ELSEVIER

Journal of Fluorine Chemistry 102 (2000) 215–218

JOURNAL OF FLUORINE CHEMISTRY

www.elsevier.com/locate/jfluchem

Reactions of benzeneselenenyl fluoride generated by XeF_2-$(PhSe)_2$ system with electron-deficient alkenes

Kenji Uneyama*, Shigemoto Hiraoka, Hideki Amii

Department of Applied Chemistry, Faculty of Engineering, Okayama University, Tsushimanaka, Okayama 700-8530, Japan

Received 29 June 1999; received in revised form 19 July 1999; accepted 12 August 1999

Dedicated to Professor Paul Tarrant on the occasion of his 85th birthday

Abstract

Fluoro-benzeneselenenylation of electron-deficient alkenes with benzeneselenenyl fluoride [PhSeF] generated in situ by the reaction of diphenyl diselenide and xenon difluoride proceeded smoothly in dichloromethane. The product yields increased remarkably in higher concentration of the seleno-reagent. The reactive seleno-reagent PhSeF may be stabilized in the higher concentration presumably by the favorable association of the reagent.

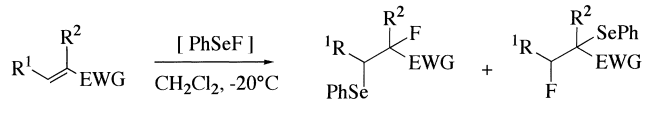
Keywords: Benzeneselenenyl fluoride; Fluoro-selenenylation; Organoselenium compound; 1,2-addition; β-fluorinated selenides

1. Introduction

Recently, the efficient methods for monofluorination have been extensively studied [1–8]. Fluoro-selenenylation of alkenes is one of the attractive methods for introduction of fluorine atom into a molecule because the selenenium moiety of the fluorinated selenides are versatile for the further chemical modifications [9].

Other electrophilic selenenylating reagents have been reported and the organoselenium compounds can be used for further synthetic transformation by photolysis, chemical- and electrochemical oxidation and reduction and other chemical modifications [10–12]. Generally, when the electronegativity of X in benzeneselenenyl reagents (PhSeX; X = Cl, Br, CN, OH, OAc, OTf, NR_2, etc.) becomes stronger, the electrophilicity of the phenylseleno group increases. Since fluorine is the most electronegative element, it is expected to strongly activate the seleno-moiety of the benzeneselenenyl fluoride. Several fluoroselenenylation systems such as $PhSeNR_2$-Py·HF/CH_2Cl_2 [13], PhSeBr-AgF/CH_2Cl_2 [14], $PhSeNR_2$-AgF/CH_3CN [15], $PhSeNR_2$-Py·9HF/CH_2Cl_2 [16], $(PhSe)_2$-Et_3N·3HF/CH_2Cl_2/electrooxidation [17] have been studied. Fluoroselenenylation of α-diazoketones and α-diazoesters affording the α-fluoro-α,β-unsaturated ketones and esters using a PhSeBr-AgF system has been reported by Tomoda [18]. We have demonstrated that XeF_2-$(PhSe)_2$ in CH_2Cl_2 can generate a benzeneselenenyl fluoride equivalent which undergoes a facile fluoroselenenylation of electron-rich alkenes [19]. Likewise, substituted acetylenes and phosphaalkynes were also converted to 2-fluoroalkenylselenides [20] and vicinal bis(phenylselenenyl)phosphaalkenes [21], respectively, by this system. On the other hand, $PhSeF_3$ or $PhSeF_5$ generated in situ with an excess of XeF_2 gave mainly difluorinated alkenes [22].

In the $(PhSe)_2$-XeF_2 system, the electron rich alkenes reacted very fast, mostly within a minute to give 1,2-adducts in good yields. But, electron deficient alkenes reacted slowly to afford the adducts in very poor yields [19]. Here, we describe a method which facilitates the effective fluoroselenenylation of electron-deficient alkenes. It appears that benzeneselenenyl fluoride decomposes before completion of the desired reaction with electron-deficient alkenes (2 h at 0°C). After surveying the reaction conditions, we have found that the concentration of the seleno-reagent was critical. The higher concentration of the reagent remarkably improved the yields of fluoro-selenenyl compounds (Scheme 1).



