All-Carbon-Substituted Vinylsilane Stable to TBAF: Synthesis of Allyldimethylvinylsilane and Its Pd-Catalyzed Cross-Coupling under Mild Conditions

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General Procedure:

General Experimental

Unless otherwise stated, reactions were performed under a nitrogen atmosphere using commercially obtained anhydrous solvents as received. Alkylolithium reagents were titrated with 1,10-phenanthroline as an indicator in ether.¹ All other commercially obtained reagents were used as received. All reactions were magnetically stirred and monitored by thin-layer chromatography (TLC) using E. Merck silica gel 60 F254 pre-coated plates (0.25-mm). Column or flash chromatography was performed with the indicated solvents using silica gel (particle size 0.032-0.063 nm) purchased from Bodman. ¹H and ¹³C NMR were recorded on Bruker Advance DPX-500 using acetone-*d*₆ as the solvent. Chemical shifts (δ) are given in parts per million (ppm) relative to internal solvent (acetone-*d*₆: ¹H @2.05 ppm, ¹³C @ 29.84 ppm), and coupling constants (*J*) are given in hertz (Hz).

Experimentals

Dimethyl[bis(2-methylprop-2-en-1-yl)]silane (1b):

¹ Stanetty, P.; Mihovilovic, M.D. *J. Org. Chem.* **1997**, 62, 1514-1515.

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To a vigorously stirred suspension of Mg (1.5 mol) in THF (200 mL) was added 1.5 mL of BrCH₂CH₂Br and heated until bubbling was observed. After the bubbling finished, a solution of 1-chloro-2-methyl-1-propene (1.3 mol), dichlorodimethylsilane (0.5 mol), and THF (800 mL) was added dropwise at the speed that kept the reaction at a gentle reflux. After the addition, the reaction mixture was allowed to reflux for 1 hr. The resulting mixture was diluted with 1 L of hexane at rt and 30 mL of saturated NH₄Cl aqueous solution was added dropwise. The mixture was filtered then washed with water. Dried on Na₂SO₄, evaporated and distilled (bp. 178-9 °C)² to afford 80 g of clear liquid as the desired product (95% yield). ¹H NMR (500 MHz, Acetone): δ 4.58 (m, 2 H); 4.48 (s, 2 H); 1.70 (m, 6 H); 1.59 (d, *J* = 0.8 Hz, 4 H); 0.05 (d, *J* = 3.2 Hz, 6 H). ¹³C NMR (500 MHz, Acetone): δ 144.11, 108.98, 27.55, 25.42, -2.68.

(3E)-4-[allyl(dimethyl)silyl]-1-phenylbut-3-en-1-ol (3a):

To a stirred solution of diallyldimethylsilane (1.00 mL, 5.5 mmol, 1.1 eq) and KO^tBu (1.0 M THF, 5.0 mL, 5 mmol, 1 eq) in 30 mL THF at -78 °C, *n*-BuLi (2.5 M in hexanes, 2.0 mL, 5.0 mmol, 1 eq) was added dropwise. The resulting mixture was stirred at -78 °C for 1 hr. Then benzaldehyde (0.51 mL, 5.0 mmol, 1 eq) was added dropwise and the resulting solution was stirred at -78 °C for 0.5 h. The reaction was quenched with the addition of sat. NaHCO₃ aqueous solution and extracted with a 30% solution of EtOAc in Hexanes, dried with Na₂SO₄, filtered and evaporated. The product was purified by flash chromatography on silica gel (10% EtOAc/hexane) to afford the desired product as colorless oil (0.83 g, 67% yield). ¹H NMR (500 MHz, Acetone): δ 7.35 (d, *J* = 7.1 Hz, 2 H); 7.30 (t, *J* = 7.4 Hz, 2 H); 7.21 (t, *J* = 7.2 Hz, 1 H); 6.12 (dt, *J* = 18.7, 6.6 Hz, 1 H); 5.77-5.69 (m, 1 H); 5.63 (d, *J* = 18.7 Hz, 1 H); 4.81-4.71 (m, 3 H); 4.22 (d, *J* = 4.1 Hz, 1 H); 2.57-2.45 (m, 4 H); 1.52 (d, *J* = 8.1 Hz, 2 H); 0.01 (s, 6 H). ¹³C NMR (500 MHz, Acetone): δ 146.39, 145.65, 135.82, 131.17, 128.73, 127.59, 126.74, 113.15, 73.86, 48.09, 24.16, -3.37.

