Pergamon

Tetrahedron Letters, Vol. 35, No. 47, pp. 8817-8820, 1994
Elsevier Science Ltd
Printed in Great Britain
0040-4039/94 $7.00+0.00

0040-4039(94)01867-7

Reaction of Selenothioic Acid *S*-Alkyl Esters with Electron Deficient Alkynes: Selective Synthesis of Cyclic Selenides and Acyclic Divinyl Selenides

Toshiaki Murai,* Hiroya Takada, Takahiro Kanda, and Shinzi Kato*

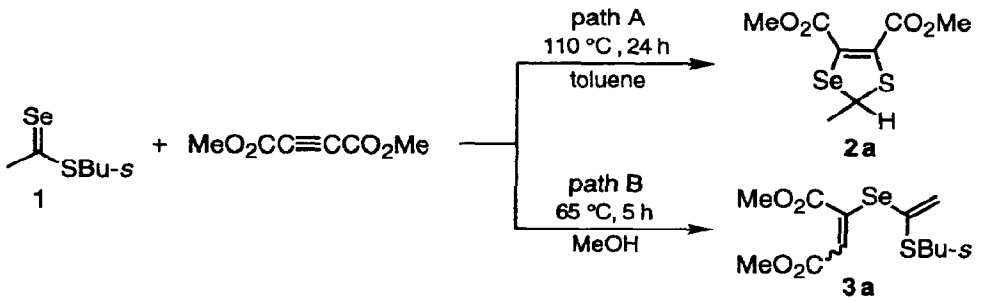
Department of Chemistry, Faculty of Engineering,
Gifu University, Yanagido, Gifu 501-11, Japan

Abstract: The reaction of selenothioic acid *S*-alkyl esters with electron deficient alkynes was carried out under reflux in toluene to give cyclic selenides in good yields. On the contrary, the similar reaction in MeOH or CH_2Cl_2 with Et_3N afforded acyclic divinyl selenides in good to high yields.

The chemistry of organoselenium compounds has been widely studied over the past twenty years.[1] However, the compounds synthesized have usually been restricted to alkyl or aryl derivatives. For example, although various kinds of vinyl selenides have been synthesized, most of them involve PhSe group.[2,3] It is probably due to the lack of general sources to construct organoselenium compounds. Very recently, we have disclosed the potential utilities of selenothioic acid *S*-alkyl esters **1**[4] and have established their facile synthetic methods.[5] Herein, we report the reaction of the esters 1 with electron deficient alkynes to give cyclic selenides and acyclic divinyl selenides selectively by simply changing the solvent used.

The ester **1a** was treated with dimethylacetylene dicarboxylates (DMAD) under the reflux in toluene for 24 h (Scheme I, path A). The reaction mixture gradually turned to yellow from reddish purple. After the column chromatography on silica gel, cyclic selenide **2a** was obtained in 79 % yield.[6] On the other hand, the similar reaction in MeOH for 5 h afforded acyclic divinyl selenide **3a** with an *E* to *Z* selectivity of 24 : 76 in 61 % yield (Scheme I, path B). In each case, the reaction selectively proceeded, and the formation of the other product was not observed.

Scheme I



Scheme II

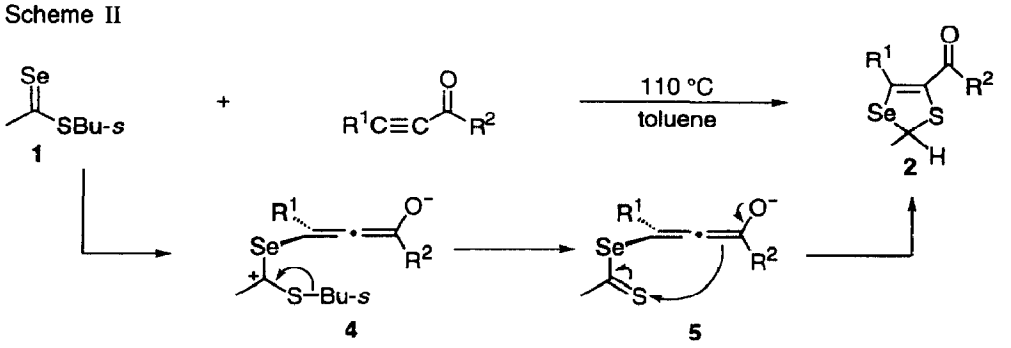


Table I. Synthesis of Cyclic Selenides **2** [a]

R^1	R^2	time / h	product	yield / % [b]
MeO_2C	OMe	24	2a	79
H	Me	73	2b	55
H	OMe	48	2c	41
H [c]	OEt	92	2d	38
H	$OCH_2CH{=}CH_2$	114	2e	30
Me	OMe	27	2f	trace
Ph	OEt	56	2g	trace

[a] Reaction conditions are as follows : **1** (1 mmol) , acetylene (1 mmol) , toluene (6 mL). [b] Isolated yield. [c] Selenothioic acid *S*-*n*-butyl ester was used as a starting material.

