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Supplementary Information

Modular Synthesis of Allyl Vinyl Ethers for the Enantioselective Construction of Functionalized Quaternary Stereocenters

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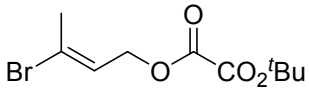
General procedure for the synthesis of allyl *tert*-butyl oxalates 7-10:

To a solution of the 3-halo-2-butenol in dichloromethane was added triethyl amine. The mixture was stirred for 5 min at ambient temperature and then cooled to 0 °C. A solution of *tert*-butyl 2-chloro-2-oxoacetate in dichloromethane was added over 5 min and the mixture was stirred at 0 °C for the specified time. Water was added and the mixture was extracted with dichloromethane. The combined extracts were washed with aqueous HCl (0.1 M), saturated aqueous sodium bicarbonate, brine, dried over Na_2SO_4 and concentrated under reduced pressure to provide the corresponding allyl *tert*-butyl oxalates. These were used in the next step without purification.

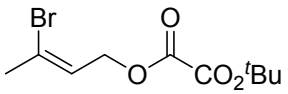
(*E*)-3-Bromobut-2-enyl *tert*-butyl oxalate (7):



The reaction of (*E*)-3-bromo-2-butenol (**3**)[1] (310 mg, 2.06 mmol), triethylamine (0.35 mL, 2.48 mmol) and *tert*-butyl 2-chloro-2-oxoacetate (405 mg, 2.48 mmol) in dichloromethane (5 mL) for 3 h, according to the general procedure, provided 478 mg (83%) of **7**; R_f = 0.20 (hexanes/EtOAc, 96:4).

IR (neat): 2983, 2920, 1760, 1736, 1371, 1327, 1260, 1194, 1138, 943, 841 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 6.09 (tq, 1H, *J* = 7.8, 1.4, CH_3C=C*H*), 4.68 (br d, 2H, *J* = 7.8, OC*H*$_2$), 2.36 (m, 3H, C*H*$_3$C=CH), 1.56 (s, 9H, C(C*H*$_3$)$_3$); ^{13}C NMR (75 MHz, $CDCl_3$): δ 158.2 (*C*O$_2$(CH$_3$)$_3$ or *C*O$_2$CH$_2$), 156.6 (*C*O$_2$CH$_2$ or *C*O$_2$(CH$_3$)$_3$), 128.5 (Br*C*=CH), 124.6 (BrC=*C*H), 85.2 (*C*(CH$_3$)$_3$, 62.5 (O*C*H$_2$), 27.7 (C(*C*H$_3$)$_3$), 23.9 (*C*H$_3$C=CH); HRMS (ESI, pos.): *m/z* 278.0156 (278.0154 calc. for $C_{10}H_{15}BrO_4$ (M^+)).

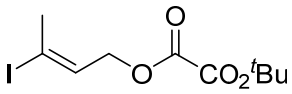
(*Z*)-3-Bromobut-2-enyl *tert*-Butyl oxalate (8):



The reaction of (*Z*)-3-bromo-2-butenol (**4**)[2] (2.60 g, 17.33 mmol), triethylamine (2.89 mL, 20.79 mmol) and *tert*-butyl 2-chloro-2-oxoacetate (3.41 g, 20.8 mmol) in dichloromethane (25 mL) for 2 h, according to the general procedure, provided 4.31 g (89%) of **8**; R_f = 0.24 (hexanes/EtOAc, 95:5).

IR (neat): 2982, 1762, 1736, 1371, 1320, 1194, 1135, 950, 843 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 5.92 (tq, 1H, *J* = 6.3, 1.3, CH_3C=C*H*), 4.84 (dq, 2H, *J* = 6.3, 1.3, OC*H*$_2$), 2.35 (apparent q, 3H, *J* = 1.3, C*H*$_3$C=CH), 1.56 (s, 9H, C(C*H*$_3$)$_3$); ^{13}C NMR (75 MHz, $CDCl_3$): δ 158.3 (*C*O$_2$(CH$_3$)$_3$ or *C*O$_2$CH$_2$), 156.7 (*C*O$_2$CH$_2$ or *C*O$_2$(CH$_3$)$_3$), 127.8 (Br*C*=CH), 122.3 (BrC=*C*H), 85.0 (*C*(CH$_3$)$_3$, 66.0 (O*C*H$_2$), 29.0 (*C*H$_3$C=CH), 27.7 (C(*C*H$_3$)$_3$); HRMS (APPI, pos.): *m/z* 278.0155 (278.0154 calc. for $C_{10}H_{15}BrO_4$ (M^+)).

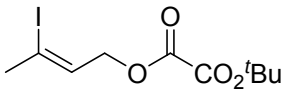
(*E*)-3-Iodobut-2-enyl *tert*-Butyl oxalate (9):



The reaction of (*E*)-3-iodo-2-butenol (**5**)[3] (1.75 g, 8.85 mmol), triethylamine (1.48 mL, 10.6 mmol) and *tert*-butyl 2-chloro-2-oxoacetate (1.74 g, 10.6 mmol) in dichloromethane (10 mL) for 1 h, according to the general procedure, provided 2.10 g (75%) of **9**; R_f = 0.21 (hexanes/EtOAc, 95:5).

IR (neat): 2983, 1761, 1737, 1371, 1329, 1310, 1263, 1193, 1139, 945, 842 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 6.38 (tq, 1H, *J* = 7.4, 1.5, CH_3C=C*H*), 4.64 (br d, *J* = 7.4, OC*H*$_2$), 2.52 (m, 3H, C*H*$_3$C=CH), 1.56 (s, 9H, C(C*H*$_3$)$_3$); ^{13}C NMR (75 MHz, $CDCl_3$): δ 158.1 (*C*O_2(CH_3)$_3$ or *C*O_2CH_2), 156.5 (*C*O_2CH_2 or *C*O_2(CH_3)$_3$), 133.1 (IC=*C*H), 102.9 (I*C*=CH), 85.2 (*C*(CH_3)$_3$, 62.5 (O*C*H$_2$), 28.3 (*C*H$_3$C=CH), 27.8 (C(*C*H$_3$)$_3$; HRMS (ESI, pos.): *m/z* 326.0015 (326.0015 calc. for $C_{10}H_{15}IO_4$ (M^+)).

(*Z*)-3-Iodobut-2-enyl *tert*-Butyl oxalate (10):



The reaction of (*Z*)-3-iodo-2-butenol (**6**)[4] (1.58 g, 7.98 mmol), triethylamine (1.34 mL, 9.57 mmol) and *tert*-butyl 2-chloro-2-oxoacetate (1.57 g, 9.57 mmol) in dichloromethane (10 mL) for 1 h, according to the general procedure, provided 2.01 g (77%) of **10**; R_f = 0.28 (hexanes/EtOAc, 95:5).

IR (neat): 2981, 1763, 1735, 1658, 1394, 1370, 1258, 1193, 1139, 1082, 950, 843 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 5.81 (tq, 1H, *J* = 6.1, 1.4, CH_3C=C*H*), 4.77 (dq, 2H, *J* = 6.1, 1.4, OC*H*$_2$), 2.57 (apparent q, 3H, *J* = 1.4, C*H*$_3$C=CH), 1.56 (s, 9H, C(C*H*$_3$)$_3$); ^{13}C NMR (75 MHz, $CDCl_3$): δ 158.3 (*C*O_2(CH_3)$_3$ or *C*O_2CH_2), 156.7 (*C*O_2CH_2 or *C*O_2(CH_3)$_3$), 128.5 (C=*C*H-CH_2), 105.6 (*C*=CH-CH_2), 85.1 (*C*(CH_3)$_3$, 70.7 (O*C*H$_2$), 33.9 (*C*H$_3$C=CH), 27.7 (*C*H$_3$)$_3$; HRMS (ESI, pos.): *m/z* 326.0006 (326.0015 calc. for $C_{10}H_{15}IO_4$ (M^+)).

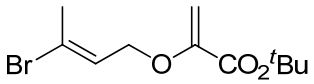
General procedure for the synthesis of allyl vinyl ethers:

A CEM Discover® microwave reactor was used for the microwave experiments. All reactions involving microwave heating were conducted in sealed reaction vessels. The temperature of the reaction mixture was monitored with an infrared sensor and the mixture was at the preset temperature (100 °C) in approximately 60s.

To a solution of the allyl *tert*-butyl oxalate in toluene in a 35 mL microwave vial was added a solution of the Petasis reagent (2.2 equiv.) in toluene.[5] The vial was sealed and the mixture was heated with stirring at 100 °C until completion of the reaction. The mixture was then cooled to ambient temperature, hexane (10 mL) was added, and the mixture was stirred for 5 min. The precipitated solids were removed by filtration through a pad of Celite® and the filtrate was

concentrated under reduced pressure (for the iodo compounds, this residue was briefly treated with aqueous HCl as described). The residue was purified by flash chromatography on silica gel (hexane:EtOAc, 99:1) to provide the allyl vinyl ethers.

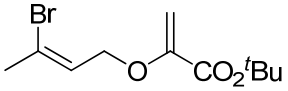
***tert*-Butyl (*E*)-2-((3-bromobut-2-enyl)oxy)acrylate (11):**



The reaction of **7** (478 mg, 1.71 mmol) and the Petasis reagent (5.60 mL of 0.67 M solution in toluene, 3.76 mmol) for 15 min according to the general procedure, provided after purification by flash column chromatography 190 mg (40%) of **11** as a yellow oil; R_f = 0.26 (hexanes/EtOAc, 96:4).

IR (neat): 2979, 2932, 1729, 1370, 1209, 1153, 1125, 845 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 6.12 (tq, 1H, *J* = 6.8, 1.3, CH_3C=C*H*), 5.29 (d, 1H, *J* = 2.6, C=C*H*H), 4.53 (d, 1H, *J* = 2.6, C=CH*H*), 4.26 (br d, 2H, *J* = 6.8, OCH_2), 2.32-2.29 (m, 3H, CH_3C=CH), 1.52 (s, 9H, C(CH_3)$_3$); ^{13}C NMR (75 MHz, $CDCl_3$): δ 162.0 (*C*=O), 151.7 (*C*=CH_2), 126.5 (C=*C*H-CH_2), 125.2 (*C*=CH-CH_2), 94.0 (C=*C*H_2), 82.0 *C*(CH_3)$_3$), 65.0 (O*C*H_2), 28.0 (C(*C*H_3)$_3$), 24.0 (*C*H_3C=C); HRMS (ESI, pos.): *m/z* 276.0362 (276.0361 calc. for $C_{11}H_{17}BrO_3$ (M^+)).

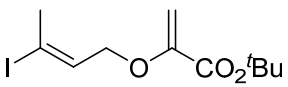
***tert*-Butyl (*Z*)-2-((3-bromobut-2-enyl)oxy)acrylate (12):**



The reaction of **8** (900 mg, 3.22 mmol) and the Petasis reagent (10.6 mL of 0.67 M solution in toluene, 7.08 mmol) for 15 min according to the general procedure, provided after purification by flash column chromatography 540 mg (61%) of **12** as a yellow oil; R_f = 0.27 (hexanes/EtOAc, 95:5).

IR (neat): 2978, 2930, 1727, 1620, 1392, 1368, 1207, 1152, 1036, 849 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 5.97-5.90 (m, 1H, CH_3C=C*H*), 5.28 (d, 1H, *J* = 2.6, C=C*H*H), 4.58 (d, 1H, *J* = 2.6, C=CH*H*), 4.45-4.39 (m, 2H, OCH_2), 2.33 (apparent q, 3H, *J* = 1.3, CH_3C=CH), 1.52 (s, 9H, C(CH_3)$_3$); ^{13}C NMR (75 MHz, $CDCl_3$): δ 162.1 (*C*=O), 151.5 (*C*=CH_2), 124.9 (*C*=CH-CH_2), 124.5 (C=*C*H-CH_2), 93.9 (C=*C*H_2), 82.0 (*C*(CH_3)$_3$, 68.2 (O*C*H_2), 28.8 (*C*H_3C=C), 28.0 (C(*C*H_3)$_3$; HRMS (ESI, pos.): *m/z* 276.0356 (276.0361 calc. for $C_{11}H_{17}BrO_3$ (M^+)).

***tert*-Butyl (*E*)-2-((3-iodobut-2-en-1-yl)oxy)acrylate (13):**

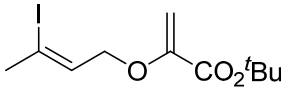


The reaction of **9** (100 mg, 0.30 mmol) and the Petasis reagent (1 mL of 0.67 M solution in toluene, 0.67 mmol) for 5 min according to the general procedure provided the crude product. This was

dissolved in dichloromethane (5 mL), the solution was washed with aqueous HCl (0.2 M, 2 x 3 mL) and the organic phase was concentrated. The residue was purified by flash column chromatography to provide 54 mg (56%) of **13** a yellow oil; R_f = 0.21 (hexanes/EtOAc, 96:4).

IR (neat): 2979, 2931, 1727, 1619, 1369, 1328, 1284, 1254, 1149, 1069, 1023, 996, 842 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 6.41 (tq, 1H, *J* = 6.5, 1.5, CH_3C=C*H*), 5.28 (d, 1H, *J* = 2.6, C=C*H*H), 4.53 (d, 1H, *J* = 2.6, C=CH*H*), 4.24 (br d, 2H, *J* = 6.5, OC*H*$_2$), 2.47 (m, 3H, C*H*$_3$C=CH), 1.50 (s, 9H, C(C*H*$_3$)$_3$); ^{13}C NMR (75 MHz, $CDCl_3$): δ 161.9 (*C*=O), 151.5 (*C*=CH_2), 135.2 (C=*C*H-CH_2), 99.1 (*C*=CH-CH_2), 93.8 (C=*C*H$_2$), 82.0 *C*(CH$_3$)$_3$), 65.2 (O*C*H$_2$), 28.3 (*C*H$_3$C=C), 28.0 (C(*C*H$_3$)$_3$); HRMS (APPI, pos.): *m/z* 324.0236 (324.0222 calc. for $C_{11}H_{17}IO_3$ (M^+)).

***tert*-Butyl (*Z*)-2-((3-iodobut-2-en-1-yl)oxy)acrylate (14):**



The reaction of **10** (270 mg, 0.83 mmol) and the Petasis reagent (2.8 mL of 0.67 M solution in toluene, 1.87 mmol) for 5 min according to the general procedure provided the crude product. This was dissolved in dichloromethane (10 mL) and the solution was washed with aqueous HCl (0.2 M, 2 x 10 mL) and the organic phase was concentrated. The residue was purified by flash column chromatography to provide 153 mg (57%) of **14** a yellow oil; R_f = 0.24 (hexanes/EtOAc, 96:4).

IR (neat): 2978, 2934, 1724, 1618, 1392, 1368, 1254, 1206, 1148, 1085, 1031, 847 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 5.89-5.82 (m, 1H, CH_3C=C*H*), 5.28 (d, 1H, *J* = 2.6, C=C*H*H), 4.57 (d, 1H, *J* = 2.6, C=CH*H*), 4.36-4.30 (m, 2H, OC*H*$_2$), 2.54 (apparent q, 3H, *J* = 1.5, C*H*$_3$C=CH), 1.52 (s, 9H, C(C*H*$_3$)$_3$); ^{13}C NMR (75 MHz, $CDCl_3$): δ 162.0 (*C*=O), 151.5 (*C*=CH_2), 130.7 (C=*C*H-CH_2), 102.3 (*C*=CH-CH_2), 94.1 (C=*C*H$_2$), 82.0 *C*(CH$_3$)$_3$), 73.0 (O*C*H$_2$), 33.6 (*C*H$_3$C=C), 28.0 (C(*C*H$_3$)$_3$); HRMS (APPI, pos.): *m/z* 324.0231 (324.0222 calc. for $C_{11}H_{17}IO_3$ (M^+)).

General Procedure 1 for Suzuki-Miyaura cross-coupling of 13 and 14 with arylboronic acids:

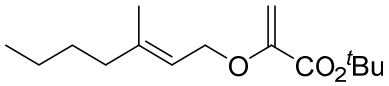
To the iodoallyl vinyl ether were added the arylboronic acid, KOH, Ag_2O and dioxane (purged with N_2 for 15 min) at room temperature followed by $PdCl_2(dppf)\cdot CH_2Cl_2$. The mixture was heated with stirring at 80 ºC until consumption of the iodo allyl vinyl ether (TLC). After cooling to ambient temperature, diethyl ether was added and the resulting solution was washed with brine, dried over Na_2SO_4 and concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel.

General Procedure 2 for Suzuki-Miyaura cross-coupling of 13 and 14 with alkylboronic acids:

To the iodoallyl vinyl ether were added the alkylboronic acid, K_2CO_3, Ag_2O and THF (purged with N_2 for 15 min) at room temperature followed by freshly prepared $Pd(PPh_3)_4$. The mixture was heated to reflux until consumption of the iodo allyl vinyl ether (TLC). After cooling

to ambient temperature, H_2O (1 mL) was added and the mixture was extracted with diethyl ether (3 x 2 mL) and the combined extracts were washed with saturated $NaHCO_3$, brine, dried over Na_2SO_4 and concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel.

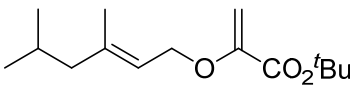
***tert*-Butyl (*E*)-2-(3-methylhept-2-enyloxy)acrylate (15a):**



The reaction of **13** (82 mg, 0.25 mmol), butylboronic acid (28 mg, 0.27 mmol), $Pd(PPh_3)_4$ (29 mg, 0.025 mmol), Ag_2O (145 mg, 0.62 mmol) and K_2CO_3 (103 mg, 0.74 mmol) in THF (1 mL) for 1 h according to General Procedure 2 provided, after purification by flash chromatography on silica gel (hexanes/EtOAc, 95:5), 39 mg (63%) of **15a** as a clear oil; R_f = 0.23 (hexanes/EtOAc, 97:3).

IR (neat): 2932, 1726, 1617, 1263, 1153, 909 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 5.42 (tq, 1H, *J* = 6.4, 1.3, CH_3C=C*H*), 5.23 (d, 1H, *J* = 2.3, C=CH*H*), 4.53 (d, 1H, *J* = 2.3, C=C*H*H), 4.31 (br d, 2H, *J* = 6.6, OCH_2), 2.06-1.98 (m, 2H, C=CCH_2), 1.67 (s, 3H, CH_3C=C), 1.51 (s, 9H, C(CH_3)$_3$), 1.46-1.24 (m, 4H, CH_2CH_2), 0.90 (t, 3H, *J* = 7.2, CH_2CH_3); ^{13}C NMR (75 MHz, $CDCl_3$): δ 162.3 (*C*=O), 152.1 (*C*=CH_2), 141.0 (CH_3C=CH), 118.8 (CH_3C=*C*H), 93.1 (C=*C*H_2), 81.6 (*C*(CH_3)$_3$, 65.5 (OCH_2), 39.2 (C=CCH_2CH_2), 29.8 ($CH_3CH_2CH_2$ or $CH_3CH_2CH_2$), 28.0 (C(*C*H_3)$_3$, 22.4 ($CH_3CH_2CH_2$ or $CH_3CH_2CH_2$), 16.6 (*C*H_3C=CH or *C*$H_3CH_2CH_2$), 14.0 (*C*$H_3CH_2CH_2$ or *C*H_3C=CH); HRMS (APPI, neg.): *m/z* 254.1875 (254.1882 calc. for $C_{15}H_{26}O_3$ (M^+)).

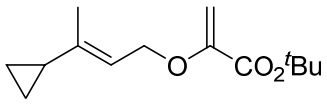
***tert*-Butyl (*E*)-2-(3,5-dimethylhex-2-enyloxy)acrylate (15b):**



The reaction of **13** (80 mg, 0.25 mmol), (2-methylpropyl)boronic acid (28 mg, 0.27 mmol), $Pd(PPh_3)_4$ (28 mg, 0.025 mmol), Ag_2O (142 mg, 0.61 mmol) and K_2CO_3 (102 mg, 0.74 mmol) in THF (1 mL) for 2h according to General Procedure 2 provided, after purification by flash chromatography on silica gel (hexanes/EtOAc, 95:5), 37mg (61%) of **15b** as a clear oil; R_f = 0.24 (hexanes/EtOAc, 97:3).

IR (neat): 2957, 2928, 2871, 1726, 1617, 1369, 1316, 1206, 1150, 1026, 847 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 5.40 (br t, 1H, *J* = 6.4, CH_3C=C*H*), 5.23 (d, 1H, *J* = 2.3, C=CH*H*), 4.53 (d, 1H, *J* = 2.3, C=C*H*H), 4.33 (br d, 2H, *J* = 6.4, OCH_2), 1.89 (br d, 2H, *J* = 7.4, $CH_2CH(CH_3)_2$), 1.81-1.71 (m, 1H, C*H*(CH_3)$_2$, 1.66-1.62 (br s, 3H, CH_3C=C), 1.51 (s, 9H, C(CH_3)$_3$), 0.85 (d, 6H, *J* = 6.5, CH(CH_3)$_2$); ^{13}C NMR (75 MHz, $CDCl_3$): δ 162.3 (*C*=O), 152.1 (*C*=CH_2), 139.8 (*i*-Bu*C*=CH), 120.3 (CH_3C=CH), 93.1 (C=*C*H_2), 81.6 (*C*(CH_3)$_3$, 65.5 (OCH_2), 49.2 (*C*$H_2CH(CH_3)_2$, 28.0 (C(*C*H_3)$_3$, 26.0 (*C*H(CH_3)$_2$, 22.4 (CH(*C*H_3)$_2$, 16.5 (*C*H_3C=C); HRMS (APPI, pos.): *m/z* 254.1875 (254.1882 calc. for $C_{15}H_{26}O_3$ (M^+)).

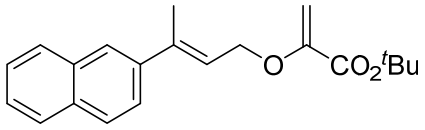
***tert*-Butyl (*E*)-2-(3-cyclopropylbut-2-enyloxy)acrylate (15c):**



The reaction of **13** (80 mg, 0.25 mmol), cyclopropylboronic acid (23 mg, 0.27 mmol), $Pd(PPh_3)_4$ (28 mg, 0.024 mmol), Ag_2O (142 mg, 0.61 mmol) and K_2CO_3 (102 mg, 0.74 mmol) in THF (1 mL) for 1 h according to General Procedure 2 provided, after purification by flash chromatography on silica gel (hexanes/EtOAc, 95:5), 37 mg (65%) of **15c** as a clear oil; R_f = 0.23 (hexanes/EtOAc, 97:3).

IR (neat): 2978, 2932, 1725, 1616, 1368, 1319, 1206, 1148, 1019 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 5.51-5.43 (br t, 1H, *J* = 6.8, CH_3C=C*H*), 5.23 (d, 1H, *J* = 2.3, C=CH*H*), 4.53 (d, 1H, *J* = 2.3, C=C*H*H), 4.31 (d, 2H, *J* = 6.5, OCH_2), 1.57 (s, 3H, CH_3C=C), 1.51 (s, 9H, C(CH_3)$_3$), 1.45-1.36 (m, 1H, C*H*CH_2CH_2), 0.64-0.54 (m, 2H, CH_2CH_2), 0.53-0.44 (m, 2H, CH_2CH_2); ^{13}C NMR (75 MHz, $CDCl_3$): δ 162.3 (*C*=O), 152.0 (*C*=CH_2), 141.5 (CH_3*C*=CH), 117.3 (CH_3C=*C*H), 93.1 (C=*C*H_2), 81.7 (*C*(CH_3)$_3$, 65.4 (O*C*H_2), 28.0 (C(*C*H_3)$_3$, 18.7 (*C*HCH_2CH_2 or *C*H_3), 14.4 (*C*H_3 or *C*HCH_2CH_2), 4.74 (*C*H_2*C*H_2); HRMS (APPI, neg.): *m/z* 238.1569 (238.1569 calc. for $C_{14}H_{22}O_3$ (M^+)).

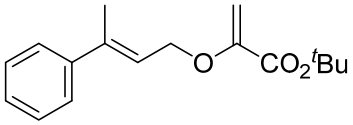
***tert*-Butyl (*E*)-2-(3-(naphthalen-2-yl)but-2-enyloxy)acrylate (15d):**



The reaction of **13** (110 mg, 0.34 mmol), 2-naphthylboronic acid (58 mg, 0.34 mmol), $PdCl_2$(dppf)·CH_2Cl_2 (4.10 mg, 0.005 mmol), Ag_2O (79 mg, 0.34 mmol) and KOH (19 mg, 0.34 mmol) in dioxane (1.2 mL) for 40 min according to General Procedure 1 provided, after purification by flash chromatography on silica gel (hexanes/EtOAc, 95:5), 75 mg (68%) of **15d** as a clear oil; R_f = 0.22 (hexanes/EtOAc, 95:5).

IR (neat): 2978, 2932, 1724, 1616, 1368, 1349, 1327, 1206, 1148, 1022, 850, 812 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 7.86-7.77 (m, 4H, Ar*H*), 7.6 (dd, 1H, *J* = 8.6, 1.9, Ar*H*), 7.50-7.40 (m, 2H, Ar*H*), 6.17 (tq, 1H, *J* = 6.1, 1.3, CC=C*H*), 5.31 (d, 1H, *J* = 2.4, C=CH*H*), 4.64 (d, 1H, *J* = 2.4, C=C*H*H), 4.59 (d, 2H, *J* = 6.1, OCH_2), 2.20 (m, 3H, CH_3C=C), 1.54 (s, 9H, C(CH_3)$_3$); ^{13}C NMR (75 MHz, $CDCl_3$): δ 162.3 (*C*=O), 152.0 (*C*=CH_2), 139.7 (ArC_{ipso}), 138.4 (Ar*C*=C), 133.4 (ArC_{ipso}), 132.8 (ArC_{ipso}), 128.2 (Ar*C*), 127.8 (Ar*C*), 127.5 (Ar*C*), 126.2 (Ar*C*), 125.9 (Ar*C*), 124.5 (Ar*C*), 124.2 (Ar*C*), 122.9 (ArC=*C*H), 93.6 (C=*C*H_2), 81.9 (*C*(CH_3)$_3$), 66.1 (O*C*H_2), 28.0 (*C*H_3)$_3$, 16.3 (*C*H_3); HRMS (APPI, pos.): *m/z* 324.1722 (324.1725 calc. for $C_{21}H_{24}O_3$ (M^+)).

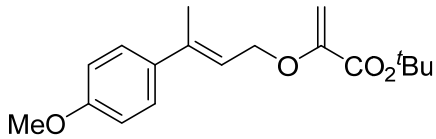
***tert*-Butyl (*E*)-2-(3-phenylbut-2-enyloxy)acrylate (15e):**



The reaction of **13** (100 mg, 0.31 mmol), phenylboronic acid (38 mg, 0.31 mmol), $PdCl_2(dppf)\cdot CH_2Cl_2$ (3.70 mg, 0.004 mmol), Ag_2O (72 mg, 0.31 mmol) and KOH (56 mg, 0.31 mmol) in dioxane (1.1 mL) for 20 min according to General Procedure 1 provided, after purification by flash chromatography on silica gel (hexanes/EtOAc, 95:5), 73 mg (87%) of **15e** as a clear oil; R_f = 0.21 (hexanes/EtOAc, 97:3).

IR (neat): 2979, 2931, 1726, 1618, 1369, 1337, 1317, 1207, 1150, 1032, 848 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 7.44-7.38 (m, 2H, Ar*H*), 7.36-7.26 (m, 3H, Ar*H*), 6.00 (tq, 1H, *J* = 6.2, 1.3, CC=C*H*), 5.29 (d, 1H, *J* = 2.4, C=CH*H*), 4.60 (d, 1H, *J* = 2.4, C=C*H*H), 4.53 (d, 2H, *J* = 6.2, OCH_2), 2.11-2.07 (m, 3H, CH_3C=C), 1.52 (s, 9H, C(CH_3)$_3$); ^{13}C NMR (75 MHz, $CDCl_3$): δ 162.2 (*C*=O), 152.0 (*C*=CH_2), 142.5 (ArC_{ipso}), 138.6 (Ph*C*=CH), 128.3 (2 x Ar*C*), 127.4 (Ar*C*), 125.8 (2 x Ar*C*), 122.3 (PhC=*C*H), 93.5 (C=*C*H_2), 81.8 (*C*(CH_3)$_3$, 66.0 (O*C*H_2), 28.0 (C(*C*H_3)$_3$, 16.4 (*C*H_3C=CH); HRMS (APPI, pos.): *m/z* 274.1581 (274.1569 calc. for $C_{17}H_{22}O_3$ (M^+)).

***tert*-Butyl (*E*)-2-((3-(4-methoxyphenyl)but-2-en-1-yl)oxy)acrylate (15f):**

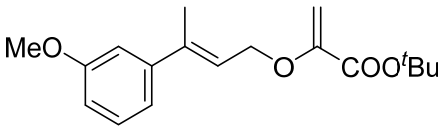


The reaction of **13** (85 mg, 0.26 mmol), 4-methoxyphenylboronic acid (39 mg, 0.26 mmol), $PdCl_2(dppf)\cdot CH_2Cl_2$ (3.30 mg, 0.004 mmol), Ag_2O (60 mg, 0.26 mmol) and KOH (14 mg, 0.26 mmol) in dioxane (1 mL) for 35 min according to General Procedure 1 provided, after purification by flash chromatography on silica gel (hexanes/EtOAc, 9:1), 60 mg (77%) of **15f** as a clear oil; R_f = 0.21 (hexanes/EtOAc, 93:7).

IR (neat): 2978, 2932, 1726, 1613, 1512, 1370, 1248, 1207, 1152, 1032 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 7.36 (d, 2H, *J* = 8.8, Ar*H*), 6.85 (d, 2H, *J* = 8.8, Ar*H*), 5.93 (tq, 1H, *J* = 6.3, 1.3, CC=C*H*), 5.28 (d, 1H, *J* = 2.4, C=CH*H*), 4.60 (d, 1H, *J* = 2.4, C=C*H*H), 4.51 (d, 2H, *J* = 6.3, OCH_2), 3.81 (s, 3H, OCH_3), 2.07 (m, 3H, CH_3C=C), 1.52 (s, 9H, C(CH_3)$_3$);

^{13}C NMR (75 MHz, $CDCl_3$): δ 162.3 (*C*=O), 159.1 (ArC_{ipso}), 152.0 (*C*=CH_2), 138.1 (ArC_{ipso}), 135.0 (Ar*C*=CH), 126.9 (2 x Ar*C*), 120.6 (ArC=*C*H), 113.6 (2 x Ar*C*), 93.4 (C=*C*H_2), 81.8 (*C*(CH_3)$_3$), 66.0 (O*C*H_2), 55.3 (O*C*H_3), 28.0 (*C*H_3)$_3$, 16.3 (*C*H_3); HRMS (APPI, neg.): *m/z* 304.1669 (304.1675 calc. for $C_{18}H_{24}O_4$ (M^+)).

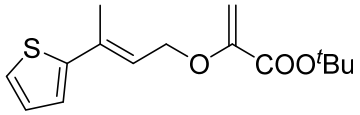
***tert*-Butyl (*E*)-2-(3-(3-methoxyphenyl)but-2-enyloxy)acrylate (15g):**



The reaction of **13** (114 mg, 0.35 mmol), 3-methoxyphenylboronic acid (53 mg, 0.35 mmol), $PdCl_2(dppf)\cdot CH_2Cl_2$ (4.10 mg, 0.005 mmol), Ag_2O (81 mg, 0.35 mmol) and KOH (20 mg, 0.35 mmol) in dioxane (1.2 mL) for 20 min according to General Procedure 1 provided, after purification by flash chromatography on silica gel (hexanes/EtOAc, 93:7), 87 mg (82%) of **15g** as a clear oil; R_f = 0.22 (hexanes/EtOAc, 93:7).

IR (neat): 2979, 2936, 1725, 1614, 1580, 1370, 1319, 1288, 1207, 1149, 1038 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 7.23 (t, 1H, *J* = 8.0, Ar*H*), 7.03-6.99 (m, 1H, Ar*H*), 6.96-6.94 (m, 1H, Ar*H*), 6.81 (br dd, 1H, *J* = 8.2, 2.5, Ar*H*), 6.01 (tq, 1H, *J* = 6.1, 1.3, CH_3C=C*H*), 5.29 (d, 1H, *J* = 2.4, C=CH*H*), 4.60 (d, 1H, *J* = 2.4, C=C*H*H), 4.52 (br d, 2H, *J* = 6.1, OCH_2), 3.82 (s, 3H, OCH_3), 2.09-2.06 (m, 3H, CH_3C=CH), 1.52 (s, 9H, C(CH_3)$_3$); ^{13}C NMR (75 MHz, $CDCl_3$): δ 162.2 (*C*=O), 159.5 (ArC_{ipso}), 152.0 (*C*=CH_2), 144.1 (ArC_{ipso}), 138.4 (CH_3C=CH), 129.2 (Ar*C*), 122.5 (CH_3C=*C*H), 118.3 (Ar*C*), 112.8 (Ar*C*), 111.6 (Ar*C*), 93.5 C=*C*H_2), 81.8 (*C*(CH_3)$_3$), 65.9 (O*C*H_2), 55.3 (O*C*H_3), 28.0 (*C*H_3)$_3$, 16.4 (*C*H_3); HRMS (APPI, neg.): *m/z* 304.1668 (304.1675 calc. for $C_{18}H_{24}O_4$ (M^+)).

