Facile and Highly Efficient Conjugate Addition of Benzeneselenol to α,β-Unsaturated Carbonyl Compounds

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Although the importance of β-selenocarbonyl compounds as potential intermediates in organic synthesis has been recognized in recent years[1,2,3], the conjugate addition of benzeneselenol to α,β-unsaturated carbonyl compounds, the standard method for the preparation of β-selenocarbonyl derivatives, is not satisfactory. The procedure using benzeneselenolate salts[2] gives only low yields of the adducts. In fact, we have found that the reaction of 2-cyclohexenone with ethanolic sodium benzeneselenolate gives β-phenylselenocyclohexanone in a poor yield (less than 10%). On the other hand, it is known that benzeneselenol itself adds to the conjugated double bonds of several chalcones[4] and

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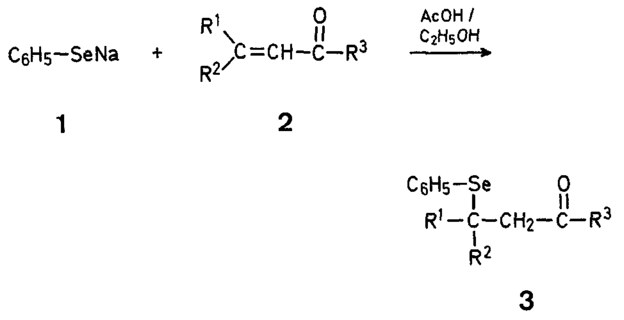
methyl vinyl ketone[3,5] to give moderate to good yields (44–81%). However, it would clearly be more advantageous to employ the procedure which avoids the necessity of handling the malodorous and air-sensitive benzeneselenol.

Recently, Sonoda and co-workers developed a new method for the *in situ* generation of benzeneselenol by treatment of phenyl trimethylsilyl selenide with methanol[5]. This process requires the preparation of the air-sensitive selenide from diphenyl diselenide.

We now report a facile and highly efficient conjugate addition of benzeneselenol, generated *in situ* from diphenyl diselenide, to α,β-unsaturated carbonyl compounds under mild reaction conditions. Addition of 1.7–2 equivalents of acetic acid to an ethanolic sodium benzeneselenolate (**1**) solution, prepared from diphenyl diselenide and sodium borohydride[6], generates a stoichiometric amount of benzeneselenol.


1 **2** **3**

The benzeneselenol so generated in a weakly acidic media smoothly reacts with a variety of α,β-unsaturated carbonyl compounds (**2**) except sterically hindered enones such as isophorone and $\Delta^{1(9)}$-2-octalone to give β-phenylselenocarbonyl derivatives in excellent yields. Typical examples of the conjugate addition of benzeneselenol are shown in the Table. Thus, the reaction can be performed in a one-pot operation and the procedure is remarkably simple and mild enough to be used on complex systems containing other sensitive functional groups.

Synthetically, the high yield of the conjugate addition of benzeneselenol enables a number of useful transformations based on the *syn*-elimination of phenyl selenoxide[3] to be performed. The application of this reaction in synthesis is currently under investigation.

Table. Conjugate Addition of the *in situ* Generated Benzenselenol to α,β-Unsaturated Carbonyl Compounds **2**

