Thermolysis and Photolysis of Stable *Se*-Nitrososelenols

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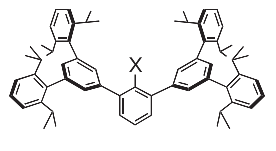
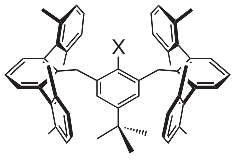
The thermal reactivity and photoreactivity of *Se*-nitrososelenols have been elucidated by using stable compounds protected by bowl-type substituents. Thermolysis of *Se*-nitrososelenol **1** afforded diselenide **3**, the structure of which was determined by X-ray crystallography, while tetraselenide **13** was obtained as the major product in photolysis of **1**.

There has been a growing interest in the chemistry of reactive nitrogen species relevant to cellular signal transduction. While *S*-nitrosothiols (RSNO) have been recognized to play an important role in storing, transporting, and releasing nitric oxide (NO),[1] several recent reports suggest that the *Se*-nitrosated species of selenoproteins are also involved in NO-mediated cellular functions.[2] However, *Se*-nitrososelenols (RSeNO) are more labile even than *S*-nitrosothiols because of their high tendency to undergo bimolecular decomposition, and the chemistry of this species has been almost unexplored owing to their instability. Recently, we succeeded in the synthesis of the first stable *Se*-nitrososelenol **1** by using a novel bowl-type steric protection group (denoted as Bpq), and elucidated its crystal structure and some reactivities.[3] In this communication, we report the thermolysis and photolysis of *Se*-nitrososelenol **1** providing the corresponding diselenide and tetraselenide, respectively. The synthesis and thermal stability of *Se*-nitrososelenol **2** carrying another bowl-type substituent (denoted as Bmt) are also delineated.

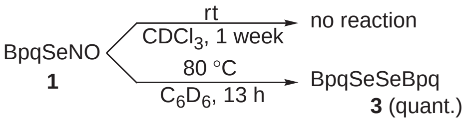


≡ BpqX
1 (X = SeNO)



≡ BmtX
2 (X = SeNO)

It is well-known that, unless protected by a bulky substituent, *S*-nitrosothiols readily decompose to disulfides and NO, especially in the case of aromatic derivatives.[1,4] *Se*-nitrososelenols are likely to undergo such reaction more easily because the selenium–nitrogen bond of the Se–NO group is considered to be weaker than the sulfur–nitrogen bond of the S–NO group. du Mont and co-workers reported that even a *Se*-nitrososelenol carrying the extremely bulky $(Me_3Si)_3C$ group can be observed only at −78 °C, above which temperature the compound decomposes forming NO.[5] We recently reported that *Se*-nitrososelenol **1** bearing a Bpq group is stable at room temperature both in the crystalline state and in solution; no decomposition was observed in $CDCl_3$ after 1 week at room temperature.[3] On the other hand, **1** was converted to diselenide **3** quantitatively after heated in C_6D_6 at 80 °C for 13 h (Scheme 1).[6] While such thermal stability of **1** is remarkable for a *Se*-nitrososelenol, it is much lower than that of the corresponding *S*-nitrosothiol, BpqSNO (**4**).[7] In the thermolysis of **4** under the same conditions, 38% of **4** remained intact even after 60 h, and the formation of the corresponding disulfide, BpqSSBpq, was not observed.[7] Obviously, the reactivity of *Se*-nitrososelenols toward bimolecular decomposition is much higher than that of *S*-nitrosothiols. It is notable that diselenide **3** has not been obtained by other methods typical for preparation of diselenides. For example, in the oxidation of BpqSeH (**5**) with hydrogen peroxide or iodine, no formation of **3** was observed because of the steric protection effect of the Bpq group.[8] These results are also indicative of the high reactivity of *Se*-nitrososelenols.



Scheme 1.

The crystal structure of **3** is shown in Figure 1.[9] The Se–Se bond length is 2.3546(5) Å, which is slightly longer than those of other crowded diaryl diselenides such as $Mes^*_2Se_2$ (**6**) (2.345(2) Å)[10] and $(2,6\text{-}Mes_2C_6H_4)_2Se_2$ (**7**) (2.339(1) Å)[11] (Mes* = 2,4,6-tri-*tert*-butylphenyl, Mes = 2,4,6-trimethylphenyl) although it is shorter than that of $[(Me_3Si)_3C]_2Se_2$ (**8**) (2.388(1) Å).[12] The C–Se–Se–C torsion angle of **3** (111.76(10)°) is larger than that of **6** (93.3(3)°)[10] but smaller than those of **7** (128.3°)[11] and **8** (180°).[12]

We previously reported the synthesis of the stable selenenic acid, BmtSeOH (**9**), protected by a Bmt group.[13] The stable *S*-nitrosothiol carrying the Bmt group, BmtSNO (**10**), was recently synthesized by Okazaki and co-workers.[14] The preparation and

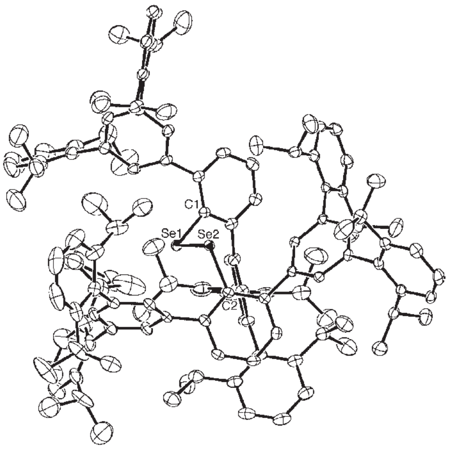
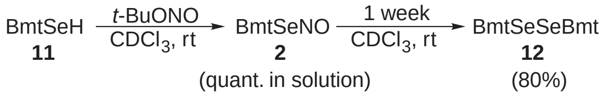


