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Synthesis and Thermal Reaction of 1,3-Bis(alkylseleno)allenes

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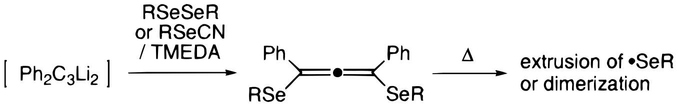
ABSTRACT

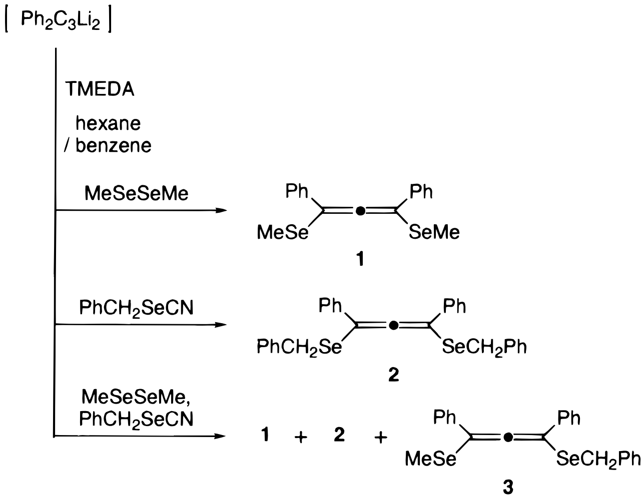


Reactions of Ph_2C_3 dianion, prepared from 1,3-diphenylpropyne and *n*-butyllithium, with dimethyl diselenide and benzylselenocyanate yielded 1,3-bis(methylseleno)-1,3-diphenylpropadiene and 1,3-bis(benzylseleno)-1,3-diphenylpropadiene, respectively, and the reaction with a mixture of dimethyl diselenide and benzylselenocyanate gave 1-benzylseleno-3-methylseleno-1,3-diphenylpropadiene together with the symmetric products. Thermal reactions of the 1,3-bis(alkylseleno)allenes afforded (*E*)- and (*Z*)-1,3,4,6-tetraphenyl-3-hexene-1,5-diynes along with compounds derived from cyclic dimer of the allene or diselenide via radical pathway.

Allene chemistry has been widely studied,[1,2] and substituted allenes by heteroatoms have also received attention.[2] Recently, we reported the synthesis and reaction of sulfur-substituted allenes, and the thermal reactions of 1,3-bis(alkylthio)allenes have been found to yield thiophene derivatives.[3] Several selenium-substituted allenes are also known as isolable compounds or reactive intermediates.[4] We also synthesized the 1,3-bis(alkylseleno)allenes, and it was found that thermal reactions of the selenium-substituted allenes are different from those of corresponding sulfur-substituted allenes and afforded enediyne derivatives. In this paper, we report the synthesis and thermal reaction of 1,3-bis(alkylseleno)allenes.

When a benzene solution of 2 equiv of dimethyl diselenide was added dropwise to Ph_2C_3 dianion (1,3-dilithioallene), prepared[5] from 1,3-diphenylpropyne and *n*-butyllithium in hexane solution, in the presence of TMEDA (*N*,*N*,*N*′,*N*′-tetramethylethylenediamine), and the solution was stirred for additional 30 min, 1,3-bis(methylseleno)-1,3-diphenylpropadiene (**1**[6]) was obtained in 70% yield after purification by column chromatography on silica gel (Scheme 1). TMEDA

Scheme 1



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[1] For reviews, see: (a) *The Chemistry of the Allenes*; Landor, S. R., Ed.; Academic Press: New York, 1982; Vols. 1−3. (b) *The Chemistry of Ketenes, Allenes and Related Compounds*; Patai, S., Ed.; Wiley: New York, 1980; Vols. 1 and 2. (c) Brandsma, L.; Verkruijsse, H. D. *Synthesis of Acetylenes, Allenes and Cumulenes*; Elsevier: New York, 1980. (d) Pasto, D. J. *Tetrahedron* **1984**, *40*, 2805. (e) Smadja, W. *Chem. Rev.* **1983**, *83*, 263. (f) Baldwin, J. E.; Fleming, R. H. *Fortschr. Chem. Forsch.* **1970**, *15*, 281. (g) Huché, M. *Tetrahedron* **1980**, *36*, 331. (h) Mavrov, M. V.; Kucherov, V. F. *Russ. Chem. Rev.* **1967**, *36*, 233. (i) Griesbaum, K. *Angew. Chem., Int. Ed. Engl.* **1966**, *5*, 933.

