

# A facile regio- and stereocontrolled synthesis of (*Z*)-1-en-3-yn-2-ylstannanes *via* alkynyliodonium tosylates coupling with *gem*-stannyl zirconocene alkenes

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Acetylenic stannanes react with  $\text{Cp}_2\text{Zr}(\text{H})\text{Cl}$  ( $\text{Cp} = \eta^5\text{-C}_5\text{H}_5$ ) giving organozirconium(IV) complexes, which are trapped with alkynyliodonium tosylates in the presence of  $\text{Pd}(\text{PPh}_3)_4$  to afford (*Z*)-1-en-3-yn-2-ylstannanes.

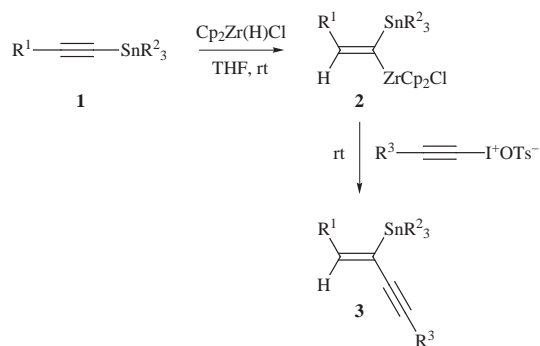
## Introduction

Conjugated enynes are of great interest in organic synthesis,<sup>1,2</sup> because they are incorporated in a number of natural products and can be readily converted in a stereospecific manner into the corresponding diene system.<sup>3,4</sup> A number of methods for the preparation of conjugated enynes have been previously reported. The synthesis of enynes has been performed by the coupling of haloalkynes with vinyl metals such as vinylboron,<sup>5</sup> vinylcopper,<sup>6</sup> vinylzinc,<sup>7</sup> vinylaluminium<sup>8</sup> or vinylmagnesium reagents.<sup>9</sup> Takahashi and co-workers have reported the coupling of alkenylzirconium compounds with alkynyl halides which give substituted enynes.<sup>10</sup> However the coupling of *gem*-stannyl zirconocene alkenes with alkynyl halides has not been reported. We tried to synthesize (*Z*)-1-en-3-yn-2-ylstannanes *via gem*-stannyl zirconocene alkenes (**2**) coupling with alkynyl halides such as phenylethynyl iodide, but were unsuccessful. Considering the electrophilicity of alkynyliodonium tosylates,<sup>11</sup> we tried to react them with the *gem*-stannyl zirconocene alkenes (**2**), produced by hydrozirconation of acetylenic stannanes<sup>12</sup> (**1**).

## Results and discussion

$\text{Cp}_2\text{Zr}(\text{H})\text{Cl}$ <sup>13</sup> adds to acetylenic stannanes (**1**) in THF at room temperature stereospecifically with high regioselectivity to yield vinyl Zr(IV) complexes (**2**) which react with alkynyliodonium tosylates at room temperature in the presence of  $\text{Pd}(\text{PPh}_3)_4$  to afford (*Z*)-1-en-3-yn-2-ylstannanes (**3**) (Scheme 1). Yields are good to excellent (Table 1).

The configuration of (*Z*)-1-en-3-yn-2-ylstannane **3a** was confirmed from compound **4** which was obtained by treatment



$\text{R}^1 = \text{Ph}, \text{CH}_2\text{OCH}_3$ ;  $\text{R}^2 = \text{Ph}, \text{Bu}, \text{Et}$ ;  $\text{R}^3 = \text{Ph}, n\text{-C}_5\text{H}_{11}, \text{CH}_2\text{OCH}_3$

Scheme 1

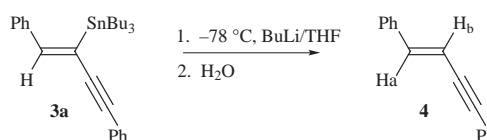
Table 1 The synthesis of compound **3a-i**, **4** and **5**<sup>a</sup>

