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Efficiency of Acid- and Mercury-Catalyzed Cyclization Reactions in the Synthesis of Tetrahydrofurans from Allylsilyl Alcohols

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The scope of the acid-catalyzed and mercury-catalyzed cyclization reactions of allylsilyl alcohols is described. This methodology has been found to be an efficient approach to the synthesis of highly substituted tetrahydrofurans. The stereoselectivity of the cyclization is dependent both on the substitution of the starting alcohol and on the catalyst. A plausible mechanism has been proposed that is consistent with the results.

Introduction

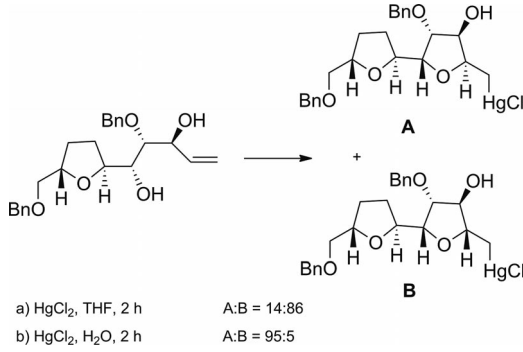
Substituted tetrahydrofurans are structural motifs present in a great number of natural products, such as macrodiolides,[1] lignans,[2] amphidinolides,[3] or antibiotic polyethers.[4] As a result of their important biological activities, considerable effort has been directed towards developing new stereoselective routes to these oxacycles.[5]

An efficient and widely used methodology for the synthesis of tetrahydrofurans is the electrophilic cyclization of γ,δ-unsaturated alcohols.[6]

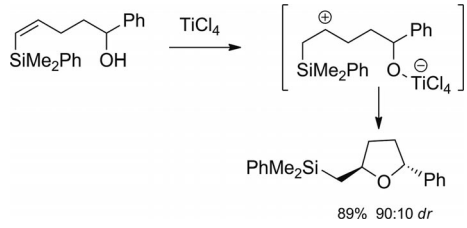
Among others,[7] a commonly employed approach is the mercury-catalyzed cyclization reaction. It has been reported that the stereoselectivity of mercury-catalyzed cyclization reactions depends on several factors, such as the nature of the mercury salt,[8] the structure of the unsaturated alcohol,[9] and the presence or not of additives, such as water,[10] in the reaction media (Scheme 1).

An alternative strategy to the synthesis of tetrahydrofurans is the acid-catalyzed cyclization of unsaturated alcohols, although this route has shown major limitations. However, Hosomi and co-workers[11] reported that the cyclization of vinylsilyl alcohols in the presence of a Lewis acid proceeds with high *trans* selectivity. A plausible mechanism for this reaction involves electrophilic addition to the vinylsilane to give a β-silyl carbocation, which is then trapped by the internal hydroxy group to give the tetrahydrofuran derivative (Scheme 2).

Moreover, allylsilanes have been widely recognized as valuable synthons in controlling, in a very effective way, the regio- and stereochemical outcome of many chemical transformations,[12] especially in the area of stereoselective allylation processes.[10] Thus, these organosilicon compounds are nucleophilic units that are stable towards most reagents and reaction conditions and are thus able to react with a wide range of electrophiles.



Scheme 1. Mercury-catalyzed cyclization of unsaturated alcohols.



Scheme 2. Acid-catalyzed cyclization of vinylsilyl alcohols.

For many years our research group has been involved in the study of the synthetic applications of allylsilanes containing an electrophilic moiety within the same molecule.[13] The so-called allylsilane-terminated cyclization of these substrates has allowed the synthesis of different-sized

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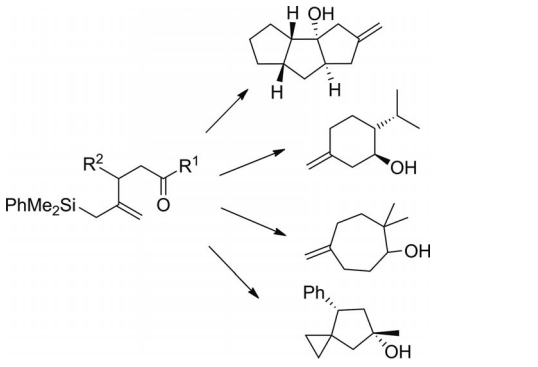
carbocycles, such us methylenecyclopentanols,[14] methylenecyclohexanols,[15] methylenecycloheptanols,[16] or spirocyclopropylcyclopentanols[17] (Scheme 3).



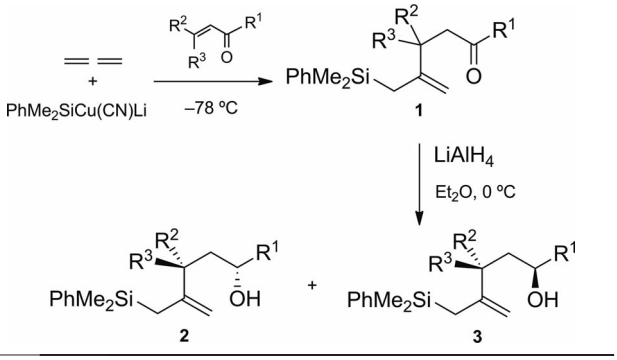
Scheme 3. Synthesis of different-sized carbocycles from allylsilyl ketones.

Results and Discussion

In this paper we describe an interesting approach towards the synthesis of tetrahydrofurans from allylsilyl alcohols by mercury-catalyzed cyclization and acid-catalyzed reactions.

Thus, following our methodology for the silylcupration of allene and the capture of the intermediate cuprate with α,β-unsaturated carbonylic compounds we were able to prepare allylsilyl aldehydes and ketones **1a**–**i** in high yields. The corresponding allylsilyl alcohols needed for this study were readily obtained by reduction with $LiAlH_4$ in a quantitative manner (Table 1).

Table 1. Synthesis of allylsilyl alcohols **2** and **3**.

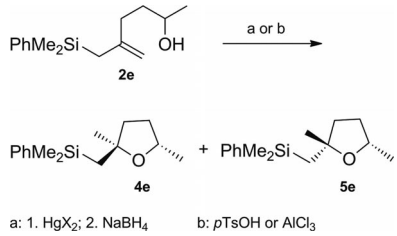


Entry	Compound[a] R1	R2	R3		Ratio 2/3	Yield [%]
1	H	H	H	**2a**		90
2	H	Me	H	**2b**		91
3	H	Pr	H	**2c**		92
4	H	Ph	H	**2d**		90
5	Me	H	H	**2e**		89
6	Et	H	H	**2f**		92
7	Me	Me	Me	**2g**		90
8	Me	Ph	H	**2h/3h**	50:50	90
9	Ph	Ph	H	**2i/3i**	50:50	88

[a] All the alcohols are obtained as racemic mixtures.

First, we studied the scope of this methodology in the synthesis of substituted tetrahydrofurans, comparing the efficiency of the acid-catalyzed and mercury-catalyzed cyclization reactions of allylsilyl alcohol **2e**. The results are shown in Table 2.

Table 2. Cyclization of allylsilyl alcohol **2e**.