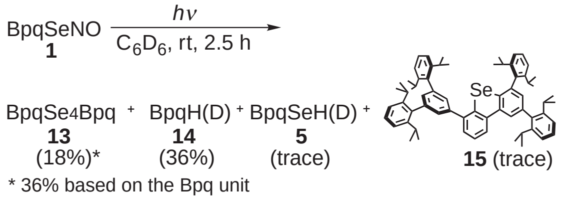
Figure 1. ORTEP drawing of **3** (50% probability). Selected bond lengths (Å), bond angles (deg) and torsion angle (deg): Se(1)–Se(2), 2.3546(5); C(1)–Se(1), 1.933(3); C(2)–Se(2), 1.942(2); C(1)–Se(1)–Se(2), 98.60(7); Se(1)–Se(2)–C(2), 101.07(7); C(1)–Se(1)–Se(2)–C(2), 111.76(10).

stability of *Se*-nitrososelenol **2** with the same substituent were then examined. When selenol **11** was treated with an excess amount of *tert*-butyl nitrite, quantitative formation of the corresponding *Se*-nitrososelenol **2** was observed (Scheme 2).[15] In the ^{77}Se NMR spectrum ($CDCl_3$), **2** showed a signal at δ 2125, an extremely low-field for organoselenium compounds, similarly to **1** (δ 2229). Although *Se*-nitrososelenol **2** was relatively stable in solution, **2** was gradually converted to diselenide **12** at room temperature. Removal of the solvent from the solution containing **2** afforded a mixture of **2** and **12**, and it was difficult to isolate **2** as pure specimen. These results again indicate the readiness of the bimolecular decomposition of a *Se*-nitrososelenol. Similarly to **3**, diselenide **12** is difficult to prepare by the usual method; **12** was obtained only in 4% yield by oxidation of selenol **11** with hydrogen peroxide.[13] Facile formation of diselenides **3** and **12** from the corresponding *Se*-nitrososelenols implies that nitrosation of a selenol followed by thermolysis of the generated *Se*-nitrososelenol serves as a good method to obtain sterically hindered diselenides otherwise difficult of access.



Scheme 2.

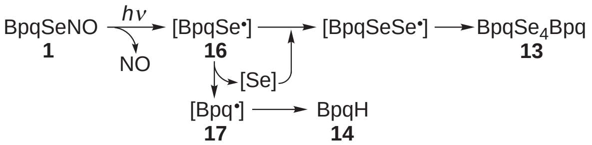
Photolysis of a *Se*-nitrososelenol was investigated with the isolable Compound **1**. While **1** was insensitive to ambient room light, irradiation of **1** in C_6D_6 with a 400-W high pressure mercury lamp led to complete decomposition of **1** after 2.5 h at room temperature (Scheme 3). Tetraselenide **13** and BpqH (**14**) were obtained as the main products along with a trace of selenol **5** and the dibenzoselenophene derivative **15**.[6]



Scheme 3.

In contrast with thermolysis of **1**, formation of diselenide **3** was not observed by ^{1}H NMR monitoring during the course of the reaction. These results can be explained by the possible mechanism shown in Scheme 4, which is based on the following hypotheses: (i) a part of selanyl radical **16** generated by homolysis of the Se–N bond of **1** further decomposes to Bpq• (**17**) with loss of atomic selenium, which is incorporated into **16**; (ii) in diselenide **3** and the corresponding triselenide, $BpqSe_3Bpq$ (**18**), the steric repulsion between the two Bpq groups is very strong while it is relieved in tetraselenide **13**, and if a small amount of **3** and **18** are formed during the reaction, they are readily converted to **13** under the conditions of this photoreaction. The relative yields of **13** and **14** are consistent with this mechanism. A trace amount of selenol **5** and dibenzoselenophene **15** are considered to be formed by hydrogen abstraction or intramolecular cyclization of selanyl radical **16**, respectively.

Further investigations on the detailed mechanism of these reactions including the direct observation of selanyl radical **16** are currently in progress.



Scheme 4.

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6 The new compounds **3**, **13**, and **15** gave satisfactory spectral data and elemental analyses. For details, see Supporting Information.

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8 The corresponding selenenic acid and selenenyl iodide were obtained, respectively. The details of the reaction will be described elsewhere.

9 Crystallographic data for $\mathbf{3}\cdot 2C_6H_{14}\cdot C_6H_6$: $M_r = 2148.92$, triclinic, space group $P\bar{1}$, $a = 15.666(4)$, $b = 18.165(4)$, $c = 22.937(5)$ Å, $\alpha = 91.938(5)^\circ$, $\beta = 91.524(4)^\circ$, $\gamma = 92.373(5)^\circ$, $V = 6515(3)$ Å^3, $Z = 2$, $D_{calcd} = 1.095$ g cm^{-3}, $T = 120$ K, $R1 = 0.0523$ ($I > 2\sigma(I)$), $wR2 = 0.1271$ (all data).

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14 M. Itoh, K. Takenaka, R. Okazaki, N. Takeda, and N. Tokitoh, *Chem. Lett.*, **2001**, 1206. It was reported that complete conversion of *S*-nitrosothiol **10** to BmtSSBmt requires heating in refluxing benzene for 75 h.

15 **2**: ^{77}Se NMR ($CDCl_3$, 95 MHz) δ 2125. UV–vis ($CHCl_3$) λ_{max} 467 (ε ca. 160) nm. IR ($CHCl_3$) 1582 cm^{-1} (ν(N=O)). For other spectral data, see Supporting Information.

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