SHORT PAPER

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Stereoselective synthesis of substituted allyl selenide by the reaction of (*E*)-3-selanyl vinylzirconocene chloride with aldehydes or acyl chlorides

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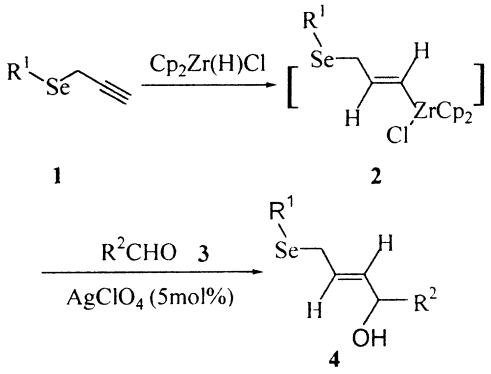
A regio- and stereoselective synthesis of substituted allyl selenides is described. Hydrozirconation of propargyl selenides and its further reaction with aldehydes or acyl chlorides afford 4-selanyl allyl alcohols or 4-selanyl-2-en-1-one, respectively.

Keywords: ally selenides, 3-selanyl vinylzirconocene chloride, stereoselective synthesis

Allyl selenides are important intermediates in organic synthesis. They are recognized as useful synthons of selenium-stabilised allylic anions and can be regioselectively α-alkylated.[1] They can carry out[2,3] sigmatropic rearrangements to give allyl alcohols.[2] The selanyl group of allyl selenides can be substituted by a Grignard reagent in the presence of a Ni catalyst.[3] Therefore, the synthesis of allyl selenides is of interest in organic synthesis and many synthetic methods for preparing allyl selenide have been developed. [1b, 4] Hydrozirconation has emerged as a unique hydrometallation with some attractive features, such as high regioselectivity and stereoselectivity.[5] Hydrozirconation of simple alkynes and 1-heteroatom (such as Si, B, Sn, *etc.*) substituted alkynes has been extensively investigated and been used in organic synthesis. [6] However, there are limited reports based on the hydrozirconation of 3-heteroatom substituted alkynes. [7] Recently, we have studied the hydrozirconation of acetylenic selenides and the reaction of the formed intermediates α or β-selanyl substituted vinylzirconocene chlorides with various electrophiles.[8] As an extension of our studies, we wish to report herein the hydrozirconation of propargyl selenides and its further reaction with aldehydes or acyl chlorides, in the presence of catalytic amounts of $AgClO_4$ or $CuBr{\cdot}SMe_2$, to afford substituted allyl selenides regio- and stereoselectively.

The (*E*)-3-selanyl vinylzirconocene chlorides (**2**) can be synthesised regio- and stereoselectively by hydrozirconation of propargyl selenides (**1**). The intermediates **2** react smoothly with aldehydes **3** in CH_2Cl_2 at room temperature in the presence of 5mol% $AgClO_4$ to afford 4-selanyl allyl alcohols **4** (Scheme 1). The results are summarized in Table 1.

The intermediates **2** also can react smoothly with acyl chlorides **5** in CH_2Cl_2 at room temperature in the presence of 15mol% $CuBr{\cdot}SMe_2$ to afford 4-selanyl-2-en-1-one **6** (Scheme 2).



Scheme 1

Table 1 Preparation of 4-selanyl allyl alcohols **4a–4g**

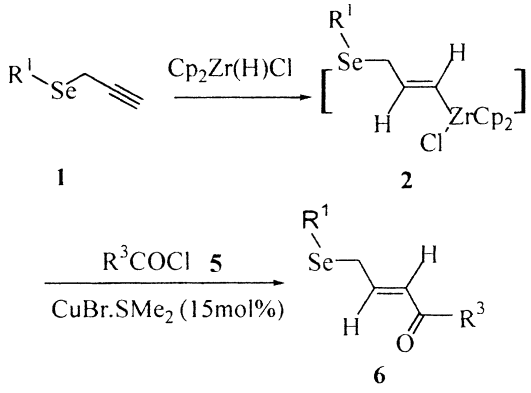
Entry	R^1	R^2	Product	Yield/%[a]
1	C_6H_5-	*p*-$CH_3C_6H_4$-	**4a**	55
2	C_6H_5-	C_6H_5-	**4b**	63
3	C_6H_5-	*p*-ClC_6H_4-	**4c**	76
4	C_6H_5-	*p*-$NO_2C_6H_5$-	**4d**	75
5	Et	*p*-$CH_3C_6H_5$-	**4e**	58
6	Et	C_6H_5-	**4f**	61
7	Et	*p*-$NO_2C_6H_5$-	**4g**	73

