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Unexpected Mild Protection of Alcohols as 2-*O*-THF and 2-*O*-THP Ethers Catalysed by Cp_2TiCl Reveal an Intriguing Role of the Solvent in the Single-Electron Transfer Reaction

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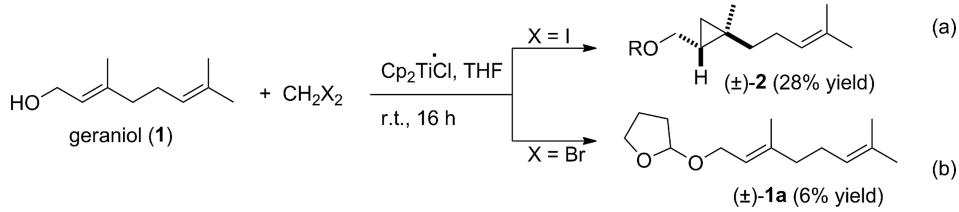
A method for the conversion of primary, secondary and tertiary alcohols into the corresponding THF ethers at room temperature and primary and secondary alcohols into the corresponding THP ethers, has been developed using titanium(III) species generated from a catalytic amount of titanocene dichloride or (4*R*,5*R*)-(–)-2,2-dimethyl-α,α,α′,α′-tetra(1-naphthyl)-1,3-dioxolane-4,5-dimethanolatotitanium(IV) dichloride: acetonitrile adduct together with manganese(0) as a reductant and bromoform in THF or THP as the solvent. A radical mechanism is proposed for this transformation revealing an intriguing role of the solvent in the single-electron transfer reactions catalysed by the low valent Ti^{III} system.

Introduction

The protection of a hydroxyl group is a common step in organic chemistry. The tetrahydrofuranyl (THF)[1] and tetrahydropyranyl (THP)[2] ethers are very important protecting groups in multi-step organic syntheses[2g,3] as well as in peptide, nucleotide, carbohydrate, terpenoid and steroid chemistry.[4] These ethers are stable to a wide range of reagents including metal hydrides, metal triflates, Grignard and organolithium reagents, ylides, alkylating and acylating reagents as well as strongly alkaline conditions.[2a,5]

Furthermore they can be hydrolysed to give the parent alcohol under mildly acidic conditions.[5] A THP ether can be converted directly to a range of functional groups.[6] Although a number of methods have been reported for the preparation of THF and THP ethers, some of these use expensive or toxic reagents, elevated temperatures and high catalyst loadings and a lengthy work-up procedure. In some instances the methods are incompatible with particular functional groups.[1,2]

During research to develop a cyclopropanation of allylic alcohols by low-valent titanium, we obtained the THF ether of geraniol [(±)-**1a**] instead of a cyclopropyl derivative, when the reaction was carried out in THF with alkyl halides other than methylene iodide (Scheme 1).[7] This observation led us to study the unexpected reaction which has proved to be a mild, efficient method for the protection of a wide variety of alcohols mediated by Ti^{III} species. In this paper we report the first tetrahydrofuranylation and tetrahydropyranylation of alcohols catalysed by Cp_2TiCl in the presence of an alkyl halide and tetrahydrofuran or tetrahydropyran. This method affords the 2-*O*-tetrahydrofuranyl ethers of primary, secondary and tertiary allylic and benzylic alcohols under mild conditions and at room temperature and the 2-*O*-tetrahydropyranyl ethers of primary and secondary allylic and benzylic alcohols.



Scheme 1. Preparation of compound (±)-**1a**.

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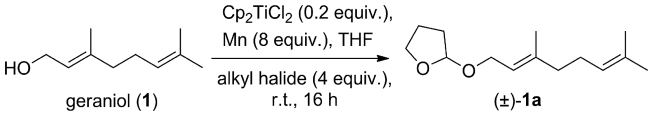
Results and Discussion

Bis(cyclopentadienyl)titanium(III) chloride, $Cp_2Ti^{III}Cl$, known as Nugent's reagent,[8] has become a very popular reagent in radical reactions because of its soft one-electron reductive character.[9] This complex is tolerated by a variety of functional groups.[10] We prepared Cp_2TiCl in situ by stirring a red solution of the commercially available Cp_2TiCl_2 (0.2 equiv.) with manganese dust (8 equiv.) in dry and degassed tetrahydrofuran to give a green solution of the Ti^{III} complex.[11] Our initial experiments involved stirring a THF solution of geraniol and $Cp_2Ti^{III}Cl$ with a series of alkyl halides at room temperature overnight (Table 1). We observed that the THF ether of the hydroxyl group was formed in the presence of alkyl di- and tribromides (entries 3–6, Table 1) but not in the presence of monohalides (entries 1–2, Table 1). The best yields were obtained with $CHBr_3$ and CH_3CHBr_2 due to the generation of stable halogenated radicals.

Table 1. Tetrahydrofuranylation of geraniol (**1**) using different alkyl halides.



Entry	Alkyl halide	Yield [%]
1	CH_3CH_2Br	n.r.[a]
2	$CH_3(CH_2)_4I$	n.r.[a]
3	CH_2Br_2	6%[b]
4	$(CH_3)_2CBr_2$	29%[b]
5	$CHBr_3$	81%[b]
6	CH_3CHBr_2	73%[b]

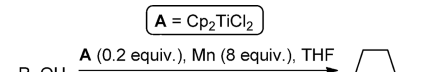
[a] n.r.: no reaction. [b] Determined from the GC chromatogram of the crude mixture.

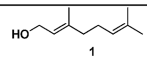
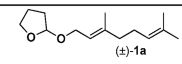
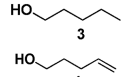
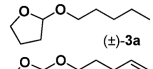
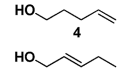
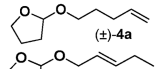
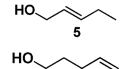
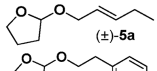
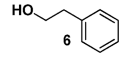
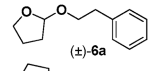
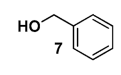
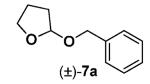
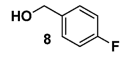
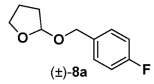
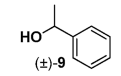
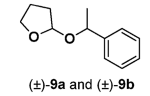
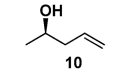
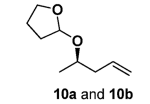
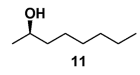
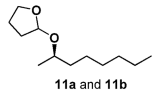
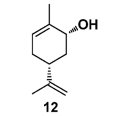
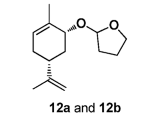
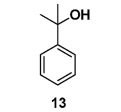
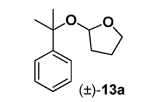
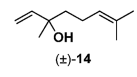
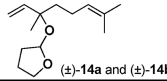
It has been reported that Mn^0 promotes the protection of alcohols by THF.[1c] Consequently in order to determine the role of each component under our conditions, we carried out the reaction in the absence of Ti, with Mn dust, Rieke Mn,[12] Mn activated by HCl[13] (8 equiv.), with only Ti^{III} and with both reagents in different amounts. The results showed that both Ti^{III} and manganese(0) were required and that the reaction was not mediated by manganese alone.

