Monatshefte für Chemie 138, 863–865 (2007)
DOI 10.1007/s00706-007-0642-1
Printed in The Netherlands

Monatshefte für Chemie
Chemical Monthly

Zinc-Mediated Cleavage of Diselenides: A Novel Synthesis of Selenoformates in Aqueous Media

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Received February 13, 2007; accepted (revised) February 28, 2007; published online June 4, 2007

Summary. An efficient procedure was developed for the preparation of selenoformates by means of an one-pot zinc-mediated reaction of diaryl diselenides and chloroformates in aqueous media.

Keywords. Selenoformates; Zinc selenolate; Diselenides; Chloroformates.

Introduction

There is no doubt that selenium-containing organic molecules have played and continue to play an important role in biology and medicine. A wide range of organic selenides are now accepted as useful antibiotics, antiinflammatory agents, antioxidants, and antiviral agents [1]. Although numerous reports on the synthesis of organoselenium compounds have already been published [2], most of them, with the exception of two recent reports [3], require the handling of unstable reagents, strongly acidic or basic reaction conditions, and two-step procedures. Hence, the development of a one-step synthesis method using stable reagents under neutral conditions is in demand.

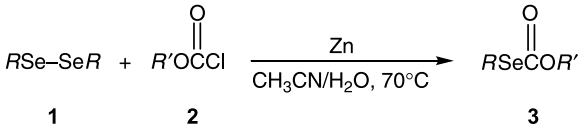
Among the methods for the introduction of a selenium moiety into organic molecules, the use of selenide anions is especially convenient and common. In general, the methods for the preparation of selenide anions include reductive cleavage of the Se–Se bond by various reducing agents such as sodium borohydride [4], sodium [5], samarium diiodide [6], lithium aluminum hydride [7], reaction of *Grignard* reagents with selenium [8], and of selenol with sodium hydride or even with aqueous sodium hydroxide under certain conditions [9].

In the last decade, organometallic reactions in aqueous media have attracted considerable attention in organic synthesis [10]. Transition metal selenolates or complexes have been widely used in the synthesis of organoselenium compounds [11–13], but reports exploring zinc selenolates are rare [14].

In connection with our ongoing work in aqueous organometallic reactions [14a–e], we report herein that zinc powder promotes the cleavage of the Se–Se bond of diselenides **1** to form a selenide anion (RSe^-), which then reacts with different chloroformates **2** to give selenoformates **3** in CH_3CN–H_2O mixture as solvent at 70°C (Scheme 1).

Results and Discussion

Among a few reported methods for the preparation of selenoformates, we can cite those involving the treatment of phenylselenotris(trimethylsilyl)silane



Scheme 1

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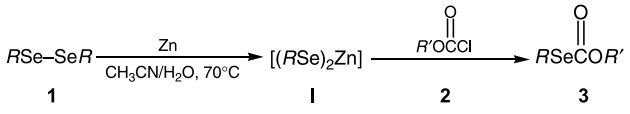
with chloroformates in benzene and in the presence of tetrakis(triphenylphosphine)palladium(0) [15], the reaction of phenylselenol with chloroformates in benzene and in the presence of pyridine [16], the reaction of sodium phenylselenoate – prepared by the reduction of diphenyl diselenide with sodium borohydride – with chloroformates [17], and water accelerated Sm/*TMS*Cl reductive cleavage of the Se–Se bonds followed by subsequent reaction with methylchloroformate [18]. These methods suffer from laborious removal of by-products, such as diaryl diselenides, or in some cases, hardly to obtain reagents.

We now introduce another procedure for the preparation of selenoformates from various chloroformates and aryl diselenides by reductive cleavage of Se–Se bond promoted by cheap and reactive metallic zinc powder. The effects of several solvents were examined and the best results were obtained with the acetonitrile-water (5:1) system. The consumption of zinc powder during the preliminary treatment of diselenide **1** with zinc is attributed to the formation of the zinc selenolate intermediate **I**, which further undergoes nucleophilic displacement with chloroformate **2** to afford the selenoformates **3** (Scheme 2) in 65–78% yield as shown in Table 1.

To conclude, an efficient one-pot synthesis method of selenoformates was developed based on the zinc-mediated reaction of diselenides with chloroformates. The present method has the advantages of operational simplicity, neutral, and mild reaction conditions, lack of toxicity, and low costs.



Scheme 2

Experimental

^{1}H (300 MHz) and ^{13}C (75 MHz) NMR spectra were recorded using a Bruker AQS-300 Avance spectrometer. IR spectra were obtained using an ABB FTLA 2000 instrument. Mass spectra were recorded with a Hewlett-Packard model 5973 instrument.