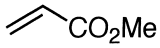
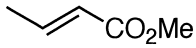
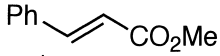
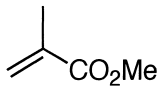
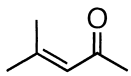
1 **2** **3**

Scheme 1

* Corresponding author. Tel.: +81-86-251-8075; fax: +81-86-257-8075.
E-mail address: uneyamak@cc.okayama-u.ac.jp (K. Uneyama).

0022-1139/00/$ – see front matter
PII: S0022-1139(99)00282-1

Table 1
Fluoroselenenylation of electron-deficient alkenes

Entry	Substrate **1**		(0.2 mol l^{-1})[a]		1.0 mol l^{-1}	
			2 + **3** yield (%)[b]	Ratio (**2** : **3**)	**2** + **3** yield (%)	Ratio (**2** : **3**)
a		**1a**	49	(20 : 80)	58	(30 : 70)
b		**1b**	24	(0 : 100)	44	(0 : 100)
c		**1c**	50	(0 : 100)	75	(0 : 100)
d		**1d**	34	(80 : 20)	57	(70 : 30)
e		**1e**	24	(0 : 100)	79	(0 : 100)

[a] The concentration of [PhSeF] in dichloromethane.
[b] All yields are determined by ^{19}F NMR.

2. Results and discussion

A survey of the data in Table 1 shows that fluoroselenenylation of electron-deficient alkenes gave moderate yields of the fluoroselenenylated products at higher concentration. Because of the instability of the products, the yields were determined by ^{19}F NMR integration (Table 1).

The benzeneselenenyl fluoride was generated at −20°C and allowed to react with alkenes in the temperature range between −20 and 0°C. The addition reaction was mostly completed at the temperature within 2 h. The higher concentration of [PhSeF] equivalent was found to be more effective to the reaction of [PhSeF] with electron deficient alkenes as shown in Fig. 1. Interestingly, the reaction with 1-octene proceeded very fast at the temperature within 10 min and was not affected by the concentration of the selenoreagent.

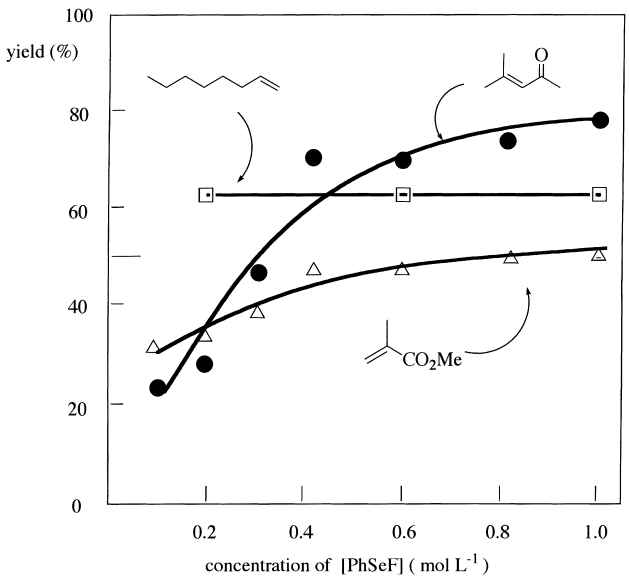


Fig. 1. Effect of concentration of [PhSeF] (−20 → 0°C).

Unfortunately, much higher concentration of the reagent was not achieved because of the low solubility of diphenyl diselenide in dichloromethane at lower temperatures. The effect of the concentration is not clear at this moment, but it might be plausible that benzeneselenenyl fluoride [PhSeF] was stabilized in the higher concentration due to the possible association of the reagent which made the lifetime of the reagent longer and the desired reaction effective. Calculation of heats of formation of [PhSeF] as a monomer and its dimer by PM3 of Mac Spartan Plus revealed that the dimer is more stable by 18 kcal/mol than the monomer.

Regioselectivity was highly dependent on the substituent of the α,β-unsaturated carbonyl compounds. Carbomethoxy group retarded the reaction rate and induced electrophilic selenenylation at the α-carbon of methyl acrylate as a major reaction pathway. On the other hand, substitution of β-methyl and β-phenyl groups resulted in exclusive selenenylation at the α-carbon atom (entries 1, 2, and 5). The regiochemistry may arise from the stabilization of the inspient carbocation by the electron donating β-substituents. Meanwhile, the α-methyl group (entry 4) made β-selenenylation slightly favorable presumably due to electronic and steric effects of the α-methyl group.