Furthermore the number of equivalents of both the titanium complex and the manganese were crucial to the success of the reaction. The THF ethers were not obtained in the absence of an alkyl bromide. We concluded that the optimum conditions involved titanocene dichloride (**A**) (0.2 equiv.), manganese dust (8 equiv.) and the alkyl halide (either $CHBr_3$ or CH_3CHBr_2, 4 equiv.) in THF at room temperature for 16 h.

In order to examine the generality of the procedure, the reaction was carried out with a series of alcohols using both $CHBr_3$ and CH_3CHBr_2 (Table 2). The Ti^{III} species was obtained by reduction of the Ti^{IV} with the manganese(0) under an argon atmosphere in dry THF. After the reaction mixture had turned a characteristic green colour corresponding to the presence of Ti^{III}, a solution of the alcohol together with the alkyl halide (4 equiv.) was added (red colour) and the reaction was stirred for 16 h at room temperature. It is worth noting the progressive colour change observed in the reaction solution, which turn from red to green again, confirming the involvement of Ti^{IV}/Ti^{III} species in the reaction mixture.[9c] It was then quenched with water and the crude product was purified by column chromatography. In all cases the reaction proceeded in good yield when $CHBr_3$ was used as the alkyl halide (Table 2).

Table 2. Tetrahydrofuranylation of alcohols using a catalytic amount of Cp_2TiCl_2.



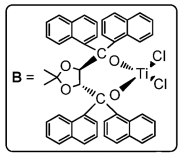
Entry	Substrate	THF ether	Yield[a,b]	Yield[a,c]
1			73%	81%
2			94%	77%[d]
3			64%	89%[d]
4			52%	87%[d]
5			64%	67%[d]
6			58%[d]	62%
7			54%[d]	71%[d]
8			77%[d,e]	85%[d,e]
9			48%[d,e]	69%[e]
10			58%[d,e]	71%[d,e]
11			77%[e]	81%[d,e]
12			87%	95%[d]
13			21%[e]	80%[d,e]

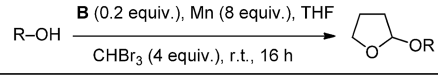
[a] Determined from the GC chromatogram of the crude mixture. [b] CH_3CHBr_2. [c] $CHBr_3$. [d] 10 mol-% Cp_2TiCl_2. [e] Mixture of diasteroisomers.

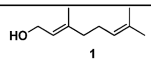
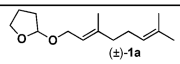
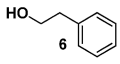
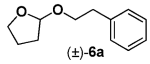
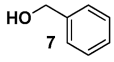
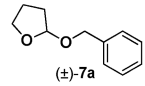
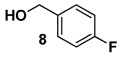
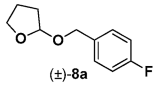
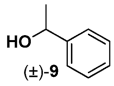
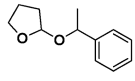
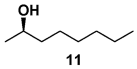
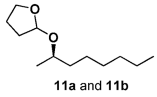
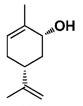
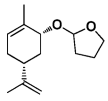
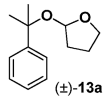
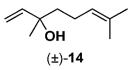
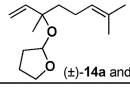
A chiral center is created in the THF ether. Consequently in order to study the possible enantioselectivity of the reaction and to shed some light on its mechanism, we explored

the use of the chiral titanium complex (**B**) with $CHBr_3$. This complex was easily converted into the Ti^{III} form in situ using manganese dust in dry, degassed tetrahydrofuran. Although the reaction did not proceed with any enantioselective,[14] the yield of the THF ethers was almost quantitative in all the cases that we examined (Table 3).

Table 3. Tetrahydrofuranylation of alcohols using a catalytic amount of the chiral titanium complex **B**.





Entry	Substrate	THF ether	Yield[a]
1	 **1**	 (±)-**1a**	>99%
2	 **6**	 (±)-**6a**	>99%
3	 **7**	 (±)-**7a**	>99%
4	 **8**	 (±)-**8a**	>99%
5	 (±)-**9**	 (±)-**9a** and (±)-**9b**	>99%[b]
6	 **11**	 **11a** and **11b**	>99%[b]
7	 **12**	 **12a** and **12b**	>99%[b]
8	 **13**	 (±)-**13a**	97%
9	 (±)-**14**	 (±)-**14a** and (±)-**14b**	86%[b]

[a] Determined from the GC chromatogram of the crude mixture. [b] Mixture of diasteroisomers.

Our results have shown that primary, secondary, tertiary, allylic and benzylic alcohols can be converted into their THF ethers at room temperature in good to excellent yield by the complex **A**, and quantitatively by the complex **B**. Our previous report on the titanium(III) mediated cyclopropanation[7] showed that this would only proceed when THF was used as the solvent revealing the important role of the solvent in these reactions.

It has been reported that the principal Ti^{III} species which are formed in THF by the reduction of Cp_2TiX_2 (X = Cl, Br, I) involve a mixture of Cp_2TiX and $(Cp_2TiX)_2$, in which the vacant co-ordination sites are occupied by a THF molecule.[15] It was suggested that the half-open structure **D** (Scheme 2) with an accessible co-ordination site might be the an active reagent in solution.[15] Furthermore stereochemical investigations on the pinacolization of unsaturated aldehydes have suggested that pentavalent co-ordination on a Ti^{III} complex may be possible.[16]

In the light of this we propose a mechanism (Scheme 2) in which the THF and the alcohol are both co-ordinated to the partially opened dimeric titanium species **D** which behaves as a template. The conversion of the alcohols to the corresponding THF acetals involves a free radical mechanism catalysed by titanocene. The colour changes (red to green) confirms the involvement of Ti^{IV} (cycle 2 in Scheme 2) and Ti^{III} in the reaction.[9c]

