

# Current topics of cyclic benzopolychalcogenides containing sulfur and selenium—synthesis and reactions

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*Abstract:* The chemistry of cyclic benzopolychalcogenides, such as benzopentathiepins, benzotetrathiins, and benzotrithioles and related compounds, has been widely studied to establish the synthetic methods and the stabilization with substituents on the benzene ring and to reveal the chemical properties of the polychalcogenide ring.

## INTRODUCTION

Recently, much attention has been focused on the chemistry of the compounds involving multilinked chalcogen atoms, such as cyclic polysulfides and polychalcogenides, from the viewpoint of synthetic and structural chemistry. For example, the natural product varacin was found to contain typical cyclic polysulfide, benzopentathiepin, in the molecule and to show biological activity (Scheme 1) [1]. We have also studied extensively the chemistry of cyclic benzopolychalcogenides containing sulfur, selenium, and tellurium, in order to establish their synthetic methods, reactivity, and structure.

Consequently, we have succeeded in the synthesis and characterization of five, six and seven membered cyclic benzopolychalcogenides containing sulfur, selenium, and tellurium. Here, current topics of cyclic benzopolychalcogenides are described.

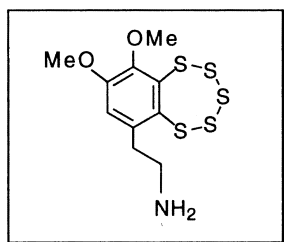
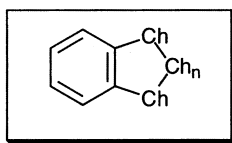
## SYNTHESIS AND STRUCTURE OF BENZOPOLYCHALCOGENIDES

Although there have been many reports on the synthesis of benzopentathiepin, which has a seven membered ring constructed with five sulfur atoms on benzene ring [2], only a few report for benzotrithiole and benzotetrathiin having five and six membered ring systems, respectively, have been published to date [3]. This fact suggests that benzopentathiepin is very stable and, on the other hand, benzotrithiole and benzotetrathiin are labile structurally. The stability of these compounds was also estimated by MM2 calculation as shown in the Table 1. Thus, benzotrithiole and benzotetrathiin appear to be very labile because of the small torsional angle for C–S–S–S, 55° and 50°, respectively.

Practically, we could easily obtain benzopentathiepin by treatment of benzenedithiol with elemental sulfur in liquid ammonia [5], but benzotetrathiin or benzotrithiole were not detected at all in this reaction. These results suggest that we need to use a substituent to stabilize kinetically the trithiole and tetrathiin ring systems. Introduction of methyl, isopropyl, or methoxy groups adjacent to the sulfur atoms of the ring led to success in the synthesis of benzotrithioles and benzotetrathiins. The five membered benzotrithioles having substituents on benzene ring were synthesized by the reaction of the corresponding 1,3-benzodithiastannoles, as equivalents of the benzenedithiolate dianions, with thionyl or selenonyl chloride followed by reduction with samarium iodide [6]. The ORTEP by X-ray crystallography and selected structural data for three benzopolychalcogenides having two methoxy groups on benzene ring

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**Varacin****Benzopolychalcogenide**

Ch = S, Se, Te  
n = 0, 1, 2

**Scheme 1****Table 1** MM2 calculation of cyclic benzopolysulfides

	Benzotrithiole	Benzotetrathiin	Benzopentathiepin		
				X-ray [4]	
Bond lengths (Å)	C-S1	1.779	1.779	1.774	1.774(5)
	S1-S2	2.056	2.026	2.041	2.041(2)
Bond angles (°)	C-S1-S2	97.0	108.2	102.5	104.5(2)
	S1-S2-S3	80.7	104.3	103.6	104.6(1)
Torsional angles (°)	C-S1-S2-S3	55.0	50.1	87.2	88.6

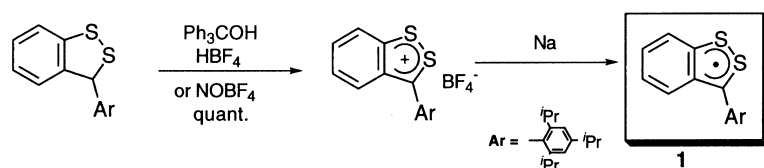
**Table 2** Selected crystallographical data of dimethoxybenzopolusulfides

	Trithiole	Tetrathiin	Pentathiepin	
Bond lengths (Å)	C-S1	1.770(6)	1.800(1)	1.769(5)
	S1-S2	2.064(3)	2.028(6)	2.033(3)
Bond angles (°)	C-S1-S2	93.4(2)	105.6(5)	103.8(2)
	S1-S2-S3	95.5(1)	98.7(3)	104.5(1)
Torsional angles (°)	C-S1-S2-S3	40.3(2)	60.4(5)	93.1(2)

are shown in the Table 2 [7]. We can point out a characteristic feature for the structure, thus the torsional angles for C–S–S–S of are 40° and 60° for benzotrithiole and benzotetrathiin, respectively, as expected in the MM2 calculation. These results have also shown the stabilization effect of the substituents in the formation of benzotrithiole and benzotetrathiin. By use of these substituents effects, we could obtain many kinds of cyclic benzopolychalcogenides containing sulfur and/or selenium atoms in the chalcogenide ring [7].