Entry	Reagent	Molar equiv.	Temp. [°C]	Time [h]	Ratio[a] **4e/5e**	Yield [%]
1	$Hg(OCOCF_3)_2$	1	–40→0	2	50:50	79
2	$Hg(OAc)_2$	1	–40→0	4	50:50	70[b]
3	$Hg(OAc)_2$	1	–60→0	16	50:50	65[c]
4	$HgCl_2$	1	r.t.	4		–
5	TsOH	0.2	0	1	50:50	75
6	$AlCl_3$	1	–78	2	55:45	62

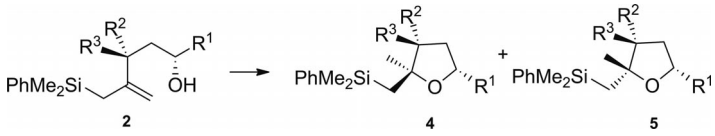
[a] The ratios of isomers **4e** and **5e** were determined by ^1H NMR analysis. [b] A 1:1 mixture of the corresponding 1-hydroxymethyl-THF derivatives were also obtained in a yield of 9%. [c] A 1:1 mixture of the corresponding 1-hydroxymethyl THF derivatives were also obtained in a yield of 7%.

As shown in Table 2, the mercury-catalyzed cyclization reaction of **2e** with $Hg(OCOCF_3)_2$ afforded a 1:1 mixture of tetrahydrofurans **4e** and **5e** in good yield. Similar results were obtained by using $Hg(OAc)_2$, although the yield was slightly decreased due to the formation of minor amounts of the 1-hydroxymethyl-THF derivatives.[18] However, with $HgCl_2$, no cyclization products were obtained. In contrast to the results reported by Landais and co-workers, the stereoselectivity of this kinetically controlled mercury-catalyzed cyclization reaction is not affected by the nature of the mercury salt, nor by the temperature of the reaction.[8]

The acid-catalyzed cyclization also yielded an equimolar mixture of diastereoisomers **4e** and **5e**. The use of a Lewis acid ($AlCl_3$) provided similar results to the Brønsted acid (*p*TsOH) with regard to stereoselectivities, although the yield was lower.

With these results in hand we decided to study the influence of the substituents of the allylsilyl alcohol on the stereoselectivity of the cyclization. The results are shown in Table 3. The cyclization of allylsilanes **2b**–**2g** with mercuric salts provided the substituted tetrahydrofurans **4b**–**g** and **5b**–**g** in good yields as nearly 1:1 mixtures of diastereoisomers (Table 3, entries 2, 4, 5, 8, 10 and 12). On the other hand, the stereoselectivity of the acid-catalyzed cyclization of allylsilyl alcohols depends on their substitution patterns. Thus, allylsilanes **2b** and **2d** bearing an allylic substituent gave 2,2,3-trisubstituted tetrahydrofurans in high yields and with moderate selectivity towards the stereoisomers **4b** and

Table 3. Scope of the cyclization of allylsilyl alcohols **2a**–**g**.



Entry	Compound R1	R2	R3		Reagent	Molar equiv.	Temperature [°C]	Time [h]	Ratio[a] **4/5**	Yield [%]
1	H	H	H	**2a**	$Hg(OAc)_2$	1	–40→0	2		70
2	H	Me	H	**2b**	$Hg(OAc)_2$	1	–40→0	4	50:50	68
3	H	Me	H	**2b**	*p*TsOH	0.3	0	1.5	66:34	78
4	H	Pr	H	**2c**	$Hg(OAc)_2$	1	–40→0	2	66:34	85
5	H	Ph	H	**2d**	$Hg(OAc)_2$	1	–40→0	4	50:50	68
6	H	Ph	H	**2d**	*p*TsOH	0.3	0	1.5	73:27	79
7	H	Ph	H	**2d**	$AlCl_3$	0.5	–78	2	72:28	67[b]
8	Me	H	H	**2e**	$Hg(OCOCF_3)_2$	1	–40→0	2	50:50	79
9	Me	H	H	**2e**	*p*TsOH	0.2	0	1	50:50	75
10	Et	H	H	**2f**	$Hg(OAc)_2$	1	–40→0	2.5	50:50	70
11	Et	H	H	**2f**	*p*TsOH	0.2	0	1.5	50:50	72
12	Me	Me	Me	**2g**	$Hg(OAc)_2$	1	–40→0	2	66:34	74

[a] The ratios of isomers **4** and **5** were determined by ^{1}H NMR analysis. [b] Yield calculated from the recovered starting material.

4d with a *trans* arrangement between the R^2 and the silylmethyl substituent (up to 3:1 *dr*; Table 3, entries 3 and 6), whereas substrates **2e**,**f** with an alkyl substituent as R^1 provided substituted tetrahydrofurans as equimolar mixtures of diastereoisomers **4** and **5** (Table 3, entries 9, 11).

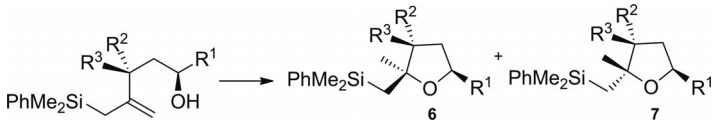
We next decided to study the influence of both substituents $R^1 \neq H$ and $R^2 \neq H$. Allylsilanes **2h**,**i** and **3h**,**i** underwent cyclization to provide mixtures of two diastereoisomers in high yields, the major isomers (**4** or **6**) being those with a 2,3-*trans* relationship between the R^2 and the sil-

Table 4. Scope of the cyclization of allylsilyl alcohols **2h**,**i**.

Entry	Compound R1	R2	R3		Reagent	Molar equiv.	Temperature [°C]	Time [h]	Ratio[a] **4/5**	Yield [%]
1	Me	Ph	H	**2h**	$Hg(OCOCF_3)_2$	1	–40→0	6	60:40	75
2	Me	Ph	H	**2h**	*p*TsOH	0.2	0	1	83:17	87
3	Me	Ph	H	**2h**	$AlCl_3$	1	–78	2	71:29	65[b]
4	Me	Ph	H	**2h**	$CHCl_3$[c]	–	62	1	72:28	35
5	Ph	Ph	H	**2i**	*p*TsOH	0.2	0	1	81:19	82
6	Ph	Ph	H	**2i**	$AlCl_3$	1	–78	2	70:30	69[b]
7	Ph	Ph	H	**2i**	$CHCl_3$[c]	–	62	1	60:40	34

[a] The ratios of isomers **4** and **5** were determined by ^{1}H NMR analysis. [b] Yield calculated from the recovered starting material. [c] $CHCl_3$ was used as solvent.

Table 5. Scope of the cyclization of allylsilyl alcohols **3h**,**i**.



Entry	Compound R1	R2	R3		Reagent	Molar equiv.	Temperature [°C]	Time [h]	Ratio[a] **6/7**	Yield [%]
1	Me	Ph	H	**3h**	$Hg(OCOCF_3)_2$	1	–40→0	5	63:37	80
2	Me	Ph	H	**3h**	*p*TsOH	0.2	0	1	78:22	86
3	Me	Ph	H	**3h**	$AlCl_3$	1	–78	2	74:26	65[b]
4	Me	Ph	H	**3h**	$CHCl_3$[c]	–	62	2	76:24	33
5	Ph	Ph	H	**3i**	*p*TsOH	0.2	0	1	77:23	79
6	Ph	Ph	H	**3i**	$AlCl_3$	1	–78	2	78:22	69[b]
7	Ph	Ph	H	**3i**	$CHCl_3$[c]	–	62	2	78:22	37