Product	R <sup>1</sup>	R <sup>2</sup>	R <sup>3</sup>	Mp/°C	Yield (%) <sup>b</sup>
<b>3a</b>	Ph	Bu	Ph	oil	81
<b>3b</b>	Ph	Bu	CH <sub>3</sub> OCH <sub>2</sub>	oil	76
<b>3c</b>	Ph	Ph	CH <sub>3</sub> OCH <sub>2</sub>	138–139	72
<b>3d</b>	Ph	Ph	n-C <sub>5</sub> H <sub>11</sub>	125–126	74
<b>3e</b>	CH <sub>3</sub> OCH <sub>2</sub>	Bu	Ph	oil	78
<b>3f</b>	CH <sub>3</sub> OCH <sub>2</sub>	Bu	n-C <sub>5</sub> H <sub>11</sub>	oil	75
<b>3g</b>	CH <sub>3</sub> OCH <sub>2</sub>	Bu	CH <sub>3</sub> OCH <sub>2</sub>	oil	68
<b>3h</b>	CH <sub>3</sub> OCH <sub>2</sub>	Ph	n-C <sub>5</sub> H <sub>11</sub>	139–140	66
<b>3i</b>	CH <sub>3</sub> OCH <sub>2</sub>	Et	CH <sub>3</sub> OCH <sub>2</sub>	oil	70
<b>4</b>	Ph	Ph	Ph	oil	90
<b>5</b>	Ph	Ph	Ph	49–50	81

<sup>a</sup> The products were identified by MS, <sup>1</sup>H NMR and IR spectroscopy.

<sup>b</sup> Isolated yield.

of **3a** with *n*-butyllithium in THF followed by hydrolysis; the reaction occurs stereoselectively (Scheme 2).<sup>14,15</sup> Particularly

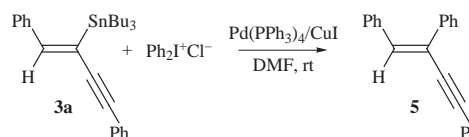


Scheme 2

diagnostic for the stereochemistry of **4** was the coupling constant between the vicinal protons H<sub>a</sub> and H<sub>b</sub> which show a typical value of  $J_{\text{HH}}$  of 16 Hz which is consistent with an *E* configuration. Therefore, we could confirm that the 1-en-3-yn-2-ylstannanes **3** have a *Z* configuration.

(*Z*)-1-En-3-yn-2-ylstannanes (**3**) are important, useful synthetic intermediates and are effective precursors for preparation of conjugated enynes. For example, the coupling of (*Z*)-1-en-3-yn-2-ylstannane **3a** with diphenyliodonium chloride at room temperature in the presence of  $\text{Pd}(\text{PPh}_3)_4$  and  $\text{CuI}$  affords (*E*)-1,2,4-triphenylbut-1-en-3-yne (**5**) in 81% yield (Scheme 3).

The hydrozirconation/coupling strategy provides a direct route to (*Z*)-1-en-3-yn-2-ylstannanes from acetylenic stannanes.



Scheme 3

The method has some attractive advantages such as mild reaction conditions, a simple procedure, shorter reaction times and high regio- and stereoselectivity.

## Experimental

<sup>1</sup>H NMR spectra were recorded on an AZ-300 spectrometer with TMS as internal standard. Mass spectra were obtained on a Finigan 8230 mass spectrometer. IR spectra were determined on a PE-683 instrument as neat films. All reactions were carried out in pre-dried glassware (140 °C, 4 h) and cooled under a stream of dry nitrogen. All solvents were dried, deoxygenated and redistilled before use.

### General procedure for the synthesis of 3a–i

A mixture of Cp<sub>2</sub>Zr(H)Cl (1 mmol) and **1** (1 mmol) in THF (5 ml) was stirred at room temperature for 40 min to yield a clear solution. Into the resulting solution were added Pd(PPh<sub>3</sub>)<sub>4</sub> (0.05 mmol) and alkynylodonium tosylates (1 mmol), and the mixture was stirred at room temperature for 3 h. The solvent was removed by rotary evaporator under reduced pressure. The residue was extracted with light petroleum (3 × 6 ml) and filtered through a short plug of silica gel. After evaporation of the filtrate, the residue was purified by preparative TLC on silica gel eluting with light petroleum.

**(Z)-1,4-Diphenyl-2-(tributylstannyl)but-1-en-3-yne 3a.** A pale yellow oil (Found: C, 68.30; H, 7.75. Calc. for C<sub>28</sub>H<sub>38</sub>Sn: C, 68.17; H, 7.76%);  $\nu_{\max}(\text{film})/\text{cm}^{-1}$ : 3080, 2200, 1610, 1480, 1015, 750;  $\delta_{\text{H}}(300 \text{ MHz}; \text{CDCl}_3)$ : 7.42–7.02 (m, 11H, Ph, HC=), 1.50–0.65 (m, 27H, Bu);  $m/z$  494 (M<sup>+</sup>, 1.5%), 291 (M – SnBu<sub>3</sub>, 6.0), 57 (100).

