Supporting Information

Chalcogeno-Morita-Baylis-Hillman Reaction of Enones with Acetals:

Simple α -Alkoxyalkylation of Enones

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Figure S1 The ORTEP drawing of **7**.

Experimental Section

General Remarks: Melting points were obtained with a Yanagimoto micro-melting-point apparatus and are uncorrected. IR spectra of solids (KBr) and liquids (NaCl) were recorded on a JASCO IRA-100 spectrophotometer. ^1H -NMR spectra were recorded on a JEOL EX-400 (400 MHz) spectrometer with tetramethylsilane as an internal standard. The J values are given in Hz. ^{13}C -NMR spectra were obtained on a JEOL EX-400 spectrometer with CDCl_3 as an internal standard ($\delta = 77.0$). Mass spectra were recorded on a JEOL JMS-SX102A spectrometer with a direct-insertion probe at 70 eV. Elemental analyses of new compounds were performed by Yanaco CHN Corder MT-5. All chromatographic isolations were accomplished with BW-350 (Fuji Silysia) for column chromatography or with Kieselgel 60 PF254 containing gypsum (Merck) for preparative TLC. CH_2Cl_2 and MeCN were purified and dried by standard procedures and freshly distilled prior to use. The recycling preparative HPLC was performed by LC-918 liquid chromatography (Japan Analytical Industry Co., Ltd.) equipped with JAIGEL-1H and -2H columns (polystyrene gels).

General procedure for reactions of 1 or 2 with acetal 3: To a stirred solution of 1-[2-(methylsulfanyl)phenyl]propenone (**1**) (178 mg, 1.0 mmol) and benzaldehyde dimethyl acetal (**3**) (76 mg, 0.5 mmol) in dry CH_2Cl_2 (1.6 mL) was added dropwise $\text{BF}_3 \cdot \text{Et}_2\text{O}$ (127 μL , 1.0 mmol) at $-40\text{ }^\circ\text{C}$. The mixture was stirred at the same temperature for 1 h and then worked up as follows. Method A (Quenching with Et_3N): The reaction mixture was quenched by the addition of Et_3N (140 μL , 1.0 mmol). After the whole mixture was stirred at the same temperature for 10 min, it was poured into saturated aqueous NaCl and extracted with CH_2Cl_2 . The combined organic layers were dried over MgSO_4 and concentrated under reduced pressure. The residue was purified by the recycling preparative HPLC with chloroform. Method B (Quenching with saturated aqueous NaHCO_3): The reaction mixture was poured into a NaHCO_3 solution and extracted with CH_2Cl_2 . The combined organic layers were dried over MgSO_4 and concentrated under reduced pressure. The residue was purified by the recycling preparative HPLC with chloroform.

2-(Methoxyphenylmethyl)-1-(2-methylsulfanylphenyl)propenone (4)

Light yellow oil; IR (NaCl) 1646 (C=O) cm^{-1} ; ^1H NMR (CDCl_3) 2.37 (3 H, s, SMe), 3.36 (3 H, s, OMe), 5.44 and 6.10 (each 1 H, s, olefinic H), 5.67 (1 H, s, benzylic H), 7.11 (1 H, dt, $J = 1$ and 7.3, ArH), 7.22-7.43 (8 H, m, ArH); ^{13}C NMR (CDCl_3) 16.6 (q), 57.0 (q), 80.3 (d), 124.0 (d), 126.5 (t), 126.8 (d), 127.4 (2 $\times$ d), 127.7 (d), 128.2 (2 $\times$ d), 129.7 (d), 130.9 (d), 137.3 (s), 139.2 (s), 139.4 (s), 149.4 (s), 196.7 (s); LRMS (EI) m/z 298 (15%, M^+), 177 (100); Anal. Calcd for $\text{C}_{18}\text{H}_{18}\text{O}_2\text{S}$: C, 72.45; H, 6.08. Found: C, 72.30; H, 6.06.

