Tetrathiaselenepin Ring Fused to Benzene and Naphthalene

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Benzo[1,2,3,4,5]tetrathiaselenepin is an unstable cyclic polychalcogenide. Isopropyl and/or methoxy groups at the neighboring of polychalcogen ring sterically stabilized the unstable ring. Replacing of aromatic unit from benzene to naphthalene also gave thermodynamic stability to the ring. Synthesis, characterization, and stability of some novel polychalcogenides are reported.

Since pioneer research by Fehér and Langer,[1] various types of cyclic polysulfides[2a] such as benzopentathiepins (**BPT**) and benzotrithioles have been studied for over three decades because of their chemical, theoretical, and biological interest.[2b] They exhibit unique chemical properties such as skeletal rearrangements, unusual structures, ring inversion, and transfer of sulfur atoms to acceptors.[3] Compared to syntheses and reactions of linear or cyclic polysulfides, only a few examples of cyclic polychalcogenides have been reported. Selenium is more polarizable than sulfur, and therefore synthesis of stable compounds having Se–Se and/or Se–S linkages is attractive in the viewpoint of application to material sciences.[4] Here, an asymmetric ring such as [1,2,3,4,5]tetrathiaselenepin is attempted to develop on aromatics concerning modification of typical **BPT** to benzo[1,2,3,4,5]tetrathiaselenepin (**BTTSe**). **BPT** is the most popular aromatic cyclic polysulfide[2] whereas **BTTSe** or benzo[1,2,3,4,5]pentaselenepin (**BPSe**) is hitherto unknown. **BPSe** is difficult to synthesize by available methods due to unusual selenium extrusion and dynamic nature of flexible polyselenide linkage (Figure 1).[5]

Seven-membered chalcogen rings are of great interest owing to their diversity in nature and cytotoxic activity.[6] Seven-membered multi-chalcogen frameworks are also intriguing due to the rich chalcogen chemistry associated with flexible Se–S bond, intramolecular ring rearrangement through selenium extrusion,[7] and for their inherent stability.

In course of our studies for the synthesis of **BTTSe**,[8,14] it was observed that the product is unstable and readily converted into oligomeric insoluble products. Generally, five- and six-membered cyclic benzopolysulfides are labile and substituents are required at their neighboring positions to stabilize these rings[9] but seven-membered chalcogen rings are stable. **BTTSe** contains seven-membered polychalcogen ring, therefore the results were different than similar polysulfide rings. This paper describes the synthetic and stabilization aspects of [1,2,3,4,5]-tetrathiaselenepin ring fused to aromatics.

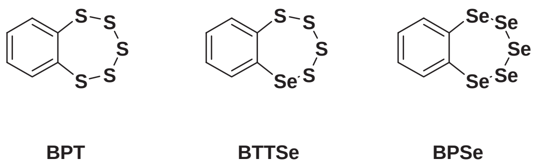
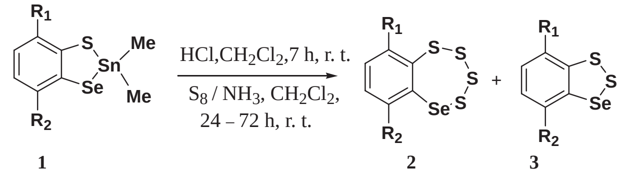


Figure 1.

Table 1. Synthesis of benzo[1,2,3,4,5]tetrathiaselenepin

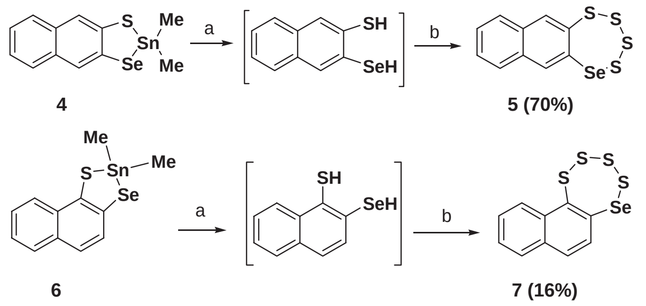


Entry	Substrate	Substituent		Chalcogen	Solvent	Time/h	Product	
	1	R_1	R_2				**2**[a]	**3**[b]
1	**1a**	H	H	S_8/NH_3[c]	CH_2Cl_2	36	—	—
2	**1a**	H	H	S_2Cl_2	CH_2Cl_2[d]	3	—	—
3	**1b**	^{i}Pr	H	S_8/NH_3	CH_2Cl_2	36	54 (**2b**)	6 (**3b**)
4	**1c**	OMe	OMe	S_8/NH_3	CH_2Cl_2	36	45 (**2c**)	30 (**3c**)
5	**1d**	^{i}Pr	^{i}Pr	S_8/NH_3	CH_2Cl_2	36	—	70 (**3d**)

[a]Isolated yield of seven-membered ring in %. [b]Isolated yield of five-membered ring in %. [c]Reactions were also carried out with S_2Cl_2 in presence or absence of $BF_3{\cdot}OEt_2$. [d]Solvents were changed from CH_2Cl_2 to THF/C_6H_6.

