Electrophilic Addition of Benzeneselenenyl Chloride to Alkenes Bearing an Electron-withdrawing Substituent[1]

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Reaction of benzeneselenenyl chloride with alkenes bearing electron-withdrawing substituents was found to afford a mixture of regioisomeric adducts formed *via* the electrophilic addition of the phenylseleno group. The isomer distribution can be accounted for by postulating the interaction in the episelenonium ion intermediate of the phenylseleno group with the electron-withdrawing substituent.

Alkenyl phenyl selenides bearing an electron-withdrawing substituent on the α-olefinic carbon atom are valuable in organic synthesis as dienophiles[2] or radical acceptors.[3] Although their preparation is possible *via* addition of a phenylseleno moiety to electron-deficient alkene and subsequent elimination of a gegenanion and proton,[3,4] the nature of the addition is not always clear, the base catalysis of some reactions suggesting nucleophilic character.[4] We now report that reaction of benzeneselenenyl chloride with alkenes bearing an electron-withdrawing substituent at 20 °C in the absence of a catalyst gave a mixture of regioisomeric adducts; this result contrasts with a previous report.[3] The results indicate that the reaction proceeds through electrophilic addition of a phenylseleno moiety to the electron-deficient double bond. We also describe the effect of an α-substituent at the double bond upon the distribution of the regioisomers.

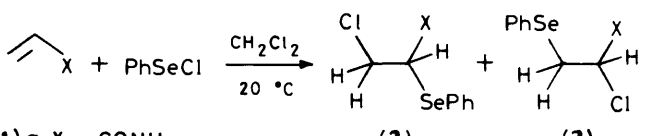
Table. Yields and isomer ratios of the adducts[a]

Entry	Alkene	Time (h)	Product	Yield[b] (%)	Isomer ratio[c]
1	(**1a**)	3	(**2a**), (**3a**)	94	73:27
2	(**1b**)	60	(**2b**), (**3b**)	92	67:33
3	(**1c**)	72	(**2c**), (**3c**)	60	63:37
4	(**1d**)	72	(**2d**), (**3d**)	88	93:7
5	(**1e**)	48	(**2e**), (**3e**)	68	82:18
6	(**4a**)	72	(**5a**), (**6a**)	93	89:11
7	(**4b**)	24	(**5b**), (**6b**)	86	82:18
8	(**4c**)	18	(**5c**), (**6c**)	89	95:5

[a] Carried out using alkene (5 mmol) and benzeneselenenyl chloride (5 mmol) in dichloromethane at 20 °C. [b] Determined by ^{1}H n.m.r. [c] Determined by ^{13}C n.m.r.

Results and Discussion

On addition of benzeneselenenyl chloride to a solution of acrylamide (**1a**) in dichloromethane, the red colour of the former disappeared and a yellow solution was formed. This was stirred for 3 h at 20 °C and gave (^{1}H n.m.r. measurement) the adducts (**2a**) and (**3a**) (94%) and diphenyl diselenide (4%). The isomer ratio (**2a**):(**3a**) 73:27 was determined by the peak height ratio in the ^{13}C n.m.r. spectrum. The shielding constant of a chlorine atom is greater than that of a phenylseleno group (> 10 p.p.m.[5]) thus, the triplets at 44.3 and 29.8 p.p.m. were assigned to (**2a**) and (**3a**) respectively and the doublets at 45.2 and 55.9 p.p.m. to (**2a**) and (**3a**) respectively. The mixture of (**2a**) and (**3a**) was isolated by column chromatography in an analytically pure form. Treatment of the electron-deficient alkenes (**1b**—**e**) gave the analogous adducts (**2b**—**e**) and (**3b**—**e**) in good to excellent yields (see Scheme 1). In these cases the colour of benzeneselenenyl chloride did not disappear immediately and the reaction time was longer (24—72 h; see Table). Our studies indicate that the formation of the regioisomers cannot be rationalized in terms of nucleophilic addition (Michael type addition) of chlorine followed by the capture of the anionic intermediate by a selenium moiety; rather electrophilic addition of a phenylseleno group as a first step and the formation of an episelenonium ion intermediate such as (**7**) is implicated.