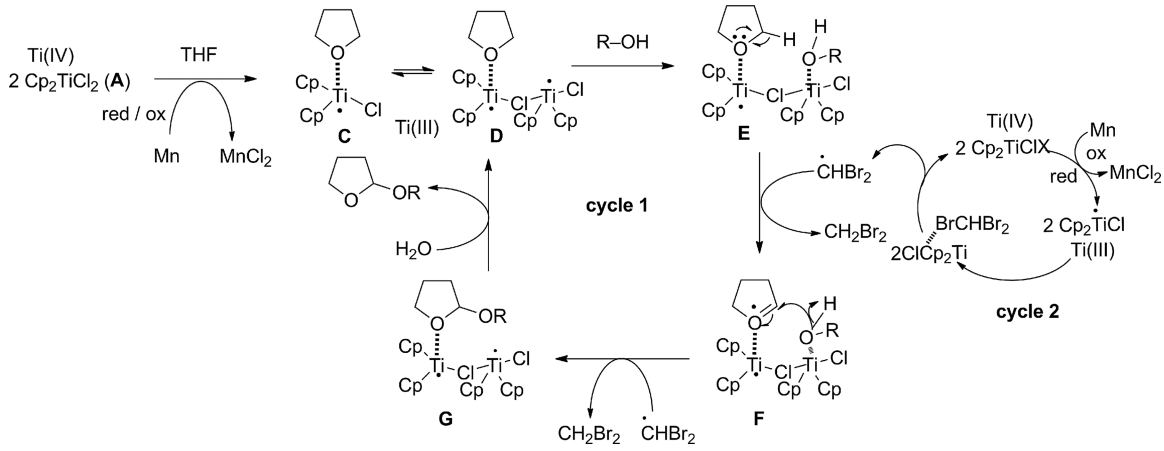
The proposed mechanism involves coupled cycles in which the Ti^{III} species is regenerated at various stages by the excess Mn^0 and both a molecule of THF and another of the corresponding alcohol[7,17] are coordinated in the half-open structure **D** affording the **E** structure. In one of these (cycle 2, Scheme 2), the Ti^{III} species generates the dibromomethane radical from $CHBr_3$. Two of these radicals then play a major role in the primary cycle (cycle 1, Scheme 2) in which the acetal is formed. One abstracts a hydrogen atom from the α-position of a co-ordinated THF to form dibromomethane and the heteroatom stabilized radical **F**. The other dibromomethyl radical abstracts a hydrogen atom from the titanium-alcohol complex.[7,18] Combination of this oxygen radical with a THF radical affords the THF ether.

In support of this mechanism dibromomethane and (±)-2-(1-bromoethyl)tetrahydrofuran were detected in the reaction mixture by mass spectrometry when $CHBr_3$ and CH_3CHBr_2 respectively, were used as alkyl halides. The formation of a 2-bromotetrahydrofuran intermediate in the reaction mechanism, which had been proposed previously,[1b,1c] could not be detected by mass spectrometry (MS).

Furthermore treatment of Cp_2TiCl and $CHBr_3$ with 2,4,6-collidine and TMSCl in THF as potential Ti^{IV} regenerating agents, did not yield the expected 4-bromobutyl trimethylsilyl ether or 4-bromobutanol.[19] Interestingly when these reagents were used in the cyclopropanation reaction with CH_2I_2 (Scheme 1), the corresponding 4-iodobutyl trimethylsilyl ether and 4-iodobutanol were obtained but the THF ether was not detected.

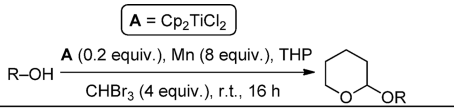
A similar mechanism is postulated for the chiral titanium complex **B**. Its greater steric rigidity and lower conformational mobility may account for the increase in yield.

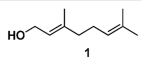
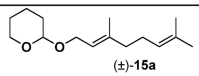
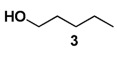
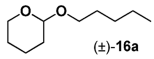
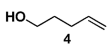
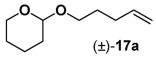
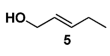
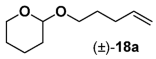
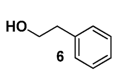
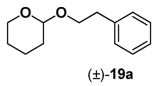
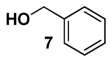
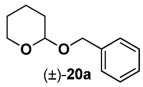
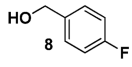
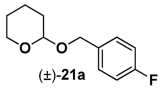
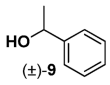
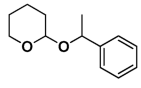
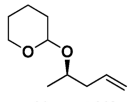
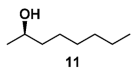
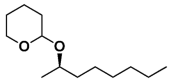
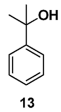
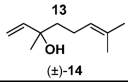
The protection of hydroxyl groups as their tetrahydropyranyl ethers is another commonly used strategy in synthesis because of their stability in the presence of strong bases and nucleophiles along with its ability to be converted directly in other functional groups.[2,6] Consequently Cp_2TiCl was generated in dry degassed tetrahydropyran and tested against a number of alcohols using $CHBr_3$ as the alkyl halide. The results (Table 4) showed that primary alcohols were converted into the corresponding THP ethers in good yield at room temperature (entries 1–7, Table 4) but



Scheme 2. Proposed mechanism for the formation of THF ethers.

Table 4. Tetrahydropyranylation of alcohols using a catalytic amount of Cp_2TiCl_2.

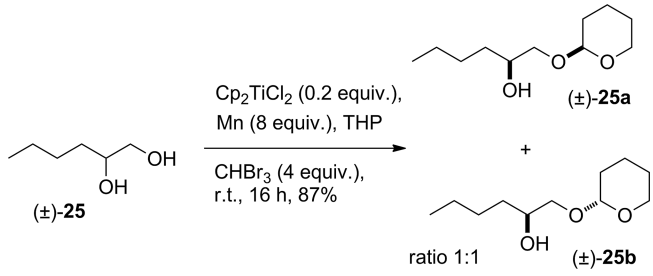


Entry	Substrate	THF ether	Yield[a]
1	 1	 (±)-**15a**	90%
2	 3	 (±)-**16a**	73%
3	 4	 (±)-**17a**	71%
4	 5	 (±)-**18a**	72%
5	 6	 (±)-**19a**	86%
6	 7	 (±)-**20a**	88%
7	 8 F	 (±)-**21a** F	89%
8	 (±)-**9**	 (±)-**22a** and (±)-**22b**	33%[b,c]
9	 10	 **23a** and **23b**	27%[b,c]
10	 11	 **24a** and **24b**	39%[b,c]
11	 13	–	n.r.[d]
12	 (±)-**14**	–	n.r.[d]

[a] Determined from the GC chromatogram of the crude mixture. [b] The reaction was carried out at 60 °C. [c] Mixture of diasteroisomers. [d] n.r.: no reaction.

secondary alcohols (entries 8–10, Table 4) were only converted in moderate yield at 60 °C. Tertiary alcohols did not react (entries 11–12, Table 4). The formation of the THP ethers may be explained by a similar mechanism to that which has been proposed for THF ethers (Scheme 2). To the best of our knowledge, it has not previously been obtained Cp_2TiCl in THP. Poorer access of the THP to the coordination site of the partially opened dimeric structure might account for the moderate yield and more limited scope of the tetrahydropyranylation reaction. The use of the titanium complex **B** did not improve the yield.