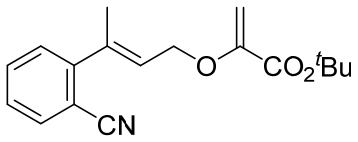
***tert*-Butyl (*E*)-2-((3-(thiophen-2-yl)but-2-en-1-yl)oxy)acrylate (15h):**



The reaction of **13** (101 mg, 0.31 mmol), 2-thienylboronic acid (0.31 mmol), $PdCl_2(dppf)\cdot CH_2Cl_2$ (0.004 mmol), Ag_2O (0.31 mmol) and KOH (0.31 mmol) in dioxane (1.1 mL) for 4h according to General Procedure 1 provided, after purification by flash chromatography on silica gel (hexanes/EtOAc, 95:5), 37 mg (43%) of **15h** as clear oil; R_f = 0.20 (hexanes/EtOAc, 97:3).

IR (neat): 2979, 1723, 1617, 1369, 1315, 1206, 1148, 849 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 7.16 (dd, 1H, *J* = 5.1, 1.2, Ar*H*), 7.05 (dd, 1H, *J* = 3.6, 1.2, Ar*H*), 6.97 (dd, 1H, *J* = 5.1, 3.6, Ar*H*), 6.13 (tq, 1H, *J* = 6.4, 1.3, CH_3C=C*H*), 5.29 (d, 1H, *J* = 2.5, C=CH*H*), 4.59 (d, 1H, *J* = 2.5, C=C*H*H), 4.50 (br d, 2H, *J* = 6.4, OCH_2), 2.12-2.09 (m, 3H, CH_3C=CH), 1.52 (s, 9H, C(CH_3)$_3$); ^{13}C NMR (75 MHz, $CDCl_3$): δ 162.2 (*C*=O), 152.0 (*C*=CH_2), 146.4 (ArC_{ipso}), 132.7 (CH_3C=CH), 127.3 (CH_3C=*C*H), 124.3 (Ar*C*), 123.4 (Ar*C*), 120.5 (Ar*C*), 93.6 (C=*C*H_2), 81.9 (*C*(CH_3)$_3$), 65.5 (O*C*H_2), 28.0 (*C*H_3)$_3$, 16.3 (*C*H_3); HRMS (APPI, neg.): *m/z* 280.1120 (280.1133 calc. for $C_{15}H_{20}O_3S$ (M^+)).

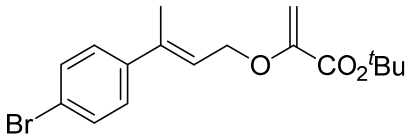
***tert*-Butyl (*E*)-2-((3-2-cyanophenyl)but-2-en-1-yl)oxy)acrylate (15i):**



The reaction of **13** (90 mg, 0.27 mmol), 2-cyanophenylboronic acid (0.27 mmol), $PdCl_2(dppf)\cdot CH_2Cl_2$ (0.004 mmol), Ag_2O (0.27 mmol) and KOH (0.27 mmol) in dioxane (1 mL) for 4h according to General Procedure 1 provided, after purification by flash chromatography on silica gel (hexanes/EtOAc, 9:1), 38 mg (47%) of **15i** as clear oil; R_f = 0.20 (hexanes/EtOAc, 93: 7).

IR (neat): 2979, 2933, 2225, 1724, 1619, 1370, 1336, 1317, 1288, 1206, 1148, 1030 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 7.66 (dd, 1H, *J* = 8.0, 1.4, Ar*H*), 7.54 (dt, 1H, *J* = 7.7, 1.4, Ar*H*), 7.38-7.32 (m, 1H, Ar*H*), 5.87 (tq, 1H, *J* = 6.0, 1.4, CC=C*H*), 5.32 (d, 1H, *J* = 2.6, C=CH*H*), 4.64 (d, 1H, *J* = 2.6, C=C*H*H), 4.55 (d, 2H, *J* = 6.0, OCH_2), 3.81 (s, 3H, OCH_3), 2.15 (m, 3H, CH_3C=C), 1.52 (s, 9H, C(CH_3)$_3$); ^{13}C NMR (75 MHz, $CDCl_3$): δ 162.1 (*C*=O), 151.8 (*C*=CH_2), 148.2 (Ar*C*$_{ipso}$), 136.9 (Ar*C*=CH), 133.3 (Ar*C*), 132.6 (Ar*C*), 128.5 (Ar*C*), 127.6 (ArC=*C*H or Ar*C*), 127.5 (Ar*C* or ArC=*C*H), 118.4 (*C*N), 110.6 (Ar*C*$_{ipso}$ (*C*-CN)), 93.8 (C=*C*H_2), 81.9 (*C*(CH_3)$_3$), 65.4 (O*C*H_2), 28.0 (*C*H_3)$_3$, 18.0 (*C*H_3); HRMS (APPI, neg.): *m/z* 299.1520 (299.1521 calc. for $C_{18}H_{21}NO_3$ (M^+)).

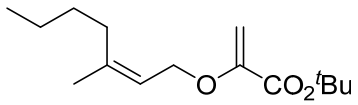
***tert*-Butyl (*E*)-2-((3-(4-bromophenyl)but-2-en-1-yl)oxy)acrylate (15j):**



The reaction of **13** (97 mg, 0.30 mmol), 4-bromophenylboronic acid (60 mg, 0.30 mmol), $PdCl_2(dppf)\cdot CH_2Cl_2$ (3.30 mg, 0.004 mmol), Ag_2O (69 mg, 0.30 mmol) and KOH (17 mg, 0.30 mmol) in dioxane (1.1 mL) for 40 min according to General Procedure 1 provided, after purification by flash chromatography on silica gel (hexanes/EtOAc, 9:1), 63 mg (60%) of **15j** as a clear oil; R_f = 0.26 (hexanes/EtOAc, 92:8).

IR (neat): 2979, 2932, 1724, 1617, 1484, 1368, 1335, 1316, 1206, 1148, 1007, 848, 812 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 7.43 (d, 2H, *J* = 8.5, Ar*H*), 7.27 (d, 2H, *J* = 8.5, Ar*H*), 6.00 (tq, 1H, *J* = 6.1, 1.3, CC=C*H*), 5.29 (d, 1H, *J* = 2.5, C=CH*H*), 4.59 (d, 1H, *J* = 2.5, C=C*H*H), 4.50 (d, 2H, *J* = 6.1, OCH_2), 2.06 (m, 3H, CH_3C=C), 1.52 (s, 9H, C(CH_3)$_3$); ^{13}C NMR (75 MHz, $CDCl_3$): δ 162.1 (*C*=O), 151.9 (*C*=CH_2), 141.4 (Ar*C*$_{ipso}$), 137.6 (Ar*C*=CH), 131.4 (2 x Ar*C*), 127.4 (2 x Ar*C*), 122.9 (Ar*C*$_{ipso}$ (C-Br) or ArC=*C*H), 121.3 (ArC=*C*H or Ar*C*$_{ipso}$ (C-Br)), 93.5 (C=*C*H_2), 81.9 (*C*(CH_3)$_3$), 65.8 (O*C*H_2), 28.0 (*C*H_3)$_3$, 16.3 (*C*H_3); HRMS (APPI, neg.): *m/z* 352.0684 (352.0674 calc. for $C_{17}H_{21}BrO_3$ (M^+)).

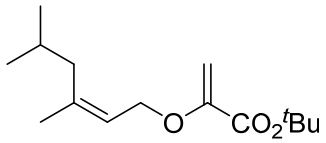
***tert*-Butyl (*Z*)-2-(3-methylhept-2-enyloxy)acrylate (16a):**



The reaction of **14** (75 mg, 0.23 mmol), butylboronic acid (26 mg, 0.25 mmol), $Pd(PPh_3)_4$ (26 mg, 0.023 mmol), Ag_2O (133 mg, 0.57 mmol) and K_2CO_3 (95 mg, 0.69 mmol) in THF (1 mL) for 1 h according to General Procedure 2 provided, after purification by flash chromatography on silica gel (hexanes/EtOAc, 95:5), 38 mg (67%) of **16a** as a clear oil; R_f = 0.24 (hexanes/EtOAc, 97:3).

IR (neat): 2961, 2931, 2867, 1729, 1617, 1370, 1324, 1207, 1154, 848 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 5.46-5.41 (br t, 1H, *J* = 6.3, CH_3C=C*H*), 5.23 (d, 1H, *J* = 2.3, C=CH*H*), 4.53 (d, 1H, *J* = 2.3, C=C*H*H), 4.28 (d, 2H, *J* = 6.7, OCH_2), 2.06 (t, 2H, *J* = 7.4, C=CCH_2), 1.74 (m, 3H, C=CCH_3), 1.51 (s, 9H, C(CH_3)$_3$), 1.44-1.26 (m, 4H, CH_2CH_2), 0.90 (t, 3H, CH_2CH_3); ^{13}C NMR (75 MHz, $CDCl_3$): δ 162.2 (*C*=O), 152.1 (*C*=CH_2), 141.7 (Bu*C*=C), 119.4 (C=*C*H), 92.9 (C=*C*H_2), 81.6 (*C*(CH_3)$_3$), 65.0 (O*C*H_2), 32.0, 30.2, 27.9, 23.4, 22.6, 13.9; HRMS (APPI, neg.): *m/z* 254.1879 (254.1882 calc. for $C_{15}H_{26}O_3$ (M^+)).

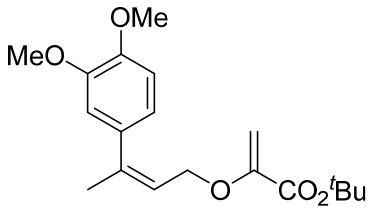
***tert*-Butyl (*Z*)-2-(3,5-dimethylhex-2-enyloxy)acrylate (16b):**



The reaction of **14** (50 mg, 0.15 mmol), (2-methylpropyl)boronic acid (17 mg, 0.16 mmol), $Pd(PPh_3)_4$ (17 mg, 0.014 mmol), Ag_2O (87 mg, 0.37 mmol) and K_2CO_3 (62 mg, 0.45 mmol) in THF (1 mL) for 3 h according to General Procedure 2 provided, after purification by flash chromatography on silica gel (hexanes/EtOAc, 95:5), 24 mg (63%) of **16b** as a clear oil; R_f = 0.24 (hexanes/EtOAc, 97:3).

IR (neat): 2957, 2930, 2871, 1727, 1616, 1460, 1369, 1317, 1254, 1206, 1150, 1019 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 5.54-5.46 (br t, 1H, *J* = 6.5, CH_3C=C*H*), 5.23 (d, 1H, *J* = 2.3, C=CH*H*), 4.53 (d, 1H, *J* = 2.4, C=C*H*H), 4.28 (br d, 2H, *J* = 6.6, OCH_2), 1.94 (d, 2H, 7.3, CH_2CH(CH_3)$_2$), 1.85-1.75 (m, 1H, C*H*(CH_3)$_2$, 1.75-1.70 (m, 3H, CH_3C=C), 1.51 (s, 9H, C(CH_3)$_3$), 0.88 (d, 6H, *J* =6.5, CH(CH_3)$_2$; ^{13}C NMR (75 MHz, $CDCl_3$): δ 162.3 (*C*=O), 152.1 (CH_3C=CH_2), 140.4 (*i*Bu*C*=CH), 120.7 (*C*=CH), 93.0 (C=*C*H_2), 81.7 (*C*(CH_3)$_3$, 65.1 (O*C*H_2), 41.6 (*C*H_2CH(CH_3)$_2$, 28.0 (C(*C*H_3)$_3$, 26.7 (*C*H(CH_3)$_2$ or *C*H_3C=C), 23.7 (*C*H_3C=C or *C*H(CH_3)$_2$), 22.5 (CH(*C*H_3)$_2$; HRMS (APPI, pos.): *m/z* 254.1880 (254.1882 calc. for $C_{15}H_{26}O_3$ (M^+)).

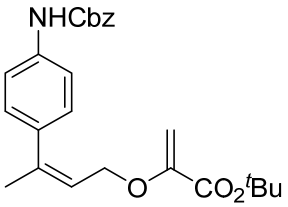
***tert*-Butyl (*Z*)-2-(3-(3,4-dimethoxyphenyl)but-2-enyloxy)acrylate (16c):**



The reaction of **14** (88 mg, 0.27 mmol), 3,4-dimethoxyphenylboronic acid (49 mg, 0.27 mmol), $PdCl_2(dppf)\cdot CH_2Cl_2$ (3.30 mg, 0.004 mmol), Ag_2O (62 mg, 0.27 mmol) and KOH (15 mg, 0.27 mmol) in dioxane (1 mL) for 30 min according to General Procedure 1 provided, after purification by flash chromatography on silica gel (hexanes/EtOAc, 93:7), 60 mg (67%) of **16c** as a clear oil; R_f = 0.21 (hexanes/EtOAc, 95:5).

IR (neat): 2976, 2937, 1724, 1616, 1513, 1460, 1370, 1318, 1255, 1205, 1146, 1025, 911, 849 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 6.88-6.81 (d, 1H, *J* = 8.0, Ar*H*), 6.79-6.72 (m, 2H, Ar*H*), 5.78-5.72 (tq, 1H, *J* = 7.0, 1.4, CC=C*H*), 5.16 (d, 1H, *J* = 2.3, C=CH*H*), 4.37 (d, 1H, *J* = 2.3, CC=C*H*H), 4.20 (br dd, 2H, *J* = 7.0, 1.1, CCH_2), 3.89 (s, 3H, ArOCH_3), 3.85 (s, 3H, ArOCH_3), 2.10 (m, 3H, C=CCH_3), 1.51 (s, 9H, C(CH_3)$_3$); ^{13}C NMR (75 MHz, $CDCl_3$): δ 162.2 (*C*=O), 151.7 (ArC_{ipso}), 148.5 (ArC_{ipso}), 148.3 (*C*=CH_2), 142.4 (Ph*C*=CH), 133.2 (ArC_{ipso}), 121.0 (ArC=*C*H), 120.0 (Ar*C*), 111.2 (Ar*C*), 110.9 (Ar*C*), 93.2 (C=*C*H_2), 81.7 (*C*(CH_3)$_3$, 66.1 (*C*H_2-O), 55.87 (O*C*H_3), 55.80 (O*C*H_3), 28.0 (*C*H_3)$_3$, 25.3 (*C*H_3); HRMS (APPI, pos.): *m/z* 334.1778 (334.1780 calc. for $C_{19}H_{26}O_5$ (M^+)).

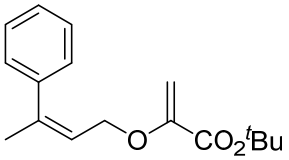
***tert*-Butyl (*Z*)-2-(3-(4-(benzyloxycarbonylamino)phenyl)but-2-enyloxy)acrylate (16d):**



The reaction of **14** (95 mg, 0.29 mmol), 4-Cbz-aminophenylboronic acid boronic acid (79 mg, 0.29 mmol), $PdCl_2(dppf)\cdot CH_2Cl_2$ (3.60 mg, 0.004 mmol), Ag_2O (67 mg, 0.29 mmol) and KOH (16 mg, 0.29 mmol) in dioxane (1.1 mL) for 30 min according to General Procedure 1 provided, after purification by flash chromatography on silica gel (hexanes/EtOAc, 85:15), 102 mg (84 %) of **16d** as a clear oil; R_f = 0.25 (hexanes/EtOAc, 85:15); IR (neat): 3350, 2977, 1710, 1614, 1593, 1525, 1316, 1208, 1149, 1050 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 7.45-7.27 (br m, 7H, Ar*H*), 7.12 (br d, 2H, Ar*H*, *J* = 6.8), 6.95-6.65 (br, 1H, N*H*) 5.73 (br t, 1H, *J* = 6.8, C=C*H*), 5.20 (br s, 2H, ArCH_2O), 5.15 (d, 1H, 2.3, C=CH*H*), 4.33 (d, 1H, 2.3, CC=C*H*H), 4.20 (br d, 2H, *J* = 6.8, OCH_2), 2.07 (br s, 3H, C=CCH_3), 1.50 (s, 9H, C(CH_3)$_3$); ^{13}C NMR (75 MHz, $CDCl_3$): δ 162.3 (*C*=O), 153.4 (*C*(O)NH_2), 151.6 (*C*=CH_2), 141.2 (ArC_{ipso}), 137.1 (ArC_{ipso}), 136.0 (ArC_{ipso}), 135.6 (Ph*C*=CH), 128.6 (2 x Ar*C*) 128.5 (2 x Ar*C*), 128.38 (2 x Ar*C*), 128.33 (2 x Ar*C*), 121.6 (ArC=*C*H), 118.4

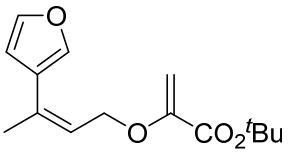
(Ar*C*), 93.3 (C=*C*H$_2$), 81.7 (*C*(CH$_3$)$_3$, 67.0 (Ph*C*H$_2$ or O*C*H$_2$), 66.0 (O*C*H$_2$ or Ph*C*H$_2$), 28.0 (*C*H$_3$)$_3$, 25.1 (*C*H$_3$); HRMS (APPI, pos.): *m/z* 254.1875 (254.1882 calc. for $C_{15}H_{26}O_3$ (M^+)).

***tert*-Butyl (*Z*)-2-(3-phenylbut-2-enyloxy)acrylate (16e):**



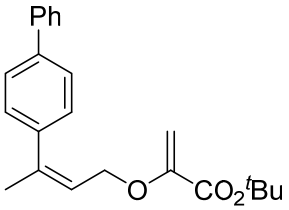
The reaction of **14** (100 mg, 0.30 mmol), phenylboronic acid (36 mg, 0.30 mmol), PdCl$_2$(dppf)·CH$_2$Cl$_2$ (3.30 mg, 0.004 mmol), Ag$_2$O (69 mg, 0.30 mmol) and KOH (17 mg, 0.30 mmol) in dioxane (1.1 mL) for 20 min according to General Procedure 1 provided, after purification by flash chromatography on silica gel (hexanes/Et$_2$O, 9:1), 59 mg (72%) of **16e** as a clear oil; R_f = 0.22 (hexanes/Et$_2$O, 96:4); IR (neat): 2978, 2935, 1723, 1617, 1368, 1319, 1205, 1148, 912 cm^{-1}; ^{1}H NMR (300 MHz, CDCl$_3$): δ 7.38-7.23 (m, 3H, Ar*H*), 7.21-7.14 (m, 2H, Ar*H*), 5.77 (tq, 1H, *J* = 6.7, 1.4, C=CC*H*CH$_2$), 5.14 (d, 1H, *J* = 2.3, C=CH*H*), 4.33 (d, 1H, *J* = 2.3, C=C*H*H), 4.21 (br dq, 2H, *J* = 6.7, 1.4 OC*H*$_2$), 2.10 (m, 3H, C*H*$_3$C=C), 1.51 (s, 9H, COC(C*H*$_3$)$_3$); ^{13}C NMR (75 MHz, CDCl$_3$): δ 162.2 (*C*=O), 151.7 (*C*=CH$_2$), 141.8 (Ph*C*=CH), 140.5 (Ar*C*$_{ipso}$), 128.2 (2 x Ar*C*), 127.7 (2 x Ar*C*), 127.4 (Ar*C*), 121.7 (PhC=*C*H), 93.2 (C=*C*H$_2$), 81.7 (*C*CH$_3$)$_3$, 66.1 (*C*H$_2$O), 28.0 (*C*H$_3$)$_3$, 25.3 (C=C*C*H$_3$); HRMS (APPI, neg.): *m/z* 274.1556 (274.1569 calc. for $C_{17}H_{22}O_3$ (M^+)).

***tert*-Butyl (*Z*)-2-((3-(furan-3-yl)but-2-en-1-yl)oxy)acrylate (16f):**



The reaction of **14** (99 mg, 0.30 mmol), 3-furanylboronic acid (34 mg, 0.30 mmol), PdCl$_2$(dppf)·CH$_2$Cl$_2$ (3.67 mg, 0.004 mmol), Ag$_2$O (69 mg, 0.30 mmol) and KOH (17 mg, 0.30 mmol) in dioxane (1.2 mL) for 3h according to General Procedure 1 provided, after purification by flash chromatography on silica gel (hexanes/EtOAc, 97:3), 51 mg (65%) of **16f** as a clear oil; R_f = 0.24 (hexanes/EtOAc, 97:3); IR (neat): 2923, 2853, 1727, 1619, 1456, 1368, 1320, 1256, 1206, 1152, 1023, 956, 873 cm^{-1}; ^{1}H NMR (300 MHz, CDCl$_3$): δ 7.41 (d, 2H, *J* = 1.4, Ar*H*), 6.41 (t, 1H, *J* = 1.4, Ar*H*), 5.71 (tq, 1H, *J* = 6.6, 1.3, CH$_3$C=C*H*), 5.23 (d, 1H, *J* = 2.4, C=CH*H*), 4.48 (d, 1H, *J* = 2.4, C=C*H*H), 4.37 (br m, 2H, *J* = 6.6, OC*H*$_2$), 2.04 (br q, 3H, *J* = 1.3, C*H*$_3$C=CH), 1.52 (s, 9H, C(C*H*$_3$)$_3$); ^{13}C NMR (75 MHz, CDCl$_3$): δ 162.2 (*C*=O), 151.7 (*C*=CH$_2$), 143.0 (Ar*C*), 140.4 (Ar*C*), 132.2 (CH$_3$*C*=CH or Ar*C*$_{ipso}$), 124.3 (Ar*C*$_{ipso}$ or CH$_3$*C*=CH), 121.7 (CH$_3$C=*C*H), 110.1 (Ar*C*), 93.4 (C=*C*H$_2$), 81.8 (*C*(CH$_3$)$_3$), 65.8 (OCH$_2$), 28.0 (C(*C*H$_3$)$_3$), 24.1 (*C*H$_3$C=CH); HRMS (APPI, pos.): *m/z* 264.1345 (264.1362 calc. for $C_{15}H_{20}O_4$ (M^+)).

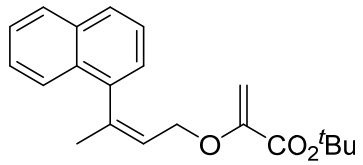
***tert*-Butyl (*Z*)-2-(3-(biphenyl-4-yl)but-2-enyloxy)acrylate (16g):**



The reaction of **14** (98 mg, 0.30 mmol), 4-biphenylboronic acid (59 mg, 0.30 mmol), $PdCl_2(dppf)\cdot CH_2Cl_2$ (3.70 mg, 0.004 mmol), Ag_2O (69 mg, 0.30 mmol) and KOH (17 mg, 0.30 mmol) in dioxane (1.1 mL) for 30 min according to General Procedure 1 provided, after purification by flash chromatography on silica gel (hexanes/EtOAc, 93:7), 70 mg (67%) of **16g** as a clear oil; R_f = 0.25 (hexanes/EtOAc, 93:7).

IR (neat): 2976, 2935, 1724, 1616, 1368, 1318, 1205, 1147, 1012 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 7.63-7.53 (m, 4H, Ar*H*), 7.47-7.40 (m, 2H, Ar*H*), 7.37-7.25 (m, 3H, Ar*H*), 5.81 (tq, 1H, *J* = 6.7, 1.4, C=C*H*), 5.17 (d, 1H, *J* = 2.3, C=CH*H*), 4.37 (d, 1H, *J* = 2.3, C=C*H*H), 4.27 (br dd, 2H, *J* = 6.7, 1.2, OCH_2), 2.14 (m, 3H, C=CCH_3), 1.51 (s, 9H, C(CH_3)$_3$); ^{13}C NMR (75 MHz, $CDCl_3$): δ 162.3 (*C*=O), 151.7 (*C*=CH_2), 141.4 (Ar*C*$_{ipso}$), 140.7 (Ar*C*$_{ipso}$), 140.2 (Ar*C*$_{ipso}$), 139.5 (Ph*C*=CH), 128.8 (2 x Ar*C*), 128.2 (2 x Ar*C*), 127.4 (Ar*C*), 127.0 (2 x Ar*C*), 126.9 (2 x Ar*C*), 122.0 (ArC=*C*H), 93.3 (C=*C*H_2), 81.7 (*C*(CH$_3$)$_3$, 66.1 (O*C*H_2), 28.0 (*C*H$_3$)$_3$, 25.2 (*C*H$_3$); HRMS (APPI, neg.): *m/z* 423.2047 (423.2046 calc. for $C_{25}H_{29}NO_5$ (M^+)).

***tert*-Butyl (*Z*)-2-(3-(naphthalen-1-yl)but-2-enyloxy)acrylate (16h):**



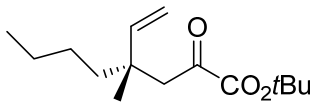
The reaction of **14** (101 mg, 0.31 mmol), 1-naphthylboronic acid (53 mg, 0.31 mmol), $PdCl_2(dppf)\cdot CH_2Cl_2$ (3.80 mg, 0.004 mmol), Ag_2O (72 mg, 0.31 mmol) and KOH (17 mg, 0.31 mmol) in dioxane (1.1 mL) for 1 h according to General Procedure 1 provided, after purification by flash chromatography on silica gel (hexanes/EtOAc, 93:7), 80 mg (80%) of **16h** as clear oil; R_f = 0.22 (hexanes/EtOAc, 93:7).

IR (neat): 2975, 2934, 1724, 1617, 1369, 1316, 1205, 1147, 1020 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 7.90-7.74 (m, 3H, Ar*H*), 7.51-7.40 (m, 3H, Ar*H*), 7.27-7.22 (m, 1H, Ar*H*), 6.02 (tq, 1H, *J* = 6.4, 1.5, CH_3C=C*H*), 5.04 (d, 1H, *J* = 2.4, C=CH*H*), 4.19 (d, 1H, *J* = 2.4, C=C*H*H), 3.99-3.91 (br m, 2H, OCH_2), 2.16 (br q, 3H, *J* = 1.4, CH_3C=C), 1.48 (s, 9H, C(CH_3)$_3$); ^{13}C NMR (75 MHz, $CDCl_3$): δ 162.2 (*C*=O), 151.7 (*C*=CH_2), 140.0 (Ar*C*$_{ipso}$), 138.8 (Ar*C*=C), 133.7 (Ar*C*$_{ipso}$), 130.6 (Ar*C*$_{ipso}$), 128.4 (Ar*C*), 127.5 (Ar*C*), 126.2 (Ar*C*), 125.9 (Ar*C*), 125.5 (Ar*C*), 125.2 (Ar*C*), 124.9 (Ar*C*), 123.9 (ArC=*C*H), 93.2 (C=CH_2), 81.6 *C*(CH$_3$)$_3$), 66.4 (O*C*H_2), 28.0 (C(*C*H$_3$)$_3$), 26.1 (*C*H$_3$C=C); HRMS (APPI, neg.): *m/z* 324.1721 (324.1725 calc. for $C_{21}H_{24}O_3$ (M^+)).

General procedure for the rearrangement of 15 to 17:

To a suspension of $Cu(OTf)_2$ in ether was added **15** and the mixture was stirred at ambient temperature for 1 h. To the resulting solution was added a solution of the allyl vinyl ether in ether. The resulting solution was stirred at ambient temperature for the specified time. The solution was concentrated and the residue was purified by flash chromatography on silica gel to provide **17**.

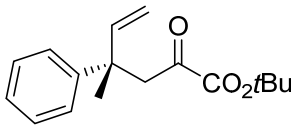
***tert*-Butyl (*S*)-4-methyl-2-oxo-4-vinyloctanoate (17a):**



Treatment of **15a** (60 mg, 0.24 mmol) with the complex derived from $Cu(OTf)_2$ (8.7 mg, 0.024 mmol) and (*R*,*R*)-2,2'-isopropylidene-bis(4-phenyl-2-oxazoline) (8 mg, 0.024 mmol) in ether (1 mL) for 92 h according to the general procedure provided, after purification by flash chromatography on silica gel (hexanes/EtOAc, 97:3), 35 mg (58%) of **17a** as a clear oil; R_f = 0.27 (hexanes/EtOAc, 97:3).

IR (neat): 3084, 2958, 2930, 1720, 1460, 1370, 1283, 1257, 1155, 1056, 1008, 914, 866 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 5.81 (dd, 1H, *J* = 17.5, 10.8, C*H*=CH_2), 5.00 (dd, 1H, *J* = 10.8, 1.0, CH=C*H*$_2$), 4.93 (dd, 1H, *J* = 17.5, 1.0, CH=C*H*$_2$), 2.90 (d, 1H, *J* = 14.2, C*H*$_2$C(O)), 2.68 (d, 1H, *J* = 14.2, C*H*$_2$C(O)), 1.54 (s, 9H, C(C*H*$_3$)$_3$), 1.45-1.35 (m, 2H, C*H*$_2$CH$_2$), 1.30-1.15 (m, 4H, C*H*$_2$CH$_2$), 1.09 (s, 3H, C*H*$_3$), 0.88 (t, 3H, *J* = 7.0, CH_2C*H*$_3$); ^{13}C NMR (75 MHz, $CDCl_3$): δ 195.2 (*C*(O)CO$_2$*t*Bu), 161.3 (*C*O$_2$*t*Bu), 145.1 (*C*H=CH_2), 112.6 (CH=*C*H2), 83.7 (*C*(CH$_3$)$_3$), 47.9 (*C*H$_2$C(O)), 40.7 (*C*H$_2$), 39.8 (*C*quat.), 27.8 (C(*C*H$_3$)$_3$), 26.2 (*C*H$_2$), 23.2 (*C*H$_2$), 22.7 (*C*H$_3$), 14.0 (*C*H$_3$); HRMS (APPI, pos.): *m/z* 254.1875 (254.1882 calc. for $C_{15}H_{26}O_3$ (M^+)); HPLC: Chiralpak AS-H (hexane/*i*-PrOH, 99.5:0.5, flow rate 1 mL min^{-1}, λ= 254 nm): t_{major} = 3.70; t_{minor} 3.25 min; 98% ee.

***tert*-Butyl (*S*)-4-methyl-2-oxo-4-phenylhex-5-enoate (17e):**

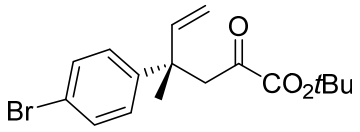


Treatment of **15e** (30 mg, 0.11 mmol) with the complex derived from $Cu(OTf)_2$ (4 mg, 0.011 mmol) and (*R*,*R*)-2,2'-isopropylidenebis(4-phenyl-2-oxazoline) (3.70 mg, 0.011 mmol) in ether (0.5 mL) for 67 h according to the general procedure provided, after purification by flash chromatography on silica gel (hexanes/EtOAc, 98:2), 16 mg (53%) of **17e** as a clear oil; R_f= 0.21 (hexanes/EtOAc, 98:2).

IR (neat): 2980, 1720, 1413, 1289, 1257, 1155, 1055, 1008, 920, 838 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 7.32-7.28 (m, 4H, Ar*H*), 7.23-7.15 (m, 1H, Ar*H*), 6.15 (dd, 1H, *J* = 17.4, 10.7, C*H*=CH_2), 5.14 (dd, 1H, *J* = 10.7, 0.8, CH=C*H*H), 5.09 (dd, 1H, *J* = 17.4, 0.8, CH=CH*H*), 3.29 (s,

2H, C*H*$_2$C(O)), 1.52 (s, 3H, CH$_3$), 1.45 (s, 9H, C(C*H*$_3$)$_3$); ^{13}C NMR (75 MHz, CDCl$_3$): δ 194.3 (*C*(O)CO$_2$*t*Bu), 160.8 (*C*O$_2$*t*Bu), 145.6 (Ar*C*$_{ipso}$), 145.0 (*C*H=CH$_2$), 128.4 (2 x Ar*C*), 126.5 (Ar*C*), 126.3 (2 x Ar*C*), 112.8 (CH=*C*H$_2$), 83.7 (*C*(CH$_3$)$_3$), 48.0 (*C*H$_2$C(O)), 43.6 (Ar-*C*-CH$_3$), 27.7 (C(*C*H$_3$)$_3$), 25.2 (Ar-C-*C*H$_3$); HRMS (APPI, pos.): *m/z* 274.1575 (274.1569 calc. for C$_{17}$H$_{22}$O$_3$ (M$^+$)); HPLC: Chiralpak AD-H (hexane/*i*-PrOH, 99.6/0.4, flow rate 1 mL min^{-1}, λ= 254 nm): t_{major} = 6.77; t_{minor} 7.50 min; 45% ee.

***tert*-Butyl (*S*)-4-(4-bromophenyl)-4-methyl-2-oxohex-5-enoate (17j):**



Treatment of **15j** (50 mg, 0.14 mmol) with the complex derived from Cu(OTf)$_2$ (5.2 mg, 0.014 mmol) and (*R*,*R*)-2,2'-isopropylidenebis(4-phenyl-2-oxazoline) (4.8 mg, 0.014 mmol) in ether (0.5 mL) for 120 h according to the general procedure provided, after purification by flash chromatography on silica gel (hexanes/EtOAc, 98:2), 49 mg (48%) of **17j** as a clear oil; R_f = 0.22 (hexanes/EtOAc, 98:2).

