Tetrahedron Letters,Vol.30,No.11 pp 1311-1314,1989 0040-4039/89 $3.00 + .00
Printed in Great Britain Pergamon Press plc

REGIOSELECTIVE SYNTHESIS OF HIGHLY SUBSTITUTED ARYLSILANES BY THE REACTION OF THE TRIMETHYLSILYL-SUBSTITUTED VINYLALLENONES WITH ENAMINES

Kung K. Wang*, Yemane W. Andemichael, and Sujitra Dhumrongvaraporn
Department of Chemistry, West Virginia University
Morgantown, West Virginia 26506

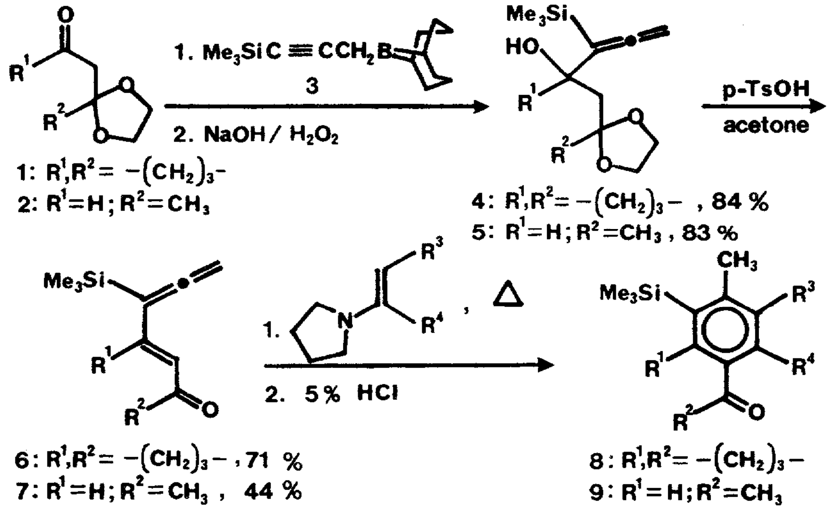
Abstract: Condensation of the trimethylsilyl-substituted vinylallenones 6 and 7 with enamines proceeded smoothly and provided highly substituted arylsilanes regioselectively after acidic workup.

Many interesting reactions of arylsilanes have been reported.[1] In a variety of cases, selective cleavage of the silicon-phenyl bond by electrophiles produced benzene derivatives having the substitution patterns difficult to obtain by conventional electrophilic aromatic substitution reactions. The fluoride-induced carbodesilylation[2] and related reactions[3] have also been investigated. The use of the trimethylsilyl group to protect the more reactive ortho sites of benzamides has also been realized, allowing the subsequent metalation reaction to occur at the alternative ortho positions.[4] However, despite these rapid developments, their applications are limited because of the lack of general synthetic methodologies for arylsilanes. We wish to report here a regioselective, convergent route to highly substituted arylsilanes.

We recently described a facile route to the trimethylsilyl-substituted α-allenic alcohols by the reaction of aldehydes and ketones with propargylborane 3.[5] By starting from the readily available monoprotected 1,3-dicarbonyl compounds 1[6] and 2[7], α-allenic alcohols 4 and 5 were thus synthesized (Scheme I). Acid-catalyzed deketalization followed by dehydration produced the corresponding trimethylsilyl-substituted vinylallenones 6 and 7. Subsequent condensations with enamines[8] under mild reaction conditions gave the highly substituted arylsilanes 8 and 9 (Table I).

The reaction of the electron-poor butadienes with enamines has been well studied.[10] The initially formed 1,3-cyclohexadiene derivatives, upon treatment with active manganese dioxide[10a] or 2,3-dichloro-5,6-dicyanobenzoquinone,[11] have been converted to the corresponding benzenes. Prolonged heating under pressure at 200°C to promote dehydrogenation has also resulted in aromatization.[10a] In comparison, the presence of an additional unsaturation in vinylallenones 6 and 7 allows a spontaneous aromatization at room temperature. It is also interesting to note that the reaction with the enamine derived from unsymmetrical acetophenone produced only one isomer. The assembly of the aromatic unit from 1-(trimethylsilyl)propyne, the monoprotected 1,3-dicarbonyl compounds, and enamines provides great flexibility in the introduction of various types of substituents to the desired positions around the highly substituted aromatic ring.