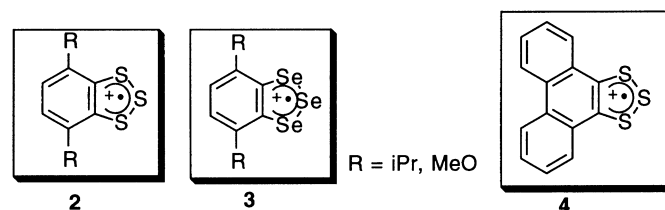
## REACTIONS OF BENZOPOLYCHALCOGENIDES

As above mentioned, we could establish the synthetic method of many kinds of benzopolychalcogenides. Next, our interests were directed to the study on the reactivity of the obtained benzopolychalcogenides [8]. The first dithioly radical (**1**) was obtained from 1,2-benzodithiole via the benzodithiolium salt by oxidation with  $\text{Ph}_3\text{COH}/\text{HBF}_4$  or  $\text{NOBF}_4$  followed by reduction with metallic sodium (Scheme 2).



Scheme 2

The bulky substituent was found to play an important role for stabilization of both benzodithiolium cation and dithioly radical. We have also succeeded in the formation of other interesting species (Scheme 3), benzotrithiolium, benzotriselenolium and phenanthrotrithiolium radical cations (**2**, **3** and **4**) [9].



Scheme 3

6,10-Diethyl[1,2,3]1-trithiole[h]benzopentathiepin (**TTBP**) [10] having both trithiole and pentathiepin rings fused to a benzene ring was oxidized with *mcpba* to give the corresponding four sulfoxides (**5–8**) as shown in Scheme 4. We have found that these two sets of sulfoxides (compounds **5** and **6**, compounds **7** and **8**) are conformational isomers based on interconversion of pentathiepin ring each other by spectroscopy and X-ray crystallography after isolation. The ORTEP drawings of these isomers by X-ray crystallography are shown in Fig. 1. We investigated the interconversion of the pairs of conformers by NMR and the obtained kinetic parameters are shown in Scheme 5. These results suggest that the conformational exchange occurs slowly at room temperature and that trithiolobenzopentathiepin **TTBP** has the possibility of giving a chiral sulfoxide by asymmetric oxidation.

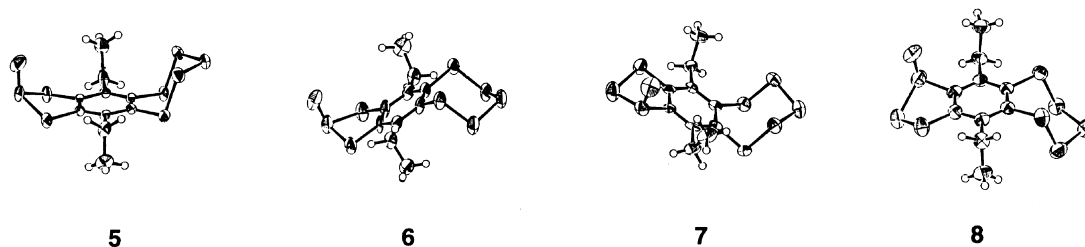
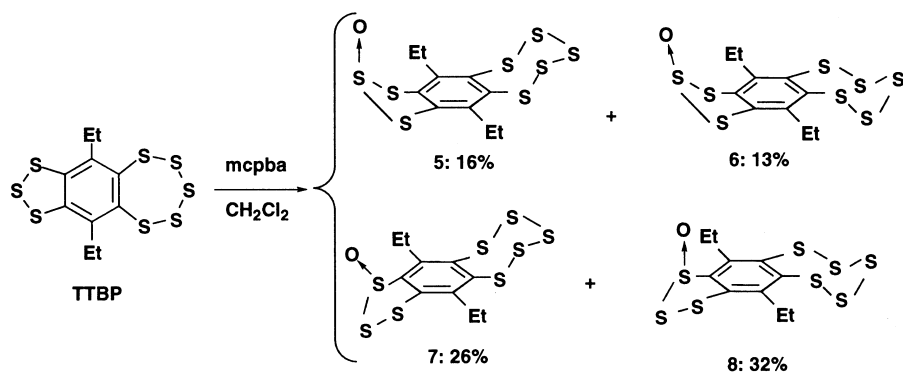
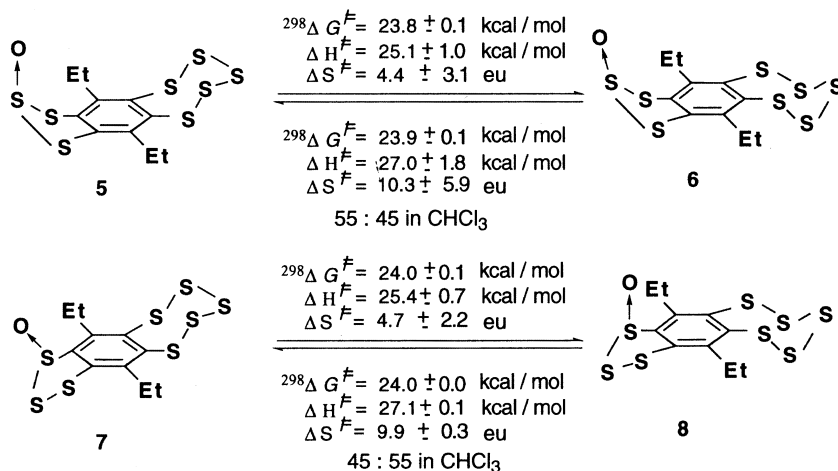


