13**) can be synthesized in diastereomerically pure form. More importantly, the chiral cyclobutanols e.g. (**16**) can be detached from the carbohydrate auxiliary without destruction of any of the existing chiral centers.

General instrumentation: The ^{1}H- and ^{13}C-NMR spectra were recorded on a Bruker AM-400, or a Bruker AM-200 spectrometer. All optical rotations were determined for solutions in chloroform (c=1) using a Perkin-Elmer-241 polarimeter. IR-spectra were recorded with a Perkin-Elmer-1430 spectrometer. Melting points are uncorrected. Column chromatography was performed on silica gel 0.2-0.06 mm. Anhydrous diethyl ether was obtained by distillation of the commercial product from sodium and benzophenone. Trichloroacetyl chloride was distilled prior to use. Petroleum ether refers to the fraction boiling between 40-60°C. The organic exctracts were dried with $MgSO_4$. All reactions involving air- or moisture-sensitive reagents were carried out under an argon atmosphere.

***Z*-Propenyl-2,3,4,6-tetra-*O*-benzyl-β-D-galactopyranoside (3):**

The enol ether **3** was formed from **2** (10 g, 17.2 mmol) by treatment with potassium *tert*-butoxide (1,0 g, 8.9 mmol) in DMSO (80 ml) analogously to the procedure described by Gigg et al.[13]. The crude product was recrystallized from petroleum ether, Yield 7.0 g (70%), colourless needles, mp 95°C, $[\alpha]_D^{25} = 9.7$.

Anal. calcd. for $C_{37}H_{40}O_6$ (580.7) C 76.53 H 6.94; Found C 76.57 H 7.01.

^{1}H-NMR (400 MHz, $CDCl_3$), δ= 7.36-7.24 (m, 20H, aromat.); 6.21 (dd, 1H, $J_{1'-2'}$=6.3Hz, $J_{1'-3'}$=1.6Hz, H-1'); 4.94 (d, 1H, J=11.8Hz, CH_2Ph); 4.90 (d, 1H, J=11.5Hz, CH_2Ph); 4.77 (d, 1H, J=10.7Hz, CH_2Ph); 4.75 (d, 1H, J=11.9Hz, CH_2Ph); 4.71 (d, 1H, J=11.9Hz, CH_2Ph); 4.61 (d, 1H, J=11.6Hz, CH_2Ph); 4.55 (d, 1H, J_{1-2}=7.7Hz, H-1); 4.53 (dq, 1H, $J_{2'-1'}$=$J_{2'-3'}$=6.5Hz, H-2'); 4.43 (d, 1H, J=11.7Hz, CH_2Ph); 4.39 (d, 1H, J=11.7Hz, CH_2Ph); 3.94 (dd, 1H, J_{2-1}=7.8Hz, J_{2-3}=9.8Hz, H-2); 3.91 (d, 1H, J_{4-3}=2.9Hz, H-4); 3.60-3.56 (m, 3H, H-5, H-6a, H-6b); 3.53 (dd, 1H, J_{3-4}=2.9Hz, J_{3-2}=9.8, H-3); 1.63 (dd, 3H, $J_{3'-2'}$=6.8Hz; $J_{3'-1'}$=1.6Hz; CH_3-3').

^{13}C-NMR (50.3 MHz, $CDCl_3$), δ= 143.0 (C-1'); 138.7, 138.6, 138.5, 137.9 (C_{arom}ipso); 128.5-127.6 (C_{arom}); 103.5 (C-2'); 102.9 (C-1); 81.9, 79.1, 73.8, 73.4 (C-2, C-3, C-4, C-5); 75.3, 74.6, 73.6, 73.0 (4x $\underline{C}H_2Ph$); 68.6 (C-6); 9.6 (C-3').

General Procedure for the Cycloaddition of Chloro-Substituted Ketenes to Enol Ethers:

To a solution of the enol ether (0.7 mmol) in anhydrous diethyl ether (10 ml) and activated zinc (2.1 mmol), obtained by stirring zinc powder (1,0 g) in a solution of $CuSO_4xH_2O$ (100 mg/30 ml water) for 1 h, subsequent washing with water, acetone and diethyl ether and drying *in vacuo*, a solution of the acid chloride (1.4 mmol) in anhydrous diethyl ether (2 ml) was added at room temperature within a period of 30 min using a motor syringe. After additional stirring for 30 min the mixture was diluted with 50 ml diethyl ether and washed three times with portions of 20 ml sat. aq. $NaHCO_3$ containing EDTA (0.2N) in order to remove zinc salts.

General Procedure for the Reduction of Cyclobutanones Using $NaBH_4$:

To an ice-cold solution of the crude cyclobutanone (0.7 mmol) in 2-propanol (10 ml), a suspension of $NaBH_4$ (38 mg, 1 mmol) in 2-propanol (1 ml) was added. The reaction was generally complete within 10 min. The mixture was diluted with diethyl ether (20 ml) and washed with brine. The organic layer was separated, dried and concentrated *in vacuo*.

(3′*S*,4′*S*)-(2′,2′-Dichloro-4′-methyl-1′-oxocyclobut-3′-yl)-2,3,4,6-tetra-*O*-benzyl-β-D-galactopyranoside (7);
(2′*S*,3′*S*,4′*R*)-(1′,1′-Dichloro-4′-hydroxy-3′-methylcyclobut-2′-yl)-2,3,4,6-tetra-*O*-benzyl-β-D-galactopyranoside (9a) and the (2′*R*,3′*R*,4′*S*)-isomer (9b):

Reaction of **3** (800 mg, 1.4 mmol) with dichloroketene according to the general procedure gave the crude cyclobutanone **7**.IR: $\tilde{\nu}$=1810cm^{-1}.

