One-Pot Conversion of Allyl Alcohols into Selenochroman Derivatives

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A one-pot conversion of allyl alcohols into selenochroman derivatives was achieved by treatment with a phenyl trimethylsilyl selenide (TMSSePh)–$AlBr_3$ reagent system.

Key words selenochroman; selenide; allyl alcohol; aluminum bromide

Selenochroman derivatives appear to have interesting chemical properties, and the pioneering works on the chemistry of those compounds by Kataoka's group have opened the new field of organoselenium chemistry.[1)] Although several procedures for the synthesis of selenium-containing heterocyclic compounds have been documented,[2)] reported methods for the preparation of selenochroman derivatives have been quite limited.[3)] Recently, we reported a novel preparation of 4-substituted selenochromans through intramolecular cyclization of allyl phenyl selenides.[4)] For a more convenient method of constructing the selenochromans, we have intensively attempted a one-pot conversion of allyl alcohols into 4-substituted selenochroman derivatives.

In our previous report,[5)] 4-phenylselenochroman was unexpectedly obtained in the reaction of cinnamyl alcohol with phenyl trimethylsilyl selenide (TMSSePh)[6)] and aluminum bromide ($AlBr_3$). In order to generalize this transformation, the reaction of several allyl alcohols, **3**—**12**, with the TMSSePh–$AlBr_3$ system was examined.

Table 1 shows the results of a survey for the one-pot conversion of allyl alcohols into selenochroman derivatives. As mentioned above, simple cinnamyl alcohol (**1**) was transformed into 4-phenylselenochroman (**2**) when 1.2 eq of TMSSePh and 1.0 eq of $AlBr_3$ were used.[5)] *Cis* alcohol **3** was also converted to **2** with 2.0 eq of TMSSePh and $AlBr_3$ (condition A), but the reactivity was quite low. When 1-phenyl-2-propen-1-ol (**4**) was employed as a substrate, the same product **2** was obtained in moderate yield. This indicates that cinnamyl phenyl selenide is formed as an intermediate in the reaction of **4**.[4)] The reaction of 3-phenyl-2-buten-1-ol (**5**) proceeded to give 4-methyl-4-phenylselenochroman (**13**) in high yield. On the other hand, the reaction of 3,3-diphenyl-2-propen-1-ol (**6**) by condition A gave the corresponding selenochroman **14** in only poor yield, accompanied by allyl selenide **19** in 41% yield. In order to improve this reaction, we examined an alternative procedure (condition B), in which the stepwise addition of $AlBr_3$ was employed. An improvement of the yield in the reaction with **6** under condition B was observed. A spiro type product **15** was obtained from both allyl alcohols **7** and **8**. However, *ortho*-ethoxy cinnamyl alcohol (**9**) was converted to the corresponding selenochroman **16** in very low yield. When *para*-oxygenated cinnamyl alcohol **10** was used as a substrate, no selenochroman was detected but the corresponding cinnamyl phenyl selenide **20** was isolated. In contrast to the above results, the reaction of *meta*-ethoxy compound **11** proceeded smoothly to afford the desired product **17** in 58% yield. Non-cinnamyl type allyl alcohol was also examined. When prenyl alcohol (**12**) was employed, 4,4-dimethylselenochroman (**18**) was formed, although its chemical yield was low.[7)]

In conclusion, we have demonstrated that certain allylic type alcohols can be transformed into selenochroman compounds in one-pot by treatment with the TMSSePh–$AlBr_3$ combination. Studies of the detailed mechanism of this reaction are in progress.

Experimental

General Melting points were measured using a Yanagimoto micro melting point hot-plate apparatus and are uncorrected. IR spectra were recorded on a JASCO A-102 or FTIR-350 spectrophotometer. NMR spectra were taken in $CDCl_3$ with a Varian VXR-500, VXR-200 or Hitachi R-1500 (60 MHz) instrument. The chemical shifts are reported as δ ppm, and couplings are expressed in Hz. FAB-MS were recorded with a VG-70SE instrument using *m*-nitrobenzyl alcohol as the matrix. Elemental analyses were carried out on a Yanaco MT-5 CHN analyzer. Silica gel column chromatography was carried out with Wako-gel C-200. Merck Silica gel 60 F254 plates (No. 5744) were used for the preparative TLC. CH_2Cl_2 and $AlBr_3$ were used after distillation. All reactions were carried out under argon atmosphere.