The difference in the reaction rates of the primary and secondary alcohols suggested a possible chemoselectivity which was examined with (±)-hexane-1,2-diol [(±)-**25**] (Scheme 3). Only the primary alcohol was protected in 87% yield and no secondary THP ether could be detected. Further experiments are in progress to improve the yield and extend the scope of the tetrahydropyranylation reaction.



Scheme 3. Tetrahydropyranylation of hexane-1,2-diol [(±)-**25**].

Conclusions

We have managed to develop a new catalytic method for the protection of hydroxyl groups as their THF or THP ethers using $Cp_2Ti^{III}Cl$ or the reduced form of a chiral titanium complex in THF or THP and $CHBr_3$ or CH_3CHBr_2 with manganese as a reductant. We have obtained the corresponding THF ethers from primary, secondary, tertiary, allylic and benzylic alcohols under mild conditions in good to excellent yields. The THP ethers from primary, secondary, allylic and benzylic alcohols were formed in moderate

yields. This unexpected reaction has revealed an interesting participation of the solvent (THF and THP) which may arise from an efficient co-ordination with the dimeric species $(Cp_2TiCl)_2$.[15] In addition this reaction would imply that previously proposed dimeric half-open complex may be the active reagent in solution to bring the alcohol and the THF/THP together.[15]

Experimental Section

General Experimental Methods: Unless otherwise noted, materials and reagents were obtained from commercial suppliers and were used without further purification. Tetrahydrofuran was freshly distilled from Na and strictly deoxygenated for 30 min under argon prior to use. Air- and moisture-sensitive reactions were performed under an argon atmosphere. Purification by semipreparative and analytical HPLC was performed with a Hitachi/Merck L-6270 apparatus equipped with a differential refractometer detector (RI-7490). A LiChrospher® Si 60 (5 μm) LiChroCart® (250 mm × 4 mm) column and a LiChrospher® Si 60 (10 μm) LiChroCart® (250 mm × 10 mm) were used in isolation experiments. Silica gel (Merck) was used for column chromatography. TLC was performed on Merck Kiesegel 60 F_{254}, 0.25 mm thick plates. Melting points were measured with a Reichert-Jung Kofler block and are uncorrected. Enantiomeric excesses (*ee*) were measured with a GC using a Cyclosil B chiral column. Optical rotations were determined with a digital polarimeter. Infrared spectra were recorded on a FT-IR spectrophotometer and reported as wave number (cm^{-1}). ^1H and ^{13}C NMR measurements were recorded on Varian Unity 400 MHz and Agilent 500 MHz spectrometers with $SiMe_4$ as the internal reference. Chemical shifts were referenced to $CDCl_3$ (δ_H = 7.25, δ_C = 77.0). NMR assignments were made using a combination of 1D and 2D techniques. Multiplicities are described using the following abbreviations: s = singlet, d = doublet, t = triplet, q = quartet; quint = quintuplet; sext = sextuplet; m = multiplet, br. = broad. High-Resolution Mass Spectroscopy (HRMS) were recorded with a double-focusing magnetic sector mass spectrometer in positive ion mode or in a QTOF mass spectrometer in positive ion APCI mode or in positive ion electrospray mode at 20 V cone voltage.

Preparation of Compound 12: This compound was obtained by means of the procedure described in the literature and its spectroscopic data were identical to those described in the literature.[7,20]

General Procedure for the Protection of Alcohols Mediated by Ti^{III}: A mixture of complex A or B (0.13 mmol) and Mn dust (279 mg, 5.12 mmol) in strictly deoxygenated THF or THP (25.4 mL) under an Ar atmosphere was stirred at room temperature for 15 min. The solution turned green. Then, a solution of the corresponding alcohol (0.64 mmol) and the corresponding alkyl halide (2.56 mmol) in strictly deoxygenated THF or THP (2.5 mL) was added, and the mixture was stirred for 16 h. The reaction was quenched with distilled water (20 mL), extracted with ethyl acetate (3 × 50 mL), dried with anhydrous Na_2SO_4, and evaporated under reduced pressure. The resulting crude product was purified by column chromatography on silica gel using mixtures of hexanes and ethyl acetate as eluent to afford the corresponding tetrahydrofuranyl or tetrahydropyranyl ethers.

(±)-(*E*)-2-[(3,7-Dimethylocta-2,6-dien-1-yl)oxy]tetrahydrofuran [(±)-1a]: Spectroscopic data of compound (±)-**1a** were identical to those described in the literature.[7]

(±)-2-(Pentyloxy)tetrahydrofuran [(±)-3a]: Colourless oil. IR (film): $\tilde{\nu}_{max}$ = 2920, 1262 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 5.08 (dd, J = 4.8, 1.2 Hz, 1 H), 3.84 (m, 2 H), 3.61 (m, 1 H), 3.34 (m, 1 H), 2.01–1.79 (m, 4 H), 1.55 (q, J = 7.0 Hz, 2 H), 1.31 (m, 4 H), 0.89 (t, J = 7.0 Hz, 3 H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 103.7, 67.3, 66.7, 32.3, 29.4, 28.3, 23.5, 22.4, 14.0 ppm. HRMS (CI^+): calcd. for $C_9H_{19}O_2$ $[M + H]^+$ 159.1385, found 159.1384.

(±)-2-(Pent-4-en-1-yloxy)tetrahydrofuran [(±)-4a]: Yellow oil. IR (film): $\tilde{\nu}_{max}$ = 2939, 1641, 1442, 1094, 1040, 917 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ = 5.80 (ddt, J = 17.2, 10.2, 6.8 Hz, 1 H), 5.08 (dd, J = 4.4, 1.6 Hz, 1 H), 4.99 (ddd, J = 17.2, 3.4, 1.6 Hz, 1 H), 4.93 (m, 1 H), 3.85 (m, 2 H), 3.64 (dt, J = 9.6, 6.8 Hz, 1 H), 3.36 (dt, J = 9.6, 6.8 Hz, 1 H), 2.08 (q, J = 6.8 Hz, 2 H), 1.99–1.80 (m, 4 H), 1.65 (m, 2 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 138.3, 114.6, 103.8, 66.8, 66.5, 32.3, 30.4, 28.9, 23.5 ppm. HRMS (ESI^+): calcd. for $C_9H_{16}O_2Na$ $[M + Na]^+$ 179.1048, found 179.1050.

