Peterson (Silyl-Wittig) Methylenation of Carbonyl Compounds Using Nafion-H® Catalyzed Hydroxy-Trimethylsilane Elimination of β-Hydroxysilanes[1]

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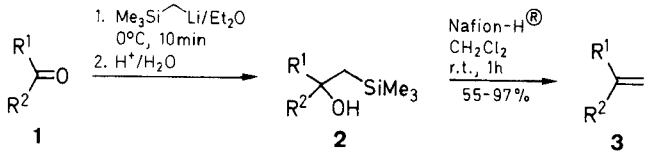
The Peterson (silyl-Wittig) methylenation of carbonyl compounds is significantly improved by convenient hydroxy-trimethylsilane elimination of the intermediate β-hydroxysilanes using perfluoroalkanesulfonic acid (Nafion-H®) catalysis. These high yield reactions proceed at room temperature, and the workup involves only filtration of the catalyst.

Methylenation of carbonyl compounds is one of the most widely used reactions in organic chemistry. It can be effected by the Wittig reaction, using Tebbe's reagent, by Peterson's reaction, or by other less general methods.[2] Although Peterson's silyl-Wittig reaction was extensively used for the preparation of internal olefins, relatively few methylenations were reported using this method.[3] In most cases, the adducts of the trimethylsilylalkyl carbanions and the carbonyl compounds spontaneously undergo dehydroxytrimethylsilylations to form the internal olefins. The intermediate β-hydroxysilanes, in the methylenation reactions are, however, usually stable under the reaction conditions, and are isolated prior to their subsequent conversion. This can be achieved by treatment with bases such as sodium hydride or potassium hydride, or by acid catalyzed reactions at high temperatures.[4] *In situ* treatment of the β-hydroxysilane, with acetyl chloride or thionyl chloride was also reported to give olefins in moderate yields.[5]

We now report a significant improvement of the Peterson methylenation of carbonyl compounds by hydroxy-trimethylsilane elimination of β-hydroxysilanes under very mild conditions using Nafion-H® catalysis. Nafion-H®, a solid polymeric resinsulfonic acid has found widespread use in many synthetic transformations.[6] Many acid catalyzed reactions that otherwise require drastic conditions had been effected under relatively mild conditions using this convenient solid acid catalyst.[5]



1 2 3

The carbonyl compounds **1** were reacted with trimethylsilylmethyllithium under standard conditions and the β-hydroxysilanes **2** products were subsequently treated with catalytic amounts of Nafion-H® at room temperature to afford the desired olefins **3**.

As shown in the Table, acyclic methylene compounds, **3a–d**, as well as cyclic methylene compounds, **3e–g**, could be prepared through their corresponding β-hydroxysilanes **2**. Preparation of compound **3g**, a hindered olefin, exemplifies the usefulness of the reaction. Cyclopropylmethanols are usually unstable to acids, and rearranged products are obtained in acid catalyzed reactions. However, **3a** was prepared without any such complications. It may be due to the exceptional stabilization of the β-carbocationic intermediate by the β-trimethylsilyl group. Consequently, no significant charge-delocalization into the cyclopropyl group is involved. The mechanism of the reaction is suggested to involve initial protonation of the hydroxyl group by the superacid Nafion-H®, followed by E_2-elimination.

The advantage of the reported procedure over previous methods is in the easy workup. The catalyst is simply filtered, and solvent removed to give the olefin in high yield. The catalyst can be regenerated without any loss of activity by washing with dry diethyl ether and then drying it in an oven at 120°C for 2 h. The regenerated catalyst was found to be as effective as the original.

It is interesting to note that no olefin isomerization was observed under the reaction conditions. Such isomerizations leading to the thermodynamically more stable isomeric olefins was anticipated. The heterogeneous nature of the reaction, and the mild conditions seemingly do not favor the formation of rearranged products. All the olefins prepared were found to be stable under the reaction conditions for extended periods of time.

The present method provides an easy access to methylene compounds **3** from β-hydroxysilanes **2**, which in turn can be readily prepared from the carbonyl compounds **1** with trimethylsilylmethyllithium.

Et_2O was distilled from Na-benzophenone ketyl immediately before use. Nafion-H[6] (prepared from commercial Du Pont resin) was dried at 120°C for 30 min before use. All the precursor carbonyl compounds, and Me_3SiCH_2Li (1 M solution in pentane) were obtained from Aldrich. GC/MS analyses were performed on a Finnigan-Mat/Incos-50 mass spectrometer equipped with a Varian 3400 gas chromatograph. ^1H- and ^{13}C-NMR were recorded on a Varian VXR-200 or a Bruker-250 instrument.