2-(Methoxyphenylmethyl)-1-(2-methylselanylphenyl)propenone (5)

Light yellow oil; IR (NaCl) 1651 (C=O) cm^{-1} ; ^1H NMR (CDCl_3) 2.23 (3 H, s, SeMe), 3.36 (3 H, s, OMe), 5.44 and 5.98 (each 1 H, s, olefinic H), 5.61 (1 H, s, benzylic H), 7.14 (1 H, dt, $J = 1$ and 7.8, ArH), 7.26 (1 H, dt, $J = 1$ and 7.8, ArH), 7.32-7.45 (7 H, m, ArH); ^{13}C NMR (CDCl_3) 7.0 (q), 57.2 (q), 81.0 (d), 124.3 (d), 124.8 (t), 127.4 (2 $\times$ d), 127.9 (d), 128.4 (2 $\times$ d), 129.0 (d), 131.6 (d), 131.7 (d), 136.4 (s), 137.1 (s), 139.2 (s), 149.1 (s), 196.9 (s); LRMS (EI) m/z 346 (25%, M^+), 331 (100); Anal. Calcd for $\text{C}_{18}\text{H}_{18}\text{O}_2\text{Se}$: C, 62.61; H, 5.25. Found: C, 62.48; H, 5.30.

(1R*, 1'R*, 3S*)-3-(Methoxyphenylmethyl)-1-methyl-4-oxothiochromanium tetrafluoro borate (6)

White crystal*; mp = 141.5-142 $^{\circ}\text{C}$ ($\text{CH}_3\text{CN}/\text{CH}_2\text{Cl}_2$); IR (KBr) 1691 (C=O), 1063 (BF_4^-) cm^{-1} ; ^1H NMR (CD_3CN) 3.21 (3H, s, SMe), 3.27 (3H, s, OMe), 3.57 (1H, ddd, $J = 3.4, 3.9, 5.3$, 3-H), 4.07 (1H, dd, $J = 3.9, 13.4$, SCH_2), 4.28 (1H, dd, $J = 5.3, 13.4$, SCH_2), 5.04 (1H, d, $J = 3.4$, benzylic H), 7.18-7.20 (2H, m, ArH), 7.31-7.40 (3H, m, ArH), 7.80-7.92 (3H, m, ArH), 8.20 (1H, dd, $J = 2, 8$, ArH); ^{13}C NMR (CDCl_3) 30.5 (q), 41.3 (t), 50.1 (d), 58.0 (q), 84.7 (d), 127.7 (2 $\times$ d), 129.3 (s), 129.4

(d), 129.5 (2 × d), 130.4 (d), 130.9 (d), 134.1 (s), 134.3 (d), 136.4 (d), 138.1 (s), 189.2 (s) ; LRMS (EI): m/z 121 (100%), m/z 386 (M^+) was not observed.

*This crystal contained a trace amount of CH_3CN (recrystallization solvent) and it could not be completely removed. So Elemental analysis was failed to agree.

(1R*, 1'R*, 3S*)-3-(Methoxyphenylmethyl)-1-methyl-4-oxoselenochromanium tetrafluoroborate (7)

Colorless crystal*; mp = 150.5-151 °C (CH_3CN/Et_2O); IR (KBr) 1681 (C=O), 1062 (BF_4^-) cm^{-1} ; 1H NMR (CD_3CN) 2.93 (3H, s, SeMe), 3.28 (3H, s, OMe), 3.42-3.45 (1H, m, 3-H), 4.11 (1H, dd, J = 3.4, 12.2, $SeCH_2$), 4.28 (1H, dd, J = 3.9, 12.2, $SeCH_2$), 5.00 (1H, d, J = 2.9, benzylic H), 7.09 (2H, dd, J = 2 and 7.3, ArH), 7.31-7.38 (3H, m, ArH), 8.17 (1H, dd, J = 1, 7.3, ArH); ^{13}C NMR ($CDCl_3$) 27.7 (q), 40.4 (t), 52.1 (d), 58.0 (q), 86.1 (d), 127.5 (2 × d), 129.4 (d), 129.6 (2 × d), 131.0 (s), 131.3 (d), 131.6 (d), 133.4 (d), 135.6 (s), 136.4 (d), 138.0 (s), 191.0 (s); LRMS (EI): m/z 121 (100%), m/z 434 (M^+) was not observed.