IR (neat): 2979, 2935, 1720, 1490, 1396, 1370, 1290, 1256, 1155, 1054, 1008, 921, 824 cm^{-1}; ^{1}H NMR (300 MHz, CDCl$_3$): δ 7.41 (d, 2H, *J* = 8.7, Ar*H*), 7.18 (d, 2H, *J* = 8.7, Ar*H*), 6.08 (dd, 1H, *J* = 17.4, 10.7, C*H*=CH$_2$), 5.15 (dd, 1H, *J* = 10.7, 0.7, CH=C*H*H), 5.08 (dd, 1H, *J* = 17.4, 0.7, CH=CH*H*), 3.26 (AB system, 2H, *J* = 15.3, C*H*$_2$C(O)), 1.49 (s, 3H, CH$_3$), 1.46 (s, 9H, C(C*H*$_3$)$_3$); ^{13}C NMR (75 MHz, CDCl$_3$): δ 193.8 (*C*(O)CO$_2$*t*Bu), 160.7 (*C*O$_2$*t*Bu), 144.57 (*C*H=CH$_2$), 144.52 (Ar*C*$_{ipso}$), 131.4 (2 x Ar*C*), 128.3 (2 x Ar*C*), 120.5 (Ar*C*-Br), 113.2 (CH=*C*H2), 84.0 (*C*(CH$_3$)$_3$), 47.8 (*C*H$_2$C(O)), 43.3 (Ar-*C*-CH$_3$), 27.7 (C(*C*H$_3$)$_3$), 25.2 (Ar-C-*C*H$_3$); HRMS (APPI, pos.): *m/z* 352.0667 (352.0674 calc. for C$_{17}$H$_{21}$BrO$_3$ (M$^+$)); HPLC: Chiralpak AD-H (hexane/*i*-PrOH, 99.6/0.4, flow rate 1 mL min^{-1}, λ= 254 nm): t_{major} = 8.06; t_{minor} 9.04 min; 56% ee.

References

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2. (a) X.-Y. Lu, G.-X. Zhu and S.-M. Ma, *Chin. J. Chem.,* 1993, **11**, 267; (b) E. Piers, C. L. Harrison and C. Zetina-Rocha *Org. Lett.,* 2001, **3**, 3245.
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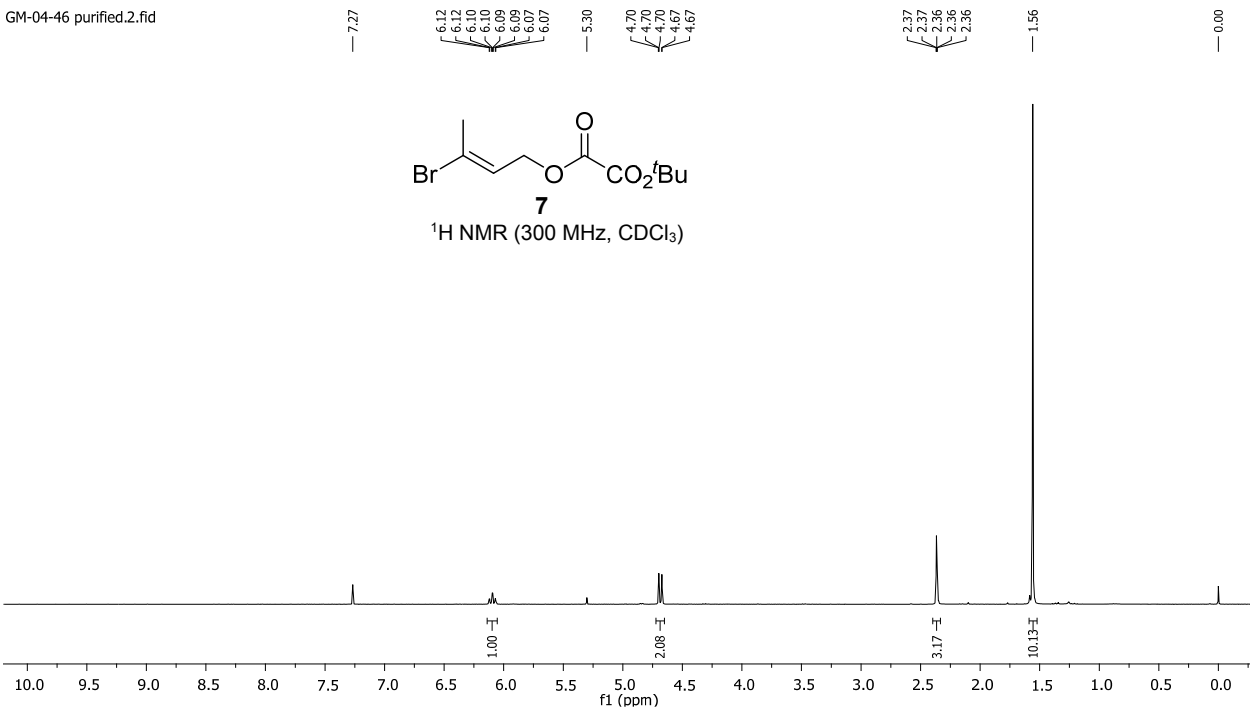
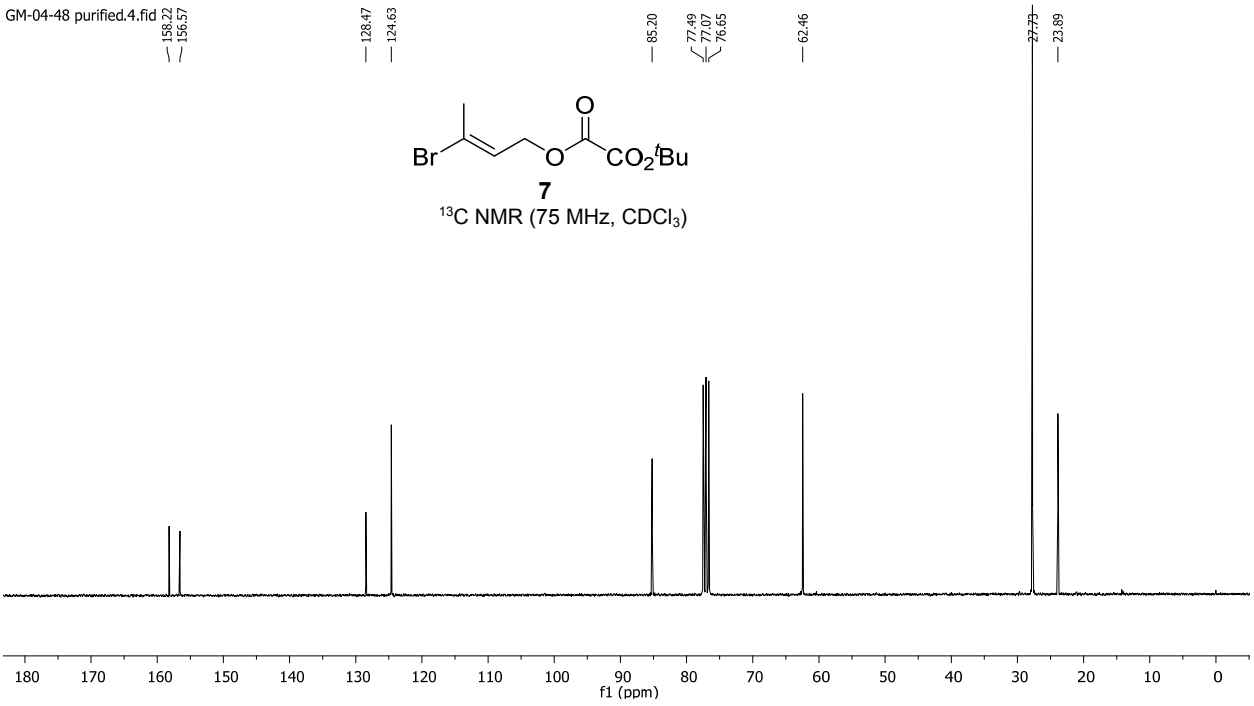
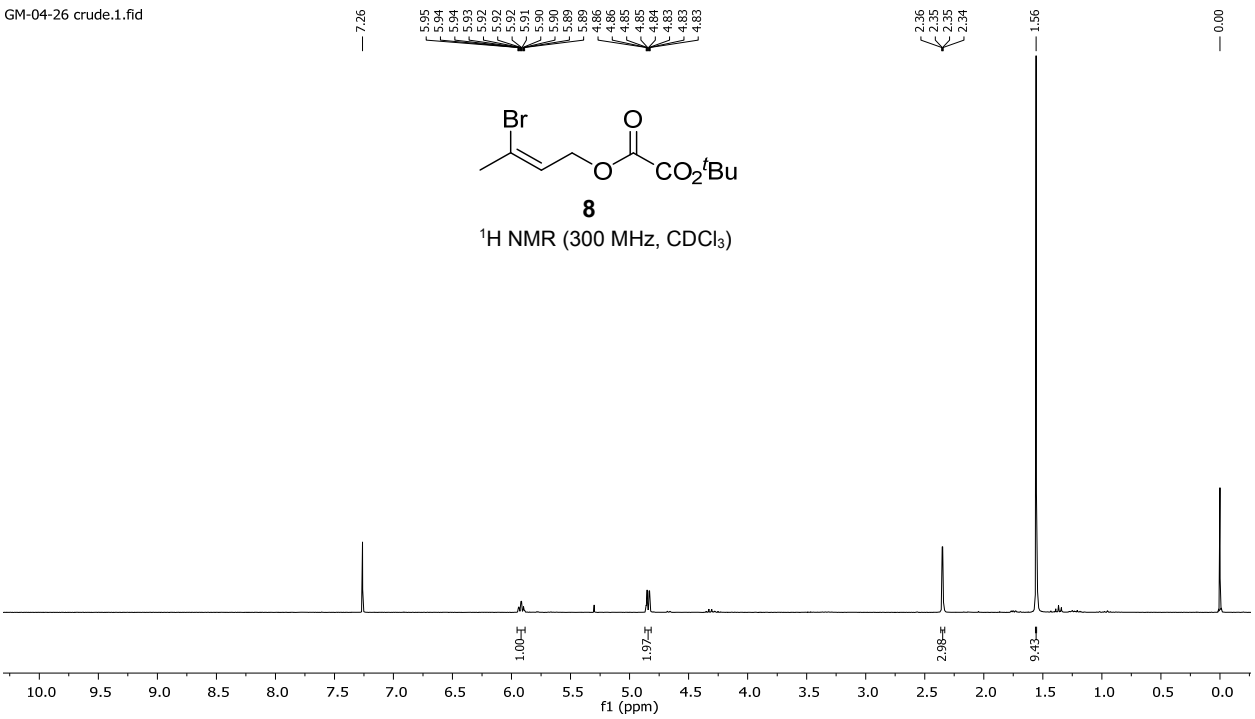
5. J. F. Payack, D. L. Hughes, D. Cai, I. F. Cottrell and T. R. Verhoeven *Org. Prep. Proc. Int.,* 1995, **27**, 707. In our studies, the purity of titanocene dichloride used to prepare the Petasis reagent was found to be critical for the successful methylenation of **9** and **10**. The reported yields of **13** and **14** were obtained when 99+% pure, commercial titanocene dichloride was used. The use of titanocene dichloride with lower purity (97%, commercial) significantly reduced the yield of the methylenation reaction.

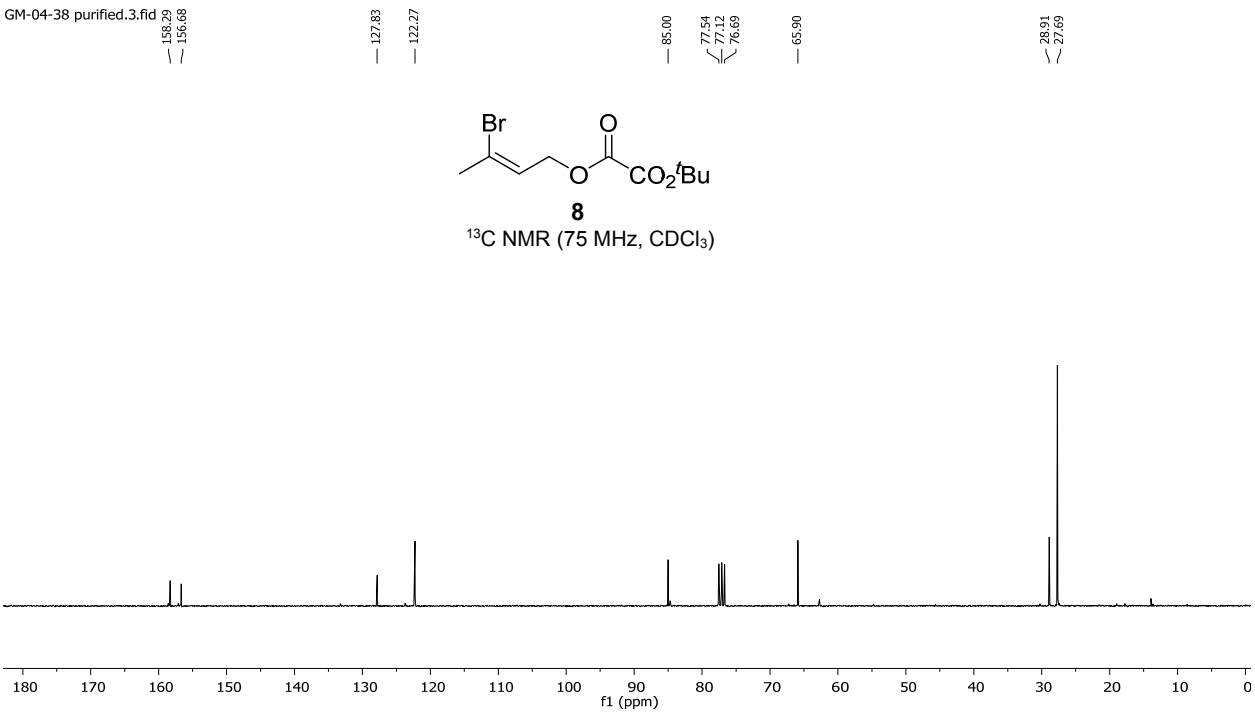

GM-04-46 purified.2.fid
7.27
6.12
6.12
6.10
6.10
6.09
6.09
6.07
6.07
5.30
4.70
4.70
4.70
4.67
4.67
2.37
2.37
2.36
2.36
2.36
1.56
0.00
Br
O
O
CO2tBu
7
1H NMR (300 MHz, CDCl3)
1.00
2.08
3.17
10.13
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


GM-04-48 purified.4.fid
158.22
156.57
128.47
124.63
85.20
77.49
77.07
76.65
62.46
27.73
23.89
Br
O
O
CO2tBu
7
13C NMR (75 MHz, CDCl3)
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)



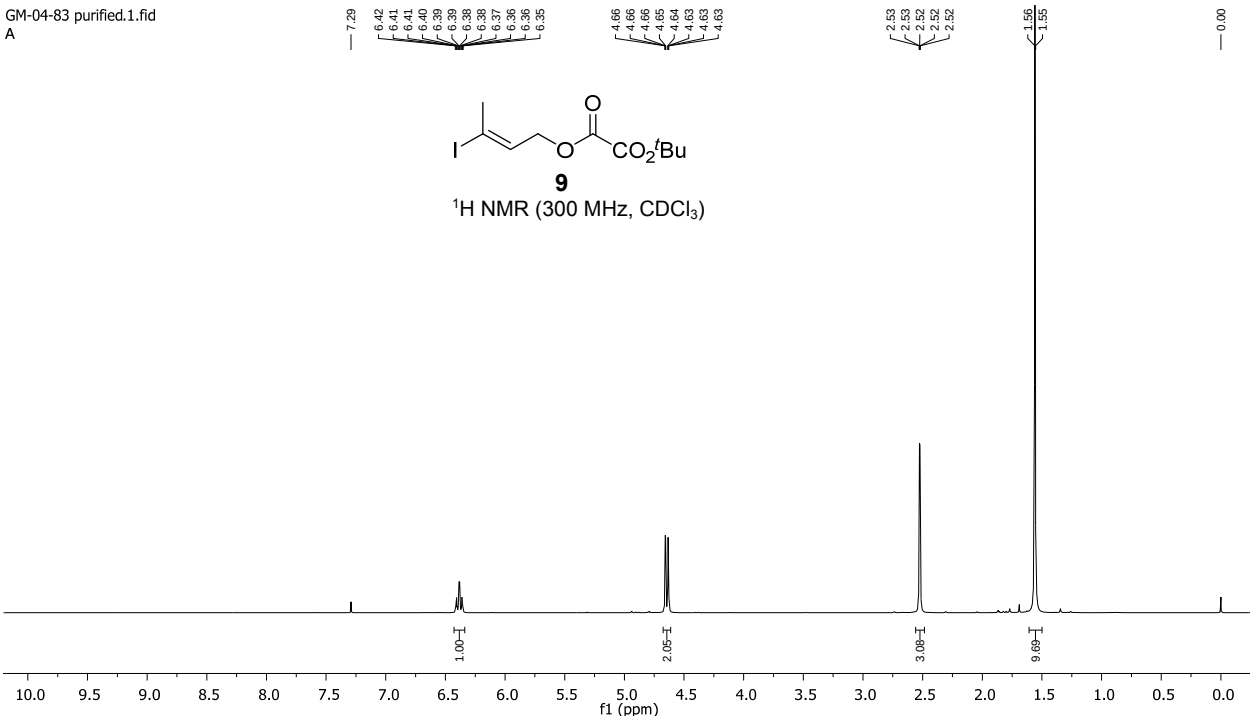
8

^{1}H NMR (300 MHz, $CDCl_3$)



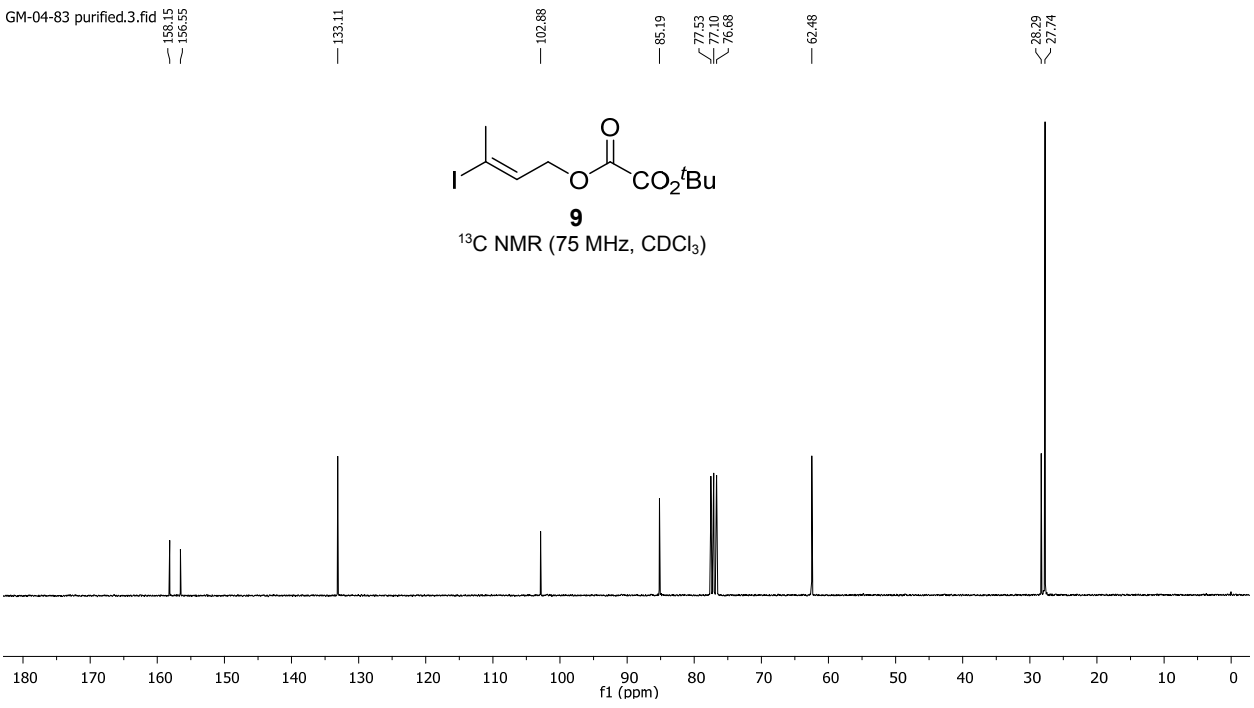
8

^{13}C NMR (75 MHz, $CDCl_3$)



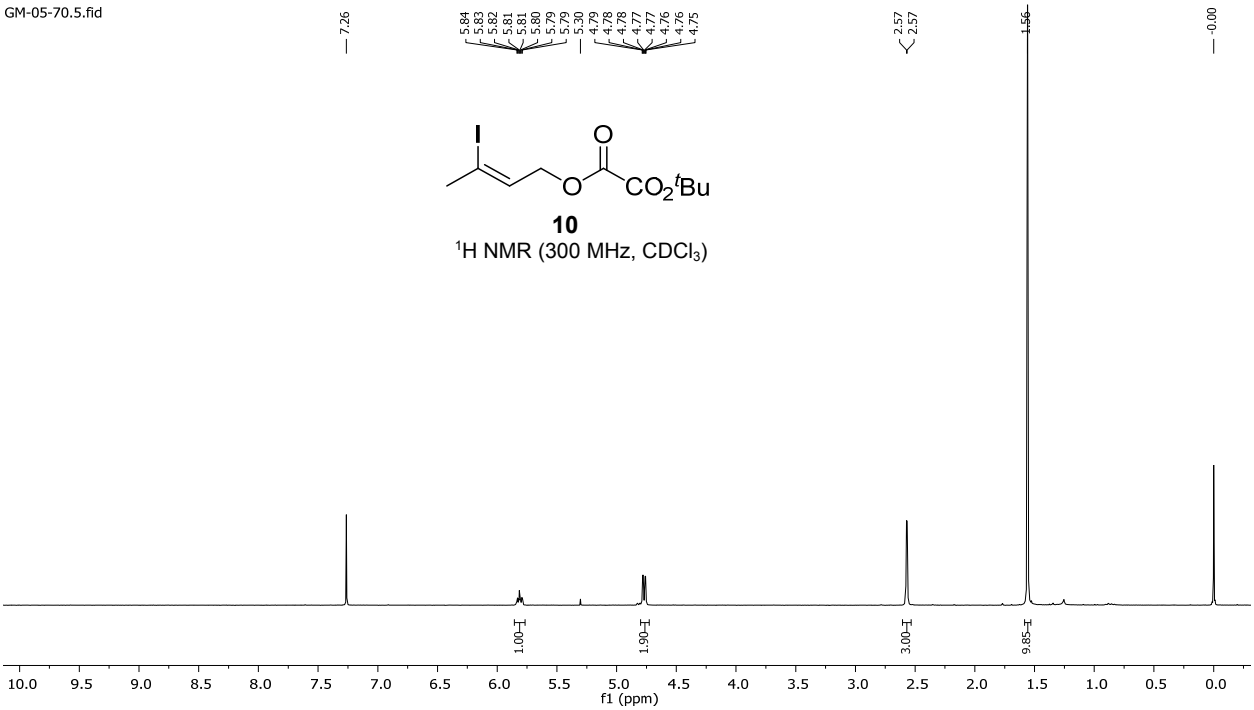
9

^{1}H NMR (300 MHz, $CDCl_3$)



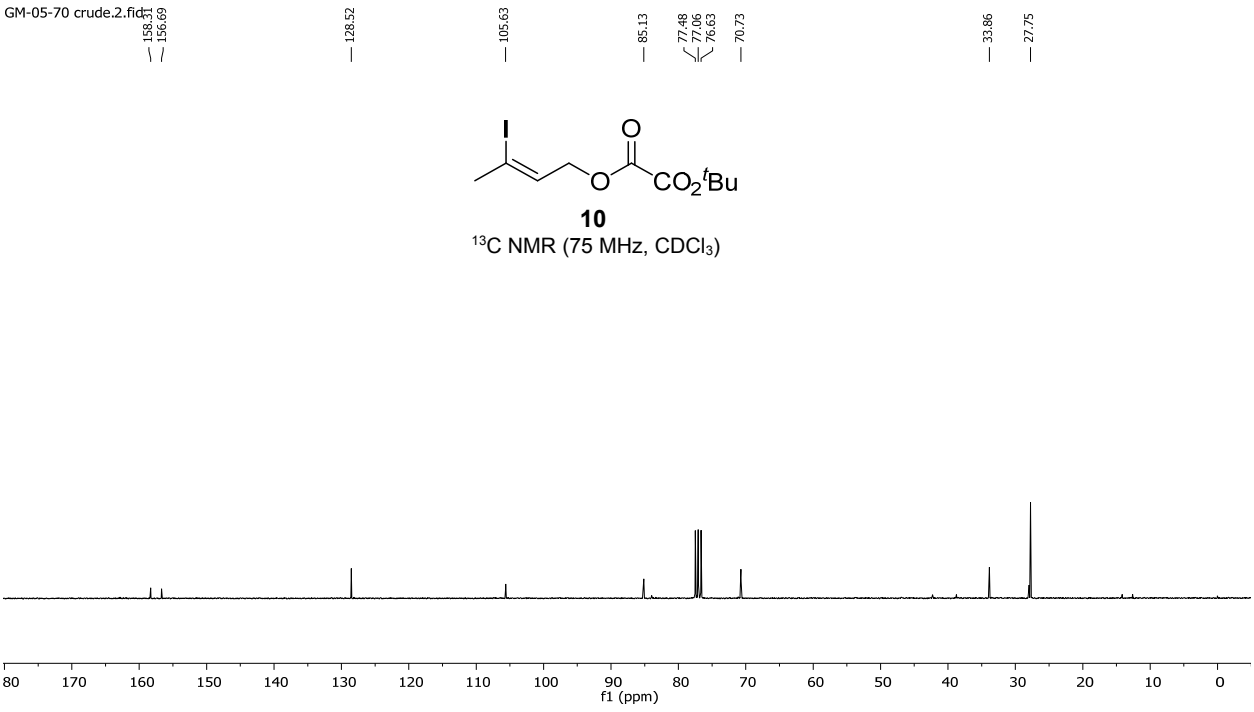
9

^{13}C NMR (75 MHz, $CDCl_3$)



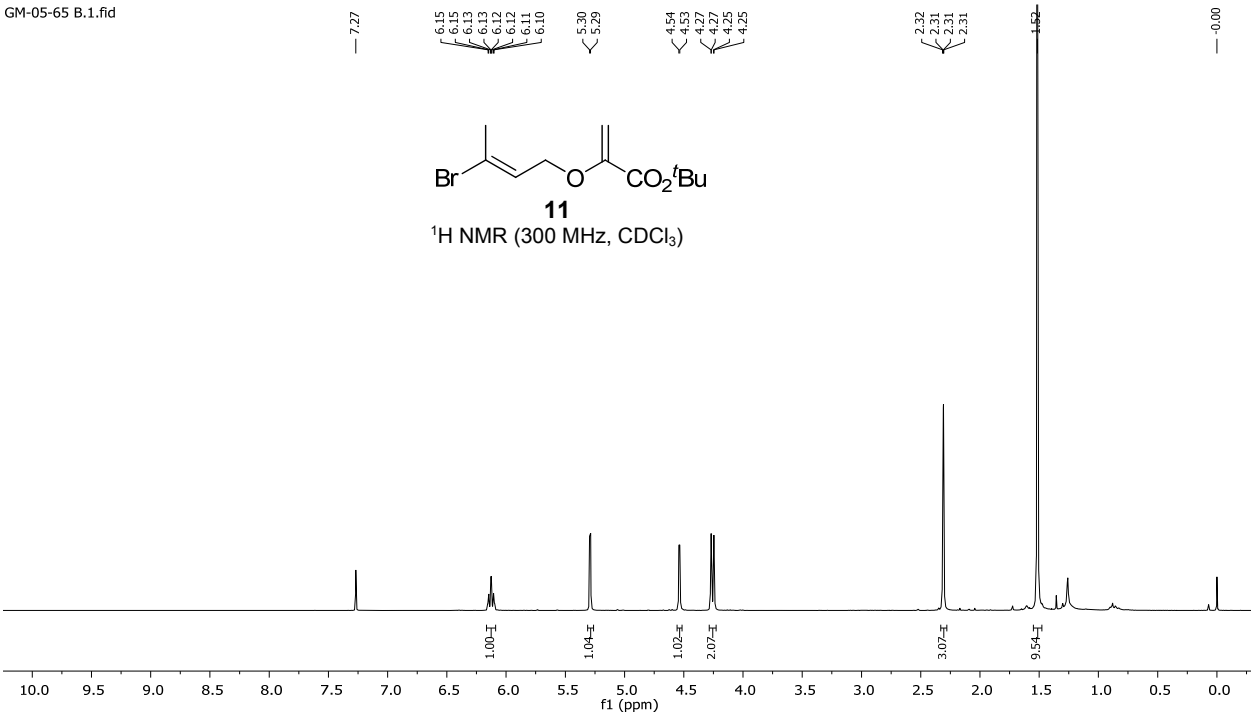
10

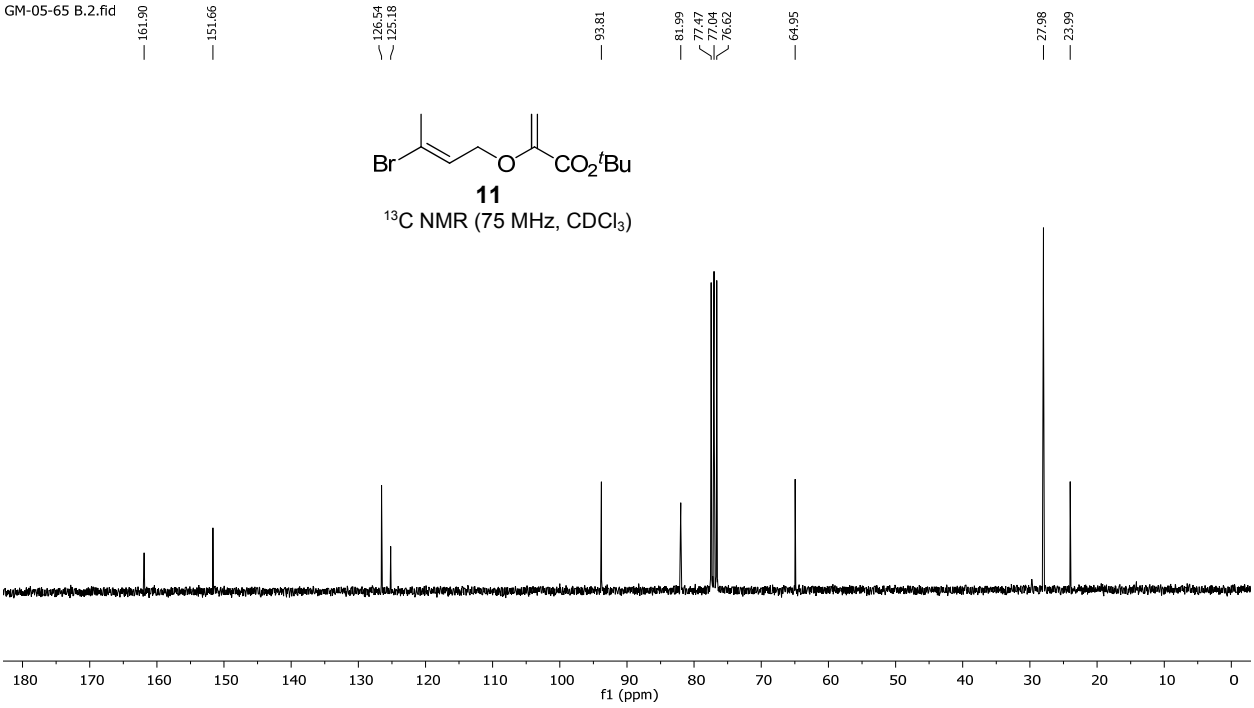
^{1}H NMR (300 MHz, $CDCl_3$)