(5E)-6-[allyl(dimethyl)silyl]-1-phenylhex-5-en-3-ol (3d):

² For literature boiling point see: Nasiak, L. D.; Post, H. W. *J. Org. Chem.* **1959**, *24*, 489-96 and references therein.

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To a stirred solution of diallyldimethylsilane (0.2 mL, 1.1 mmol, 1.1 eq) and KO^tBu (1.0 M THF, 1.0 mL, 1 mmol, 1 eq) in 6 mL THF at -78°C, *n*-BuLi (2.5 M in hexanes, 0.4 mL, 1.0 mmol, 1 eq) was added dropwise. The resulting mixture was stirred at -78 °C for 1 hr. Then CuCN (109 mg, 1.2 mmol, 1.2 eq) was added at -78° C. After stirred for 0.5 h, to the resulting mixture was added hydrocinnamaldehyde (145 µL, 1.0 mmol, 1 eq) dropwise and the resulting mixture was stirred at -78° C for 0.5 h and at rt for 12 hr. The reaction was quenched with the addition of water and extracted with EtOAc, dried with Na₂SO₄, filtered and evaporated. The crude was purified by flash chromatography on silica gel (10% EtOAc/hexane) to afford the desired product as colorless oil (162 mg, 59% yield). ¹H NMR (500 MHz, Acetone): δ 7.25 (t, *J* = 7.4 Hz, 2 H); 7.20 (d, *J* = 6.9 Hz, 2 H); 7.14 (t, *J* = 7.2 Hz, 1 H); 6.18 (dt, *J* = 18.6, 6.7 Hz, 1 H); 5.69 (dt, *J* = 18.7, 1.4 Hz, 1 H); 4.84-4.75 (m, 2 H); 3.68-3.60 (m, 2 H); 2.81-2.75 (m, 1 H); 2.69-2.61 (m, 1 H); 2.33-2.29 (m, 2 H); 1.79-1.63 (m, 2 H); 1.55 (d, *J* = 8.1 Hz, 2 H); 0.03 (s, 6 H). ¹³C NMR (500 MHz, Acetone): δ 146.07, 143.55, 135.85, 130.89, 129.19, 129.06, 126.37, 113.18, 70.32, 46.16, 39.70, 32.57, 24.23, -3.30.

(4E)-5-[allyl(dimethyl)silyl]-2-methylpent-4-en-2-ol (3b):

To a stirred solution of diallyldimethylsilane (2.00 mL, 11 mmol, 1.1 eq) and KO^tBu (1.0 M THF, 10.0 mL, 10 mmol, 1 eq) in 60 mL THF at -78°C, *n*-BuLi (2.5 M in hexanes, 4 mL, 10 mmol, 1 eq) was added dropwise. The resulting mixture was stirred at -78 °C for 1hr, and was added ZnCl₂ (1.0 M in ether, 10 mL, 10 mmol, 1 eq) and stirred for an additional 10 minutes at -78 °C. Then acetone (0.81 mL, 10 mmol, 1.1 eq) was added dropwise. The resulting mixture was stirred at -78 °C for 0.5 h and then at 0 °C for 1 h. The reaction was quenched with the addition of a sat. NaHCO₃ aqueous solution was extracted with a 30% solution of EtOAc in Hexanes, dried with Na₂SO₄, filtered and evaporated. The residue was purified by flash chromatography on silica gel (10% EtOAc/hexane) to afford the desired product as colorless oil (1.07 g, 54% yield). ¹H NMR (500 MHz, Acetone): δ 6.21 (dt, *J* = 18.6, 7.0 Hz, 1 H); 5.83-5.73 (m, 1 H); 5.65 (d, *J* = 18.6 Hz, 1 H); 4.85-4.75 (m, 2 H); 3.30 (s, H); 2.27 (d, *J* = 6.9 Hz, 2 H); 1.57 (d, *J* = 8.1 Hz, 2 H); 1.13 (s, 6 H); 0.05 (s, 6H). ¹³C NMR (500 MHz, Acetone): δ 145.96, 135.87, 131.49, 113.14, 69.98, 52.42, 29.52, 24.25, -3.30.

