A Convenient Synthesis of Pyrrolo-Annelated 1,3-Diselenole-2-thione and 1,3-Diselenol-2-one Derivatives *via* Dipyrrolo-Annelated 1,2,5,6-Tetraselenocine Derivatives

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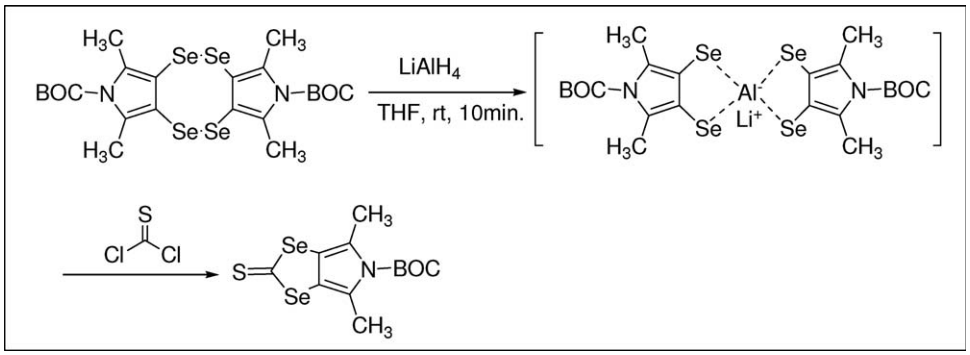

The reaction of 2,5-dimethyl-3,4-diselenocyanato-1*H*-pyrrole by $NaBH_4$ or $NaOCH_3$ led to tetraselenide **7** in quantitative yield. Treatment of protected tetraselenide **8** with $LiAlH_4$ afforded the aluminum complex intermediate that was converted into pyrrole-annelated 1,3-diselenolo-2-thione **9** in excellent yield. Similarly, treatment of tetraselenide **8** with $LiAlH_4$ followed by TFA afforded 1,2-diselenol intermediate that was converted into pyrrole-annelated 1,3-diselenolo-2-one **10** upon treatment of diimidazole carbonate.

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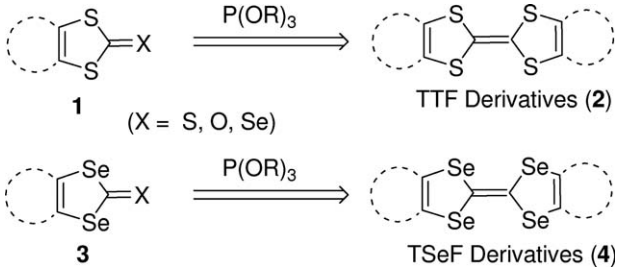
INTRODUCTION