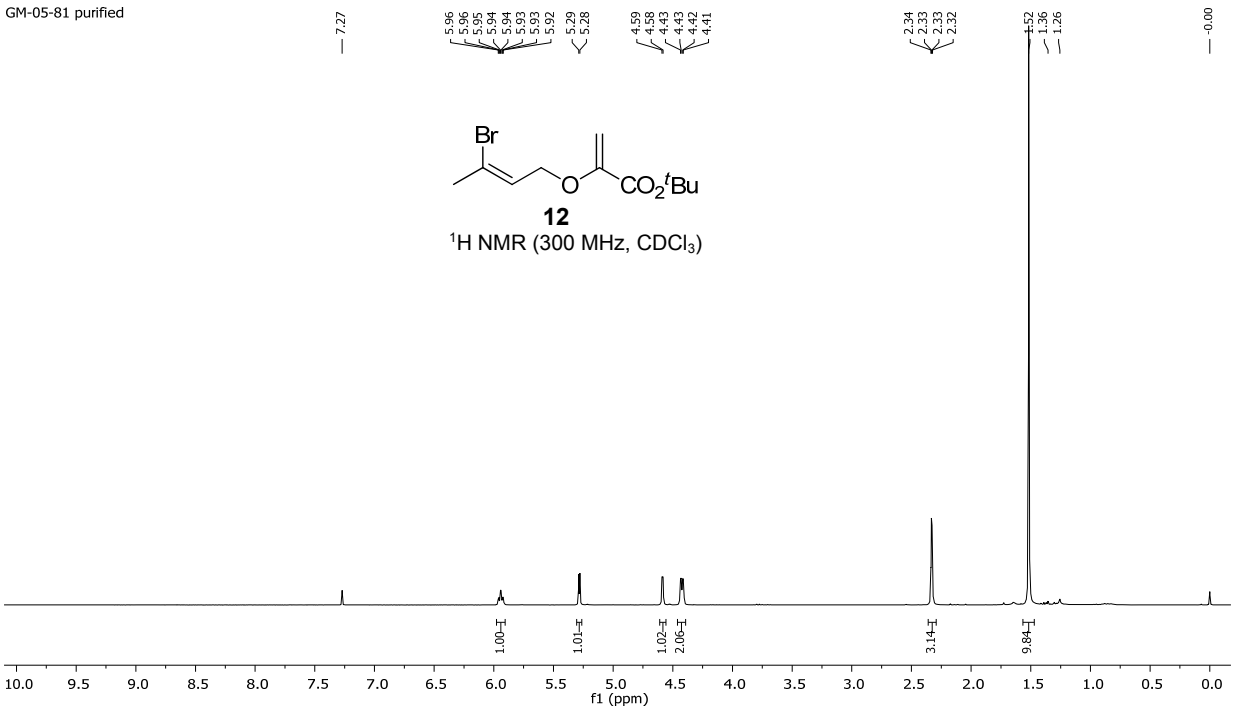


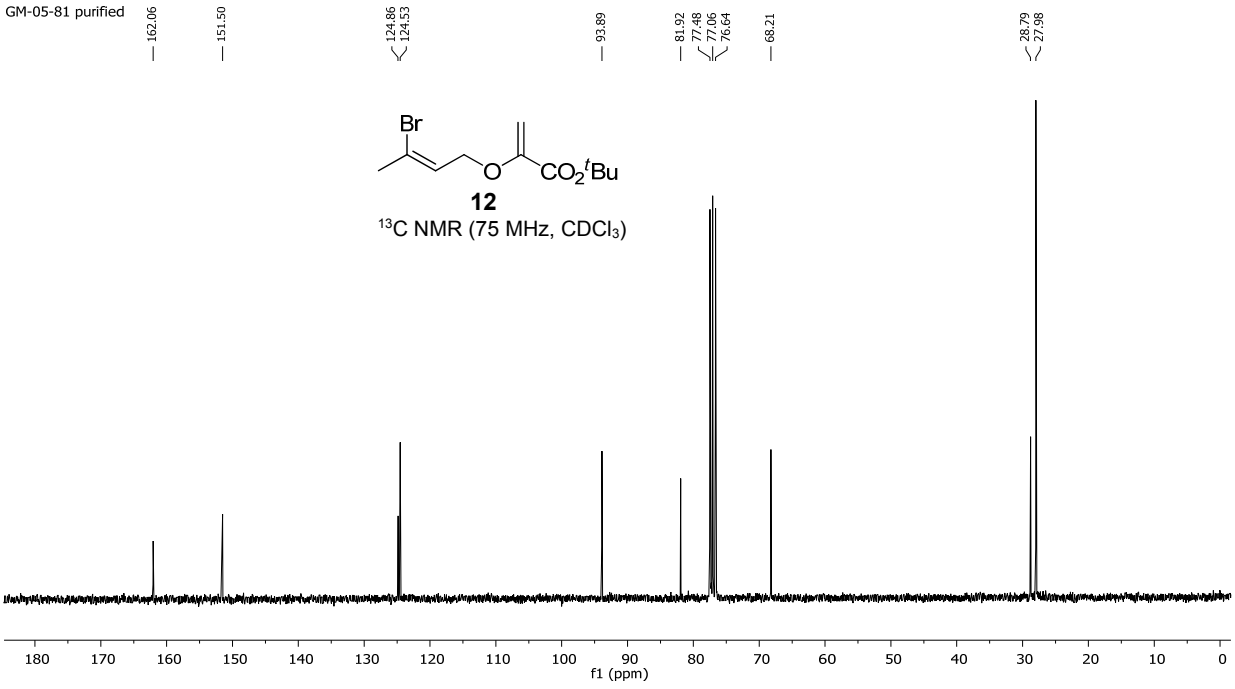
10

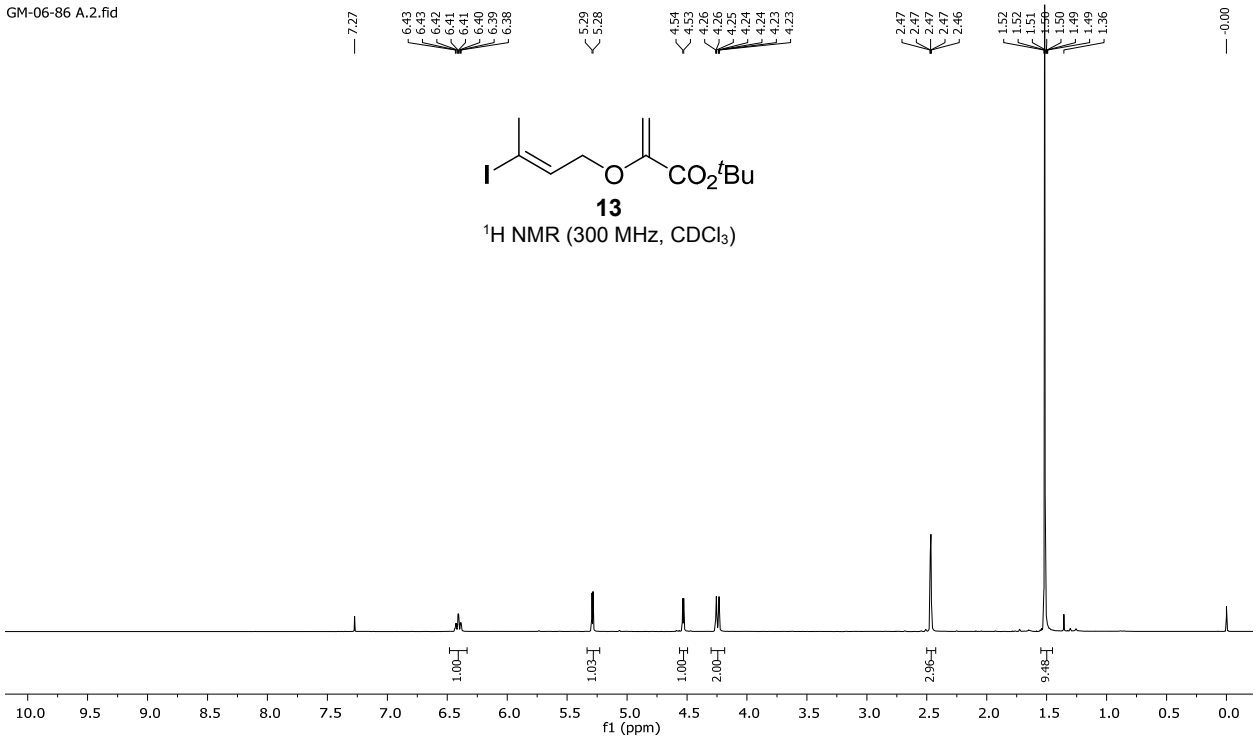
^{13}C NMR (75 MHz, $CDCl_3$)

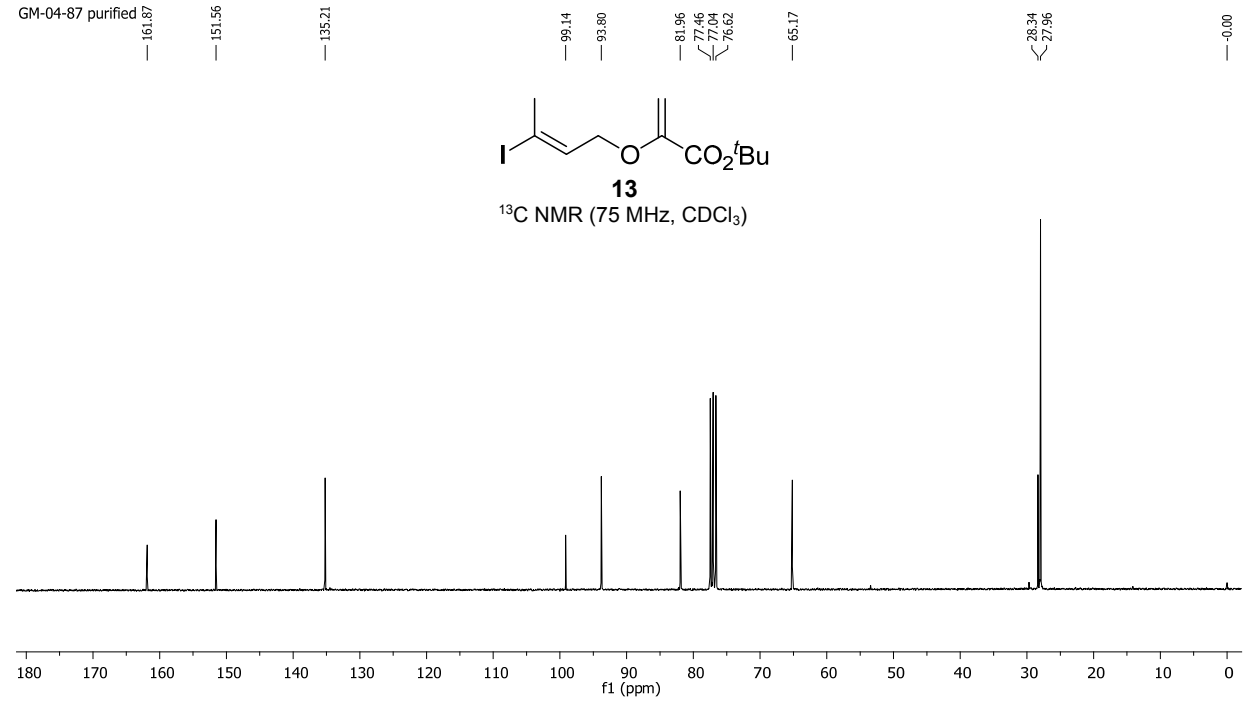

GM-05-65 B.1.fid
7.27
6.15
6.15
6.13
6.13
6.12
6.12
6.11
6.10
5.30
5.29
4.54
4.53
4.27
4.27
4.25
4.25
2.32
2.31
2.31
2.31
1.62
-0.00
Br
O
CO2tBu
11
1H NMR (300 MHz, CDCl3)
1.00
1.04
1.02
2.07
3.07
9.54
f1 (ppm)

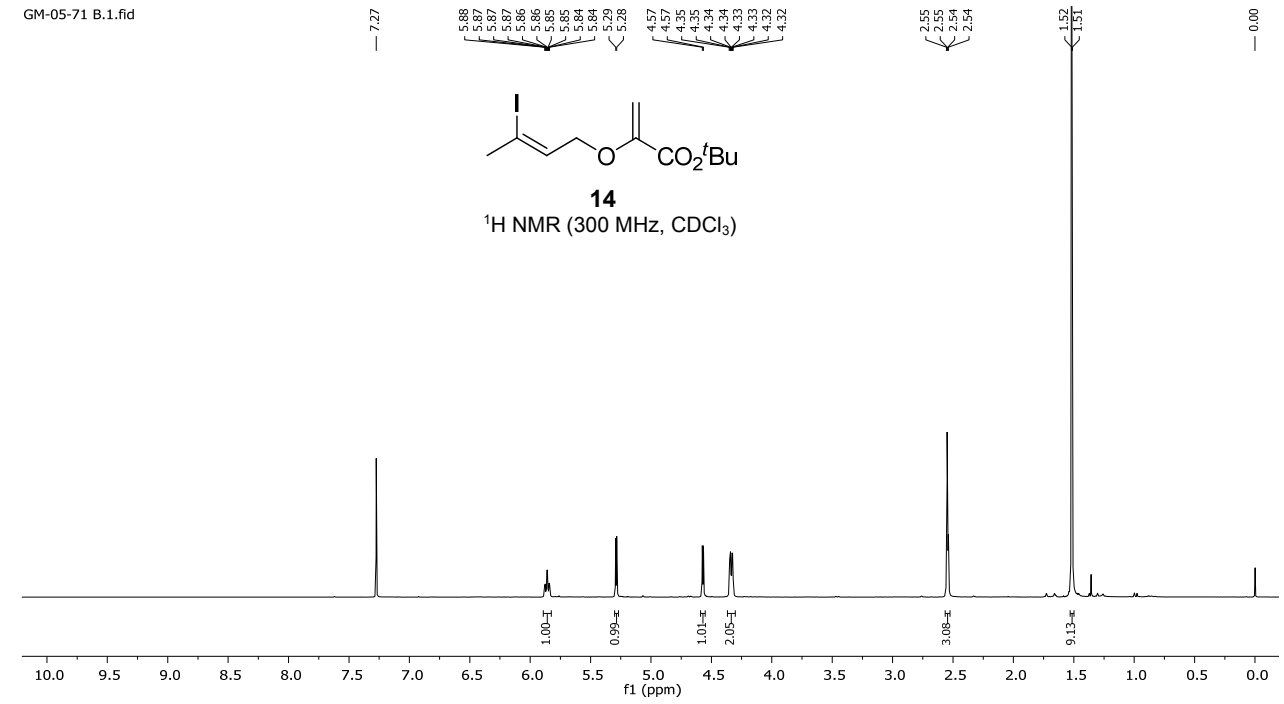

GM-05-65 B.2.fid
161.90
151.66
126.54
125.18
93.81
81.99
77.47
77.04
76.62
64.95
27.98
23.99
Br
O
CO2tBu
11
13C NMR (75 MHz, CDCl3)
f1 (ppm)


GM-05-81 purified
7.27
5.96
5.96
5.95
5.94
5.94
5.93
5.93
5.92
5.29
5.28
4.59
4.58
4.43
4.43
4.42
4.41
2.34
2.33
2.33
2.32
1.52
1.36
1.26
0.00
Br
O
CO2tBu
12
1H NMR (300 MHz, CDCl3)
1.00
1.01
1.02
2.06
3.14
9.84
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


GM-05-81 purified
162.06
151.50
124.86
124.53
93.89
81.92
77.48
77.06
76.64
68.21
28.79
27.98
Br
O
CO2tBu
12
13C NMR (75 MHz, CDCl3)
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

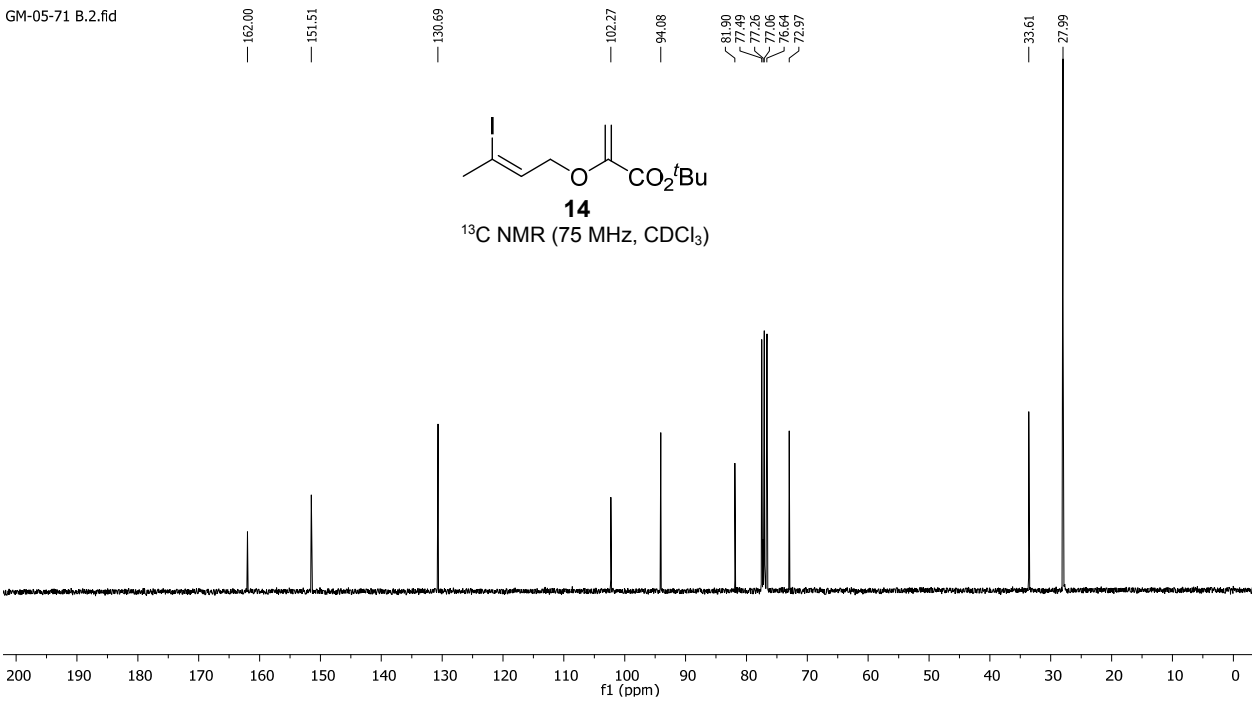

GM-06-86 A.2.fid
7.27
6.43
6.43
6.42
6.41
6.41
6.40
6.39
6.38
5.29
5.28
4.54
4.53
4.26
4.26
4.25
4.24
4.24
4.23
4.23
2.47
2.47
2.47
2.47
2.46
1.52
1.52
1.51
1.50
1.50
1.49
1.49
1.36
0.00
I
O
CO2tBu
13
1H NMR (300 MHz, CDCl3)
1.00
1.03
1.00
2.00
2.96
9.48
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


GM-04-87 purified
161.87
151.56
135.21
99.14
93.80
81.96
77.46
77.04
76.62
65.17
28.34
27.96
0.00
I
O
CO2tBu
13
13C NMR (75 MHz, CDCl3)
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)



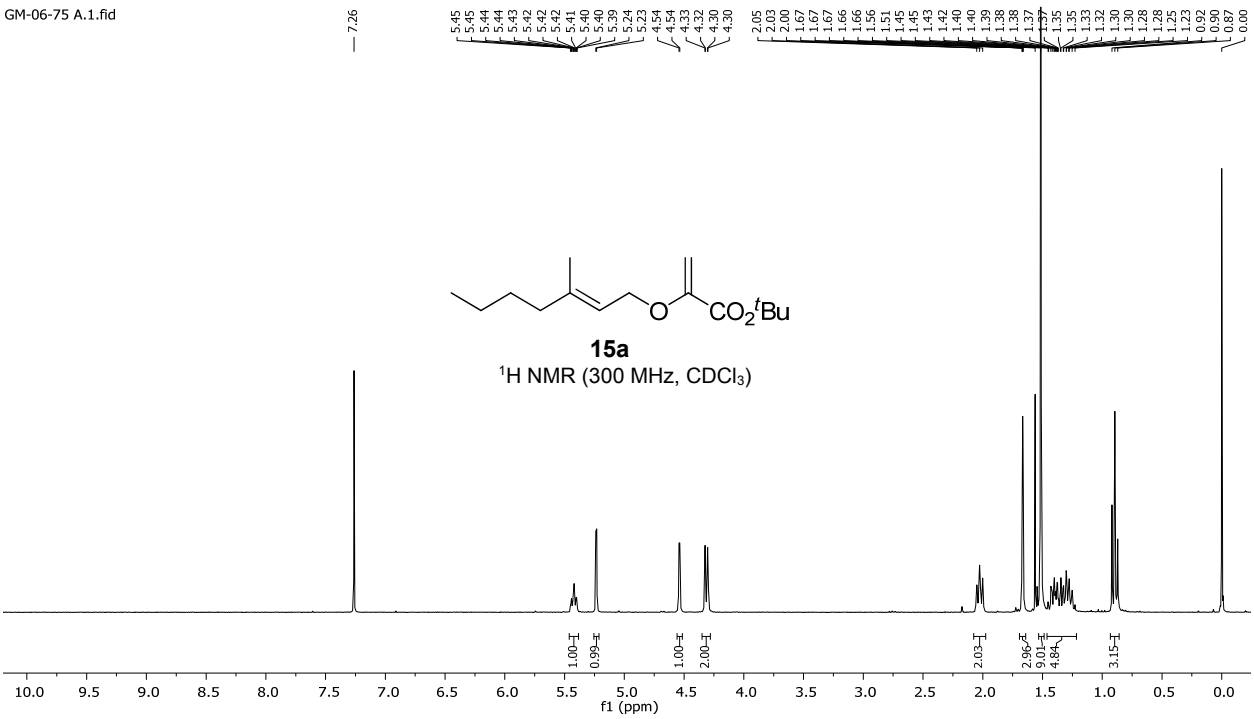
14

^{1}H NMR (300 MHz, $CDCl_3$)



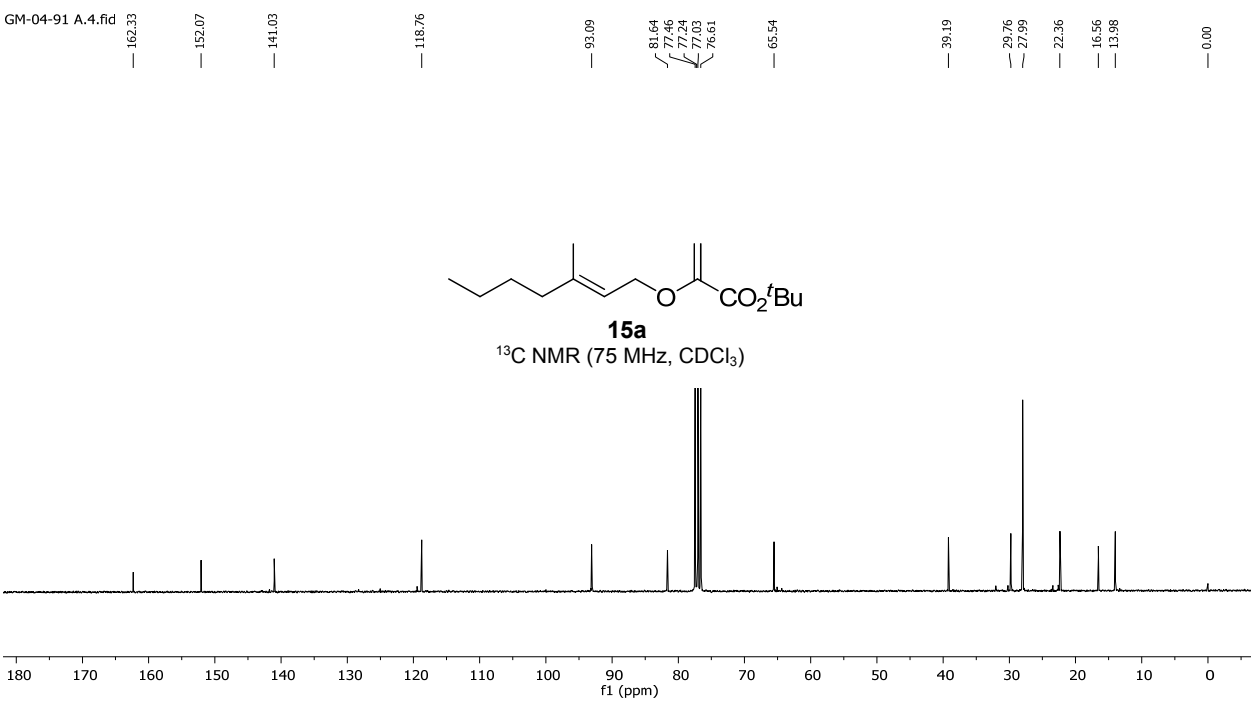
14

^{13}C NMR (75 MHz, $CDCl_3$)



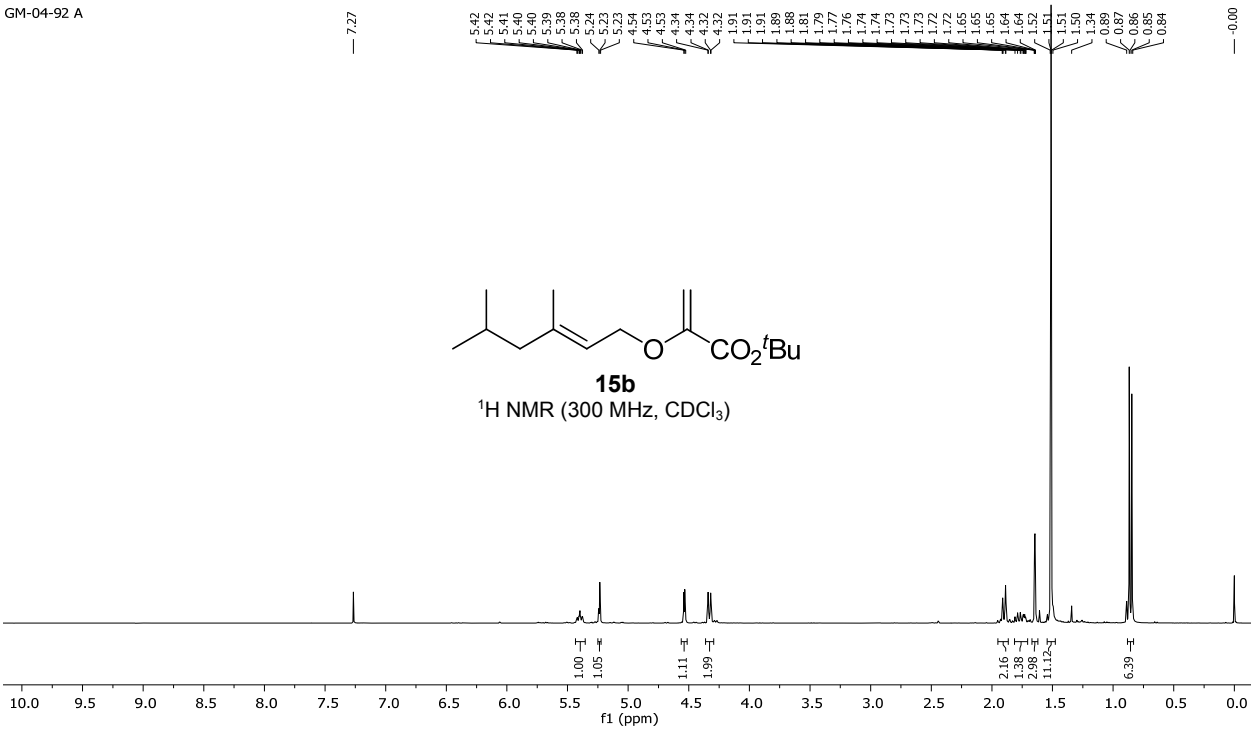
15a

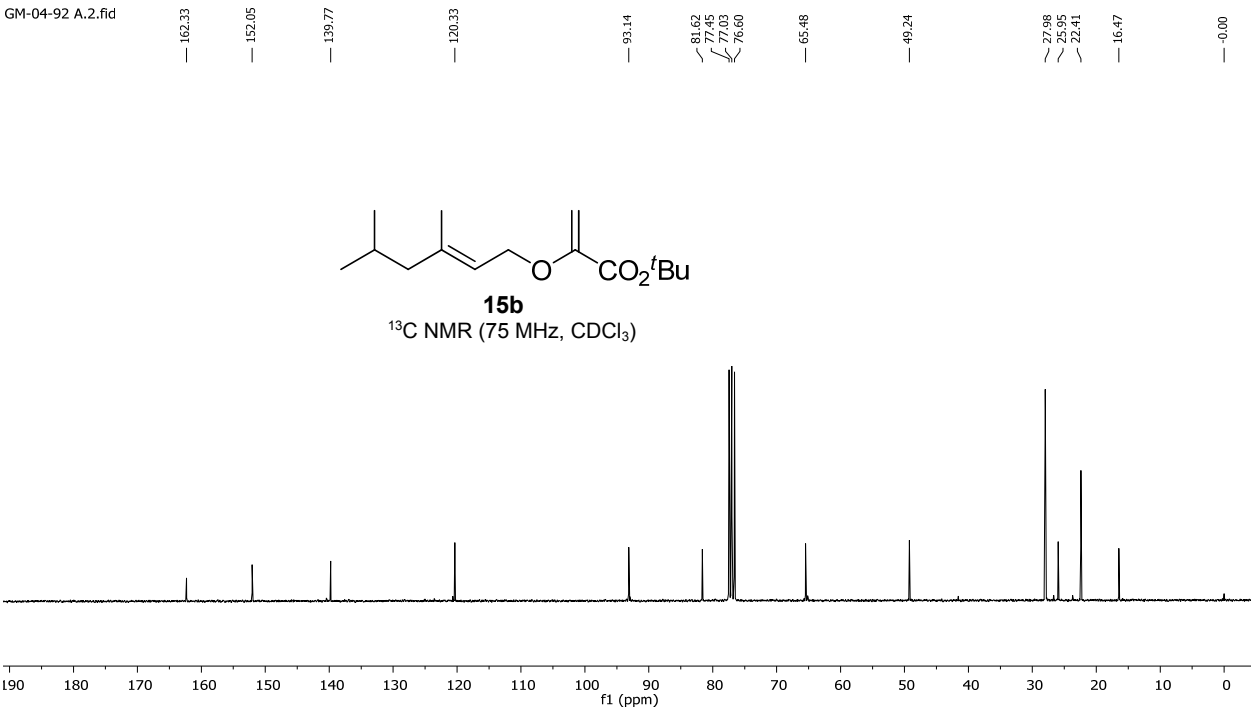
^{1}H NMR (300 MHz, $CDCl_3$)



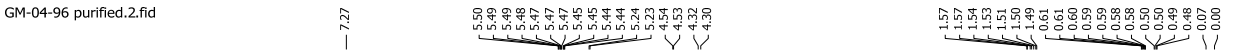
15a

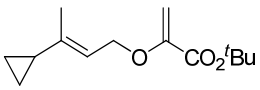
^{13}C NMR (75 MHz, $CDCl_3$)


GM-04-92 A
7.27
5.42
5.42
5.41
5.40
5.40
5.39
5.38
5.38
5.24
5.23
5.23
4.54
4.53
4.53
4.34
4.34
4.32
4.32
1.91
1.91
1.91
1.89
1.88
1.81
1.79
1.77
1.76
1.74
1.74
1.73
1.73
1.73
1.72
1.72
1.65
1.65
1.64
1.64
1.52
1.51
1.51
1.50
1.34
0.89
0.87
0.86
0.85
0.84
-0.00
O
CO2tBu
15b
1H NMR (300 MHz, CDCl3)
1.00
1.05
1.11
1.99
2.16
1.38
2.98
11.12
6.39
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


GM-04-92 A.2.fid
162.33
152.05
139.77
120.33
93.14
81.62
77.45
77.03
76.60
65.48
49.24
27.98
25.95
22.41
16.47
-0.00
O
CO2tBu
15b
13C NMR (75 MHz, CDCl3)
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

GM-04-96 purified.2.fid

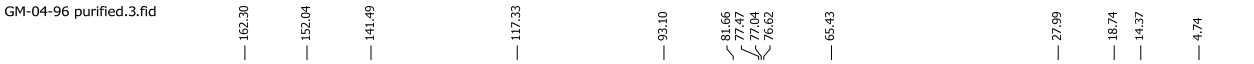


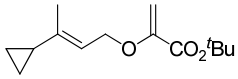


15c

^{1}H NMR (300 MHz, $CDCl_3$)