(±)-(*E*)-2-(Pent-2-en-1-yloxy)tetrahydrofuran [(±)-5a]: Colourless oil. IR (film): $\tilde{\nu}_{max}$ = 2964, 2877, 1671, 1459, 1348, 1185, 1122, 1087 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 5.66 (m, 1 H), 5.46 (m, 1 H), 5.07 (dd, J = 3.6, 2.0 Hz, 1 H), 4.04 (m, 1 H), 3.80 (m, 3 H), 1.98–1.92 (m, 3 H), 1.86–1.81 (m, 2 H), 1.78–1.70 (m, 1 H), 0.92 (t, J = 7.6 Hz, 3 H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 135.8, 125.0, 102.8, 67.6, 66.6, 32.1, 25.1, 23.3, 13.1 ppm. HRMS (ESI^+): calcd. for $C_9H_{16}O_2Na$ $[M + Na]^+$ 179.1048, found 179.1042.

(±)-2-Phenethoxytetrahydrofuran [(±)-6a]: Colourless oil. IR (film): $\tilde{\nu}_{max}$ = 3021, 2987, 1620, 926 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 7.30–7.18 (m, 5 H), 5.12 (dd, J = 4.0, 2.8 Hz, 1 H), 3.89 (dt, J = 9.7, 7.3 Hz, 1 H), 3.83 (t, J = 7.2 Hz, 2 H), 3.61 (dt, J = 9.7, 7.3 Hz, 1 H), 2.88 (t, J = 7.2 Hz, 2 H), 2.00–1.96 (m, 1 H), 1.93–1.87 (m, 2 H), 1.85–1.76 (m, 1 H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 139.0, 128.8 (2 C), 128.2 (2 C), 126.0, 103.7, 67.8, 66.8, 36.3, 32.3, 23.4 ppm. HRMS (CI^+): calcd. for $C_{12}H_{17}O_2$ $[M + H]^+$ 193.1229, found 193.1226.

(±)-2-(Benzyloxy)tetrahydrofuran [(±)-7a]: Colourless oil. IR (film): $\tilde{\nu}_{max}$ = 2949, 2882, 1038, 1026, 734, 697 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 7.37–7.26 (m, 5 H), 5.22 (dd, J = 4.0, 2.0 Hz, 1 H), 4.72 (d, J = 12.0 Hz, 1 H), 4.48 (d, J = 12.0 Hz, 1 H), 3.92 (m, 2 H), 2.08–1.99 (m, 1 H), 1.97–1.91 (m, 2 H), 1.89–1.79 (m, 1 H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 138.2, 128.2 (2 C), 127.7 (2 C), 127.3, 102.9, 68.6, 66.8, 32.2, 23.3 ppm. HRMS (CI^+): calcd. for $C_{11}H_{13}O_2$ $[M - H]^+$ 177.0916, found 177.0916.

(±)-2-[(4-Fluorobenzyl)oxy]tetrahydrofuran [(±)-8a]: Colourless oil. IR (film): $\tilde{\nu}_{max}$ = 2884, 1604, 1510, 1222, 1085, 1037, 825 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ = 7.31–7.28 (m, 2 H), 7.03–6.98 (m, 2 H), 5.19 (t, J = 3.0 Hz, 1 H), 4.66 (d, J = 11.6 Hz, 1 H), 4.42 (d, J = 11.6 Hz, 1 H), 3.96–3.86 (m, 2 H), 2.05–1.98 (m, 1 H), 1.96–1.91 (m, 2 H), 1.89–1.80 (m, 1 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 162.2 (d, $J_{C,F}$ = 244 Hz), 134.1, 129.6, 129.5, 115.3, 115.0, 103.1, 68.1, 67.0, 32.3, 23.4 ppm. HRMS (ESI^+): calcd. for $C_{11}H_{13}O_2F$ $[M]^+$ 196.0900, found 196.0905.

(±)-(2*R,1′*R**)-2-(1-Phenylethoxy)tetrahydrofuran and (±)-(2*R**,1′*S**)-2-(1-Phenylethoxy)tetrahydrofuran [(±)-9a and (±)-9b]:** Diasteroisomer (±)-**9a**; Colourless oil: t_R = 10.9 min, petroleum ether/ethyl acetate (90:10), flow: 3.0 mL/min. IR (film): $\tilde{\nu}_{max}$ = 2974, 1450, 1283, 1019, 759, 699 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ = 7.35–7.25 (m, 5 H), 4.96 (dd, J = 4.4, 1.2 Hz, 1 H), 4.78 (q, J = 6.8 Hz, 1 H), 3.95 (ddd, J = 16.0, 8.4, 6.0 Hz, 1 H), 3.85 (m, 1 H), 2.09–2.00 (m, 1 H), 1.92–1.78 (m, 3 H),1.42 (d, J = 6.8 Hz, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 143.7, 128.4 (2 C), 127.4, 126.5 (2 C), 101.1, 73.4, 66.8, 32.3, 24.4, 23.5 ppm. HRMS (CI^+): calcd. for $C_{12}H_{15}O_2$ $[M - H]^+$ 191.1072, found 191.1068.

Diasteroisomer (±)-9b: Colourless oil; t_R = 13.0 min, petroleum ether/ethyl acetate (90:10), flow: 3.0 mL/min. IR (film): $\tilde{\nu}_{max}$ = 2974, 2883, 1451, 1182, 1086, 1016, 986, 758, 698 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.34–7.29 (m, 4 H), 7.24–7.20 (m, 1 H), 5.34 (dd, J = 4.8, 1.2 Hz, 1 H), 4.73 (q, J = 6.4 Hz, 1 H), 3.71 (m, 2 H), 2.05–1.76 (m, 4 H), 1.43 (d, J = 6.4 Hz, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 144.9, 128.2 (2 C), 126.9, 125.8 (2 C), 102.0, 73.5, 66.8, 32.5, 23.4, 22.3 ppm. HRMS (CI$^+$): calcd. for $C_{12}H_{15}O_2$ [M – H]$^+$ 191.1072, found 191.1063.

(2*R,2′*R*)-2-(pent-4-en-2-yloxy)tetrahydrofuran and (2*S**,2′*R*)-2-(Pent-4-en-2-yloxy)tetrahydrofuran (10a and 10b):** Mixture of diasteroisomers. Colourless oil. IR (film): $\tilde{\nu}_{max}$ = 3075, 2971, 2930, 1035, 916 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 5.83–5.71 (m, 2 H), 5.22–4.98 (m, 4 H), 3.90–3.69 (m, 6 H), 2.30–2.22 (m, 2 H), 2.17–2.09 (m, 2 H), 2.00–1.77 (m, 8 H), 1.14 (d, J = 6.4 Hz, 3 H), 1.09 (d, J = 6.0 Hz, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 135.4, 135.0, 116.8, 116.4, 103.0, 101.3, 72.5, 71.0, 66.6, 66.5, 41.9, 40.8, 32.5, 32.4, 23.4 (2 C), 21.3, 19.1 ppm. HRMS (ESI$^+$): calcd. for $C_9H_{16}O_2Na$ [M + Na]$^+$ 179.1048, found 179.1051.