Scheme I



1: $R^1,R^2 = -(CH_2)_3-$
2: $R^1=H; R^2=CH_3$

4: $R^1,R^2 = -(CH_2)_3-$, 84 %
5: $R^1=H; R^2=CH_3$, 83 %

6: $R^1,R^2 = -(CH_2)_3-$, 71 %
7: $R^1=H; R^2=CH_3$, 44 %

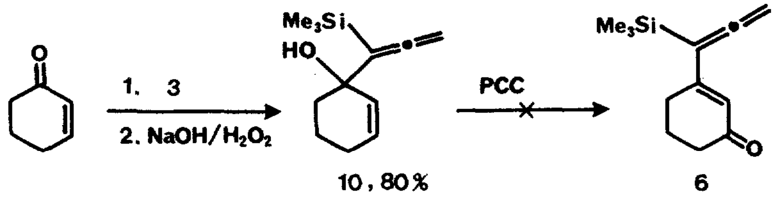
8: $R^1,R^2 = -(CH_2)_3-$
9: $R^1=H; R^2=CH_3$

Table I. Regioselective Synthesis of Highly Substituted Arylsilanes

arylsilane	R^3	R^4	reaction time[a], h	isolated yield,[b] %
8a	$-(CH_2)_3-$		0.5	92
8b	$-(CH_2)_4-$		3	62
8c	$-(CH_2)_5-$		3.5	66
8d	H	C_6H_5	3	51
9a	$-(CH_2)_3-$		6	67
9b	$-(CH_2)_4-$		10	65
9c	$-(CH_2)_5-$		15	51

[a] At the reflux temperature of benzene. [b] The isolated products have been characterized by IR, ^1H (270 MHz, $CDCl_3$) and ^{13}C (67.9 MHz, $CDCl_3$) NMR spectral data.[9]

Since the trimethylsilyl-substituted vinylallenone is the key intermediate of this synthetic methodology, we have attempted to develop other routes to these compounds. It has been reported that the oxidation of cyclic tertiary allylic alcohols with pyridinium chlorochromate (PCC) afforded the transposed 3-alkyl α,β-unsaturated ketones in exellent yield.[12] Therefore, it occurred to us that if 2-cyclohexenone is treated with 3 followed by the oxidation of the resulting alcohol 10 with PCC, vinylallenone 6 could be produced. Indeed, condensation of cyclohexenone with 3 afforded 10 in 80% isolated yield. Unfortunately, the oxidation with PCC produced a complex mixture. We have also attempted to synthesize 6 by treating 3 with 3-ethoxy-2-cyclohexenone. Although 6 was obtained after acidic workup, the reaction time was longer (5 h) and frequently gave low isolated yield (23%). Condensation with 3-(butylthio)-2-cyclohexenone failed to give 6.



Vinylallenes have found many useful synthetic applications and their synthetic potentials have been recognized.[13] We are currently investigating the use of a variety of readily available monoprotected 1,3-dicarbonyl compounds[14] to react with propargylboranes[15] for vinylallenone synthesis. Condensation of vinylallenones with other dienophiles is also being studied to determine the full scope and limitations of this annulation strategy for the synthesis of highly substituted aromatic compounds.[16]

