Supporting Information

Intramolecular Umpolung allylation of Imines

Miao Zhan, ‡ Xiang Pu, ‡ Bin He, Dawen Niu, and Xia Zhang*

Department of Emergency, State Key Laboratory of Biotherapy, West China Hospital, Sichuan University, and Collaborative Innovation Center for Biotherapy, Chengdu 610041, China

Table of Contents

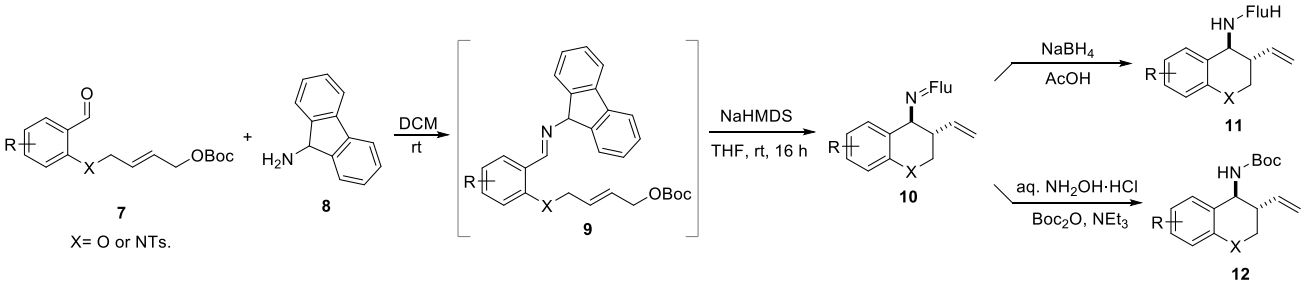
General Information

Anhydrous solvents [tetrahydrofuran (THF) and dichloromethane (DCM)] were purchased from Adamas or Energy Chemicals, and used as received. Tricyclohexyl phosphine (PCy_3) was purchased from Adamas and used as received. $PdCl_2{\cdot}(CH_3CN)_2$, $PdCl_2$, $[PdCl(allyl)]_2$ were purchased from Energy Chemicals and used as received. DBU (Energy Chemicals), TBD (Sigma), Et_3N (Energy Chemicals), LiO^tBu (Aladdin), NaO^tBu (Sigma), LiHMDS (Sigma, solid), NaHMDS (Sigma or TCI, solid), KHMDS (Sigma, solid) were used as received. 9*H*-fluoren-9-amine hydrocholide salt was purchased from TCI and used as received. *N*-fluorenyl imine and allylic carbonates used in this work were prepared according to literature procedures. NMR yields were determined by using 2-methyl naphthalene as an internal standard.

General Analytical Information

All new compounds were characterized by NMR spectroscopy and high-resolution mass spectroscopy (HRMS). NMR spectra were recorded on a Bruker AMX 400 spectrometer and were calibrated using TMS or residual deuterated solvent as an internal reference ($CDCl_3$: 7.26 ppm for ^1H NMR and 77.16 ppm for ^{13}C NMR). HRMS spectra were recorded on a Shimadzu LCMS-IT-TOF.

General Procedures for Intramolecular Umpolung Allylation of Imines



General Reaction Procedure A:

A screw-capped vial containing aldehyde **7** (0.50 mmol) and 9*H*-fluoren-9-amine **8** (0.50 mmol) in dry CH_2Cl_2 (5.0 mL) was stirred at 25 °C for 5 h. The mixture was concentrated to give the corresponding *N*-fluorenyl imine **9** (without purification) and was transferred into a nitrogen-filled glove-box. Dry THF (6.0 mL) was added into the vial via a syringe, followed by NaHMDS (96 mg, 0.53 mmol, 1.05 equiv). The vial was sealed with a cap containing a PTFE septum, removed from the glove box, and kept at 25 °C for 16 h.

A small aliquot of the reaction solution was concentrated, diluted with $CDCl_3$, and taken a ^1H NMR spectrum to determine the dr of **10**.

General Reaction Procedure B:

A screw-capped vial containing aldehyde **7** (0.50 mmol) and 9*H*-fluoren-9-amine **8** (0.50 mmol) in dry CH_2Cl_2 (5.0 mL) was stirred at 25 °C for 5 h. The mixture was concentrated to give the corresponding *N*-fluorenyl imine **9** (without purification) and was transferred into the glove-box. $PdCl_2$ (6 mol %), PCy_3 (24 mol %) and THF (6.0 mL) were added into the vial, followed by NaHMDS (1.05 equiv). The vial was sealed

with a cap containing a PTFE septum, removed from the glove box, and kept at 25 °C for 16 h. A small aliquot of the reaction solution was concentrated, diluted with $CDCl_3$, and taken a ^1H NMR spectrum to determine the dr of **10**.

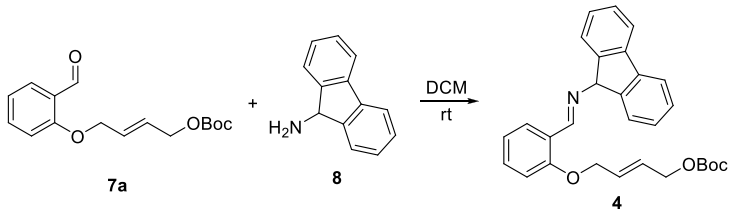
General Workup Procedure A:

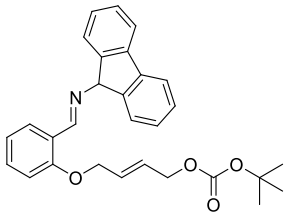
At the end of the reaction, the mixture was concentrated, and CH_2Cl_2 (3 mL) was added, followed by $NaBH_4$ (1.5 mmol, 57 mg), and cooled in an ice water bath. AcOH (10 mmol, 0.6 mL) was added slowly for at least 15 minutes while the reaction mixture was rapidly stirred (**CAUTION**: gas evolution). The resulting mixture was warmed to room temperature, and stirred for 1-2 h. The reaction mixture was then cooled in an ice-water bath, and NaOH (10% aq., 5 mL) was added slowly while the reaction mixture was rapidly stirred. The reaction mixture was warmed to room temperature, and stirred for 30 min. The layers were separated, and the aqueous layer was extracted with CH_2Cl_2 (5 mL) twice. The combined organic layers were washed with brine (5 mL), and dried over Na_2SO_4. The mixture was concentrated under reduced pressure and purified by flash chromatography to afford the product **11**.

General Workup Procedure B:

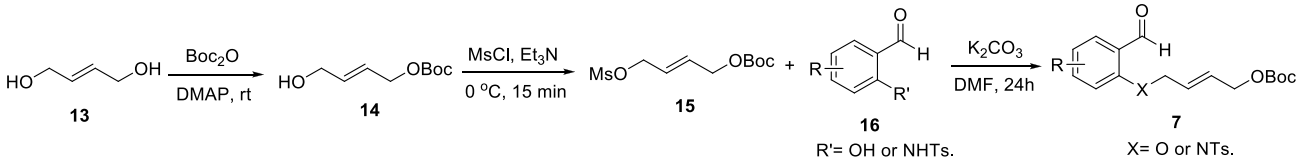
The mixture was concentrated and hydroxylamine hydrochloride (1.0 M in Ethanol/ H_2O= 4/1, 2 mL) was added. The resulting mixture was left at room temperature until the imine product was fully consumed (TLC, ~5 h). The mixture was then extracted with Et_2O (5 mL) to remove fluorenone. The aqueous layer was basified with saturated aq. Na_2CO_3 to pH > 9, and extracted with CH_2Cl_2 three times. To the combined organic layers were added Et_3N (200 µL) and Boc_2O (200 µL). The mixture was left at room temperature until full consumption of the primary amine, as indicated by TLC analysis. The mixture was concentrated and subjected to flash chromatography to give the corresponding carbamate **12**.

Characterization Data of for Allyl Carbonates





(*E*)-4-(2-((*E*)-(9H-fluoren-9-ylimino)methyl)phenoxy)but-2-enyl tert-butyl carbonate (4). *N*-fluorenyl imine **4** used in this manuscript was prepared following reported procedures.[1] Aldehyde **7a** and 9*H*-fluoren-9-amine **8** (1:1 mixture) in dry CH_2Cl_2 (0.2 M) was stirred at 25 °C for 5 h. The mixture was concentrated to give the corresponding *N*-fluorenyl imine **4**, which is pure enough for further reactions. **^{1}H NMR (400 MHz, $CDCl_3$) δ:** 9.26 (s, 1H), 7.99 (dd, *J* = 7.7, 1.5 Hz, 1H), 7.76 (d, *J* = 7.4 Hz, 2H), 7.43 – 7.27 (m, 7H), 6.96 – 6.89 (m, 2H), 6.10 (dt, *J* = 15.8, 4.8 Hz, 1H), 6.01 (dt, *J* = 15.7, 5.5 Hz, 1H), 5.43 (s, 1H), 4.67 (d, *J* = 4.4 Hz, 2H), 4.64 (d, *J* = 5.6 Hz, 2H), 1.49 (s, 9H); **^{13}C NMR (101 MHz, $CDCl_3$) δ**: 159.4, 157.8, 153.4, 145.1, 141.2, 132.3, 129.4, 128.5, 128.2, 127.5, 127.1, 125.5, 124.9, 121.2, 120.2, 112.2, 82.5, 75.2, 68.0, 66.5, 27.9; **HRMS (DART-TOF)** calculated for $C_{29}H_{30}NO_4^+$ $[M+H]^+$ m/z 456.2169, found 456.2179.

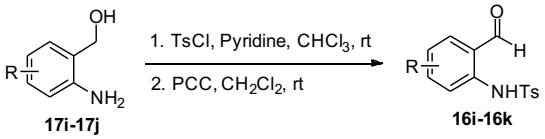


(*E*)-*tert*-butyl 4-hydroxybut-2-enyl carbonate (14).

To a solution of (*E*)-but-2-ene-1,4-diol **13** (0.88 g, 10 mmol) in CH_2Cl_2 (20 mL, 0.5 M), Boc_2O (1.64 g, 7.5 mmol) and 4-dimethylaminopyridine (61 mg, 0.5 mmol) were added. The solution was stirred overnight. The solvent was removed by rotary evaporation and the reaction mixture was purified directly by flash column chromatography using petroleum ether/ethyl acetate (5/1) as eluents to afford the product **14** as a colorless oil (0.99 g, 5.3 mmol, 71%). **^{1}H NMR (400 MHz, $CDCl_3$)** δ: 5.96 (dtt, *J* = 15.5, 4.9, 1.0 Hz, 1H), 5.84 (dtt, *J* = 15.5, 6.0, 1.4 Hz, 1H), 4.57 (ddd, *J* = 5.8, 2.2, 1.1 Hz, 2H), 4.17 (d, *J* = 4.2 Hz, 2H), 1.49 (s, 9H); **^{13}C NMR (101 MHz, $CDCl_3$) δ**: 153.4, 134.1, 124.9, 82.4, 66.8, 62.8, 27.9; **HRMS (DART-TOF)** calculated for $C_9H_{16}NaO_4^+$ $[M+Na]^+$ m/z 211.0941, found 211.0947.