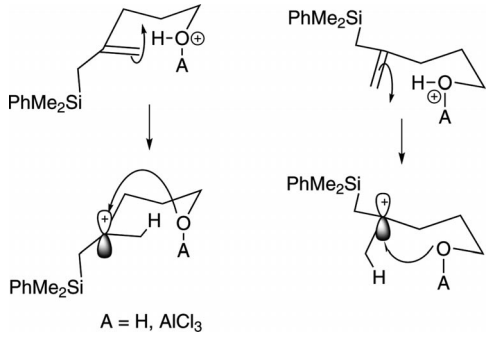
[a] The ratios of isomers **6** and **7** were determined by ^{1}H NMR analysis. [b] Yield calculated from the recovered starting material. [c] $CHCl_3$ was used as solvent.

ylmethyl group. As shown in Tables 4 and 5, in general, the acid-catalyzed cyclization provided higher stereoselectivities than the corresponding mercury-catalyzed cyclization reaction.[19] Note that a solution of these allylsilyl alcohols in chloroform at reflux also underwent cyclization. In this case, HCl generated in situ would be the catalyst.[20]

On the other hand, the acid-mediated cyclizations showed the best stereoselectivities and yields when *p*TsOH was used as the catalyst (Table 4, entries 2 and 5; Table 5, entry 2). However, the cyclization of stereoisomers **2h** and **2i** proceeded with better stereoselectivity (up to 5:1 *dr*; Table 4, entries 2 and 5) than the corresponding cyclization of **3h** and **3i** (up to 3.5:1 *dr*; Table 5, entries 2 and 5).

A plausible mechanism for this acid-catalyzed cyclization involves the electrophilic addition of the proton to the allylsilane moiety to give a stabilized carbocation β to the silicon, which, in turn, is trapped by the internal hydroxy group. In the reactive conformation, the C–Si bond is oriented parallel to the empty p orbital of the intermediate carbocation to allow the corresponding σ-p hyperconjugative stabilization and therefore intramolecular attack of the nucleophile will occur *anti* to the hindered silyl group.

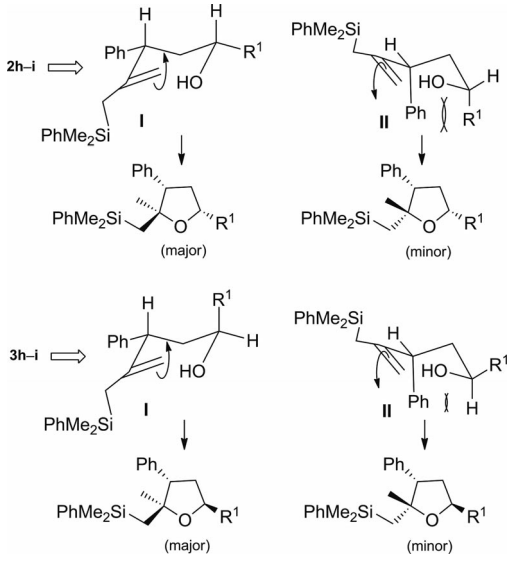
Hosomi and co-workers[11b] reported that the protonation step in the acid-catalyzed cyclization of vinylsilyl alcohols occurs through the attachment of a proton or $AlCl_3$ to the hydroxy group to form an oxonium ion, which will then deliver the proton to the double bond.[21] Moreover, they reported that the addition of the hydroxy group and the proton proceeds stereospecifically on the same side of the π bond. Based on these observations, we will assume the same *syn* addition for our allylsilanes (Scheme 4).



Scheme 4. Mechanism of the acid-catalyzed cyclization.

With regard to the stereochemical outcome of the cyclization reaction, two different reactive conformations can be drawn, namely **I** and **II** (Scheme 5).

In conformer **II**, an unfavorable steric interaction between the 1,3-diaxial substituents (Ph and H) would account for the major product proceeding from conformer **I**. This hypothesis is consistent with the fact that cyclization of allylsilyl alcohols **2h** and **2i** proceeded with higher stereoselectivity than the corresponding cyclization of **3h** and **3i**, namely because the diaxial steric strain between Ph and R^1 is greater.



Scheme 5. Stereochemical outcome of the cyclization.

Conclusions

We have shown that allylsilyl alcohols undergo both mercury and acid-catalyzed cyclization reactions to give substituted tetrahydrofurans in high yields. The stereoselectivity of the ring-forming process depends both on the nature of the catalyst and on the substitution pattern of the allylsilane. A mechanism for the reaction has been proposed that is consistent with the stereochemical outcome of the cyclization process.

Experimental Section

General: All the reactions were carried out under argon or nitrogen in dried glassware unless otherwise indicated. Materials were obtained from commercial suppliers and used without further purification unless otherwise noted. Solvents were dried and distilled according to the standard protocols. Flash column chromatography was performed on silica gel by using the indicated solvent. The syntheses and spectroscopic data of allylsilyl aldehydes and ketones **1a**–**i** have been described previously.[14a,15]

Synthesis of Allylsilyl Alcohols 2 and 3: A solution of the allylsilyl aldehydes or ketones **1a**–**i** (2 mmol) in dry ether (2 mL) was added to a suspension of $LiAlH_4$ (1.7 mmol) in dry diethyl ether (8 mL) at 0 °C. The mixture was stirred for 1 h at 0 °C and then quenched with $NaHCO_3$ (10%, 4 mL) and NaOH (20%, 4 mL). The organic layer was dried, the solvent evaporated, and the mixture was purified by flash chromatography (EtOAc/hexane) to give alcohols **2** and **3**.

(2*SR*,4*SR*)-5-[Dimethyl(phenyl)silylmethyl]-4-phenyl-5-hexen-2-ol (2h): Chromatography gave complete separation of the diastereoisomeric alcohols. Colorless oil (45%). IR (film): $\tilde{\nu}_{max}$ = 3385, 1633, 1599, 1249, 1113 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ = 7.75–7.71 (m, 2 H), 7.55–7.51 (m, 3 H), 7.46–7.41 (m, 2 H), 7.37–7.29 (m, 3 H), 5.08 (s, 1 H), 4.93 (s, 1 H), 3.61–3.48 (m, 1 H), 3.35 (dd, *J* = 10.1, 4.4 Hz, 1 H), 1.99–1.74 (m, 3 H), 1.92 (d, *J* = 14.0 Hz, 1 H),

1.76 (d, J = 14.0 Hz, 1 H), 1.21 (d, J = 6.6 Hz, 3 H), 0.52 (s, 3 H, CH_3Si), 0.47 (s, 3 H, CH_3Si) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 149.8 (C), 143.4 (C), 139.3 (C), 133.9 (CH), 129.2 (CH), 128.5 (CH), 128.0 (CH), 126.5 (CH), 107.8 (CH_2), 65.4 (CH), 48.9 (CH), 44.0 (CH_2), 26.0 (CH_2), 24.5 (CH_3), –2.5 (CH_3), –2.9 (CH_3) ppm. MS (EI): m/z = 324 $[M]^+$, 309 $[M – Me]^+$, 247 $[M – Ph]^+$, 135 $[SiMe_2Ph]^+$. $C_{21}H_{28}OSi$ (324.54): calcd. C 77.72, H 8.70; found C 78.04, H 8.98.