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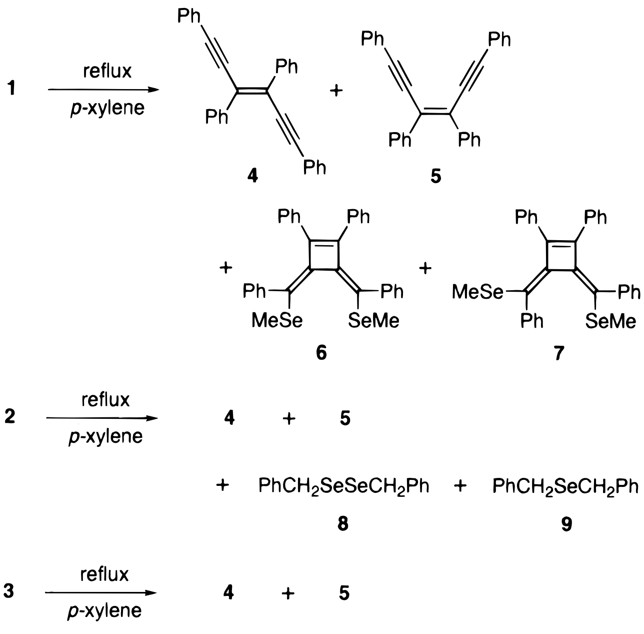
was found to be indispensable to this reaction, and the yield was lowered (22%) when the reaction was carried out without TMEDA. Similarly, reaction of the dianion with 2 equiv of benzylselenocyanate in the presence of TMEDA yielded 1,3-bis(benzylseleno)-1,3-diphenylpropadiene (**2**[6]) in 64% yield. Reaction of the dianion with a mixture of dimethyl diselenide and benzylselenocyanate afforded unsymmetric allene **3**[6] in 17% yield together with symmetric allenes **1** (26%) and **2** (5%). 3,3-Bis(alkylseleno)-1,3-diphenylpropyne, which has possibility to form in these reactions, was not detected in all the cases. Methyl signals of **1** was observed at higher fields (^{1}H: δ 2.14; ^{13}C: δ 7.1) than those of corresponding sulfur analogue (^{1}H: δ 2.24; ^{13}C: δ 15.6)[3] on the ^{1}H and ^{13}C NMR spectra in $CDCl_3$, and absorption maxima of **1** and **2** were observed at 298 and 307 nm in cyclohexane, respectively, which are shifted to longer wavelengths compared with those of the corresponding sulfur analogues.

1,3-Bis(methylseleno)allene **1** reacted in refluxing *p*-xylene to give (*E*)- and (*Z*)-1,3,4,6-tetraphenyl-3-hexene-1,5-diynes (**4**[7] and **5**[8]), the framework of which is known as an important building block of several naturally occurring antitumor antibiotics[9] and as a substrate of the Masamune−Bergman reaction,[10] (*Z*,*Z*)-1,2-bis(α-(methylseleno)benzylidene)-3,4-diphenylcyclobutene (**6**[6]), and the *E*,*Z*-isomer **7**[6] in yields of 34, 7, 21, and 9%, respectively, after 3 d (Scheme 2).

Scheme 2



Enediynes **4** and **5** have recently synthesized, and assignment of the *E*- and *Z*-isomers was made on the basis of their spectral properties.[11] The structure of enediynes **4** and **5** was confirmed by X-ray analysis of *E*-isomer **4** (Figure 1).[12] It was also found that *Z*−*E* isomerization occurred between **4** and **5** under the conditions, and ca. 2:1 mixture of **4** and **5** was obtained from **5** in a refluxing *p*-xylene after 1.5 h.