[a]Isolated yield.

Table 2 Preparation of 4-selanyl-2-en-1-one **6a–6f**

Entry	R^1	R^3	Product	Yield/% [a]
1	C_6H_5-	*p*-$CH_3C_6H_5$-	**6a**	72
2	C_6H_5-	C_6H_5-	**6b**	78
3	C_6H_5-	*n*-C_3H_7-	**6c**	75
4	Et	*p*-$CH_3C_6H_5$-	**6d**	69
5	Et	C_6H_5-	**6e**	72
6	Et	*p*-$NO_2C_6H_5$-	**6f**	76

[a]Isolated yield.



Scheme 2

The (*E*)-configuration of all the products **4a**–**4g** and **6a**–**6f** was confirmed by the coupling constants of the vinylic protons (15.04 – 15.76Hz).

In conclusion, hydrozirconation of propargyl selenides and its further reaction with aldehydes or acyl chlorides provide a convenient method for the synthesis of substituted allyl selenides. The present procedure has the advantages of readily available starting materials, simple procedures, mild reaction conditions and regio- and stereoselectivity. Due to the versatile reactivity of allyl selenide, the obtained 4-selanyl allyl alcohols or 4-selanyl-2-en-1-one are the potential precursors of substituted allyl alcohol or α, β-unsaturated ketones

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† This is a Short Paper, there is therefore no corresponding material in *J Chem. Research (M).*

respectively. Further transformation of the substituted allyl selenides is in progress in our laboraotry.

Experimental

All ^{1}H NMR spectra were measured in $CDCl_3$ and recorded on Brucker Avance – 400 (400MHz) spectrometer with TMS as the internal standard, chemical shifts are expressed in ppm and *J* values are given in Hz. IR spectra were run on a Bruck vector 22 spectrometer. EIMS were determined with a HP5989B mass spectrometer. All the reactions in this paper were performed under nitrogen atmosphere. CH_2Cl_2 were dried over CaH_2 and distilled before use. Propargyl selenides [9] and hydrozirconocene chloride [(10)] were prepared according to literature procedure.

General procedure for the synthesis of **4a–4g**: A mixture of hydrozirconocene chloride (1.2mmol) and propargyl selenide (**1**) (1.0mmol) in CH_2Cl_2 was stirred at room temperature for 20min. To the resulting clear solution was added aldehyde **3** (1.0mmol) followed by $AgClO_4$ (5mol%). The reaction mixture turned dark brown gradually. After stirring for 20-30min, the reaction mixture was quenched with saturated $NaHCO_3$ aqueous solution. Extractive workup (EtOAc) followed by purification with flash chromatography (silica/hexanes-EtOAc 4:1) gave 4-selanyl allyl alcohols **4a–4g**.

4a: oil. ^{1}H NMR ($CDCl_3$, 400 MHz): 7.47 (d, 2H, *J* = 7.52 Hz), 7.26-7.21 (m, 3H), 7.12–7.10 (m, 4H), 5.89–5.87 (m, 1H), 5.52 (dd, 1H, *J* = 6.60, 15.12 Hz), 5.07 (d, 1H, *J* = 6.52 Hz), 3.51 (d, 2H, *J* = 7.72 Hz), 2.33 (s, 3H), 1.78 (br, 1H). IR (film): 3384, 3033, 2922, 964cm^{-1}. Mass spectrum, *m/e*: 318 (M^+, 10), 161 (M^+–SePh, 38), 119 (*p*-$CH_3C_6H_4CO^+$, 100). Anal. Calcd. For $C_{17}H_{18}OSe$: C, 64.35; H, 5.72. Found: C, 64.71; H, 6.08.