Allyl Carbonates (7).

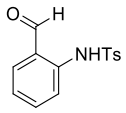
To a solution of 1.0 equiv of the (*E*)-*tert*-butyl 4-hydroxybut-2-enyl carbonate (**14**) in dry CH_2Cl_2 (0.5 M), 1.2 equiv of Et_3N was added, and cooled in an ice water bath. Then, 1.1 equiv of MsCl was added slowly, and stirred for 15 min. The mixture was quenched with saturated aq. $NaHCO_3$, extracted with CH_2Cl_2. and dried over Na_2SO_4. The mixture was concentrated under reduced pressure and used without further purification. Then, 2.0 equiv of K_2CO_3, 0.90 equiv of compound **16** and DMF (0.5 M) were added. The mixture was stirred at 25 °C for 24 h. The mixture was diluted with EtOAc, washed with brine, and dried over Na_2SO_4. The mixture was concentrated under reduced pressure and purified by flash chromatography to afford the compound **7**.



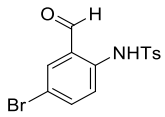
17i-17j **16i-16k**

N-(2-formylphenyl)-4-methylbenzenesulfonamide derivatives (**16i-16k**) were prepared according to the literature procedure[2].

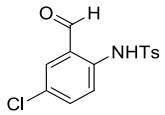
A dry and nitrogen-flushed 100 mL flask, equipped with a magnetic stirring bar and a septum, was charged with a solution of 2-aminobenzyl alcohol **17** (10 mmol) in $CHCl_3$ (50 mL). TsCl (1.1 equiv) and pyridine (0.05 mL) were added, and the reaction mixture was stirred for 12 h at room temperature. Then, the solvent was removed in vacuo. Without purification, the crude product was dissolved in dichloromethane (25 mL) and PCC (1.2 equiv) was added. The reaction mixture was stirred for 4 h at room temperature and then filtered through celite followed by washing with CH_2Cl_2 and evaporation in vacuo. Purification by flash chromatography furnished 2-tosylaminobenzaldehyde derivatives **(16i-16k)**.



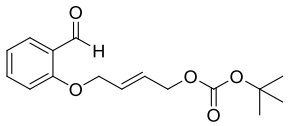
***N*-(2-formylphenyl)-4-methylbenzenesulfonamide (16i).** A dry and nitrogen-flushed 100 mL flask, equipped with a magnetic stirring bar and a septum, was charged with a solution of 2-aminobenzyl alcohol **17i** (1.23 g, 10 mmol) in $CHCl_3$ (50 mL). TsCl (2.09 g, 11 mmol) and pyridine (0.05 mL) were added, and the reaction mixture was stirred for 12 h at room temperature. Then, the solvent was removed in vacuo. Without purification, the crude product was dissolved in dichloromethane (25 mL) and PCC (2.59 g, 12 mmol) was added. The reaction mixture was stirred for 4 h at room temperature and then filtered through celite, followed by washing with CH_2Cl_2 and evaporation in vacuo. Chromatographic purification on silica gel using petroleum ether/dichloromethane (1/3) as eluents furnished **16i** (2.48 g, 9 mmol, 90%). **^{1}H NMR (400 MHz, $CDCl_3$)** δ: 10.79 (s, 1H), 9.83 (s, 1H), 7.77 (d, *J* = 8.4 Hz, 2H), 7.68 (d, *J* = 8.4 Hz, 1H), 7.59 (dd, *J* = 7.7, 1.6 Hz, 1H), 7.51 (td, *J* = 8.0, 1.6 Hz, 1H), 7.24 (d, *J* = 8.1 Hz, 2H), 7.16 (td, *J* = 7.5, 0.9 Hz, 1H), 2.36 (s, 3H); **^{13}C NMR (101 MHz, $CDCl_3$) δ**: 195.1, 144.3, 140.0, 136.5, 136.2, 135.9, 129.9, 127.4, 123.1, 122.0, 117.8, 21.6;



***N*-(4-bromo-2-formylphenyl)-4-methylbenzenesulfonamide (16j).** A dry and nitrogen-flushed 100 mL flask, equipped with a magnetic stirring bar and a septum, was charged with a solution of (2-amino-5-bromophenyl)methanol **17j** (2.02 g, 10 mmol) in $CHCl_3$ (50 mL). TsCl (2.09 g, 11 mmol) and pyridine (0.05 mL) were added, and the reaction mixture was stirred for 12 h at room temperature. Then, the solvent was removed in vacuo. Without purification, the crude product was dissolved in dichloromethane (25 mL) and PCC (2.59 g, 12 mmol) was added. The reaction mixture was stirred for 4 h at room temperature and then filtered through celite followed by washing with CH_2Cl_2 and evaporation in vacuo. Chromatographic purification on silica gel using petroleum ether/dichloromethane (1/3) as eluents furnished **16j** (3.01 g, 8.5 mmol, 85%). **^{1}H NMR (400 MHz, $CDCl_3$)** δ: 10.64 (s, 1H), 9.76 (s, 1H), 7.75 (d, *J* = 8.3 Hz, 2H), 7.70 (d, *J* = 2.0 Hz, 1H), 7.64 – 7.56 (m, 2H), 7.25 (d, *J* = 7.7 Hz, 2H), 2.38 (s, 3H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ: 193.8, 144.6, 139.1, 138.7, 138.3, 136.2, 130.0, 127.4, 123.3, 119.9, 115.5, 21.7; **HRMS (DART-TOF)** calculated for $C_{14}H_{12}BrNNaO_3S^+$ $[M+Na]^+$ m/z 375.9613, found 375.9640.

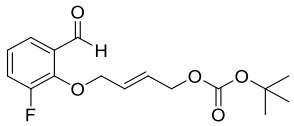


***N*-(4-chloro-2-formylphenyl)-4-methylbenzenesulfonamide (16k).** A dry and nitrogen-flushed 100 mL flask, equipped with a magnetic stirring bar and a septum, was charged with a solution of (2-amino-5-chlorophenyl)methanol **17k** (1.58 g, 10 mmol) in $CHCl_3$ (50 mL). TsCl (2.09 g, 11 mmol) and pyridine (0.05 mL) were added, and the reaction mixture was stirred for 12 h at room temperature. Then, the solvent was removed in vacuo. Without purification, the crude product was dissolved in dichloromethane (25 mL) and PCC (2.59 g, 12 mmol) was added. The reaction mixture was stirred for 4 h at room temperature and then filtered through celite, followed by washing with CH_2Cl_2 and evaporation in vacuo. Chromatographic purification on silica gel using petroleum ether/dichloromethane (1/3) as eluents furnished **16k** (2.51 g, 8.1 mmol, 81%). **^{1}H NMR (400 MHz, $CDCl_3$)** δ: 10.62 (s, 1H), 9.77 (s, 1H), 7.75 (d, *J* = 8.4 Hz, 2H), 7.68 (d, *J* = 8.9 Hz, 1H), 7.56 (d, *J* = 2.5 Hz, 1H), 7.46 (dd, *J* = 8.9, 2.5 Hz, 1H), 7.25 (d, *J* = 9.0 Hz, 2H), 2.38 (s, 3H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ: 193.9, 144.6, 138.6, 136.2, 135.8, 135.3, 130.0, 128.5, 127.4, 123.0, 119.7, 21.7; **HRMS (DART-TOF)** calculated for $C_{14}H_{12}ClNNaO_3S^+$ $[M+Na]^+$ m/z 332.0119, found 332.0083.

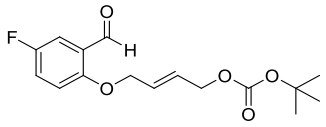


(*E*)-tert-butyl 4-(2-formylphenoxy)but-2-enyl carbonate (7a). To a solution of (*E*)-*tert*-butyl 4-hydroxybut-2-enyl carbonate **14** (188 mg, 1 mmol) in dry CH_2Cl_2 (2 mL), Et_3N (121 mg, 1.2 mmol) was added, and cooled in an ice water bath. Then, MsCl (159 mg, 1.1 mmol) was added dropwise, and stirred for 15 min. The mixture was quenched with saturated aq. $NaHCO_3$, extracted with CH_2Cl_2. and dried over Na_2SO_4. The mixture was concentrated under reduced pressure and used without further purification. Then, K_2CO_3

(276 mg, 2 mmol), 2-hydroxybenzaldehyde **16a** (110 mg, 0.9 mmol) and DMF (2 mL) were added. The mixture was stirred at 25 °C for 24 h. The mixture was diluted with EtOAc, washed with brine, and dried over Na_2SO_4. The mixture was concentrated under reduced pressure and purified by flash chromatography using petroleum ether/ethyl acetate (1/10) as eluents to afford **7a** (231 mg, 0.79 mmol, 79%, two steps). **^{1}H NMR (400 MHz, $CDCl_3$)** δ: 10.52 (s, 1H), 7.84 (dd, *J* = 7.7, 1.6 Hz, 1H), 7.53 (ddd, *J* = 8.7, 7.4, 1.8 Hz, 1H), 7.04 (t, *J* = 7.5 Hz, 1H), 6.96 (d, *J* = 8.4 Hz, 1H), 6.11 – 5.92 (m, 2H), 4.68 (d, *J* = 3.7 Hz, 2H), 4.62 (d, *J* = 4.3 Hz, 2H), 1.49 (s, 9H); **^{13}C NMR (101 MHz, $CDCl_3$) δ**: 189.8, 160.9, 153.3, 136.0, 128.7, 128.7, 127.6, 125.2, 121.1, 112.9, 82.6, 68.1, 66.4, 27.9; **HRMS (DART-TOF)** calculated for $C_{16}H_{20}NaO_5^+$ $[M+Na]^+$ m/z 315.1203, found 315.1209.