1-[(2E)-3-[allyl(dimethyl)silyl]prop-2-en-1-yl]cyclohexanol (3c):

Followed the procedure above and used cyclohexanone to replace acetone to perform the reaction, the desired compound was obtained (1.17 g, 52% yield). ¹H NMR (500 MHz, Acetone): δ 6.24 (dt, *J* = 18.6, 6.9 Hz, 1 H); 5.82-5.74 (m, 1 H); 5.65 (d, *J* = 18.6 Hz, 1H); 4.83-4.76 (m, 2 H); 3.05 (s, 1 H OH); 2.25 (dd, *J* = 1.2, 6.9 Hz, 2 H); 1.67-1.59 (m, 2 H); 1.56 (d, *J* = 8.0 Hz, 2 H); 1.53-1.45 (m, 3 H); 1.42-1.34 (m, 4 H); 1.27-1.17 (m, 1 H); 0.04 (s, 6 H). ¹³C NMR (500 MHz, Acetone): δ 145.44, 135.90, 131.51, 113.11, 70.76, 51.41, 38.10, 26.60, 24.30, 22.73, -3.28.

(3E)-4-[dimethyl(2-methylprop-2-en-1-yl)silyl]-3-methyl-1-phenylbut-3-en-1-ol (3e):

To a stirred solution of dimethyl[bis(2-methylprop-2-en-1-yl)]silane (**1b**) (2.35 mL, 11 mmol, 1.1 eq) and KO^tBu (1.0 M THF, 10.0 mL, 10 mmol, 1 eq) in 60 mL ether at -78 °C, *n*-BuLi (2.5 M in hexanes, 4 mL, 10 mmol, 1 eq) was added dropwise. The resulting mixture was stirred at -78 °C for 1 hr, and was warmed to 0 °C and stirred at this temperature for 1 hr. Then the reaction mixture was cooled down to -78 °C and benzaldehyde (1.11 mL, 11 mmol, 1.1 eq) was added dropwise and the resulting solution was stirred at -78 °C for 0.5 h. The reaction was quenched with the addition of sat. NaHCO₃ aqueous solution and extracted with a 30% solution of EtOAc in Hexanes, dried with Na₂SO₄, filtered and evaporated. The product was purified by flash chromatography on silica gel (10% EtOAc/hexane) to afford the desired product as colorless oil (1.73 g, 63% yield). ¹H NMR (500 MHz, Acetone): δ 7.35 (d, *J* = 7.2 Hz, 2 H); 7.29 (t, *J* = 7.6 Hz, 2 H); 7.23-7.17 (m, 1 H); 5.21 (s, 1 H); 4.84-4.80 (m, 1 H); 4.55-4.52 (m, 1 H); 4.45 (s, 1 H); 4.02 (d, *J* = 4.0 Hz, 1 H OH); 2.49 (dd, *J* = 7.9, 13.2 Hz, 1 H); 2.42 (dd, *J* = 5.2, 13.2 Hz, 1 H); 1.83 (s, 3 H); 1.66 (s, 3 H); 1.59 (s, 2 H); 0.09 (d, *J* = 3.7 Hz, 6 H). ¹³C NMR (500 MHz, Acetone): δ 153.84, 146.63, 144.49, 128.73, 127.59, 126.75, 125.78, 108.80, 73.20, 54.04, 28.80, 25.38, 22.71, -1.18.

