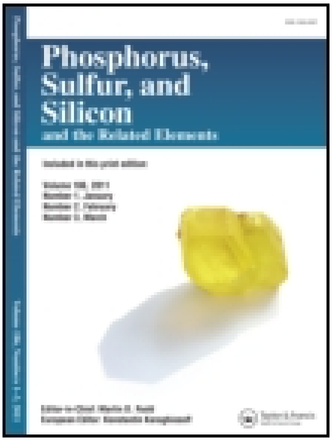

Phosphorus, Sulfur, and Silicon and the Related Elements

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Syntheses of the First Se-Nitrososelenol and Related Compounds

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Syntheses of the First *Se*-Nitrososelenol and Related Compounds

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The first stable Se-*nitrososelenol (RSeNO) and selenonitrate (RSeNO$_2$) were synthesized by taking advantage of bowl-type steric protection groups, and their spectral properties and reactivities were elucidated. X-ray crystallographic analysis established their structures.*

Keywords Bowl-type molecule; *Se*-nitrososelenol; selenonitrate; steric protection

INTRODUCTION

S-Nitrosothiols (RSNO) have been attracting increasing attention in view of their role as potential biocatalysts and reagents for the storage and transport of nitric oxide (NO) in vivo[1,2] although the elucidation of their properties has often been hampered by their inherent instability. Thionitrates (RSNO$_2$) have also been recognized as important species from the viewpoints of their physiological activity and synthetic utility.[3,4] Whereas *Se*-nitrososelenols (RSeNO) and selenonitrates (RSeNO$_2$) are very intriguing species as the selenium analogues of *S*-nitrosothiols and thionitrates, there has been no report on their synthesis. Previously we reported the synthesis and isolation of the stable *S*-nitrosothiols and thionitrates bearing bowl-type substituents.[5,6]

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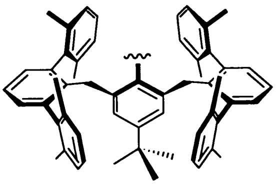


1 ≡ Bmt

FIGURE 1 Structure of **1**.

Here we report the syntheses of the first stable *Se*-nitrososelenol and selenonitrate by taking advantage of bowl-type steric protection groups.

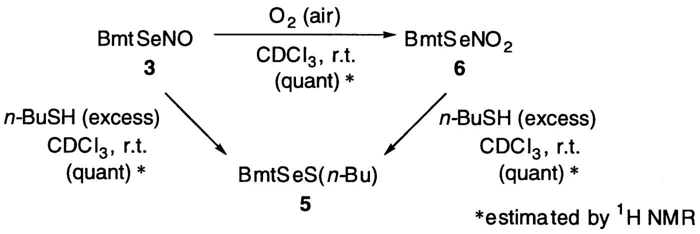
RESULTS AND DISCUSSION

Because the selenium-nitrogen bond of the Se-NO functionality is considered to be weaker than the sulfur-nitrogen bond of the S-NO functionality, *Se*-nitrososelenols are supposed to be more labile than *S*-nitrosothiols. However, we previously reported that *S*-nitrosothiols can have a long life time if their bimolecular decomposition is sterically suppressed by bowl-type substituents.[5,6] This methodology is expected also to be effective for stabilization of *Se*-nitrososelenols. We previously reported the synthesis of a stable selenenic acid (RSeOH) by taking advantage of the bowl-type steric protection group **1** (denoted as Bmt) (Figure 1) and demonstrated three processes included in the catalytic cycle of glutathione peroxidase experimentally.[7] We first examined the nitrosation of selenol **2** bearing the Bmt group. When selenol **2** was treated with *tert*-butyl nitrite, quantitative formation of the corresponding *Se*-nitrososelenol **3** was observed (Scheme 1). In ^{77}Se NMR ($CDCl_3$),

SCHEME 1

3 showed a signal at δ 2125, an extremely low-field for organoselenium compounds. Although *Se*-nitrososelenol **3** was relatively stable in solution, **3** was gradually converted to diselenide **4** at room temperature. Removal of the solvent from the solution containing **3** afforded a mixture of **3** and **4**, and it was difficult to isolate **3** as pure specimen. Okazaki and coworkers reported that an *S*-nitrosothiol bearing the same substituent, BmtSNO, is stable at room temperature and that heating in refluxing benzene is necessary for its conversion to the corresponding disulfide, BmtSSBmt.[8] These results demonstrate that bimolecular decomposition of an *Se*-nitrososelenol is much easier than that of an *S*-nitrosothiol.