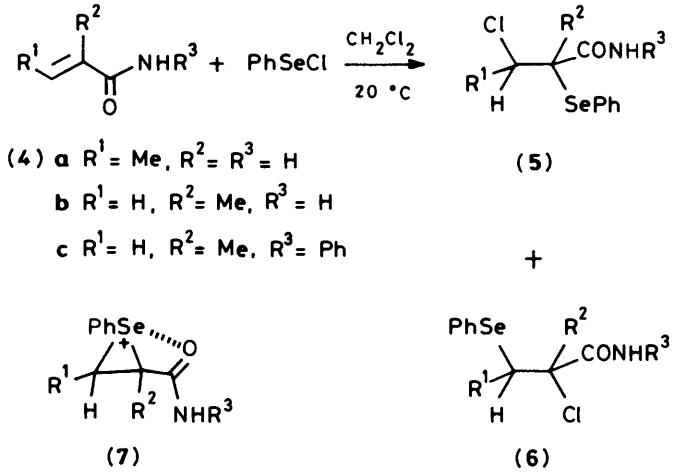
(1) a X = $CONH_2$
b X = CO_2Et
c X = CN
d X = CHO
e X = COMe

(2) (3)

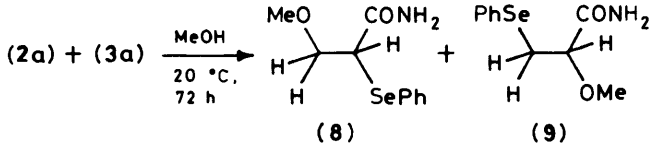
Scheme 1.

The effect of a methyl substituent at the double bond upon the distribution of regioisomers was next investigated. The formation of the isomer (**5**) was increased by the introduction of methyl group into either the β- or α-position of the double bond of (**4a**) and (**4b**) (Entries 6 and 7 in the Table). With (**4a**) the electron-donating effect of the methyl group may be responsible for the increased formation of (**5a**) whereas with (**4b**), steric hindrance caused by the methyl group may explain the decrease in the formation of (**6b**). The introduction of a phenyl group onto the nitrogen atom allowed the almost exclusive formation of (**5c**) (Entry 8). These results are rationalized in terms of an episelenonium ion intermediate (**7**) in which interaction between the selenium atom and the amide oxygen occurs. An analogous interaction between selenium and oxygen has been postulated in the literature to explain the regio- and stereoselectivity of electrophilic addition of a phenylseleno moiety to allylic alcohols.[6]

The electrophilic nature of the addition reaction was further confirmed by the methanolysis of the adducts (**2a**) and (**3a**). Thus a mixture of (**2a**) and (**3a**) (73:27) stirred in methanol at 20 °C for 72 h, allowed the methoxy group to replace the chlorine atom to afford a mixture of the regioisomers (**8**) and (**9**) (79:21) (73%) (Scheme 3). The carbon–chlorine bond fission should be assisted by the participation of a phenylseleno group to form the episelenonium ion intermediate.



Scheme 2.



Scheme 3.

Experimental

I.r. spectra were recorded with a JASCO IR-810 spectrophotometer. ^1H And ^{13}C n.m.r. spectra were obtained with a JEOLCO JNM-FX-100 instrument on solutions in $CDCl_3$ with Me_4Si as an internal standard. Mass spectra were measured on a JEOL JMS-DX 300 mass spectrometer.