4b: oil. ^{1}H NMR ($CDCl_3$, 400 MHz): 7.46 (d, 2H, *J* = 6.82 Hz), 7.29–7.25 (m, 3H), 7.22–7.20 (m, 4H), 5.92–5.84 (m, 1H), 5.51 (dd, 1H, *J* = 6.68, 15.12 Hz), 5.09 (d, 1H, *J* = 6.64 Hz), 3.50 (d, 2H, *J* = 7.64 Hz), 1.75 (br, 1H). IR (film): 3405, 3042, 2923, 965cm^{-1}. Mass spectrum, *m/e*: 304 (M^+, 5), 147 (M^+–SePh, 60), 105 ($C_6H_5CO^+$, 100). Anal. Calcd. For $C_{16}H_{16}OSe$: C, 63.37; H, 5.32. Found: C, 63.03; H, 5.60.

4c: oil. ^{1}H NMR ($CDCl_3$, 400 MHz): 7.43 (d, 2H, *J* = 7.84 Hz), 7.24–7.18 (m, 5H), 7.07 (d, 2H, *J* = 8.36 Hz), 5.85–5.82 (m, 1H), 5.41 (dd, 1H, *J* = 6.80, 15.12 Hz), 5.02 (d, 1H, *J* = 6.80 Hz), 3.47 (d, 2H, *J* = 7.44 Hz), 2.08 (s, 1H). IR (film): 3463, 3055, 2926, 967cm^{-1}. Mass spectrum, *m/e*: 340 (M^+, 4, ^{37}Cl), 338 (M^+, 10, ^{35}Cl), 183 (M^+–SePh, 3, ^{37}Cl), 181(M^+–SePh, 10, ^{35}Cl), 141 (*p*-$ClC_6H_4CO^+$, 32, ^{37}Cl), 139 (*p*-$ClC_6H_4CO^+$, 100, ^{35}Cl). Anal. Calcd. For $C_{16}H_{15}ClOSe$: C, 56.91; H, 4.46. Found: C, 56.64; H, 4.80

4d: oil. ^{1}H NMR ($CDCl_3$, 400 MHz): 8.11 (d, 2H, *J* = 8.76 Hz), 7.46–7.43 (m, 2H), 7.32 (d, 2H, *J* = 8.60 Hz), 7.26–7.19 (m, 3H), 5.93–5.87 (m, 1H), 5.39 (dd, 1H, *J* = 7.28, 15.08 Hz), 5.16 (d, 1H, *J* = 7.28 Hz), 3.49 (d, 2H, *J* = 7.72 Hz), 1.92 (br, 1H). IR (film): 3412, 3050, 2925, 964cm^{-1}. Mass spectrum, *m/e*: 349 (M^+, 9), 192 (M^+–SePh, 45), 150 (*p*-$NO_2C_6H_4CO^+$, 100). Anal. Calcd. For $C_{16}H_{15}NO_3Se$: C, 55.18; H, 4.34; N, 4.02. Found: C, 55.46; H, 4.30; N, 4.31.

4e: oil. ^{1}H NMR ($CDCl_3$, 400 MHz): 7.28 (d, 2H, *J* = 7.21 Hz), 7.15 (d, 2H, *J* = 7.63 Hz), 5.90–5.81 (m, 1H), 5.70 (dd, 1H, *J* = 6.50, 15.73 Hz), 5.17 (d, 1H, *J* = 6.48 Hz), 3.21 (d, 2H, *J* = 7.54 Hz), 2.51–2.48 (q, 2H, *J* = 7.45 Hz), 2.34 (s, 3H), 1.88 (br, 1H), 1.35 (t, 3H, *J* = 7.44 Hz). IR (film): 3386, 3043, 2925, 963cm^{-1}. Mass spectrum, *m/e*: 270 (M^+, 7), 161 (M^+–SeEt, 68), 119 (*p*-$CH_3C_6H_4CO^+$, 100). Anal. Calcd. For $C_{13}H_{18}OSe$: C, 57.99; H, 6.74. Found: C, 57.72; H, 6.89