**(Z)-5-Methoxy-1-phenyl-2-(tributylstannyl)pent-1-en-3-yne 3b.** A pale yellow oil (Found: C, 62.68; H, 8.34. Calc. for C<sub>24</sub>H<sub>38</sub>OSn: C, 62.50; H, 8.30%);  $\nu_{\max}(\text{film})/\text{cm}^{-1}$ : 3085, 2205, 1590, 1482, 1020, 810;  $\delta_{\text{H}}(300 \text{ MHz}; \text{CDCl}_3)$ : 7.50–7.10 (m, 6H, Ph, HC=), 4.10 (s, 2H, CH<sub>2</sub>O), 3.28 (s, 3H, OCH<sub>3</sub>), 1.70–0.60 (m, 27H, Bu);  $m/z$  462 (M<sup>+</sup>, 4.2%), 447 (M – CH<sub>3</sub>, 7.7), 291 (SnBu<sub>3</sub>, 6.5), 147 (100), 57 (9.4).

**(Z)-5-Methoxy-1-phenyl-2-(triphenylstannyl)pent-1-en-3-yne 3c.** A pale yellow solid, mp 138–139 °C (from methanol) (Found: C, 68.93; H, 5.05. Calc. for C<sub>30</sub>H<sub>26</sub>OSn: C, 69.13; H, 5.03%);  $\nu_{\max}(\text{KBr})/\text{cm}^{-1}$ : 3080, 3020, 2340, 1490, 1440, 1075;  $\delta_{\text{H}}(300 \text{ MHz}; \text{CDCl}_3)$ : 7.45–7.00 (m, 21H, Ph, HC=), 4.10 (s, 2H, CH<sub>2</sub>O), 3.25 (s, 3H, OCH<sub>3</sub>);  $m/z$  477 (M – CH<sub>2</sub>OCH<sub>3</sub>, 9.2%), 351 (SnPh<sub>3</sub>, 100).

**(Z)-1-Phenyl-2-(triphenylstannyl)non-1-en-3-yne 3d.** A pale yellow solid, mp 125–126 °C (from methanol) (Found: C, 72.62; H, 5.92. Calc. for C<sub>33</sub>H<sub>32</sub>Sn: C, 72.42; H, 5.89%);  $\nu_{\max}(\text{KBr})/\text{cm}^{-1}$ : 3080, 3010, 2360, 1590, 1490, 1440, 1075, 1030;  $\delta_{\text{H}}(300 \text{ MHz}; \text{CDCl}_3)$ : 7.50–7.05 (m, 21H, Ph, HC=), 2.20–0.70 (m, 11H, C<sub>5</sub>H<sub>11</sub>);  $m/z$  477 (M – C<sub>5</sub>H<sub>11</sub>, 98%), 351 (SnPh<sub>3</sub>, 93.9), 280 (100).

**(Z)-5-Methoxy-1-phenyl-3-(tributylstannyl)pent-3-en-1-yne 3e.** A pale yellow oil (Found: C, 62.68; H, 8.34. Calc. for C<sub>24</sub>H<sub>38</sub>OSn: C, 62.50; H, 8.30%);  $\nu_{\max}(\text{film})/\text{cm}^{-1}$ : 3085, 2210, 1610, 1580, 1015, 810;  $\delta_{\text{H}}(300 \text{ MHz}; \text{CDCl}_3)$ : 7.45–7.25 (m, 5H, Ph), 5.95 (t, *J* 6.0 Hz, 1H, HC=), 4.17 (d, *J* 6.0 Hz, 2H, OCH<sub>2</sub>), 3.26 (s, 3H, CH<sub>3</sub>O), 1.85–0.80 (m, 27H, Bu);  $m/z$  462 (M<sup>+</sup>, 7.4%), 447 (M – CH<sub>3</sub>, 4.6), 291 (SnBu<sub>3</sub>, 83.6), 147 (100).