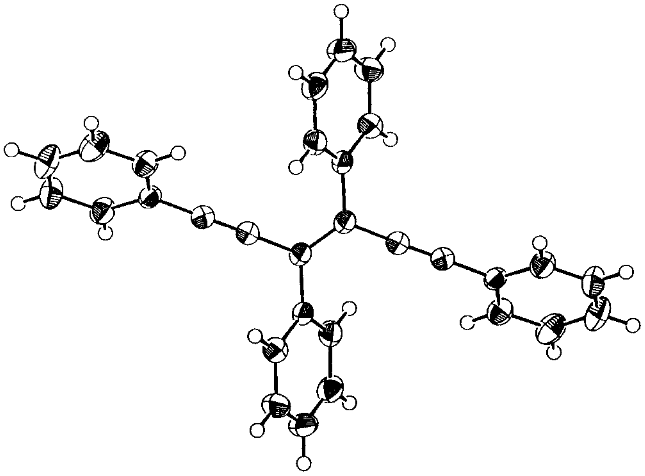


Figure 1. Crystal structure of **4** showing 50% probability displacement ellipsoids.

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(4) (a) Pourcelot, G.; Cadiot, P. *Bull. Soc. Chim. Fr.* **1966**, 3016; 3024. (b) Petrov, M. L.; Radchenko, S. I.; Kupin, V. S.; Petrov, A. A. *J. Org. Chem. USSR* **1973**, *9*, 683. (c) Braverman, S.; Duar, Y. *Tetrahedron Lett.* **1978**, 1493. (d) Braverman, S.; Freund, M.; Goldberg, I. *Tetrahedron Lett.* **1980**, *21*, 3617. (e) Reich, H. J.; Shah, S. K.; Gold, P. M.; Olson, R. E. *J. Am. Chem. Soc.* **1981**, *103*, 3112. (f) Reich, H. J.; Kelly, M. J. *J. Am. Chem. Soc.* **1982**, *104*, 1119. (g) Tada, M.; Nagasaka, R. *Bull. Chem. Soc. Jpn.* **1995**, *68*, 3221.

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(6) All new compounds gave satisfactory elemental analysis, and IR, NMR, and mass spectral data correlated with the assigned structures.

(7) **4**: Mp 156.2−157.2 °C (pale yellow prisms from benzene/hexane); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.27−7.31 (m, 10H), 7.39 (t, 2H, $J = 7.30$ Hz), 7.46 (t, 4H, $J = 7.30$ Hz), 7.98 (d, 4H, $J = 7.30$ Hz); ^{13}C NMR (125 MHz, $CDCl_3$) δ 90.9, 98.6, 123.2, 127.8, 128.3 (duplicate), 128.4, 128.6, 129.2, 131.4, 139.0; IR (KBr) ν_{max} 3097, 3025, 1600, 1500, 1450, 1320, 1240, 1180, 1040, 780, 760, 740, 692 cm^{-1}; UV (cyclohexane) λ_{max} 269 (ϵ 3.16×10^4), 367 (ϵ 3.30×10^4) nm; MS (*m/z*) 380 (M^+), 302. Anal. Calcd for $C_{30}H_{20}$: C, 94.70; H, 5.30. Found: C, 94.82; H, 5.41.

(8) **5:** Mp 105.0−106.1 °C (pale yellow needles from benzene/hexane); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.20−7.23 (m, 6H), 7.30−7.35 (m, 10H), 7.54−7.56 (m, 4H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 91.8, 96.8, 123.4, 127.8, 128.0, 128.4, 128.5, 129.2, 129.7, 131.6, 137.5; IR (KBr) ν_{max} 3050, 3017, 2926, 1597, 1486, 1441, 1415, 1266, 1029, 909, 766, 756, 698 cm^{-1}; UV (cyclohexane) λ_{max} 269 (ϵ 2.55×10^4), 361 (ϵ 2.00×10^4) nm; MS (*m/z*) 380 (M^+), 302, 189. Anal. Calcd for $C_{30}H_{20}$: C, 94.70; H, 5.30. Found: C, 94.96; H, 5.55.