3. Experimental

^{1}H NMR (200 MHz), ^{13}C NMR (50 MHz), and ^{19}F NMR (188 MHz) were recorded in $CDCl_3$ on a Varian Gemini-200 and VXR-200. Chemical shifts for ^{1}H and ^{13}C NMR are reported in ppm downfield from TMS. ^{19}F NMR spectra were obtained using C_6F_6 as an internal standard (−162.3 ppm), but are reported as chemical shifts upfield

from $CFCl_3$. Yields of the 1,2-adducts shown in Table 1 are calculated by the relative integral of the crude product obtained by a simple extraction of the reaction mixture to the internal standard 1,3-bistrifluoromethylbenzene added to the mixture, because of the partial hydrolysis of the 1,2-addition products during the separation by a column chromatography.

All reactions were performed under N_2 atmosphere. Two-necked flask of 30 ml equipped with a septum cap, and a Teflon-coated magnetic stirring bar was charged with XeF_2 (67.7 mg, 0.4 mmol). At −20°C, diphenyldiselenide (125 mg, 0.4 mmol) dissolved in CH_2Cl_2 was added. After the solution was stirred for about 15 min, olefins (0.8 mmol) dissolved in CH_2Cl_2 was added. The mixture was stirred for 2 h. The mixture was washed with saturated aqueous $NaHCO_3$ and brine, dried ($MgSO_4$) and then concentrated to give the crude product as an oil. The product was purified by a silica gel chromatography.

3.1. Methyl 2-fluoro-3-(phenylseleno) propanoate (**2a**)

IR(neat): 1760 cm^{-1}. ^1H NMR (200 MHz, $CDCl_3$): δ 3.1 ∼ 3.5 (m, 2H), 3.72 (s, 3H), 5.10 (ddd, 1H, $^2J_{HF} = 47.0$, $^3J_{HH} = 6.5$, 5.2 Hz), 7.2 ∼ 7.3 (m, 3H), 7.5 ∼ 7.7 (m, 2H). ^{13}C NMR (50 MHz, $CDCl_3$): δ 28.6 (d, $^2J_{CF} = 22$ Hz), 52.5, 88.0 (d, $^1J_{CF} = 186$ Hz), 127.8, 128.6, 129.2, 133.8, 136.0, 168.7 (d, $^2J_{CF} = 24$ Hz). ^{19}F NMR (188 MHz, $CDCl_3$): δ −185.4 ∼ −184.9 (m, ^1H); Anal. Calc. for $C_{10}H_{11}FO_2Se$: C, 45.99; H, 4.25; Found: C, 45.68; H, 4.54%.

3.2. Methyl 3-fluoro-2-(phenylseleno) propanoate (**3a**)

IR(neat): 1730 cm^{-1}. ^1H NMR (200 MHz, $CDCl_3$): δ 3.72 (s, 3H), 3.87 (ddd, ^1H, $^3J_{HF} = 10.3$, $^3J_{HH} = 5.2$, 5.2 Hz), 4.65 (ddd, 1H, $^2J_{HF} = 47.0$, $^2J_{HH} = 10.3$, $^3J_{HH} = 5.2$ Hz), 4.74 (ddd, 1H, $^2J_{HF} = 47.0$, $^2J_{HH} = 10.3$, $^3J_{HH} = 5.2$ Hz), 7.26 ∼ 7.40 (m, 3H), 7.6 ∼ 7.7 (m, 2H). ^{13}C NMR (50 MHz, $CDCl_3$): δ 41.3 (d, $^2J_{CF} = 19$ Hz), 52.5, 81.9 (d, $^1J_{CF} = 177$ Hz), 126.0, 129.2, 129.3, 136.0, 170.6. ^{19}F NMR (188 MHz, $CDCl_3$): δ −204.9 (ddd, 1F, $^2J_{HF} = 47.0$, 47.0, $^3J_{HF} = 10.3$ Hz); Anal. Calc. for $C_{10}H_{11}FO_2Se$: C, 45.99; H, 4.25; Found: C, 45.66; H, 4.62%.

