Tetrahedron Letters

Tetrahedron Letters 46 (2005) 1479–1481

Synthesis of 1-alkylselenocyclobutene via intermediate allenyl selenoketene

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Received 22 September 2004; revised 27 December 2004; accepted 7 January 2005

Abstract—Reactions of 2-alkynyl arylethynyl selenide **1** with alkyl iodides **3** in the presence of lithium aluminium hydride via allenyl selenoketene **2** afforded cyclobutene **4**. Allenyl group of the intermediate allenyl selenoketene **2** was monitored by React IR.

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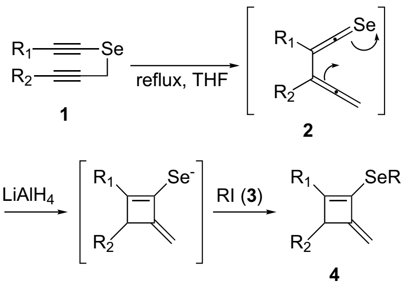
1. Introduction

The selenoketene has been extensively investigated because of the interesting properties and reactivities using theoretical calculations.[1] The selenoketene is found to be more reactive than ketene[2] in prototype reactions such as ketene-ynol rearrangement, electrophilic and nucleophilic addition and [2+2] cycloaddition.[3] Recently, we have reported allenyl selenoketene formation via a [3+3] sigmatropic rearrangement by trapping with primary amines and its cyclization, however, we could not trap the intermediate, allenyl selenoketene.[4] Herein, we investigated interesting reactivities of allenyl selenoketene and an evident for the allenyl selenoketene by using React IR.

2. Results and discussion

Selenide **1** was obtained by a method previously reported.[4] In brief, 2-pentynyl chloride was added to THF solution of the lithium alkyneselenoate, generated in situ from phenylacetylene, *n*-BuLi and elementary selenium, and the mixture was stirred at room temperature for 1.5 h. Subsequent silica gel flash column chromatography afforded 2-alkynyl arylethynyl selenide **1**.

We investigated reactions of 2-alkynyl arylethynyl selenide **1** with alkyl iodides **3** in the presence of lithium aluminium hydride. The reaction gave 1-alkylseleno-3-alkyl-2-aryl-4-methylidenecyclobutenes **4** (Scheme 1).



Scheme 1.

In a typical procedure, the selenide **1** was refluxed under argon atmosphere. To the mixture in the presence of lithium aluminium hydride, methyl iodide **1a** was added and stirred for 1 h. After standard workup 3-ethyl-4-methylidene-1-methylseleno-2-phenylcyclobutene **4a** was isolated in a 70% yield as yellow oil.[5] At first, we could not conclude whether the correct structure of the product is 1-alkylselenocyclobutene type **4** or 2,5-dihydroselenophene. The structure of **4** was determined by the studies of IR, ^{1}H, ^{13}C, ^{77}Se NMR, COSY, HMBC, HMQC, MS and elemental analysis. $^{2}J(^{77}\text{Se}–^{1}\text{H})$ value ($J = 108$ Hz) was observed at the singlet methyl signal of **4a**. Spin system of CH_3–CH_2–CH– was observed in the spectra of COSY and HMBC of **4a**. In the mass spectrum (EI) of every **4**, the stable fragment ion peaks of the corresponding alkyl ($M^+ - R$) and alkylseleno ($M^+ - Se–R$) groups were observed together with

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Keywords: Allenyl selenoketene; Cyclobutene; React IR.