A variety of unsymmetrically substituted alkynes were reacted with the ester **1** to yield cyclic selenides **2** (Scheme II and Table I). Although longer reaction time was necessary, the reaction with terminal alkynes regioselectively proceeded to give **2** in good yields. The structure of the products was clearly supported by ^1H and ^{13}C NMR spectra, CI-Mass spectra, and microanalyses.[7] The regiochemistry of the product was unequivocally determined by the ^2J coupling of olefinic proton with selenium. The present reaction may begin with the nucleophilic attack of the ester **1** to the alkynes at the carbon remote from electron-withdrawing groups analogously to the reaction of heteronucleophiles with activated alkynes.[8] The following process may involve several allenic intermediates such as **4** and **5**. In the final step, the intramolecular thiophilic attack of the linear anion in **5** may take place to lead to the product **2**.

The synthesis of acyclic divinyl selenides **3** was carried out with Et_3N, MeOH and CH_2Cl_2 as a solvent (Scheme III).[9] The results using *S*-*n*-butyl ester were summarized in Table II. The use of Et_3N dramatically enhanced the reaction rate. For example, the reaction with DMAD was complete within 30 sec at room temperature (entry 1). As the substituents on alkynyl carbons being more bulky, the reaction was retarded, and the formation of *E*-isomers became predominant (entries 2 - 5). The steric factor to influence the regioselectivity was further observed for the reaction of internal alkynes. Only *Z*-isomers of **3** were obtained as a detectable product (entries 6, 7). The reaction of Scheme III may also proceed via the initial attack of the ester **1** on the alkyne in an *anti* fashion followed by the Et_3N-mediated proton abstraction to form the intermediate **6**.

Scheme III

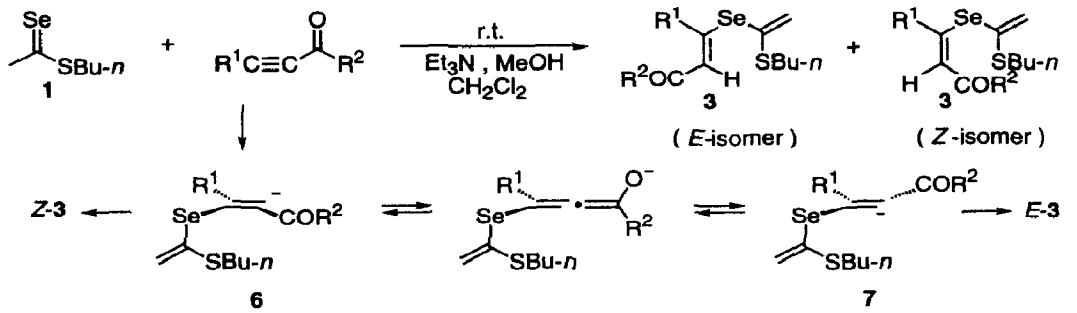


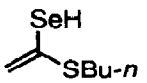
Table II. Synthesis of Acyclic Divinyl Selenides 3 [a]

entry	R^1	R^2	time	product	yield / % [b]	E / Z [c]
1	MeO_2C	OMe	20 sec	3a'	72	11 / 89
2	H	Me	3 sec	3b	78	13 / 87
3	H	OMe	20 sec	3c	77	49 / 51
4	H	OEt	30 min	3d	67	55 / 45
5	H	$OCH_2CH{=}CH_2$	3.5 h	3e	63	88 / 12
6 [d]	Me	OMe	7 h	3f	47	Z- isomer only
7	Ph	Me	8 h	3h	34	Z- isomer only

[a] Reaction conditions are as follows: 1(1 mmol), alkyne (1 mmol), Et_3N (1 mmol), MeOH (1-2 portions or 1 mmol), CH_2Cl_2 (4 mL). [b] Isolated yield. [c] The ratio of *E*- and *Z*- isomers was determined by ^1H NMR spectra. [d] Selenothioic acid *S-sec*-butyl ester was used as a starting material.

When protonation of **6** quickly occurs prior to the equilibration,[10] Z-isomers appear to be obtained. In contrast, the formation of thermodynamically more stable products may be predominant when two vinyl anions **6** and **7** are in equilibrium.