3.3. Methyl 3-fluoro-2-(phenylseleno) butanoate (**3b**)

IR(neat): 1736 cm^{-1}. ^1H NMR (200 MHz, $CDCl_3$): δ 1.50 (dd, 3H, $^3J_{HF} = 24.1$, $^3J_{HH} = 6.2$ Hz), 3.58 (s, 3H), 3.5 ∼ 3.6 (m, 1H), 4.94 (ddq, 1H, $^2J_{HF} = 47.2$, $^3J_{HH} = 6.9$, 6.2 Hz), 7.2 ∼ 7.4 (m, 3H), 7.5 ∼ 7.6 (m, 2H). ^{13}C NMR (50 MHz, $CDCl_3$): δ 18.9 (d, $^2J_{CF} = 23$ Hz), 48.2 (d, $^2J_{CF} = 21$ Hz), 52.2, 89.8 (d, $^1J_{CF} = 173$ Hz), 126.8, 129.0, 129.2, 135.6, 170.7. ^{19}F NMR (188 MHz, $CDCl_3$): δ −165.1 ∼ −164.4 (m, 1 F); Anal. Calc. for $C_{11}H_{13}FO_2Se$: C, 48.01; H, 4.76; Found: C, 47.82; H, 4.45%.

3.4. Methyl 3-fluoro-3-phenyl-2-(phenylseleno) propanoate (**3c**)

IR(neat): 1736 cm^{-1}. ^1H NMR (200 MHz, $CDCl_3$): δ 3.69 (s, 3H), 4.03 (dd, 1H, $^3J_{HF} = 8.7$, $^3J_{HH} = 10.5$ Hz), 5.77 (dd, 1H, $^2J_{HF} = 46.4$, $^3J_{HH} = 10.5$ Hz), 7.2 ∼ 7.3 (m, 3H), 7.5 ∼ 7.6 (m, 2H). ^{19}F NMR (188 MHz, $CDCl_3$): δ −154.9 (dd, 1 F, J = 46.4, 8.7 Hz); Anal. Calc. for $C_{11}H_{13}FO_2Se$: C, 45.99; H, 4.25; Found: C, 46.05.; H, 4.14%.

3.5. Methyl 2-fluoro-2-methyl-3-(phenylseleno) propanoate (**2d**)

IR(neat): 1766 cm^{-1}. ^1H NMR (200 MHz, $CDCl_3$): δ 1.65 (d, 3H, $^3J_{HF} = 21.0$ Hz), 3.37 (d, ^1H, $^3J_{HF} = 18.0$ Hz), 18.0 Hz), 3.40 (dd, 1H, $^3J_{HF} = 24.4$ Hz), 3.68 (s, 3H), 7.2 ∼ 7.3 (m, 3H), 7.5 ∼ 7.6 (m, 2H). ^{13}C NMR (50 MHz, $CDCl_3$): d 23.8 (d, $^2J_{CF} = 24$ Hz), 35.3 (d, $^2J_{CF} = 24.7$ Hz), 52.5, 94.7 (d, $^1J_{CF} = 185$ Hz), 127.5, 129.1, 129.6, 133.4, 170.9 (d, $^2J_{CF} = 25.4$ Hz). ^{19}F NMR (188 MHz, $CDCl_3$): δ −151.2 ∼ −150.5 (m, 1 F); Anal. Calc. for $C_{11}H_{13}FO_2Se$: C, 48.01; H, 4.76; Found: C, 48.00; H, 5.16%.

3.6. Methyl 3-fluoro-2-methyl-2-(phenylseleno) propanoate (**3d**)

IR(neat): 1734 cm^{-1}. ^1H NMR (200 MHz, $CDCl_3$): δ 1.52 (s, 3H), 3.53 (s, 3H), 4.40 (dd, 1H, $^2J_{HF} = 47.8$, $^2J_{HH} = 9.0$ Hz), 4.70 (dd, 1H, $^2J_{HF} = 47.4$, $^2J_{HH} = 9.0$ Hz), 9.0 Hz), 7.2 ∼ 7.4 (m, 3H), 7.5 ∼ 7.6 (m, 2H). ^{13}C NMR (50 MHz, $CDCl_3$): δ 20.2 (d, $^3J_{CF} = 3.0$ Hz), 48.5 (d, $^2J_{CF} = 18$ Hz), 52.8, 86.7 (d, $^1J_{CF} = 180$ Hz), 125.9, 129.5, 130.3, 138.6, 172.4 (d, $^3J_{CF} = 2.0$ Hz). ^{19}F NMR (188 MHz, $CDCl_3$): δ −209.8 ∼ −209.4 (m, 1 F); Anal. Calc. for $C_{11}H_{13}FO_2Se$: C, 48.01; H, 4.76; Found: C, 48.28; H, 4.81%.