(2*R,2′*R*)-(Octan-2-yloxy)tetrahydropyran and (2*S**,2′*R*)-(Octan-2-yloxy)tetrahydrofuran (11a and 11b):** Diasteroisomer **11a**; Colourless oil: t_R = 13.7 min, petroleum ether/ethyl acetate (100:0), flow: 3.0 mL/min. $[\alpha]_D^{20}$ = +3.8 (c = 0.8, MeOH). IR (film): $\tilde{\nu}_{max}$ = 2924, 2854, 1458, 1034 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 5.20 (d, J = 4.4, 1.6 Hz, 1 H), 3.89 (dt, J = 7.6, 5.6 Hz, 1 H), 3.82 (dt, J = 7.6, 5.2 Hz, 1 H), 3.63 (sext, J = 6.0 Hz, 1 H), 2.02–1.74 (m, 3 H), 1.48 (m, 1 H), 1.38–1.23 (m, 9 H), 1.15 (d, J = 6.0 Hz, 3 H), 0.87 (t, J = 6.4 Hz, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 103.4, 73.7, 66.5, 36.7, 32.5, 31.8, 29.4, 25.6, 23.5, 22.6, 21.7, 14.1 ppm. HRMS (CI$^+$): calcd. for $C_{12}H_{25}O_2$ [M + H]$^+$ 201.1855, found 201.1848.

Diasteroisomer 11b: Colourless oil: t_R = 14.8 min, petroleum ether/ethyl acetate (100:0), flow: 3.0 mL/min. IR (film): $\tilde{\nu}_{max}$ = 2924, 2854, 1458, 1034 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ = 5.21 (br. d, J = 4.0 Hz, 1 H), 3.84 (m, 2 H), 3.69 (m, 1 H), 2.03–1.92 (m, 1 H), 1.91–1.76 (m, 3 H), 1.46 (m, 1 H), 1.36–1.24 (m, 9 H), 1.08 (d, J = 6.0 Hz, 3 H), 0.86 (t, J = 6.4 Hz, 3 H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 100.8, 71.0, 66.6, 37.5, 32.5, 31.9, 29.2, 25.7, 23.5, 22.6, 19.4, 14.0 ppm. HRMS (CI$^+$): calcd. for $C_{12}H_{25}O_2$ [M + H]$^+$ 201.1855, found 201.1848.

(2*R)-2-{[(1*R*,5*R*)-2-methyl-5-(prop-1-en-2-yl)cyclohex-2-en-1-yl]-oxy}tetrahydrofuran and (2*S**)-2-{[(1*R*,5*R*)-2-Methyl-5-(prop-1-en-2-yl)cyclohex-2-en-1-yl]oxy}tetrahydrofuran (12a and 12b):** Mixture of diasteroisomers. Colourless oil: IR (film): $\tilde{\nu}_{max}$ = 2968, 2942, 2918, 2884, 1645, 1453, 1084, 1032 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 5.52–5.47 (m, 2 H), 5.28 (dd, J = 3.6, 2.4 Hz, 1 H), 5.26 (dd, J = 4.0, 2.4 Hz, 1 H), 4.70 (br. s, 4 H), 4.25 (m, 1 H), 4.08 (m, 1 H), 3.95–3.82 (m, 4 H), 2.24–2.19 (m, 6 H), 2.06–1.80 (m, 10 H), 1.70 (s, 6 H), 1.67 (s, 6 H), 1.52–1.34 (m, 2 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 149.1 (2 C), 135.3, 135.2, 124.5, 124.4, 109.0, 108.9, 105.5, 100.5, 77.4, 73.3, 66.8, 66.6, 40.8, 40.6, 36.8, 34.0, 32.55, 32.53, 30.9, 30.8, 23.44, 23.36, 20.4 (2 C), 19.3, 19.2 ppm. HRMS (ESI$^+$): calcd. for $C_{14}H_{22}O_2Na$ [M + Na]$^+$ 245.1517, found 245.1523.

(±)-2-[(2-Phenylpropan-2-yl)oxy]tetrahydrofuran [(±)-13a]: Yellow oil. IR (film): $\tilde{\nu}_{max}$ = 2978, 1161, 1068, 1037, 1012, 993, 764, 700 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.41 (m, 2 H), 7.31 (m, 2 H), 7.21 (m, 1 H), 5.09 (dd, J = 4.4, 2.8 Hz, 1 H), 3.92 (dt, J = 7.8, 6.8 Hz, 1 H), 3.74 (dt, J = 7.8, 5.6 Hz, 1 H), 2.06–1.96 (m, 1 H), 1.88–1.83 (m, 2 H), 1.80–1.67 (m, 1 H), 1.65 (s, 3 H), 1.49 (s, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 147.3, 128.1 (2 C), 126.7, 125.7 (2 C), 99.9, 77.3, 66.8, 33.3, 31.5, 27.4, 23.8 ppm. HRMS (ESI$^+$): calcd. for $C_{13}H_{18}O_2Na$ [M + Na]$^+$ 229.1204, found 229.1194.

(±)-(2*R,1*R**)-2-[(3,7-Dimethylocta-1,6-dien-3-yl)oxy]tetrahydrofuran and (±)-(2*R**,1*S**)-2-[(3,7-Dimethylocta-1,6-dien-3-yl)oxy]-tetrahydrofuran [(±)-14a and (±)-14b]:** Diastereoisomer (±)-**14a**; Yellow oil: t_R = 5.4 min, petroleum ether/ethyl acetate (95:5), flow: 1.0 mL/min. IR (film): $\tilde{\nu}_{max}$ = 2968, 2927, 1639, 1452, 1412, 1376, 1112 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 5.79 (dd, J = 10.8, 17.2 Hz, 1 H), 5.28 (dd, J = 5.0, 2.0 Hz, 1 H), 5.15–5.06 (m, 3 H), 3.92 (dt, J = 7.6, 6.4 Hz, 1 H), 3.77 (dt, J = 7.6, 6.4 Hz, 1 H), 2.00–1.93 (m, 4 H), 1.91–1.73 (m, 3 H), 1.66 (s, 3 H), 1.58 (s, 3 H), 1.55–1.49 (m, 1 H), 1.33 (s, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 143.4, 131.2, 124.6, 114.2, 99.2, 78.1, 66.7, 41.6, 33.3, 25.7, 23.9, 23.1, 22.4, 17.6 ppm. HRMS (CI$^+$): calcd. for $C_{14}H_{25}O_2$ [M + H]$^+$ 225.1855, found 225.1848.