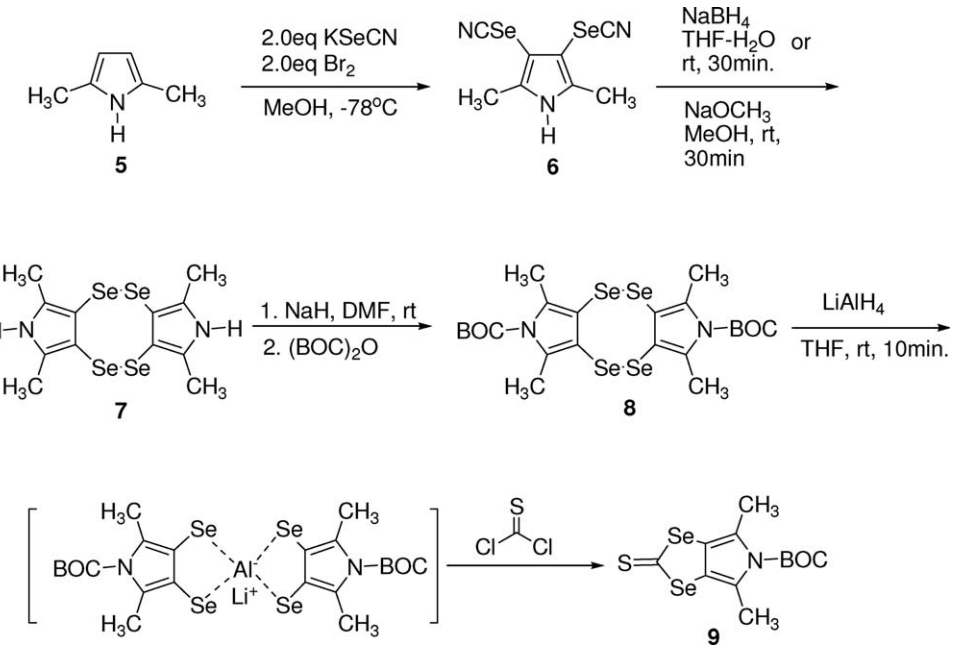
1,3-Dithiole-2-thiones (**1**) or 1,3-diselenole-2-thiones (**3**) have received considerable attention as a well known precursor for the synthesis of tetrathiafulvalenes (TTFs, **2**) or tetraselenofulvalenes (TSeFs, **4**) [1]. 1,3-Dithiole-2-thiones (**1**) in the presence of $P(OR)_3$ undergo reductive coupling to afford the corresponding TTFs, which has been intensively studied for more than 40 years, because radical cation salts derived from them have great potential use as molecular superconductors [2]. TTFs have also been examined extensively as good candidates of organic field effect transistors due to their potential applications in low cost and structurally flexible electronics [3]. Recently, TTF-based molecular or supramolecular systems were investigated for new applications to molecular sensors, redox-fluorescent switches, multi-input systems for logic gates, and others [4]. To sustain TTFs- or TSeFs-related studies, it is necessary for a variety of synthetic routes for precursors of TTFs or TSeFs to be developed. However, in contrast to 1,3-dithiole-2-thiones, the routes for synthesis of 1,3-diselenole-2-thione and its analogs are pretty limited [5]. Here, we wish to report a convenient synthesis of pyrrole-annelated 1,3-diselenole-2-thione and its analogs via dipyrrolo-annelated 1,2,5,6-tetraselenocine.



RESULTS AND DISCUSSION

In our previous study, we reported that electron-rich hetero-aromatic compounds such as pyrrole could undergo electrophilic substitution with treatment of $KSCN/Br_2$ to afford 3,4-dithiocyanated pyrroles and then subsequent reduction of 3,4-dithiocyanopyrrole by $NaBH_4$ or $NaOCH_3$ led to eight-membered 1,2,5,6-tetrathiocine ring system [6]. We envisioned that the condition used in our previous study could be equally applied for the synthesis of 3,4-diselenocyanated pyrroles and 1,2,5,6-tetraselenocines. To our delight, diselenocyanation of 2,5-dimethylpyrrole (**5**) was smoothly achieved with treatment of potassium selenocyanate and bromine at −78°C in 82% isolated yield. Then, 3,4-