When an excess amount of 1-butanethiol was added to a solution of *Se*-nitrososelenol **3**, the corresponding selenenyl sulfide **5** was obtained quantitatively (Scheme 2). Air oxidation of **3** afforded the corresponding selenonitrate **6** quantitatively, which was isolated as stable colorless crystals. This is the first example of a stable selenium analogue of organic nitrates. The ^{77}Se NMR ($CDCl_3$) spectrum of **6** showed a signal at δ 1437. In the IR spectrum, bands at 1529 and 1284 cm^{-1} were



SCHEME 2

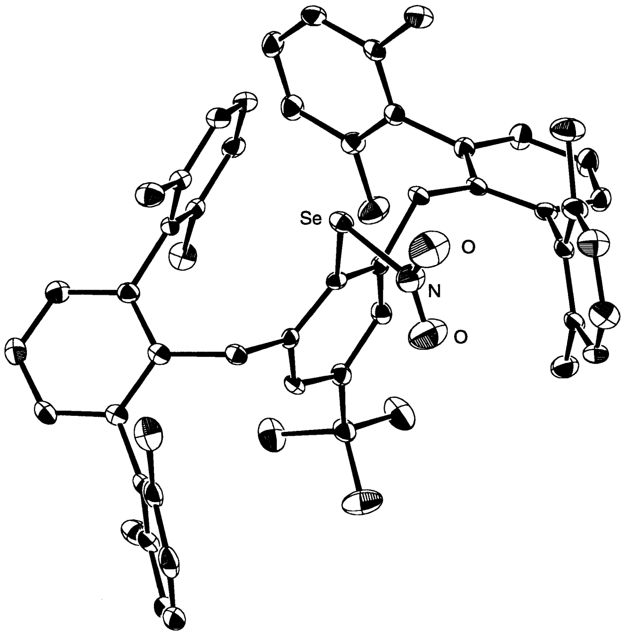
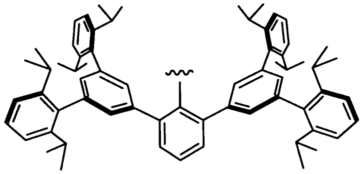


FIGURE 2 ORTEP drawing of **6** (50% probability).

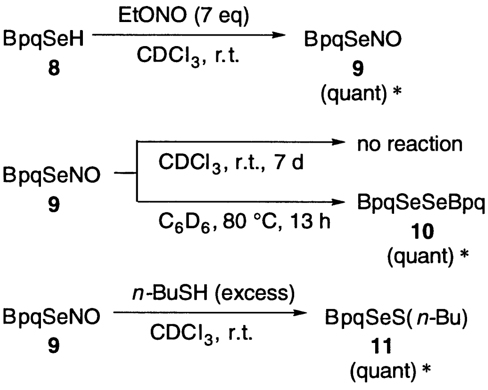


7 ≡ Bmt

FIGURE 3

observed, which correspond to the asymmetric and symmetric stretching of NO_2, respectively. The structure of **6** was established by X-ray crystallographic analysis (Figure 2). For a selenonitrate, there are two other possible tautomeric forms, a selenenyl nitrite form (R-Se-O-NO) and a seleninyl nitrite form (R-Se(O)-NO). The present results clearly indicate that **6** has a selenonitrate form (R-Se-NO_2). Selenonitrate **6** easily reacted with 1-butanethiol to produce selenenyl sulfide **5**.