Reaction of the Acylamide (**1a**) *with Benzeneselenenyl Chloride: General Procedure.*—Benzeneselenenyl chloride (9.88 g, 50 mmol) in dichloromethane (25 ml) was added to a solution of acrylamide (3.55 g, 50 mmol) in dichloromethane (25 ml) to give discharge of the red colour and immediate formation of a pale yellow solution. The latter was stirred at ambient temperature for 3 h, when a white precipitate gradually separated. This was filtered off and washed with dichloromethane, and the combined filtrate and washings were evaporated off to give a white solid. ^1H And ^{13}C n.m.r. spectroscopy of this solid revealed the presence of β-chloro-α-(phenylseleno)propionamide (**2a**), and α-chloro-β-(phenylseleno)propionamide (**3a**) (73:27, 94%), and diphenyl diselenide (4%). The adduct mixture (**2a**) and (**3a**) was isolated by column chromatography [SiO_2 200 mesh, dichloromethane as eluant] as a white solid (Found: C, 40.8; H, 3.75; N, 5.3. $C_9H_{10}ClNOSe$ requires C, 41.16; H, 3.84; N, 5.33%); $\nu_{max.}$(KBr) 3 395, 3 200, 1 655, 1 440, 745, and 700 cm^{-1}; δ_H (100 MHz) 2.4—2.6 [2 H, m, (**3a**)], 3.6—4.1 [3 H, m, (**2a**)], 4.43 [1 H, dd, *J* 9.4 and 5.6 Hz, (**3a**)], 7.1—7.4 (3 H, m), 7.4—7.7 (2 H, m), and 7.7—7.9 (2 H, br s); δ_C (25 MHz) (**2a**) 44.3 (t), 45.2 (d), 170.4 (s), and phenyl signals; (**3a**) 29.8 (t), 55.9 (d), 168.7 (s).

Ethyl β-*Chloro*-α-(*phenylseleno*)*propionate* (**2b**) *and Ethyl* α-*Chloro*-β-(*phenylseleno*)*propionate* (**3b**) (67:33) (Found: C, 45.45; H, 4.5. $C_{11}H_{13}ClO_2Se$ requires C, 45.30; H, 4.49%); $\nu_{max.}$(film) 2 980, 1 730, 1 440, 1 020, 740, and 695 cm^{-1}; δ_H (100 MHz) 1.24 (3 H, t, *J* 7.1 Hz), 3.7—4.0 (3 H, m), 4.16 (2 H, q, *J* 7.1 Hz), 7.1—7.4 (3 H, m), and 7.4—7.7 (2 H, m); δ_C (25 MHz) (* two signals overlapping) (**2b**), 14.0 (q), 43.5 (t), 43.8 (d), 61.4 (t), 128.0 (s), 129.3 (d),* 134.0 (d), 136.0 (d),* and 169.9 (s); (**3b**), 14.0 (q), 30.5 (t), 54.8 (d), 62.1 (t), 128.0 (s), 129.2 (d),* 134.0 (d), 136.0 (d),* and 168.2 (s).

β-*Chloro*-α-(*phenylseleno*)*propiononitrile* (**2c**) *and* α-*Chloro*-β-(*phenylseleno*)*propiononitrile* (**3c**) (63:37) (Found: C, 44.35; H, 3.35; N, 5.7. C_9H_8NClSe requires C, 44.20; H, 3.30; N, 5.73%); $\nu_{max.}$(film) 2 940, 2 240, 1 475, 1 435, 1 020, 740, and 690 cm^{-1}; δ_H (100 MHz) 3.5—4.0 (3 H, m), 7.2—7.5 (3 H, m), and 7.5—7.8 (2 H, m); δ_C (**2c**), 27.4 (d), 43.2 (t), 117.3 (s), and phenyl signals; (**3c**), 31.9 (t), 41.8 (d), 116.2 (s), and phenyl signals.

β-*Chloro*-α-(*phenylseleno*)*propionaldehyde* (**2d**) *and* α-*Chloro*-β-(*phenylseleno*)*propionaldehyde* (**3d**) (93:7): *m/z* 247.9497, 249.9501 (C_9H_9OClSe requires 247.9506, 249.9477); $\nu_{max.}$(film) 1 720, 1 700, 1 475, 1 435, 740, and 685 cm^{-1}; δ_H (100 MHz) 3.27 [1 H, d, *J* 6.8 Hz, (**3d**)], 3.29 [1 H, d, *J* 8.3 Hz, (**3d**)], 3.7—3.9 [3 H, m, (**2d**)], 4.30 [1 H, ddd, *J* 8.3, 6.8, and 2.4 Hz, (**3d**)], 7.1—7.4 (3 H, m), 7.4—7.6 (2 H, m), 9.37 [1 H, d, *J* 2.4 Hz, (**3d**)], and 9.48 [1 H, s, (**2d**)]; δ_C (25 MHz) (**2d**), 40.3 (t), 51.7 (d), 190.0 (s), and phenyl signals; (**3d**), 28.2 (t), 60.7 (d), 192.0 (s), and phenyl signals.