^{1}H-NMR (400 MHz, $CDCl_3$), δ= 7.37-7.24 (m, 20H, aromat.); 4.96-4.90 (m, 3H, 3xCH_2Ph); 4.87-4.64 (m, 4H, H-1, H-2′, 2xCH_2Ph); 4.61 (d, 1H, J=11.6Hz, CH_2Ph); 4.44 (d, 1H, J=11.8Hz, CH_2Ph); 4.41 (d, 1H, J=11.7Hz, CH_2Ph); 3.90 (d, 1H, J_{4-3}=2.6Hz, H-4); 3.87 (dd, 1H, J_{2-1}=7.6Hz, J_{2-3}=9.0Hz, H-2); 3.78 (dq, 1H, $J_{4'-3'}$=9.0Hz, $J_{4'-CH3'}$=7.8Hz, H-4′); 3.73-3.51 (m, 4H, H-3, H-5, H-6a, H-6b); 1.32 (d, 3H, $J_{CH3-3'}$=7.8Hz, CH_3′).

^{13}C-NMR (100.6 MHz, $CDCl_3$), δ= 196.5 (C=O); 138.5-137.8 (C_{arom}ipso); 128.5-127.6 (C_{arom}); 102.6 (C-1); 87.5 (C-2′); 82.0, 79.3, 76.0, 74.0, 73.7 (C-2, C-3, C-4, C-5, C-3′); 75.4-73.0 (4x$\underline{C}H_2$Ph); 68.7 (C-6); 54.4 (C-3′); 9.5 (CH_3′).

Compound **7** was reduced with $NaBH_4$ (76 mg, 2 mmol) in iPrOH (20 ml) according to the general procedure outlined above. After chromatography, **9a** and **9b** (2′R, 3′R, 4′S) were obtained in an overall yield of 60%. The two diastereomers were separated by chromatography on silica gel. The major diastereomer was isolated in a yield of 44% (440 mg) as an oil. $[\alpha]_D^{25}$= -22.1; R_f=0.16 (petroleum ether-EtOAc 6:1); minor diastereomer **9b** (10%, 98 mg) $[\alpha]_D^{25}$= -0.16; R_f=0.10 (petroleum ether-EtOAc 6:1).

Anal. calcd. for $C_{39}H_{42}O_7Cl_2$ (693.6) C 67.53 H 6.10 Cl 10.22; Found C 66.89 H 6.16 Cl 10.09.

Compound **9a**: ^{1}H-NMR (400 MHz, $CDCl_3$), δ= 7.35-7.22 (m, 20H, aromat.); 5.05 (d, 1H, J=10.8Hz, CH_2Ph); 4.92 (d, 1H, J=11.6Hz, CH_2Ph); 4.79 (d, 1H, J=11.8Hz, CH_2Ph); 4,75-4.69 (m, 4H, H-1, H-2′, 2xCH_2Ph); 4.61 (d, 1H, J=11.6Hz, CH_2Ph); 4.44 (d, 1H, J=11.7Hz, CH_2Ph); 4.39 (d, 1H, J=11.7Hz, CH_2Ph); 4.36 (m, 1H, H-4′); 3.89 (d, 1H, J_{4-3}=2.9Hz, H-4); 3.86 (dd, 1H, J_{2-1}=7.8Hz, J_{2-3}=9.8Hz, H-2); 3.60-3.53 (m, 4H, H-3, H-5, H-6a, H-6b); 2.92 (ddq, 1H, $J_{3'-4'}$=$J_{3'-2'}$=8.5Hz, $J_{3'-CH3'}$=7.7Hz, H-3′); 2.57 (d, 1H, $J_{OH-4'}$=11.0Hz, OH); 1.14 (d, 3H, $J_{CH3'-3'}$=7.7Hz, CH_3′).

^{13}C-NMR (100.6 MHz, $CDCl_3$), δ= 138.6-137.9 (C_{arom}ipso); 128.4-127.5 (C_{arom}); 101.7 (C-1); 91.1 (C-1′); 81.9, 79.3, 76.4, 74.1, 73.8, 73.6 (C-2, C-3, C-4, C-5, C-2′, C-4′); 75.0, 74.6, 73.4, 73.3 (4x$\underline{C}H_2$Ph); 68.6 (C-6); 37.7 (C-3′); 6.6 (CH_3′).

Compound **9b**: ^{1}H-NMR (400 MHz, $CDCl_3$), δ= 7.35-7.22 (m, 20H, aromat.); 4.93 (d, 1H, J= 11.7Hz, CH_2Ph); 4.91 (d, 1H, J= 10.8Hz, CH_2Ph); 4.78 (d, 1H, J= 10.9Hz, CH_2Ph); 4,73, 4.69 (2xd, 2H, J= 11.8Hz, CH_2Ph); 4.60 (d, 1H, J= 11.7Hz, CH_2Ph); 4.44-4.23 (m, 5H, J= 11.8Hz, CH_2Ph, J_{1-2}= 7.8Hz, H-1, H-2′, H-4′); 3.93-3.88 (m, 2H, J_{2-1}= 7.8Hz, J_{2-3}= 9.6Hz, H-2, H-4); 3.63-3.45 (m, 4H, J_{3-2}= 9.8Hz, J_{3-4}= 2.9Hz, H-3, H-5, H-6a, H-6b); 2.92 (ddq, 1H, $J_{3'-4'}$= $J_{3'-2'}$= $J_{3'-CH3'}$= 8.4Hz, H-3′); 2.57 (d, 1H, $J_{OH-4'}$= 11.1Hz, OH); 1.10 (d, 3H, $J_{CH3'-3'}$= 7.7Hz, CH_3′).