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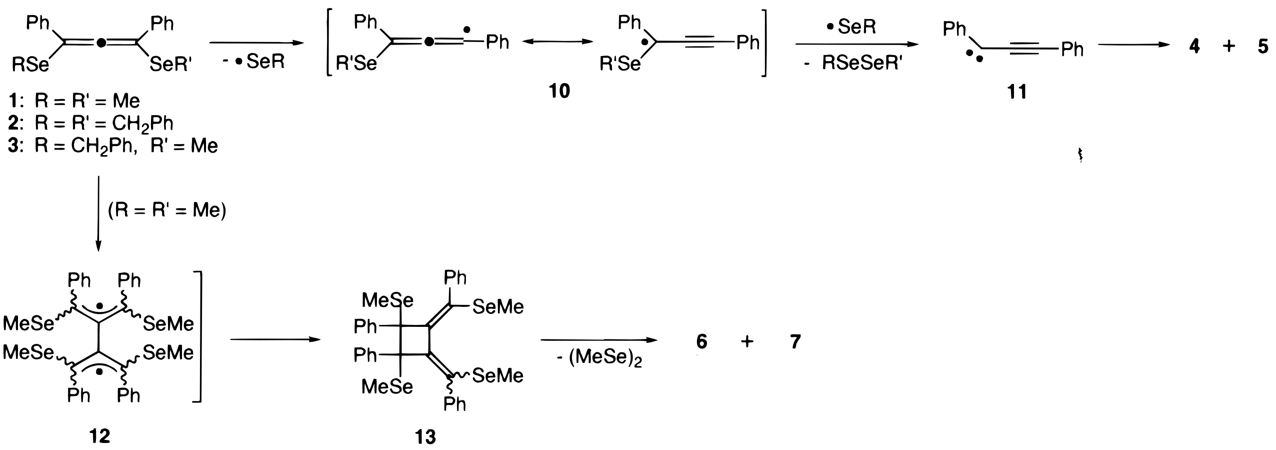
Scheme 3



Thermal reaction of 1,3-bis(benzylseleno)allene **2** proceeded smoothly in a refluxing *p*-xylene, and enediynes **4** and **5** were formed in 36 and 8% yields, respectively, together with dibenzyl diselenide **8** (57%) and dibenzyl selenide **9** (25%) after 1.5 h. In the thermal reaction of unsymmetric allene **3**, the reaction was intricate, and only enediyne compounds **4** (28%) and **5** (7%) were isolated. The thermal reactivities of selenium-substituted allenes **1** and **2** were found to be different from those of the corresponding sulfur-substituted allenes,[3] and the difference of the reactivities may be due to smaller bond dissociation energy of carbon−selenium bond than that of carbon−sulfur bond. The thermal reactions of sulfur-substituted allenes **1**, **2**, and **3** were found to proceed via radical mechanism since an addition of galvinoxyl in the reaction of **1** and **2** inhibited both reactions.

One plausible mechanism is shown in Scheme 3. Homolytic cleavage of the carbon−selenium bond of allenes **1**, **2**, and **3** gives radical **10** with extrusion of seleno radical. An attack of the seleno radical to the selenium atom of **10** yields carbene **11** followed by dimerization of **11** to afford enediyne compounds **4** and **5**. In the case of allene **1**, addition between *sp*-hybridized carbons also occurs to give biradical intermediate **12** followed by intramolecular cyclization to form cycloadduct **13**. Under the conditions, further reaction occurs to give cyclobutene derivatives **6** and **7** with extrusion of dimethyl diselenide. The reason cyclobutene derivative was not obtained in the case of allene **2** is maybe due to fast cleavage of the carbon−selenium bond and/or repulsion between two benzyl groups in formation of the carbon−carbon bond.

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Supporting Information Available: Detailed information of the X-ray crystallographic analysis of **4** including structure diagram, details of data collection and reduction and structure solution and refinement, tables of positional and thermal parameters, and bond lengths, angles, and torsional angles. Detailed experimental procedures and spectral data including ^{1}H and ^{13}C NMR, IR, and mass spectra, and elemental analysis of **1**, **2**, **3**, **6**, and **7**.

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(12) Crystal structure analysis for **4**: formula $C_{30}H_{20}$, M_r = 380.48, crystal dimensions 0.20 × 0.20 × 0.20 mm, a = 9.150(2), b = 9.118(2), c = 12.576(1) Å, β = 91.25(2)°, V = 1035.8(3) Å^3, ρ_{calct} = 1.220 g cm^{-3}, Z = 2, monoclinic, space group $P2_1/n$ (No. 14), Rigaku AFC7R diffractometer, λ = 0.71069 Å, T = 296 K, 2667 measured reflections, 2520 unique, R = 0.039, R_w = 0.037.