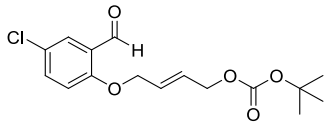


(*E*)-tert-butyl 4-(2-fluoro-6-formylphenoxy)but-2-enyl carbonate (7b). To a solution of (*E*)-*tert*-butyl 4-hydroxybut-2-enyl carbonate **14** (188 mg, 1 mmol) in dry CH_2Cl_2 (2 mL), Et_3N (121 mg, 1.2 mmol) was added, and cooled in an ice water bath. Then, MsCl (159 mg, 1.1 mmol) was added dropwise, and stirred for 15 min. The mixture was quenched with saturated aq. $NaHCO_3$, extracted with CH_2Cl_2. and dried over Na_2SO_4. The mixture was concentrated under reduced pressure and used without further purification. Then, K_2CO_3 (276 mg, 2 mmol), 3-fluoro-2-hydroxybenzaldehyde **16b** (126 mg, 0.9 mmol) and DMF (2 mL) were added. The mixture was stirred at 25 °C for 24 h. The mixture was diluted with EtOAc, washed with brine, and dried over Na_2SO_4. The mixture was concentrated under reduced pressure and purified by flash chromatography using petroleum ether/ethyl acetate (1/10) as eluents to afford **7b** (230 mg, 0.74 mmol, 74%, two steps). **^{1}H NMR (400 MHz, $CDCl_3$) δ:** 10.40 (d, *J* = 0.4 Hz, 1H) , 7.63 – 7.59 (m, 1H), 7.33 (ddd, *J* = 11.6, 8.1, 1.6 Hz, 1H), 7.14 – 7.07 (m, 1H), 6.07 – 5.92 (m, 2H), 4.77 (d, *J* = 5.4 Hz, 2H), 4.59 (d, *J* = 5.6 Hz, 2H), 1.49 (s, 9H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ:189.0 (d, *J* = 3.3 Hz), 155.2 (d, *J* = 249.1 Hz), 153.3, 149.0 (d, *J* = 10.9 Hz), 130.6 (d, *J* = 2.0 Hz), 129.0, 128.6, 123.9 (d, *J* = 7.3 Hz), 123.6 (d, *J* = 3.3 Hz), 122.9 (d, *J* = 19.4 Hz), 82.5, 74.3 (d, *J* = 7.0 Hz), 66.2, 27.9; **^{19}F NMR (376 MHz, $CDCl_3$)** δ: -128.76; **HRMS (DART-TOF)** calculated for $C_{16}H_{19}FNaO_5^+$ $[M+Na]^+$ m/z 333.1109, found 333.1115.

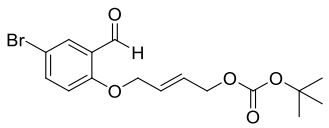


(*E*)-tert-butyl 4-(4-fluoro-2-formylphenoxy)but-2-enyl carbonate (7c). To a solution of (*E*)-*tert*-butyl 4-hydroxybut-2-enyl carbonate **14** (188 mg, 1 mmol) in dry CH_2Cl_2 (2 mL), Et_3N (121 mg, 1.2 mmol) was added, and cooled in an ice water bath. Then, MsCl (159 mg, 1.1 mmol) was added dropwise, and stirred for 15 min. The mixture was quenched with saturated aq. $NaHCO_3$, extracted with CH_2Cl_2. and dried over Na_2SO_4. The mixture was concentrated under reduced pressure and used without further purification. Then, K_2CO_3 (276 mg, 2 mmol), 5-fluoro-2-hydroxybenzaldehyde **16c** (126 mg, 0.9 mmol) and DMF (2 mL) were added. The mixture was stirred at 25 °C for 24 h. The mixture was diluted with EtOAc, washed with brine, and dried

over Na_2SO_4. The mixture was concentrated under reduced pressure and purified by flash chromatography using petroleum ether/ethyl acetate (1/10) as eluents to afford **7c** (239 mg, 0.77 mmol, 77%, two steps). **^{1}H NMR (400 MHz, $CDCl_3$) δ:** 10.45 (d, *J* = 3.1 Hz, 1H), 7.51 (dd, *J* = 8.2, 3.3 Hz, 1H), 7.23 (ddd, *J* = 9.1, 7.6, 3.3 Hz, 1H), 6.94 (dd, *J* = 9.1, 3.9 Hz, 1H), 6.07 – 5.93 (m, 2H), 4.66 (d, *J* = 3.6 Hz, 2H), 4.62 (d, *J* = 4.1 Hz, 2H), 1.49 (s, 9H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ: 188.6 (d, *J* = 1.7 Hz), 157.2 (d, *J* = 242.8 Hz), 157.2 (d, *J* = 1.9 Hz), 153.3, 128.4, 128.0, 126.0 (d, *J* = 5.9 Hz), 122.5 (d, *J* = 24.0 Hz), 114.6 (d, *J* = 7.3 Hz), 114.3 (d, *J* = 23.5 Hz), 82.6, 68.8, 66.3, 27.9; **^{19}F NMR (376 MHz, $CDCl_3$)** δ: -122.06; **HRMS (DART-TOF)** calculated for $C_{16}H_{19}FNaO_5^+$ $[M+Na]^+$ m/z 333.1109, found 333.1115.

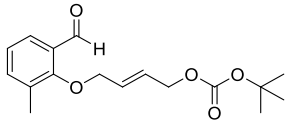


(*E*)-tert-butyl 4-(4-chloro-2-formylphenoxy)but-2-enyl carbonate (7d). To a solution of (*E*)-*tert*-butyl 4-hydroxybut-2-enyl carbonate **14** (188 mg, 1 mmol) in dry CH_2Cl_2 (2 mL), Et_3N (121 mg, 1.2 mmol) was added, and cooled in an ice water bath. Then, MsCl (159 mg, 1.1 mmol) was added dropwise, and stirred for 15 min. The mixture was quenched with saturated aq. $NaHCO_3$, extracted with CH_2Cl_2. and dried over Na_2SO_4. The mixture was concentrated under reduced pressure and used without further purification. Then, K_2CO_3 (276 mg, 2 mmol), 5-chloro-2-hydroxybenzaldehyde **16d** (141 mg, 0.9 mmol) and DMF (2 mL) were added. The mixture was stirred at 25 °C for 24 h. The mixture was diluted with EtOAc, washed with brine, and dried over Na_2SO_4. The mixture was concentrated under reduced pressure and purified by flash chromatography using petroleum ether/ethyl acetate (1/10) as eluents to afford **7d** (235 mg, 0.72 mmol, 72%, two steps). **^{1}H NMR (400 MHz, $CDCl_3$)** δ: 10.44 (s, 1H), 7.79 (d, *J* = 2.7 Hz, 1H), 7.47 (dd, *J* = 8.9, 2.8 Hz, 1H), 6.92 (d, *J* = 8.9 Hz, 1H), 6.07 – 5.94 (m, 2H), 4.66 (d, *J* = 3.4 Hz, 2H), 4.62 (dd, *J* = 4.6, 0.9 Hz, 2H), 1.49 (s, 9H); **^{13}C NMR (101 MHz, $CDCl_3$) δ**: 188.4, 159.3, 153.3, 135.4, 128.2, 128.1, 128.1, 126.9, 126.1, 114.6, 82.6, 68.5, 66.2, 27.9; **HRMS (DART-TOF)** calculated for $C_{16}H_{19}ClNaO_5^+$ $[M+Na]^+$ m/z 349.0813, found 349.0818.

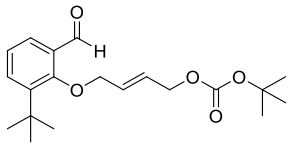


(*E*)-4-(4-bromo-2-formylphenoxy)but-2-enyl tert-butyl carbonate (7e). To a solution of (*E*)-*tert*-butyl 4-hydroxybut-2-enyl carbonate **14** (188 mg, 1 mmol) in dry CH_2Cl_2 (2 mL), Et_3N (121 mg, 1.2 mmol) was added, and cooled in an ice water bath. Then, MsCl (159 mg, 1.1 mmol) was added dropwise, and stirred for 15 min. The mixture was quenched with saturated aq. $NaHCO_3$, extracted with CH_2Cl_2. and dried over Na_2SO_4. The mixture was concentrated under reduced pressure and used without further purification. Then, K_2CO_3 (276 mg, 2 mmol), 5-bromo-2-hydroxybenzaldehyde **16e** (181 mg, 0.9 mmol) and DMF (2 mL) were added. The mixture was stirred at 25 °C for 24 h. The mixture was diluted with EtOAc, washed with brine, and dried over Na_2SO_4. The mixture was concentrated under reduced pressure and purified by flash chromatography using petroleum ether/ethyl acetate (1/10) as eluents to afford **7e** (263 mg, 0.71 mmol, 71%, two steps). **^{1}H NMR (400 MHz, $CDCl_3$) δ:** 10.42 (s, 1H), 7.93 (d, *J* = 2.6 Hz, 1H), 7.60 (dd, *J* = 8.9, 2.6 Hz, 1H), 6.87 (d, *J*

= 8.9 Hz, 1H), 6.06 – 5.94 (m, 2H), 4.66 (d, *J* = 3.3 Hz, 2H), 4.62 (d, *J* = 3.8 Hz, 2H), 1.49 (s, 9H); **^{13}C NMR (101 MHz, $CDCl_3$) δ**:188.3, 159.7, 153.3, 138.3, 131.3, 128.2, 128.1, 126.5, 115.0, 114.0, 82.6, 68.5, 66.2, 27.9; **HRMS (DART-TOF)** calculated for $C_{16}H_{19}BrNaO_5^+$ $[M+Na]^+$ m/z 393.0308, found 393.0313.

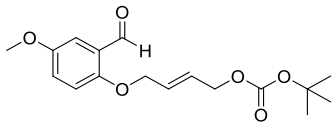


(*E*)-tert-butyl 4-(2-formyl-6-methylphenoxy)but-2-enyl carbonate (7f). To a solution of (*E*)-*tert*-butyl 4-hydroxybut-2-enyl carbonate **14** (188 mg, 1 mmol) in dry CH_2Cl_2 (2 mL), Et_3N (121 mg, 1.2 mmol) was added, and cooled in an ice water bath. Then, MsCl (159 mg, 1.1 mmol) was added dropwise, and stirred for 15 min. The mixture was quenched with saturated aq. $NaHCO_3$, extracted with CH_2Cl_2. and dried over Na_2SO_4. The mixture was concentrated under reduced pressure and used without further purification. Then, K_2CO_3 (276 mg, 2 mmol), 2-hydroxy-3-methylbenzaldehyde **16f** (123 mg, 0.9 mmol) and DMF (2 mL) were added. The mixture was stirred at 25 °C for 24 h. The mixture was diluted with EtOAc, washed with brine, and dried over Na_2SO_4. The mixture was concentrated under reduced pressure and purified by flash chromatography using petroleum ether/ethyl acetate (1/10) as eluents to afford **7f** (233 mg, 0.76 mmol, 76%, two steps). **^{1}H NMR (400 MHz, $CDCl_3$) δ:** 10.35 (d, *J* = 0.4 Hz, 1H), 7.69 (dd, *J* = 7.7, 1.2 Hz, 1H), 7.45 (dd, *J* = 7.4, 0.8 Hz, 1H), 7.15 (t, *J* = 7.6 Hz, 1H), 6.11 – 5.95 (m, 2H), 4.62 (dd, *J* = 5.4, 0.8 Hz, 2H), 4.47 (dd, *J* = 5.1, 0.8 Hz, 2H), 2.33 (s, 3H), 1.50 (s, 9H); **^{13}C NMR (101 MHz, $CDCl_3$) δ**:190.4, 160.3, 153.4, 137.7, 132.5, 129.6, 129.1, 128.0, 126.7, 124.6, 82.5, 75.3, 66.4, 27.9, 16.0; **HRMS (DART-TOF)** calculated for $C_{17}H_{22}NaO_5^+$ $[M+Na]^+$ m/z 329.1359, found 329.1370.