Substrates Allyl alcohols **1** and **12** were commercially available, and **4**,[8)] **5**,[9)] **6**,[10)] **7**,[11)] **8**,[11)] **9**[12)] and **10**[13)] were synthesized according to the reported methods.

***(Z)*-3-Phenyl-2-propen-1-ol (3)** Compound **3** was prepared by the reduction of ethyl (*Z*)-3-phenyl-2-propenoate, which was derived by Ando's method.[14)]

Diisobutylaluminium hydride (DIBAL) (1.0 M solution in toluene, 1.36 ml, 1.36 mmol) was added to a solution of (*Z*)-3-phenylpropanoate[14)] (120 mg, 0.68 mmol) in dry toluene (1.0 ml) at −78 °C, and the mixture was stirred for 30 min at the same temperature. A small portion of methanol and 1 N NaOH aqueous solution were added to the reaction mixture. After extraction with ether, the organic layer was washed with brine, dried over $MgSO_4$, and evaporated to give a residue which was purified by silica gel column chromatography with ethyl acetate–hexane (1 : 5). (*Z*)-3-Phenyl-2-propen-1-ol (**3**)[15)] was obtained as a colorless oil (70.7 mg, 77%).

***(E)*-3-(3-Ethoxyphenyl)-2-propen-1-ol (11)** DIBAL (1.0 M solution in toluene, 20 ml, 20 mmol) was added to a solution of ethyl (*E*)-3-(3-ethoxyphenyl)propionate[16)] (2.0 g, 9.1 mmol) in dry toluene (20 ml) at −78 °C, and the mixture was stirred for 2 h at the same temperature. The reaction mixture was poured into 1 N NaOH aqueous solution. After extraction with ether, the organic layer was washed with brine, dried over $MgSO_4$, and evaporated to give a residue which was purified by silica gel column chromatography with ethyl acetate–hexane (1 : 10). Pure **11** was obtained as a colorless oil (1.27 g, 71%). ^{1}H-NMR (200 MHz) δ: 1.41 (3H, t, J=7.0), 4.03 (2H, q, J=7.0), 4.31 (2H, d, J=5.5), 6.34 (1H, dt, J=15.8, 5.5), 6.57 (1H, d, J=15.8), 6.79 (1H, dd, J=7.8, 2.4), 6.89—7.00 (2H, m), 7.21 (1H, t, J=7.8). IR ($CHCl_3$) cm^{-1}: 3300, 2960, 1575, 1475, 1440, 1380. HR-MS (FAB): Calcd for $C_{11}H_{14}O_2$ (M^+): 178.0994. Found: 178.1011.

Selenochroman Synthesis. Typical Procedure for Condition A (Run 4) To a mixture of TMSSePh[6)] (481.9 mg, 2.10 mmol), $AlBr_3$ (280.3 mg, 1.05 mmol) and CH_2Cl_2 (4.8 ml), a solution of **5** (155.8 mg, 1.05 mmol) in CH_2Cl_2 (1.5 ml) was added dropwise *via* a cannula over a period of 10 min. After stirring for 5 h at room temperature (r.t.), the reaction mixture was poured into 1 N NaOH aqueous solution and extracted with CH_2Cl_2. The organic layer was washed with brine, dried over $MgSO_4$, and evaporated to give a residue which was purified by silica gel column chromatography with CH_2Cl_2–hexane (1 : 10). Diphenyldiselenide (112.8 mg) was obtained from