General Procedure for the Synthesis of Selenoformates
In a 50 cm^3 round bottom flask, fitted with a reflux condenser, were placed 3.2 mmol Zn powder, 0.64 mmol diselenide, 20 cm^3 CH_3CN, and 4 cm^3 H_2O. The mixture was stirred at 70°C for 2 h. Then 3.2 mmol chloroformate **2** were added at once and stirring was continued at that temperature for the appropriate time (Table 1) in ambient atmosphere. After completion of the reaction, the solution was filtered, MeCN was evaporated, diethyl ether (20 cm^3) was added, the mixture was washed with H_2O (3×20 cm^3), and the organic layer was dried (Na_2SO_4). The solvent was evaporated *in vacuo* to give the corresponding selenoformate, which was purified by preparative TLC (silica gel, eluent *n*-heptane:*EtOAc* = 10:1). Products **3a**–**3f** were shown to be identical with those described in Refs. [17, 18] by means of their spectroscopic data.

n-Butyl (4-chlorophenylseleno)formate (**3g**, $C_{11}H_{13}ClO_2Se$)
Yellow oil; IR (neat): $\bar{\nu} = 1725$ (C=O) cm^{-1}; ^{1}H NMR ($CDCl_3$): $\delta = 0.89$ (t, $J = 6.8$ Hz, CH_3), 1.36 (sex, $J = 6.8$ Hz, CH_2CH_3), 1.68 (quint, $J = 6.9$ Hz, OCH_2CH_2), 4.26 (t, $J = 6.9$ Hz, OCH_2), 7.26 (d, $J = 8.4$ Hz, *Ph*), 7.55 (d, $J = 8.4$ Hz, *Ph*) ppm; ^{13}C NMR ($CDCl_3$): $\delta = 13.6$, 18.9, 30.7, 68.5, 124.3, 129.5, 135.6, 137.1, 166.4 ppm; MS: m/z (%) = 293 ($(M+2)^+$, 28), 291 (M^+, 75), 192 (7), 190 (22), 156 (20), 57 (100), 41 (69), 29 (65).

2-Methyl-1-propyl (4-chlorophenylseleno)formate
(**3h**, $C_{11}H_{13}ClO_2Se$)
Yellow oil; IR (neat): $\bar{\nu} = 1722$ (C=O) cm^{-1}; ^{1}H NMR ($CDCl_3$): $\delta = 0.85$ (d, $J = 6.7$ Hz, $2 \times CH_3$), 1.89 (m, $CHMe_2$), 3.98 (d, $J = 6.6$ Hz, OCH_2), 7.26 (d, $J = 9.1$ Hz, *Ph*), 7.48 (d, $J = 9.1$ Hz, *Ph*) ppm; ^{13}C NMR ($CDCl_3$): $\delta = 18.9$, 27.9, 74.5, 124.3, 129.5, 135.6, 137.1, 166.4 ppm; MS: m/z (%) = 293 ($(M+2)^+$, 18), 291 (M^+, 52), 192 (8), 190 (23), 156 (19), 57 (100), 41 (91), 29 (53).

Table 1. Synthesis of selenoformates **3** from diselenides **1** and chloroformates **2** (Scheme 2)

Entry	*R*	*R′*	Reaction time/h	Product	Isolated yield/%
1	*Ph*	CH_3	2.5	**3a**	74
2	*Ph*	$CH_3(CH_2)_2CH_2$	1.8	**3b**	73
3	*Ph*	$(CH_3)_2CHCH_2$	3.3	**3c**	73
4	*Ph*	$CH_3(CH_2)_6CH_2$	3	**3d**	71
5	*Ph*	*Ph*	1	**3e**	78
6	4-ClC_6H_4	CH_3	4	**3f**	72
7	4-ClC_6H_4	$CH_3(CH_2)_2CH_2$	5.5	**3g**	68
8	4-ClC_6H_4	$(CH_3)_2CHCH_2$	4.25	**3h**	65
9	4-ClC_6H_4	$CH_3(CH_2)_6CH_2$	3.3	**3i**	68
10	4-ClC_6H_4	*Ph*	2	**3j**	73

n-Octyl (4-chlorophenylseleno)formate (**3i**, $C_{15}H_{21}ClO_2Se$) Pale yellow oil; IR (neat): $\bar{\nu} = 1721$ (C=O), 1116 cm^{-1}; ^1H NMR ($CDCl_3$): $\delta = 0.76$ (t, $J = 6.9$ Hz, CH_3), 1.07–1.21 (m, $5 \times CH_2$), 1.53 (quint, $J = 6.7$ Hz, OCH_2CH_2), 4.13 (t, $J = 6.6$ Hz, OCH_2), 7.20 (d, $J = 8.2$ Hz, *Ph*), 7.41 (d, $J = 8.2$ Hz, *Ph*) ppm; MS: m/z (%) = 349 ($(M+2)^+$, 4), 347 (M^+, 11), 192 (34), 190 (100), 156 (47), 128 (15), 112 (11), 71 (69), 57 (78), 43 (53), 41 (32), 29 (11).