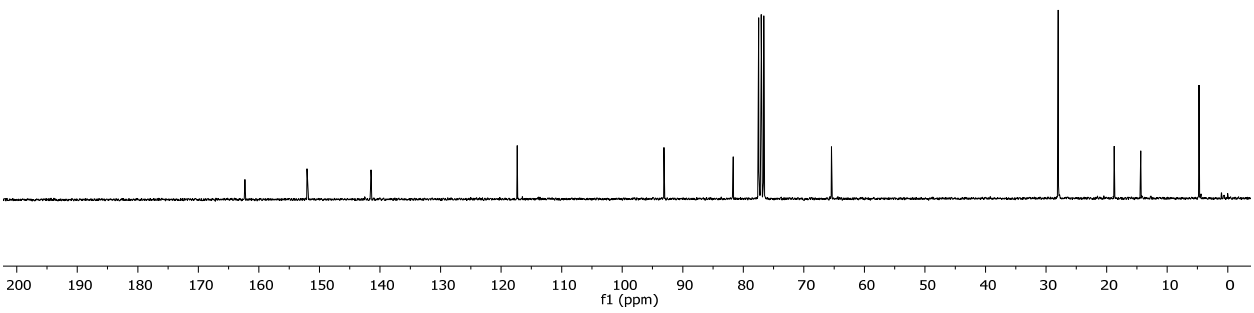
GM-04-96 purified.3.fid

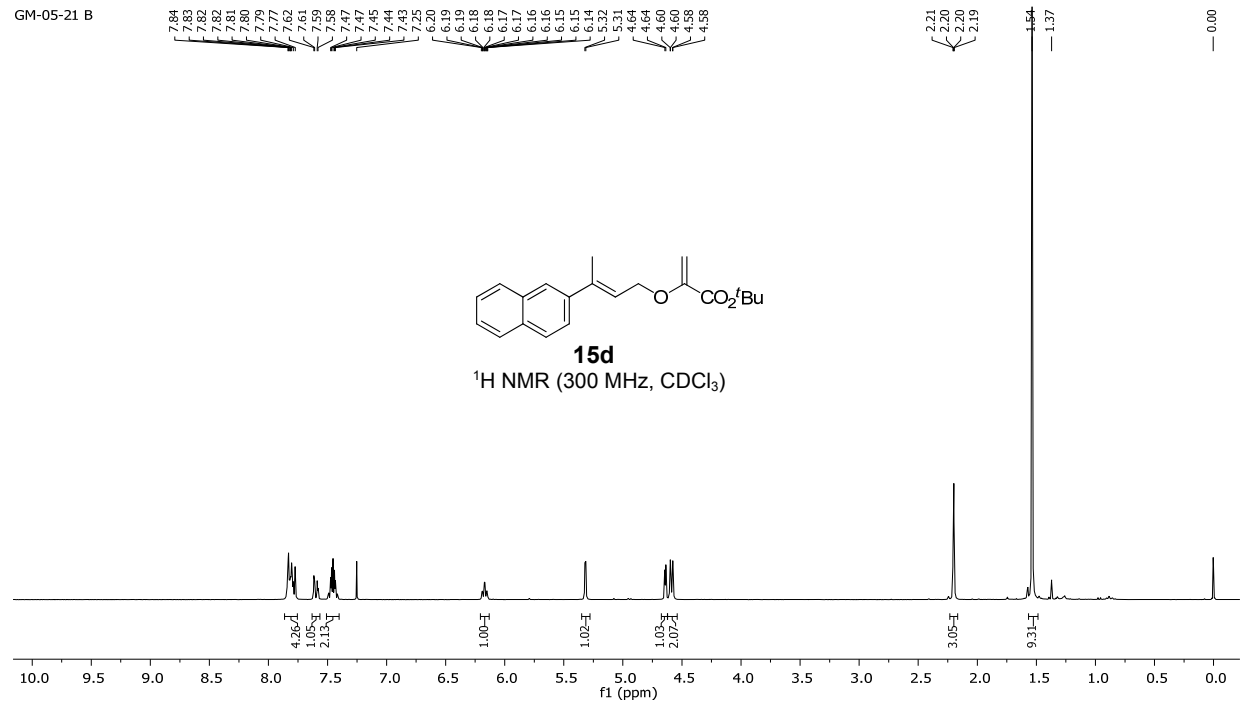


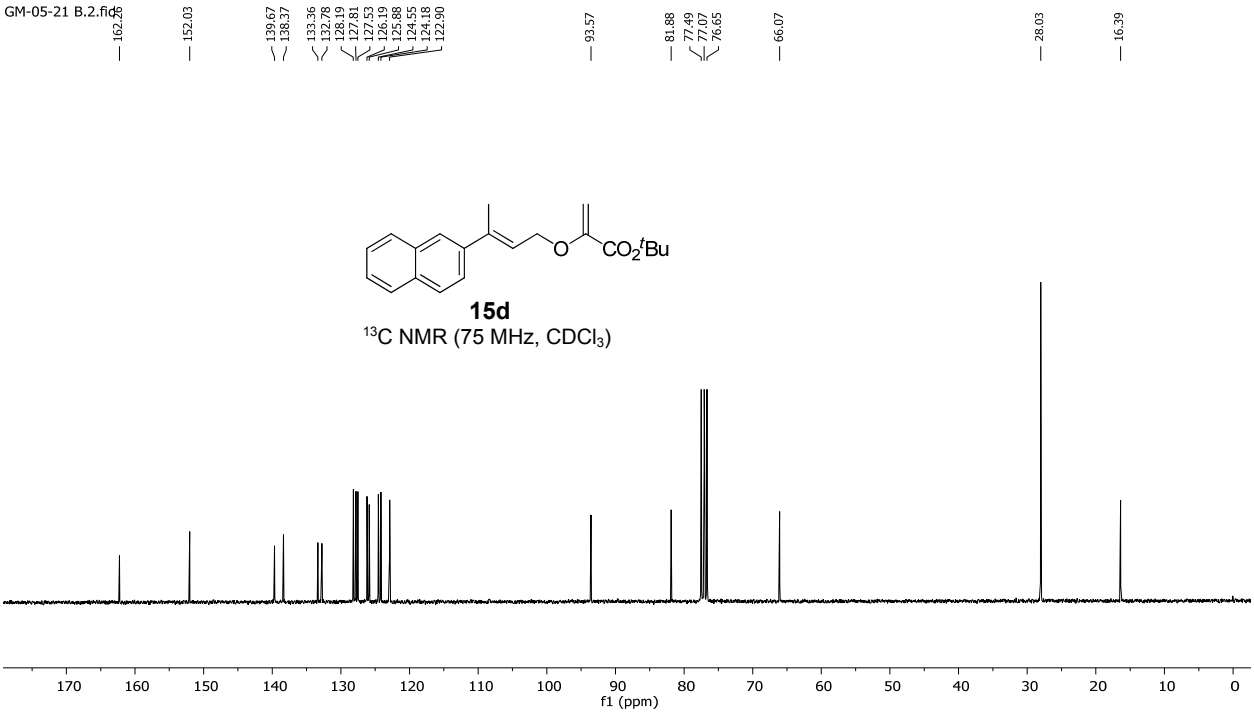


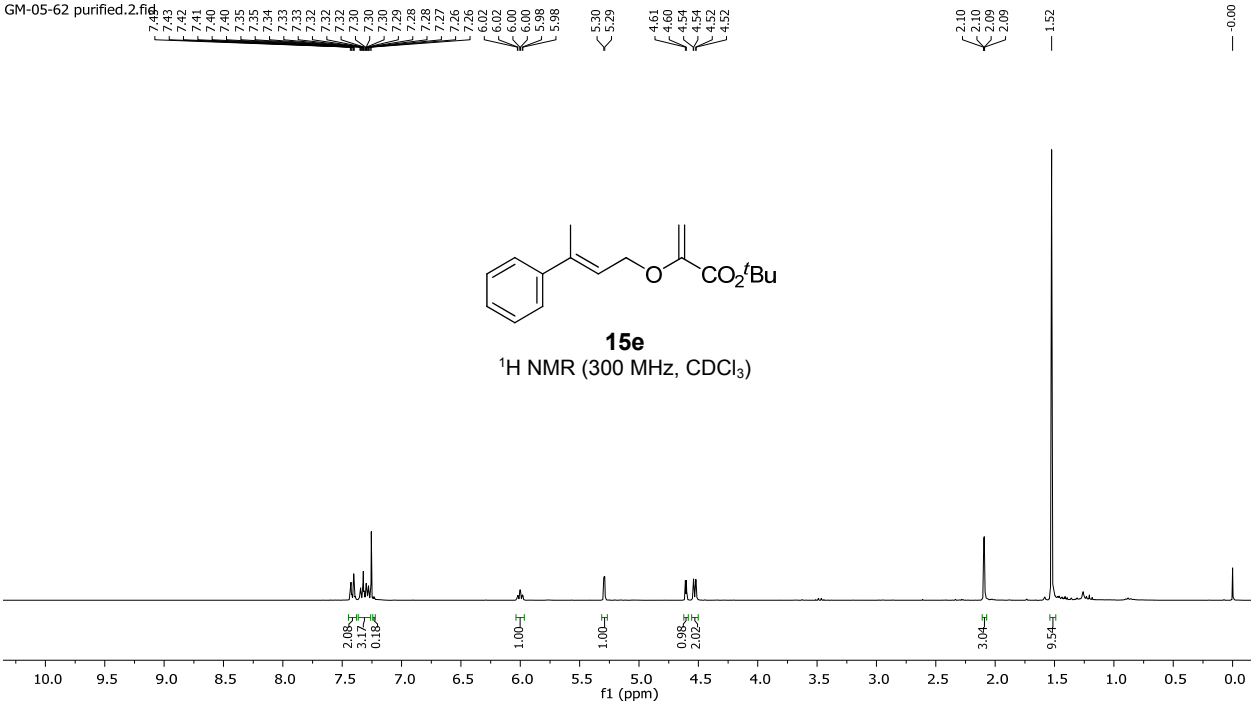
15c

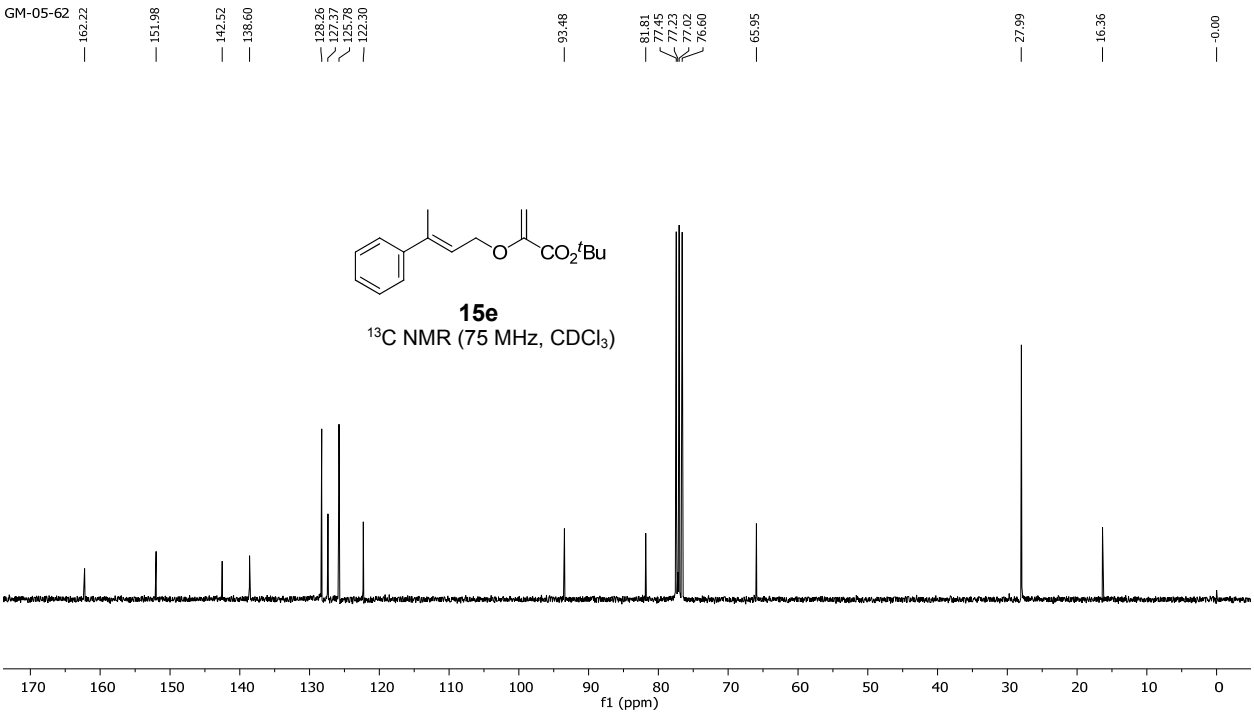
^{13}C NMR (75 MHz, $CDCl_3$)

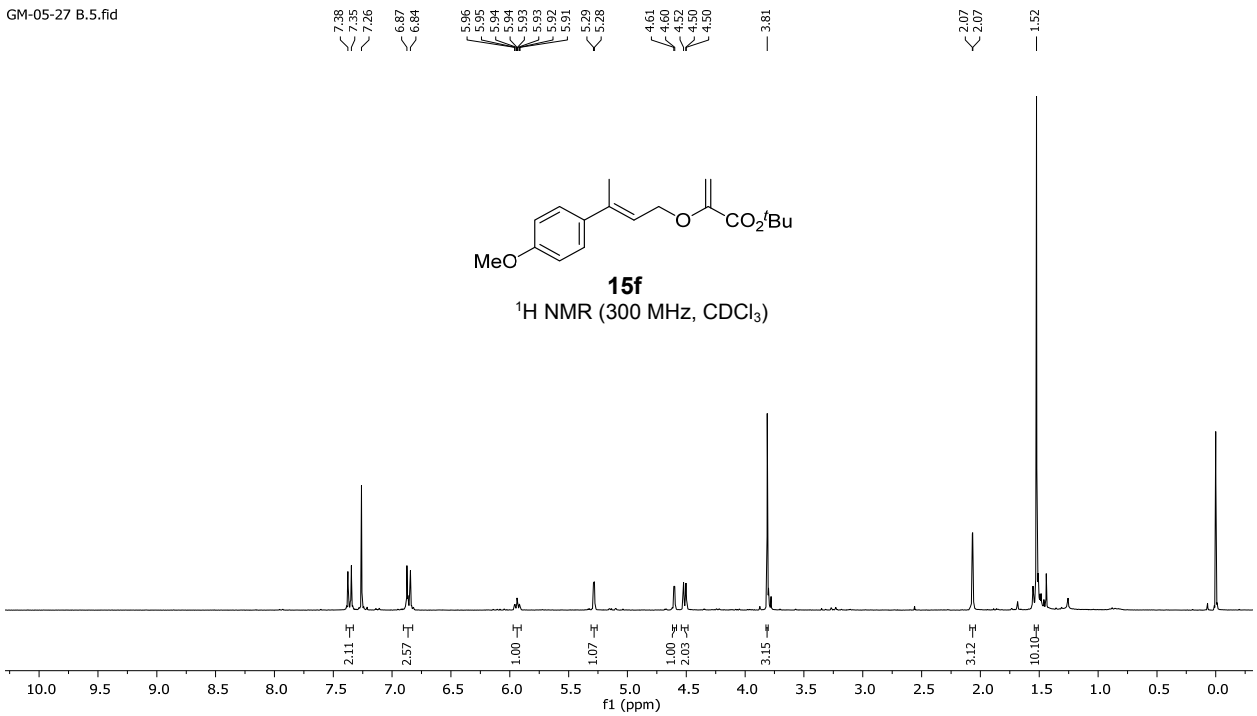



GM-05-21 B
7.84 7.83 7.82 7.82 7.81 7.80 7.79 7.77 7.62 7.61 7.59 7.58 7.47 7.47 7.45 7.44 7.43 7.25 6.20 6.19 6.19 6.18 6.18 6.17 6.17 6.16 6.16 6.15 6.15 6.14 5.32 5.31 4.64 4.64 4.60 4.60 4.58 4.58
2.21 2.20 2.20 2.19
1.54
1.37
0.00
O
CO2tBu
15d
1H NMR (300 MHz, CDCl3)
4.26 1.05 2.13 1.00 1.02 1.03 2.07 3.05 9.31
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


GM-05-21 B.2.fid
162.26
152.03
139.67 138.37 133.36 132.78 128.19 127.81 127.53 126.19 125.88 124.55 124.18 122.90
93.57
81.88 77.49 77.07 76.65
66.07
28.03
16.39
O
CO2tBu
15d
13C NMR (75 MHz, CDCl3)
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

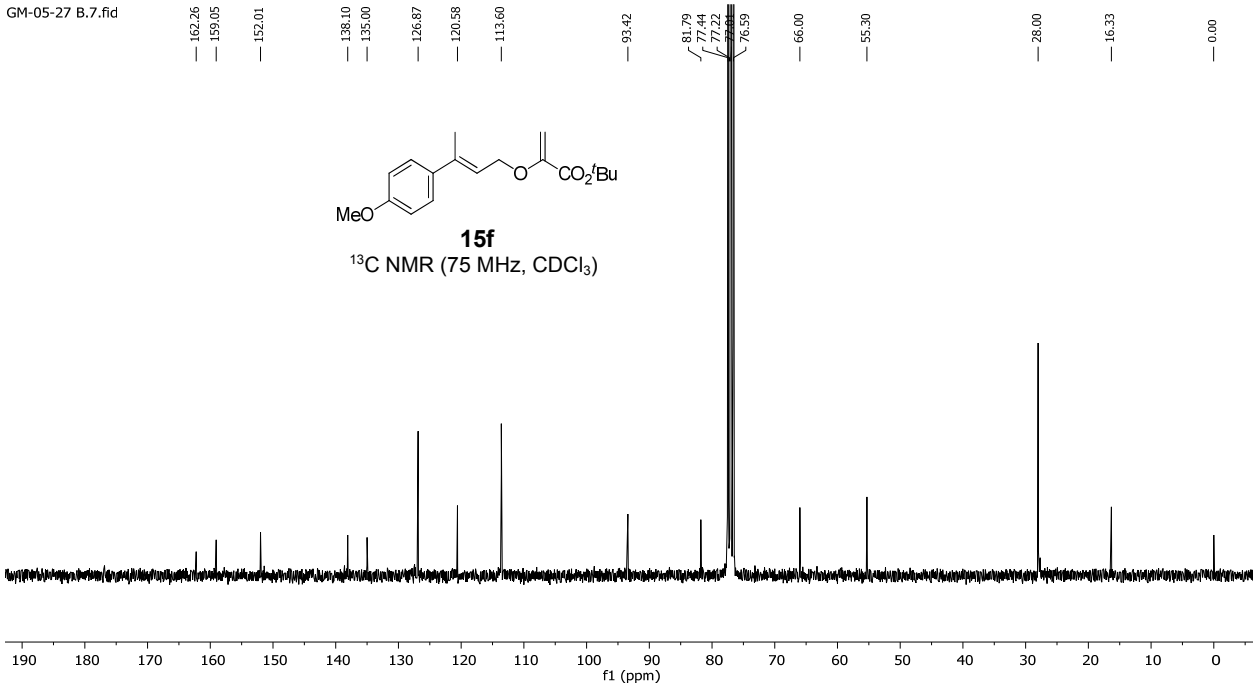

GM-05-62 purified.2.fid
7.46 7.43 7.42 7.41 7.40 7.40 7.35 7.35 7.34 7.33 7.33 7.32 7.32 7.32 7.30 7.30 7.30 7.29 7.28 7.28 7.27 7.26 7.26 6.02 6.02 6.00 6.00 5.98 5.98
5.30 5.29
4.61 4.60 4.54 4.54 4.52 4.52
2.10 2.10 2.09 2.09
1.52
-0.00
O
CO2tBu
15e
1H NMR (300 MHz, CDCl3)
2.08 3.17 0.18 1.00 1.00 0.98 2.02 3.04 9.54
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


GM-05-62
162.22
151.98
142.52
138.60
128.26 127.37 125.78
122.30
93.48
81.81 77.45 77.23 77.02 76.60
65.95
27.99
16.36
-0.00
O
CO2tBu
15e
13C NMR (75 MHz, CDCl3)
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)



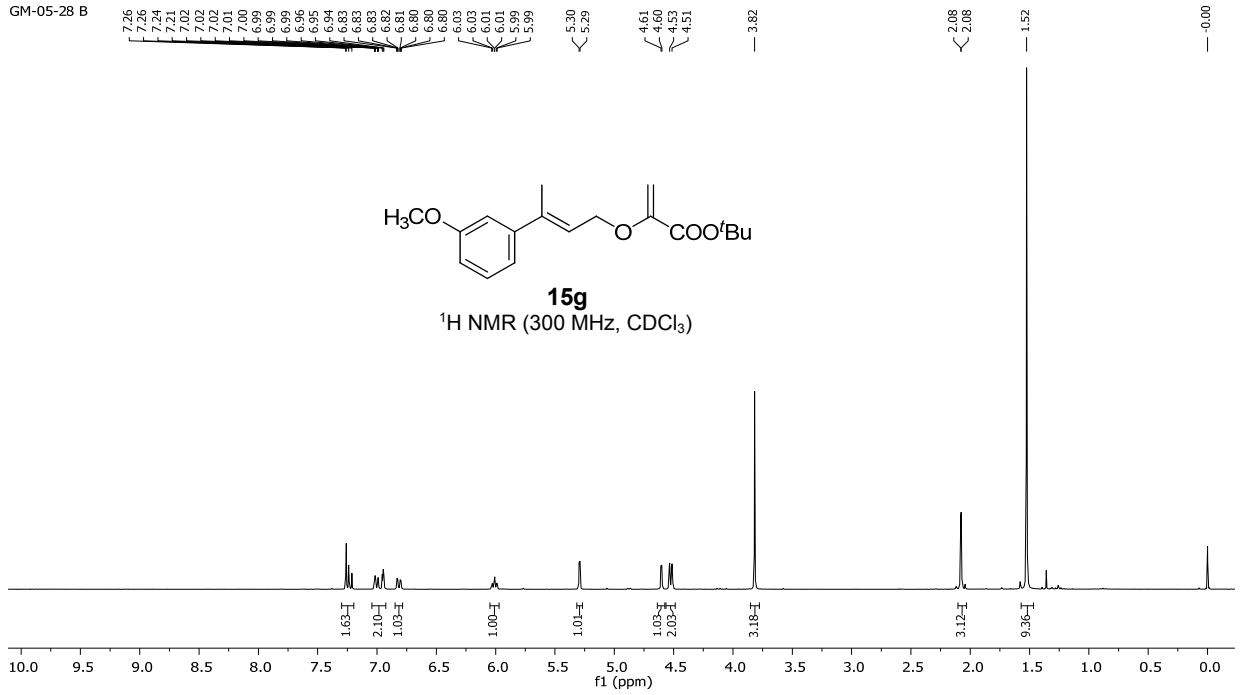
15f

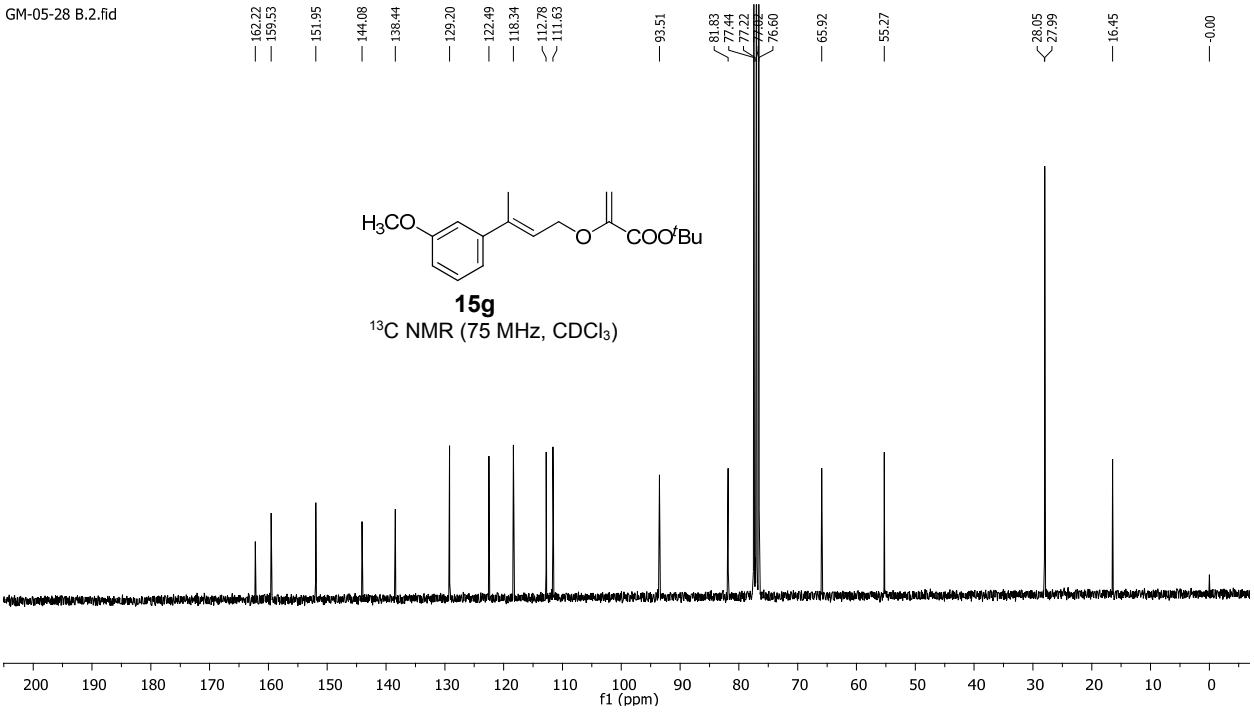
^{1}H NMR (300 MHz, $CDCl_3$)

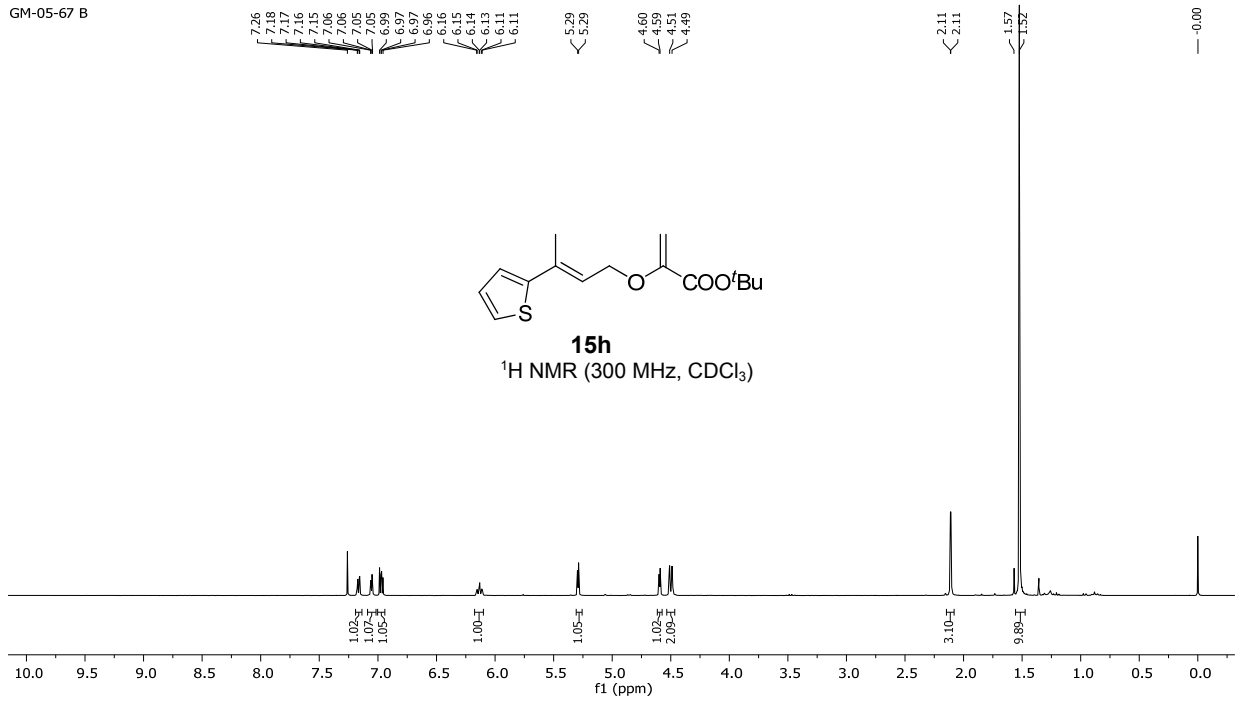


15f

^{13}C NMR (75 MHz, $CDCl_3$)

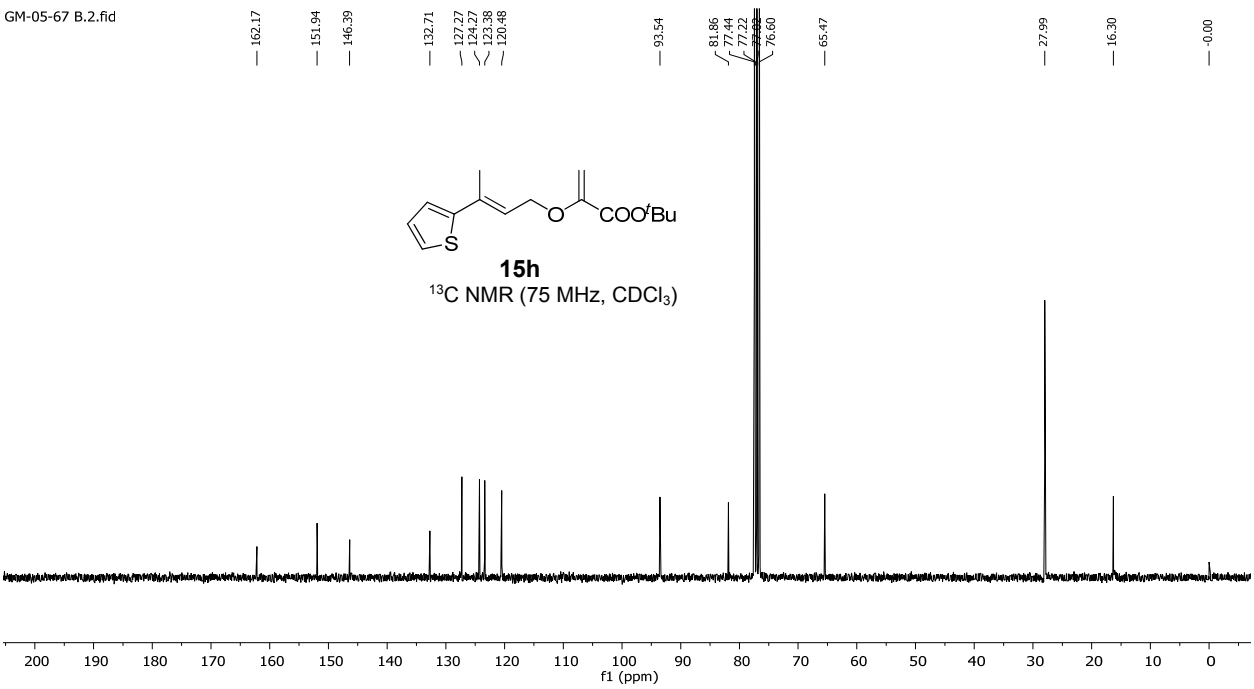

GM-05-28 B
7.26
7.26
7.24
7.21
7.02
7.02
7.02
7.01
7.00
6.99
6.99
6.99
6.96
6.95
6.94
6.83
6.83
6.83
6.82
6.81
6.80
6.80
6.80
6.03
6.03
6.01
6.01
5.99
5.99
5.30
5.29
4.61
4.60
4.53
4.51
3.82
2.08
2.08
1.52
-0.00
H3CO
O
COOtBu
15g
1H NMR (300 MHz, CDCl3)
1.63
2.10
1.03
1.00
1.01
1.03
2.03
3.18
3.12
9.36
f1 (ppm)


GM-05-28 B.2.fid
162.22
159.53
151.95
144.08
138.44
129.20
122.49
118.34
112.78
111.63
93.51
81.83
77.44
77.22
77.00
76.60
65.92
55.27
28.05
27.99
16.45
-0.00
H3CO
O
COOtBu
15g
13C NMR (75 MHz, CDCl3)
f1 (ppm)



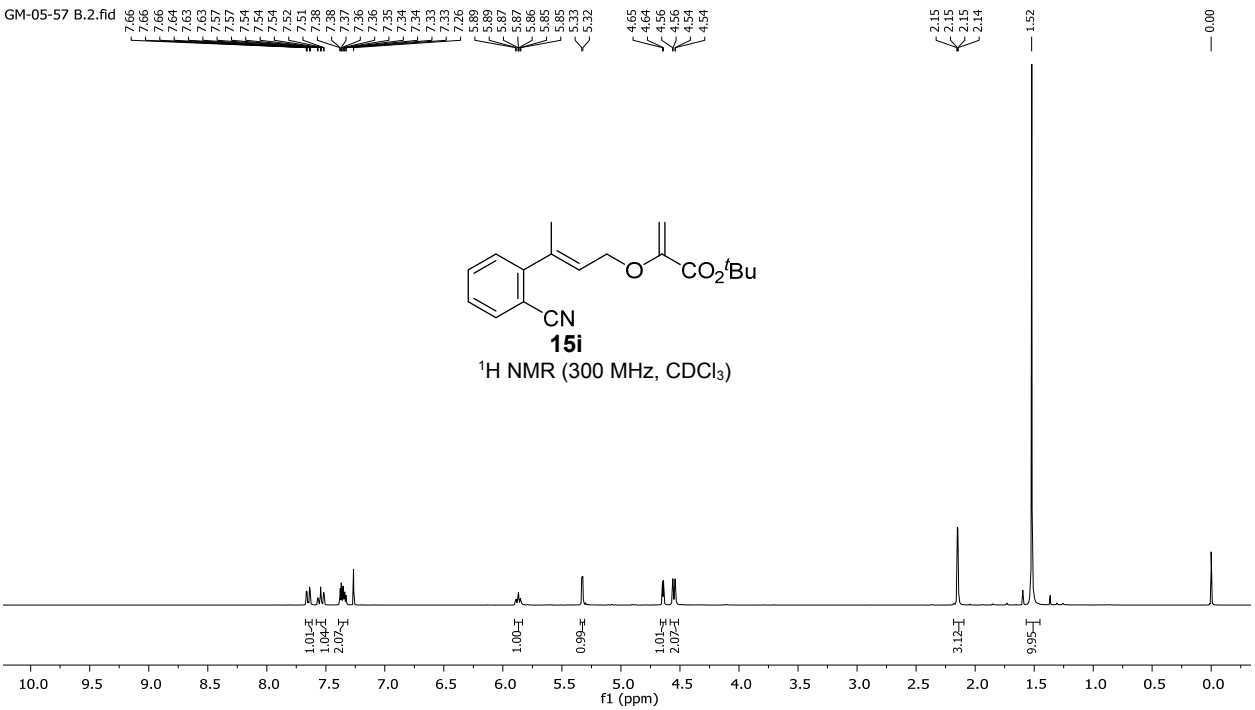
15h

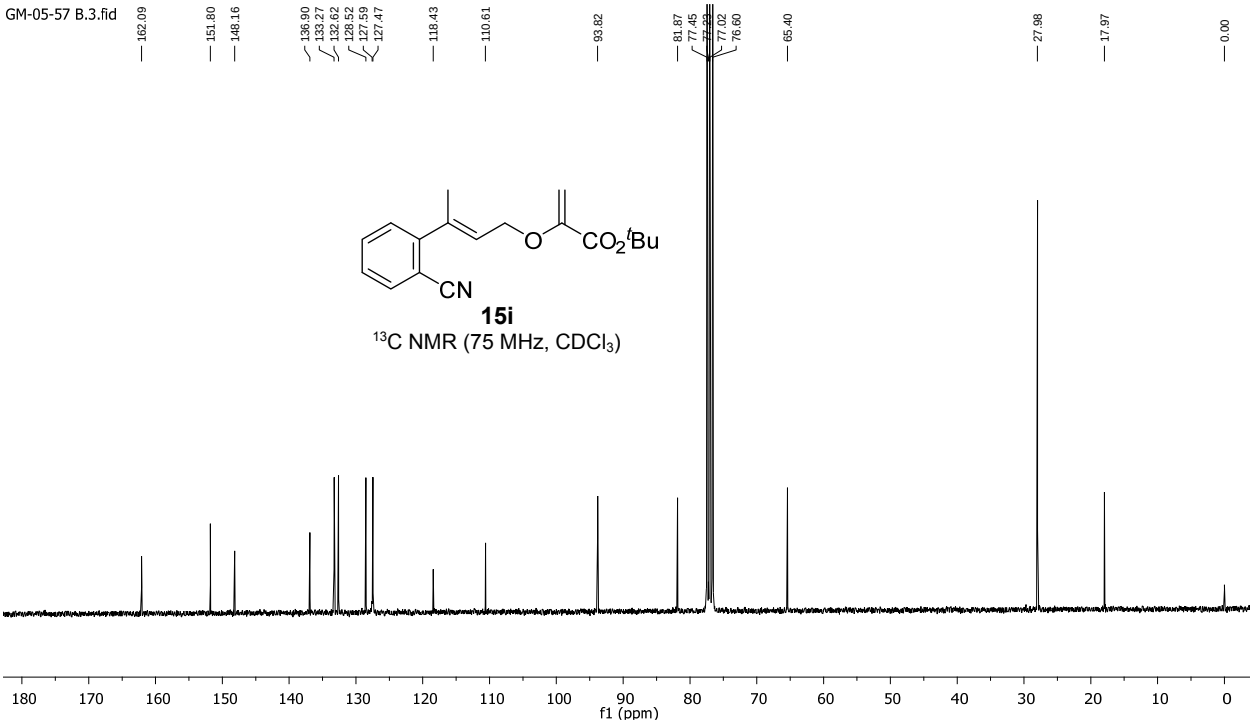
^{1}H NMR (300 MHz, $CDCl_3$)