The following procedure for the synthesis of 8a is representative. To a 100-mL flask containing 5.0 mmol of propargylborane 3[5a] was added 0.78 g (0.65 mL, 5.0 mmol) of 1 at room temperature. After 1.5 h, the usual oxidative workup was carried out and the organic layer was separated and washed with water. The solvent was then evaporated and the residue was distilled to give 1.13 g (84%) of 4 (bp 75°C, 0.02 torr) as a colorless liquid. To a 100-mL flask were then added 1.07 g of 4 (4.0 mmol), 5 mL of acetone, and 0.02 g of p-toluenesulfonic acid and the reaction mixture was heated to reflux for 3 h. After acetone was evaporated, 15 mL of hexane was added and the mixture was washed with water, dried over MgSO$_4$, and concentrated to afford 0.58 g (71%) of 6 as a viscous light yellow liquid.[9,17] Vinylallenone 6 (0.41 g, 2.0 mmol) and 0.27 g of 1-(1-cyclopentenyl)-pyrrolidine (2.0 mmol) were dissolved in 5 mL of dry benzene and the reaction mixture was warmed at reflux for 0.5 h. The reaction mixture was then washed with 3 mL of 5% HCl and 5 mL of water, dried over MgSO$_4$, and concentrated. Recrystallization of the residue from 1.5 mL of ether at -15°C afforded 0.50 g (92%) of 8a as a white solid: mp 88-89°C; IR (KBr) 1665, 1245, 845 cm^{-1}; ^{1}H NMR (CDCl$_3$) δ 3.35 (2H, t, J=7.5 Hz), 3.04 (2H, t, J=5.8 Hz), 2.80 (2H, t, J=7.6 Hz), 2.59 (2H, t, J=6.6 Hz), 2.39 (3H, s), 2.04 (4H, m); ^{13}C NMR (CDCl$_3$) δ 200.09, 149.67, 147.43, 145.46, 143,49, 135.31, 127.54, 40.00, 35.35, 32.67, 31.64, 24.20, 23.45, 22.00, 3.90. Anal. Calcd for C$_{17}$H$_{24}$OSi: C, 74.94; H, 8.88. Found: C, 74.77; H, 8.97.

Acknowledgment. We thank the donors of the Petroleum Research Fund, administered by the American Chemical Society, for financial support of this work.

References and Notes

(1) (a) Colvin, E.W. Silicon in Organic Synthesis; Butterworths: London, 1981; Chapter 10. (b) Larson, G.L. J. Organometal. Chem. 1987, 337, 195-430.
(2) Mills, R.J.; Snieckus, V. Tetrahedron Lett. 1984, 25, 483-486.
(3) Shankaran, K.; Snieckus, V. Tetrahedron Lett. 1984, 25, 2827-2830.
(4) Mills, R.J.; Snieckus, V. J. Org. Chem. 1983, 48, 1565-1568.
(5) (a) Wang, K.K.; Nikam, S.S.; Ho, C.D. J. Org. Chem. 1983, 48, 5376-5377.
(b) Wang, K.K.; Liu, C. J. Org. Chem. 1985, 50, 2578-2580.
(6) Mertes, M.P. J. Org. Chem. 1961, 26, 5236-5238. We observed that by treating 1.2 equiv of 1,3-cyclohexanedione with ethylene glycol at 50°C for 6 h, monoethylene ketal 1 was obtained by vacuum distillation in 61% isolated yield, containing less

than 3% diketal.

(7) Kelly, T.R.; Ananthasubramanian, L.; Borah, K.; Gillard, J.W.; Goemer, R.N., Jr.; King, P.F.; Lyding, J.M.; Tsang, W.G.; Vaya, J. Tetrahedron 1984, 40, 4569-4577.

(8) (a) Stork, G.; Brizzolara, A.; Landesman, H.; Szmuszkovicz, J.; Terrell, R. J. Am. Chem. Soc. 1963, 85, 207-222. (b) Carlson, R.; Nilsson, A. Acta Chem. Scand., Ser. B 1984, 38, 49-53.