In summary, the synthesis of cyclic selenides and acyclic divinyl selenides was attained by employing selenothioic acid *S*-alkyl esters **1** and electron deficient alkynes. The reaction selectively produced either selenides by choosing the appropriate solvent. Furthermore, the transformation of Scheme III can formally be considered as the addition of eneselenol **8**, the reactivity of which has been of interest but scarcely been studied compared with the reaction of benzeneselenol.[3] Further application of the esters 1 and vinyl selenides will be reported in due course.



8

Acknowledgment. This work was supported by the Grant-in-Aid for Scientific Research on Priority Area of Reactive Organometallics No. 05236102 and partially by the Grant-in-Aid for Scientific Research provided from the Ministry of Education, Science and Culture, Japan.

References and Notes

(1) For reviews: *The Chemistry of Organoselenium and Tellurium Compounds*, Patai, S.; Rappoport, R. Ed.; John Wiley & Sons, New York 1987; *Organoselenium Chemistry*, Liotta, D. Ed.; Wiley-Interscience, New York 1987.

(2) Comasseto, J. V. *J. Organomet. Chem.* **1983**, *253*, 131; Detty, M. R.; Murray, B. J. *J. Am. Chem. Soc.* **1983**, *105*, 883; Back, T. G.; Krishna, M. V. *J. Org. Chem.* **1988**, *53*, 2533; Back, T. G.; Krishna, M. V.; Muralidharan, K. R. *J. Org. Chem.* **1989**, *54*, 4146; Kataoka, T.; Yoshimatsu, M.; Shimizu, H.; Hori, M. *Tetrahedron Lett.* **1990**, *31*, 5927; Ogawa, A.; Yokoyama, K.; Yokoyama, H.; Sekiguchi, M.; Kambe, N.; Sonoda, N. *Tetrahedron Lett.* **1990**, *31*, 5931; Ogawa, A.; Yokoyama, H.; Yokoyama, K.; Masawaki, T.; Kambe, N.; Sonoda, N. *J. Org. Chem.* **1991**, *56*, 5721; Ogawa, A.; Takami, N.; Sekiguchi, M.; Yokoyama, H.; Kuniyasu, H.; Ryu, I.; Sonoda, N. *Chem. Lett.* **1991**, 2241; Kuniyasu, H.; Ogawa, A.; Miyazaki, S.; Ryu, I.; Kambe, N.; Sonoda, N. *J. Am. Chem. Soc.*, **1991**, *113*, 9796.; Komatsu, N.; Nisibayashi, Y.; Sugita, T.; Uemura, S. *J. Chem. Soc., Chem, Commun.* **1992**, *46*.

(3) Wadsworth, D. H.; Detty, M. R. *J. Org. Chem.* **1980**, *45*, 4611; Comasseto, J. V.; Ferreira, J. T. B.; Petragnani, N. *J. Organomet. Chem.* **1981**, *216*, 287; Ogawa, A.; Obayashi, R. Sekiguchi, M.; Masawaki, T.; Kambe, N.; Sonoda, N. *Tetrahedron Lett.* **1992**, *33*, 1329.

(4) Kato, S.; Komuro, T.; Kanda, T.; Ishihara, H.; Murai, T. *J. Am. Chem. Soc.* **1993**, *115*, 3000.

(5) Murai, T.; Hayashi, A.; Kanda, T.; Kato, S. *Chem. Lett.* **1993**, 1469.

(6) The reaction of dithioic acid *S*-allyl ester with DMAD without solvent at room temperature was reported to give the cyclic product after several days: Drozd, V. N.; Popova, O. A. *Tetrahedron Lett.* **1979**, 4491.