General procedure for the cross-coupling:

To a solution of **3** (1.1 mmol, 1.1 eq) in THF (10 ml) stirred at rt under N₂, EtOH (0.32 ml, 5.5 mmol, 5.5 eq), TBAF 1 M THF (2.2 mL, 2.2 mmol, 2.2 eq) and Pd₂(dba)₃ or (Allyl)PdCl)₂ (0.05 mmol, 0.05 eq) was added. The resulting mixture was stirred at rt for 0.5 h and to which was

added aryl iodide (1 mmol, 1 eq). The resulting mixture was allowed to react for 4 hr [when $\text{Pd}_2(\text{dba})_3$ was used as catalyst] or 24 hr [when $(\text{AllylPdCl})_2$ was used as catalyst]. The reaction was worked up by the addition of water. Extracted with EtOAc, dried over Na_2SO_4 , filtered and evaporated, the residue was purified by flash chromatography on silica gel to afford the desired product.³

(3E)-3-methyl-1,4-diphenylbut-3-en-1-ol (4f)

By following the general procedure described above, **4f** was obtained as a colorless oil (177 mg, 74% yield). ^1H NMR (500 MHz, Acetone): δ 7.42 (d, $J = 7.3$ Hz, 2 H); 7.33-7.27 (m, 4 H); 7.23-7.15 (m, 4 H); 6.24 (s, 1 H); 4.92 (ddd, $J = 4.1, 5.2, 8.2$ Hz, 1 H); 4.20 (d, $J = 4.1$ Hz, 1 H); 2.57 (dd, $J = 8.2, 13.3$ Hz, 1 H); 2.50 (dd, $J = 5.2, 13.3$ Hz, 1 H); 1.89 (d, $J = 1.2$ Hz, 3 H). ^{13}C NMR (500 MHz, Acetone): δ 146.78, 139.28, 136.56, 129.58, 128.79, 128.46, 127.60, 126.74, 126.72, 73.08, 52.07, 18.49. FAB $(\text{M}+\text{K})^+$ Calcd for $\text{C}_{17}\text{H}_{18}\text{O}$: 277.0994; found: 277.0995.

1-[4-[(1E)-4-hydroxy-2-methyl-4-phenylbut-1-en-1-yl]phenyl]ethanone (4h)

By following the general procedure described above, **4h** was obtained as a white solid (239 mg, 85% yield). ^1H NMR (500 MHz, Acetone): δ 7.93 (d, $J = 8.3$ Hz, 2 H); 7.42 (d, $J = 7.2$ Hz, 2 H); 7.34-7.30 (m, 4 H); 7.22 (t, $J = 7.3$ Hz, 1 H); 6.31 (s, 1 H); 4.96-4.94 (m, 1 H); 4.27 (d, $J = 4.2$ Hz, 1 H OH); 2.63-2.50 (m, 5 H); 1.95 (d, $J = 1.2$ Hz, 3 H). ^{13}C NMR (500 MHz, Acetone): δ 197.32, 146.68, 144.01, 139.43, 135.69, 129.63, 128.90, 128.81, 127.69, 127.66, 126.70, 73.03, 52.17, 26.57, 18.78. FAB $(\text{M}+\text{H})^+$ Calcd for $\text{C}_{19}\text{H}_{21}\text{O}_2$: 281.1541; found: 281.1542.

(3E)-4-(4-methoxyphenyl)-3-methyl-1-phenylbut-3-en-1-ol (4i)

³ For the characterization of products not presented here, see: Li, L. and Navasero, N. *Org. Lett.* **2004**, 6, 3091-94.