Fig. 1 ORTEP of compounds **5**, **6**, **7** and **8** by X-ray crystallography.

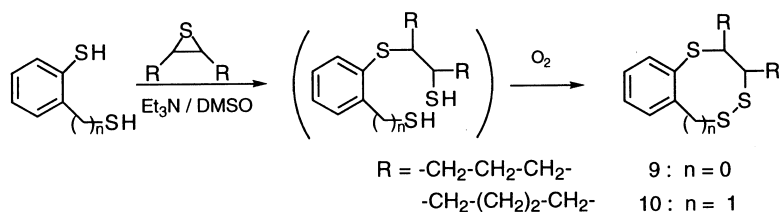


Scheme 4



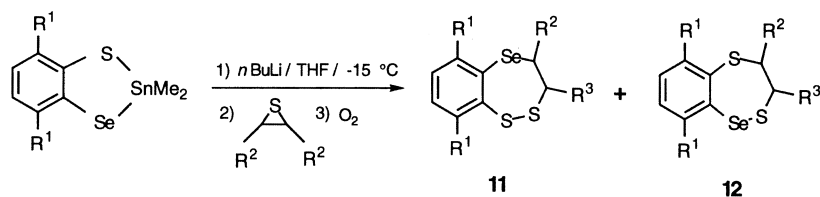
Scheme 5

The 1,2,5-benzotrithiepin (**9**) and 2,3,6-benzotrithiocin (**10**) are characterized as a benzopolysulfides containing three chemically different sulfur atoms in a cyclic sulfide ring. These compounds have been synthesized by treatment of benzenedithiols and 2-mercaptomethyl benzenethiol with thiiranes in the presence of triethylamine (Scheme 6) [12]. Thus, air oxidation of intermediate dithiols generated by nucleophilic attack of thiolate anion toward methylene carbon of thirane gave cyclic products, trithiepin **9** and trithiocin **10**.



Scheme 6

Moreover, we have succeeded in the introduction of a selenium atom into a trichalcogenepin ring by the reaction of benzeneselenathiastannole as a substrate with thiirane in the presence of butyllithium (Scheme 7). Interestingly, in this reaction, an addition of a proton source to the reaction system before reaction with thiirane affected drastically the yields and product ratios as shown in Run 1–4 of Table 3. It is interesting to note the formation of 1,2,5-benzoselenadithiepin (**12**) having selenenyl sulfide bonding, -Se-S-, in the trichalcogenepin ring besides 1,2,5-benzodi-thiaselenepin (**11**), because it is well



Scheme 7

Table 3 Synthesis of 1,2,5-benzotrithalcohenepins

Run	R <sup>1</sup>	R <sup>2</sup>	R <sup>3</sup>	Additive	Yield (%)	
					11	12
1	H	H	H		15	34
2	H	H	H	HCl	70	2
3	H	-CH <sub>2</sub> (CH <sub>2</sub> ) <sub>2</sub> CH <sub>2</sub> -			4	40
4	H	-CH <sub>2</sub> (CH <sub>2</sub> ) <sub>2</sub> CH <sub>2</sub> -		AcOH	40	0
5	H	-CH <sub>2</sub> (CH <sub>2</sub> ) <sub>2</sub> CH <sub>2</sub> -		H <sub>2</sub> O	4	86
6	<sup>i</sup> Pr	H	H		16	20
7	<sup>i</sup> Pr	H	H	AcOH	82	0

known that the nucleophilicity of the selenolate anion is much higher than that of the thiolate anion. The formation of product **12** shows that the thiolate anion preferentially attacked the methylene carbon in the thirane ring to form sulfide bonding. The effect of addition of proton source was interpreted in term of control of nucleophilicity of thiolate and selenolate anion by protonation.

In conclusion, we have succeeded in the synthesis of many cyclic benzopolychalcogenides containing sulfur and selenium. Moreover, we have performed many kinds of reactions of these cyclic benzopolychalcogenides, to show their versatility.

## ACKNOWLEDGEMENTS

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