(9) Spectral data for 6, 7, 8c, 8d, and 9a. 6: IR (neat) 1905, 1650, 1585, 1250, 845 cm^{-1}; ^{1}H NMR δ 5.90 (1H,s), 4.66 (2H,s), 2.41 (2H,t,J=6.0 Hz), 2.30 (2H,t,J=6.7 Hz), 1.92 (2H,m), 0.14 (9H,s); ^{13}C NMR δ 213.47, 199.54, 158.70, 126.10, 100.44, 71.94, 37.20, 28.70, 22.44, -0.59. 7: IR (neat) 1905, 1660, 1585, 1250, 840 cm^{-1}; ^{1}H NMR δ 7.12 (1H,dt,J=19.2 and 1 Hz), 6.18 (1H,dt,J=19.2 and 1 Hz), 4.69 (2H,t,J=1 Hz), 2.23 (3H,s), 0.22 (9H,s); ^{13}C NMR δ 216.14, 198.07, 143.11, 129.77, 96.68, 70.32, 26.77, -1.10. 8c: mp 76-77°C; IR (KBr) 1660, 1250, 840 cm^{-1}; ^{1}H NMR δ 3.07 (2H,t), 2.87 (4H,m), 2.60 (2H,t), 2.42 (3H,s), 1.95 (2H,quintet), 1.76 (2H,m), 1.69 (2H,m), 1.59 (2H,m), 0.41 (9H,s); ^{13}C NMR δ 202.32, 148.22, 145.64, 145.36, 141.96, 135.16, 131.60, 40.32, 32.67, 31.22, 29.97, 28.85, 26.93, 26.41, 23.12, 22.69, 3.89. Anal. Calcd for $C_{19}H_{28}OSi$: C, 75.94; H, 9.39. Found: C, 75.58; H, 9.60. 8d: mp 94-95°C; IR (KBr) 1675, 1255, 850, 765, 700 cm^{-1}; ^{1}H NMR δ 7.4-7.15 (5H,m), 6.95 (1H,s), 3.04 (2H,t), 2.57 (2H,t), 2.49 (3H,s), 2.07 (2H,quintet), 0.46 (9H,s); ^{13}C NMR δ 198.99, 151.87, 148.24, 144.30, 142.96, 136.35, 132.74, 130.02, 128.12, 127.80, 126.50, 39.78, 32.75, 25.19, 22.88, 3.65. Anal. Calcd for $C_{20}H_{24}OSi$: C, 77.87; H, 7.84. Found: C, 77.31; H, 8.07. 9a: IR (KBr) 1660, 1250, 830 cm^{-1}; ^{1}H NMR δ 7.81 (1H,s), 3.28 (2H,t), 2.84 (2H,t), 2.57 (3H,s) 2.41 (3H, s), 2.07 (2H, quintet), 0.36 (9H, s); ^{13}C NMR δ 199.83, 146.48, 145.14, 144.34, 136.27, 134.28, 131.34, 34.53, 31.42, 28.17, 24.40, 20.30, 0.07. Anal. Calcd for $C_{15}H_{22}OSi$: C, 73.11; H, 9.00. Found: C, 73.12; H, 9.17.

(10) (a) Danishefsky, S.; Cunningham, R. J. Org. Chem. 1965, 30, 3676-3679. (b) Berchtold, G.A.; Ciabattoni, J.; Tunick, A.A. J. Org. Chem. 1965, 30, 3679-3683.

(11) House, H.O.; Cronin, T.H. J. Org. Chem. 1965, 30, 1061-1070.

(12) Dauben, W.G.; Michno, D.M. J. Org. Chem. 1977, 42, 682-685.

(13) (a) Snider, B.B.; Burbaum, B.W. J. Org. Chem. 1983 , 48, 4370-4374. (b) Reich, H.J.; Eisenhart, E.K. J. Org. Chem. 1984, 49, 5282-5283. (c) Angelov, C.M.; Mondeshka, D.M.; Tancheva, T.N. J. Chem. Soc., Chem. Commun. 1985, 647-648. (d) Keck, G.E.; Kachensky, D.F. J. Org. Chem. 1986, 51, 2487-2593.

(14) Vankar, Y.D.; Chaudhuri, N.C.; Rao, C.T. Tetrahedron Lett. 1987, 28, 551-554.

(15) Zweifel, G.; Pearson, N.R. J. Org.Chem. 1981, 46, 829-830.

(16) (a) Danheiser, R. L.; Gee, S. K.; Perez, J. J. Am. Chem. Soc. 1986, 108, 806-810. (b) Boger, D. L.; Mullican, M. D. J. Org. Chem. 1984, 49, 4033-4044.

(17) (a) Attempts to further purify 6 by vacuum distillation or silica gel column resulted in decomposition. (b) We very recently discovered that acid-catalyzed deketalization and dehydration of crude 4 without purification by distillation could be accomplished by heating the mixture in acetone at 50°C for 1 h. This reduced the amount of decomposition of 6 and an 88% overall yield of 6 from 1 was obtained. (c) Acid-catalyzed hydrolysis of 5 to 4-hydroxy-5-(trimethylsilyl)-5,6-heptadien-2-one (85% isolated yield, bp 58-60°C, 0.03 torr) was carried out in ethanol at reflux for 6 h. Subsequent acid-catalyzed dehydration to 7 (52% isolated yield, bp 50-51°C, 0.03 torr) was carried out in acetone at reflux for 72 h.

(Received in USA 13 December 1988)