(2′R,3′S)-3′-(2,3,4,6-Tetra-*O*-benzyl-β-D-galactopyranosyl)-4′,4′-dichloro-2′-methylbutyric Acid Methyl Ester (8):

The enol ether **3** (500 mg, 0.9 mmol) was reacted with dichloroketene according to the general procedure. The crude reaction product **7** was dissolved in methanol (5 ml). A total of 8 mg sodium was added over 24 h. The reaction was followed by TLC. The reaction was kept at 0°C. The mixture was neutralized with Amberlyst 15 ion-exchange resin, filtered and concentrated *in vacuo*. Chromatography yielded 330 mg (53%) of **8** as an oil. $[\alpha]_D^{25}$= -8.1.

Anal. calcd. for $C_{40}H_{44}O_8Cl_2$ (723.7) C 66.39 H 6.13 Cl 9.80; Found C 65.77 H 5.98 Cl 9.58.

^{1}H-NMR (400 MHz, $CDCl_3$), δ= 7.41-7.24 (m, 20H, aromat.); 5.98 (d, $J_{4'-3'}$=5.3Hz, H-4′); 5.01 (d, 1H, J=10.6Hz, CH_2Ph); 4.95 (d, 1H, J=11.4Hz, CH_2Ph); 4.77 (d, 1H, J=11.7Hz, CH_2Ph); 4.76 (d, 1H, J_{1-2}=7.6Hz, H-1); 4.70-4.67 (m, 2H, J=10.4Hz, J=11.7Hz, 2xCH_2Ph); 4.56 (d, 1H, J=11.4Hz, CH_2Ph); 4.46 (d, 1H, J=11.7Hz, CH_2Ph); 4.41 (d, 1H, J=11.7Hz, CH_2Ph); 4.30 (dd, 1H, $J_{3'-2'}$=$J_{3'-4'}$=5.4Hz, H-3′); 3.87 (d, 1H, J_{4-3}=2.8Hz, H-4); 3.78 (dd, 1H, J_{2-1}=7.6Hz, J_{2-3}=9.7Hz, H-2); 3.57 (s, 3H, OCH_3); 3.56-3.50 (m, 3H, H-5, H-6a, H-6b); 3.52 (dd, 1H, J_{3-4}=3.0Hz, J_{3-2}=9.9Hz, H-3); 3.09 (dq, 1H, $J_{2'-CH3}$=7.1Hz, $J_{2'-3'}$=5.6Hz, H-2′); 1.23 (d, 3H, $J_{CH3'-2'}$=7.1Hz, CH_3′).

^{13}C-NMR (100.6 MHz, $CDCl_3$), δ= 173.1 (C-1′); 138.7-137.9 (C_{arom}ipso); 128.4-127.2 (C_{arom}); 104.2 (C-1); 82.7, 82.0, 79.5, 73.9 (C-2, C-3, C-4, C-5); 75.2, 74.6, 73.5, 73.3 (4x$\underline{C}H_2$Ph); 73.4 (C-3′); 72.7 (C-4′); 68.6 (C-6); 51.7 (OCH_3); 43.1 (C-2′); 11.4 (CH_3′).

(1′*S*,2′*S*,3′*S*,4′*R*)-(1′-Chloro-4′-hydroxy-3′-methylcyclobut-2′-yl)-2,3,4,6-tetra-*O*-benzyl-β-D-galactopyranoside (12), and (1′*R*, 2′*S*,3′*R*,4′*R*)-(1′-chloro-4′-hydroxy-3′-methylcyclobut-2′-yl)-2,3,4,6-tetra-*O*-benzyl-β-D-galacto-pyranoside (13):

To a refluxing solution of **9a** (100 mg, 0.14 mmol) in benzene (3 ml) were added 40 µl (0.15 mmol) of Bu_3SnH and 5 mg of azobisisobutyronitrile (AIBN). After 1h the same amounts of Bu_3SnH and AIBN were added and after one more hour the mixture was cooled to room temperature, diluted with benzene (15 ml) and stirred with sat. aq. KF (5 ml). The organic layer was separated, dried and concentrated *in vacuo*. Chromatography gave **12** (48 mg, 52%), **13** (16 mg, 20%) and **14** (7 mg, 8%) as oils.

Compound **12:** $[\alpha]_D^{25}$= 9.3

Anal. calcd. for $C_{39}H_{43}O_7Cl_1$ (659.2) C 71.05 H 6.57 Cl 5.37; Found C 71.06 H 6.53 Cl 5.38.