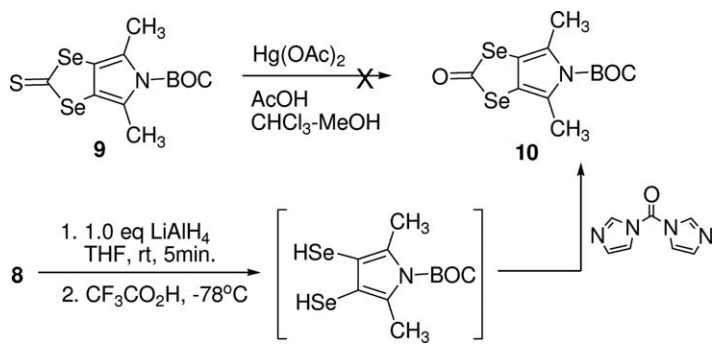
Scheme 1



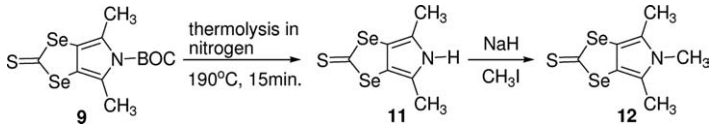
diselenocyanated pyrrole **6** was reacted with $NaBH_4$, and the cyclic eight-membered tetraselenide **7** through two diselenide bond formations was obtained in quantitative yield. Synthetic and mechanistic studies for conversion of organoselenocyanates into the corresponding diselenides with treatment of $NaBH_4$, NaH, and KOH were well documented in the literature [7]. However, the reaction rate toward the formation of tetraselenide **7** was so fast that the effort to isolate any intermediate was not successful. Similar example such as a cyclic tetraselenide formation can be found in the reference we reported [6]. It was interesting that the tetraselenide **7** was also obtained in excellent yield upon treatment with $NaOCH_3$. The compound **7** turned out to be highly stable and can be stored for long time without decomposition. Protection of **7** with BOC provided **8** in 90% yield. Compound **8** was reacted with $LiAH_4$ to afford the metal complex intermediate as shown in (Scheme 1), which was then reacted with thiophosgene to give thione **9** in 85% yield. It is noteworthy that BOC group of **8** was well survived even after treated with $LiAlH_4$.

The attempt to convert thione (**9**) into one (**10**) was not successful under the condition used in the literature [8]. However, 1,3-diselenole-2-one **10** was successfully synthesized in good yield by following another route as shown in Scheme 2. Reduction of **8** with $LiAlH_4$ and followed by treatment with trifluoroacetic acid afforded 1,2-diselenol intermediate, which was *in situ* reacted with diimidazole carbonate to form 1,3-diselenolo-2-one in 85% yield. During the work-up process, the attempt to isolate the 1,2-diselenol intermediate through recrystallization or chromatography was not successful due to

Scheme 2



Scheme 3



its labile property under ambient environment. However, quite pure crude 1,2-diselenol could be isolated from simple work-up procedure, and it was confirmed by NMR and IR.

BOC group of thione **9** was easily removed by simple thermolysis under nitrogen or argon environment to give **11** and the resulting freed N—H was converted into **12** via simple alkylating procedures as shown in Scheme 3.

With the compounds, **9**, **10**, and **12** in hands, reductive couplings for the synthesis of the corresponding pyrrolo-annelated TSeF derivatives were initially attempted using $P(OR)_3$ but failed to give the products in meaningful yields. Further synthetic studies for pyrolo-annelated TSeF derivatives using **9**, **10**, and **12** are being under investigation.

In conclusion, we demonstrated a short and convenient route to synthesize pyrrolo-annelated 1,3-diselenolo-2-thiones **9**, **11**, **12** and pyrrolo-annelated 1,3-diselenolo-2-one **10** in excellent yields, respectively, via a 1,2,5,6-tetraselenocine derivative. The 1,2,5,6-tetraselenocine derivative **7** easily formed from 3,4-diselenocyanopyrrole was highly stable to be handled and provided useful building block to synthesize 1,3-diselenole-2-thiones. It is believed that the method developed in this study will be useful as another simple and high-yielding synthetic route for the synthesis of pyrrolo-annelated 1,3-diselenolo-2-thione derivatives.

EXPERIMENTAL

2,5-Dimethyl-3,4-diselenocyanopyrrole (6). To a solution of potassium selenocyanate (30.3 g, 0.21 mol) in MeOH (250 mL) at −78°C was slowly added a precooled solution of Br_2 (33.5 g, 0.21 mol) in MeOH (250 mL). The reaction mixture was stirred at −40°C for 45 min and followed by the addition of precooled solution of 2,5-dimethylpyrrole (10.0 g, 0.10 mL) in MeOH (175 mL). The reaction mixture was poured into a mixture of ice (260 g) and NaCl (40 g). After ice melted, the resulting precipitate was collected through filtration, washed with water, and dried. The crude was purified by recrytallization in dichloromethane/hexane (1:4) to give the product (29.3 g, 82%) as a grey solid; ^{1}H NMR (360 MHz, DMSO-d_6) δ 9.30 (s, 1H), 2.33 (s, 6H); ^{13}C NMR (90 MHz, DMSO-d_6) δ 134.67, 103.65, 100.30, 12.54.