*This crystal contained a trace amount of CH_3CN (recrystallization solvent) and it could not be completely removed. So Elemental analysis was failed to agree.

(1'R*, 3R*)-(Methoxyphenylmethyl)selenochroman-4-one (8-syn)

Product *syn*-**8** was isomerized to the *anti*-isomer *anti*-**8** during separation of the raw product by preparative TLC on silica gel eluting with hexane/AcOEt (5:1). The converting ratio was *syn:anti* = 7:3.

Yellow oil; IR (NaCl) 1677 (C=O) cm^{-1} ; 1H NMR ($CDCl_3$) 3.03-3.07 (2 H, m, -CHCO and CH_2Se), 3.31 (3 H, s, OMe), 3.51 (1 H, dd, J = 11.7 and 12.7, CH_2Se), 5.13 (1 H, d, J = 4.9, benzylic H), 7.20 (1 H, dt, J = 1.0, and 7.0, ArH), 7.25-7.38 (7 H, m, ArH), 8.05 (1 H, dd, J = 1.0 and 7.0, ArH); ^{13}C

NMR (100 MHz; CDCl₃) 18.9 (t), 55.5 (d), 57.6 (q), 80.6 (d), 125.7 (d), 126.9 (2 × d), 127.8 (d), 128.5 (2 × d), 130.1 (d), 130.6 (d), 132.9 (d), 133.9 (s), 136.1 (s), 139.5 (s), 194.9 (s); LRMS (EI) *m/z* 332 (5%, M⁺), 121 (100%); HRMS (C₁₇H₁₆O₂Se) found 332.0322, calcd 332.0316.

(1'R*, 3S*)-(Methoxyphenylmethyl)selenochroman-4-one (8-*anti*)

Pale yellow plates; mp = 95-95.5 °C (CH₂Cl₂/hexane); IR (KBr) 1682 (C=O) cm⁻¹; ¹H NMR (CDCl₃) 2.58 (1 H, dd, *J* = 7.3 and 12.7, -CHCO), 3.12 (3 H, s, OMe), 3.21 (1 H, ddd, *J* = 3.4, 7.3, and 8.3, CHCO), 3.30 (1 H, dd, *J* = 3.4 and 12.7, CH₂Se), 4.94 (1 H, d, *J* = 8.3, benzylic H), 7.21 (1 H, dt, *J* = 2, and 7.3, ArH), 7.31-7.50 (6 H, m, ArH), 7.49 (1 H, d, *J* = 7.3, ArH), 8.09 (1 H, dd, *J* = 1 and 7.3, ArH); ¹³C NMR (CDCl₃) 20.1 (t), 53.1 (d), 56.9 (q), 81.8 (d), 125.6 (d), 126.8 (d), 127.7 (2 × d), 128.5 (2 × d), 129.4 (d), 130.5 (d), 132.9 (d), 133.4 (s), 135.6 (s), 138.4 (s), 195.8 (s); LRMS (EI) *m/z* 332 (5%, M⁺), 121 (100%); Anal. Calcd for C₁₇H₁₆O₂Se: C, 61.64; H, 4.87. Found: C, 61.36; H, 5.09.

(1'R*, 3S*)-(Methoxyphenylmethyl)thiochroman-4-one (9-*anti*)

Yellow oil; IR (NaCl) 1680 (C=O) cm⁻¹; ¹H NMR (CDCl₃) 2.64 (1 H, dd, *J* = 7.7 and 13.3, -CHCO) 3.17-3.22 (4 H, m, OMe and CH₂S), 3.28 (1 H, dd, *J* = 3.4 and 13.2, CH₂S), 4.99 (1 H, d, *J* = 7.7, benzylic H), 7.15-7.39 (6 H, m, ArH), 7.45 (2 H, d, *J* = 7.7, ArH), 8.10 (1 H, dd, *J* = 1.5 and 7.7, ArH); ¹³C NMR (CDCl₃) 27.9 (t), 53.0 (d), 56.9 (q), 80.7 (d), 124.8 (d), 127.0 (d), 127.6 (2 × d), 128.3 (d), 128.5 (2 × d), 129.7 (d), 130.7 (s), 133.1 (d), 138.3 (s), 141.3 (s), 194.0 (s); LRMS (EI) *m/z* 284 (15%, M⁺), 121 (100%); HRMS (C₁₇H₁₆O₂Se) found 284.0863, calcd 284.0871.