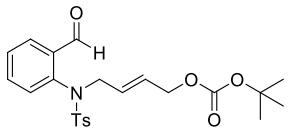


(*E*)-tert-butyl 4-(2-tert-butyl-6-formylphenoxy)but-2-enyl carbonate (7g). To a solution of (*E*)-*tert*-butyl 4-hydroxybut-2-enyl carbonate **14** (188 mg, 1 mmol) in dry CH_2Cl_2 (2 mL), Et_3N (121 mg, 1.2 mmol) was added, and cooled in an ice water bath. Then, MsCl (159 mg, 1.1 mmol) was added dropwise, and stirred for 15 min. The mixture was quenched with saturated aq. $NaHCO_3$, extracted with CH_2Cl_2. and dried over Na_2SO_4. The mixture was concentrated under reduced pressure and used without further purification. Then, K_2CO_3 (276 mg, 2 mmol), 3-(*tert*-butyl)-2-hydroxybenzaldehyde **16g** (160 mg, 0.9 mmol) and DMF (2 mL) were added. The mixture was stirred at 25 °C for 24 h. The mixture was diluted with EtOAc, washed with brine, and dried over Na_2SO_4. The mixture was concentrated under reduced pressure and purified by flash chromatography using petroleum ether/ethyl acetate (1/10) as eluents to afford **7g** (244 mg, 0.70 mmol, 70%, two steps). **^{1}H NMR (400 MHz, $CDCl_3$) δ:** 10.27 (s, 1H), 7.71 (dd, *J* = 7.6, 1.7 Hz, 1H), 7.59 (dd, *J* = 7.8, 1.7 Hz, 1H), 7.16 (t, *J* = 7.6 Hz, 1H), 6.15 – 6.02 (m, 2H), 4.65 (d, *J* = 4.3 Hz, 2H), 4.51 (d, *J* = 3.0 Hz, 2H), 1.51 (s, 9H), 1.42 (s, 9H); **^{13}C NMR (101 MHz, $CDCl_3$) δ:** 190.5, 161.7, 153.4, 144.0, 133.7, 130.2, 129.1, 127.9,

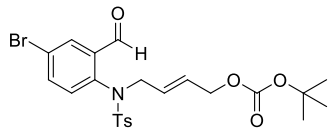
127.0, 124.2, 82.5, 78.2, 66.6, 35.3, 31.0, 27.9; **HRMS (DART-TOF)** calculated for $C_{20}H_{28}NaO_5^+$ $[M+Na]^+$ m/z 371.1829, found 371.1836.



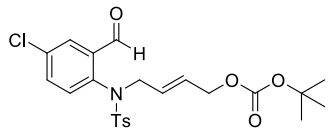
(*E*)-tert-butyl 4-(2-formyl-4-methoxyphenoxy)but-2-enyl carbonate (7h). To a solution of (*E*)-*tert*-butyl 4-hydroxybut-2-enyl carbonate **14** (188 mg, 1 mmol) in dry CH_2Cl_2 (2 mL), Et_3N (121 mg, 1.2 mmol) was added, and cooled in an ice water bath. Then, MsCl (159 mg, 1.1 mmol) was added dropwise, and stirred for 15 min. The mixture was quenched with saturated aq. $NaHCO_3$, extracted with CH_2Cl_2. and dried over Na_2SO_4. The mixture was concentrated under reduced pressure and used without further purification. Then, K_2CO_3 (276 mg, 2 mmol), 2-hydroxy-5-methoxybenzaldehyde **16h** (137 mg, 0.9 mmol) and DMF (2 mL) were added. The mixture was stirred at 25 °C for 24 h. The mixture was diluted with EtOAc, washed with brine, and dried over Na_2SO_4. The mixture was concentrated under reduced pressure and purified by flash chromatography using petroleum ether/ethyl acetate (1/10) as eluents to afford **7h** (229 mg, 0.71 mmol, 71%, two steps). **^{1}H NMR (400 MHz, $CDCl_3$) δ:**10.48 (s, 1H), 7.33 (d, *J* = 3.3 Hz, 1H), 7.11 (dd, *J* = 9.1, 3.3 Hz, 1H), 6.92 (d, *J* = 9.1 Hz, 1H), 6.08 – 5.92 (m, 2H), 4.64 – 4.59 (m, 4H), 3.80 (s, 3H), 1.49 (s, 9H); **^{13}C NMR (101 MHz, $CDCl_3$) δ**:189.5, 155.7, 154.0, 153.3, 129.0, 127.5, 125.5, 123.6, 114.9, 110.5, 82.5, 68.9, 66.4, 55.9, 27.9 ; **HRMS (DART-TOF)** calculated for $C_{17}H_{22}NaO_6^+$ $[M+Na]^+$ m/z 345.1309, found 345.1312.



(*E*)-tert-butyl 4-(N-(2-formylphenyl)-4-methylphenylsulfonamido)but-2-enyl carbonate (7i). To a solution of (*E*)-*tert*-butyl 4-hydroxybut-2-enyl carbonate **14** (188 mg, 1 mmol) in dry CH_2Cl_2 (2 mL), Et_3N (121 mg, 1.2 mmol) was added, and cooled in an ice water bath. Then, MsCl (159 mg, 1.1 mmol) was added dropwise, and stirred for 15 min. The mixture was quenched with saturated aq. $NaHCO_3$, extracted with CH_2Cl_2. and dried over Na_2SO_4. The mixture was concentrated under reduced pressure and used without further purification. Then, K_2CO_3 (276 mg, 2 mmol), *N*-(2-formylphenyl)-4-methylbenzenesulfonamide **16i** (248 mg, 0.9 mmol) and DMF (2 mL) were added. The mixture was stirred at 25 °C for 24 h. The mixture was diluted with EtOAc, washed with brine, and dried over Na_2SO_4. The mixture was concentrated under reduced pressure and purified by flash chromatography using petroleum ether/ethyl acetate (1/15) as eluents to afford **7i** (303 mg, 0.68 mmol, 68%, two steps). **^{1}H NMR (400 MHz, $CDCl_3$) δ:** 10.35 (s, 1H), 8.01 – 7.96 (m, 1H), 7.51 – 7.41 (m, 4H), 7.28 (d, *J* = 8.7 Hz, 2H), 6.74 – 6.69 (m, 1H), 5.73 (dt, *J* = 14.7, 6.7 Hz, 1H), 5.59 (dt, *J* = 15.5, 5.8 Hz, 1H), 4.61 – 4.47 (m, 1H), 4.38 (d, *J* = 5.6 Hz, 2H), 4.00 – 3.85 (m, 1H), 2.45 (s, 3H), 1.44 (s, 9H); **^{13}C NMR (101 MHz, $CDCl_3$) δ**: 190.0, 153.1, 144.4, 141.3, 136.0, 134.5, 134.2, 129.9, 129.8, 128.8, 128.7, 128.1, 128.0, 127.9, 82.5, 66.0, 53.3, 27.8, 21.7; **HRMS (DART-TOF)** calculated for $C_{23}H_{27}NNaO_6S^+$ $[M+Na]^+$ m/z 468.1451, found 468.1459.

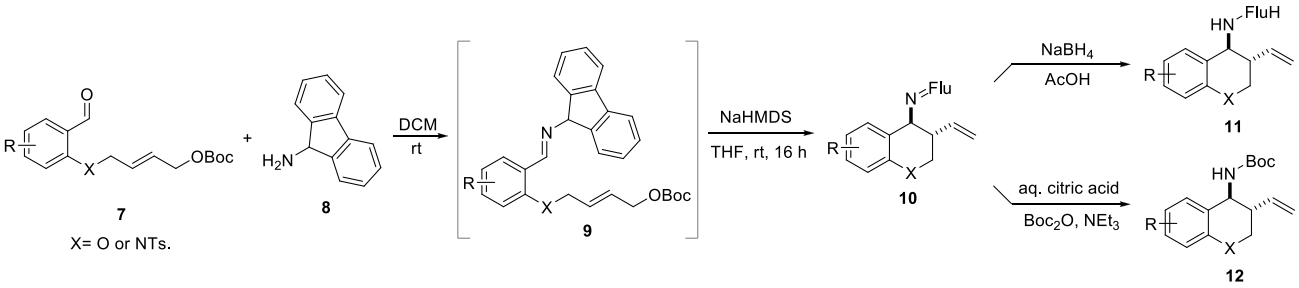


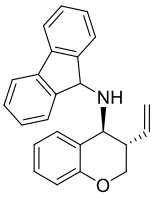
(*E*)-4-(N-(4-bromo-2-formylphenyl)-4-methylphenylsulfonamido)but-2-enyl tert-butyl carbonate (7j). To a solution of (*E*)-*tert*-butyl 4-hydroxybut-2-enyl carbonate **14** (188 mg, 1 mmol) in dry CH_2Cl_2 (2 mL), Et_3N (121 mg, 1.2 mmol) was added, and cooled in an ice water bath. Then, MsCl (159 mg, 1.1 mmol) was added dropwise, and stirred for 15 min. The mixture was quenched with saturated aq. $NaHCO_3$, extracted with CH_2Cl_2. and dried over Na_2SO_4. The mixture was concentrated under reduced pressure and used without further purification. Then, K_2CO_3 (276 mg, 2 mmol), *N*-(4-bromo-2-formylphenyl)-4-methylbenzenesulfonamide **16j** (319 mg, 0.9 mmol) and DMF (2 mL) were added. The mixture was stirred at 25 °C for 24 h. The mixture was diluted with EtOAc, washed with brine, and dried over Na_2SO_4. The mixture was concentrated under reduced pressure and purified by flash chromatography using petroleum ether/ethyl acetate (1/15) as eluents to afford **7j** (351 mg, 0.67 mmol, 67%, two steps). **^{1}H NMR (400 MHz, $CDCl_3$)** δ: 10.27 (s, 1H), 8.09 (d, *J* = 2.4 Hz, 1H), 7.56 (dd, *J* = 8.5, 2.5 Hz, 1H), 7.47 (d, *J* = 8.3 Hz, 2H), 7.30 (d, *J* = 8.0 Hz, 2H), 6.57 (d, *J* = 8.5 Hz, 1H), 5.70 (dt, *J* = 14.5, 6.6 Hz, 1H), 5.59 (dt, *J* = 15.5, 5.6 Hz, 1H), 4.64 – 4.47 (m, 1H), 4.38 (d, *J* = 5.4 Hz, 2H), 3.96 – 3.77 (m, 1H), 2.45 (s, 3H), 1.44 (s, 9H); **^{13}C NMR (101 MHz, $CDCl_3$) δ**: 188.5, 153.1, 144.7, 140.1, 137.4, 137.0, 134.1, 131.8, 130.4, 130.0, 129.7, 128.0, 127.5, 123.2, 82.6, 65.9, 53.1, 27.8, 21.8; **HRMS (DART-TOF)** calculated for $C_{23}H_{26}BrNNaO_6S^+$ $[M+Na]^+$ m/z 546.0556, found 546.0569.