**(Z)-1-Methoxy-3-(tributylstannyl)dec-2-en-4-yne 3f.** A pale yellow oil (Found: C, 60.54; H, 9.70. Calc. for C<sub>23</sub>H<sub>44</sub>OSn: C, 60.68; H, 9.74%);  $\nu_{\max}(\text{film})/\text{cm}^{-1}$ : 3080, 3020, 2340, 1490, 1000;  $\delta_{\text{H}}(300 \text{ MHz}; \text{CDCl}_3)$ : 6.50 (t, *J* 6.0 Hz, 1H, HC=), 3.80 (d, *J* 6.0

Hz, 2H, OCH<sub>2</sub>), 3.20 (s, 3H, CH<sub>3</sub>O), 2.40–0.70 (m, 38H, Bu, C<sub>5</sub>H<sub>11</sub>);  $m/z$  425 (M – CH<sub>3</sub>O, 6.2%), 399 (M – C<sub>4</sub>H<sub>9</sub>, 100), 291 (SnBu<sub>3</sub>, 7.1), 165 (M – SnBu<sub>3</sub>, 73.9).

**(Z)-1,6-Dimethoxy-3-(tributylstannyl)hex-2-en-4-yne 3g.** A pale yellow oil (Found: C, 56.13; H, 8.95. Calc. for C<sub>20</sub>H<sub>38</sub>O<sub>2</sub>Sn: C, 55.97; H, 8.92%);  $\nu_{\max}(\text{film})/\text{cm}^{-1}$ : 2200, 1570, 1480, 1180;  $\delta_{\text{H}}(300 \text{ MHz}; \text{CDCl}_3)$ : 6.00 (t, *J* 6.0 Hz, 1H, HC=), 4.20 (d, *J* 6.0 Hz, 2H, OCH<sub>2</sub>CH=), 4.10 (s, 2H, CH<sub>2</sub>O), 3.29 (s, 3H, OCH<sub>3</sub>), 3.26 (s, 3H, OCH<sub>3</sub>), 1.75–0.65 (m, 27H, Bu);  $m/z$  430 (M<sup>+</sup>, 3.2%), 399 (M – CH<sub>3</sub>O, 43.0), 291 (SnBu<sub>3</sub>, 17.9), 165 (M – SnBu<sub>3</sub>, 42.0), 57 (100).

**(Z)-1-Methoxy-3-(triphenylstannyl)dec-2-en-4-yne 3h.** A pale yellow solid, mp 139–140 °C (from methanol) (Found: C, 67.69; H, 6.22. Calc. for C<sub>29</sub>H<sub>32</sub>OSn: C, 67.60; H, 6.26%);  $\nu_{\max}(\text{KBr})/\text{cm}^{-1}$ : 3070, 2360, 1640, 1480, 1440, 1100, 740, 690;  $\delta_{\text{H}}(300 \text{ MHz}; \text{CDCl}_3)$ : 7.60–7.00 (m, 15H, Ph), 6.12 (t, *J* 6.0 Hz, 1H, HC=), 3.75 (d, *J* 6.0 Hz, 2H, OCH<sub>2</sub>), 3.20 (s, 3H, CH<sub>3</sub>O), 1.40–0.70 (m, 11H, C<sub>5</sub>H<sub>11</sub>);  $m/z$  516 (M<sup>+</sup>, 3.2%), 351 (SnPh<sub>3</sub>, 30.7), 262 (100).

**(Z)-1,6-Dimethoxy-3-(triethylstannyl)hex-2-en-4-yne 3i.** A pale yellow oil (Found: C, 48.95; H, 7.55. Calc. for C<sub>14</sub>H<sub>26</sub>O<sub>2</sub>Sn: C, 48.73; H, 7.59%);  $\nu_{\max}(\text{film})/\text{cm}^{-1}$ : 3100, 3010, 2340, 1610, 1450, 1085, 890;  $\delta_{\text{H}}(300 \text{ MHz}; \text{CDCl}_3)$ : 6.10 (t, *J* 6.0 Hz, 1H, HC=), 4.08 (s, 2H, CH<sub>2</sub>O), 3.75 (d, *J* 6.0 Hz, 2H, OCH<sub>2</sub>CH=), 3.30 (s, 3H, OCH<sub>3</sub>), 3.20 (s, 3H, OCH<sub>3</sub>), 1.40–0.70 (m, 15H, Et);  $m/z$  346 (M<sup>+</sup>, 1.6%), 279 (100), 207 (SnEt<sub>3</sub>, 3.8).