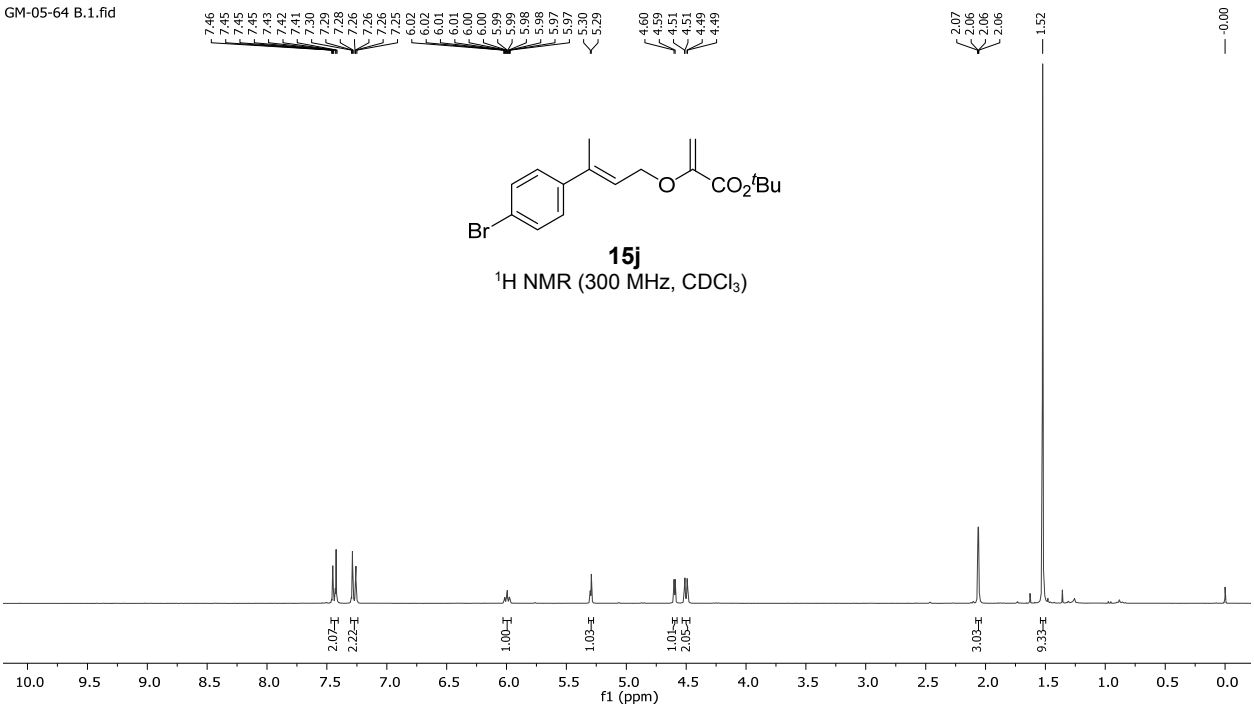


15h

^{13}C NMR (75 MHz, $CDCl_3$)

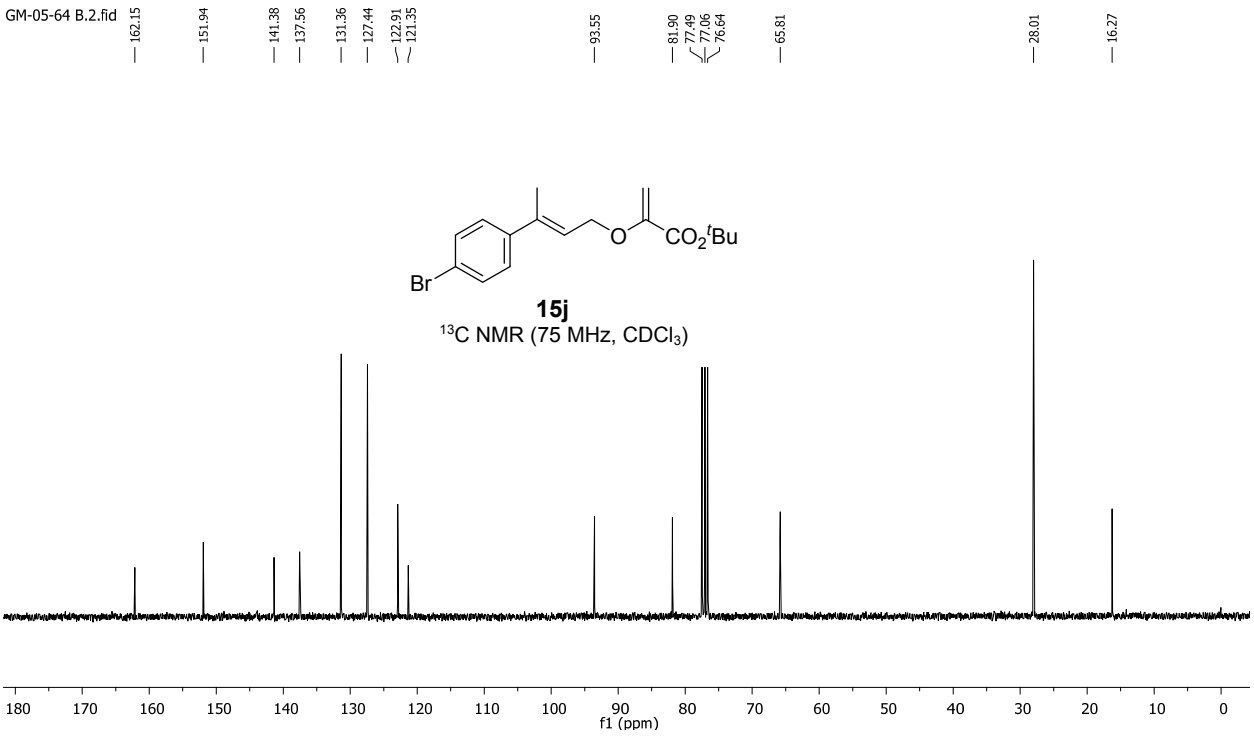

GM-05-57 B.2.fid
CO2tBu
CN
15i
1H NMR (300 MHz, CDCl3)
f1 (ppm)


GM-05-57 B.3.fid
CO2tBu
CN
15i
13C NMR (75 MHz, CDCl3)
f1 (ppm)



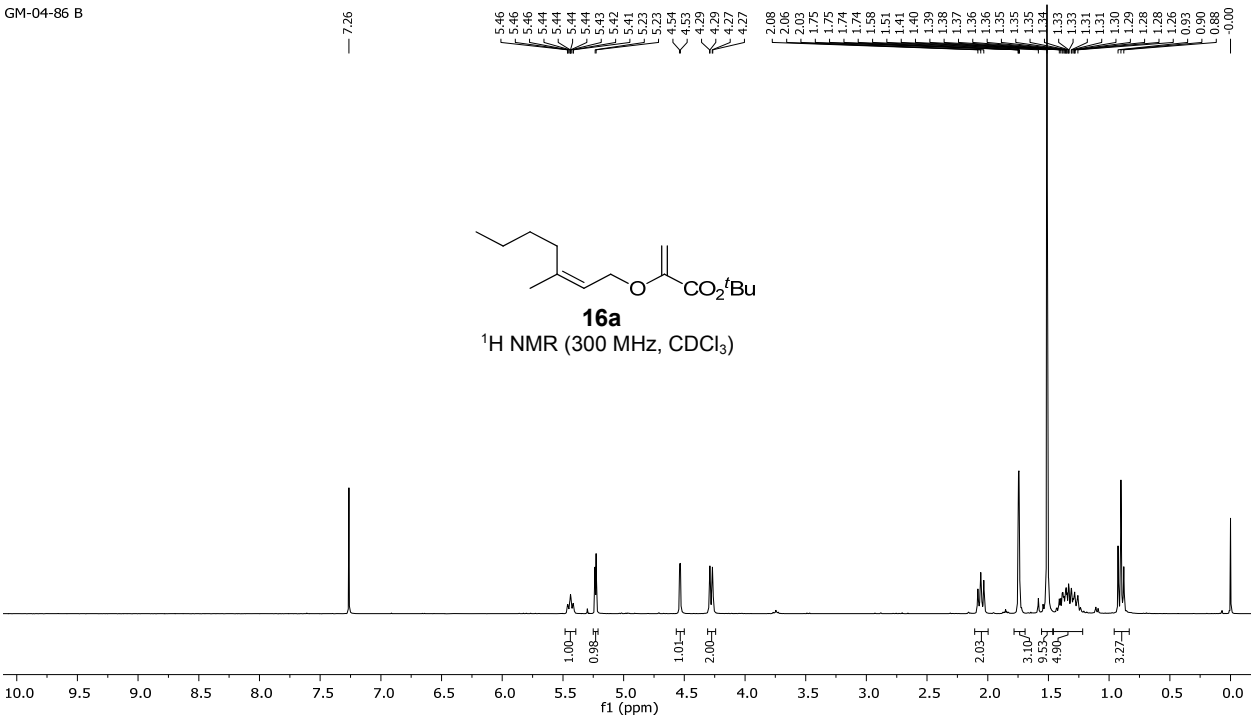
15j

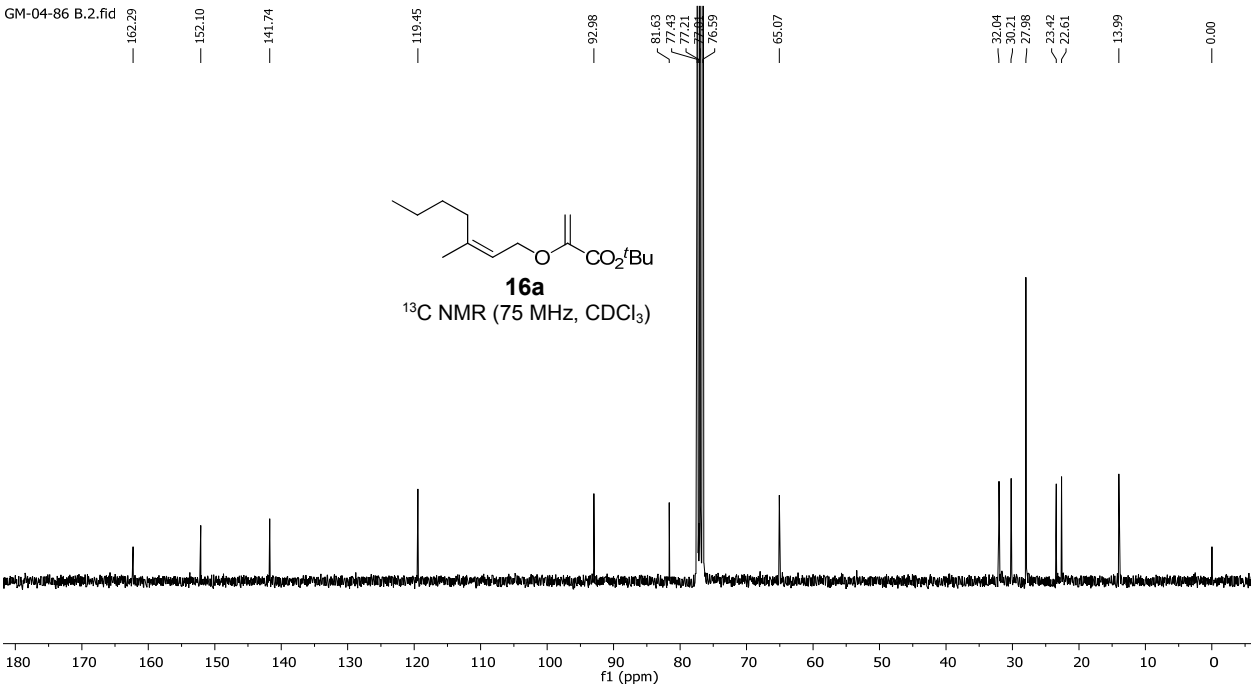
^{1}H NMR (300 MHz, $CDCl_3$)

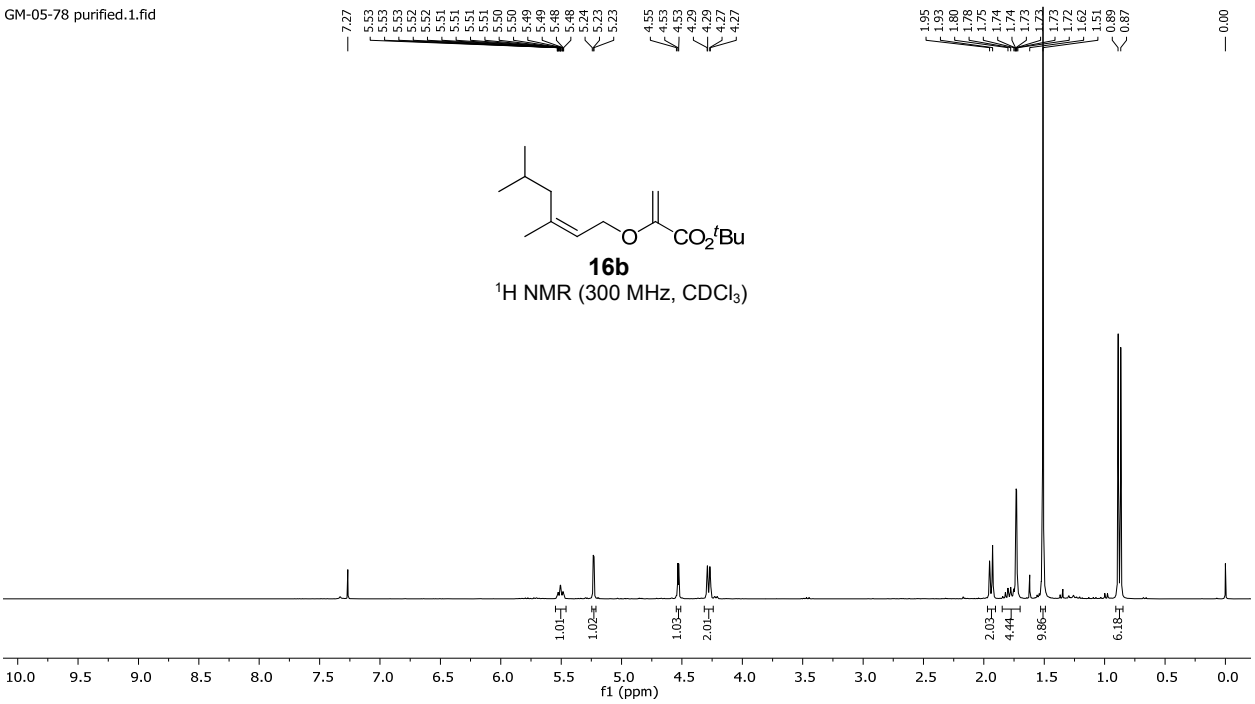


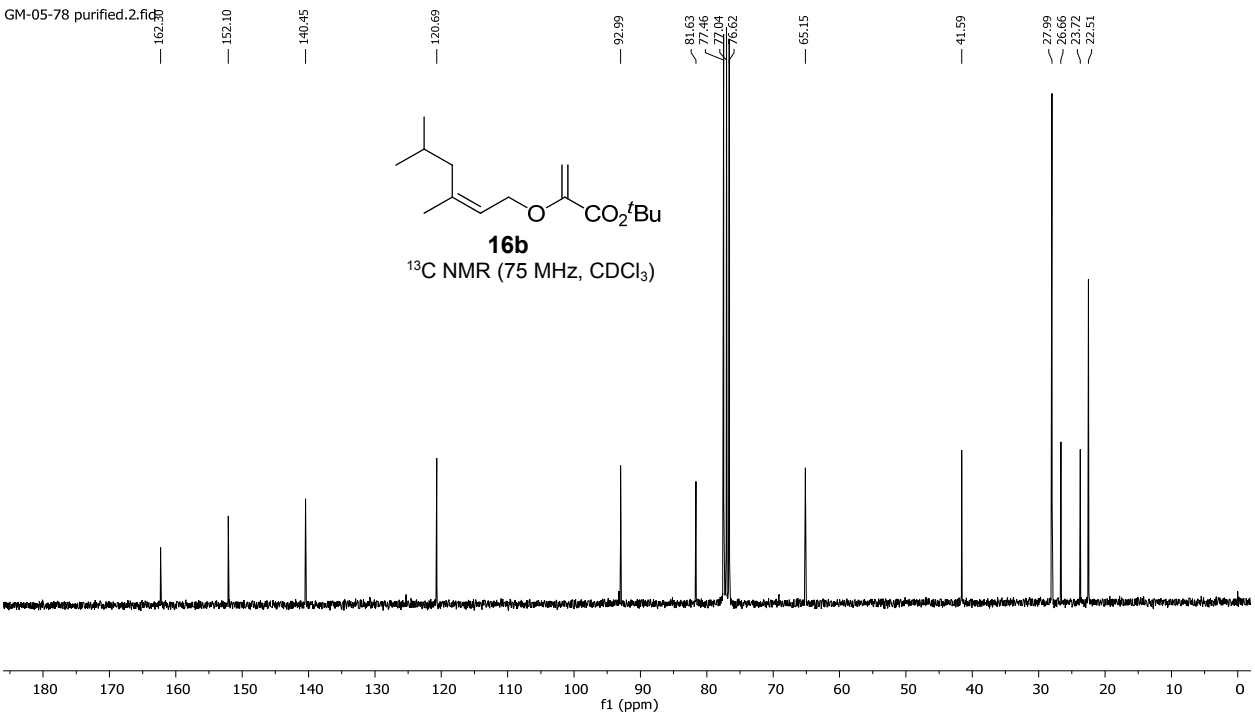
15j

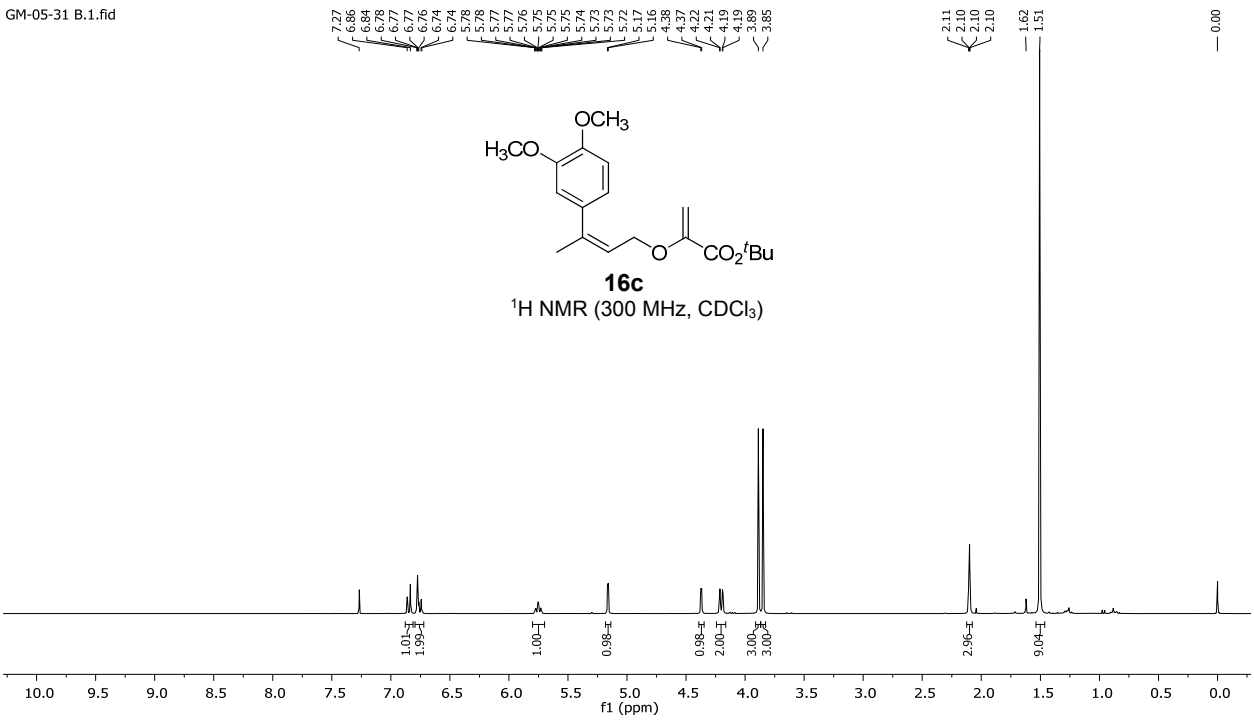
^{13}C NMR (75 MHz, $CDCl_3$)


GM-04-86 B
7.26
5.46
5.46
5.46
5.44
5.44
5.44
5.44
5.43
5.42
5.41
5.23
5.23
4.54
4.53
4.29
4.29
4.27
4.27
2.08
2.06
2.03
1.75
1.75
1.74
1.74
1.58
1.51
1.41
1.40
1.39
1.38
1.37
1.36
1.36
1.35
1.35
1.35
1.34
1.33
1.33
1.31
1.31
1.30
1.29
1.28
1.28
1.26
0.93
0.90
0.88
-0.00
O
CO2tBu
16a
1H NMR (300 MHz, CDCl3)
1.00
0.98
1.01
2.00
2.03
3.10
9.53
4.90
3.27
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


GM-04-86 B.2.fid
162.29
152.10
141.74
119.45
92.98
81.63
77.43
77.21
76.79
76.59
65.07
32.04
30.21
27.98
23.42
22.61
13.99
0.00
O
CO2tBu
16a
13C NMR (75 MHz, CDCl3)
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

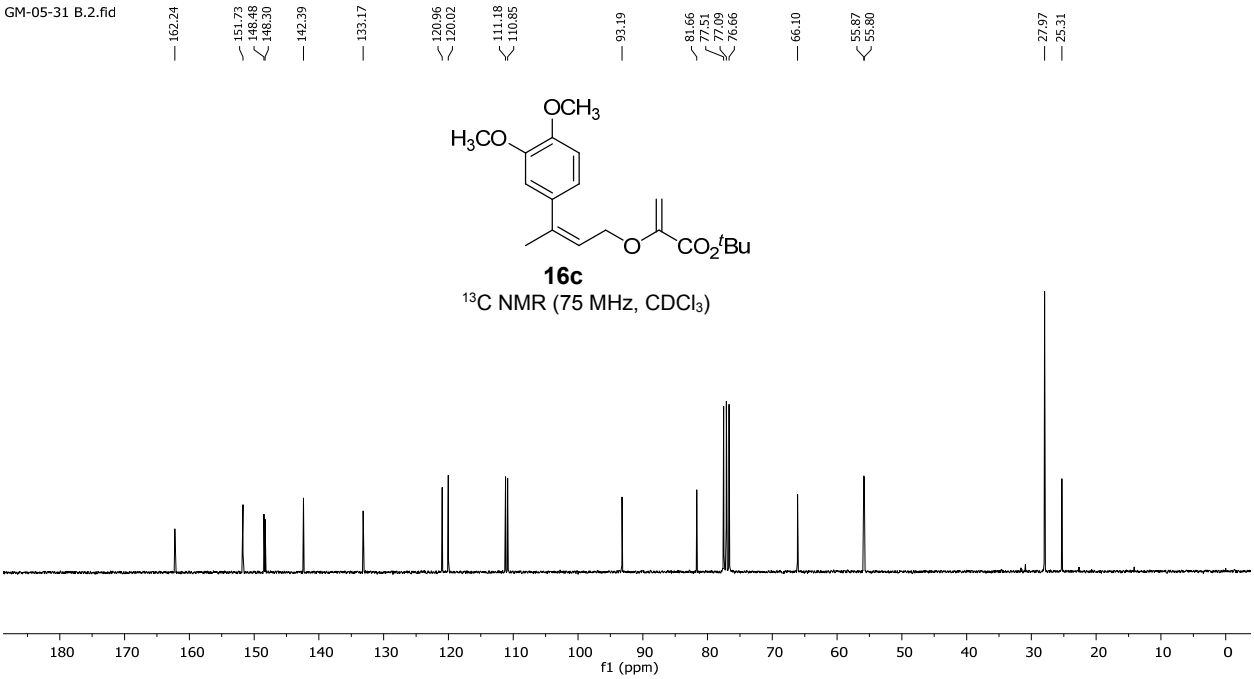

GM-05-78 purified.1.fid
7.27
5.53
5.53
5.53
5.52
5.52
5.51
5.51
5.51
5.50
5.50
5.49
5.49
5.48
5.48
5.24
5.23
5.23
4.55
4.53
4.53
4.29
4.29
4.27
4.27
1.95
1.93
1.80
1.78
1.75
1.74
1.74
1.73
1.73
1.73
1.72
1.62
1.51
0.89
0.87
0.00
O
CO2tBu
16b
1H NMR (300 MHz, CDCl3)
1.01
1.02
1.03
2.01
2.03
4.44
9.86
6.18
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


GM-05-78 purified.2.fid
162.30
152.10
140.45
120.69
92.99
81.63
77.46
77.04
76.62
65.15
41.59
27.99
26.66
23.72
22.51
O
CO2tBu
16b
13C NMR (75 MHz, CDCl3)
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)



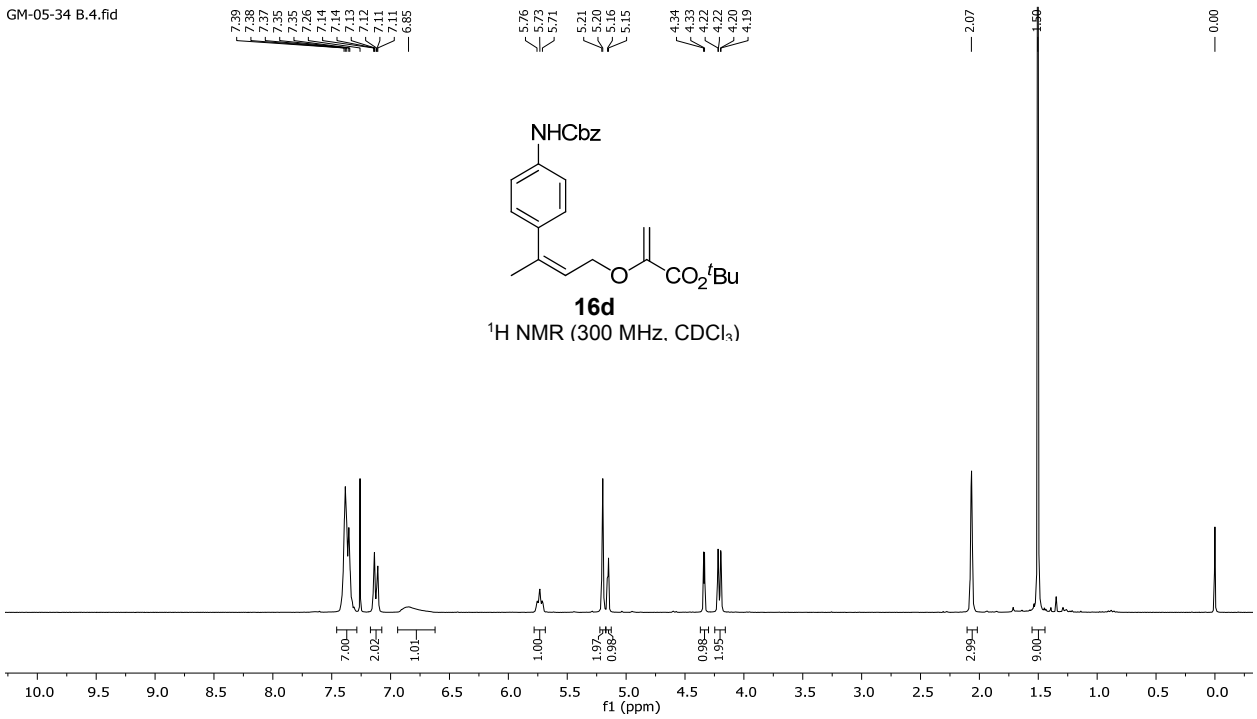
16c

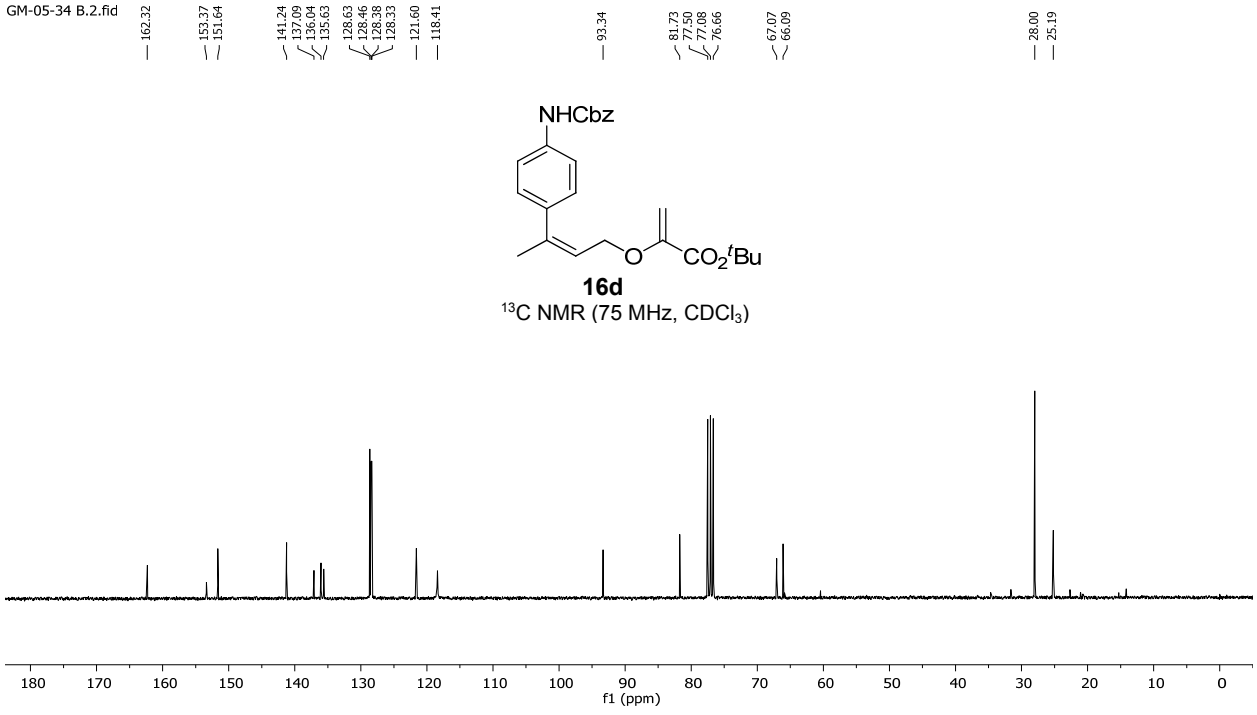
^{1}H NMR (300 MHz, $CDCl_3$)