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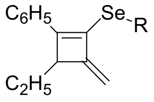
doi:10.1016/j.tetlet.2005.01.019



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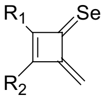

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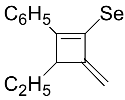
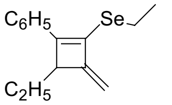
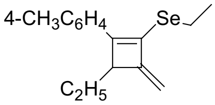
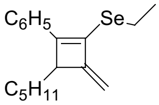
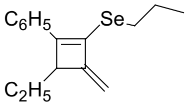
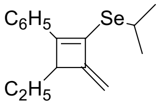
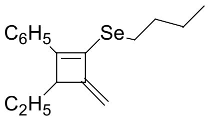
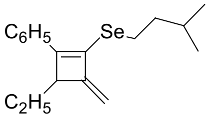
molecular peak. The possibility of the formation of 2,5-dihydroselenophene was ruled out by these observations. A ring closure of selenoketene **2** was reported to occur under the thermal reaction conditions in the absence of nucleophiles to afford 2-methylidene-3-cyclobutene-1-selone **5**.[6] The present reaction by the addition of alkyl iodides **3** in the presence of lithium aluminium hydride gave **4** not **5**. Several 1-alkylseleno-3-alkyl-2-aryl-4-methylidenecyclobutenes **4** were obtained from the reaction of selenide **1** with the corresponding alkyl iodides **3** in moderate yields (Table 1).

The yields using haloalkanes bearing longer carbon chains tended to decrease. Though we tried synthesis of 2-alkylcyclobutenes **4**, unfortunately it was failed. In the case of 2-alkylcyclobutenes, though the product **4** was apparently confirmed to be formed in the reaction mixture from the result of TLC monitoring, **4** could not be isolated for the decomposition on the process of purification by a silica gel column chromatography. The purification process gave several identifiable products, desired corresponding **4** yielded in very low yield.

Table 1. Synthesis of 1-alkylseleno-3-alkyl-2-aryl-4-methylidenecyclobutenes **4**

Entry	RI (**3**)	Product (**4**)	Yield (%)[a]
1	CH_3I		70 (**4a**)
2	C_2H_5I		74 (**4b**)
3	C_2H_5I		34 (**4c**)
4	C_2H_5I		29 (**4d**)
5	n-C_3H_7I		65 (**4e**)
6	$(CH_3)_2CHI$		47 (**4f**)
7	n-C_4H_9I		45 (**4g**)
8	$(CH_3)_2CH(CH_2)_2I$		45 (**4h**)

[a] Isolated yield.

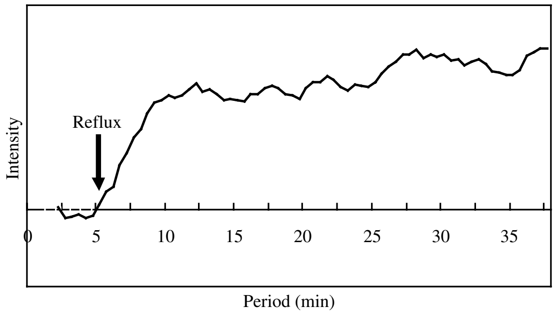


Figure 1. React IR analysis: generation of allenyl group by refluxing of 2-pentynyl phenylethynyl selenide **1**. Arrow indicates a refluxing start of the reaction mixture.

To confirm a generation of allenyl selenoketene intermediate **2** by heating of selenide **1**, React IR analysis of the reaction mixture was conducted.[7] A reaction was conducted on the selenide **1** in anhydrous THF under argon atmosphere using flask fitted with the React IR probe, monitoring typical absorbance for the allenyl group. After 5 min when it started to reflux, the absorbance of the allenyl group increased drastically. The generation of allenyl group was reached on a plateau level in 10 min (Fig. 1). The generation of allenyl selenoketene intermediate **2** was confirmed by refluxing of selenide **1** with a certainty. The allenyl selenoketene intermediate **2** leads to 1-alkylselenocyclobutenes **4**, by the reactions with the corresponding alkyl iodides. Alkylselenocyclobutene and alkylthiocyclobutene were important molecules as a precursor for the preparation of cyclobutenone.[8] This paper provides not only characterization of 1-alkylselenocyclobutenes **4** but also the preparation method of **4**.

Acknowledgements

We thank Professor Robert J. Linhardt for the critical reading of our manuscript.