Diasteroisomer (±)-14b: Yellow oil: t_R = 6.5 min, petroleum ether/ethyl acetate (95:5), flow: 1.0 mL/min. IR (film): $\tilde{\nu}_{max}$ = 2968, 2927, 1639, 1452, 1412, 1376, 1112 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 5.92 (dd, J = 17.6, 10.4 Hz, 1 H), 5.31 (dd, J = 5.0, 1.7 Hz, 1 H), 5.15–5.07 (m, 3 H), 3.93 (m, 1 H), 3.77 (m, 1 H), 2.00–1.93 (m, 4 H), 1.91–1.73 (m, 3 H), 1.67 (s, 3 H), 1.59 (s, 3 H), 1.55–1.49 (m, 1 H), 1.26 (s, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 144.0, 131.2, 124.7, 113.4, 99.0, 77.8, 66.8, 40.1, 33.5, 25.7, 23.9, 23.2, 22.5, 17.6 ppm. HRMS (CI$^+$): calcd. for $C_{14}H_{25}O_2$ [M + H]$^+$ 225.1855, found 225.1853.

(±)-(*E*)-2-[(3,7-Dimethylocta-2,6-dien-1-yl)oxy]tetrahydropyran [(±)-15a]: Spectroscopic data of compound (±)-**15a** were identical to those described in the literature.[21]

(±)-2-(Pentyloxy)tetrahydropyran [(±)-16a]: Colourless oil. IR (film): $\tilde{\nu}_{max}$ = 2929, 903, 745 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ = 4.56 (dd, J = 6.5, 5.5 Hz, 1 H), 3.86 (ddd, J = 11.2, 7.6, 3.4 Hz, 1 H), 3.73 (dt, J = 9.6, 6.9 Hz, 1 H), 3.49 (m, 1 H), 3.37 (dt, J = 9.6, 6.9 Hz, 1 H), 1.86–1.79 (m, 1 H), 1.74–1.68 (m, 1 H), 1.62–1.49 (m, 4 H), 1.35–1.24 (m, 6 H), 0.88 (m, 3 H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 98.8, 67.7, 62.3, 30.8, 29.4, 28.4, 25.5, 22.6, 19.7, 14.1 ppm. HRMS (ESI$^+$): calcd. for $C_{10}H_{20}O_2Na$ [M + Na]$^+$ 195.1361, found 195.1371.

(±)-2-(Pent-4-en-1-yloxy)tetrahydropyran [(±)-17a]: Colourless oil. IR (film): $\tilde{\nu}_{max}$ = 2934, 2887, 1671, 1452, 1350, 1185, 1122, 1027 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ = 5.82 (ddt, J = 16.8, 10.0, 6.6 Hz, 1 H), 5.02 (ddd, J = 16.8, 4.0, 1.5 Hz, 1 H), 4.95 (m, 1 H), 4.57 (dd, J = 4.3, 2.8 Hz, 1 H), 3.86 (ddd, J = 11.3, 7.9, 3.3 Hz, 1 H), 3.74 (dt, J = 9.6, 6.6 Hz, 1 H), 3.49 (m, 1 H), 3.39 (dt, J = 9.6, 6.6 Hz, 1 H), 2.13 (m, 2 H), 1.86–1.80 (m, 1 H), 1.74–1.67 (m, 3 H), 1.60–1.50 (m, 4 H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 138.4, 114.6, 98.8, 66.9, 62.3, 30.7, 30.4, 28.9, 25.5, 19.6 ppm. HRMS (ESI$^+$): calcd. for $C_{10}H_{18}O_2Na$ [M + Na]$^+$ 193.1204, found 193.1205.

(±)-(*E*)-2-(Pent-2-en-1-yloxy)tetrahydropyran [(±)-18a]: Colourless oil. IR (film): $\tilde{\nu}_{max}$ = 2931, 2886, 1671, 1454, 1352, 1208, 1121, 1024 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 5.75 (m, 1 H), 5.56 (m, 1 H), 4.63 (t, J = 3.6 Hz, 1 H), 4.18 (dd, J = 11.6, 6.0 Hz, 1 H), 3.89 (m, 2 H), 3.49 (m, 1 H), 2.06 (quint, J = 7.2 Hz, 2 H), 1.88–1.79 (m, 1 H), 1.75–1.68 (m, 1 H), 1.62–1.50 (m, 4 H), 0.99 (t, J = 7.2 Hz, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 136.2, 125.0, 97.8, 67.9, 62.2, 30.7, 25.5, 25.3, 19.6, 13.3 ppm. HRMS (ESI$^+$): calcd. for $C_{10}H_{18}O_2Na$ [M + Na]$^+$ 193.1204, found 193.1199.

(±)-2-Phenethoxytetrahydropyran [(±)-19a]: Spectroscopic data of compound (±)-**19a** were identical to those described in the literature.[2a]

(±)-2-(Benzyloxy)tetrahydropyran [(±)-20a]: Spectroscopic data of compound (±)-**20a** were identical to those described in the literature.[2a]

(±)-2-[(4-Fluorobenzyl)oxy]tetrahydropyran [(±)-21a]: Colourless oil. IR (film): $\tilde{\nu}_{max}$ = 2929, 2886, 1606, 1510, 1226, 1104, 1025, 827 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ = 7.34–7.31 (m, 2 H), 7.05–6.99 (m, 2 H), 4.74 (d, J = 12.0 Hz, 1 H), 4.68 (t, J = 3.6 Hz, 1 H), 4.46 (d, J = 12.0 Hz, 1 H), 3.90 (ddd, J = 11.6, 8.2, 3.4 Hz, 1 H), 3.54 (m, 1 H), 1.90–1.80 (m, 1 H), 1.77–1.69 (m, 1 H), 1.67–1.52 (m, 4 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 162.3 (d, $J_{C,F}$ = 244 Hz), 134.0, 129.6, 129.5, 115.3, 115.1, 97.7, 68.1, 62.2, 30.5, 25.4, 19.4 ppm. HRMS (ESI^+): calcd. for $C_{12}H_{15}O_2FNa$ [M + Na]$^+$ 233.0954, found 233.0947.