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By following the general procedure described above, **4i** was obtained as a white solid (188 mg , 70 % yield). ^1H NMR (500 MHz, Acetone): δ 7.41 (d, J = 7.2 Hz, 2 H); 7.31 (t, J = 7.6 Hz, 2 H); 7.21 (t, J = 7.3 Hz, 1 H); 7.13 (d, J = 8.5 Hz, 2 H); 6.86 (d, J = 8.7 Hz, 2 H); 6.17 (s, 1 H); 4.90 (ddd, J = 4.0, 5.3, 8.1 Hz, 1 H); 4.15 (d, J = 4.0 Hz, 1 H OH); 3.77 (s, 3 H); 2.54 (dd, J = 8.1, 13.2 Hz, 1 H); 2.48 (dd, J = 5.3, 13.2 Hz, 1 H); 1.88 (d, J = 1.1 Hz, 3 H). ^{13}C NMR (500 MHz, Acetone): δ 158.87, 146.83, 134.74, 131.72, 130.72, 128.76, 128.03, 127.56, 126.71, 114.19, 73.10, 55.39, 52.20, 18.45. FAB (M-H) $^+$ Calcd for $\text{C}_{18}\text{H}_{19}\text{O}_2$: 267.1386; found: 267.1385.

ethyl 4-[(1E)-4-hydroxy-2-methyl-4-phenylbut-1-en-1-yl]benzoate (4g)

By following the general procedure described above, **4g** was obtained as a colorless syrup (255 mg , 85 % yield). ^1H NMR (500 MHz, Acetone): δ 7.95 (d, J = 8.3 Hz, 2 H); 7.42 (d, J = 7.2 Hz, 2 H); 7.32 (t, J = 7.8 Hz, 4 H); 7.22 (t, J = 7.3 Hz, 1 H); 6.31 (s, 1 H); 4.96-4.94 (m, 1 H); 4.32 (q, J = 7.1 Hz, 2 H); 4.27 (d, J = 4.2 Hz, 1 H); 2.60 (dd, J = 9.0, 13.3 Hz, 1 H); 2.54 (dd, J = 5.3, 13.3 Hz, 1 H); 1.95 (d, J = 1.2 Hz, 3 H); 1.35 (t, J = 7.1 Hz, 3 H). ^{13}C NMR (500 MHz, Acetone): δ 166.55, 146.69, 144.02, 139.39, 129.92, 129.58, 128.81, 127.66, 126.69, 73.02, 61.25, 52.14, 18.74, 14.57. FAB (M+H) $^+$ Calcd for $\text{C}_{20}\text{H}_{23}\text{O}_3$: 311.1648; found: 311.1647.

(3E)-4-(2-methoxyphenyl)-3-methyl-1-phenylbut-3-en-1-ol (4j)

By following the general procedure described above, **4h** was obtained as a colorless oil (30 mg , 11 % yield). ^1H NMR (500 MHz, Acetone): δ 7.42 (d, J = 7.1 Hz, 2 H); 7.31 (t, J = 7.6 Hz, 2 H); 7.22-7.16 (m, 2 H); 7.13 (d, J = 7.5 Hz, 1 H); 6.92 (d, J = 8.1 Hz, 1 H); 6.88 (t, J = 7.4 Hz, 1 H); 6.27 (s, 1 H); 4.92-4.88 (m, 1 H); 4.09 (d, J = 3.9

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Hz, 1 H OH); 3.77 (s, 3 H); 2.58 (dd, $J = 8.0, 13.2$ Hz, 1 H); 2.51 (dd, $J = 5.4, 13.0$ Hz, 1 H); 1.80 (d, $J = 1.3$ Hz, 3 H). ^{13}C NMR (500 MHz, Acetone): δ 158.01, 146.71, 135.83, 130.94, 128.76, 128.48, 127.83, 127.57, 126.76, 124.27, 120.55, 111.26, 73.10, 55.57, 51.85, 18.54. FAB (M+K) $^{+}$ Calcd for $\text{C}_{18}\text{H}_{19}\text{O}_2$ K: 307.1101; found: 307.1100.

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