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# Synthesis of Benzo[*c*]selenophene and Derivatives via New Routes

**Emad Aqad, M. V. Lakshmikantham, Michael P. Cava,* Grant A. Broker, and Robin D. Rogers**

*Department of Chemistry, University of Alabama, Tuscaloosa, Box 870336,
Tuscaloosa, Alabama 35487-0336*

*mcava@bama.ua.edu*

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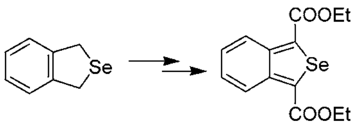
## ABSTRACT



**Benzo[c]selenophene has been generated via facile bromination–dehydrobromination as well as oxidation of the 1,3-dihydrobenzo[c]selenophene. Benzo[c]selenophene thus generated has been lithiated in situ and treated with ClCOOEt to give the first functionalized derivative subject to X-ray crystallographic analysis.**

The highly reactive *o*-quinonoid heterocycles benzo[*c*]furan (**1**) and benzo[*c*]thiophene (**2**) have received much attention, both from synthetic and theoretical points of view.[1] The practical synthesis of **2** was achieved by us almost 32 years ago,[2] and its potential as a building block in $\pi$-conjugated polymers was realized later by Wudl.[3] The remarkably small band gap[4] of poly-**2** initiated the search of other *o*-quinonoid heterocycle-based polymers. In this regard, polymers derived from the unstable benzo[*c*]selenophene (**3**) and its derivatives have received only scant attention. The only stable derivative viz. the dicyanocompound **6** was obtained in an unusual reaction from *o*-xylene dicyanide.[5] In fact, the only patent describing the preparation of conductive polybenzo[*c*]selenophene was reported in 1991 but was not further examined.[6] Recently, we reported the synthesis, functionalization, and isolation of stable benzo[*c*]tellurophenes (**4**).[7] In contrast, the unstable benzo[*c*]selenophene (**3**) was generated by us via a base-catalyzed dehydration of selenoxide (**5**) with aqueous alkali but was not examined further.[8] The parent **3** gives Diels−Alder adducts very rapidly, in agreement with the poor aromatic character of the compound. $^1$H NMR data and theoretical analysis indicate that the structure in which 6$\pi$ electrons are delocalized on the heterocyclic ring is more representative than the benzenoid one.[9] Herein, we would like to report new routes toward the generation of benzo[*c*]selenophene. The synthesis and X-ray molecular structure of a stable benzo[*c*]selenophene derivative is presented.

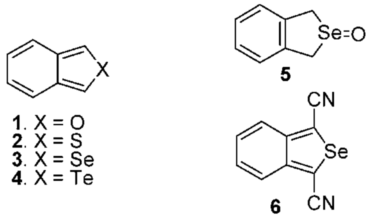


**Figure 1.**

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[1] (a) Iddon, B. *Adv. Heterocycl. Chem.* **1972**, *14*, 331 (b) Dean, F. M. Furans and Their Benzo Derivatives. In *Comprehensive Heterocyclic Chemistry*; Katrizky, A. R., Rees, C. W., Eds.; Pergamon Press: Elmsford, 1984; Vol. 4, pp 531−712. (c) Friedrichsen W. *Adv. Heterocycl. Chem.* **1980**, *26*, 135. (d) Geyer, W.; Mayer, R. In *Methoden Der Organischen Chemie (Houben-Weyl)*; Kreher, R. P., Ed.; Georg Thieme Verlag: Stuttgart, 1994; , Vol E6b, part 2a, pp 275−332.

[2] Cava, M. P.; Pollack, N. M.; Mamer O. A.; Mitchel, M. J. *J. Org. Chem.* **1971**, *36*, 3932.

[3] Wudl, F.; Kobayashi, M.; Heeger A. J. *J. Org. Chem.* **1984**, *49*, 3382.

[4] (a) Colaneri, N.; Kobayashi, M.; Heeger, A. J.; Wudl, F. *Synth. Met.* **1986**, *14*, 45 (b) Kobayashi, M.; Colaneri, N.; Boysel, M.; Wudl, F.; Heeger A. *J. Chem. Phys.* **1985**, *82*, 5717.