Phenyl (4-chlorophenylseleno)formate (**3j**, $C_{13}H_9ClO_2Se$) Yellow oil; IR (neat): $\bar{\nu} = 1725$ (C=O) cm^{-1}; ^{13}C NMR ($CDCl_3$): $\delta = 121.3$, 123.9, 126.5, 129.67, 129.77, 136.1, 137.2, 151.7, 165.8 ppm; MS: m/z (%) = 313 ($(M+2)^+$, 7), 311 (M^+, 20), 285 (29), 283 (91), 192 (35), 190 (100), 156 (42), 77 (41), 65 (35), 51 (12), 39 (23).

Acknowledgements

The authors thank the *K.N. Toosi* University of Technology Research Council and Kermanshah Oil Refining Company for financial assistance.

References

[1] Lucas MA, Ngugen OTK, Schiesser CH, Zheng S-L (2000) Tetrahedron **56**: 3995 and references cited therein
[2] a) Krief A, Hevesi L (1988) Organoselenium Chemistry, vol 1. Springer-Verlag, Berlin; b) Krief A (1991) In Comprehensive Organometallic Chemistry; Trost BM (ed) Pergamon, Oxford, p 85; c) Patai S, Rappoport Z (1986) The Chemistry of Organic Selenium and Tellurium Compounds, vol 1. Wiley, New York; d) Patai S, Rappoport Z (1987) The Chemistry of Organic Selenium and Tellurium Compounds, vol 2. Wiley, New York
[3] a) Ranu BC, Mandal T, Samanta S (2003) Org Lett **5**: 1439; b) Nishino T, Okada M, Kuroki T, Watanabe T, Nishiyama Y, Sonoda N (2002) J Org Chem **67**: 8696
[4] Sharpless KB, Laura RF (1973) J Am Chem Soc **95**: 2697
[5] Aynsley EE, Greenwood NN, Leach JB (1966) Chem Ind (London) 379
[6] Zhang Y, Yu Y, Lin R (1993) Synth Commun **23**: 189
[7] Suzuki H, Yoshinaga M, Takaoka K, Hiroi Y (1985) Synthesis 497
[8] a) Klayman DL, Gunther WHH (1973) Organic Selenium Compounds: Their Chemistry and Biology, John Wiley, New York, p 191; b) Liotta D, Sunay U, Santiesteban H, Markiewicz W (1981) J Org Chem **46**: 2605
[9] Taboury F (1903) Bull Soc Chim Fr **29**: 761
[10] a) Lubineau A, Auge J, Queneau Y (1994) Synthesis 741; b) Li CJ (1993) Chem Rev **93**: 2023
[11] Meunier P, Gaotheron B, Mazouz A (1986) J Chem Soc Chem Commun 424
[12] Osuka A, Ohmasa N, Suzuki H (1982) Synthesis 857
[13] Bao W, Zhang Y (1995) Synth Commun **25**: 1825
[14] a) Movassagh B, Shamsipoor M (2005) Synlett 121; b) Movassagh B, Shamsipoor M (2005) Synlett 1316; c) Movassagh B, Shamsipoor M, Joshaghani M (2004) J Chem Res (S) 148; d) Movassagh B, Mirshojaei F (2003) Monatsh Chem **134**: 831; e) Movassagh B, Fazeli A (2006) Z Naturforsch **61b**: 194; f) Huang X, Xu X-H (1998) Synth Commun **28**: 807; g) Zhao X, Yu Z, Yan S, Wu S, Liu R, He W, Wang L (2005) J Org Chem **70**: 7338
[15] Schiesser CH, Skidmore MA (1997) J Chem Soc Perkin Trans 1 2689
[16] Bachi MD, Bosch E (1992) J Org Chem **57**: 4696
[17] Lucas MA, Schiesser CH (1996) J Org Chem **61**: 5754
[18] Wang L, Zhang Y (1999) Synth Commun **29**: 3107