3.7. 4-Fluoro-4-methyl-3-(phenylseleno)-2-pentanone (**3e**)

IR(neat): 1706 cm^{-1}. ^1H NMR (200 MHz, $CDCl_3$): δ 1.47 (d, 3H, $^3J_{HF} = 7.3$ Hz), 1.58 (d, 3H, $^3J_{HF} = 7.0$ Hz), 2.27 (s, 3H), 3.75 (d, 1H, $^3J_{HF} = 17.2$ Hz), 7.2 ∼ 7.3 (m, 3H), 7.5 ∼ 7.6 (m, 2H). ^{13}C NMR (50 MHz, $CDCl_3$): δ 25.5 (d, $^2J_{CF} = 4.5$ Hz), 26.1 (d, $^2J_{CF} = 3.5$ Hz), 29.2, 63.1 (d, $^2J_{CF} = 23$ Hz), 95.1 (d, $^1J_{CF} = 171$ Hz), 128.4, 129.2, 129.4, 134.4, 203.4. ^{19}F NMR (188 MHz, $CDCl_3$): δ −135.6 ∼ −134.7 (m, 1 F); Anal. Calc. for $C_{12}H_{15}FOSe$: C, 52.76; H, 5.53; Found: C, 52.64; H, 5.90%.

Acknowledgements

We are grateful to the Ministry of Education, Culture, Sports and Science of Japan for the financial support (Grand

in Aid for Priority Area, No. 11120233) and to Dr. Toshimasa Katagiri for the PM3 calculation of the heats of formation.

References

[1] S. Rozen, O. Lerman, M. Kol, J. Chem. Soc., Chem. Commun. (1981) 443.
[2] G.A. Olah, J.T. Welch, Y.D. Vankar, M. Nojima, I. Kerekes, J.A. Olah, J. Org. Chem. 44 (1979) 3872.
[3] N. Yoneda, T. Abe, T. Fukuhara, A. Suzuki, Chem. Lett. (1983) 1135.
[4] A. Hedhli, A. Baklouti, J. Org. Chem. 59 (1994) 5277.
[5] S. Stavber, T. Sotler, M. Zupan, Tetrahedron Lett. 35 (1994) 1105.
[6] M. Zupan, J. Iska, S. Stavber, J. Org. Chem. 63 (1998) 878.
[7] S. Stavber, T. Sotler-Pecan, M. Zupan, Tetrahedron 50 (1994) 12235.
[8] I. Ikeda, H. Watanabe, T. Hirao, H. Kurosawa, J. Fluorine Chem. 69 (1994) 97.
[9] H. Asai, K. Uneyama, Chem. Lett. (1995) 1123.
[10] D.L.J. Clive, Tetrahedron 34 (1978) 1049.
[11] D.L.J. Clive, Aldrichimica Acta 11 (1978) 1049.
[12] H.J. Reich, Acc. Chem. Res. 12 (1979) 22.
[13] K.C. Nicolaou, N.A. Petassi, D.A. Claremon, Tetrahedron 41 (1985) 4835.
[14] S. Tomoda, Y. Usuki, Chem. Lett. (1989) 1235.
[15] J.R. McCarthy, D.P. Matthews, C.L. Barney, Tetrahedron Lett. 31 (1990) 973.
[16] C. Saluzzo, G. Alvernhe, D. Anker, Tetrahedron Lett. 31 (1990) 663.
[17] K. Uneyama, H. Asai, Y. Dan-oh, H. Matta, Electrochimica Acta. 42 (1997) 2005.
[18] Y. Usuki, M. Iwaoka, S. Tomoda, J. Chem. Soc., Chem. Commun. (1992) 1148.
[19] K. Uneyama, M. Kanai, Tetrahedron Lett. 31 (1990) 3583.
[20] H. Poleschner, M. Heydenreich, K. Spindler, G. Haufe, Synthesis (1994) 1043.
[21] K.K. Laali, W. Fiedler, M. Regitz, J. Chem. Soc., Chem. Commun. (1997) 1641.
[22] S.A. Lermontov, S. Zavorin, I. Bakhtin, A.N. Pushin, N.S. Zefirov, P.J. Stang, J. Fluorine Chem. 87 (1998) 75.