(2*RS*,4*SR*)-5-[Dimethyl(phenyl)silylmethyl]-4-phenyl-5-hexen-2-ol (3h): White solid (45%), m.p. 91–92 °C. IR (film): $\tilde{\nu}_{max}$ = 3460, 1629, 1548, 1249, 1113 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ = 7.61–7.57 (m, 2 H), 7.46–7.43 (m, 3 H), 7.34–7.24 (m, 3 H), 7.15–7.12 (m, 2 H), 4.91 (s, 1 H), 4.81 (s, 1 H), 3.61–3.51 (m, 1 H), 2.99 (t, J = 7.5 Hz, 1 H), 1.86–1.81 (m, 2 H), 1.76 (d, J = 14.1 Hz, 1 H), 1.58 (d, J = 14.1 Hz, 1 H), 1.32 (s, 1 H), 1.07 (d, J = 6.1 Hz, 3 H), 0.38 (s, 3 H, CH_3Si), 0.33 (s, 3 H, CH_3Si) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 148.6 (C), 143.5 (C), 139.1 (C), 133.7 (CH), 129.2 (CH), 128.4 (CH), 128.1 (CH), 127.9 (CH), 126.5 (CH), 107.7 (CH_2), 66.2 (CH), 49.2 (CH), 43.9 (CH_2), 25.6 (CH_2), 23.2 (CH_3), –2.6 (CH_3), –3.3 (CH_3) ppm. MS (EI): m/z = 324 $[M]^+$, 309 $[M – Me]^+$, 247 $[M – Ph]^+$, 135 $[SiMe_2Ph]^+$. $C_{21}H_{28}OSi$ (324.54): calcd. C 77.72, H 8.70; found C 78.06, H 9.02.

(1*RS*,3*SR*)-4-[Dimethyl(phenyl)silylmethyl]-1,3-diphenyl-4-penten-1-ol (2i): Chromatography gave complete separation of the diastereoisomeric alcohols. Colorless oil (44%). IR (film): $\tilde{\nu}_{max}$ = 3375, 1633, 1249, 1112 cm^{-1}. ^1H NMR (300 MHz, [D_6]acetone): δ = 7.55–7.49 (m, 2 H), 7.36–7.14 (m, 13 H), 4.83 (s, 1 H), 4.68 (s, 1 H), 4.29–4.23 (m, 1 H), 4.13 (d, J = 4.7 Hz, 1 H, OH), 3.62 (dd, J = 11.0, 3.8 Hz, 1 H), 2.15 (ddd, J = 13.9, 10.2, 3.8 Hz, 1 H), 2.04–1.96 (m, 1 H), 1.77 (d, J = 13.9 Hz, 1 H), 1.62 (d, J = 13.9 Hz, 1 H), 0.33 (s, 3 H, CH_3Si), 0.30 (s, 3 H, CH_3Si) ppm. ^{13}C NMR (75 MHz, [D_6]acetone): δ = 150.9 (C), 147.5 (C), 144.0 (C), 139.7 (C), 134.3 (CH), 129.6 (CH), 129.3 (CH), 129.0 (CH), 128.8 (CH), 128.5 (CH), 127.4 (CH), 127.0 (CH), 126.3 (CH), 108.0 (CH_2), 71.4 (CH), 49.6 (CH), 45.5 (CH_2), 26.1 (CH_2), –2.4 (CH_3), –2.5 (CH_3) ppm. MS (EI): m/z = 368 $[M – H_2O]^+$, 309 $[M – Ph]^+$, 135 $[SiMe_2Ph]^+$. $C_{26}H_{30}OSi$ (386.61): calcd. C 80.78, H 7.82; found C 81.12, H 8.12.

(1*SR*,3*SR*)-4-[Dimethyl(phenyl)silylmethyl]-1,3-diphenyl-4-penten-1-ol (3i): Colorless oil (44%). IR (film): $\tilde{\nu}_{max}$ = 3395, 1633, 1245, 1109 cm^{-1}. ^1H NMR (300 MHz, [D_6]acetone): δ = 7.43–7.09 (m, 15 H), 4.92 (s, 1 H), 4.72 (s, 1 H), 4.49 (td, J = 6.9, 4.2 Hz, 1 H), 4.16 (d, J = 4.2 Hz, 1 H, OH), 3.18 (t, J = 7.4 Hz, 1 H), 2.27–2.10 (m, 2 H), 1.69 (d, J = 13.9 Hz, 1 H), 1.52 (d, J = 13.9 Hz, 1 H), 0.18 (s, 3 H, CH_3Si), 0.15 (s, 3 H, CH_3Si) ppm. ^{13}C NMR (75 MHz, [D_6]acetone): δ = 149.7 (C), 146.5 (C), 144.5 (C), 139.6 (C), 134.2 (CH), 129.6 (CH), 129.0 (CH), 128.9 (CH), 128.4 (CH), 128.4 (CH), 127.8 (CH), 127.0 (CH), 126.9 (CH), 108.2 (CH_2), 72.4 (CH), 49.4 (CH), 44.9 (CH_2), 25.9 (CH_2), –2.6 (CH_3), –2.6 (CH_3) ppm. MS (EI): m/z = 368 $[M – H_2O]^+$, 309 $[M – Ph]^+$, 135 $[SiMe_2Ph]^+$.

Synthesis of Tetrahydrofurans 4–7 by the Use of Mercury Salts: A solution of the corresponding alcohol (1 mmol) in dry THF (1 mL) was added to a suspension of the mercury salt (1.09 mmol) and $CaCO_3$ (2.17 mmol) in dry THF (9 mL) at –40 °C. The stirred mixture was warmed to 0 °C and then $NaBH_4$ (0.72 mmol) in a 2.5 M solution of NaOH (4 mL) was added dropwise at 0 °C. The reaction mixture was vigorously stirred at 0 °C for 1 h and then a saturated NaCl solution was added (4 mL). The aqueous layer was extracted with diethyl ether and the combined extracts were washed with brine, dried with $MgSO_4$, and the solvents evaporated in vacuo to give an oil that was purified by chromatography (EtOAc/hexane).

Synthesis of Tetrahydrofurans 4–7 by Acid Catalysis: The acid catalyst in CH_2Cl_2 (0.5 mL) was added to a solution of the alcohol (1 mmol) in CH_2Cl_2 (5 mL). The mixture was stirred under the conditions shown in Tables 2–5) and then quenched with a saturated solution of $NaHCO_3$ (5 mL). The organic layer was washed three times with $NaHCO_3$, dried with $MgSO_4$, evaporated in vacuo, and purified by flash chromatography (EtOAc/hexane). The relative stereochemistries of the tetrahydrofurans were assigned on the basis of NOE experiments.

2-Methyl-2-[dimethyl(phenyl)silylmethyl]tetrahydrofuran (4a): Colorless oil (70%). ^1H NMR (300 MHz, $CDCl_3$): δ = 7.59–7.52 (m, 2 H), 7.41–7.33 (m, 3 H), 3.81–3.76 (m, 2 H), 1.98–1.85 (m, 2 H), 1.71–1.62 (m, 2 H), 1.39 (d, J = 14.7 Hz, 1 H), 1.28 (d, J = 14.7 Hz, 1 H), 1.21 (s, 3 H), 0.39 [s, 6 H, $(CH_3)_2Si$] ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 140.1 (C), 133.6 (CH), 128.7 (CH), 127.7 (CH), 82.9 (C), 66.3 (CH_2), 39.4 (CH_2), 30.5 (CH_2), 28.5 (CH_3), 26.0 (CH_2), –1.2 (CH_3), –1.3 (CH_3) ppm. MS (EI): m/z = 233 $[M – 1]^+$, 219 $[M – Me]^+$, 157 $[M – Ph]^+$, 135 $[SiMe_2Ph]^+$. $C_{14}H_{22}OSi$ (234.41): calcd. C 71.73, H 9.46; found C 72.04, H 9.75.