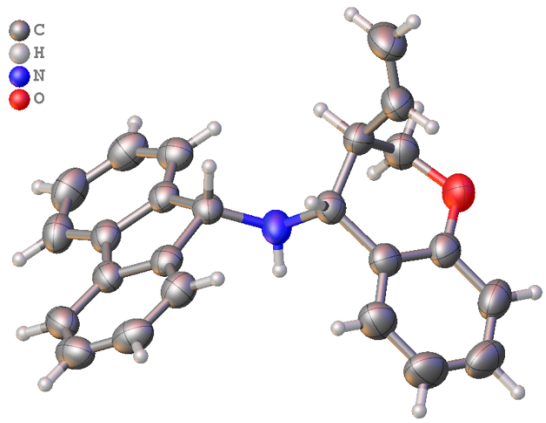


(*E*)-tert-butyl 4-(N-(4-chloro-2-formylphenyl)-4-methylphenylsulfonamido)but-2-enyl carbonate (7k). To a solution of (*E*)-*tert*-butyl 4-hydroxybut-2-enyl carbonate **14** (188 mg, 1 mmol) in dry CH_2Cl_2 (2 mL), Et_3N (121 mg, 1.2 mmol) was added, and cooled in an ice water bath. Then, MsCl (159 mg, 1.1 mmol) was added dropwise, and stirred for 15 min. The mixture was quenched with saturated aq. $NaHCO_3$, extracted with CH_2Cl_2. and dried over Na_2SO_4. The mixture was concentrated under reduced pressure and used without further purification. Then, K_2CO_3 (276 mg, 2 mmol), *N*-(4-chloro-2-formylphenyl)-4-methylbenzenesulfonamide **16k** (279 mg, 0.9 mmol) and DMF (2 mL) were added. The mixture was stirred at 25 °C for 24 h. The mixture was diluted with EtOAc, washed with brine, and dried over Na_2SO_4. The mixture was concentrated under reduced pressure and purified by flash chromatography using petroleum ether/ethyl acetate (1/15) as eluents to afford **7k** (341 mg, 0.71 mmol, 71%, two steps). **^{1}H NMR (400 MHz, $CDCl_3$)** δ: 10.28 (s, 1H), 7.94 (d, J = 2.6 Hz, 1H), 7.47 (d, *J* = 8.3 Hz, 2H), 7.41 (dd, *J* = 8.5, 2.6 Hz, 1H), 7.30 (d, *J* = 8.0 Hz, 2H), 6.64 (d, *J* = 8.5 Hz, 1H), 5.70 (dt, *J* = 14.5, 6.7 Hz, 1H), 5.59 (dt, *J* = 15.5, 5.6 Hz, 1H), 4.64 – 4.45 (m, 1H), 4.38 (d, *J* = 5.4 Hz, 2H), 3.97 – 3.73 (m, 1H), 2.45 (s, 3H), 1.44 (s, 9H); **^{13}C NMR (101 MHz, $CDCl_3$) δ**: 188.6, 153.1, 144.7, 139.6, 137.2, 135.3, 134.2, 134.0, 130.4, 130.0, 129.5, 128.7, 128.0, 127.5, 82.6, 65.9, 53.2, 27.8, 21.8; **HRMS (DART-TOF)** calculated for $C_{23}H_{26}ClNNaO_6S^+$ $[M+Na]^+$ m/z 502.1062, found 502.1069.

Characterization Data for Compounds in Scheme 2





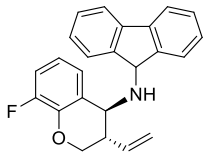


***N*-(9H-fluoren-9-yl)-3-vinylchroman-4-amine (11a)**, Following the **General Reaction Procedure A**, a mixture of aldehyde **7a** (0.50 mmol, 146 mg) and 9*H*-fluoren-9-amine **8** (0.50 mmol, 91 mg) in dry CH_2Cl_2 (5.0 mL) was stirred at 25 °C for 5 h. The mixture was concentrated to give the corresponding *N*-fluorenyl imine **4** (without purification) and was transferred into the glove-box. THF (6.0 mL) was added into the vial, followed by NaHMDS (96 mg, 0.53 mmol, 1.05 equiv). The mixture was stirred for 16 h at 25 °C. The reaction was worked up following **General Workup Procedure A**. At the end of the reaction, the mixture was concentrated, and CH_2Cl_2 (3 mL) was added, followed by $NaBH_4$ (1.5 mmol, 57 mg), and cooled in an ice water bath. AcOH (10 mmol, 0.6 mL) was added slowly for at least 15 minutes while the reaction mixture was rapidly stirred (**CAUTION**: gas evolution). The resulting mixture was warmed to room temperature, and stirred for 1-2 h. The reaction mixture was then cooled in an ice-water bath, and NaOH (10% aq., 5 mL) was added slowly while the reaction mixture was rapidly stirred. The reaction mixture was warmed to room temperature, and stirred for 30 min. The layers were separated, and the aqueous layer was extracted with CH_2Cl_2 (5 mL) twice. The combined organic layers were washed with brine (5 mL), dried over Na_2SO_4, and concentrated under reduced pressure. Chromatographic purification on silica gel using petroleum ether/ethyl acetate (20/1) as eluents afforded **11a** as a white solid (108 mg, 0.32 mmol, 64%) in >20:1 *trans:cis*

diastereomeric ratio.

By using **General Reaction Procedure B**, a screw-capped vial containing aldehyde **7a** (0.50 mmol, 146 mg) and 9*H*-fluoren-9-amine **8** (0.50 mmol, 91 mg) in dry CH_2Cl_2 (5.0 mL) was stirred at 25 °C for 5 h. The mixture was concentrated to give the corresponding *N*-fluorenyl imine **4** (without purification) and was transferred into the glove-box. $PdCl_2$ (5.3 mg, 0.03 mmol, 6 mol %), PCy3 (34 mg, 0.12 mmol, 24 mol %), and THF (6.0 mL) were added into the vial, followed by NaHMDS (96 mg, 0.53 mmol, 1.05 equiv). The vial was sealed with a cap containing a PTFE septum, removed from the glove box, and kept at 25 °C for 16 h. The reaction was worked up following **General Workup Procedure A**. **11a** was obtained as a white solid (131 mg, 0.39 mmol, 77%) in 18:1 *trans:cis* diastereomeric ratio.

***trans*-diastereomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ:** 7.75 – 7.69 (m, 3H), 7.63 – 7.59 (m, 1H), 7.42 – 7.29 (m, 4H), 7.14 – 7.08 (m, 1H), 7.03 (dd, *J* = 8.0, 1.6 Hz, 1H), 6.80 (t, *J* = 7.1 Hz, 2H), 5.58 (ddd, *J* = 17.6, 10.4, 7.6 Hz, 1H), 5.05 (s, 1H), 4.95 – 4.80 (m, 2H), 4.65 (dd, *J* = 10.5, 2.2 Hz, 1H), 4.15 – 4.08 (m, 1H), ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.78 – 3.75 (m, 1H), 2.45 – 2.33 (m, 1H), 1.90 (br s, 1H); **^{13}C NMR (101 MHz, $CDCl_3$) δ**: 154.7, 146.7, 145.9, 140.9, 140.7, 136.5, 130.6, 129.0, 128.4, 127.5, 127.5, 125.4, 125.4, 123.2, 120.6, 120.3, 120.1, 116.9, 116.8, 64.9, 62.1, 53.6, 41.6; **HRMS (DART-TOF)** calculated for $C_{24}H_{21}NNaO^+$ $[M+Na]^+$ m/z 362.1515, found 362.1523.

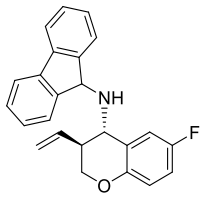


***N*-(9H-fluoren-9-yl)-8-fluoro-3-vinylchroman-4-amine (11b).** Following the **General Reaction Procedure A**, a mixture of aldehyde **7b** (0.50 mmol, 155 mg) and 9*H*-fluoren-9-amine **8** (0.50 mmol, 91 mg) in dry CH_2Cl_2 (5.0 mL) was stirred at 25 °C for 5 h. The mixture was concentrated to give the corresponding *N*-fluorenyl imine (without purification) and was transferred into the glove-box. THF (6.0 mL) was added into the vial, followed by NaHMDS (96 mg, 0.53 mmol, 1.05 equiv). The mixture was stirred for 16 h at 25 °C. The reaction was worked up following **General Workup Procedure A**. At the end of the reaction, the mixture was concentrated, and CH_2Cl_2 (3 mL) was added, followed by $NaBH_4$ (1.5 mmol, 57 mg), and cooled in an ice water bath. AcOH (10 mmol, 0.6 mL) was added slowly for at least 15 minutes while the reaction mixture was rapidly stirred (**CAUTION**: gas evolution). The resulting mixture was warmed to room temperature, and stirred for 1-2 h. The reaction mixture was then cooled in an ice-water bath, and NaOH (10% aq., 5 mL) was added slowly while the reaction mixture was rapidly stirred. The reaction mixture was warmed to room temperature, and stirred for 30 min. The layers were separated, and the aqueous layer was extracted with CH_2Cl_2 (5 mL) twice. The combined organic layers were washed with brine (5 mL), dried over Na_2SO_4, and concentrated under reduced pressure. Chromatographic purification on silica gel using petroleum ether/ethyl acetate (20/1) as eluents afforded **11b** as a white solid (84 mg, 0.24 mmol, 47%) in >20:1 *trans:cis* diastereomeric ratio.

By using **General Reaction Procedure B**, a screw-capped vial containing aldehyde **7b** (0.50 mmol, 155 mg) and 9*H*-fluoren-9-amine **8** (0.50 mmol, 91 mg) in dry CH_2Cl_2 (5.0 mL) was stirred at 25 °C for 5 h. The

mixture was concentrated to give the corresponding *N*-fluorenyl imine (without purification) and was transferred into the glove-box. $PdCl_2$ (5.3 mg, 0.03 mmol, 6 mol %), PCy_3 (34 mg, 0.12 mmol, 24 mol %), and THF (6.0 mL) were added into the vial, followed by NaHMDS (96 mg, 0.53 mmol, 1.05 equiv). The vial was sealed with a cap containing a PTFE septum, removed from the glove box, and kept at 25 °C for 16 h. The reaction was worked up following **General Workup Procedure A**. **11b** was obtained as a white solid (71 mg, 0.2 mmol, 40%) in 12:1 *trans:cis* diastereomeric ratio.