General procedure for reactions of 1 or 2 with acetal 14: To a stirred solution of 1-[2-(methylsulfanyl)phenyl]propenone (**1**) (89 mg, 0.5 mmol) and 2-phenyl-1,3-dioxolane (**14**) (150 mg, 1.0 mmol) in dry CH₃CN (1.6 mL) was added dropwise BF₃·Et₂O (195 mg, 1.5 mmol) at 0°C. The mixture was stirred at the same temperature for 2 h and then worked up as follows. Method A

(Quenching with Et₃N): The reaction mixture was quenched by the addition of Et₃N (210 μ l, 1.5 mmol) and treated in a manner similar to that used for the reaction with **3**. The residue was purified by preparative TLC eluting with hexane/AcOEt (5:1). Method B (Quenching with saturated aqueous NaHCO₃): The reaction mixture was poured into a NaHCO₃ solution and treated in a manner similar to that used for the reaction with **3**.

2-[(2-Hydroxyethoxy)phenylmethyl]-1-(2-methylsulfanylphenyl)propenone (15)

Yellow oil; IR (NaCl) 3418 (OH), 1652 (C=O) cm⁻¹; ¹H NMR (CDCl₃) δ 2.34 (1 H, br s, OH), 2.40 (3 H, s, SMe), 3.55-3.65 (2 H, m, -CH₂OCH), 3.75 (2 H, br s, CH₂OH), 5.62 (1 H, s, benzylic H), 5.70 and 5.92 (each 1 H, s, olefinic H), 7.14 (1 H, dt, J = 1.5 and 7.5, ArH), 7.27-7.43 (8 H, m, ArH); ¹³C NMR (CDCl₃) δ 16.7 (q), 61.9 (t), 70.7 (t), 79.1 (d), 124.2 (d), 127.0 (d), 127.5 (2 $\times$ d), 127.9 (t), 128.0 (d), 128.5 (2 $\times$ d), 129.7 (d), 131.1 (d), 137.4 (s), 139.2 (s), 139.3 (s), 149.6 (s), 197.2 (s); LRMS (EI) m/z 328 (9%, M⁺), 177 (100%); HRMS (C₁₉H₂₀O₃S) found 328.1142, calcd 328.1133.

2-[(2-Hydroxyethoxy)phenylmethyl]-1-(2-methylselanylphenyl)propenone (16)

Yellow oil; IR (NaCl) 3330 (OH), 1642 (C=O) cm⁻¹; ¹H NMR (CDCl₃) δ 2.24 (3 H, s, SeMe), 2.36 (1 H, br s, OH), 3.53-3.63 (2 H, m, CH₂OCH), 3.73 (2 H, br s, CH₂OH), 5.60 (1 H, s, benzylic H), 5.63 and 5.84 (each 1 H, s, olefinic H), 7.16 (1 H, dt, J = 1.5 and 7.5, ArH), 7.29 (1 H, dt, J = 1.5 and 7.5, ArH), 7.35 (3 H, dt, J = 1.5 and 7.5, ArH), 7.41 (2 H, dd, J = 1.5 and 7.5, ArH), 7.47 (2 H, dt, J = 1.5 and 7.5, ArH); ¹³C NMR (CDCl₃) δ 7.0 (q), 61.8 (t), 70.6 (t), 79.7 (d), 124.4 (d), 125.9 (t), 127.5 (2 $\times$ d), 128.0 (d), 128.5 (2 $\times$ d), 129.2 (d), 131.3 (d), 131.7 (d), 136.2 (s), 137.2 (s), 139.0 (s), 149.2 (s), 197.2 (s); LRMS (EI) m/z 376 (28%, M⁺), 149 (100%); Anal. Calcd for C₁₉H₂₀O₃Se: C, 60.80; H, 5.37. Found: C, 60.61; H, 5.39.

