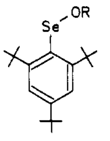
Communications

Organoselenium Chemistry. Preparation and Reactions of 2,4,6-Tri-*tert*-butylbenzeneselenenic Acid

Summary: The preparation and chemistry of 2,4,6-tri-*tert*-butylbenzeneselenenic acid and several of its esters and amides are described.

Sir: Selenenic acids play a central role in the oxidation and reduction chemistry of selenium.[1–3] Nevertheless, only areneselenenic acids and esters stabilized by coordination to ortho nitro or carbonyl substituents have been observed;[1a–d,2,3a] other selenenic acids disproportionate to diselenides and seleninic acids too rapidly to permit spectroscopic observation.[1a,2a] We not report the first observation of a selenenic acid lacking coordinating substituents that disproportionates sufficiently slowly to permit spectroscopic observation.[4]

Selenenate ester **1b** was prepared according to Scheme I (Ar = 2,4,6-tri-*tert*-butylphenyl) by reaction of the selenenyl bromide **3** with methanolic sodium methoxide. Dry solutions of **1b** were indefinitely stable and could be concentrated. The ester was characterized by ^{1}H NMR, in which $^3J_{\mathrm{SeH}}$ = 9 Hz,[5] and by ^{77}Se NMR, IR, and mass spectroscopy. It was independently synthesized by transesterification of the selenenate ester **1d** which formed by [2,3] sigmatropic rearrangement of selenoxide **4**[1d] and by comproportionation[1e] of the diselenide **5** and the seleninic acid **2a** (see below). The ethyl selenenate **1c** was also prepared and upon oxidation gave the chiral ethyl seleninate **2c** which showed diastereotopicity in its ^{1}H NMR spectrum.



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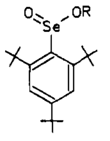

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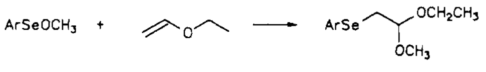
a R = H
b R = CH_3
c R = CH_2CH_3
d R = $C(CH_3)_2CH{=}CH_2$

The selenenic acid **1a** was prepared by hydrolysis of the ester **1b** in aqueous acetonitrile, acetone, or THF (Figure 1).[2b] The reaction was monitored by both ^{1}H and ^{77}Se NMR which initially showed formation of methanol and **1a** followed by buildup of the disproportionation products diselenide **5** and seleninic acid **2a**. Under optimum conditions as much as 80% of selenenic acid **1a** was present. Both the selenenate ester hydrolysis and selenenic acid disproportionation reactions were strongly solvent-dependent and were catalyzed by acid and base. In nonhydroxylic solvents the rate of disproportionation of selenenic acid **1a** was much faster than its rate of formation by either selenoxide elimination or hydrolysis.[6] Compound **1a** was independently prepared by selenoxide elimination of phenethyl 2,4,6-tri-*tert*-butylphenyl selenoxide in aqueous acetone[7,8] and was characterized by its ^{77}Se NMR spectrum and its chemical derivatization.

We have used **1a** and **1b** to test several of the reactions commonly ascribed to selenenic acids and esters (Table I). Benzyl mercaptan, benzylamine, and *m*-chloroperbenzoic acid reacted with **1a** and **1b** to give the expected selenosulfide **7**, selenenamide **6**, and seleninic acid **2a** and ester **2b**. Reaction of selenenic acid **1a** with methanol regenerated **1b**. The selenenic acid did not react with olefins such as styrene or ethyl vinyl ether; disproportionation occurred more rapidly than addition. The methyl selenenate **1b**, however, reacted over a period of days with ethyl vinyl ether to give the acetal selenide **8**.



$$ArSeOCH_3 + CH_2{=}CHOCH_2CH_3 \longrightarrow ArSeCH_2CH(OCH_3)OCH_2CH_3$$

8 65%

Selenenic acids disproportionate to give diselenides and seleninic acids with an equilibrium strongly favoring the disproportionation products.[1e,2a,3b] We also failed to detect selenenic acid **1a** at equilibrium, but mixtures of diselenide **5** and seleninic acid **2a** in chloroform reacted with ethyl vinyl ether to give the selenide aldehyde **9** and with methanol to give methyl selenenate **1b** in as much as 43% yield, along with methyl seleninate **2b** and starting diselenide **5**. We believe that **5** and **2a** comproportionated to form small amounts of **1a**, which was trapped irreversibly by ethyl vinyl ether or methanol. It was confirmed by independent experiments that selenenic acid **1a** esterified much faster than seleninic acid **2a**. Mixtures of **5** and **2b** did not react with either methanol or ethyl vinyl ether.