***trans*-diastereomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ**: 7.76 – 7.68 (m, 3H), 7.62 – 7.58 (m, 1H), 7.43 – 7.30 (m, 4H), 6.93 (ddd, *J* = 11.0, 7.9, 1.7 Hz, 1H), 6.81 – 6.77 (m, 1H), 6.75 – 6.69 (m, 1H), 5.54 (ddd, *J* = 17.4, 10.5, 7.5 Hz, 1H), 5.05 (s, 1H), 4.91 dt, *J* = 10.4, 1.2 Hz, 1H), 4.85 (dt, *J* = 17.3, 1.4 Hz, 1H), 4.68 (dd, *J* = 10.5, 2.4 Hz, 1H), 4.24 (ddd, *J* = 10.5, 2.2, 1.6 Hz, 1H), 3.76 (t, *J* = 1.6, 1H), 2.43 – 2.36 (m, 1H), 1.90 (br s, 1H); **^{13}C NMR (101 MHz, $CDCl_3$) δ**: 151.4 (d, *J* = 245.2 Hz), 146.4, 145.6, 143.1 (d, *J* = 11.0 Hz), 140.9, 140.7, 135.9, 128.5, 127.6, 127.5, 125.6 (d, *J* = 1.6 Hz), 125.5 (d, *J* = 3.5 Hz), 125.4, 125.3, 120.3, 120.1, 119.8 (d, *J* = 7.2 Hz), 117.1, 115.1 (d, *J* = 17.9 Hz), 65.2, 62.1, 53.0 (d, *J* = 2.7 Hz), 41.3; **^{19}F NMR (376 MHz, $CDCl_3$)** δ: -136.74; **HRMS (DART-TOF)** calculated for $C_{24}H_{21}FNO^+$ $[M+H]^+$ m/z 358.1602, found 358.1613.

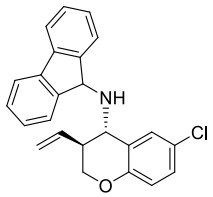


***N*-(9H-fluoren-9-yl)-6-fluoro-3-vinylchroman-4-amine (11c).** Following the **General Reaction Procedure A**, a mixture of aldehyde **7c** (0.50 mmol, 155 mg) and 9*H*-fluoren-9-amine **8** (0.50 mmol, 91 mg) in dry CH_2Cl_2 (5.0 mL) was stirred at 25 °C for 5 h. The mixture was concentrated to give the corresponding *N*-fluorenyl imine (without purification) and was transferred into the glove-box. THF (6.0 mL) was added into the vial, followed by NaHMDS (96 mg, 0.53 mmol, 1.05 equiv). The mixture was stirred for 16 h at 25 °C. The reaction was worked up following **General Workup Procedure A**. At the end of the reaction, the mixture was concentrated, and CH_2Cl_2 (3 mL) was added, followed by $NaBH_4$ (1.5 mmol, 57 mg), and cooled in an ice water bath. AcOH (10 mmol, 0.6 mL) was added slowly for at least 15 minutes while the reaction mixture was rapidly stirred (**CAUTION**: gas evolution). The resulting mixture was warmed to room temperature, and stirred for 1-2 h. The reaction mixture was then cooled in an ice-water bath, and NaOH (10% aq., 5 mL) was added slowly while the reaction mixture was rapidly stirred. The reaction mixture was warmed to room temperature, and stirred for 30 min. The layers were separated, and the aqueous layer was extracted with CH_2Cl_2 (5 mL) twice. The combined organic layers were washed with brine (5 mL), dried over Na_2SO_4, and concentrated under reduced pressure. Chromatographic purification on silica gel using petroleum ether/ethyl acetate (20/1) as eluents afforded **11c** as a white solid (71 mg, 0.20 mmol, 40%) in >20:1 *trans:cis* diastereomeric ratio.

By using **General Reaction Procedure B**, a screw-capped vial containing aldehyde **7c** (0.50 mmol, 155 mg) and 9*H*-fluoren-9-amine **8** (0.50 mmol, 91 mg) in dry CH_2Cl_2 (5.0 mL) was stirred at 25 °C for 5 h. The mixture was concentrated to give the corresponding *N*-fluorenyl imine (without purification) and was

transferred into the glove-box. $PdCl_2$ (5.3 mg, 0.03 mmol, 6 mol %), PCy_3 (34 mg, 0.12 mmol, 24 mol %), and THF (6.0 mL) were added into the vial, followed by NaHMDS (96 mg, 0.53 mmol, 1.05 equiv). The vial was sealed with a cap containing a PTFE septum, removed from the glove box, and kept at 25 °C for 16 h. The reaction was worked up following **General Workup Procedure A**. **11c** was obtained as a white solid (113 mg, 0.32 mmol, 63%) in 14.8:1 *trans:cis* diastereomeric ratio.

***trans*-diastereomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ:** 7.76 – 7.67 (m, 3H), 7.61 – 7.58 (m, 1H), 7.44 – 7.30 (m, 4H), 6.86 – 6.79 (m, 1H), 6.76 – 6.66 (m, 2H), 5.53 (ddd, *J* = 17.4, 10.5, 7.6 Hz, 1H), 5.05 (s, 1H), 4.90 (dt, *J* = 10.8, 1.2 Hz, 1H), 4.81 (dt, *J* = 17.3, 1.4 Hz, 1H), 4.58 (dd, *J* = 10.6, 2.3 Hz, 1H), 4.09 (ddd, *J* = 10.6, 2.4, 1.6 Hz, 1H), 3.66 (t, *J* = 1.7 Hz, 1H), 2.39 – 2.33 (m, 1H), 1.85 (br s, 1H); **^{13}C NMR (101 MHz, $CDCl_3$) δ**: 156.8 (d, *J* = 238.3 Hz), 150.6 (d, *J* = 1.9 Hz), 146.3, 145.5, 140.9, 140.7, 136.1, 128.6, 128.5, 127.6, 127.5, 125.4, 125.3, 124.0 (d, *J* = 6.7 Hz), 120.3, 120.2, 117.9 (d, *J* = 7.9 Hz), 117.0, 116.2 (d, *J* = 19.5 Hz), 116.0 (d, *J* = 20.3 Hz), 65.0, 62.2, 53.5, 41.5; **^{19}F NMR (376 MHz, $CDCl_3$)** δ: -123.85; **HRMS (DART-TOF)** calculated for $C_{24}H_{21}FNO^+$ $[M+H]^+$ m/z 358.1602, found 358.1606.

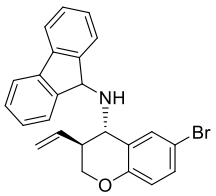


6-chloro-*N*-(9H-fluoren-9-yl)-3-vinylchroman-4-amine (11d). Following the **General Reaction Procedure A**, a mixture of aldehyde **7d** (0.50 mmol, 163 mg) and 9*H*-fluoren-9-amine **8** (0.50 mmol, 91 mg) in dry CH_2Cl_2 (5.0 mL) was stirred at 25 °C for 5 h. The mixture was concentrated to give the corresponding *N*-fluorenyl imine (without purification) and was transferred into the glove-box. THF (6.0 mL) was added into the vial, followed by NaHMDS (96 mg, 0.53 mmol, 1.05 equiv). The mixture was stirred for 16 h at 25 °C. The reaction was worked up following **General Workup Procedure A**. At the end of the reaction, the mixture was concentrated, and CH_2Cl_2 (3 mL) was added, followed by $NaBH_4$ (1.5 mmol, 57 mg), and cooled in an ice water bath. AcOH (10 mmol, 0.6 mL) was added slowly for at least 15 minutes while the reaction mixture was rapidly stirred (**CAUTION**: gas evolution). The resulting mixture was warmed to room temperature, and stirred for 1-2 h. The reaction mixture was then cooled in an ice-water bath, and NaOH (10% aq., 5 mL) was added slowly while the reaction mixture was rapidly stirred. The reaction mixture was warmed to room temperature, and stirred for 30 min. The layers were separated, and the aqueous layer was extracted with CH_2Cl_2 (5 mL) twice. The combined organic layers were washed with brine (5 mL), dried over Na_2SO_4, and concentrated under reduced pressure. Chromatographic purification on silica gel using petroleum ether/ethyl acetate (20/1) as eluents afforded **11d** as a white solid (80 mg, 0.22 mmol, 43%) in >20:1 *trans:cis* diastereomeric ratio.

By using **General Reaction Procedure B**, a screw-capped vial containing aldehyde **7d** (0.50 mmol, 163 mg) and 9*H*-fluoren-9-amine **8** (0.50 mmol, 91 mg) in dry CH_2Cl_2 (5.0 mL) was stirred at 25 °C for 5 h. The mixture was concentrated to give the corresponding *N*-fluorenyl imine (without purification) and was transferred into the glove-box. $PdCl_2$ (5.3 mg, 0.03 mmol, 6 mol %), PCy3 (34 mg, 0.12 mmol, 24 mol %),

and THF (6.0 mL) were added into the vial, followed by NaHMDS (96 mg, 0.53 mmol, 1.05 equiv). The vial was sealed with a cap containing a PTFE septum, removed from the glove box, and kept at 25 °C for 16 h. The reaction was worked up following **General Workup Procedure A**. **11d** was obtained as a white solid (86 mg, 0.23 mmol, 46%) in 14:1 *trans:cis* diastereomeric ratio.

***trans*-diastereomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ**: 7.76 – 7.64 (m, 3H), 7.61 – 7.57 (m, 1H), 7.44 – 7.30 (m, 4H), 7.05 (dd, *J* = 8.7, 2.6 Hz, 1H), 6.92 (d, *J* = 2.6 Hz, 1H), 6.72 (d, *J* = 8.8 Hz, 1H), 5.49 (ddd, *J* = 17.4, 10.5, 7.5 Hz, 1H), 5.04 (s, 1H), 4.89 (dt, *J* = 10.4, 1.2 Hz, 1H), 4.81 (dt, *J* = 17.3, 1.4 Hz, 1H), 4.60 (dd, *J* = 10.6, 2.4 Hz, 1H), 4.10 (ddd, *J* = 10.6, 2.3, 1.6 Hz, 1H), 3.65 (t, J = 1.7 Hz, 1H), 2.38 – 2.32 (m, 1H), 1.84 (br s, 1H); **^{13}C NMR (101 MHz, $CDCl_3$) δ**: 153.3, 146.2, 145.4, 140.9, 140.7, 135.9, 130.2, 129.0, 128.6, 128.5, 127.6, 127.5, 125.4, 125.3, 124.9, 124.6, 120.3, 120.2, 118.3, 117.0, 65.0, 62.1, 53.2, 41.2; **HRMS (DART-TOF)** calculated for $C_{24}H_{21}ClNO^+$ $[M+H]^+$ m/z 374.1306, found 374.1312.