(2*RS*,3*RS*)-2,3-Dimethyl-2-[dimethyl(phenyl)silylmethyl]tetrahydrofuran (4b): Chromatography gave complete separation of the diastereoisomeric tetrahydrofurans. Colorless oil (52%). ^1H NMR (300 MHz, $CDCl_3$): δ = 7.57–7.51 (m, 2 H), 7.37–7.31 (m, 3 H), 3.80–3.73 (m, 1 H), 3.71–3.63 (m, 1 H), 2.02–1.94 (m, 1 H), 1.92–1.85 (m, 1 H), 1.63–1.50 (m, 1 H), 1.37 (d, J = 14.9 Hz, 1 H), 1.20 (d, J = 14.9 Hz, 1 H), 1.00 (s, 3 H), 0.89 (d, J = 6.6 Hz, 3 H), 0.37 [s, 6 H, $(CH_3)_2Si$] ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 140.9 (C), 133.7 (CH), 128.7 (CH), 127.7 (CH), 84.6 (C), 64.7 (CH_2), 44.0 (CH), 33.7 (CH_2), 29.7 (CH_2), 23.6 (CH_3), 14.8 (CH_3), –0.8 (CH_3), –1.0 (CH_3) ppm. MS (EI): m/z = 247 $[M – 1]^+$, 233 $[M – Me]^+$, 171 $[M – Ph]^+$, 135 $[SiMe_2Ph]^+$. $C_{15}H_{24}OSi$ (248.44): calcd. C 72.52, H 9.74; found C 72.84, H 10.05.

(2*SR*,3*RS*)-2,3-Dimethyl-2-[dimethyl(phenyl)silylmethyl]tetrahydrofuran (5b): Colorless oil (26%). ^1H NMR (300 MHz, $CDCl_3$): δ = 7.58–7.51 (m, 2 H), 7.39–7.31 (m, 3 H), 3.71–3.62 (m, 1 H), 3.59–3.49 (m, 1 H), 2.00–1.93 (m, 1 H), 1.86–1.78 (m, 1 H), 1.61–1.51 (m, 1 H), 1.21 (s, 3 H), 1.09 (d, J = 14.9 Hz, 1 H), 0.94 (d, J = 6.6 Hz, 3 H), 0.78 (d, J = 14.9 Hz, 1 H), 0.39 (s, 3 H, CH_3Si), 0.38 (s, 3 H, CH_3Si) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 141.1 (C), 133.7 (CH), 128.7 (CH), 127.7 (CH), 84.5 (C), 64.7 (CH_2), 45.3 (CH), 33.3 (CH_2), 27.6 (CH_3), 23.1 (CH_2), 14.5 (CH_3), –0.8 (CH_3), –1.1 (CH_3) ppm. MS (EI): m/z = 247 $[M – 1]^+$, 233 $[M – Me]^+$, 171 $[M – Ph]^+$, 135 $[SiMe_2Ph]^+$.

2-Methyl-2-[dimethyl(phenyl)silylmethyl]-3-propyltetrahydrofuran [(2*RS*,3*SR*)-4c and (2*SR*,3*SR*)-5c]: Chromatography gave tetrahydrofurans **4c** and **5c** as a mixture. Colorless oil (85%).

4c: ^1H NMR (300 MHz, $CDCl_3$): δ = 7.61–7.53 (m, 2 H), 7.39–7.32 (m, 3 H), 3.84–3.73 (m, 1 H), 3.72–3.66 (m, 1 H), 2.02–1.96 (m, 1 H), 1.78–1.69 (m, 1 H), 1.61–1.49 (m, 1 H), 1.39–1.25 (m, 4 H), 1.32 (d, J = 14.9 Hz, 1 H), 1.25 (d, J = 14.9 Hz, 1 H), 1.01 (s, 3 H), 0.88 (t, J = 6.6 Hz, 3 H), 0.40 [s, 6 H, $(CH_3)_2Si$] ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 140.8 (C), 133.5 (CH), 128.5 (CH), 127.6 (CH), 84.2 (C), 64.7 (CH_2), 49.4 (CH), 32.4 (CH_2), 31.6 (CH_2), 29.7 (CH_2), 23.9 (CH_3), 22.1 (CH_2), 14.4 (CH_3), –0.9 (CH_3), –1.2 (CH_3) ppm. MS (EI): m/z = 275 $[M]^+$, 261 $[M – Me]^+$, 199 $[M – Ph]^+$, 135 $[SiMe_2Ph]^+$.

5c: Recognisable signals: ^1H NMR (300 MHz, $CDCl_3$): δ = 3.72–3.66 (m, 1 H), 3.62–3.54 (m, 1 H), 2.02–1.96 (m, 1 H), 1.78–1.69 (m, 1 H), 1.61–1.49 (m, 1 H), 1.39–1.25 (m, 4 H), 0.95 (t, J = 6.8 Hz, 3 H), 0.79 (d, J = 14.5 Hz, 1 H), 0.42 (s, 3 H, CH_3Si), 0.41 (s, 3 H, CH_3Si) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 141.0 (C),

133.5 (CH), 128.5 (CH), 127.6 (CH), 84.1 (C), 64.7 (CH_2), 51.3 (CH), 32.4 (CH_2), 31.2 (CH_2), 27.8 (CH_3), 23.4 (CH_2), 22.1 (CH_2), 14.5 (CH_3), –0.9 (CH_3), –1.2 (CH_3) ppm.

(2*RS*,3*SR*)-2-Methyl-2-[dimethyl(phenyl)silylmethyl]-3-phenyltetrahydrofuran (4d): Chromatography gave complete separation of the diastereoisomeric tetrahydrofurans. Colorless oil (58%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.66–7.59 (m, 2 H), 7.42–7.39 (m, 3 H), 7.36–7.26 (m, 3 H), 7.25–7.18 (m, 2 H), 4.10–4.03 (m, 1 H), 3.92–3.87 (m, 1 H), 3.08 (t, J = 8.5 Hz, 1 H), 2.35–2.27 (m, 2 H), 1.42 (d, J = 14.9 Hz, 1 H), 1.32 (d, J = 14.9 Hz, 1 H), 0.91 (s, 3 H), 0.48 (s, 3 H, CH_3Si), 0.45 (s, 3 H, CH_3Si) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 141.0 (C), 140.5 (C), 133.7 (CH), 128.7 (CH), 128.3 (CH), 128.1 (CH), 127.7 (CH), 126.5 (CH), 85.2 (C), 64.9 (CH_2), 55.7 (CH), 31.7 (CH_2), 29.9 (CH_2), 24.8 (CH_3), –0.94 (CH_3) ppm. MS (EI): m/z = 310 $[M]^+$, 295 $[M - Me]^+$, 233 $[M - Ph]^+$, 135 $[SiMe_2Ph]^+$. $C_{20}H_{26}OSi$ (310.51): calcd. C 77.36, H 8.44; found C 77.68, H 8.75.

(2*SR*,3*SR*)-2-Methyl-2-[dimethyl(phenyl)silylmethyl]-3-phenyltetrahydrofuran (5d): Colorless oil (21%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.53–7.47 (m, 2 H), 7.39–7.31 (m, 5 H), 7.29–7.21 (m, 3 H), 3.91–3.76 (m, 2 H), 3.06 (dd, J = 11.2, 7.2 Hz, 1 H), 2.46–2.31 (m, 1 H), 2.28–2.15 (m, 1 H), 1.34 (s, 3 H), 1.15 (d, J = 14.9 Hz, 1 H), 0.42 (d, J = 14.9 Hz, 1 H), 0.36 (s, 3 H, CH_3Si), 0.33 (s, 3 H, CH_3Si) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 140.7 (C), 139.8 (C), 133.5 (CH), 128.4 (CH), 128.1 (CH), 127.5 (CH), 126.6 (CH), 84.8 (C), 64.6 (CH_2), 56.7 (CH), 30.5 (CH_2), 28.1 (CH_3), 24.2 (CH_2), –0.9 (CH_3), –1.2 (CH_3) ppm. MS (EI): m/z = 310 $[M]^+$, 295 $[M - Me]^+$, 233 $[M - Ph]^+$, 135 $[SiMe_2Ph]^+$.