(±)-(2*R,1′*R**)-2-(1-Phenylethoxy)tetrahydropyran and (±)-(2*R**,1′*S**)-2-(1-Phenylethoxy)tetrahydropyran [(±)-22a and (±)-22b]:** Spectroscopic data of compound (±)-**22a** and (±)-**22b** were identical to those described in the literature.[2a]

(2*R,2′*R*)-2-(Pent-4-en-2-yloxy)tetrahydropyran and (2*S**,2′*R*)-2-(Pent-4-en-2-yloxy)tetrahydropyran (23a and 23b):** Diasteroisomer **23a**; Colourless oil: t_R = 28 min, petroleum ether/ethyl acetate (90:10), flow: 3.0 mL/min. $[\alpha]_D^{20}$ = –6.9 (c = 0.1, $CDCl_3$). IR (film): $\tilde{\nu}_{max}$ = 2931, 2886, 1454, 1204, 1121 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 5.85 (ddt, J = 17.2, 10.2, 7.1 Hz, 1 H), 5.08 (ddt, J = 17.2, 2.2, 1.5 Hz, 1 H), 5.03 (ddt, J = 10.0, 2.2, 1.5 Hz, 1 H), 4.71 (t, J = 3.5 Hz, 1 H), 3.90 (ddd, J = 11.2, 7.8, 3.4 Hz, 1 H), 3.84 (sext, J = 6.2 Hz, 1 H), 3.48 (m, 1 H), 2.38 (m, 1 H), 2.22 (m, 1 H), 1.85–1.78 (m, 1 H), 1.73–1.68 (m, 1 H), 1.58–1.49 (m, 4 H), 1.11 (d, J = 6.2 Hz, 3 H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 135.4, 116.7, 95.9, 70.9, 62.4, 42.0, 31.2, 25.6, 19.7, 18.8 ppm. HRMS (ESI^+): calcd. for $C_{10}H_{18}O_2Na$ [M + Na]$^+$ 193.1204, found 193.1200.

Diasteroisomer 23b: Colourless oil; t_R = 29 min, petroleum ether/ethyl acetate (90:10), flow: 3.0 mL/min. $[\alpha]_D^{20}$ = –2.8 (c = 0.1, $CDCl_3$). IR (film): $\tilde{\nu}_{max}$ = 2934, 2885, 1462, 1208, 1108 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 5.78 (ddt, J = 17.5, 10.5, 7.0 Hz, 1 H), 5.06–5.01 (m, 2 H), 4.66 (t, J = 3.0 Hz, 1 H), 3.90 (m, 1 H), 3.81 (sext, J = 6.5 Hz, 1 H), 3.51 (m, 1 H), 2.37 (m, 1 H), 2.18 (m, 1 H), 1.85–1.78 (m, 1 H), 1.73–1.65 (m, 1 H), 1.54–1.48 (m, 4 H), 1.21 (d, J = 6.3 Hz, 3 H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 134.9, 116.9, 98.0, 72.6, 62.8, 40.7, 31.0, 25.5, 21.2, 20.0 ppm. HRMS (ESI^+): calcd. for $C_{10}H_{18}O_2Na$ [M + Na]$^+$ 193.1204, found 193.1198.

(2*R,2′*R*)-(Octan-2-yloxy)tetrahydropyran and (2*S**,2′*R*)-(Octan-2-yloxy)tetrahydropyran (24a and 24b):** Mixture of diasteroisomers; colourless oil. IR (film): $\tilde{\nu}_{max}$ = 2936, 2897, 1022, 912 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 4.70 (t, J = 4.5 Hz, 1 H), 4.62 (m, 1 H), 3.94–3.86 (m, 2 H), 3.75 (sext, J = 6.4 Hz, 1 H), 3.70 (sext, J = 6.4 Hz, 1 H), 3.48 (m, 2 H), 1.86–1.78 (m, 2 H), 1.73–1.66 (m, 2 H), 1.59–1.49 (m, 10 H), 1.31–1.25 (m, 18 H), 1.20 (d, J = 8.0 Hz, 3 H), 1.09 (d, J = 7.5 Hz, 3 H), 0.87 (t, J = 8.5 Hz, 6 H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 98.6, 95.6, 73.9, 71.2, 62.9, 62.4, 37.6, 36.5, 31.8 (2 C), 31.4, 31.2, 29.43, 29.40, 25.8, 25.6, 25.5, 25.4, 22.65, 22.62, 21.6, 20.1, 19.7, 19.1, 14.09, 14.08 ppm. HRMS (ESI^+): calcd. for $C_{13}H_{26}O_2Na$ [M + Na]$^+$ 237.1830, found 237.1843.

(±)-(*S)-1-[(*S**)-Tetrahydro-2*H*-pyran-2-yl]oxyhexan-2-ol and (±)-(*S**)-1-[(*R**)-Tetrahydro-2*H*-pyran-2-yl]oxyhexan-2-ol [(±)-25a] and [(±)-25b]:** Diasteroisomer (±)-**25a**; Colourless oil; t_R = 17 min, petroleum ether/ethyl acetate (90:10), flow: 3.0 mL/min. $[\alpha]_D^{20}$ = +7.1 (c = 0.1, $CDCl_3$). IR (film): $\tilde{\nu}_{max}$ = 3406, 2929, 1454, 1204, 1121 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 4.57 (dd, J = 5.0, 2.0 Hz, 1 H), 3.94–3.89 (m, 1 H), 3.78–3.74, (m, 1 H), 3.64 (dd, J = 10.5, 2.0 Hz, 1 H), 3.56–3.52 (m, 1 H), 3.50 (dd, J = 10.5, 8.0 Hz, 1 H), 3.14 (d, J = 2.0 Hz, OH), 1.86–1.81 (m, 1 H), 1.78–1.74 (m, 1 H), 1.61–1.51 (m, 4 H), 1.47–1.30 (m, 6 H), 0.90 (t, J = 7.0 Hz, 3 H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 100.1, 74.1, 70.6, 63.2, 32.7, 30.8, 27.7, 25.2, 22.7, 20.0, 14.0 ppm. HRMS (ESI^+): calcd. for $C_{11}H_{22}O_3Na$ [M + Na]$^+$ 225.1461, found 225.1459.

Diasteroisomer (±)-25b: Colourless oil; t_R = 19 min, petroleum ether/ethyl acetate (90:10), flow: 3.0 mL/min. $[\alpha]_D^{20}$ = 4.5 (c = 0.1, $CDCl_3$). IR (film): $\tilde{\nu}_{max}$ = 3408, 2931, 2886, 1454, 1221, 1104 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 4.56 (dd, J = 5.0, 2.0 Hz, 1 H), 3.92–3.86 (m, 1 H), 3.77–3.74, (m, 2 H), 3.53–3.49 (m, 1 H), 3.32 (t, J = 9.5 Hz, 1 H), 2.60 (s, OH), 1.85–1.72 (m, 2 H), 1.59–1.31 (m, 10 H), 0.90 (t, J = 7.0 Hz, 3 H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 100.1, 73.0, 70.6, 63.0, 32.9, 30.7, 27.7, 25.3, 22.7, 19.9, 14.0 ppm. HRMS (ESI^+): calcd. for $C_{11}H_{22}O_3Na$ [M + Na]$^+$ 225.1461, found 225.1465.

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