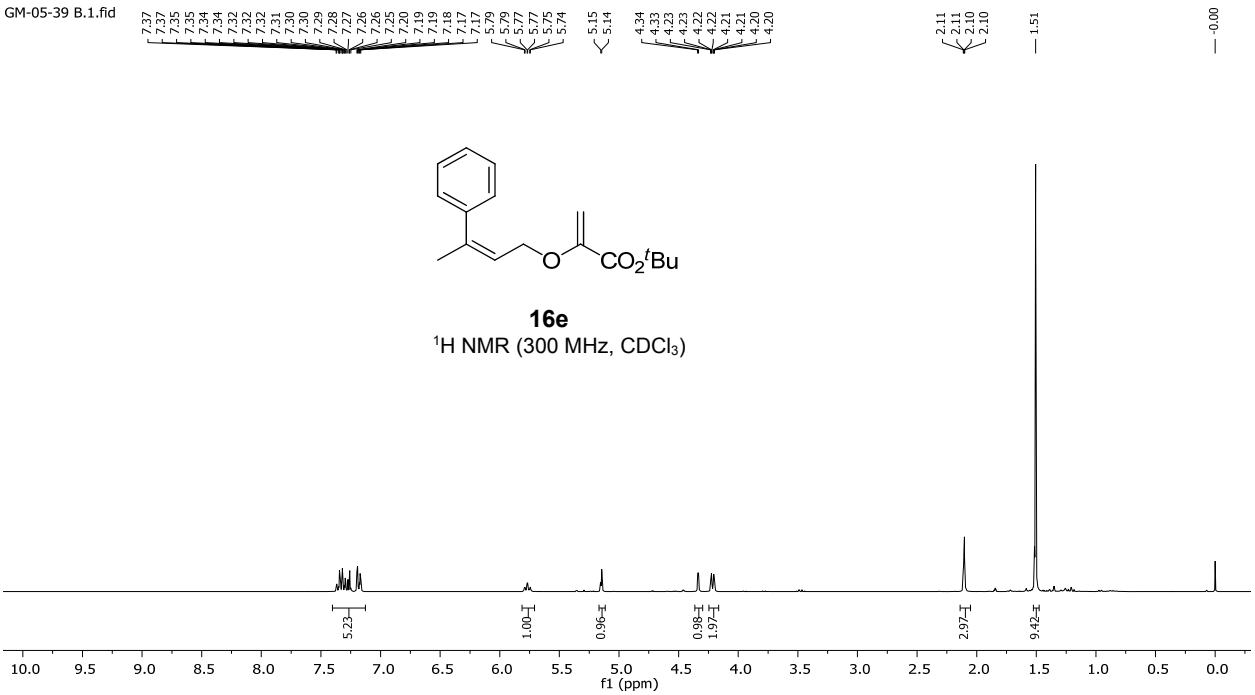


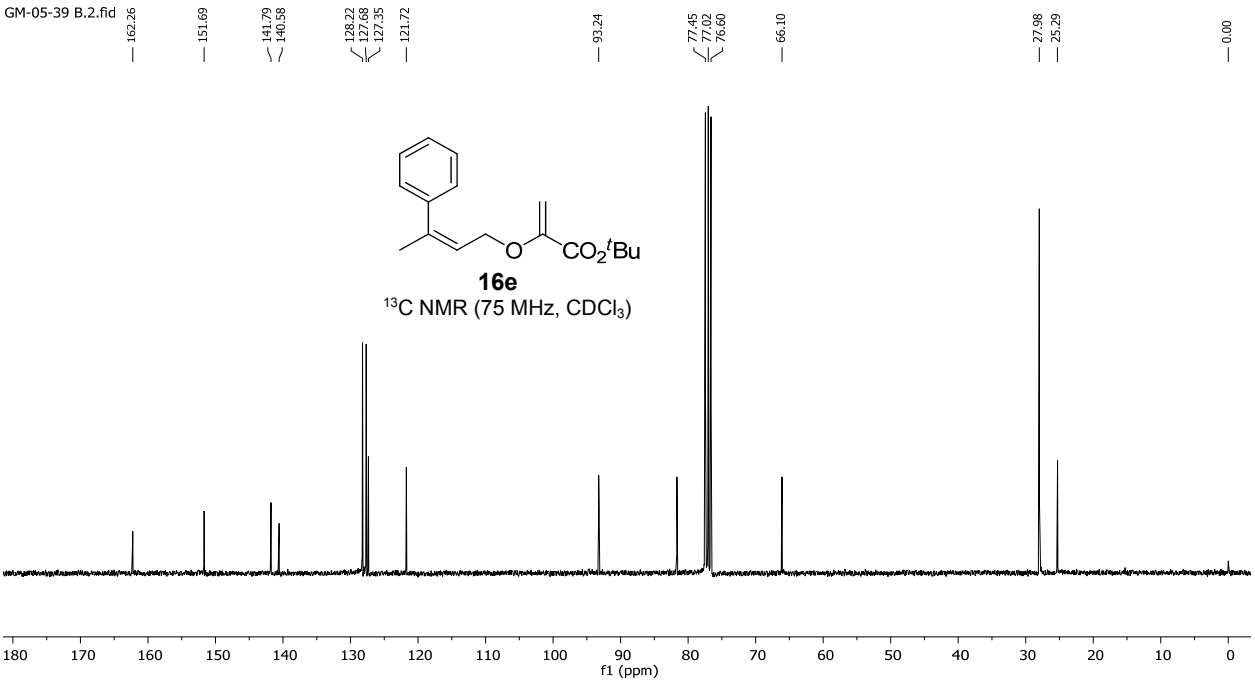
16c

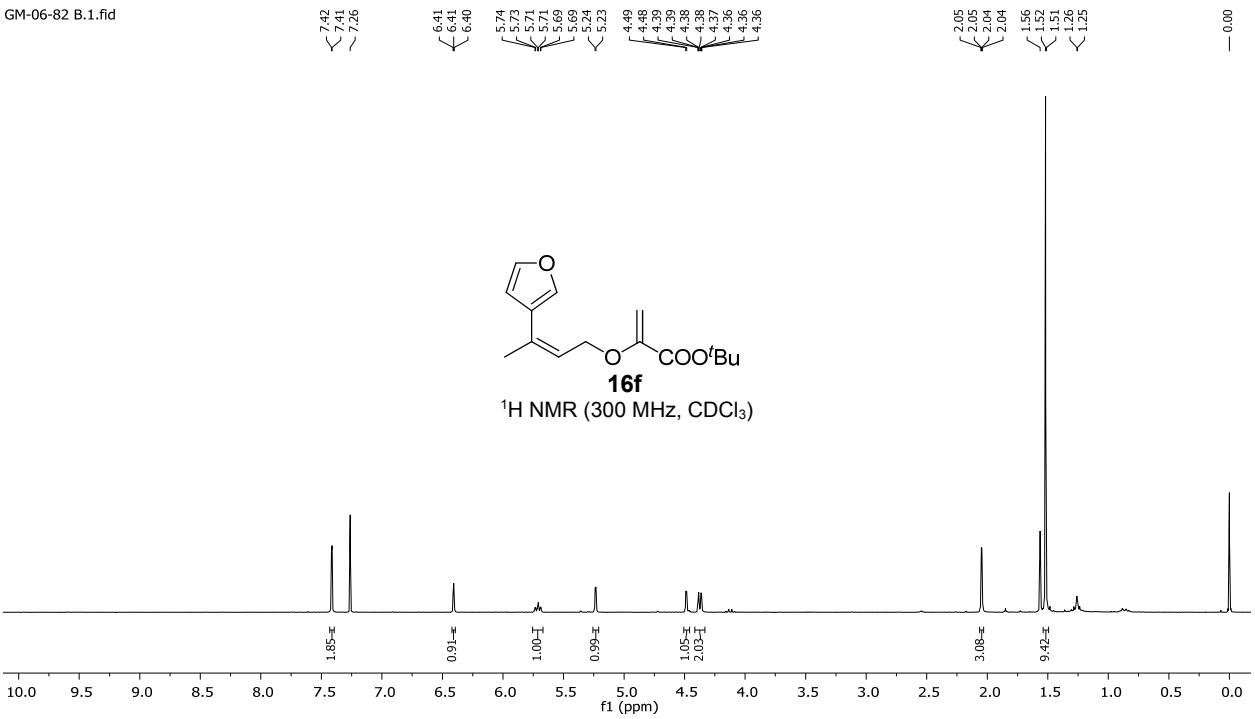
^{13}C NMR (75 MHz, $CDCl_3$)

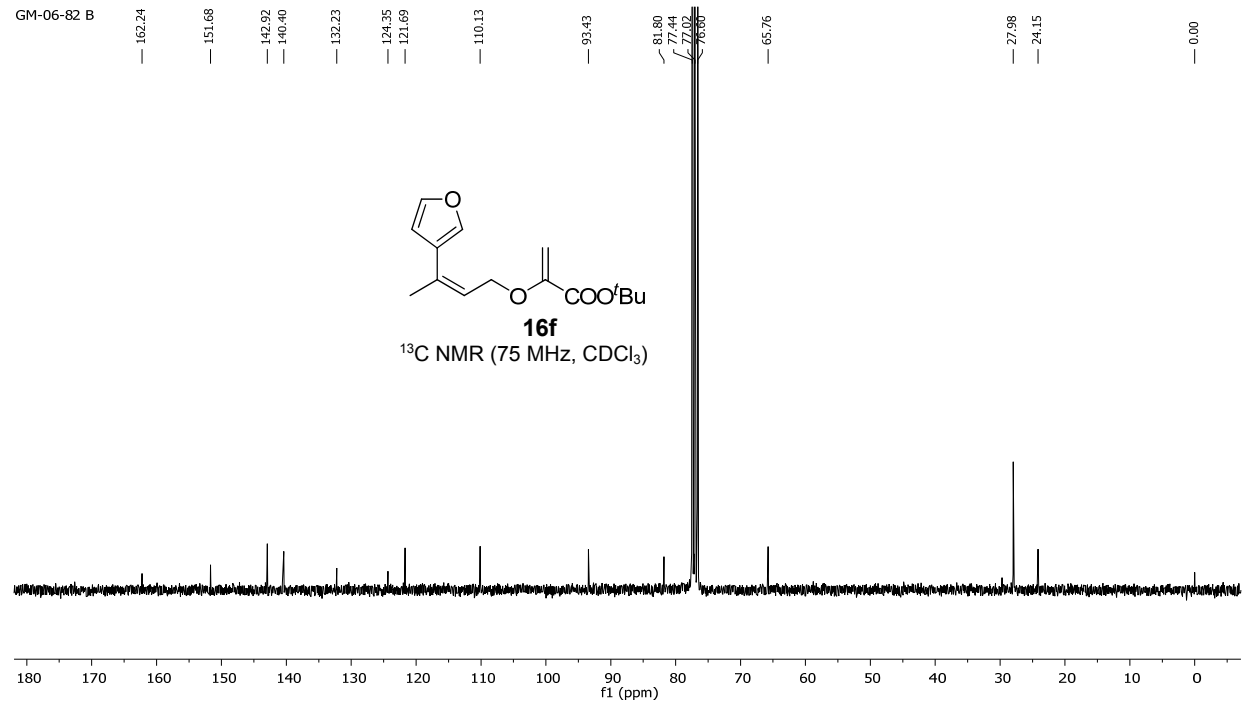

GM-05-34 B.4.fid
NHCbz
O
CO2tBu
16d
1H NMR (300 MHz, CDCl3)
f1 (ppm)

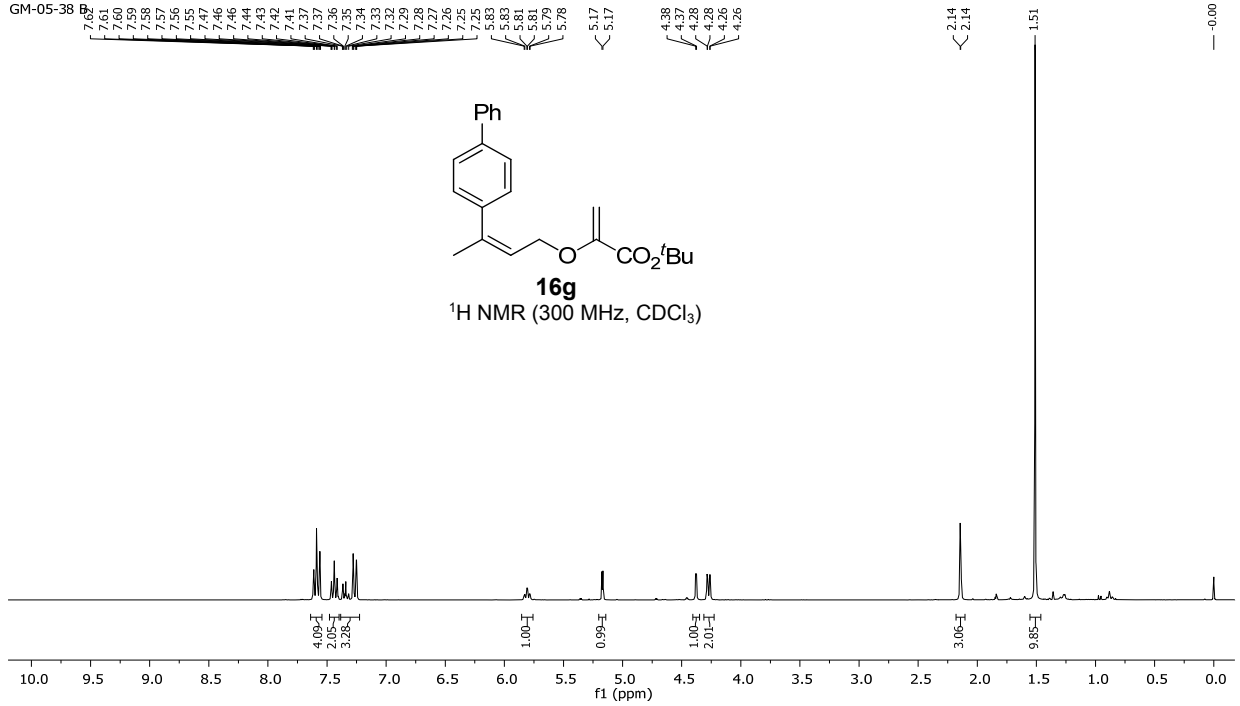

GM-05-34 B.2.fid
NHCbz
O
CO2tBu
16d
13C NMR (75 MHz, CDCl3)
f1 (ppm)


GM-05-39 B.1.fid
7.37
7.37
7.35
7.35
7.34
7.34
7.32
7.32
7.32
7.31
7.30
7.30
7.29
7.28
7.27
7.26
7.26
7.25
7.20
7.19
7.19
7.18
7.17
7.17
5.79
5.79
5.77
5.77
5.75
5.74
5.15
5.14
4.34
4.33
4.23
4.23
4.22
4.22
4.21
4.21
4.20
4.20
2.11
2.11
2.10
2.10
1.51
-0.00
O
CO2tBu
16e
1H NMR (300 MHz, CDCl3)
5.23
1.00
0.96
0.98
1.97
2.97
9.42
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


GM-05-39 B.2.fid
162.26
151.69
141.79
140.58
128.22
127.68
127.35
121.72
93.24
77.45
77.02
76.60
66.10
27.98
25.29
0.00
O
CO2tBu
16e
13C NMR (75 MHz, CDCl3)
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

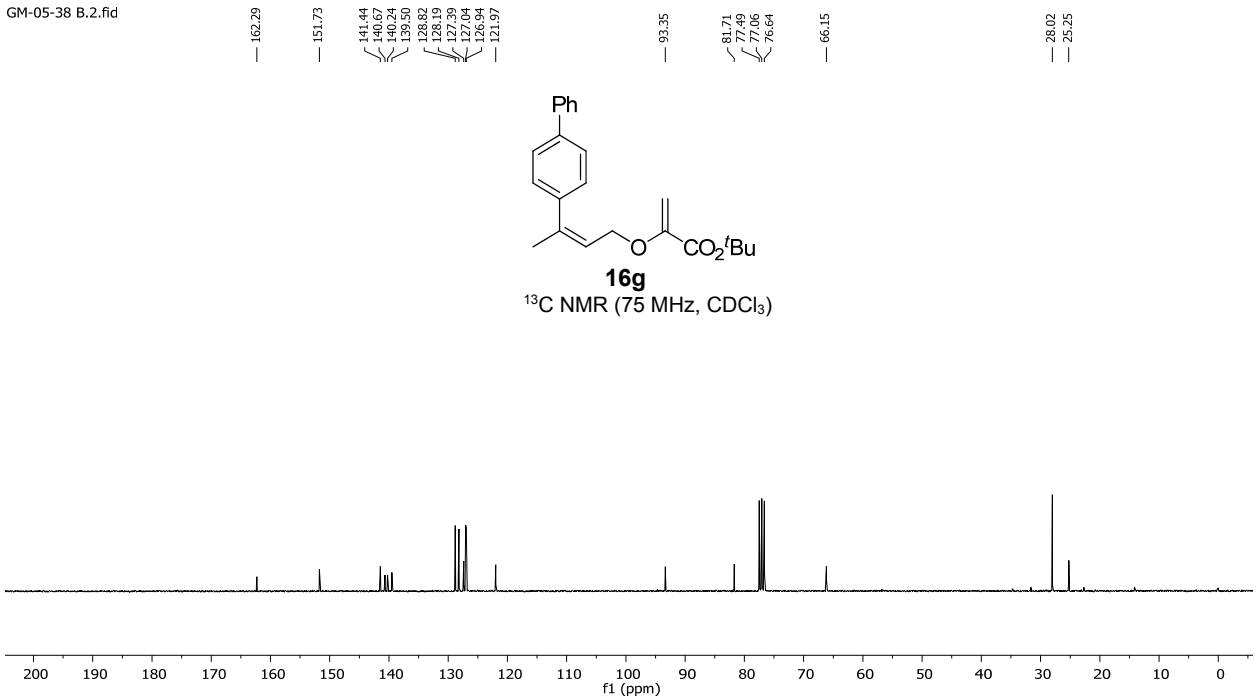

GM-06-82 B.1.fid
7.42
7.41
7.26
6.41
6.41
6.40
5.74
5.73
5.71
5.71
5.69
5.69
5.24
5.23
4.49
4.48
4.39
4.39
4.38
4.38
4.37
4.36
4.36
4.36
2.05
2.05
2.04
2.04
1.56
1.52
1.51
1.26
1.25
0.00
O
O
COO^{t}Bu
16f
^{1}H NMR (300 MHz, CDCl$_3$)
1.85
0.91
1.00
0.99
1.05
2.03
3.08
9.42
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


GM-06-82 B
162.24
151.68
142.92
140.40
132.23
124.35
121.69
110.13
93.43
81.80
77.44
77.02
76.60
65.76
27.98
24.15
0.00
O
O
COO^{t}Bu
16f
^{13}C NMR (75 MHz, CDCl$_3$)
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)



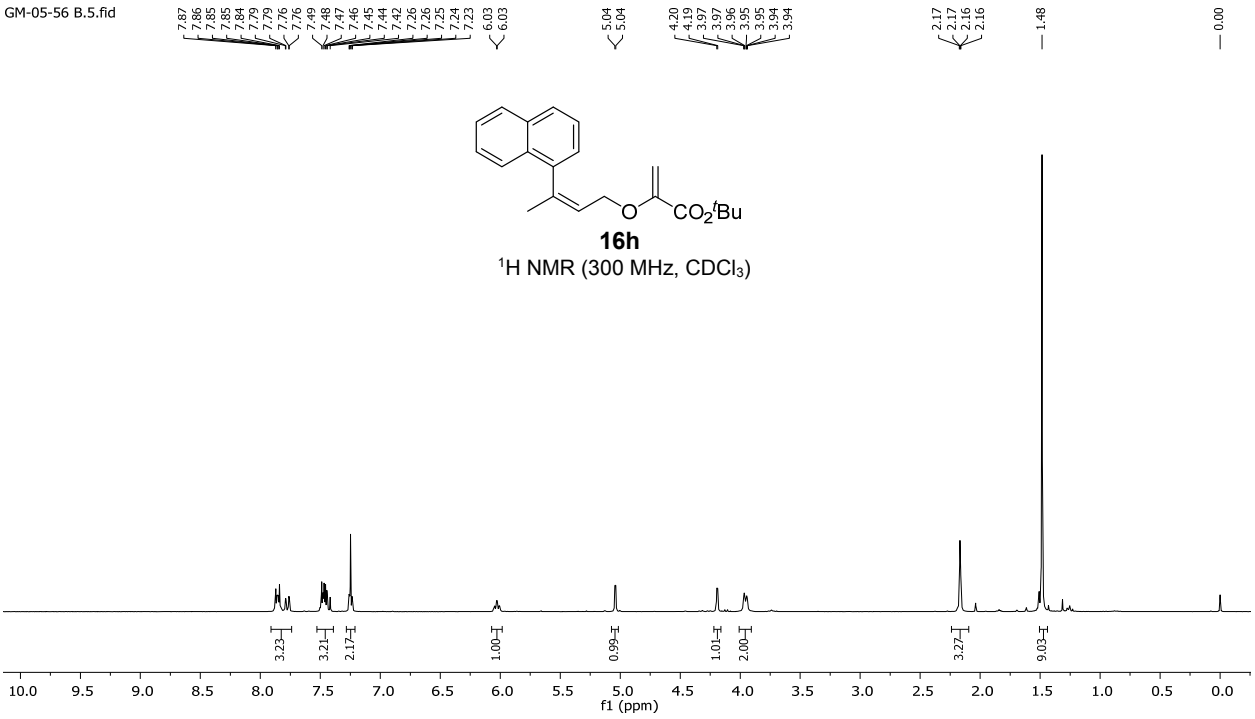
16g

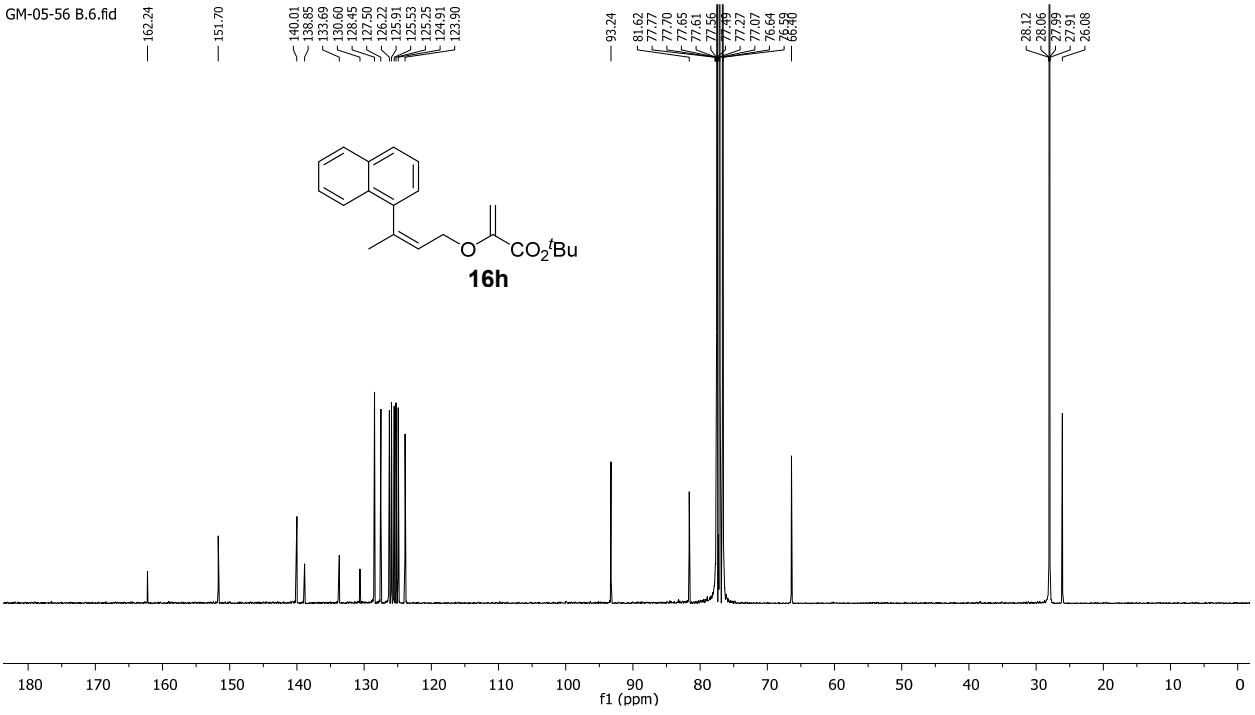
^{1}H NMR (300 MHz, $CDCl_3$)

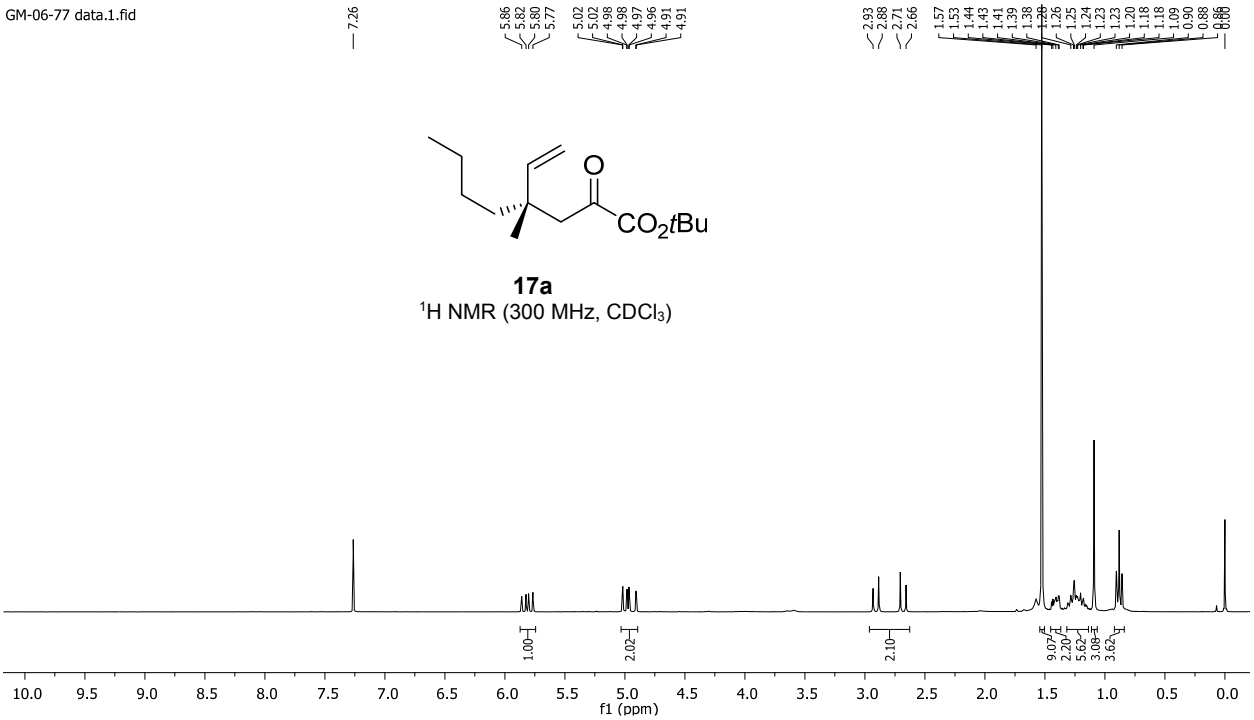


16g

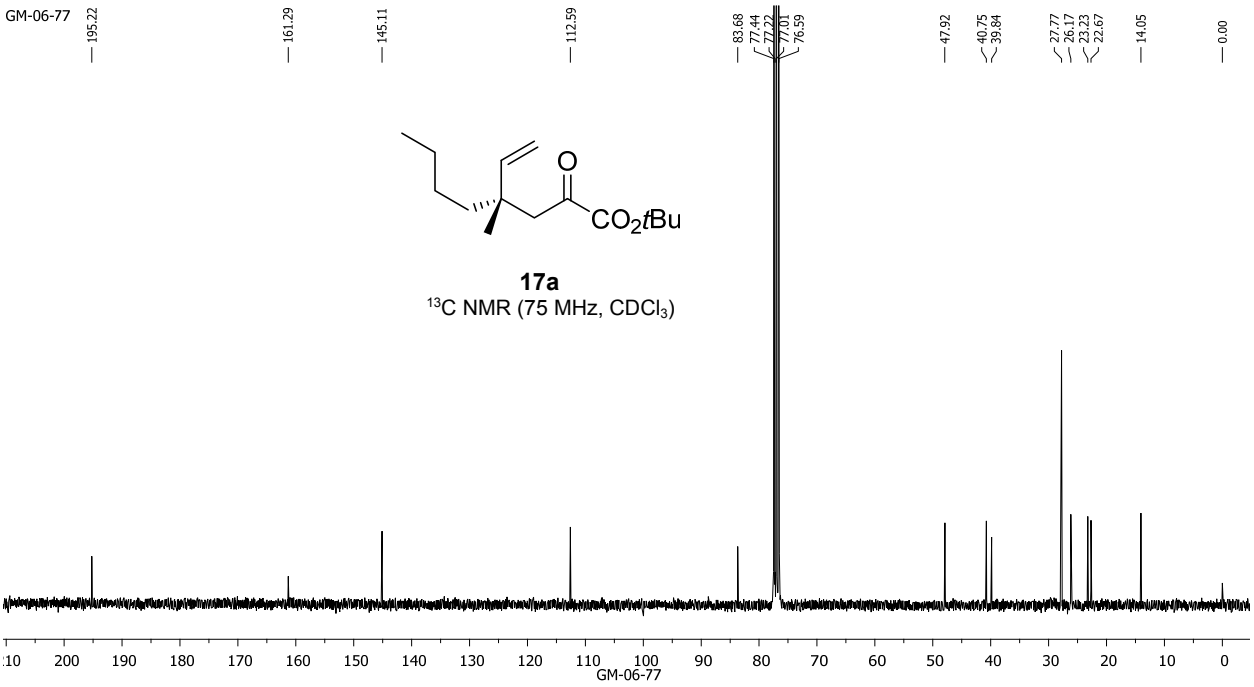
^{13}C NMR (75 MHz, $CDCl_3$)


GM-05-56 B.5.fid
7.87 7.86 7.85 7.85 7.84 7.79 7.79 7.76 7.76 7.49 7.48 7.47 7.46 7.45 7.44 7.42 7.26 7.26 7.25 7.24 7.23 6.03 6.03
5.04 5.04
4.20 4.19 3.97 3.97 3.96 3.95 3.95 3.94 3.94
2.17 2.17 2.16 2.16
1.48
0.00
O
CO2tBu
16h
1H NMR (300 MHz, CDCl3)
3.23 3.21 2.17 1.00 0.99 1.01 2.00 3.27 9.03
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

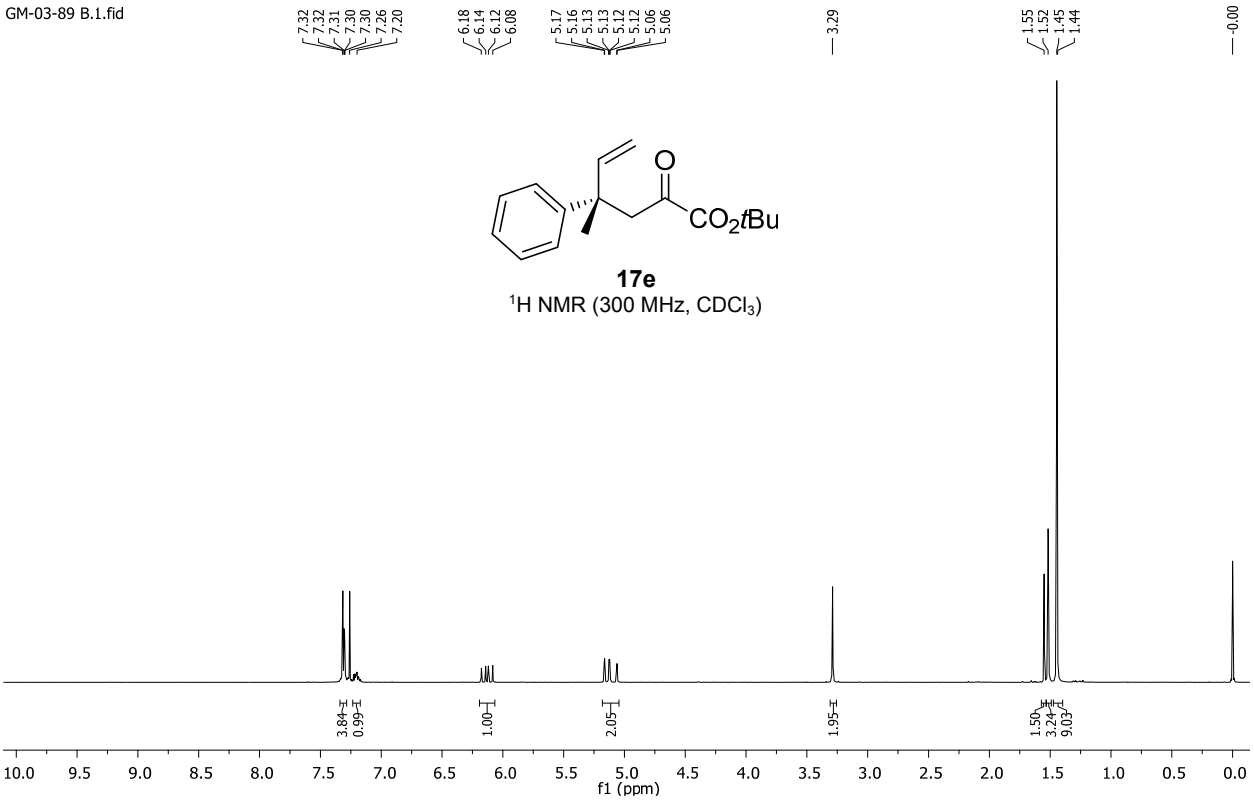

GM-05-56 B.6.fid
162.24
151.70
140.01 138.85 133.69 130.60 128.45 127.50 126.22 125.91 125.53 125.25 124.91 123.90
93.24
81.62 77.77 77.70 77.65 77.61 77.56 77.49 77.27 77.07 76.64 76.58 66.40
28.12 28.06 27.99 27.91 26.08
O
CO2tBu
16h
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)