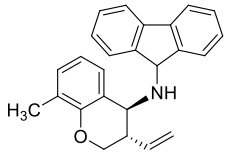


6-bromo-*N*-(9H-fluoren-9-yl)-3-vinylchroman-4-amine (11e). Following the **General Reaction Procedure A**, a mixture of aldehyde **7e** (0.50 mmol, 186 mg) and 9*H*-fluoren-9-amine **8** (0.50 mmol, 91 mg) in dry CH_2Cl_2 (5.0 mL) was stirred at 25 °C for 5 h. The mixture was concentrated to give the corresponding *N*-fluorenyl imine (without purification) and was transferred into the glove-box. THF (6.0 mL) was added into the vial, followed by NaHMDS (96 mg, 0.53 mmol, 1.05 equiv). The mixture was stirred for 16 h at 25 °C. The reaction was worked up following **General Workup Procedure A**. At the end of the reaction, the mixture was concentrated, and CH_2Cl_2 (3 mL) was added, followed by $NaBH_4$ (1.5 mmol, 57 mg), and cooled in an ice water bath. AcOH (10 mmol, 0.6 mL) was added slowly for at least 15 minutes while the reaction mixture was rapidly stirred (**CAUTION**: gas evolution). The resulting mixture was warmed to room temperature, and stirred for 1-2 h. The reaction mixture was then cooled in an ice-water bath, and NaOH (10% aq., 5 mL) was added slowly while the reaction mixture was rapidly stirred. The reaction mixture was warmed to room temperature, and stirred for 30 min. The layers were separated, and the aqueous layer was extracted with CH_2Cl_2 (5 mL) twice. The combined organic layers were washed with brine (5 mL), dried over Na_2SO_4, and concentrated under reduced pressure. Chromatographic purification on silica gel using petroleum ether/ethyl acetate (20/1) as eluents afforded **11e** as a white solid (92 mg, 0.22 mmol, 44%) in >20:1 *trans:cis* diastereomeric ratio.

By using **General Reaction Procedure B**, a screw-capped vial containing aldehyde **7e** (0.50 mmol, 186 mg) and 9*H*-fluoren-9-amine **8** (0.50 mmol, 91 mg) in dry CH_2Cl_2 (5.0 mL) was stirred at 25 °C for 5 h. The mixture was concentrated to give the corresponding *N*-fluorenyl imine (without purification) and was transferred into the glove-box. $PdCl_2$ (5.3 mg, 0.03 mmol, 6 mol %), PCy3 (34 mg, 0.12 mmol, 24 mol %), and THF (6.0 mL) were added into the vial, followed by NaHMDS (96 mg, 0.53 mmol, 1.05 equiv). The vial was sealed with a cap containing a PTFE septum, removed from the glove box, and kept at 25 °C for 16 h.

The reaction was worked up following **General Workup Procedure A**. **11e** was obtained as a white solid (65 mg, 0.16 mmol, 31%) in 9:1 *trans:cis* diastereomeric ratio.

***trans*-diastereomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ**: 7.75 – 7.66 (m, 3H), 7.61 – 7.56 (m, 1H), 7.45 – 7.30 (m, 4H), 7.19 (dd, *J* = 8.7, 2.5 Hz, 1H), 7.04 (d, *J* = 2.4 Hz, 1H), 6.67 (d, *J* = 8.7 Hz, 1H), 5.48 (ddd, *J* = 17.4, 10.5, 7.5 Hz, 1H), 5.04 (s, 1H), 4.89 (dt, *J* = 10.4, 1.2 Hz, 1H), 4.81 (dt, *J* = 17.3, 1.4 Hz, 1H), 4.59 (dd, *J* = 10.6, 2.4 Hz, 1H), 4.10 (ddd, *J* = 10.6, 2.3, 1.7 Hz, 1H), 3.64 (t, J = 1.7 Hz, 1H), 2.38 – 2.30 (m, 1H), 1.85 (br s, 1H); **^{13}C NMR (101 MHz, $CDCl_3$) δ**: 153.8, 146.2, 145.4, 140.9, 140.7, 135.9, 133.1, 131.8, 128.6, 128.5, 127.6, 127.5, 125.4, 125.3, 125.2, 120.3, 120.2, 118.8, 117.0, 112.2, 65.0, 62.1, 53.1, 41.1; **HRMS (DART-TOF)** calculated for $C_{24}H_{21}BrNO^+$ $[M+H]^+$ m/z 418.0801, found 418.0807.

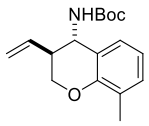


***N*-(9H-fluoren-9-yl)-8-methyl-3-vinylchroman-4-amine (11f).** Following the **General Reaction Procedure A**, a mixture of aldehyde **7f** (0.50 mmol, 153 mg) and 9*H*-fluoren-9-amine **8** (0.50 mmol, 91 mg) in dry CH_2Cl_2 (5.0 mL) was stirred at 25 °C for 5 h. The mixture was concentrated to give the corresponding *N*-fluorenyl imine (without purification) and was transferred into the glove-box. THF (6.0 mL) was added into the vial, followed by NaHMDS (96 mg, 0.53 mmol, 1.05 equiv). The mixture was stirred for 16 h at 25 °C. The reaction was worked up following **General Workup Procedure A**. At the end of the reaction, the mixture was concentrated, and CH_2Cl_2 (3 mL) was added, followed by $NaBH_4$ (1.5 mmol, 57 mg), and cooled in an ice water bath. AcOH (10 mmol, 0.6 mL) was added slowly for at least 15 minutes while the reaction mixture was rapidly stirred (**CAUTION**: gas evolution). The resulting mixture was warmed to room temperature, and stirred for 1-2 h. The reaction mixture was then cooled in an ice-water bath, and NaOH (10% aq., 5 mL) was added slowly while the reaction mixture was rapidly stirred. The reaction mixture was warmed to room temperature, and stirred for 30 min. The layers were separated, and the aqueous layer was extracted with CH_2Cl_2 (5 mL) twice. The combined organic layers were washed with brine (5 mL), dried over Na_2SO_4, and concentrated under reduced pressure. Chromatographic purification on silica gel using petroleum ether/ethyl acetate (20/1) as eluents afforded **11f** as a white solid (133 mg, 0.38 mmol, 75%) in >20:1 *trans:cis* diastereomeric ratio.

By using **General Reaction Procedure B**, a screw-capped vial containing aldehyde **7f** (0.50 mmol, 153 mg) and 9*H*-fluoren-9-amine **8** (0.50 mmol, 91 mg) in dry CH_2Cl_2 (5.0 mL) was stirred at 25 °C for 5 h. The mixture was concentrated to give the corresponding *N*-fluorenyl imine (without purification) and was transferred into the glove-box. $PdCl_2$ (5.3 mg, 0.03 mmol, 6 mol %), PCy3 (34 mg, 0.12 mmol, 24 mol %), and THF (6.0 mL) were added into the vial, followed by NaHMDS (96 mg, 0.53 mmol, 1.05 equiv). The vial was sealed with a cap containing a PTFE septum, removed from the glove box, and kept at 25 °C for 16 h. The reaction was worked up following **General Workup Procedure A**. **11f** was obtained as a white solid (140 mg, 0.40 mmol, 79%) in 8:1 *trans:cis* diastereomeric ratio.

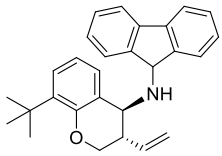
***trans*-diastereomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ**: 7.75 – 7.68 (m, 3H), 7.63 – 7.58 (m, 1H), 7.43 – 7.29

(m, 4H), 7.00 – 6.96 (m, 1H), 6.90 – 6.86 (m, 1H), 6.71 (t, *J* = 7.5 Hz, 1H), 5.58 (ddd, *J* = 17.3, 10.5, 7.8 Hz, 1H), 5.04 (s, 1H), 4.92 – 4.81 (m, 2H), 4.65 (dd, *J* = 10.5, 2.3 Hz, 1H), 4.17 (ddd, *J* = 10.5, 2.3, 1.7 Hz, 1H), 3.78 (t, *J* = 1.8 Hz, 1H), 2.42 – 2.36 (m, 1H), 2.17 (s, 3H), 1.84 (br s, 1H); **^{13}C NMR (101 MHz, $CDCl_3$) δ**: 152.8, 146.8, 145.9, 140.8, 140.7, 136.7, 129.9, 128.3, 128.1, 127.5, 127.4, 126.0, 125.4, 125.4, 122.5, 120.2, 120.0, 119.9, 116.6, 65.0, 62.1, 53.9, 41.5, 16.2; **HRMS (DART-TOF)** calculated for $C_{25}H_{24}NO^+$ $[M+H]^+$ m/z 354.1852, found 354.1856.



tert-butyl-8-methyl-3-vinylchroman-4-ylcarbamate (**12**).

When the above reaction was worked up following **General Workup Procedure B**. At the end of the reaction, the mixture was concentrated and hydroxylamine hydrochloride (1.0 M in Ethanol/ H_2O= 4/1, 2 mL) was added. The resulting mixture was left at room temperature until the imine product was fully consumed (TLC, ~5 h). The mixture was then extracted with Et_2O (5 mL) to remove fluorenone. The aqueous layer was basified with saturated aq. Na_2CO_3 to pH > 9, and extracted with CH_2Cl_2 three times. To the combined organic layers were added Et_3N (200 μL) and Boc_2O (200 μL). The mixture was left at room temperature until full consumption of the primary amine, as indicated by TLC analysis. The mixture was concentrated and subjected to flash chromatography using petroleum ether/ethyl acetate (15/1) as eluents to give **12** as a white solid (104 mg, 0.36 mmol, 71%). ***trans*-diastereomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ**: 7.11 (d, *J* = 7.6 Hz, 1H), 7.02 (d, *J* = 7.2 Hz, 1H), 6.81 (t, *J* = 7.5 Hz, 1H), 5.76 (ddd, *J* = 18.0, 10.4, 8.0 Hz, 1H), 5.29 (dt, *J* = 17.2, 1.2 Hz, 1H), 5.17 (dt, *J* = 10.4, 1.2 Hz, 1H), 4.76 – 4.69 (m, 1H), 4.23 (dd, *J* = 11.2, 3.3 Hz, 1H), 4.12 (dd, *J* = 11.1, 7.5 Hz, 1H), 2.69 – 2.60 (m, 1H), 2.17 (s, 3H), 1.47 (s, 9H); **^{13}C NMR (101 MHz, $CDCl_3$) δ**: 155.7, 152.9, 135.3, 130.2, 126.8, 126.0, 121.5, 120.3, 118.1, 79.8, 67.4, 50.1, 43.5, 28.5, 16.1.