4f: oil. ^{1}H NMR ($CDCl_3$, 400 MHz): 7.39–7.28 (m, 5H), 5.94–5.85 (m, 1H), 5.70 (dd, 1H, *J* = 6.56, 15.76 Hz), 5.22 (d, 1H, *J* = 6.52 Hz), 3.19 (d, 2H, *J* = 7.56 Hz), 2.51–2.46 (q, 2H, *J* = 7.56 Hz), 1.97 (br, 1H), 1.29 (t, 3H, *J* = 7.52 Hz). IR (film): 3396, 3047, 2923, 964cm^{-1}. Mass spectrum, *m/e*: 256 (M^+, 7), 147 (M^+–SeEt, 52), 105 ($C_6H_5CO^+$, 100). Anal. Calcd. For $C_{12}H_{16}OSe$: C, 56.47; H, 6.32. Found: C, 56.72; H, 6.54.

4g: oil. ^{1}H NMR ($CDCl_3$, 400 MHz): 8.20 (d, 2H, *J* = 7.0 Hz), 7.55 (d, 2H, *J* = 8.8 Hz), 5.95–5.91 (m, 1H), 5.64 (dd, 1H, *J* = 7.04, 15.16 Hz), 5.33 (d, 1H, *J* = 7.08 Hz), 3.19 (d, 2H, *J* = 7.68 Hz), 2.52–2.46 (q, 2H, *J* = 7.48 Hz), 2.15 (br, 1H), 1.35 (t, 3H, *J* = 7.48 Hz). IR (film): 3407, 3051, 2925, 965cm^{-1}. Mass spectrum, *m/e*: 301 (M^+, 6), 192 (M^+–SeEt, 96), 150 (*p*-$NO_2C_6H_4CO^+$, 100). Anal. Calcd. For $C_{12}H_{15}NO_3Se$: C, 48.01; H, 5.04; N, 4.66. Found: C, 47.80; H, 5.24; N, 4.85.

General procedure for the synthesis of **6a–6f**: A mixture of hydrozirconocene chloride (1.2mmol) and propargyl selenide (**1**) (1.0mmol) in CH_2Cl_2 was stirred at room temperature for 20min. To the resulting clear solution was added acyl chloride **5** (2.0mmol) followed by $CuBr{\cdot}SMe_2$ (15mol%). After stirring for 2–3h, the reaction mixture was quenched with saturated $NaHCO_3$ aqueous solution. After usual workup, 4-selanyl-2-en-1-one **6a–6e** were obtained.

6a: oil. ^{1}H NMR ($CDCl_3$, 400 MHz): 7.54 (d, 2H, *J* = 7.32 Hz), 7.48–7.44 (m, 3H), 7.26–7.20 (m, 4H), 6.73–6.67 (m, 1H), 6.46 (d, 1H, *J* = 15.04 Hz), 3.65 (d, 2H, *J* = 8.04 Hz), 2.36 (s, 3H). IR (film): 3041, 2924, 1667, 965cm^{-1}. Mass spectrum, *m/e*: 316 (M^+, 28), 159 (M^+–SePh, 69), 119 (*p*-$CH_3C_6H_4CO^+$, 100). Anal. Calcd. For $C_{17}H_{16}OSe$: C, 64.76; H, 5.11. Found: C, 64.42; H, 5.33.