2,5-Dimethyl-2-[dimethyl(phenyl)silylmethyl]tetrahydrofuran [(2*RS*,5*SR*)-4e and (2*SR*,5*SR*)-5e]: Chromatography gave tetrahydrofurans **4e** and **5e** as a mixture. Colorless oil (79%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.62–7.52 (m, 2 H), 7.43–7.35 (m, 3 H), 4.12–3.97 (m, 1 H), 2.08–1.94 (m, 1 H), 1.82–1.62 (m, 2 H), 1.60–1.43 (m, 1 H), 1.45 (d, J = 14.5 Hz, 1 H), 1.33 (d, J = 14.5 Hz, 1 H), 1.27 (s, 3 H, CH_3), 1.24 (d, J = 6.2 Hz, 3 H), 0.42 [s, 6 H, $(CH_3)_2Si$] ppm. Isomer A. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 140.2 (C), 133.6 (CH), 128.7 (CH), 127.7 (CH), 83.0 (C), 73.5 (CH), 39.6 (CH_2), 33.6 (CH_2), 32.0 (CH_2), 28.8 (CH_3), 21.8 (CH_3), –1.1 (CH_3) ppm. Isomer B: ^{13}C NMR (75 MHz, $CDCl_3$): δ = 140.1 (C), 133.6 (CH), 128.7 (CH), 127.7 (CH), 83.0 (C), 73.9 (CH), 40.3 (CH_2), 34.0 (CH_2), 31.0 (CH_2), 30.4 (CH_3), 22.0 (CH_3), –1.2 (CH_3) ppm. MS (EI): m/z = 248 $[M]^+$, 233 $[M - Me]^+$, 171 $[M - Ph]^+$, 135 $[SiMe_2Ph]^+$.

5-Ethyl-2-methyl-2-[dimethyl(phenyl)silylmethyl]tetrahydrofuran [(2*RS*,5*SR*)-4f and (2*SR*,5*SR*)-5f]: Chromatography gave tetrahydrofurans **4f** and **5f** as a mixture. Colorless oil (72%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.61–7.53 (m, 2 H), 7.42–7.31 (m, 3 H), 3.83–3.75 (m, 1 H), 2.05–1.95 (m, 1 H), 1.73–1.43 (m, 5 H), 1.39–1.22 (m, 2 H), 1.19 (s, 3 H, isomer A), 1.17 (s, 3 H, isomer B), 0.99–0.91 (m, 3 H), 0.36 [s, 6 H, $(CH_3)_2Si$] ppm. Isomer A: ^{13}C NMR (75 MHz, $CDCl_3$): δ = 140.2 (C), 133.6 (CH), 128.7 (CH), 127.6 (CH), 82.8 (C), 79.1 (CH), 39.4 (CH_2), 31.8 (CH_2), 31.3 (CH_2), 29.3 (CH_2), 28.5 (CH_3), 10.5 (CH_3), –1.0 (CH_3), –1.1 (CH_3) ppm. Isomer B: ^{13}C NMR (75 MHz, $CDCl_3$): δ = 140.1 (C), 133.6 (CH), 128.7 (CH), 127.6 (CH), 82.7 (C), 79.5 (CH), 40.1 (CH_2), 31.5 (CH_2), 30.9 (CH_2), 30.2 (CH_2), 29.4 (CH_3), 10.3 (CH_3), –1.2 (CH_3), –1.3 (CH_3) ppm. MS (EI): m/z = 261 $[M - 1]^+$, 247 $[M - Me]^+$, 185 $[M - Ph]^+$, 135 $[SiMe_2Ph]^+$.

2,3,3,5-Tetramethyl-2-[dimethyl(phenyl)silylmethyl]tetrahydrofuran [(2*RS*,5*SR*)-4g and (2*SR*,5*SR*)-5g]: Chromatography gave tetrahydrofurans **4g** and **5g** as a mixture. Colorless oil (87%).

4g: ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.69–7.59 (m, 2 H), 7.43–7.35 (m, 3 H), 4.21–4.09 (m, 1 H), 1.89 (dd, J = 12.1, 7.2 Hz, 1 H), 1.58 (dd, J = 12.1, 7.8 Hz, 1 H), 1.26 (d, J = 13.5 Hz, 1 H), 1.24 (d, J = 6.3 Hz, 3 H), 1.14 (s, 3 H), 1.02 (s, 3 H), 1.01 (d, J = 13.5 Hz, 1 H), 1.00 (s, 3 H), 0.47 (s, 3 H, CH_3Si), 0.42 (s, 3 H, CH_3Si) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 141.4 (C), 133.7 (CH), 128.6 (CH), 127.7 (CH), 86.5 (C), 71.1 (CH), 47.8 (CH_2), 45.0 (C), 26.2 (CH_2), 25.3 (CH_3), 24.6 (CH_3), 23.1 (CH_3), –0.3 (CH_3), –0.4 (CH_3) ppm. MS (EI): m/z = 275 $[M - 1]^+$, 261 $[M - Me]^+$, 199 $[M - Ph]^+$, 135 $[SiMe_2Ph]^+$.

5g: Recognisable signals: ^{1}H NMR (300 MHz, $CDCl_3$): δ = 4.01–3.89 (m, 1 H), 1.99 (dd, J = 12.6, 8.4 Hz, 1 H), 1.44 (dd, J = 12.6, 6.2 Hz, 1 H), 1.29 (d, J = 14.0 Hz, 1 H), 1.23 (d, J = 6.2 Hz, 3 H), 1.16 (s, 3 H), 1.01 (s, 3 H), 0.99 (s, 3 H), 0.82 (d, J = 14.0 Hz, 1 H), 0.48 (s, 3 H, CH_3Si) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 141.2 (C), 86.4 (C), 70.3 (CH), 47.4 (CH_2), 45.2 (C), 25.6 (CH_3), 24.4 (CH_3) ppm.

(2*RS*,3*SR*,5*SR*)-2,5-Dimethyl-2-[dimethyl(phenyl)silylmethyl]-3-phenyltetrahydrofuran (4h): Chromatography gave complete separation of the diastereoisomeric tetrahydrofurans. Colorless oil (72%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.63–7.60 (m, 2 H), 7.40–7.38 (m, 3 H), 7.33–7.24 (m, 3 H), 7.20–7.17 (m, 2 H), 4.17–4.06 (m, 1 H), 3.24 (dd, J = 11.2, 6.8 Hz, 1 H), 2.31–2.21 (m, 1 H), 2.03–1.92 (m, 1 H), 1.46 (d, J = 14.9 Hz, 1 H), 1.35 (d, J = 6.1 Hz, 3 H), 1.33 (d, J = 14.9 Hz, 1 H), 0.88 (s, 3 H), 0.48 (s, 3 H, CH_3Si), 0.43 (s, 3 H, CH_3Si) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 140.7 (C), 140.6 (C), 133.7 (CH), 128.6 (CH), 128.0 (CH), 127.7 (CH), 126.4 (CH), 85.0 (C), 72.4 (CH), 57.0 (CH), 39.6 (CH_2), 30.9 (CH_2), 27.4 (CH_3), 22.1 (CH_3), –0.9 (CH_3), –1.0 (CH_3) ppm. MS (EI): m/z = 323 $[M - 1]^+$, 309 $[M - Me]^+$, 247 $[M - Ph]^+$. $C_{21}H_{28}OSi$ (324.54): calcd. C 77.72, H 8.70; found C 78.04, H 9.03.