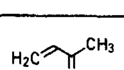
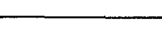
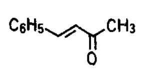
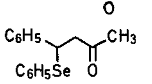
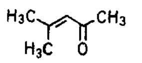
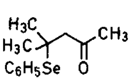
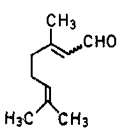
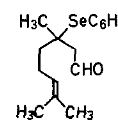
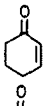
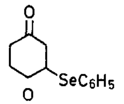
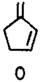
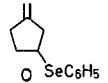
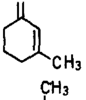
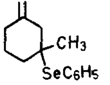
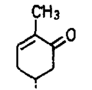
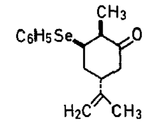
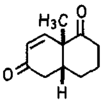
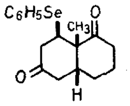
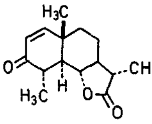
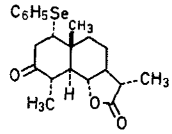
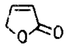
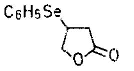
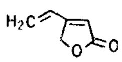
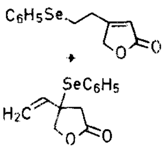
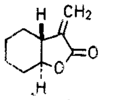
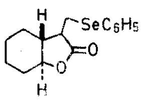
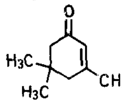
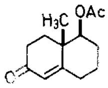
Substrate No.		Product	Reaction conditions C_6H_5SeH (equiv)/ temp./time	Yield[a] [%]	m.p.[b] [°C]	Molecular formula[c] or Lit. m.p. [°C]	^{1}H-N.M.R. (CCl_4)[d] δ [ppm]
2a			1.3/0°C/1h	99	oil	oil[3,5]	2.0 (s, 3H); 2.5–3.2 (m, 4H) 7.05–7.6 (m, 5H)
2b			1.5/25°C/2h	98	54°	$C_{16}H_{16}OSe$ (303.3)	1.83 (s, 3H); 2.98 (dd, 2H, *J* = 8, 1Hz); 4.7 (t, 1H, *J* = 8Hz); 6.8–7.5 (m, 10H)
2c			1.5/25°C/2h	95	oil	$C_{12}H_{16}OSe$ (255.2)	1.47 (s, 6H); 2.0 (s, 3H); 2.68 (s, 2H); 7.15–7.75 (m, 5H)
2d			1.5/0°C/3h	90[e,f]	oil	$C_{16}H_{22}OSe$ (309.3)	1.42 (s, 3H); 2.47 (d, 2H, *J* = 3Hz); 5.03 (t, 1H, *J* = 7 Hz); 7.0–7.7 (m, 5H); 13.73 (t, 1H, *J* = 3Hz)
2e			1.3/0°C/1h	95	oil	oil[9]	3.0–3.67 (bs, 1H); 7.0–7.7 (m, 5H)
2f			1.3/0°C/1h	94	oil	$C_{11}H_{12}OSe$ (239.2)	3.50–4.15 (m, 1H); 7.05–7.75 (m, 5H)
2g			1.5/0°C/2h	80[e,f]	58–59°	$C_{13}H_{16}OSe$ (267.2)	1.38 (s, 3H); 2.38 (q, 2H, *J* = 14Hz); 7.0–7.7 (m, 5H)
2h			1.5/0°C/2h	86[e,g,h,i]	oil	$C_{16}H_{20}OSe$ (307.3)	1.10 (d, 3H, *J* = 7Hz); 1.72 (bs, 3H); 3.87 (dd, 1H, *J* = 8, 3Hz); 4.67 (bs, 2H); 7.0–7.7 (m, 5H)
2i[7]			1.5/0°C/2h	88[h,j]	124–125°	$C_{17}H_{20}O_2Se$ (335.3)	1.45 (s, 3H); 3.95 (dd, 1H, *J* = 10, 7Hz); 7.1–7.7 (m, 5H)[m]
2j			1.5/0°C/2h	96	148–153° (dec)	$C_{21}H_{26}O_3Se$ (405.4)	1.2–1.45 (3 CH_3); 3.17 (dd, 1H, *J* = 16, 5Hz); 3.48 (dd, 1H, *J* = 5, 3Hz); 3.95 (t, 1H, *J* = 10Hz); 7.0–7.7 (m, 5H)[m,n]

Table. (Continued)