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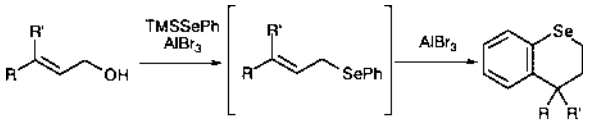
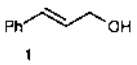
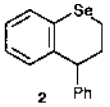
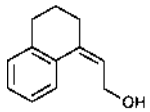
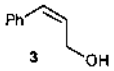
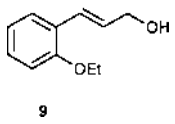
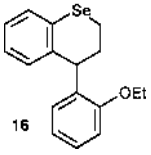
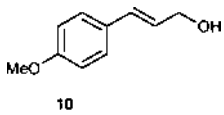
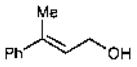
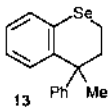
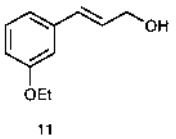
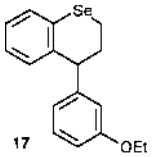
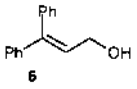
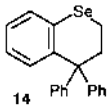
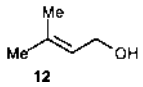
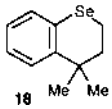
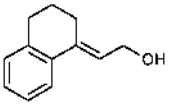
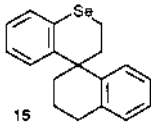
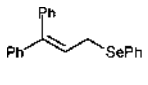
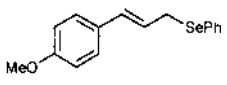
Table 1. One-Pot Synthesis of Selenochroman Derivatives from Allyl Alcohols



Run	Substrate	Condition[a]	Time (h)	Product	Yield (%)	Run	Substrate	Condition[a]	Time (h)	Product	Yield (%)
1	 **1**	A[b]	2	 **2**	69[c]	8	 **8**	B	[a]	**15**	64
2	 **3**	A	21	**2**	38	9	 **9**	B	[a]	 **16**	13
3	 **4**	A	3	**2**	41	10	 **10**	A	0.5	—[e]	0
4	 **5**	A	5	 **13**	86	11	 **11**	B	[a]	 **17**	58
5	 **6**	A	3	 **14**	15[d]	12	 **12**	B	[a]	 **18**	27
6	**6**	B	[a]	**14**	61						
7	 **7**	B	[a]	 **15**	72						

a) Condition A: After the addition of a mixture of alcohol and CH_2Cl_2 into a solution of TMSSePh (2.0 eq) and $AlBr_3$ (1.0 eq) in CH_2Cl_2, the reaction mixture was stirred for the indicated time at r.t. Condition B: $AlBr_3$ (1.0 eq) was added to a mixture of alcohol and TMSSePh (1.2 eq) in CH_2Cl_2 at −78 °C, and the mixture was warmed to r.t. After consumption of the starting alcohol was detected by TLC analysis, the reaction mixture was cooled to −78 °C, and then $AlBr_3$ (1.0 eq) was added again. The reaction mixture was warmed to r.t. and stirred for 30 min. *b*) 1.2 eq of TMSSePh was used. *c*) See Ref. 5. *d*) 1-Phenylseleno-3,3-diphenyl-2-propene (**19**) was obtained in 41% yield. *e*) 3-(4-Methoxyphenyl)-1-phenylseleno-2-propene (**20**) was obtained in 22% yield.


19


20

the less polar fraction, and **13** (257.4 mg, 86%) from the polar fraction.

Typical Procedure for Condition B (Run 6) To a mixture of TMSSePh[6] (65 mg, 0.29 mmol), $AlBr_3$ (64 mg, 0.24 mmol) and CH_2Cl_2 (0.8 ml), a solution of **6** (50 mg, 0.24 mmol) in CH_2Cl_2 (0.5 ml) was added at −78 °C, then the reaction mixture was warmed to r.t. After stirring for 30 min at r.t., the reaction mixture was cooled to −78 °C. $AlBr_3$ (64 mg, 0.24 mmol) was added to the mixture, warmed to r.t., and stirred for 30 min. The mixture was poured into 1 N NaOH aqueous solution and extracted with CH_2Cl_2. The organic layer was washed with brine, dried over $MgSO_4$ and evaporated to give a residue which was purified by silica gel column chromatography with hexane. Selenochroman **14** was obtained in a pure form (31.4 mg, 61%).