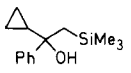
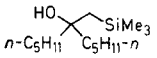
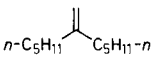
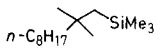
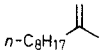
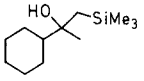
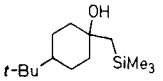
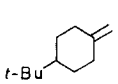
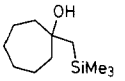
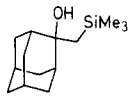
(1-Phenylethenyl)cyclopropane (3a); Typical Procedure:

(2-Cyclopropyl-2-hydroxy-2-phenylethyl)trimethylsilane **(2a)**: Phenyl cyclopropyl ketone (**1a**, 146 mg, 1 mmol) dissolved in dry Et_2O (10 mL) is placed in a 50-mL three-necked round-bottomed flask equipped with a magnetic stirrer, a nitrogen inlet and a serum cap. The flask is cooled to 0°C, and Me_3SiCH_2Li (1.2 mL of 1 M solution in pentane, 1.2 mmol) is added dropwise through a syringe. The mixture is stirred at 0°C for 10 min, then poured into 2% HCl (50 mL), and extracted with Et_2O (2 × 40 mL). The organic layers are dried ($MgSO_4$), and the solvent evaporated to afford the β-hydroxytrimethylsilylalkane **1a**; yield: 0.23 g (98%), essentially pure by GC/MS.

MS: *m/z* (%) = 216 (2, $M^+ - 18$), 193 (42), 177 (13), 147 (57), 116 (40), 105 (44), 103 (82), 75 (100).

(1-Phenylethenyl)cyclopropane **(3a)**: Compound **2a** is dissolved in CH_2Cl_2 (2 mL), and placed in a 20-mL round-bottomed flask. Nafion-H (50 mg) is added and stirred at r.t. for 1 h. GC/MS analysis showed complete conversion of **2a** to **3a** at this time. The catalyst was removed by filtration through a small cotton plug inserted in a Pasteur pipette, and the solvent evaporated to give compound **3a**; yield: 0.13 g (90%).

Table. Nafion-H® Catalyzed Transformation of β-Hydroxysilanes **2** to the Corresponding Methylene Compounds **3**

Reactant	Product[a]	Yield[b] (%)	^{1}H-NMR ($CDCl_3$/TMS) δ, J(Hz)	^{13}C-NMR ($CDCl_3$/TMS) δ	MS m/z (%)
1a 	**3a**[7] 	90	0.40–0.49 (m, 2H, cp-*cis*-CH_2), 0.64–0.74 (m, 2H, cp-*trans*-CH_2), 1.47–1.58 (m, 1H, CH), 4.79 (t, 1H, J = 1.2, H_{olef}), 5.14 (d, 1H, J = 0.84, H_{olef}), 7.12–7.24 (m, 3H_{arom}), 7.43–7.48 (m, 2H_{arom})	6.6 (C4, C5), 15.6 (C3), 108.9 (C1), 126.0 (C3′, C5′$_{arom}$), 127.4 (C4′$_{arom}$), 128.1 (C2′, C5′$_{arom}$), 141.5 (C1′$_{arom}$), 149.3 (C2)	144 (68)
1b 	**3b**[8] 	97	0.89 (t, 6H, J = 6.5, CH_3), 1.23–1.45 (m, 12H), 1.99 (t, J = 7, 4H_{allyl}), 4.69 (s, 2H_{olef})	14.1 (C7, C-7′), 22.6 (C6, C6′), 27.5 (C5, C5′), 31.7 (C4, C4′), 36.0 (C3, C3′), 108.3 (C1), 150.4 (C2)	168 (5)
1c 	**3c**[9] 	80	0.87 (t, 3H, J = 6, CH_3), 1.18–1.44 (m, 12H), 1.69 (s, 3H, CH_3), 1.95 (t, 2H, J = 7.6, C3-H)	14.2 (C10), 22.5 (CH_{3allyl}), 22.8, 27.7, 29.4, 29.6, 32.0, 37.9, 109.6 (C1), 146.4 (C2)	154 (4.8)
1d 	**3d**[10] 	70	1.12–1.35 (m, 10H), 1.71 (s, 3H, CH_3), 1.73–1.78 (m, 1H_{allyl})	20.9 (CH_3), 26.4 (C6), 26.7 (C5, C7), 31.9 (C4, C8), 45.6 (C3), 107.8 (C1), 151.3 (C2)	124 (40)
1e 	**3e**[11] 	60	0.85 (s, 9H, CH_3), 0.9–1.15 (m, 4H), 1.57–2.03 (m, 4H), 2.30–2.36 (m, 1H), 4.57 (s, 2H_{olef})	27.6 (CH_3), 28.9 (C3, C5), 32.4 (C4), 35.3 (C2, C6), 106.1 (=CH_2), 150.2 (C1)	152 (7.5)
1f 	**3f**[12] 	55	1.48–1.62 (m, 4H, C4, C5-H), 1.71–1.74 (m, 4H, C3, C6-H), 2.30 (t, 4H, J = 5, C2, C7-H), 4.70 (t, 2H, J = 0.93, H_{olef})	28.4 (C4, C5), 29.5 (C3, C6), 36.2 (C2, C7), 110.3 (C =CH_2), 152.2 (C1)	110 (19)
1g 	**3g**[13] 	88	1.60–2.10 (m, 12H), 2.48 (br s, 2H_{allyl}), 4.50 (s, 2H_{olef})	28.3 (C5), 37.3 (C4, C6), 39.1 (C2, C8), 39.7 (C3, C7, C9, C10), 100.6 (=CH_2), 158.5 (C1)	148 (100)

[a] Literature references.
[b] Isolated yields.

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