$$\underset{5}{ArSeSeAr} + \underset{2a}{ArSeO_2H} \rightleftharpoons \underset{1a}{[ArSeOH]} \xrightarrow{CH_3OH} \underset{1b}{ArSeOCH_3}$$

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(4) (a) The selenenyl iodide has been prepared: du Mont, W.-W., Kubiniok, S.; Peters, K.; von Schering, H.-G. *Angew. Chem.* **1987**, *99*, 820. (b) Ditelluride: Lange, L.; du Mont, W.-W. *J. Organomet. Chem.* **1985**, *286*, C1. (c) (2,4,6-Tri-*tert*-butylphenyl)lithium: Yoshifuji, M.; Shima, I.; Inamoto, N. *Tetrahedron Lett.* **1979**, 3963.

(5) A $^3J_{\mathrm{SeOCH}}$ = 7 Hz has been observed for methyl *o*-carbomethoxybenzeneselenenate.[1b]

(6) Similar solvent effects have been reported for sulfenic acids. Shelton, J. R.; Davis, K. E. *Int. J. Sulfur Chem.* **1973**, *8*, 205.

(7) For attempts to prepare the analogous sulfenic acid, see: Davis, F. A.; Jenkins, R. H., Jr.; Rizvi, S. Q. A.; Yocklovich, S. G. *J. Org. Chem.* **1981**, *46*, 3467.

(8) Oxidation of neither the selenol (ArSeH) nor the diselenide **5** gave selenenic acid.

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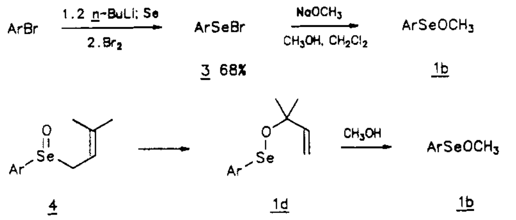
Table I. Synthesis, Reactions, and ^{77}Se Chemical Shifts of 1a and Related Compounds

no.	product (δ ^{77}Se)[a]	starting material	reagents	yield,[b] %
1a	ArSeOH (1061[c])	$ArSeOCH_3$	H_2O	80
		$ArSeCH_2CH_2C_6H_5$	*m*-CPBA	60
1b	$ArSeOCH_3$ (1269[d])	ArSeBr	CH_3ONa/CH_3OH	78
		ArSeOH	CH_3OH	53
		$(ArSe)_2/ArSeO_2H$	CH_3OH	43
		$ArSeCH_2CH{=}C(CH_3)_2$	*m*-CPBA/CH_3OH	70
1c	$ArSeOCH_2CH_3$ (1224[d])	NaH/CH_3CH_2OH	ArSeBr	70
2a	$ArSeO_2H$ (1217[d])	ArSeOH	*m*-CPBA	>95
2b	$ArSeO_2CH_2$ (1292[d])	$ArSeOCH_3$	*m*-CPBA	>95
2c	$ArSeO_2CH_2CH_3$ (1282[d])	$ArSeOCH_2CH_3$	*m*-CPBA	>95
6	$ArSeNHCH_2C_6H_5$ (680[d])	$ArSeOCH_3$	$C_6H_5CH_2NH_2$	95
		ArSeOH	$C_6H_5CH_2NH_2$	>95
7	$ArSeSCH_2C_6H_5$ (442[d])	$ArSeOCH_3$	$C_6H_5CH_2SH$	>95
		ArSeOH	$C_6H_5CH_2SH$	91
9	$ArSeCH_2CHO$	$(ArSe_2)/ArSeO_2H$	$CH_2{=}CHOCH_2CH_3$	28[e]

[a] From Me_2Se. [b] NMR yields. [c] Acetone-d_6. [d] $CDCl_3$. [e] Isolated yields.