^{1}H-NMR (400 MHz, $CDCl_3$), δ= 7.37-7.23 (m, 20H, aromat.); 4.93 (d, 1H, J=11.7Hz, CH_2Ph); 4.89 (d, 1H, J=11.0Hz, CH_2Ph); 4.75 (d, 1H, J=10.9Hz, CH_2Ph); 4.74 (d, 1H, J=11.8Hz, CH_2Ph); 4.69 (d, 1H, J=11.8Hz, CH_2Ph); 4.60 (d, 1H, J=11.6, CH_2Ph); 4.55 (d, 1H, J_{1-2}=7.7Hz, H-1); 4.43 (d, 1H, J=11.4Hz, CH_2Ph); 4.39 (d, 1H, J=11.7Hz, CH_2Ph); 4.11 (ddd, 1H, $J_{2'-1'}$=7.0Hz, $J_{2'-3'}$=8.2Hz, $J_{2'-4'}$=1.0Hz, H-2′); 4.06 (t, $J_{1'-2'}$=$J_{1'-4'}$=7.0Hz, H-1′); 3.94 (m, 1H, H-4′); 3.88 (d, 1H, J_{4-3}=2.8Hz, H-4); 3.80 (dd, 1H, J_{2-1}=7.7Hz, J_{2-3}=9.8Hz, H-2); 3.58-3.52 (m, 3H, H-5, H-6a, H-6b); 3.52 (dd, 1H, J_{3-4}=2.9Hz, J_{3-2}=9.7Hz, H-3); 2.84 (ddq, $J_{3'-2'}$=$J_{3'-4'}$=$J_{3'-CH3'}$=7.9Hz, H-3′); 2.13 (d, $J_{OH-4'}$=6.0Hz, OH); 1.08 (d, 3H, $J_{CH3'-3'}$=7.6Hz, CH_3′).

^{13}C-NMR (100.6 MHz, $CDCl_3$), δ= 138.6-137.9 (C_{arom}ipso); 128.4-127.5 (C_{arom}); 101.8 (C-1); 82.1, 79.3, 73.6, 73.5 (C-2, C-3, C-4, C-5); 75.2, 74.6, 73.5, 73.1 (4x$\underline{C}H_2$Ph); 74.1 (C-1′); 70.0 (C-2′); 68.7 (C-6); 63.7 (C-4′); 37.3 (C-3′); 7.3 (CH_3′).

Compound **13:** ^{1}H-NMR (400 MHz, $CDCl_3$), δ= 7.39-7.23 (m, 20H, aromat.); 5.08 (d, 1H, J=10.7Hz, CH_2Ph); 4.92 (d, 1H, J=11.6Hz, CH_2Ph); 4.77 (d, 1H, J=11.7Hz, CH_2Ph); 4.73 (d, 1H, J=10.7Hz, CH_2Ph); 4.68 (d, 1H, J=11.6Hz, CH_2Ph); 4.67 (dt, $J_{1'-2'}$=$J_{1'-4'}$=5.6Hz, $J_{1'-3'}$=3.3Hz, H-1′); 4.60 (d, 1H, J=11.6, CH_2Ph); 4.50 (ddd, 1H, $J_{2'-1'}$=5.3Hz, $J_{2'-3'}$=7.2Hz, $J_{2'-4'}$=1.8Hz, H-2′); 4.44 (d, 1H, J_{1-2}=7.6Hz, H-1); 4.39 (s, 2H, CH_2Ph); 4.24 (s, 1H, H-4′); 3.84 (d, 1H, J_{4-3}=2.4Hz, H-4); 3.84 (dd, 1H, J_{2-1}=7.7Hz, J_{2-3}=9.7Hz, H-2); 3.56-3.45 (m, 4H, H-3, H-5, H-6a, H-6b); 2.82 (dddq, $J_{3'-2'}$=$J_{3'-4'}$=$J_{3'-CH3'}$=7.4Hz, $J_{3'-1'}$=3.3Hz, H-3′); 2.13 (d, $J_{OH-4'}$=6.0Hz, OH); 1.21 (d, 3H, $J_{CH3'-3'}$=7.7Hz, CH_3′).

^{13}C-NMR (100.6 MHz, $CDCl_3$), δ= 138.5-137.7 (C_{arom}ipso); 128.2-127.2 (C_{arom}); 101.5 (C-1); 81.8, 79.1, 73.5, 73.5 (C-2, C-3, C-4, C-5); 74.8, 74.3, 73.3, 73.2 (4x$\underline{C}H_2$Ph); 68.8 (C-6); 68.1, 64.6 (C-1′, C-2′); 62.3 (C-4′); 41.0 (C-3′); 8.0 (CH_3′).

(1′*R*, 2′*S*, 3′*S*)-(3′-Hydroxy-2′-methylcyclobut-1′-yl)-2,3,4,6-tetra-*O*-benzyl-β-D-galactopyranoside (14):

Compound **9a** (390 mg, 0.56 mmol) was dissolved in refluxing benzene (12 ml). Over a period of 24 h, 8 eq Bu_3SnH and 2 eq AIBN were added in four equal portions. After dilution with benzene (30 ml), stirring with sat. aq. KF (15 ml), separation of the organic layer and concentration *in vacuo*, the crude product was purified by chromatography to yield 250 mg (71%) of **14** and 73 mg (20%) of the monochloro derivatives **12** + **13**.

Compound **14**, $[\alpha]_D^{25}$=-17.4 (c=0.4, $CHCl_3$).

Anal. calcd. for $C_{39}H_{44}O_7$ (624.7) C 74.97 H 7.09; Found C 74.71 H 7.19 .