4-Phenylselenochroman (**2**)[5] and 4-methyl-4-phenylselenochroman (**13**)[4]: The spectral data for these compounds were previously reported.

4,4-Diphenylselenochroman (**14**): Colorless needles; mp 146.0—148.0 °C (ether–methanol). ^{1}H-NMR (500 MHz) δ: 2.79 (2H, t, J=6.5), 2.93 (2H, t, J=6.5), 6.53 (1H, dd, J=8.0, 1.5), 6.90 (1H, td, J=8.0, 1.5), 6.98—7.02 (4H, m), 7.06 (1H, td, J=8.0, 1.5), 7.23—7.35 (7H, m). ^{13}C-NMR (125 MHz) δ: 16.4, 36.5, 53.7, 124.3, 126.5, 127.0, 128.1, 129.0, 129.3, 131.7, 142.8, 146.0. IR (KBr) cm^{-1}: 1580, 1560, 1490, 1465, 1440, 1430. FAB-MS (positive ion mode) m/z: 350 (M^+). *Anal.* Calcd for $C_{21}H_{18}Se$: C, 72.20; H, 5.19. Found: C, 72.29; H, 5.27.

Spiro[(1,2,3,4-tetrahydronaphthalene)-1,4′-selenochroman] (**15**): Colorless needles; mp 83.0—85.0 °C (ether–methanol). ^{1}H-NMR (500 MHz) δ: 1.68—1.77 (2H, m), 1.88 (1H, ddd, J=13.0, 9.5, 3.0), 2.11 (1H, ddd, J=10.5, 8.5, 3.0), 2.27 (1H, dt, J=14.0, 5.0), 2.47 (1H, td, J=16.0, 6.0), 2.79—2.94 (2H, m), 2.98 (1H, td, J=11.0, 4.0), 3.33 (1H, ddd, J=14.5, 10.0, 3.5) 6.60 (1H, dd, J=7.5, 1.5), 6.85 (1H, td, J=7.5, 1.5), 6.95—6.99 (2H, m), 7.05—7.15 (3H, m), 7.24 (1H, dd, J=7.5, 1.5). ^{13}C-NMR (125 MHz) δ: 15.6, 18.4, 30.4, 34.1, 37.1, 42.4, 124.1, 125.9, 126.1, 126.3, 127.1, 128.7, 128.9, 129.0, 131.1, 137.4, 143.7, 144.8. IR ($CHCl_3$) cm^{-1}: 2870, 1460, 1430. FAB-MS (positive ion mode) m/z: 314 (M^+). *Anal.* Calcd for $C_{18}H_{18}Se$: C, 69.01; H, 5.79. Found: C, 69.05; H, 5.56.

4-(2-Ethoxyphenyl)selenochroman (**16**): Colorless needles; mp 46.0—

48.0 °C (ether–methanol). ^{1}H-NMR (200 MHz) δ: 1.44 (3H, t, J=7.0), 2.10—2.27 (1H, m), 2.51—2.65 (1H, m), 2.79—2.87 (2H, m), 4.08 (2H, q, J=7.0), 4.63 (1H, t, J=4.8), 6.73—7.33 (8H, m). ^{13}C-NMR (50 MHz) δ: 15.0, 17.1, 27.8, 39.4, 63.5, 111.2, 120.2, 124.8, 126.9, 127.3, 128.8, 130.4, 131.4, 131.9, 138.8, 155.7. IR (KBr) cm^{-1}: 1230. FAB-MS (positive ion mode) m/z: 318 (M^+). *Anal.* Calcd for $C_{17}H_{18}OSe$: C, 64.35; H, 5.72. Found: C, 64.26; H, 5.48.