2-({2-[2-Methylsulfanylbenzoyl]-1-phenylallyloxy}ethoxy)phenylmethyl)-1-(2-methylsulfanylphenyl)propenone (17)

Yellow oil; IR (NaCl) 1655 (C=O) cm^{-1} ; ^1H NMR (CDCl_3) 2.36 (6 H, s, SMe), 3.62-3.67 (4 H, m, OCH_2), 5.58 (2 H, s, benzylic H), 5.65 and 6.16 (each 2 H, s, olefinic H), 7.07-7.42 (18 H, m); ^{13}C NMR (CDCl_3) 16.7 (2 $\times$ q), 68.6 (2 $\times$ t), 78.9 (2 $\times$ d), 124.1 (2 $\times$ d), 126.7 (2 $\times$ t), 126.9 (2 $\times$ d), 127.4 (6 $\times$ d), 127.6 (4 $\times$ d), 128.2 (2 $\times$ d), 129.7 (2 $\times$ d), 130.9 (2 $\times$ d), 131.5 (2 $\times$ d), 137.5 (2 $\times$ d), 149.6 (2 $\times$ s), 196.7 (2 $\times$ s); LRMS (EI) m/z 594 (10%, M^+), 151 (100%); HRMS ($\text{C}_{36}\text{H}_{34}\text{O}_4\text{S}_2$) found 594.1909, calcd 594.1898.

2-({2-[2-Methylselanylbenzoyl]-1-phenylallyloxy}ethoxy)phenylmethyl)-1-(2-methylselanylphenyl)propenone (18)

Yellow oil; IR (NaCl) 1645 (C=O) cm^{-1} ; ^1H NMR (CDCl_3) 2.22 (6 H, s, SeMe), 3.62-3.67 (4 H, m, OCH_2), 5.57 (2 H, s, benzylic H), 5.57 and 6.05 (each 2 H, s, olefinic H), 7.10-7.44 (18 H, m); ^{13}C NMR (CDCl_3) 7.0 (2 $\times$ q), 68.6 (2 $\times$ t), 79.5 (2 $\times$ d), 124.3 (2 $\times$ d), 125.1 (2 $\times$ t), 127.5 (2 $\times$ d), 127.7 (6 $\times$ d), 128.3 (4 $\times$ d), 129.0 (2 $\times$ d), 131.5 (2 $\times$ d), 136.2 (2 $\times$ d), 137.4 (2 $\times$ d), 139.6 (2 $\times$ d), 149.3 (2 $\times$ s), 197.0 (2 $\times$ s); LRMS (EI) m/z 690 (5%, M^+), 199 (100%); Anal. Calcd for $\text{C}_{36}\text{H}_{34}\text{O}_4\text{Se}_2$: C, 62.79; H, 4.98. Found: C, 62.75; H, 5.04.

(1'R*, 3S*)-3-[(2-Hydroxyethoxy)phenylmethyl]selenochroman-4-one (19-syn)

Yellow oil; IR (NaCl) 3436 (OH), 1672 (C=O) cm^{-1} ; ^1H NMR (CDCl_3) 2.93 (1 H, dd, $J = 3.4$ and 12.2, $-\text{CH}_2\text{Se}-$), 3.11 (1 H, dt, $J = 3.4$ and 12.2, $-\text{CH}_2\text{Se}-$), 3.44-3.80 (6 H, m, $\text{HOCH}_2\text{CH}_2\text{-O-}$ and $-\text{CHC=O}$), 5.43 (1 H, d, $J = 3.4$, benzylic H), 7.21 (1 H, dt, $J = 1.0$ and 8.0, ArH), 7.26-7.40 (7 H, m, ArH), 8.12 (1 H, d, $J = 8.0$, ArH); ^{13}C NMR (CDCl_3) 18.0 (t), 55.4 (d), 61.8 (t), 70.8 (t), 78.7 (d),

125.7 (d), 126.7 (2 × d), 127.9 (d), 128.6 (2 × d), 130.1 (d), 130.7 (d), 133.2 (d), 133.7 (s), 136.3 (s), 139.3 (s), 195.7 (s); LRMS (EI) m/z 362 (13%, M^+), 151 (100%); Anal. Calcd for $C_{18}H_{18}O_3Se$: C, 59.84; H, 5.02. Found: C, 59.69; H, 5.23.