Scheme I



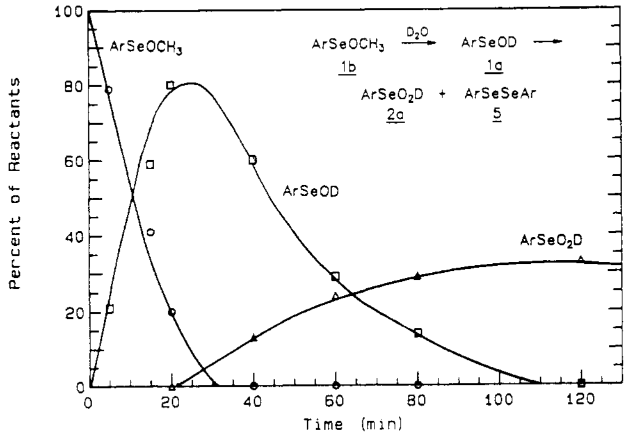


Figure 1. Hydrolysis of **1b** in 4% D_2O/CD_3CN at 25 °C. The initial concentration of **1b** was 0.032 M. The diselenide **5** precipitated and was not measured.

Selenenic acid **1a** and its esters are the first to be characterized which lack coordination by an ortho substituent. Despite the size of the 2,4,6-tri-*tert*-butylbenzene substituent,[9] selenenic acid **1a** was far less stable than the *o*-nitro-, *o*-benzoyl-, and *o*-carbomethoxybenzeneselenenic acids previously observed.[1b,c,2c] The chemical reactivity of selenenic acid **1a** and acid **1b** was consistent with that expected for selenenic acids and esters. In particular, strong evidence for the comproportionation of diselenides with seleninic acids was obtained. Finally, we have for the first time demonstrated that only the acids but not the esters disproportionate and comproportionate.

Acknowledgment. We thank the National Institutes of Health, NIADDK, for support of this research, and Dr. Carl A. Hoeger for exploratory studies on sterically hindered selenenic acids.[10]

Registry No. **1a**, 114031-53-7; **1b**, 114031-54-8; **1c**, 114031-55-9; **2a**, 114031-56-0; **2b**, 114031-57-1; **2c**, 114031-58-2; **3**, 114031-59-3; **5**, 20875-32-5; **6**, 114031-60-6; **7**, 114031-61-7; **8**, 114031-62-8; **9**, 114031-63-9; 2,4,6-(t-Bu)$_3C_6H_2$Br, 3975-77-7; 2,4,6-(t-Bu)$_3C_6H_2Se(CH_2)_2C_6H_5$, 114031-64-0; 2,4,6-(t-Bu)$_3C_6H_2SeCH_2CH{=}C(CH_3)_2$, 114031-65-1.

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[9] The size of the tri-*tert*-butylphenyl group is sufficient to stabilize ordinarily elusive functional groups such as C=S, P=As, P=Si, and P=Ge double bonds. Okazaki, R.; Ishii, A.; Fukuda, N.; Oyama, H.; Inamoto, N. *J. Chem. Soc., Chem. Commun.* **1982**, 1187. Cowley, A. H.; Lasch, J. G.; Norman, N. C.; Pakulski, M.; Whittlesey, B. R. *J. Chem. Soc., Chem. Commun.* **1983**, 881. Smit, C. N.; Lock, F. M.; Bickelhaupt, F. *Tetrahedron Lett.* **1984**, *25*, 3011. Escudie, J.; Couret, C.; Satge, J.; Andrianarison, M.; Andrianarison, J. D. *J. Am. Chem. Soc.* **1985**, *107*, 3378.

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Synthesis and Reactivity toward Acyl Chlorides and Enones of the New Highly Functionalized Copper Reagents RCu(CN)ZnI

Summary: The new and highly functionalized copper reagents RCu(CN)ZnI obtained from readily available primary and secondary alkylzinc iodides by a transmetalation in THF with the soluble salt, CuCN·2LiX, react in good yields with acyl chlorides and enones, respectively, to afford ketones and 1,4-addition products.

Sir: Copper reagents have proven to be very useful in organic synthesis.[2] Their synthetic utility would still be enhanced if highly functionalized copper compounds could be prepared. Since lithium and magnesium organometallics are generally used for their synthesis, only a few functional groups are tolerated and only a direct synthesis using primary alkyl bromides and highly activated copper[3] allows the synthesis of some functionalized copper reagents. The easy generation of functionalized zinc deriva-

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(1) Undergraduate research.

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