^{1}H-NMR (400 MHz, $CDCl_3$), δ= 7.37-7.23 (m, 20H, aromat.); 4.92 (d, 2H, J=11.6Hz, CH_2Ph); 4.76 (d, 1H, J=10.9Hz, CH_2Ph); 4.73 (d, 1H, J=11.8Hz, CH_2Ph); 4.69 (d, 1H, J=11.7Hz, CH_2Ph); 4.60 (d, 1H, J=11.7Hz, CH_2Ph); 4.42 (d, 1H, J=11.8, CH_2Ph); 4.39 (d, 1H, J=11.8Hz, CH_2Ph); 4.26 (d, 1H, J_{1-2}=7.7Hz, H-1); 4.10 (dt, 1H, $J_{1'-4'a}$=$J_{1'-2'}$=7.4Hz, $J_{1'-4'b}$=6.8Hz, H-1′); 3.98 (q, 1H, $J_{3'-2'}$=$J_{3'-4'a}$=$J_{3'-4'b}$=7.0Hz, H-3′); 3.86 (d, 1H, J_{4-3}=2.6Hz, H-4); 3.80 (dd, 1H, J_{2-1}=7.7Hz, J_{2-3}=9.7Hz, H-2); 3.55-3.46 (m, 3H, H-5, H-6a, H-6b); 3.49 (dd, 1H, J_{3-4}=3.0Hz, J_{3-2}=9.6Hz, H-3); 2.81 (dddq, $J_{2'-1'}$=$J_{2'-3'}$=$J_{2'-CH3}$=7.2Hz, $J_{2'-4'a}$=3.9Hz, H-2′); 2.67 (ddt, 1H, $J_{4'a-4'b}$=11Hz, $J_{4'a-2'}$=3.9Hz, $J_{4'a-1'}$=$J_{4'a-3'}$=6.8Hz, H-4′a); 1.99 (dt, 1H, $J_{4'b-4'a}$=11.4Hz, $J_{4'b-3'}$=$J_{4'b-1'}$=8.0Hz, H-4′b); 1.60 (s, OH); 1.13 (d, 3H, $J_{CH3-2'}$=7.4Hz, CH_3′).

^{13}C-NMR (100.6 MHz, $CDCl_3$), δ= 138.7-137.9 (C_{arom}ipso); 128.4-127.5

(C_{arom}); 101.1 (C-1); 82.2, 79.3, 73.6, 73.5 (C-2, C-3, C-4, C-5); 75.1, 74.5, 73.5, 73.1 (4x$\underline{C}H_2Ph$); 68.9 (C-6); 66.1, 61.8 (C-1', C-3'); 41.5 (C-2'); 38.5 (C-4'); 7.0 (CH_3').

(1'*R*, 2'*S*, 3'*S*)-(3'-Benzyloxy-2'-methylcyclobut-1'-yl)-2,3,4,6 -tetra-*O*-benzyl-*β*-D-galactopyranoside (15):

Compound **14** (250 mg, 0.4 mmol) was dissolved in DMF (6 ml) at 0°C and deprotonated with NaH (suspension in mineral oil, 80%), (1.5eq, 18 mg, 0.6 mmol). Benzyl bromide (2eq, 95 µl, 0.8 mmol) was added after 1h and the mixture was stirred for 15h. The reaction was stopped by addition of methanol (0.5 ml), the mixture was diluted with diethyl ether (30 ml) and washed with brine. Chromatography of the concentrated and dried organic extracts yielded 260 mg (91%) of **15**. $[\alpha]_D^{25}$= -26.4.

Anal. calcd. for $C_{46}H_{50}O_7$ (714.9) C 77.28 H 7.05; Found C 76.76 H 6.98.

^{1}H-NMR (400 MHz, $CDCl_3$), δ= 7.37-7,23 (m, 25H, aromat.); 4.95 (d, 1H, J=10.8Hz, CH_2Ph); 4.92 (d, 1H, J=11.7Hz, CH_2Ph); 4.75 (d, 1H, J=11.8Hz, CH_2Ph); 4.73 (d, 1H, J=10.8Hz, CH_2Ph); 4.68 (d, 1H, J=11.9, CH_2Ph); 4.60 (d, 1H, J=11.7Hz, CH_2Ph); 4.44 (d, 1H, J=11.8Hz, CH_2Ph); 4.43 (d, 1H, J=11.7Hz, CH_2Ph); 4.39 (d, 1H, J=10.4Hz, CH_2Ph); 4.36 (d, 1H, J=11.8Hz, CH_2Ph); 4.27 (d, 1H, J_{1-2}=7.7Hz, H-1); 4.11 (dt, 1H, $J_{1'-4'a}$=$J_{1'-2'}$=6.6Hz, $J_{1'-4'b}$=8.3Hz, H-1'); 3.85 (d, 1H, J_{4-3}=3.0Hz, H-4); 3.80 (dd, 1H, J_{2-1}=7.7Hz, J_{2-3}=9.8Hz, H-2); 3.71 (dt, 1H, $J_{3'-4'a}$=$J_{3'-2'}$=6.8Hz, $J_{3'-4'b}$=8.3Hz, H-3'); 3.56-3.46 (m, 4H, H-3, H-5, H-6a, H-6b); 2.89 (m_c, 1H, H-2'); 2.59 (ddt, 1H, $J_{4'a-4'b}$=11.0Hz, $J_{4'a-1'}$=$J_{4'a-3'}$=6.7Hz, $J_{4'a-2'}$=4Hz, H-4'a); 2.14 (ddt, 1H, $J_{4'b-4'a}$=11.2Hz, $J_{4'b-3'}$=$J_{4'b-1'}$=8.3Hz, $J_{4'b-2'}$=0.8Hz, H-4'b); 1.20 (d, 3H, $J_{CH3-2'}$=7.3Hz, CH_3').