Recently, we designed a novel bowl-type substituent **7** (Figure 3) (denoted as Bpq),[9] which can prevent dimerization of reactive species more effectively than the Bmt group, and applied it to the stabilization of an *S*-nitrosothiol.[6] Because the isolation of a stable *Se*-nitrososelenol was difficult by using the Bmt group, the use of the Bpq group was examined In the reaction of selenol **8** bearing the Bpq group with ethyl nitrite, the corresponding *Se*-nitrososelenol **9** quantitatively was formed and isolated as stable purple crystals (Scheme 3). This is the first example of a



*estimated by ^{1}H NMR

SCHEME 3

stable *Se*-nitrososelenol. In the ^{77}Se NMR spectrum ($CDCl_3$), **9** showed a signal at δ 2229. The IR spectrum of **9** showed the N–O stretching band

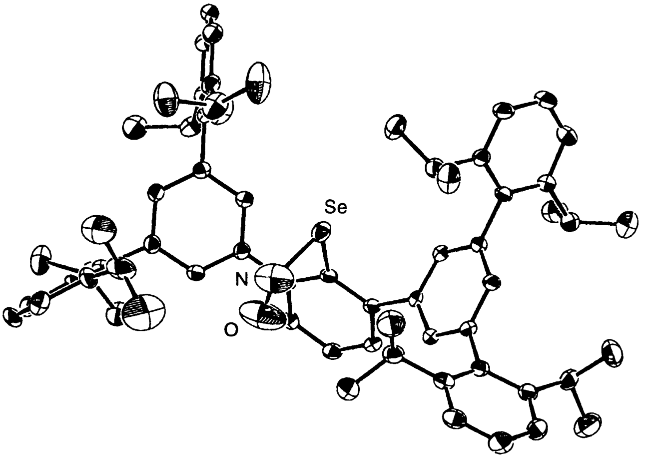


FIGURE 4 ORTEP drawing of **9** (50% probability).

at 1564 cm^{-1}. X-ray crystallographic analysis established the structure of **9** (Figure 4), where the C—Se—N—O linkage adopts syn conformation similar to BpqSNO.[6] The Se–N bond length [2.075(4) Å] and N–O bond length [1.173(5) Å] are consistent with a selenium–nitrogen single bond and a nitrogen–oxygen double bond. *Se*-Nitrososelenol **9** was found to be stable in solution at room temperature although it was converted to diselenide **10** by heating in benzene at 80°C. The reaction of **9** with 1-butanethiol afforded selenenyl sulfide **11** quantitatively, indicating that the intrinsic reactivity of the SeNO functionality with an appropriate molecule is retained despite effective steric protection by the Bpq group.

REFERENCES

[1] P. G. Wang, M. Xian, X. Tang, X. Wu, Z. Wen, T. Cai, and A. J. Janczuk, *Chem. Rev.*, **102,** 1091 (2002).
[2] D. L. H. Williams, *Org. Biomol. Chem.*, **1,** 441 (2003).
[3] G. R. J. Thatcher and H. Weldon, *Chem. Soc. Rev.*, **27,** 331 (1998).
[4] Y. H. Kim, *Phosphorus, Sulfur, and Silicon*, **74,** 249 (1993).
[5] K. Goto, Y. Hino, T. Kawashima, M. Kaminaga, E. Yano, G. Yamamoto, N. Takagi, and S. Nagase, *Tetrahedron Lett.*, **41,** 8479 (2000).
[6] K. Goto, Y. Hino, Y. Takahashi, T. Kawashima, G. Yamamoto, N. Takagi, and S. Nagase, *Chem. Lett.*, 1204 (2001).
[7] K. Goto, M. Nagahama, T. Mizushima, K. Shimada, T. Kawashima, and R. Okazaki, *Org. Lett.*, **3,** 3569 (2001).
[8] M. Itoh, K. Takenaka, R. Okazaki, N. Takeda, and N. Tokitoh, *Chem. Lett.*, 1206 (2001).
[9] K. Goto, G. Yamamoto, B. Tan, and R. Okazaki, *Tetrahedron Lett.*, **42,** 4875 (2001).