Supplementary data

A supplementary data section is provided, which includes experimental details and spectral data of compound **4**. The supplementary data is available online with the paper in ScienceDirect. Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.tetlet.2005.01.019.

References and notes

1. (a) Sukhai, R. S.; Brandsma, L. *Rec. Trav. Chim. Pays-Bas* **1979**, *98*, 55; (b) Schaumann, E.; Grabley, F. F. *Tetrahedron Lett.* **1980**, *21*, 4251; (c) Shimada, K.; Akimoto, S.; Itoh, H.; Nakamura, H.; Takikawa, Y. *Chem. Lett.* **1994**, 1743; (d) Gonzalez, A. I.; Mo, O.; Yanez, M. *J. Phys. Chem. A* **1999**, *103*, 1662; (e) Ma, N. L.; Wong, M. W. *Eur. J. Org. Chem.* **2000**, 1411.
2. (a) Brady, W. T.; Scherubel, G. A. *J. Am. Chem. Soc.* **1973**, *95*, 7447; (b) Bampfield, H. A.; Brook, P. R.; McDonald, W. S. *J. Chem. Soc., Chem. Commun.* **1975**, 132; (c) Bertrand, M.; Gil, G.; Junino, A.; Maurin, R. *Tetrahedron* **1985**, *41*, 2759; (d) Brady, W. T.; Giang, Y. S. F.; Marchand, A. P.; Wu, A. H. *J. Org. Chem.* **1987**, *52*, 3457; (e) Tidwell, T. T. *Ketenes*; Wiley: New York, 1995; (f) Huang, W.; Tidwell, T. T. *Synthesis* **2000**, *3*, 457; (g) McCaleb, K. L.; Halcomb, R. L. *Org. Lett.* **2000**, *2*, 2631.
3. Examples of intramolecular cycloadditions with allenes: (a) Landor, S. R. *The Chemistry of the Allenes*; Academic: New York, 1982; (b) *Allenes in Organic Synthesis*; Schuster, H. F., Coppola, G. M., Eds.; Wiley-Interscience: New York, 1984; (c) Crimmins, M. T. *Chem. Rev.* **1988**, *88*, 1453; (d) Arredondo, V. M.; Tian, S.; McDonald, F. E.; Marks, T. J. *J. Am. Chem. Soc.* **1999**, *121*, 3633; (e) van Henegouwen, W. G. B.; Fieseler, R. M.; Rutjes, F. P. J. T.; Hiemstra, H. *Angew. Chem., Int. Ed.* **1999**, *38*, 2214; (f) Brummond, K. M.; Lu, J. L. *J. Am. Chem. Soc.* **1999**, *121*, 5087; (g) Villar, F.; Equey, O.; Renaud, P. *Org. Lett.* **2000**, *2*, 1061.
4. Koketsu, M.; Kanoh, M.; Itoh, E.; Ishihara, H. *J. Org. Chem.* **2001**, *66*, 4099.
5. *Procedure for synthesis of 1-alkylseleno-3-alkyl-2-aryl-4-methylidenecyclobutene* **4**. A solution of 2-pentynyl phenylethynyl selenide **1** (0.25 g, 1.0 mmol) in 10 mL anhydrous THF under argon atmosphere was refluxed for 5 min. To the reaction mixture, lithium aluminium hydride (0.04 g, 1.0 mmol) and methyl iodide **3a** (0.13 mL, 2.0 mmol) was added and refluxed for 1 h. The mixture was extracted with diethyl ether and washed with saturated NaCl aqueous solution. The organic layer was dried over sodium sulfate and evaporated. The