(2*SR*,3*SR*,5*SR*)-2,5-Dimethyl-2-[dimethyl(phenyl)silylmethyl]-3-phenyltetrahydrofuran (5h): Colorless oil (15%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.47–7.44 (m, 2 H), 7.32–7.27 (m, 5 H), 7.25–7.22 (m, 3 H), 4.22–4.11 (m, 1 H), 3.23 (dd, J = 12.3, 6.1 Hz, 1 H), 2.22–2.14 (m, 1 H), 2.09–1.98 (m, 1 H), 1.35 (s, 3 H), 1.26 (d, J = 5.7 Hz, 3 H), 1.04 (d, J = 14.5 Hz, 1 H), 0.36 (d, J = 14.5 Hz, 1 H), 0.34 [s, 6 H, $(CH_3)_2Si$] ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 141.0 (C), 139.9 (C), 133.6 (CH), 128.4 (CH), 128.3 (CH), 127.5 (CH), 126.5 (CH), 84.9 (C), 73.0 (CH), 57.9 (CH), 38.7 (CH_2), 29.1 (CH_3), 26.8 (CH_2), 21.7 (CH_3), –0.5 (CH_3) ppm. MS (EI): m/z = 323 $[M - 1]^+$, 309 $[M - Me]^+$, 247 $[M - Ph]^+$.

(2*RS*,3*SR*,5*RS*)-2-Methyl-2-[dimethyl(phenyl)silylmethyl]-3,5-diphenyltetrahydrofuran (4i): Chromatography gave complete separation of the diastereoisomeric tetrahydrofurans. Colorless oil (67%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.62–7.53 (m, 2 H), 7.40–7.30 (m, 7 H), 7.27–7.15 (m, 6 H), 5.01 (dd, J = 10.3, 5.8 Hz, 1 H), 3.35 (dd, J = 12.4, 6.2 Hz, 1 H), 2.47 (ddd, J = 12.4, 6.2, 5.8 Hz, 1 H), 2.29 (td, J = 12.4, 10.3 Hz, 1 H), 1.51 (d, J = 14.6 Hz, 1 H), 1.37 (d, J = 14.6 Hz, 1 H), 0.92 (s, 3 H), 0.44 (s, 3 H), 0.40 (s, 3 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 144.3 (C), 140.8 (C), 139.4 (C), 133.9 (CH), 128.8 (CH), 128.4 (CH), 128.4 (CH), 128.2 (CH), 127.8 (CH), 127.1 (CH), 126.8 (CH), 125.6 (CH), 85.7 (C), 78.2 (CH), 57.7 (CH), 40.2 (CH_2), 31.2 (CH_2), 27.1 (CH_3), –0.6 (CH_3), –0.7 (CH) ppm. $C_{26}H_{30}OSi$ (386.61): calcd. C 80.78, H 7.82; found C 81.17, H 8.16.

(2*SR*,3*SR*,5*RS*)-2-Methyl-2-[dimethyl(phenyl)silylmethyl]-3,5-diphenyltetrahydrofuran (5i): Colorless oil (15%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.40–7.17 (m, 15 H), 5.04 (dd, J = 10.4, 5.2 Hz, 1 H), 3.37 (dd, J = 12.1, 6.2 Hz, 1 H), 2.45 (ddd, J = 12.1, 6.2, 5.2 Hz, 1 H), 2.31 (td, J = 12.1, 10.4 Hz, 1 H), 1.44 (s, 3 H), 1.10 (d, J = 14.7 Hz, 1 H), 0.46 (d, J = 14.7 Hz, 1 H), 0.28 (s, 3

H), 0.27 (s, 3 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 142.6 (C), 141.0 (C), 140.2 (C), 133.7 (CH), 128.7 (CH), 128.7 (CH), 128.4 (CH), 128.3 (CH), 127.8 (CH), 127.3 (CH), 126.8 (CH), 126.3 (CH), 85.7 (C), 78.8 (CH), 58.3 (CH), 40.2 (CH_2), 29.4 (CH_3), 26.9 (CH_2), –0.3 (CH_3), –0.4 (CH_3) ppm.

(2*RS*,3*SR*,5*RS*)-2,5-Dimethyl-2-[dimethyl(phenyl)silylmethyl]-3-phenyltetrahydrofuran (6h): Chromatography gave complete separation of the diastereoisomeric tetrahydrofurans. Colorless oil (67%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.62–7.59 (m, 2 H), 7.42–7.36 (m, 3 H), 7.33–7.20 (m, 5 H), 4.39–4.29 (m, 1 H), 3.17 (dd, J = 10.1, 8.8 Hz, 1 H), 2.51 (ddd, J = 12.7, 10.1, 8.3 Hz, 1 H), 1.86 (ddd, J = 12.7, 8.8, 4.6 Hz, 1 H), 1.39 (d, J = 14.9 Hz, 1 H), 1.29 (d, J = 6.1 Hz, 3 H), 1.23 (d, J = 14.9 Hz, 1 H), 0.91 (s, 3 H), 0.47 (s, 3 H, CH_3Si), 0.42 (s, 3 H, CH_3Si) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 140.8 (C), 140.0 (C), 133.7 (CH), 128.6 (CH), 128.4 (CH), 128.0 (CH), 127.6 (CH), 126.5 (CH), 85.7 (C), 71.5 (CH), 55.3 (CH), 38.0 (CH_2), 30.3 (CH_2), 23.9 (CH_3), 23.1 (CH_3), –0.7 (CH_3) ppm. MS (EI): m/z = 323 [M – 1]$^+$, 309 [M – Me]$^+$, 247 [M – Ph]$^+$. $C_{21}H_{28}OSi$ (324.54): calcd. C 77.72, H 8.70; found C 78.01, H 8.98.

(2*SR*,3*SR*,5*RS*)-2,5-Dimethyl-2-[dimethyl(phenyl)silylmethyl]-3-phenyltetrahydrofuran (7h): Colorless oil (19%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.52–7.45 (m, 2 H), 7.39–7.19 (m, 8 H), 4.10–4.00 (m, 1 H), 3.15 (dd, J = 11.0, 8.3 Hz, 1 H), 2.61–2.50 (m, 1 H), 1.83 (ddd, J = 12.8, 8.3, 3.9 Hz, 1 H), 1.35 (s, 3 H), 1.25 (d, J = 14.9 Hz, 1 H), 1.23 (d, J = 6.1 Hz, 3 H), 0.41 (d, J = 14.9 Hz, 1 H), 0.38 (s, 3 H, CH_3Si), 0.35 (s, 3 H, CH_3Si) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 140.7 (C), 139.4 (C), 133.5 (CH), 128.5 (CH), 128.0 (CH), 127.5 (CH), 126.5 (CH), 85.5 (C), 70.9 (CH), 56.3 (CH), 37.0 (CH_2), 28.5 (CH_3), 23.1 (CH_3), 22.9 (CH_2), –0.9 (CH_3), –1.1 (CH_3) ppm. MS (EI): m/z = 323 [M – 1]$^+$, 309 [M – Me]$^+$, 247 [M – Ph]$^+$.