### The synthesis of (E)-1,4-diphenylbut-1-en-3-yne 4

1 ml BuLi (1.1 M hexane solution) was added to a THF (5.0 ml) solution of **3a** (1.0 mmol) at –78 °C. After stirring for 30 min, the mixture was hydrolyzed with saturated aq. NH<sub>4</sub>Cl and extracted with CH<sub>2</sub>Cl<sub>2</sub> (2 × 10 ml). The organic extract was dried with MgSO<sub>4</sub>, filtered and concentrated under vacuum. The residue was purified by column chromatography with silica gel, eluting with petroleum to give (*E*)-enyne **4** (yield: 90%) as a pale yellow oil;<sup>16</sup>  $\nu_{\max}(\text{film})/\text{cm}^{-1}$ : 3010, 2190, 1590, 1480, 1240, 950, 800;  $\delta_{\text{H}}(300 \text{ MHz}; \text{CDCl}_3)$  7.50–7.00 (m, 11H, Ph, HC=), 6.43 (d, 1H, *J* 16.0 Hz, =CH).

### The synthesis of (E)-1,2,4-triphenylbut-1-en-3-yne 5

(*Z*)-1-En-3-yn-2-ylstannane **3a** (0.5 mmol) and diphenyliodonium chloride<sup>17</sup> (0.5 mmol) were dissolved in DMF (5 ml) under nitrogen at room temperature. Pd(PPh<sub>3</sub>)<sub>4</sub> (0.05 mol) and CuI (0.4 mmol) were then added. The mixture was stirred at room temperature and monitored by TLC for the disappearance of the starting organostannane. The reaction mixture was diluted with CH<sub>2</sub>Cl<sub>2</sub> (15 ml), filtered and stirred with 20% aqueous KF (10 ml) for 30 min before being dried and concentrated. The residue was purified by column chromatography on silica gel, eluting with light petroleum to give enyne **5** (yield: 81%) as a solid, mp 49–50 °C (lit.,<sup>18</sup> 49–50 °C);  $\nu_{\max}(\text{film})/\text{cm}^{-1}$ : 3090, 2210, 1590, 1460, 740;  $\delta_{\text{H}}(300 \text{ MHz}; \text{CDCl}_3)$ : 7.75–7.05 (m, 15H, Ph), 6.95 (s, 1H, HC=).

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## References

- 1 P. J. Stang and T. Kitamura, *J. Am. Chem. Soc.*, 1987, **109**, 7561.
- 2 M. M. Salter, V. Gevorgyan, S. Saito and Y. Yamamoto, *Chem. Commun.*, 1996, 17.

- 3 P. A. Magriotis and K. D. Kim, *J. Am. Chem. Soc.*, 1993, **115**, 2972.
- 4 E. J. Corey and A. Tramontano, *J. Am. Chem. Soc.*, 1984, **106**, 462.
- 5 N. Miyaura, K. Yamada, H. Suginome and A. Suzuki, *J. Am. Chem. Soc.*, 1985, **107**, 972.
- 6 A. Alexakis, G. Cahiez and J. F. Normant, *Synthesis*, 1979, 826.
- 7 M. Abarbri, J. L. Parrain, J. C. Cintrat and A. Duchêne, *Synthesis*, 1996, 82.
- 8 M. Kobayashi, L. F. Valente and E. Negishi, *synthesis*, 1980, 1034.
- 9 H. P. Dang and G. Linstrumelle, *Tetrahedron Lett.*, 1978, 191.
- 10 R. Hara, Y. Liu, W. H. Sun and T. Takahashi, *Tetrahedron Lett.*, 1997, **38**, 4103.
- 11 P. J. Stang, B. W. Surber, Z. C. Chen, K. A. Roberts and A. G. Anderson, *J. Am. Chem. Soc.*, 1987, **109**, 228.
- 12 M. W. Logue and K. Teng, *J. Org. Chem.*, 1982, **47**, 2549.
- 13 S. L. Buchwald, S. J. LaMaire, R. B. Nielsen, B. T. Watson and S. N. King, *Tetrahedron Lett.*, 1987, **28**, 3895.
- 14 B. T. Grobel and D. Seebach, *Chem. Ber.*, 1977, **110**, 867.
- 15 A. Pelter, K. Smith, D. E. Parry and K. D. Jones, *Aust. J. Chem.*, 1992, **45**, 57.
- 16 R. A. Aithen, C. Boeters and J. J. Morrison, *J. Chem. Soc., Perkin Trans. I*, 1994, 2473.
- 17 F. M. Beringer, M. Drexler, E. M. Gimpler and C. C. Lumpkin, *J. Am. Chem. Soc.*, 1953, **75**, 2705.
- 18 F. Mareuzzi, U. Azzena and G. Melloni, *J. Chem. Soc., Perkin Trans. I*, 1993, 2957.

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