2,2-Dimethylbenzo[1,3,2]thiaselenastannoles (**1a**–**1d**, Table 1)[10] were treated with concd. HCl in CH_2Cl_2 at 1:1 (v/v) for 7 h to generate the corresponding benzochalcogenols. The generated precursors were extracted with CH_2Cl_2, dried over $MgSO_4$ and immediately allowed to react with S_8/NH_3 in CH_2Cl_2. Acidification and thiation time were varied to get the target product but **BTTSe** was not isolated. This is an established method[8] to get the stable cyclic polysulfides in higher yields. During extraction, the product was converted immediately into insoluble oligomers. We also performed reaction in dark to protect the ring from photoextrusion[11] of selenium. Thiating agent was also changed from S_8 to S_2Cl_2 with or without lewis acid catalyst by changing the solvents polarity (Table 1, Entries 1 and 2), but stable **BTTSe** was not isolated. Measurements of ^1H NMR and mass spectra for the crude reaction mixture of **1a** showed the signs for the generation of **BTTSe**.

Therefore, an isopropyl group was designed at the neighboring of multichalcogen ring to protect it from further conversion (Table 1, Entry 3). Encouragingly, it gave both seven- and five-membered rings as stable compounds. **BTTSe** is unstable and substituent at the neighboring positions of ring prevented it from further conversion. Two oxymethyl groups were also introduced at the neighboring of rings and it gave two products in 45 and 30% yields, respectively (Entry 4). Mass spectra and GPLC analysis showed good agreement about the sizes of the expected rings. The effective variation of ring size was observed for **1d**, where two-isopropyl group was designed. Surprisingly, in that case only five-membered ring (**3d**) was isolated in 70% yield. The strong steric repulsion between bulky isopropyl group and polychalcogen ring from both side of the ring disallow to generate bigger size ring. If little amount of **2d** may form, immediately



Scheme 1. Reagents and conditions (a) Cond. HCl, CH_2Cl_2, 7 h, (b) S_8/NH_3, CH_2Cl_2, 48–72 h.

Table 2. ^{77}Se NMR for selenium bearing compounds

Dichalcogenastannoles		Pentachalcogenides		Trichalcogenoles	
Compd.	^{77}Se^a, δ	Compd.	^{77}Se^a, δ	Compd.	^{77}Se^a, δ
1a	57.9	—	—	—	—
1b	64.2	**2b**	711.2	**3b**	662.1
1c	72.0	**2c**	611.9	**3c**	651.0
1d	83.2	—	—	**3d**	628.0
4	53.7	**5**	709.3	—	—
6	79.5	**7**	933.1	—	—

^{a}Relative to neat Me_2Se, δ is in ppm.

it converts into favorable ring size. Large isopropyl groups force to extrude two sulfur atoms from **2d** to generate kinetically relaxed five-membered polychalcogen ring (**3d**).

For thermodynamic stabilization, aromatic unit was changed from benzene to naphthalene. Naphthalene has more delocalized π-system than that of benzene and thus it gives extra thermodynamic stability to polychalcogen ring.[12]

Naphthalenethiols[13] were converted into 2,2-dimethylnaphtho[2,3-*b*][1,3,2]selenathiastannole (**4**) and 2,2-dimethylnaphtho[1,2-*a*][1,3,2]selenathiastannole (**6**) according to our recent published method.[14]

Dichalcogenastannoles **4** and **6** were also treated with concd. HCl and successive thiation of generated intermediates with S_8/NH_3 afforded products **5** and **7** in 70 and 16% yields, respectively (Scheme 1). Here, neither five-member ring nor any other isomer was isolated. In ^{1}H and ^{13}C NMR spectra, product **5** showed asymmetric peaks compared to naphtho[2,3-*f*]pentathiepin.[14] Elemental analysis, mass spectra, and ^{77}Se NMR showed good agreement for the generation of the target rings. Naphthalene-fused polychalcogenides were found stable in air for several months and in nonpolar solvent.

^{77}Se NMR spectra showed pertinent information regarding generation of dichalcogenastannoles (**1a**–**1d**, **4**, and **6**), trichalcogenoles (**3b**–**3d**), and pentachalcogenides (**2b**, **2c**, **5**, and **7**) (Table 2). Although it is difficult to differentiate between trichalcogenole and pentachalcogenide by ^{77}Se NMR, but all signals indicated the presence of Se–S bond in their structures.[6,12] Size separation chromatography also showed different retention time for two ring sizes.

In order to understand more about stabilities of **2a** and **2d** (not isolated), theoretical calculations[15,16] were performed to measure the enthalpy of formation energy using hypothetical homodesmotic reactions from the reaction of corresponding five-membered rings with elemental sulfur. Compounds **2a** and **2d** were found much more unstable than corresponding **BPT**.

In conclusion, some novel benzopolychalcogenides having tetrathiaselenepin ring have been synthesized and stabilized by isopropyl and oxymethyl groups. Replacing of aromatic unit from benzene to naphthalene also afforded stable naphthopolychalcogenides. Our study concerning synthesis of more selenium-containing aromatic polychalcogenides, photoextrusion of selenium and thermodynamic stabilization of multicalcogen rings are in underway.

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11 Recently, we observed the extrusion of selenium from phenanthro[9,10-*b*][1,2,3,4,5]tetrathiaselenepin ring by ambient light in $CDCl_3$ by ^{1}H NMR.

12 One of our unpublished results also reveals that benzopentathiepin 1-oxide is unstable whereas naphtho[2,3-*f*]-[1,2,3,4,5]pentathiepin 1-oxide is stable.

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15 Enthalpy of formation energy was calculated with Gaussian 98 program. The geometries were optimized with restricted Becke hybrid (B3LYP) methods.

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17 Supporting Information is available on the CSJ-Journal Web site, http://www.csj.jp/journals/chem-lett/.

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