^{13}C-NMR (100.6 MHz, $CDCl_3$), δ= 138.7-138.0 (C_{arom}ipso); 128.4-127.5 (C_{arom}); 101.2 (C-1); 82.2, 79.3, 73.8, 73.5 (C-2, C-3, C-4, C-5); 75.1, 74.5, 73.5, 73.1, 70.9 (5x$\underline{C}H_2Ph$); 69.0 (C-6); 67.1, 65.9 (C-1', C-3'); 40.4 (C-2'); 35.8 (C-4'); 7.5 (CH_3').

(1*R*,2*R*,3*S*)-3-Benzyloxy-2-methylcyclobutanol (16):

Compound **15** (160 mg, 0.22 mmol) was dissolved in ethanol (10 ml) and treated with 2 ml of conc. hydrochloric acid under reflux for 24h. The mixture was diluted with diethyl ether (30 ml) and neutralised by addition of sat. aq. $NaHCO_3$ (10 ml). The organic layer was dried and concentrated *in vacuo*. Chromatography of the crude product gave 33 mg (77%) of **16**, $[\alpha]_D^{25}$= -35.2.

^{1}H-NMR (400 MHz, $CDCl_3$), δ= 7.35-7.23 (m, 5H, aromat.); 4.42 (d, 1H, J=11.7Hz, CH_2Ph); 4.36 (d, 1H, J=11.7Hz, CH_2Ph); 4.11 (dt, 1H, J_{1-4a}=J_{1-2}=6.6Hz, J_{1-4b}=8.3Hz, H-3); 3.71 (dt, 1H, J_{3-4a}=J_{3-2}=6.8Hz, J_{3-4b}=8.3Hz, H-1); 2.81 (dddq, 1H, J_{2-1}≈J_{2-3}≈6.7Hz, J_{2-4a}≈3.8Hz, J_{2-CH3}≈7.3Hz, H-2); 2.64 (ddt, 1H, J_{4a-4b}=11.8Hz, J_{4a-1}=J_{4a-3}=6.8Hz, J_{4a-2}=3.8Hz, H-4a); 2.02 (dt, 1H, J_{4b-4a}=11.3Hz, J_{4b-3}=J_{4b-1}=7.9Hz, H-4b); 1.71 (s, OH); 1.09 (d, 3H, J_{CH3-2}=7.3Hz, CH_3).

^{13}C-NMR (100.6 MHz, $CDCl_3$), δ= 138.3 (C_{arom}ipso); 128.3 (C_{arom}m); 127.6 (C_{arom}o); 127.5 (C_{arom}p); 70.9 ($\underline{C}H_2Ph$); 67.6 (C-1); 61.9 (C-3); 41.0 (C-2); 39.0 (C-4); 6.3 (CH_3).

Vinyl-2,3,4,6-tetra-*O*-pivaloyl-*β*-D-galactopyranoside (6):

Analogously to the procedure described by Ferrier et al.[14], 5g (8.6 mmol) of (2,3,4,6)-tetra-*O*-pivaloyl-*α*-D-galactopyranosyl bromide[15] **4** were reacted with 5g (17.2 mmol) of bis(formylmethyl)mercury **5** in chloroform (70 ml) to yield after crystallisation from diethyl ether 3.8g (81%) of **6** as colourless crystals; mp. 152°C, $[\alpha]_D^{25}$=-2.0.

Anal. calcd. for $C_{28}H_{46}O_{10}$ (542.6) C 61.97 H 8.54; Found C 61.89 H 8.49.

^{1}H-NMR (400 MHz, $CDCl_3$), δ= 6.35 (dd, 1H, $J_{1'-2'c}$=6.4Hz, $J_{1'-2't}$=14.0Hz, H-1'); 5.40 (d, 1H, J_{4-3}=3.2Hz, H-4); 5.30 (dd, 1H, J_{2-1}=8.0Hz, J_{2-3}=10.6Hz, H-2); 5.10 (dd, 1H, J_{3-4}=3.3Hz, J_{3-2}=10.7, H-3); 4.77 (d, 1H, J_{1-2}=7.8Hz, H-1); 4.53 (dd, 1H, $J_{2't-1'}$=13.8Hz, $J_{2't-2'c}$=2.0Hz, H-2't); 4.21 (dd, 1H, $J_{2'c-1'}$=6.4Hz, $J_{2'c-2't}$=2.0Hz, H-2'c); 4.15 (dd, 1H, J_{6a-6b}=13.6Hz, H-6a); 4.05-4.00 (m, 2H, H-5, H-6b); 1.23 (s, 9H, $(CH_3)_3$); 1.14 (s, 9H, $(CH_3)_3$); 1.12 (s, 9H, $(CH_3)_3$); 1.08 (s, 9H, $(CH_3)_3$).

^{13}C-NMR (100.6 MHz, $CDCl_3$), δ= 177.8, 177.2, 176.8, 176.6 (4xC=O); 148.8 (C-1'); 99.8 (C-1); 92.8 (C-2'); 71.4, 70.7, 68.2, 66.6 (C-2, C-3, C-4, C-5); 61.1 (C-6); 39.0, 38.8, 38.7, 38.6 (4xC_{quart}Piv); 27.1-26.9 (12xCH_3-Piv).