2-Methyl-2-[dimethyl(phenyl)silylmethyl]-3,5-diphenyltetrahydrofuran (6i and 7i): Chromatography gave tetrahydrofurans **6i** and **7i** as a mixture. Colorless oil (79%).

6i: ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.52–7.45 (m, 2 H), 7.28–7.13 (m, 13 H), 5. 18 (dd, J = 8.9, 4.2 Hz, 1 H), 3.15 (dd, J = 10.9, 8.4 Hz, 1 H), 2.88–2.80 (m, 1 H), 2.20–2.13 (m, 1 H), 1.42 (d, J = 14.6 Hz, 1 H), 1.29 (d, J = 14.6 Hz, 1 H), 0.96 (s, 3 H), 0.38 (s, 3 H, CH_3Si), 0.37 (s, 3 H, CH_3Si) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 145.1 (C), 140.8 (C), 139.4 (C), 133.8 (CH), 128.8 (CH), 128.7 (CH), 128.5 (CH), 128.3 (CH), 127.8 (CH), 126.9 (CH), 126.8 (CH), 125.8 (CH), 86.6 (C), 76.8 (CH), 56.5 (CH), 39.3 (CH_2), 30.4 (CH_2), 23.0 (CH_3), –0.4 (CH_3), –0.5 (CH_3) ppm.

7i: Recognisable signals: ^{1}H NMR (300 MHz, $CDCl_3$): δ = 4.81 (dd, J = 9.0, 3.3 Hz, 1 H), 3.13–3.08 (m, 1 H), 2.88–2.80 (m, 1 H), 2.20–2.13 (m, 1 H), 0.27 (s, 3 H, CH_3Si) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 145.3 (C), 140.9 (C), 139.2 (C), 133.8 (CH), 128.7 (CH), 128.6 (CH), 128.4 (CH), 127.8 (CH), 127.0 (CH), 126.9 (CH), 125.8 (CH), 86.3 (C), 76.8 (CH), 55.9 (CH), 38.6 (CH_2), 28.5 (CH_2), 23.9 (CH_3), –0.7 (CH_3), –0.9 (CH_3) ppm.

Supporting Information (see footnote on the first page of this article): Full characterization data for compounds **2a**–**2g** and ^{1}H and ^{13}C NMR spectra for all new compounds.

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[1] E. J. Kang, E. Lee, *Chem. Rev.* **2005**, *105*, 4348–4378.
[2] E. Aehle, U. Müller, P. C. Eklund, S. M. Willför, W. Sippl, B. Dräger, *Phytochemistry* **2011**, *72*, 2396–2405.
[3] J. Kobayashi, M. Tsuda, *Nat. Prod. Rep.* **2004**, *21*, 77–93.
[4] M. M. Faul, B. E. Huff, *Chem. Rev.* **2000**, *100*, 2407–2474.
[5] a) J. P. Wofe, M. B. Hay, *Tetrahedron* **2007**, *63*, 261–290; b) G. Jalce, X. Franck, B. Figadère, *Tetrahedron: Asymmetry* **2009**, *20*, 2537–2581; c) V. Piccialli, *Synthesis* **2007**, *17*, 2585–2607.
[6] B. Godoi, R. F. Schumacher, G. Zeni, *Chem. Rev.* **2011**, *111*, 2937–2980.
[7] a) For iodoetherification, see: M. Labelle, H. E. Morton, Y. Guindon, J. P. Springer, *J. Am. Chem. Soc.* **1988**, *110*, 4533–4540; b) for selenoetherification, see: Y. Landais, D. Planchenault, V. Weber, *Tetrahedron Lett.* **1995**, *36*, 2987–2990.
[8] O. Andrey, C. Glanzmann, Y. Landais, L. Parra-Rapado, *Tetrahedron* **1997**, *53*, 2835–2854.
[9] B. Fraser, P. Pelmutter, *J. Chem. Soc. Perkin Trans. 1* **2002**, 2896–2899.
[10] D. K. Mohapatra, S. Mohapatra, M. K. Gurjar, *Tetrahedron Lett.* **2006**, *47*, 5943–5947.
[11] a) K. Miura, T. Hondo, S. Okajima, A. Hosomi, *Tetrahedron Lett.* **1996**, *37*, 487–490; b) K. Miura, S. Okajima, T. Hondo, T. Nakagawa, T. Takahashi, A. Hosomi, *J. Am. Chem. Soc.* **2000**, *122*, 11348–11357; c) T. Akiyama, Y. Ishida, *Synlett* **1998**, 1150–1152; d) P. Mohr, *Tetrahedron Lett.* **1995**, *36*, 2453–2456.
[12] I. Fleming, A. Barbero, D. Walter, *Chem. Rev.* **1997**, *97*, 2063–2192.
[13] a) A. Barbero, F. J. Pulido, *Acc. Chem. Res.* **2004**, *37*, 817–825; b) A. Barbero, F. J. Pulido, *Synthesis* **2004**, 779–785.
[14] a) A. Barbero, C. García, F. J. Pulido, *Tetrahedron* **2000**, *56*, 2739–2751; b) A. Barbero, Y. Blanco, F. J. Pulido, *Chem. Commun.* **2001**, *66*, 7723–7728; c) A. Barbero, Y. Blanco, F. J. Pulido, *J. Org. Chem.* **2005**, *70*, 6876–6883.
[15] a) A. Barbero, P. Castreño, F. J. Pulido, *Org. Lett.* **2003**, *5*, 4045–4048; b) F. J. Pulido, A. Barbero, P. Castreño, *Eur. J. Org. Chem.* **2010**, 1307–1313.
[16] F. J. Pulido, A. Barbero, P. Castreño, *J. Org. Chem.* **2011**, *76*, 5850–5855.
[17] A. Barbero, P. Castreño, F. J. Pulido, *J. Am. Chem. Soc.* **2005**, *127*, 8022–8023.
[18] Small amounts of the oxidation products (2-hydroxymethyl-5-methyl-2-dimethyl(phenyl)silylmethyltetrahydrofurans) were also obtained.
[19] The mercuri-cyclization would proceed through a mechanism involving a bridged mercurium ion that will attack the alcohol to give a protonated tetrahydrofuran. The irreversible deprotonation step under basic conditions would lead to the corresponding mercuri-tetrahydrofuran intermediate.
[20] No protodesilylation was observed, in contrast to the results reported by other authors: a) S. R. Wilson, M. F. Price, *J. Am. Chem. Soc.* **1982**, *104*, 1124–1126; b) P. Mohr, *Tetrahedron Lett.* **1995**, *36*, 7221–7224.
[21] Hosomi[11] has proposed that the acid-catalyzed cyclization is not reversible because the recovered deuterium-labeled vinylsilane maintains both the configuration and the deuterium.

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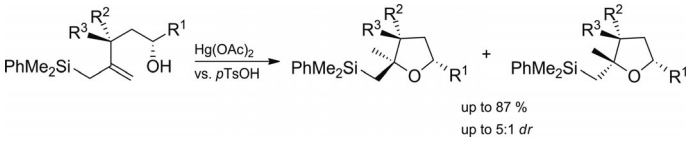

The synthesis of highly substituted tetrahydrofurans from allylsilyl alcohols is described, comparing the efficiency of the mercury- versus the acid-catalyzed cyclization.

Tetrahydrofuran Synthesis

Keywords: Synthetic methods / Cyclization / Allenes / Allylic compounds / Oxygen heterocycles / Mercury