General procedure for reactions of 1 or 2 with ortho ester 21: To a stirred solution of 1-[2-(methylsulfanyl)phenyl]propenone (**1**) (89 mg, 0.5 mmol) and trimethyl orthoformate (**21**) (106 mg, 1.0 mmol) in dry CH_3CN (1.6 mL) was added dropwise $BF_3 \cdot Et_2O$ (195 μ L, 1.5 mmol) at $-40^\circ C$. The mixture was stirred at the same temperature for 1 h and then worked up as follows. Method A (Quenching with Et_3N): The reaction mixture was quenched by the addition of Et_3N (210 μ L, 1.5 mmol) and treated in a manner similar to that used for the reaction with **3**. The residue was purified by the recycling preparative HPLC. Method B (Quenching with saturated aqueous $NaHCO_3$): The reaction mixture was poured into a $NaHCO_3$ solution and treated in a manner similar to that used for the reaction with **3**.

2-Dimethoxymethyl-1-(2-methylsulfanylphenyl)propenone (22)

Yellow oil; IR (NaCl) 1656 (C=O) cm^{-1} ; 1H NMR ($CDCl_3$) 2.44 (3 H, s, SMe), 3.43 (6 H, s, OMe), 5.39 (1 H, s, CH), 5.76 and 6.24 (each 1 H, s, olefinic H), 7.18 (1 H, dt, $J = 1.5$ and 7.5, ArH), 7.36 (1 H, dd, $J = 1.5$ and 7.5, ArH), 7.42 (1 H, dd, $J = 1.5$ and 7.5, ArH), 7.45 (1 H, dt, $J = 1.5$ and 7.5, ArH); ^{13}C NMR ($CDCl_3$) 16.6 (q), 54.3 (2 × q), 100.0 (d), 124.1 (d), 126.8 (t), 128.1 (d), 129.9 (d), 131.1 (d), 137.0 (s), 139.5 (s), 145.1 (s), 196.3 (s); LRMS (EI) m/z 252 (12%, M^+), 151 (100%); Anal. Calcd for $C_{13}H_{16}O_3S$: C, 61.88; H, 6.39. Found: C, 61.73; H, 6.43.

2-Dimethoxymethyl-1-(2-methylselenanylphenyl)propenone (23)

Yellow oil; IR (NaCl) 1650 (C=O) cm^{-1} ; 1H NMR ($CDCl_3$) 2.26 (3 H, s, SeMe), 3.44 (6 H, s, OMe), 5.38 (1 H, s, CH), 5.70 and 6.16 (each 1 H, s, olefinic H), 7.22 (1 H, dt, $J = 1$ and 7.5, ArH), 7.42 (1 H,

dt, $J = 1.5$ and 7.5 , ArH), 7.49 (1 H, dd, $J = 1$ and 7.5 , ArH), 7.69 (1 H, dd, $J = 1.5$ and 7.5 , ArH); ^{13}C NMR (CDCl_3) 6.9 (q), 54.6 ($2 \times$ q), 100.8 (d), 124.3 (d), 126.1 (t), 129.0 (d), 132.0 ($2 \times$ d), 136.5 (s), 137.1 (s), 144.9 (s), 196.4 (s); LRMS (EI) m/z 300 (30%, M^+), 75 (100%); Anal. Calcd for $\text{C}_{13}\text{H}_{16}\text{O}_3\text{Se}$: C, 52.22; H, 5.36. Found: C, 52.18; H, 5.39.