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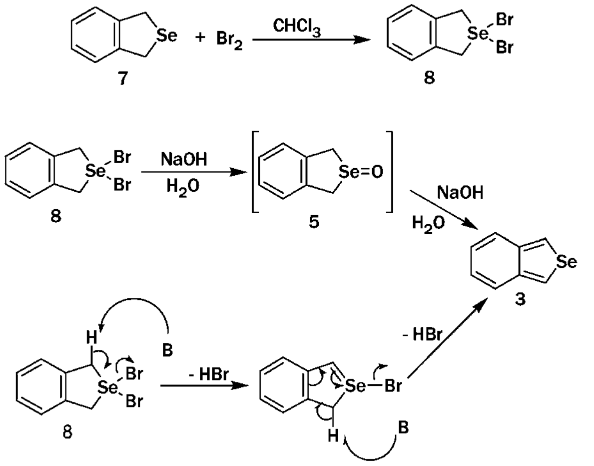
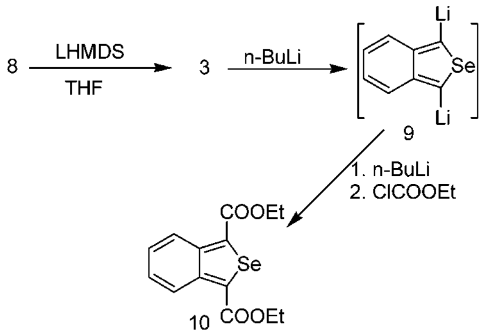
Dihydrobenzo[*c*]selenophene (**7**) was converted to the dibromo derivative **8** in quantitative yield by its reaction with 1 equiv of bromine at room temperature (Scheme 1).[10]

**Scheme 1**



Dibromide **8** obtained as small, yellow microcrystals, could not be stored for a long period of time. All subsequent reactions were therefore performed on freshly prepared samples. In earlier attempts to generate the parent benzo[*c*]selenophene (**3**), we found that the treatment of the dibromo derivative with 40% aqueous sodium hydroxide leads to the formation of **3** via the selenoxide intermediate **5** (Scheme 1).[8] In the present study, we found that treatment of the dibromide with nonaqueous bases such as 1,5-diazobicyclo[3.4.0]nonene (DBN) or lithium hexamethyldisilazide (LHMDS) in THF also generates benzo[*c*]selenophene as evidenced by its characteristic UV−vis spectrum.[11] This reaction represents the first synthesis of an *o*-quinonoid heterocycle via dehydrohalogentation. In accordance with our previous observations, compound **3** was found to be fairly stable in a cold dilute THF solution for a week but polymerized upon attempted isolation in the pure state.

**Scheme 2**



The generation of **3** under anhydrous conditions made its functionalization more feasible; thus, the in situ dilithiation could be achieved by reaction with excess *n*-butyllithium. The reaction of the dianion **9** with ethyl chloroformate gave the diester derivative **10** (Scheme 2). Interestingly enough, the monosubstituted derivative was not formed in this reaction. In contrast to the parent **3**, the diester was found to be very stable and the crystals were subjected to X-ray analysis. It represents the first example of structure determination of a stable benzo[*c*]selenophene derivative. The crystal structure revealed that the benzene and selenophene rings in **10** are planar,[12] with the ester groups oriented in a trans configuration with respect to the selenophene ring (Figure 2). The bond lengths and bond angle of interest are Se−C1, C1−C2, C2−C2A, and C1−Se−C1A. The corresponding values are 1.843(3), 1.395(4), 1.433(6) Å and 88.0(2)°. These values seem to suggest an *ortho*-quinonoid structure rather than a mesomeric structure incorporating tetravalent selenium. The crystal packing down the crystallographic axis *a* consists of alternating columns of the planar diester molecules. The crystal packing down the crystallographic axis *b* includes intermolecular interactions between the planar sheets through Se−Se instead of $\pi-\pi$ stacking (Figure 3). The Se−Se distance between these sheets is 3.657(1) Å, while the interplanar distance is 3.45 Å.

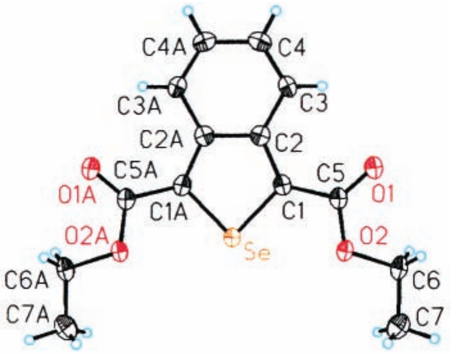


**Figure 2.** ORTEP of **10**.

Reactions of **9** with other electrophiles such as *p*-toluenesulfonic anhydride, acetyl chloride, cyanogen bromide, *N*,*N*-dimethyl formamide, and *tert*-butyldimethylsilyl

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(6) Kubota, F. JP Application 1989−86323; *Chem. Abstr.* **1991**, *115*, 20291.

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(9) Chacko E.; Bornstein, J.; Sardella, D. J. *J. Am. Chem. Soc.* **1977**, *99*, 8248.

(10) Magdesiava, N. N.; Vduin, V. A. *Khim. Geterosikl, Soedin* **1972**, *8*, 24.