(1',1'-Dichloro-4'-hydroxycyclobut-2'-yl)-2,3,4,6-tetra-*O*-pivaloyl-*β*-D-galactopyranoside (11):

Reaction of **6** with dichloroketene according to the general procedure gave the crude (2',2'-dichloro-1'-oxocyclobut-3'-yl)-2,3,4,6-tetra-*O*-pivaloyl-*β*-D-galactopyranoside **10** which was identified by IR-spectroscopy, $\tilde{\nu}$= 1813cm^{-1}.

The crude **10** (200 mg, 0.3 mmol) was reduced with $NaBH_4$ (15 mg, 0.4 mmol) in iPrOH (5 ml) as described for **7** to give the cyclobutanol **11**. Chromatography on silica gel gave 82 mg (51%) of the major diastereomer **11**, amorphous solid, $[\alpha]_D^{25}$= -25.0.

Anal. calcd. for $C_{30}H_{48}O_{11}Cl_2$ (655.6) C 54.96 H 7.48 Cl 10.82; Found C 54.96 H 7.40 Cl 10.20.

^{1}H-NMR (400 MHz, $CDCl_3$), δ= 5.40 (d, 1H, J_{4-3}=3.2Hz, H-4); 5.26 (dd, 1H, J_{2-1}=7.9Hz, J_{2-3}=10.5Hz, H-2); 5.11 (dd, 1H, J_{3-4}=3.3Hz, J_{3-2}=10.4, H-3); 4.86 (d, 1H, J_{1-2}=8.0Hz, H-1); 4.40 (m, 1H, $J_{2'-3'a}$≈$J_{2'-3'b}$≈8.5Hz, $J_{2'-4'}$=0.8Hz, H-2'); 4.16-4.11 (m, 2H, H-4', H-6a); 4.04-3.97 (m, 2H, H-6b, H-5); 2.66 (dt, 1H, $J_{3'a-3'b}$=11.7Hz, $J_{3'a-2'}$=$J_{3'a-4'}$=7.7Hz, H-3'a); 2.60 (d, 1H, $J_{OH-4'}$=9.7Hz, OH); 1.87 (dt, 1H, $J_{3'b-3'a}$=11.7Hz, $J_{3'b-2'}$=$J_{3'b-4'}$=9.2Hz, H-3'b); 1.24 (s, 9H, $(CH_3)_3$); 1.16 (s, 9H, $(CH_3)_3$); 1.15 (s, 9H, $(CH_3)_3$); 1.08 (s, 9H, $(CH_3)_3$).

^{13}C-NMR (100.6 MHz, $CDCl_3$), δ= 177.8, 177.2, 176.9, 176.8 (4xC=O); 98.8 (C-1); 90.5 (C-1'); 73.4, 2x71.8, 70.8, 68.2, 66.8 (C-2, C-3, C-4, C-5, C-2', C-4'); 61.4 (C-6); 39.0, 38.8, 38.7, 38.6 (4xC_{quart}Piv); 36.1 (C-3'); 27.2-27.1 (12xCH_3-Piv).

3-*O*-(1',1'-Dichloro-4'-hydroxy-3'-methylcyclobut-2'-yl)-1,2;5,6-di-*O*-isopropylidene-*α*-D-glucofuranose (18b); major diastereomer:

1,2;5,6-Di-*O*-isopropylidene-3-*O*-(*Z*)-propenyl-*α*-D-glucofuranose **18** was obtained according to the procedure described by Gigg[13]. (1,2;5,6-di-*O*-isopropylidene-3-*O*-allyl-*α*-D-glucofuranose **17** (1g, 3.3 mmol) was dissolved in DMSO (15 ml) and reacted at 100°C with potassium *tert*-butoxide (186 mg, 1.6 mmol).

After cyclcoaddition of **18** (200 mg, 0.66 mmol) with dichloroketene (general procedure) the crude product was reduced with $NaBH_4$ (38 mg, 1 mmol) in iPrOH (10 ml). Chromatography yielded 124 mg (45%) of **18b**, $[\alpha]_D^{25}$=+7.9.

Anal. calcd. for $C_{17}H_{26}O_7Cl_2$ (413.3) C 49.40 H 6.34 Cl 17.18; Found C 49.34 H 6.44 Cl 16.47.

^{1}H-NMR (400 MHz, $CDCl_3$), δ= 5.91 (d, 1H, J_{1-2}=3.5Hz, H-1); 4.79 (d, 1H, J_{2-1}=3.5Hz, H-2); 4.28 (dd, 1H, J_{4-3}=2.7Hz, J_{4-5}=9.0Hz, H-4); 4.38-4.32 (m, 2H, $J_{4'-OH}$≈$J_{4'-3'}$≈9.6Hz, $J_{2'-3'}$≈8.5Hz, H-2', H-4'); 4.22 (dt, 1H, J_{5-6a}=J_{5-4}=8.0Hz, J_{5-6b}=5.8Hz, H-5); 4.11-4.06 (m, 3H, H-3, H-4, H6a); 3.97 (dd, 1H, J_{6b-6a}=8.5Hz, J_{6b-5}=5.4Hz, H-6b); 2.68 (ddq, 1H, $J_{3'-4'}$=$J_{3'-2'}$=8.1Hz, $J_{3'-CH3'}$=7.7Hz, H-3'); 2.66 (d, 1H, $J_{OH-4'}$=10.4Hz, OH); 1.48 (s, 3H, CH_3); 1.40 (s, 3H, CH_3); 1.31 (s, 6H, 2xCH_3); 1.04 (d, 3H, $J_{CH3'-3'}$=7.7Hz, CH_3').