1,3,6,8-Tetramethyl-2*H*,7*H*-[1,2,5,6]tetraselenocine[3,4-*c*:8,7-*c*′]dipyrrole (7). To a solution of 2,5-dimethyl-3,4-diselenocyanopyrrole (**6**; 4 g, 13.2 mmol) in aqueous THF (80 mL, THF:H_2O = 20:1) was added $NaBH_4$ at room temperature. In stirring for 15 min, the reaction became exothermic along with evolution of hydrogen gas. As the reaction proceeded for additional 2 h, a lot of precipitates were formed. The reaction was diluted with water (100 mL), and the precipitates were collected by vacuum filtration and washed with water (20 mL). Air-dried crude was purified by reprecipitation with hot acetone to afford the product (3.3 g, 100%) as a pale yellow powder. ^{1}H NMR (360 MHz, DMSO-d_6) δ 9.90 (s, 2H), 2.26 (s, 12H); MS (*m*/*e*): 117 (18), 129 (14),147 (31), 193 (11), 207 (22), 251 (14), 267 (100), 281 (12), 325 (30), 341 (96), 355 (97), 429 (41); Anal. Calcd for $C_{12}H_{14}N_2Se_4$: C, 28.71; H, 2.81; N, 5.58; Found: C, 28.75; H, 2.79; N, 5.56.

2,7-Bis(*tert*-butoxycarbonyl)-1,3,6,8-tetramethyl-[1,2,5,6]tetraselenocine[3,4-*c*:8,7-*c*′]dipyrrole (8). To a solution of **7** (2.0 g, 3.98 mmol) in dry DMF (20 mL) was added sodium hydride (210 mg, 8.76 mmol; washed with dry hexane to remove mineral oil) in portions under nitrogen at room temperature. The reaction mixture was stirred for 5 min and followed by addition of BOC-anhydride (1.82 g, 8.36 mmol). The reaction mixture was stirred for 7 h, and water (20 mL) was carefully added to the solution. Precipitate was collected by suction filtration and washed with methanol (10 mL) and acetonitrile (20 mL) to give the product (2.5 g, 90%) as a white solid. ^{1}H NMR (360 MHz, $CDCl_3$) δ 2.62 (s, 6H), 1.60 (s, 9H); ^{13}C NMR (90 MHz, $CDCl_3$) δ 149.24, 136.95, 117.31, 84.91, 27.98, 16.46; MS (*m*/*e*): 131 (14), 160 (49), 173 (47), 185 (8), 222 (8), 252 (68, 266 (100), 331 (49), 346 (37), 424 (7), 504 (30); UV λ_{max} ($\log_{10}\varepsilon$) $CHCl_3$ 220.5 (0.72), 265.0 (1.68), 330 (0.50); Anal. Calcd for $C_{22}H_{30}N_2O_4Se_4$: C, 37.62; H, 4.31; N, 3.99; Found: C, 37.59; H, 4.33; N, 3.93.