4-*Chloro*-3-(*phenylseleno*)*butan*-2-*one* (**2e**) *and* 3-*Chloro*-4-(*phenylseleno*)*butan*-2-*one* (**3e**) (82:18) (Found: C, 46.15; H, 4.1. $C_{10}H_{11}ClOSe$ requires C, 45.91; H, 4.24%); $\nu_{max.}$(film) 3 110, 1 705, 1 473, 1 437, 1 356, 737, and 688 cm^{-1}; δ_H (100 MHz) 2.30 [3 H, s, (**3e**)], 2.39 [3 H, s, (**2e**)], 3.2—3.35 [2 H, m, (**3e**)], 3.6—4.0 [3 H, m, (**2e**)], 4.35 [1 H, dd, *J* 9.3 and 5.9 Hz, (**3e**)], 7.15—7.4 (3 H, m), and 7.4—7.65 (2 H, m); δ_C (25 MHz) (**2e**), 28.3 (q), 42.4 (t), 50.5 (d), 200.1 (s), and phenyl signals; (**3e**), 26.5 (q), 29.1 (t), 60.1 (d), 195.9 (s), and phenyl signals.

β-*Chloro*-α-(*phenylseleno*)*butyramide* (**5a**) *and* α-*Chloro*-β-(*phenylseleno*)*butyramide* (**6a**) (89:11) (Found: C, 43.35; H, 4.3; N, 5.05. $C_{10}H_{12}ClNOSe$ requires C, 43.42; H, 4.37; N, 5.06%); $\nu_{max.}$(KBr) 1 655 cm^{-1}; δ_H (100 MHz) 1.45 [3 H, d, *J* 6.8 Hz, (**6a**)], 1.73 [3 H, d, *J* 6.4 Hz, (**5a**)], 3.67 [1 H, d, *J* 9.3 Hz, (**5a**)], 4.51 [1 H, dq, *J* 6.4 and 9.3 Hz, (**5a**)], 5.80 (2 H, br s), 7.1—7.4 (3 H, m), and 7.4—7.7 (2 H, m). (The other signals of (**6a**) were not detected.); δ_C (25 MHz) (**5a**), 23.6 (q), 53.8 (d), 57.2 (d), 173.1 (s), and phenyl signals; (**6a**), 21.4 (q), 52.3 (d), 57.4 (d), and phenyl signals. (The signal due to the carbonyl carbon was not detected).

β-*Chloro*-α-*methyl*-α-(*phenylseleno*)*propionamide* (**5b**) *and* α-*Chloro*-α-*methyl*-β-(*phenylseleno*)*propionamide* (**6b**) (Found: C, 43.60; H, 4.35; N, 5.1. $C_{10}H_{12}ClNOSe$ requires C, 43.42; H, 4.37; N, 5.06%); $\nu_{max.}$(film) 1 665 cm^{-1}; δ_H (100 MHz) 1.88 (3 H, s), 3.53 (1 H, d, *J* 4.9 Hz), 3.55 (1 H, d, *J* 4.9 Hz), 6.35 (1 H, br s), 6.65 (1 H, br s), 7.1—7.4 (3 H, m), and 7.4—7.7 (2 H, m); δ_C (25 MHz) (**5b**), 29.5 (q), 40.8 (t), 72.1 (s), 173.5 (s), and phenyl signals; (**6b**), 21.9 (q), 50.8 (t), 174.0 (s), and phenyl signals. (The signal due to the α-carbon was not detected).