6b: oil. ^{1}H NMR ($CDCl_3$, 400 MHz): 7.69 (d, 2H, *J* = 8.20 Hz), 7.55–7.51 (m, 3H), 7.42–7.39 (m, 3H), 7.08–7.02 (m, 1H), 6.48 (d, 1H, *J* = 15.16 Hz), 3.65 (d, 2H, *J* = 8.12 Hz). IR (film): 3048, 2924, 1668, 968cm^{-1}. Mass spectrum, *m/e*: 302 (M^+, 32), 145 (M^+–SePh, 62), 105 ($C_6H_5CO^+$, 100). Anal. Calcd. For $C_{16}H_{14}OSe$: C, 63.79; H, 4.68. Found: C, 63.53; H, 4.69.

6c: oil. ^{1}H NMR ($CDCl_3$, 400 MHz): 7.49 (d, 2H, *J* = 6.96 Hz), 7.29–7.25 (m, 3H), 6.85–6.81 (m, 1H), 5.74 (d, 1H, *J* = 15.60 Hz), 3.55 (d, 2H, *J* = 8.04 Hz), 2.40 (t, 2H, *J* = 7.38 Hz), 1.60–1.50 (m, 2H), 0.88 (t, 3H, *J* = 7.4 Hz). IR (film): 3046, 2962, 1671,972cm^{-1}. Mass spectrum, *m/e*: 268 (M^+, 17), 111 (M^+–SePh, 100). Anal. Calcd. For $C_{13}H_{16}OSe$: C, 58.43; H, 6.03. Found: C, 58.61; H, 6.38.

6d: oil. ^{1}H NMR ($CDCl_3$, 400 MHz): 7.84 (d, 2H, J = 8.16 Hz), 7.27 (d, 2H, *J* = 8.76 Hz), 7.08–7.03 (m, 1H), 6.80 (d, 1H, *J* = 15.12 Hz), 3.39 (d, 2H, *J* = 8.08 Hz), 2.60–2.54 (q, 2H, *J* = 7.48 Hz), 2.42 (s, 3H), 1.40 (t, 3H, *J* = 7.48 Hz). IR (film): 3037, 2926, 1669, 963cm^{-1}. Mass spectrum, *m/e*: 268 (M^+, 24), 159 (M^+–SeEt, 71), 119 (*p*-$CH_3C_6H_4CO^+$, 100). Anal. Calcd. For $C_{13}H_{16}OSe$: C, 58.43; H, 6.03. Found: C, 58.06; H, 6.36.

6e: oil. ^{1}H NMR ($CDCl_3$, 400 MHz): 7.92 (d, 2H, *J* = 7.56 Hz), 7.58–7.54 (m, 1H), 7.49–7.45 (m, 2H), 7.10–7.04 (m, 1H), 6.80 (d, 1H, *J* = 15.14 Hz), 3.39 (d, 2H, *J* = 8.08 Hz), 2.60–2.54 (q, 2H, *J* = 7.44 Hz), 1.40 (t, 3H, *J* = 7.48 Hz). IR (film): 3059, 2924, 1665, 971cm^{-1}. Mass spectrum, *m/e*: 254 (M^+, 18), 145 (M^+–SeEt, 60), 105 ($C_6H_5CO^+$, 100). Anal. Calcd. For $C_{12}H_{14}OSe$: C, 56.92; H, 5.57. Found: C, 57.12; H, 5.65.

6f: oil. ^{1}H NMR ($CDCl_3$, 400 MHz): 8.32 (d, 2H, *J* = 8.9 Hz), 8.05(d, 2H, *J* = 8.9 Hz), 7.18–7.10 (m, 1H), 6.77 (d, 1H, *J* = 15.1 Hz), 3.42 (d, 2H, *J* = 8.1 Hz), 2.60 (q, 2H, *J* = 7.5 Hz), 1.42 (t, 3H, *J* = 7.5 Hz). IR (film): 3048, 2925, 1672, 970cm^{-1}. Mass spectrum, *m/e*: 299 (M^+, 30), 190 (M^+–SeEt, 100), 150 (*p*-$NO_2C_6H_5CO^+$, 35). Anal. Calcd. For $C_{12}H_{13}NO_3Se$: C, 48.33; H, 4.39; N, 4.69. Found: C, 48.20; H, 5.65; N, 4.54.

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