(11) Characteristic UV−vis spectrum of the parent benzo[*c*]selenophene (**3**) was discussed in ref 8.

(12) Crystal data for **9**: $C_{14}H_{14}O_4Se$, 325.21, orthorhombic, space group *Cmma*, $a = 6.895(2)$, $b = 22.208(7)$, $c = 8.782(3)$ Å, $V = 1344.8(7)$ Å$^3$, $Z = 4$, $D_{calcd} = 1.606$ g/cm$^{-3}$, $R_1 = 0.0196$, $wR_2 = 0.0504$ ($I > 2\sigma(I)$). Crystallographic data (excluding structure factors) for the structure in this paper have been deposited with the Cambridge Crystallographic Data Centre as supplementary publication number CCDC 209488. A copy of the data can be obtained free of charge, from CCDC, 12 Union Road, Cambridge CB2 1EZ [fax, +44(0) 1223-336033; e-mail, deposit@ccdc.cam.ac.uk].

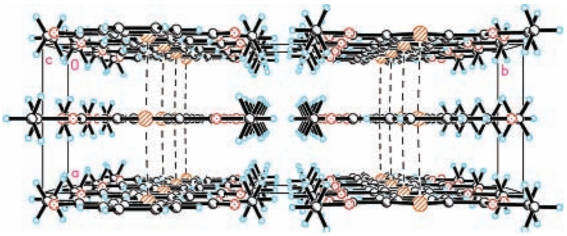
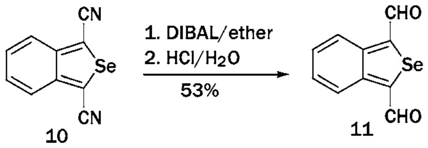


**Figure 3.** Crystal packing down the crystallographic axis *b* showing the intermolecular interactions between the planar sheets through Se−Se intermolecular interactions.

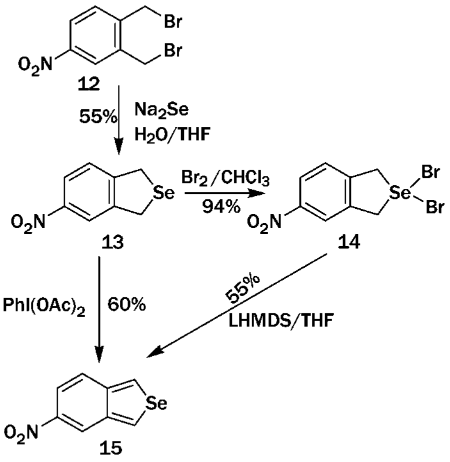
chloride have not yet been successful. Direct reaction of the parent **3** or the dianion **9** with the Vilsmeier reagent did not give the expected dialdehyde derivative **11**. However, the synthesis of **11** was achieved by the treatment of the known[5] dicyano derivative **6** with DIBAL-H and found to be very stable (Scheme 3).

**Scheme 3**



In the search for other stable benzo[*c*]selenophene derivatives, our attention was turned to the synthesis of **15**, a benzo[*c*]selenophene bearing an electron-withdrawing group ($NO_2$) on the six-membered ring. Reaction of 1,2-bis(bromomethyl)-5-nitro-benzene (**12**) with sodium selenide generated in situ furnished the dihydroselenide derivative **13** in 55% yield. Best results were obtained when the dibromide **12** was added very slowly to a dilute solution of the selenium reagent at pH = 9 (Scheme 4). Treatment of **13** with 1 equiv of bromine gave the dibromo derivative **14**. Not surprisingly, dehydrobromination proved to be facile upon treatment of **14** with LHMDS in THF at 0 °C, leading to the isolation of 5-nitro-benzo[*c*]selenophene (**15**). Although **15** was stable at ambient temperature and atmosphere for several days, it did decompose upon prolonged exposure to air and was also sensitive to acid and light. Interestingly, treatment of the dihydro derivative **13** with phenyiododiacetate in methylene chloride at room temperature also generates 5-nitro-benzo[*c*]selenophene (**15**). The smooth and direct oxidative synthesis of **15** is novel, and the scope and limitation of this method for the synthesis of other *o*-quinonoid heterocycles is currently under investigation in our laboratory.

**Scheme 4**



In conclusion, new methods for the generation of benzo[*c*]selenophenes via dehydrobromination or oxidation are described. The first X-ray molecular structure of a benzo[*c*]selenophene derivative has been determined. Benzo[*c*]selenophenes bearing electron-withdrawing groups either on the selenophene ring or the benzene ring are stable.

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**Supporting Information Available:** Experimental details. This material is available free of charge via the Internet at http://pubs.acs.org.

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