17a
^{1}H NMR (300 MHz, $CDCl_3$)

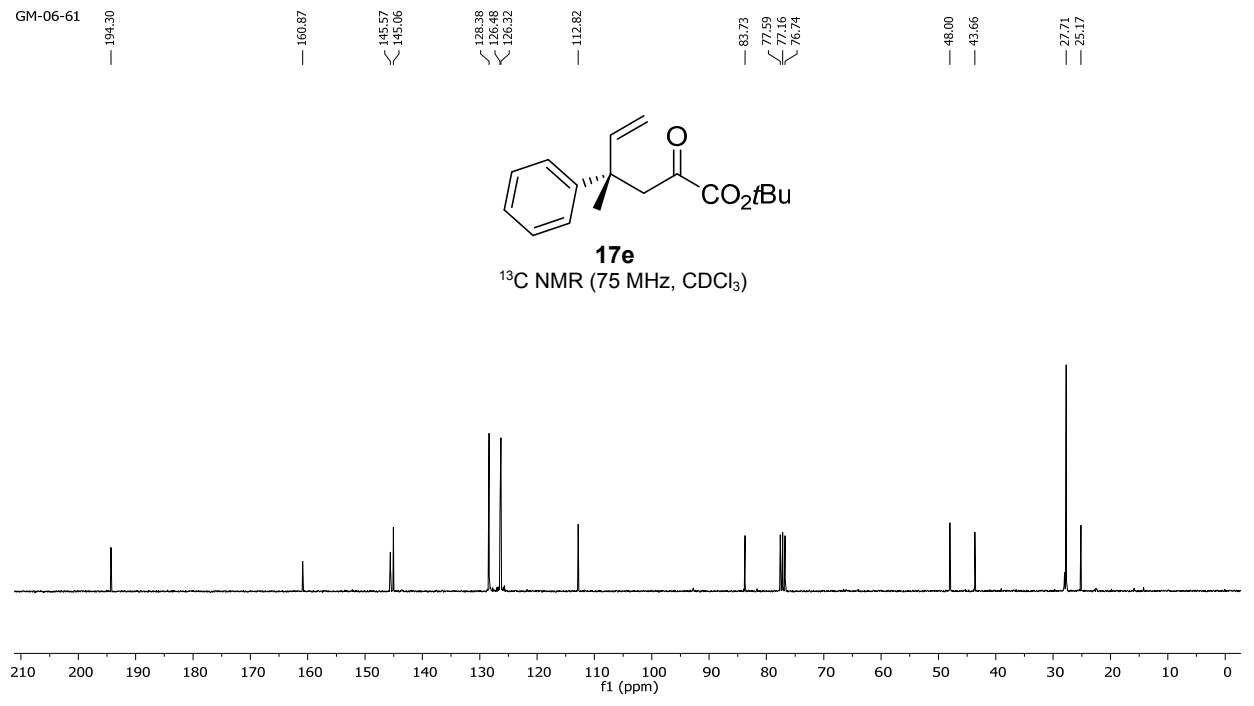


17a
^{13}C NMR (75 MHz, $CDCl_3$)



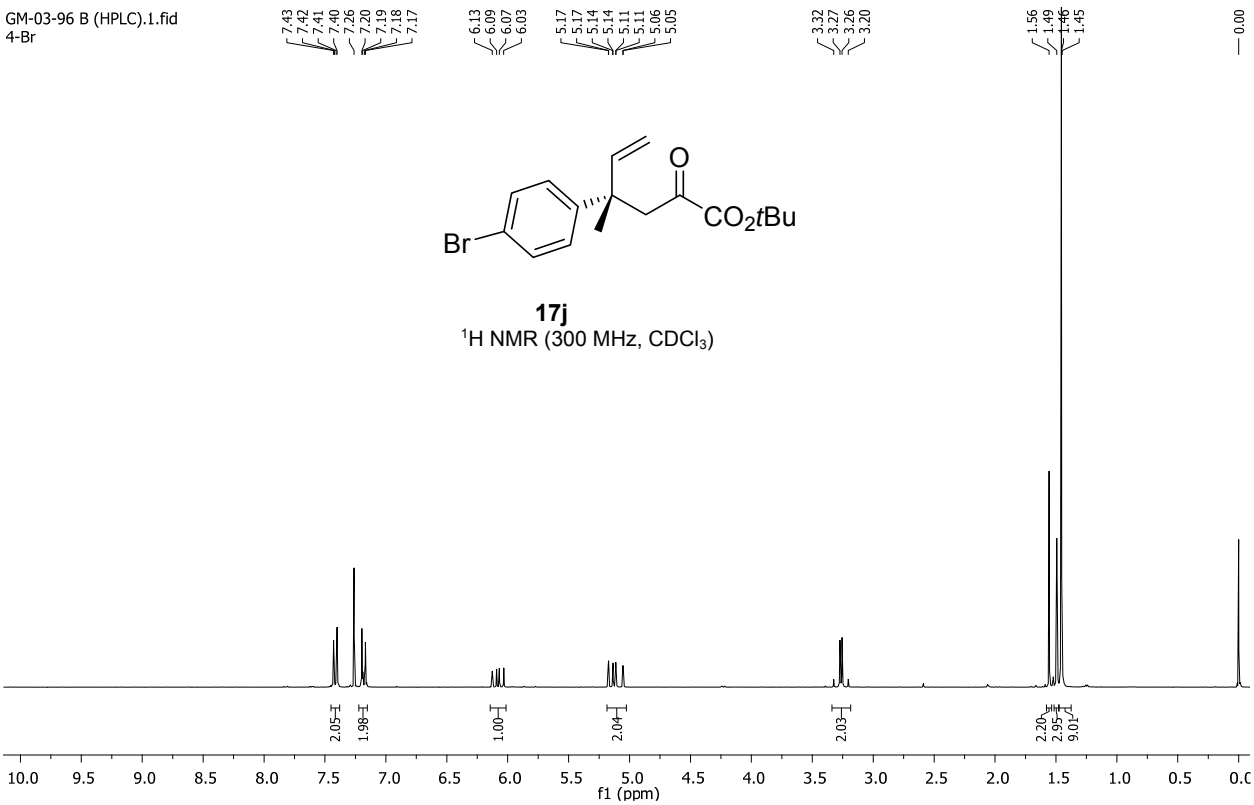
17e

^{1}H NMR (300 MHz, $CDCl_3$)



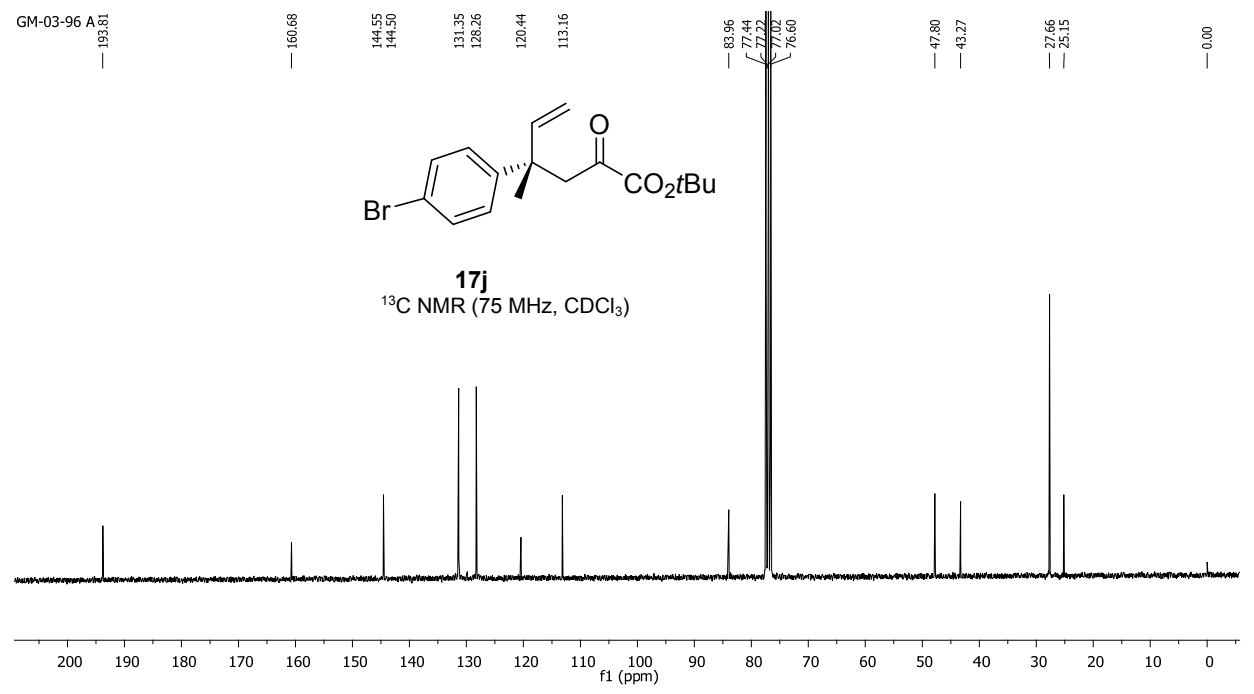
17e

^{13}C NMR (75 MHz, $CDCl_3$)



17j

^{1}H NMR (300 MHz, $CDCl_3$)



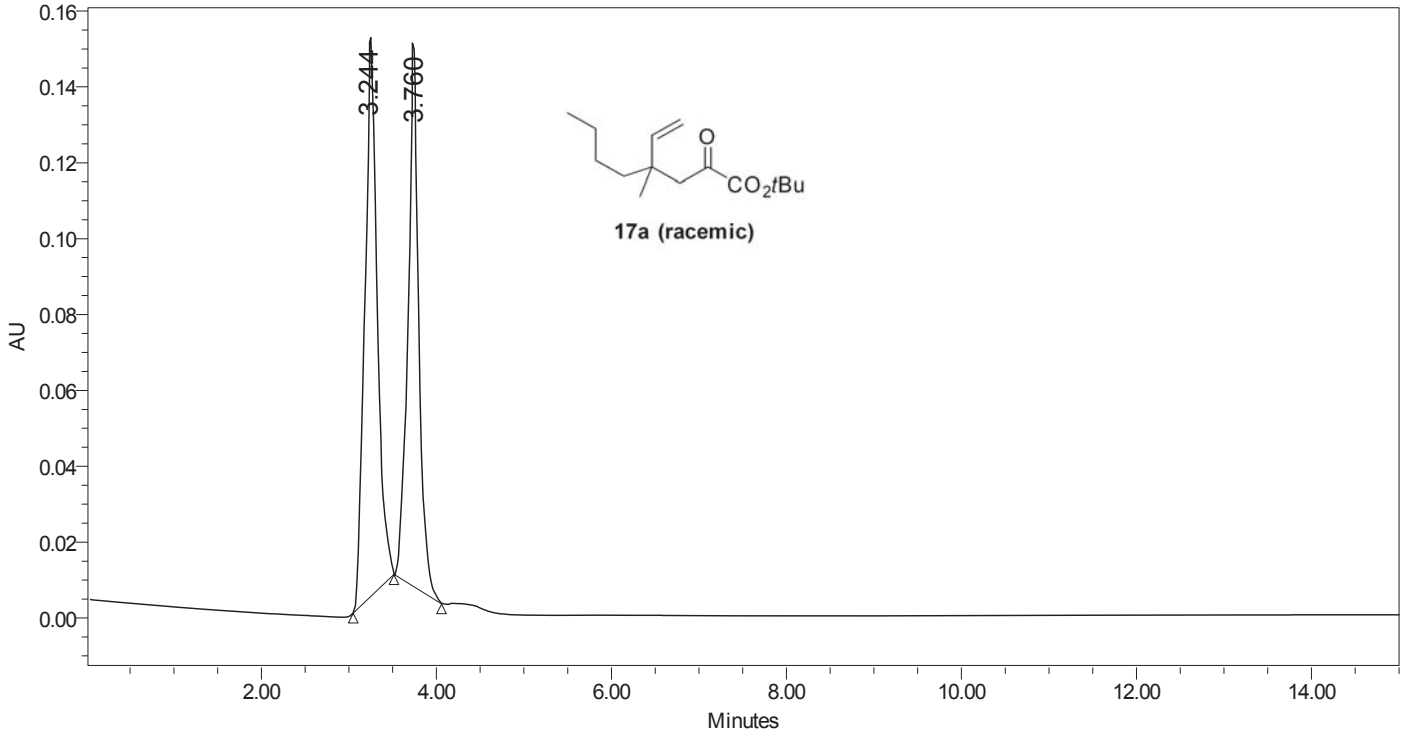
17j

^{13}C NMR (75 MHz, $CDCl_3$)

Breeze 2 HPLC System

SAMPLE INFORMATION

Sample Name:	GM-06-92 A	Acquired By:	Breeze
Sample Type:	Unknown	Date Acquired:	14/10/2016 7:41:07 PM NDT
Vial:	1	Acq. Method:	AS_H 99_5%Hex 0_5% IPA
Injection #:	1	Date Processed:	14/10/2016 7:58:27 PM NDT
Injection Volume:	10.00 ul	Channel Name:	2487Channel 1
Run Time:	15.00 Minutes	Sample Set Name	

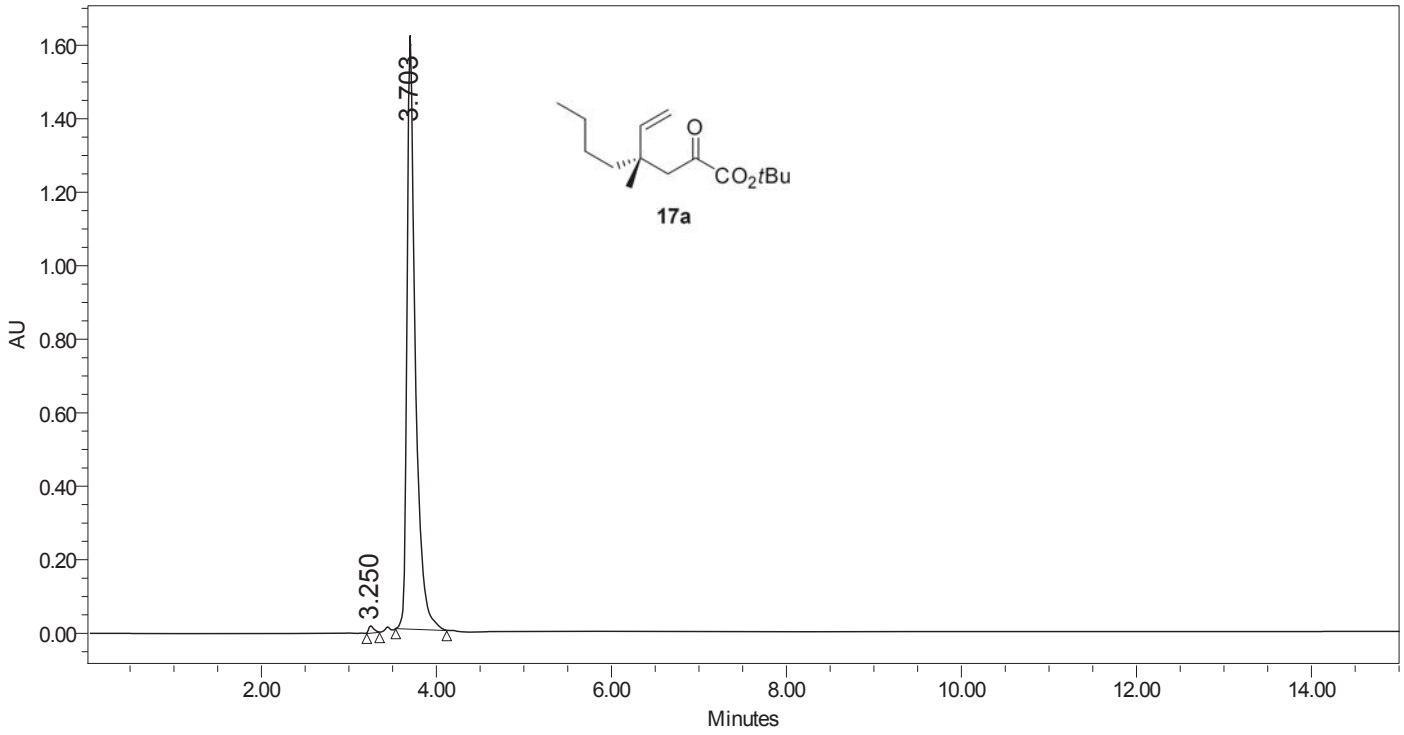


	RT (min)	Area (µV*sec)	% Area	Height (µV)	% Height
1	3.244	1367045	54.64	139092	48.41
2	3.760	1134656	45.36	148232	51.59

Breeze 2 HPLC System

SAMPLE INFORMATION

Sample Name:	GM-06-97	Acquired By:	Breeze
Sample Type:	Unknown	Date Acquired:	18/10/2016 4:05:18 PM NDT
Vial:	1	Acq. Method:	AS_H 99_5%Hex 0_5% IPA
Injection #:	1	Date Processed:	18/10/2016 4:15:56 PM NDT
Injection Volume:	10.00 ul	Channel Name:	2487Channel 1
Run Time:	15.00 Minutes	Sample Set Name	

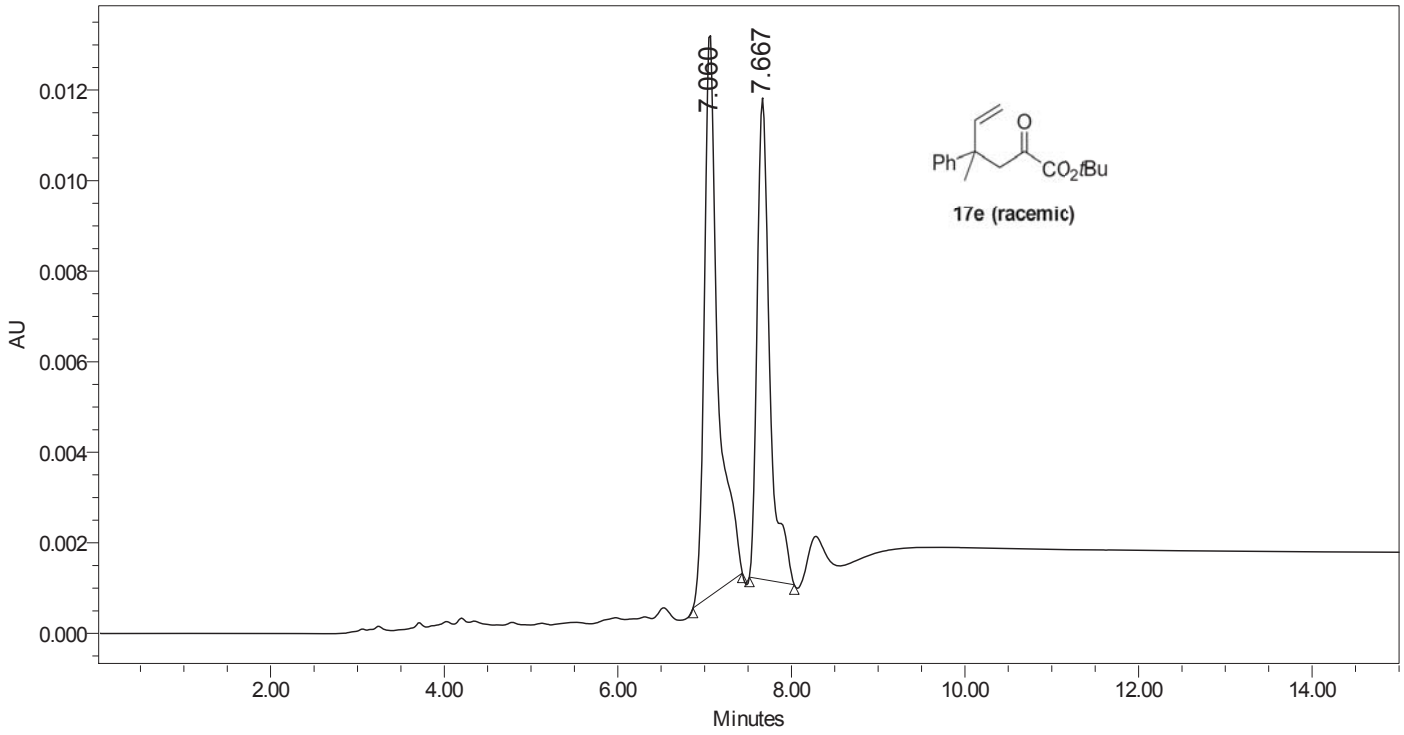


	RT (min)	Area (µV*sec)	% Area	Height (µV)	% Height
1	3.250	97998	0.95	21496	1.35
2	3.703	10239846	99.05	1574798	98.65

Breeze 2 HPLC System

SAMPLE INFORMATION

Sample Name:	GM-02-79 B racemic	Acquired By:	Breeze
Sample Type:	Unknown	Date Acquired:	08/09/2016 4:01:43 PM NDT
Vial:	1	Acq. Method:	AD_H 99_6% Hex 0_4% IPA
Injection #:	1	Date Processed:	08/09/2016 4:18:02 PM NDT
Injection Volume:	10.00 ul	Channel Name:	2487Channel 1
Run Time:	15.00 Minutes	Sample Set Name	

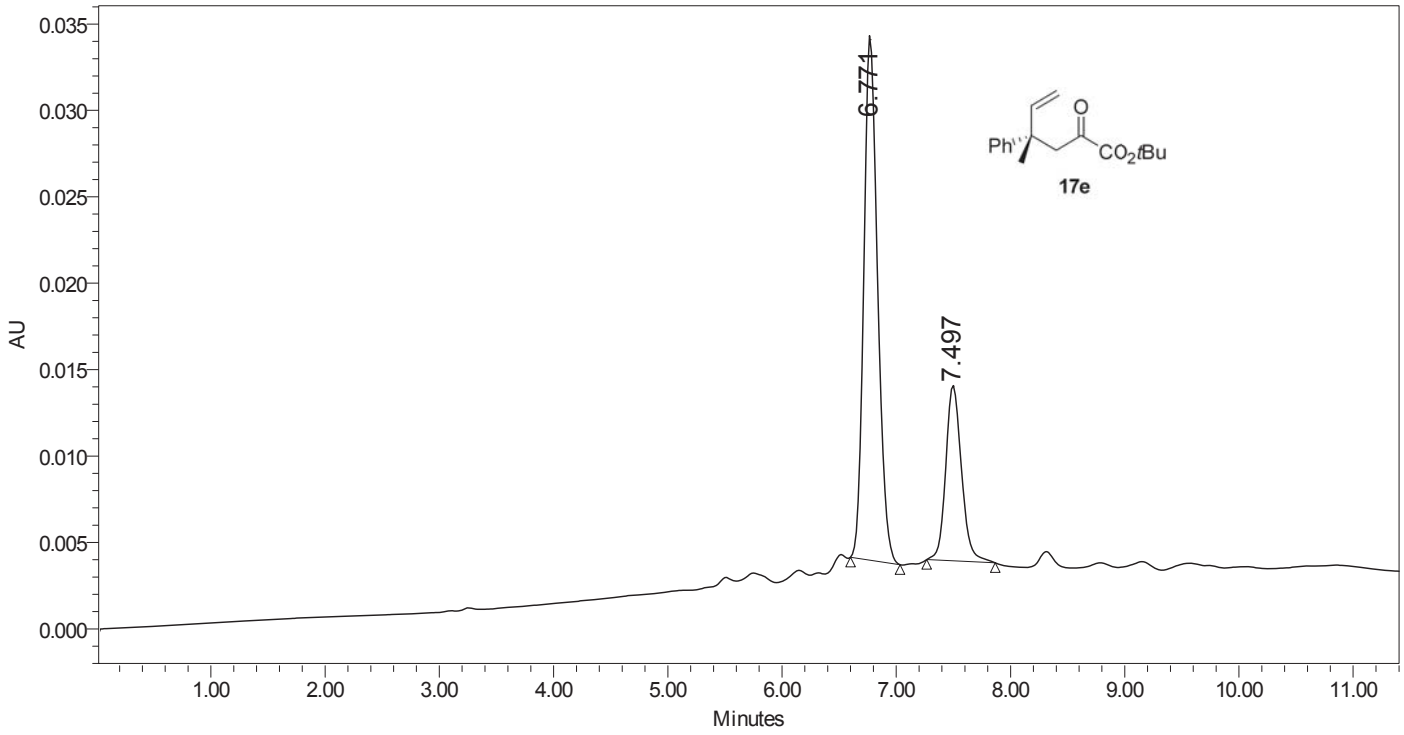


	RT (min)	Area (µV*sec)	% Area	Height (µV)	% Height
1	7.060	135885	55.90	12434	53.96
2	7.667	107196	44.10	10610	46.04

Breeze 2 HPLC System

SAMPLE INFORMATION

Sample Name:	GM-03-89	Acquired By:	Breeze
Sample Type:	Unknown	Date Acquired:	26/08/2016 12:33:50 PM NDT
Vial:	1	Acq. Method:	AD_H 99_6% Hex 0_4% IPA
Injection #:	1	Date Processed:	26/08/2016 12:45:36 PM NDT
Injection Volume:	10.00 ul	Channel Name:	2487Channel 1
Run Time:	15.00 Minutes	Sample Set Name	

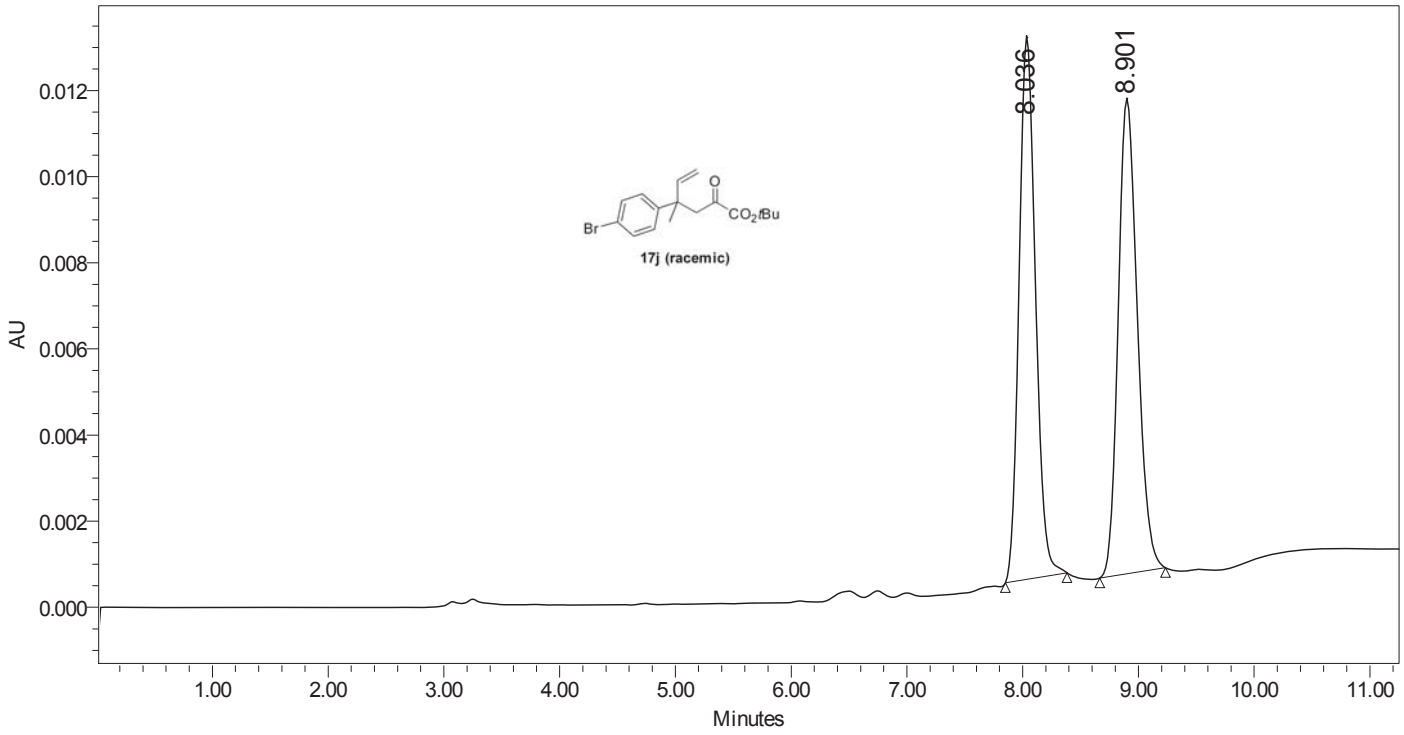


	RT (min)	Area (µV*sec)	% Area	Height (µV)	% Height
1	6.771	255610	72.51	30347	74.97
2	7.497	96905	27.49	10134	25.03

Breeze 2 HPLC System

SAMPLE INFORMATION

Sample Name:	GM-02-100 purified	Acquired By:	Breeze
Sample Type:	Unknown	Date Acquired:	23/08/2016 8:26:33 PM NDT
Vial:	1	Acq. Method:	AD_H 99_6% Hex 0_4% IPA
Injection #:	1	Date Processed:	23/08/2016 8:38:36 PM NDT
Injection Volume:	10.00 ul	Channel Name:	2487Channel 1
Run Time:	15.00 Minutes	Sample Set Name	

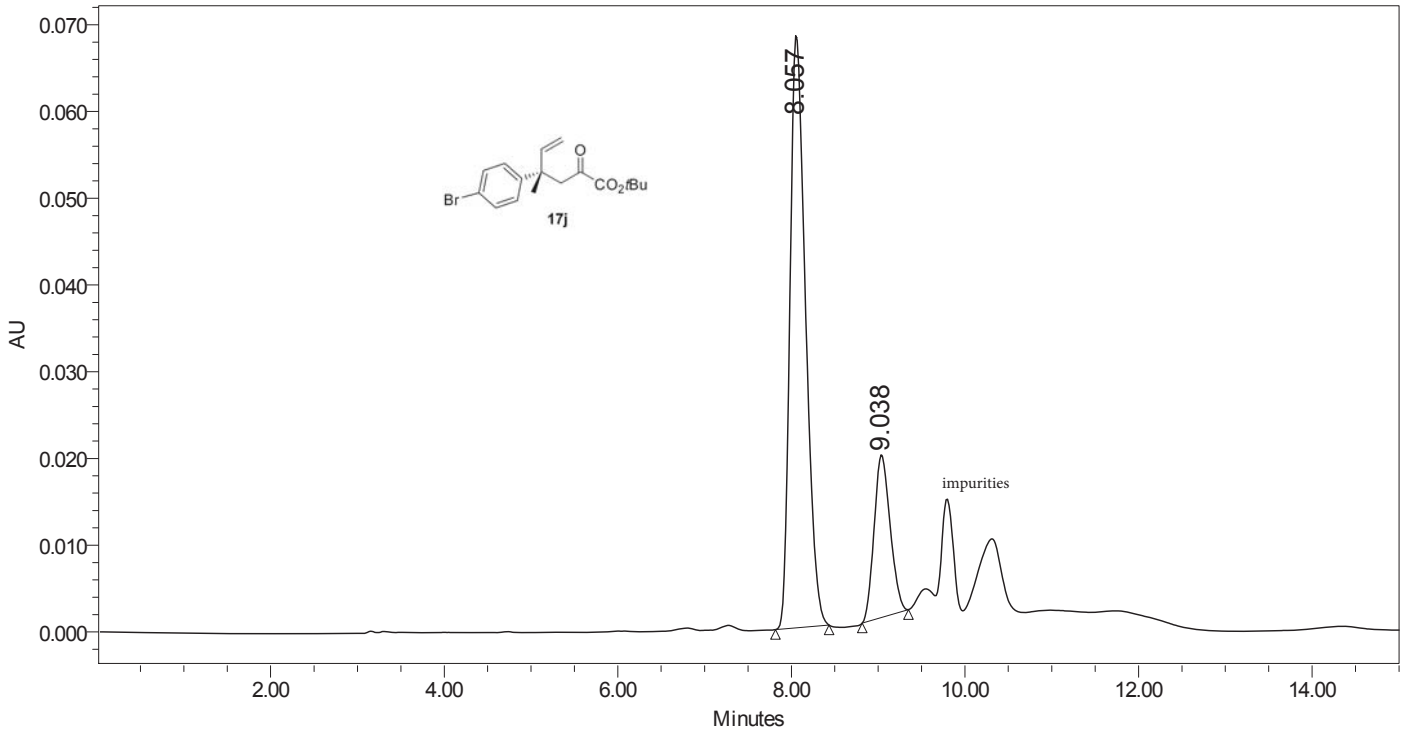


	RT (min)	Area (µV*sec)	% Area	Height (µV)	% Height
1	8.036	124362	49.47	12619	53.33
2	8.901	127043	50.53	11043	46.67

Breeze 2 HPLC System

SAMPLE INFORMATION

Sample Name:	GM-03-96 B	Acquired By:	Breeze
Sample Type:	Unknown	Date Acquired:	16/08/2015 10:06:48 PM NDT
Vial:	1	Acq. Method:	AD_H 99_6% Hex 0_4% IPA
Injection #:	1	Date Processed:	26/09/2016 10:49:04 AM NDT
Injection Volume:	10.00 ul	Channel Name:	2487Channel 1
Run Time:	15.00 Minutes	Sample Set Name	



	RT (min)	Area (µV*sec)	% Area	Height (µV)	% Height
1	8.057	851673	77.91	68520	78.49
2	9.038	241468	22.09	18781	21.51