Substrate No.		Product	Reaction conditions C_6H_5SeH (equiv)/ temp./time	Yield[a] [%]	m.p.[b] [°C]	Molecular formula[c] or Lit. m.p. [°C]	^{1}H-N.M.R. (CCl_4)[d] δ [ppm]
2k			1.3/0°C/1h	87	oil	$C_{10}H_{10}O_2Se$ (241.1)	2.0–3.1 (m, 2H); 3.6–4.8 (m, 3H); 7.0–7.7 (m, 5H)
2l[8]			1.5/0°C/2h	100[l] 88[k] 12[k]	oil	$C_{12}H_{12}O_2Se$ (267.2)	2.3–3.3 (m, 4H); 4.61 (d, 2H); 5.75 (m, 1H); 7.0–7.7 (m, 5H)[o]
2m			1.3/0°C/1h	97	74–75°	75–76°[2]	2.65–3.90 (m, 3H); 7.0–7.7 (m, 5H)
2n			1.5/25°C/3h	no reaction	—	—	—
2o			1.5/25°C/3h	no reaction		—	—

[a] Yield of pure product isolated by chromatography on silica gel unless otherwise stated.

[b] Not corrected.

[c] The microanalyses were in agreement with the calculated values (C ± 0.34, H ± 0.31).

[d] Jeol JNM C-60 HL spectrometer at 60 Hz.

[e] Elimination of benzeneselenol occurs on contact with silica gel.

[f] Product isolated and purified by distillation.

[g] Product was reduced with lithium aluminium hydride in ether and characterized.

[h] Stereochemistry tentatively assigned by ^{1}H-N.M.R. spectrometry.

[i] Yield of alcohol given.

[j] Isolated and purified by recrystallization.

[k] Determined by ^{1}H-N.M.R. spectrometry.

[l] Although the minor product is sensitive to silica gel the major product is isolated thus in 86 % yield.

[m] $CDCl_3$ solution.

[n] Recorded at 100 MHz on a Jeol JNM PS-100 spectrometer.

[o] ^{1}H-N.M.R. spectrum of major product.

Conjugate Addition of the *in situ* Generated Benzeneselenol to α,β-Unsaturated Carbonyl Compounds; Typical Procedure:

The following reaction should be performed in a well-ventilated hood since hydrogen and noxious vapors are liberated.

Sodium borohydride (49.4 mg, 1.3 mmol) is added under nitrogen in batches to a mixture of diphenyl diselenide (204 mg, 0.65 mmol) in ethanol (2.5 ml)[10,11] with stirring at room temperature *(Caution! reduction of the diselenide is exothermic and vigorous hydrogen evolution occurs)*[6]. The colorless (or faint yellow) solution of sodium benzeneselenolate obtained is cooled to 0 °C in an ice bath then acetic acid (130 μl, 2.3 mmol) is added from a microsyringe. A solution of 2-cyclohexenone (96 mg, 1.0 mmol) in ethanol (0.5 ml) is added and the resulting mixture is stirred at 0 °C for an additional hour. The mixture is poured into water (20 ml), extracted with ether (30 ml), and the extract is washed with water and saturated brine. Evaporation of the solvent leaves an oil which is purified by silica gel T.L.C. [ether/petroleum ether (1:3) as solvent] to afford *β-phenylselenocyclohexanone* as a yellow oil; yield: 240 mg (95%); b.p. 123 °C (bath temperature) 1.5 torr.

$C_{12}H_{14}OSe$	calc.	C 56.92	H 5.57
(253.2)	found	57.26	5.71

I.R. (film): ν = 1717, 745, 697 cm^{-1}.

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[1] For an excellent review on modern organoselenium chemistry, see, D. L. J. Clive, *Tetrahedron* **1978**, 1049.

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[9] K. B. Sharpless, M. W. Young, R. F. Lauer, *Tetrahedron Lett.* **1973**, 1979.

[10] Ordinary ethanol was used instead of absolute ethanol employed in the original report[6].

[11] A large part of the diphenyl diselenide remained insoluble in ethanol prior to the addition of sodium borohydride.