^{13}C-NMR (100.6 MHz, $CDCl_3$), δ= 112.0, 109.2 (2xC_{quart}isoprop.); 105.3 (C-1); 92.2 (C-1'); 83.5, 83.3, 81.4, 81.2, 74.1, 72.3 (C-2, C-3, C-4, C-5, C-2', C-4'); 67.6 (C-6); 37.9 (C-3'); 26.9, 26.8, 26.2, 25.3 (4xCH_3); 6.2 (CH_3').

5,6-*O*-Diphenylmethylidene-1,2-*O*-isopropylidene-3-*O*-prop-1'-enyl-*α*-D-glucofuranose (21):

Compound **19**[21] (1g, 3.84 mmol) was dissolved in toluene (10 ml) and 0.88 ml (4.61 mmol) of α,α-dichlorodiphenylmethane, (1.28 ml, 9.21 mmol) triethylamine and 20 mg of 4-methylaminopyridine were added. The mixture was stirred at 80°C for 3d. The solution was diluted with CH_2Cl_2 (40 ml) and washed twice with 1N HCl (10 ml) and sat. aq. $NaHCO_3$ (10 ml). After drying of the organic layer and concentration *in vacuo*, the crude product was subjected to chromatography to give 75% (1.2g) of 5,6-*O*-diphenylmethylidene-1,2-*O*-isopropylidene-3-*O*-allyl-α-D-glucofuranose. This compound (600 mg, 1.4 mmol) was treated with potassium *tert*-butoxide (80 mg, 0.7 mmol) in DMSO (5 ml) according to the procedure described in reference 11. Purification of the crude product by chromatography gave **21** as an oil, 364 mg (61%), $[\alpha]_D^{25}$=-21.0.

Anal. calcd. for $C_{25}H_{28}O_6$ (424.5) C 70.74 H 6.65; Found C 70.69 H 6.80.

^{1}H-NMR (200 MHz, $CDCl_3$), δ= 7.56-7.46 (m, 4H, aromat. m), 7.38-7.23 (m, 6H, aromat. o, p); 6.12 (dd, 1H, $J_{1'-2'}$=6.1Hz, $J_{1'-3'}$=1.6Hz, H-1'); 5.92 (d, 1H, J_{1-2}=3.6Hz, H-1); 4.58-4.52 (m, 2H, J_{2-1}=3.9Hz, H-2, H-2'); 4.45 (m, 4H, H-4, H-3, H-5, H-6a); 4.09 (dd, 1H, J_{6b-6a}=8.2Hz, J_{6b-5}=7.0Hz, H-6b); 1.56 (dd, 3H, $J_{3'-2'}$=6.8Hz; $J_{3'-1'}$=1.6Hz; CH_3-3'); 1.45 (s, 3H, CH_3); 1.31 (s, 3H, CH_3).

^{13}C-NMR (100.6 MHz, $CDCl_3$), δ= 144.2 (C-3'); 142.1, 141.9 (C_{arom}ipso); 128.1-126.2 (C_{arom}); 112.4 (C_{quart}isoprop.); 109.8 ($C_{quart}Ph_2$); 105.3 (C-2'); 103.0 (C-1); 83.4, 83.1, 80.8, 72.8 (C-2, C-3, C-4, C-5); 67.8 (C-6); 26.7, 26.2 (2x CH_3); 9.2 (C-3').

3-*O*-(1',1'-Dichloro-4'-hydroxy-3'-methylcyclobut-2'-yl)-5,6-*O*-diphenylmethylidene-1,2-*O*-isopropylidene-*α*-D-glucofuranose (21b):

Cyclcoaddition of **18** (195 mg, 0.46 mmol) with dichloroketene (general procedure) and reduction of the crude product with $NaBH_4$ (38 mg, 1 mmol) in iPrOH (10 ml)

gave after chromatography 139 mg (53%) of **21b** as a 2:1 mixture of the two diastereomers, $[\alpha]_D^{25}$=+3.18.

Anal. calcd. for $C_{27}H_{30}O_7Cl_2$ (568.4) C 60.34 H 5.63 Cl 13.19; Found C 60.37 H 5.73 Cl 10.89.

^{1}H-NMR (200 MHz, $CDCl_3$), δ= 7.35-7.22 (m, 10H, aromat.); 5.92 (d, 1H, J_{1-2}=3.6Hz, H-1); 4.86 (d, 1H, J_{2-1}=3.5Hz, H-2); 4.58-4.14 (m, 7H, H-3, H-4, H-5, H-6a, H-6b, H-2', H-4'); 2.93 (ddq, 1H, $J_{3'-4'}\approx J_{3'-2'}\approx J_{3'-CH3'}\approx$8Hz, H-3'); 1.43 (s, 3H, CH_3); 1.32 (s, 3H, CH_3); 1.02 (d, 3H, $J_{CH3'-3'}$=7.8Hz, CH_3').
^{13}C-NMR (50.3 MHz, $CDCl_3$), δ= 141.9 (C_{arom}ipso); 128.1-126.0 (C_{arom}); 112.1 (C_{quart}isoprop.); 109.9 (C_{quart}diphenyl.); 105.2 (C-1); 92.0 (C-1'); 83.5, 82.9, 81.3, 80.9, 74.0, 72.5 (C-2, C-3, C-4, C-5, C-2', C-4'); 68.3 (C-6); 37.8 (C-3'); 26.7, 26.2 (2xCH_3); 6.2 (CH_3').

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