5-*tert*-Butoxycarbonyl-4,6-dimethyl-2-thioxo-1,3-diselenolo[4,5-*c*]pyrrole (9). To a solution of **8** (7.0 g, 9.96 mmol) in dry THF (250 mL) was added $LiAlH_4$ (378 mg, 9.96 mmol) in portions under nitrogen at room temperature. In the moment, the solution turned into bright pink color, and the color disappeared at the point of final addition of $LiAlH_4$. The reaction mixture was stirred for 10 min, and thiophosgene (1.15 g, 9.96 mmol) in distilled THF was added dropwise at room temperature. The reaction was quenched by adding water (10 mL), and THF was evaporated off under reduced pressure. The residue was dissolved in ether (50 mL) and stirred for 20 min. Upon standing, aluminum salt was subsided, and the top layer was carefully decanted. The process was repeated twice more and the combined layers was washed with water, brine, and dried over sodium sulfate. Upon concentrated, the yellowish crude was obtained and crystallized in dichloromethane/methanol to provide yellowish crystals (6.7 g, 85%). mp 150–151°C; ^{1}H NMR (360 MHz, $CDCl_3$) δ 2.39 (s, 6H), 1.61 (s, 9H); MS (*m*/*e*, EI): 124 (63), 136 (30), 160 (21), 173 (37), 216 (74), 250 (41), 293 (58), 294 (34), 295 (95), 297 (100); Anal. Calcd for $C_{12}H_{15}NO_2SSe_2$: C, 36.47; H, 3.83; N, 3.47; S, 8.11; Found: C, 36.49; H, 3.87; N, 3.47; S, 8.08.

5-*tert*-Butoxycarbonyl-4,6-dimethyl-2-oxo-1,3-diselenolo[4,5-*c*]pyrrole (10). To a solution of **8** (1.5 g, 2.13 mmol) in dry THF (250 mL) was added $LiAlH_4$ (81 mg, 2.13 mmol) in

portions under nitrogen at room temperature. In the moment, the solution turned into bright pink color, and the color disappeared at the point of final addition of LAH. The reaction mixture was cooled to −78°C and followed by drop-wise addition of the solution of trifluoroacetic acid (8.52 mmol) in THF (10 mL). The mixture was stirred for 30 min, and the solution of carbonyl diimidazole (691 mg, 4.26 mmol) in dry THF (10 mL) was dropwise added. The reaction mixture was slowly allowed to room temperature for 2 h. THF was removed under reduced pressure, and a mixture of ether (50 mL) and water (20 mL) was added. After stirring for 20 min and standing, ether layer was carefully decanted, and forementioned procedure was repeated on the residue twice. The combined layers were washed with water, brine, and dried over sodium sulfate. After concentrated, the crude was purified by column chromatography on silica gel using dichloromethane/hexane (3:1) to give the product in 84% as a white needle. mp 132°C; ^{1}H NMR (360 MHz, $CDCl_3$) δ 2.44 (s, 6H), 1.61 (s, 9H); Anal. Calcd for $C_{12}H_{15}NO_3Se_2$: C, 38.01; H, 3.99; N, 3.69; Found: C, 38.08; H, 4.03; N, 3.70.

4,6-Dimethyl-2-oxo-5*H*-1,3-diselenolo[4,5-*c*]pyrrole (11). The flask containing **9** was flushed with nitrogen stream for 5 min and then heated to 190–199°C. The heating continued for around 20 min until no more bubbling (CO_2 evolution upon decarboxylation) was observed. The reaction mixture was cooled to room temperature and extracted with chloroform. After concentrated, the residue was purified by column chromatography on silica gel using chloroform to afford the product (45%). The product was used for preparation of **12** without taking spectroscopic data.

4,5,6-Triimethyl-2-thioxo-1,3-diselenolo[4,5-*c*]pyrrole (12). To a solution of **11** in dry DMF was added NaH in portions at room temperature. The reaction mixture was stirred for 1 h and methyl iodide (excess) was added. After 20 min stirring, water was added to induce precipitation. The precipitate was collected, purified by chromatography on silica gel using chloroform/hexane (3:1) to give light yellowish crystalline product (90%). ^{1}H NMR (360 MHz, $CDCl_3$) δ 3.51 (s, 3H), 2.23 (s, 6H); ^{13}C NMR (90 MHz, $CDCl_3$) δ 221.29, 121.86, 119.48, 31.42, 13.28. Anal. Calcd for $C_8H_9NSSe_2$: C, 31.08; H, 2.93; N, 4.53; S, 10.37. Found: C, 31.05; H, 2.95; N, 4.49; S, 10.32.

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