*β-Chloro-α-methyl-*N*-phenyl-α-(phenylseleno)propionamide* (**5c**) *and α-Chloro-α-methyl-*N*-phenyl-β-(phenylseleno)-propionamide* (**6c**) (95:5) (Found: C, 54.5; H, 4.65; N, 3.95. $C_{16}H_{16}ClNOSe$ requires C, 54.48; H, 4.57; N, 3.97%); $\nu_{max.}$(film) 1 670 cm^{-1}; δ_H 1.96 (3 H, s), 3.60 (1 H, d, *J* 4.9 Hz), 3.65 (1 H, d, *J* 4.9 Hz), 7.0—7.6 (10 H, m), and 8.5 (1 H, br s); δ_C (25 MHz) (**5c**), 29.5 (q), 41.1 (t), 73.3 (s), 168.1 (s), and phenyl signals; (**6c**), 22.1 (q), 50.8 (t), and phenyl signals. (The signals due to the α-carbon and carbonyl carbon were not detected).

Conversion of (**2a**) *and* (**3a**) *into β-Methoxy-α-(phenylseleno)propionamide* (**8**) *and α-Methoxy-β-(phenylseleno)propionamide* (**9**).—A solution of the adducts (**2a**) and (**3a**) (1.05 g, 4 mmol) in methanol (50 ml) was stirred at ambient temperature for 72 h. After addition of saturated aqueous $NaHCO_3$ (40 ml) and water (80 ml) the products were extracted with dichloromethane (50 ml × 5), and the combined extracts were dried ($MgSO_4$) and evaporated to give a yellow solid. Purification by column chromatography [SiO_2 200 mesh, hexane–ethyl acetate (1:1) as eluant] gave a mixture of (**8**) and (**9**) (79:21) (791 mg, 73%) as a white solid (Found: C, 46.4; H, 5.00; N, 5.4. $C_{10}H_{13}NO_2Se$ requires C, 46.52; H, 5.08; N, 5.43%); $\nu_{max.}$(KBr) 3 370, 3 180, 1 655, 1 105, 735, and 695 cm^{-1}; δ_H (100 MHz) 3.36 [3 H, s, (**8**)], 3.41 [3 H, s, (**9**)], 3.6—4.1 (3 H, m), 5.9 (1 H, br s), 6.4 (1 H, br s), 7.1—7.4 (3 H, m), and 7.4—7.7 (2 H, m); δ_C (25 MHz) (* two signals overlapping) (**8**), 45.2 (d), 58.9 (q), 72.9 (t), 127.0 (s), 128.2 (d), 129.2 (d),* 132.9 (d),* and 173.9 (s); (**9**), 30.0 (t), 58.5 (q), 81.4 (d), 127.0 (s), 128.2 (d), 129.2(d),* 132.9 (d),* and 174.3 (s).

References

1 Presented at the 49th Annual Meeting of the Chemical Society of Japan, Tokyo, April, 1984; Abstract II, p. 810.
2 K. Uneyama, K. Takano, and S. Torii, *Tetrahedron Lett.*, 1982, **23**, 1161; *Bull. Chem. Soc. Jpn.*, 1983, **56**, 2867.
3 Z. Janousek, S. Piettre, F. Gorissen-Hervens, and H. G. Viehe, *J. Organomet. Chem.*, 1983, **250**, 197.
4 G. Zima and D. Liotta, *Synth. Commun.*, 1979, **9**, 697; T. A. Hase and P. Kukkola, *ibid.*, 1980, **10**, 451.
5 J. B. Stothers, 'Carbon-13 NMR Spectroscopy,' Academic Press, New York, 1972; A. Toshimitsu, T. Aoai, S. Uemura, and M. Okano, *J. Org. Chem.*, 1980, **45**, 1953.
6 M. Shimizu, R. Takeda, and I. Kuwajima, *Tetrahedron Lett.*, 1979, 3461; D. Liotta and G. Zima, *J. Org. Chem.*, 1980, **45**, 2551; D. Liotta, G. Zima, and M. Saindane, *ibid.*, 1982, **47**, 1258.

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