(7) Selected ^{1}H-NMR spectral data: (**2a**) δ 4.88(q, J = 7.0 Hz, 1H), 3.82(s, 3H), 3.79(s, 3H), 1.87(d, J = 7.0 Hz, 3H); (**2b**) δ 7.69(s, 1H, $^2J_{H\text{-}Se}$ = 44 Hz), 4.88(q, J = 7.0 Hz, 1H), 2.30(s, 3H), 1.72(d, J = 7.0 Hz, 3H); (**2c**) δ 7.80(s, 1 H, $^2J_{H\text{-}Se}$ = 45 Hz), 5.00(q, J = 6.8 Hz, 1H), 3.78(s, 3H), 1.80(d, J = 6.8 Hz, 3H); (**2d**) δ 7.71(s, 1H, $^2J_{H\text{-}Se}$ = 46 Hz), 4.91(q, J = 6.7 Hz, 1H), 4.16(q, J = 7.2 Hz, 3H), 1.73(d, J = 6.7 Hz, 3H), 1.24(t, J = 7.2 Hz, 3 H); (**2e**) δ 7.82(s, 1H, $^2J_{H\text{-}Se}$ = 46 Hz), 6.02-5.86(m, 1H), 5.39-5.25(m, 2H), 4.98(q, J = 6.8 Hz, 1H), 4.67(d, J = 5.5 Hz, 1H), 1.80(d, J = 6.8 Hz, 3H); (***Z*-3a'**) δ 6.70 (s, 1H), 5.67(s, 2H), 3.84(s, 3H), 3.79(s, 3H), 3.08(m, 1H), 1.59(m, 2H), 1.29(d, J = 5.5 Hz, 3H), 0.79(t, J = 7.3 Hz, 3H); (***Z*-3b**) δ 8.12(d, J = 8.8 Hz, 1H), 6.87(d, J = 8.8 Hz, 1H), 5.72(s, 1H), 5.68(s, 1H), 2.73(t, J = 7.3 Hz, 2H), 2.27(s, 3H), 1.62(qui, J = 7.3 Hz, 2H), 1.43(sex, J = 7.3 Hz, 2H), 0.92 (t, J = 7.3 Hz, 3H); (***Z*-3c**) δ 8.00(d, J = 9.5 Hz, 1H), 6.38(d, J = 9.5 Hz, 1H), 5.74(s, 1H), 5.71(s, 1H), 3.77(s, 3H), 2.73(t, J = 7.0 Hz, 2H), 1.62(qui, J = 7.2 Hz, 2H), 1.43(sex, J = 7.3 Hz, 2H), 0.93(t, J = 7.3 Hz, 3H); (***E*-3d**) δ 8.13(d, J = 16 Hz, 1H), 6.18(d, J = 16 Hz, 1H), 5.81(d, J = 1.4 Hz, 1H), 5.76(d, J = 1.4 Hz, 1H), 4.19(q, J = 7.1 Hz, 2H), 2.77(t, J = 7.3 Hz, 2H), 1.64(qui, J = 7.3 Hz, 2H), 1.88(sex, J = 7.3 Hz, 2H), 1.29(t, J = 7.1 Hz, 3H), 0.94(t, J = 7.3 Hz, 3H); (***E*-3e**) δ 8.14(d, J = 16 Hz, 1H), 6.18(d, J = 16 Hz, 1H), 5.81(d, J = 1.4 Hz, 1H), 5.76(d, J = 1.4 Hz, 1H), 4.19(q, J = 7.2 Hz, 4H), 2.77(t, J = 7.3 Hz, 2H), 1.64(qui, J = 7.3 Hz, 2H), 1.88(sex, J = 7.3 Hz, 2H), 1.29(t, J = 7.1 Hz, 3H), 0.94(t, J = 7.3 Hz, 3H); (***Z*-3f**) δ 6.18(s, 1H), 5.87(s, 1H), 5.85(s, 1H), 3.72(s, 3H), 3.14(sex, J = 6.8 Hz, 1H), 2.44(s, 3H), 1.63(m, 2H), 1.32(d, J = 6.8 Hz, 3H), 1.00(t, J = 7.3 Hz, 3H); (***Z*-3h**) δ 7.34-7.29 (m, 5H), 6.75(s, 1H), 5.55(d, J = 0.73 Hz, 1H), 5.35(d, J = 0.73 Hz, 1H), 2.36(t, J = 7.0 Hz, 2H), 2.30(s, 3H), 1.57-1.20(m, 4H), 0.82(t, J = 7.0 Hz, 3H).

(8) Jung, M. E. In *Comprehensive Organic Synthesis*; Trost, B. M.; Fleming, I., Ed.; Pergamon Press: Oxford 1991; Vol.4; pp 1-67.

(9) A typical experimental procedure is as follows: To CH_2Cl_2 (4 mL) solution of selenothioic acid *S*-*sec*-butyl ester **1** (1 mmol, 0.199 g) and 3-butyne-2-one (1 mmol, 0.068 g) was added Et_3N (1 mmol, 0.14 mL) at 20 °C. The reaction mixture instantly changed to yellow. After 20 sec the resulting solution was concentrated and purified through the column chromatography on silica gel using *n*-hexane/Et_2O (10 : 1) as an eluent to give acyclic divinyl selenide **3b** as a yellow oil in 78 % yield.

(10) Houk, K. N.; Strozier, R. W.; Rozeboom, M. D.; Nagase, S. *J. Am. Chem. Soc.* **1982**, *104*, 323.

(*Received in Japan* 25 *June* 1994; *accepted* 25 *August* 1994)