4-(3-Ethoxyphenyl)selenochroman (**17**): Yellow oil. ^{1}H-NMR (500 MHz) δ: 1.39 (3H, t, J=7.0), 2.30—2.44 (2H, m), 2.89—2.93 (2H, m), 4.00 (2H, q, J=7.0), 4.15 (1H, t, J=6.0), 6.63—6.73 (2H, m), 6.74 (1H, dd, J=8.5, 2.0), 6.91 (1H, d, J=7.5), 6.99 (1H, td, J=7.5, 1.5), 7.07 (1H, td, J=7.5, 2.0), 7.18—7.33 (2H, m). ^{13}C-NMR (125 MHz) δ: 14.8, 16.6, 30.5, 45.8, 63.2, 111.9, 114.8, 120.6, 124.8, 127.9, 128.4, 128.9, 129.2, 131.3, 138.2, 145.4, 159.0. IR ($CHCl_3$) cm^{-1}: 2900, 1580, 1460, 1430. FAB-MS (positive ion mode) m/z: 318 (M^+). HR-MS (FAB): Calcd for $C_{17}H_{18}OSe$ (M^+): 318.0523. Found: 318.0520.

4,4-Dimethylselenochroman (**18**): Yellow oil. ^{1}H-NMR (200 MHz) δ: 1.32 (6H, s), 1.98 (2H, t, J=6.4), 3.01 (t, J=6.4), 6.94—7.11 (2H, m), 7.22 (1H, dd, J=7.4, 2.0), 7.39 (1H, dd, J=7.6, 1.8). ^{13}C-NMR (50 MHz) δ: 16.0, 29.0, 34.3, 37.6, 124.9, 126.0, 126.3, 129.0, 144.6. IR ($CHCl_3$) cm^{-1}: 2880, 1580, 1460, 1430. FAB-MS (positive ion mode) m/z: 226 (M^+). HR-MS (FAB): Calcd for $C_{11}H_{14}Se$ (M^+): 226.0261. Found: 226.0236.

3,3-Diphenyl-1-phenylseleno-2-propene (**19**): Colorless needles; mp 50.5—51 °C (ether–methanol). ^{1}H-NMR (60 MHz) δ: 3.63 (2H, d, J=8.2), 6.27 (1H, t, J=8.2), 6.90—7.54 (15H, m). ^{13}C-NMR (50 MHz) δ: 27.5, 124.9, 127.1, 127.2, 127.3, 127.4, 128.1, 128.2, 128.9, 129.7, 130.0, 133.8, 138.8, 141.9, 143.6. IR (KBr) cm^{-1}: 1580, 1500, 1480. FAB-MS (positive ion mode) m/z: 350 (M^+). *Anal.* Calcd for $C_{21}H_{18}Se$: C, 72.20; H, 5.19. Found: C, 72.15; H, 5.32.

(*E*)-3-(4-Methoxyphenyl)-1-phenylseleno-2-propene (**20**): Colorless prisms; mp 93.5—95.5 °C (ethanol). ^{1}H-NMR (500 MHz) δ: 3.67 (2H, d, J=6.5), 3.78 (3H, s), 6.17 (1H, dt, J=15.0, 6.5), 6.19 (1H, d, J=15.0), 6.81 (2H, d, J=9.0), 7.21 (2H, d, J=9.0), 7.23—7.26 (3H, m), 7.49—7.53 (2H, m). ^{13}C-NMR (50 MHz) δ: 30.9, 55.2, 113.9, 123.6, 127.2, 127.4, 128.9, 129.6, 130.0, 131.6, 133.8, 159.1. ^{77}Se-NMR (38 MHz) δ: 348.3. IR ($CHCl_3$) cm^{-1}: 3000, 2825, 1605, 1510, 1205, 1170, 1030, 960, 820, 690. *Anal.* Calcd for $C_{16}H_{16}OSe$: C, 63.37; H, 5.32. Found: C, 63.49; H, 5.32.

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References and Notes

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