residue was purified by flash chromatography on silica gel with *n*-hexane to give **4a** (yield 70%). *3-Ethyl-4-methylidene-1-methylseleno-2-phenyl-2-cyclobutene* **4a**. Yellow oil, ^{1}H NMR (400 MHz, $CDCl_3$) δ 0.92 (3H, t, $J = 7.4$ Hz, CH_3), 1.62–1.73 (1H, m, 1H of CH_2), 1.85–1.95 (1H, m, 1H of CH_2), 2.31 (3H, s, CH_3), 3.67 (1H, dd, $J = 3.6$, 7.6 Hz, CH), 4.69 (1H, s, 1H of CH_2), 4.86 (1H, s, 1H of CH_2), 7.26 (1H, t, $J = 7.4$ Hz, Ar), 7.37 (2H, t, $J = 7.6$ Hz, Ar), 7.57 (2H, d, $J = 7.6$ Hz, Ar); ^{13}C NMR (100 MHz, $CDCl_3$) δ 5.3, 10.5, 23.3, 50.6, 97.1, 125.3, 126.7, 128.1, 128.4, 133.7, 151.7, 154.1; ^{77}Se NMR (76 MHz, $CDCl_3$) δ 109.6; MS (EI): $m/z = 264$ [M$^+$]; Anal. Calcd for $C_{14}H_{16}Se$: C, 63.88; H, 6.13. Found: C, 63.84; H, 5.98. *1-Ethylseleno-4-methylidene-2-(4-methylphenyl)-3-pentylcyclobutene* **4c**. Yellow oil, IR (KBr) 3078, 3023, 1662 cm^{-1}, ^{1}H NMR (500 MHz, $CDCl_3$) δ 0.92 (3H, t, $J = 7.5$ Hz, CH_3), 1.44 (3H, t, $J = 7.5$ Hz, CH_3), 1.64–1.72 (1H, m, 1H of CH_2), 1.86–1.94 (1H, m, 1H of CH_2), 2.35 (3H, s, CH_3), 2.86–2.97 (2H, m, CH_2), 3.67 (1H, dd, $J = 3.6$ Hz, 7.5 Hz, CH), 4.65 (s, 1H, 1H of CH_2), 4.82 (s, 1H, 1H of CH_2), 7.18 (2H, t, $J = 8.0$ Hz, Ar), 7.55 (2H, d, $J = 8.0$ Hz, Ar); ^{13}C NMR (125 MHz, $CDCl_3$) δ 10.5, 16.5, 19.4, 21.4, 23.4, 50.6, 96.2, 123.3, 126.8, 129.0, 131.0, 138.4, 152.3, 155.8; ^{77}Se NMR (95 MHz, $CDCl_3$) δ 216.2; MS(CI) $m/z = 293$ [M$^+$+1]; Anal. Calcd for $C_{16}H_{20}Se$: C, 65.97; H, 6.92. Found: C,65.86; H, 7.30.
6. (a) Hatchard, W. R.; Schnneider, A. K. *J. Am. Chem. Soc.* **1957**, *79*, 6261; (b) Obata, N.; Takizawa, T. *Bull. Chem. Soc. Jpn.* **1977**, *50*, 2017; (c) Shimada, K.; Akimoto, S.; Takikawa, Y.; Kabuto, C. *Chem. Lett.* **1994**, 2283.
7. *Monitoring of allenyl group by React IR*. A reaction was conducted on the selenide **1** (10 mmol) under argon atmosphere using flask fitted with the React IR probe. After 5 min, the reaction mixture was refluxed. By scanning the IR spectrum once for every 30 s from 650 to 4000 cm^{-1} during the reaction, the reaction monitoring was carried out. Typical absorbance, 1955 cm^{-1}, of allenyl group was plotted in Figure 1.
8. (a) Narasaka, K.; Hayashi, Y.; Shimadzu, H.; Niihata, S. *J. Am. Chem. Soc.* **1992**, *114*, 8869; (b) Halazy, S.; Krief, A. *Tetrahedron Lett.* **1981**, *22*, 1829; (c) Halazy, S.; Krief, A. *J. Chem. Soc., Chem. Commun.* **1979**, 1136; (d) Barry, M. T.; Donald, E. K.; Henry, C. A.; Mitchell, J. B. *J. Am. Chem. Soc.* **1977**, *99*, 3088.