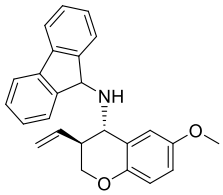


8-tert-butyl-*N*-(9H-fluoren-9-yl)-3-vinylchroman-4-amine (11g). Following the **General Reaction Procedure A**, a mixture of aldehyde **7g** (0.50 mmol, 174 mg) and 9*H*-fluoren-9-amine **8** (0.50 mmol, 91 mg) in dry CH_2Cl_2 (5.0 mL) was stirred at 25 °C for 5 h. The mixture was concentrated to give the corresponding *N*-fluorenyl imine (without purification) and was transferred into the glove-box. THF (6.0 mL) was added into the vial, followed by NaHMDS (96 mg, 0.53 mmol, 1.05 equiv). The mixture was stirred for 16 h at 25 °C. The reaction was worked up following **General Workup Procedure A**. At the end of the reaction, the mixture was concentrated, and CH_2Cl_2 (3 mL) was added, followed by $NaBH_4$ (1.5 mmol, 57 mg), and cooled in an ice water bath. AcOH (10 mmol, 0.6 mL) was added slowly for at least 15 minutes while the reaction mixture was rapidly stirred (**CAUTION**: gas evolution). The resulting mixture was warmed to room temperature, and stirred for 1-2 h. The reaction mixture was then cooled in an ice-water bath, and NaOH (10% aq., 5 mL) was

added slowly while the reaction mixture was rapidly stirred. The reaction mixture was warmed to room temperature, and stirred for 30 min. The layers were separated, and the aqueous layer was extracted with CH_2Cl_2 (5 mL) twice. The combined organic layers were washed with brine (5 mL), dried over Na_2SO_4, and concentrated under reduced pressure. Chromatographic purification on silica gel using petroleum ether/ethyl acetate (20/1) as eluents afforded **11g** as a white solid (123 mg, 0.31 mmol, 62%) in 4.2:1 *trans:cis* diastereomeric ratio.

By using **General Reaction Procedure B**, a screw-capped vial containing aldehyde **7g** (0.50 mmol, 174 mg) and 9*H*-fluoren-9-amine **8** (0.50 mmol, 91 mg) in dry CH_2Cl_2 (5.0 mL) was stirred at 25 °C for 5 h. The mixture was concentrated to give the corresponding *N*-fluorenyl imine (without purification) and was transferred into the glove-box. $PdCl_2$ (5.3 mg, 0.03 mmol, 6 mol %), PCy3 (34 mg, 0.12 mmol, 24 mol %), and THF (6.0 mL) were added into the vial, followed by NaHMDS (96 mg, 0.53 mmol, 1.05 equiv). The vial was sealed with a cap containing a PTFE septum, removed from the glove box, and kept at 25 °C for 16 h. The reaction was worked up following **General Workup Procedure A**. **11g** was obtained as a white solid (99 mg, 0.25 mmol, 50%) in 6.1:1 *trans:cis* diastereomeric ratio.

***trans*-diastereomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ:** 7.77 – 7.66 (m, 3H), 7.62 – 7.58 (m, 1H), 7.42 – 7.28 (m, 4H), 7.13 (dd, *J* = 7.7, 1.6 Hz, 1H), 6.91 (dd, *J* = 7.6, 1.5 Hz, 1H), 6.74 (t, *J* = 7.6 Hz, 1H), 5.57 (ddd, *J* = 16.6, 11.2, 7.7 Hz, 1H), 5.04 (s, 1H), 4.93 – 4.84 (m, 2H), 4.64 (dd, *J* = 10.4, 2.4 Hz, 1H), 4.19 (ddd, *J* = 10.4, 2.4, 1.8 Hz, 1H), 3.79 (t, *J* = 1.8 Hz, 1H), 2.43 – 2.37 (m, 1H), 1.83 (br s, 1H), 1.35 (s, 9H); **^{13}C NMR (101 MHz, $CDCl_3$) δ**:153.5, 146.9, 145.9, 140.8, 140.7, 137.7, 136.7, 128.7, 128.3, 127.5, 127.4, 125.9, 125.4, 123.3, 120.2, 120.0, 119.7, 116.4, 64.1, 62.1, 54.5, 41.1, 34.9, 29.7; **HRMS (DART-TOF)** calculated for $C_{28}H_{30}NO^+$ $[M+H]^+$ m/z 396.2322, found 396.2325.

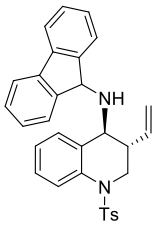


***N*-(9H-fluoren-9-yl)-6-methoxy-3-vinylchroman-4-amine (11h).** Following the **General Reaction Procedure A**, a mixture of aldehyde **7h** (0.50 mmol, 161 mg) and 9*H*-fluoren-9-amine **8** (0.50 mmol, 91 mg) in dry CH_2Cl_2 (5.0 mL) was stirred at 25 °C for 16 h. The mixture was concentrated to give the corresponding *N*-fluorenyl imine (without purification) and was transferred into the glove-box. THF (6.0 mL) was added into the vial, followed by NaHMDS (96 mg, 0.53 mmol, 1.05 equiv). The mixture was stirred for 16 h at 25 °C. The reaction was worked up following **General Workup Procedure A**. At the end of the reaction, the mixture was concentrated, and CH_2Cl_2 (3 mL) was added, followed by $NaBH_4$ (1.5 mmol, 57 mg), and cooled in an ice water bath. AcOH (10 mmol, 0.6 mL) was added slowly for at least 15 minutes while the reaction mixture was rapidly stirred (**CAUTION**: gas evolution). The resulting mixture was warmed to room temperature, and stirred for 1-2 h. The reaction mixture was then cooled in an ice-water bath, and NaOH (10% aq., 5 mL) was added slowly while the reaction mixture was rapidly stirred. The reaction mixture was warmed to room temperature, and stirred for 30 min. The layers were separated, and the aqueous layer was extracted with

CH_2Cl_2 (5 mL) twice. The combined organic layers were washed with brine (5 mL), dried over Na_2SO_4, and concentrated under reduced pressure. Chromatographic purification on silica gel using petroleum ether/ethyl acetate (20/1) as eluents afforded **11h** as a white solid (76 mg, 0.21 mmol, 41%) in >20:1 *trans:cis* diastereomeric ratio.

By using **General Reaction Procedure B**, a screw-capped vial containing aldehyde **7h** (0.50 mmol, 161 mg) and 9*H*-fluoren-9-amine **8** (0.50 mmol, 91 mg) in dry CH_2Cl_2 (5.0 mL) was stirred at 25 °C for 5 h. The mixture was concentrated to give the corresponding *N*-fluorenyl imine (without purification) and was transferred into the glove-box. $PdCl_2$ (5.3 mg, 0.03 mmol, 6 mol %), PCy3 (34 mg, 0.12 mmol, 24 mol %), and THF (6.0 mL) were added into the vial, followed by NaHMDS (96 mg, 0.53 mmol, 1.05 equiv). The vial was sealed with a cap containing a PTFE septum, removed from the glove box, and kept at 25 °C for 16 h. The reaction was worked up following **General Workup Procedure A**. **11h** was obtained as a white solid (139 mg, 0.38 mmol, 75%) in 18.7:1 *trans:cis* diastereomeric ratio.

***trans*-diastereomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ**: 7.76 – 7.68 (m, 3H), 7.65 – 7.59 (m, 1H), 7.42 – 7.29 (m, 4H), 6.75 – 6.68 (m, 2H), 6.52 (d, *J* = 2.3 Hz, 1H), 5.56 (ddd, *J* = 17.3, 10.5, 7.7 Hz, 1H), 5.06 (s, 1H), 4.88 (ddd, *J* = 10.5, 1.7, 1.0 Hz, 1H), 4.80 (dt, *J* = 17.2, 1.2 Hz, 1H), 4.57 (dd, *J* = 10.5, 2.3 Hz, 1H), 4.07 (ddd, *J* = 10.5, 2.5, 1.6 Hz, 1H), 3.67 (s, 3H), 3.62 (t, *J* = 1.6 Hz, 1H), 2.42 – 2.30 (m, 1H), 1.93 (br s, 1H); **^{13}C NMR (101 MHz, $CDCl_3$) δ**: 153.5, 148.6, 146.3, 145.9, 141.0, 140.8, 136.5, 128.4, 128.4, 127.5, 127.4, 125.6, 125.3, 123.5, 120.3, 120.1, 117.6, 116.7, 115.6, 114.6, 64.9, 62.3, 55.8, 53.7, 42.0; **HRMS (DART-TOF)** calculated for $C_{25}H_{23}NNaO_2^+$ $[M+Na]^+$ m/z 392.1621, found 392.1620.

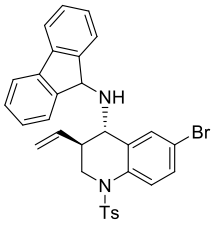


***N*-(9*H*-fluoren-9-yl)-1-tosyl-3-vinyl-1,2,3,4-tetrahydroquinolin-4-amine (11i).** Following the **General Reaction Procedure A**, a mixture of aldehyde **7i** (0.50 mmol, 223 mg) and 9*H*-fluoren-9-amine **8** (0.50 mmol, 91 mg) in dry CH_2Cl_2 (5.0 mL) was stirred at 25 °C for 5h. The mixture was concentrated to give the corresponding *N*-fluorenyl imine (without purification) and was transferred into the glove-box. THF (6.0 mL) was added into the vial, followed by NaHMDS (96 mg, 0.53 mmol, 1.05 equiv). The mixture was stirred for 16 h at 25 °C. The reaction was worked up following **General Workup Procedure A**. At the end of the reaction, the mixture was concentrated, and CH_2Cl_2 (3 mL) was added, followed by $NaBH_4$ (1.5 mmol, 57 mg), and cooled in an ice water bath. AcOH (10 mmol, 0.6 mL) was added slowly for at least 15 minutes while the reaction mixture was rapidly stirred (**CAUTION**: gas evolution). The resulting mixture was warmed to room temperature, and stirred for 1-2 h. The reaction mixture was then cooled in an ice-water bath, and NaOH (10% aq., 5 mL) was added slowly while the reaction mixture was rapidly stirred. The reaction mixture was warmed to room temperature, and stirred for 30 min. The layers were separated, and the aqueous layer was extracted with CH_2Cl_2 (5 mL) twice. The combined organic layers were washed with brine (5 mL), dried

over Na_2SO_4, and concentrated under reduced pressure. Chromatographic purification on silica gel using petroleum ether/ethyl acetate (20/1) as eluents afforded **11i** as a white solid (143 mg, 0.29 mmol, 58%) in >20:1 *trans:cis* diastereomeric ratio.

By using **General Reaction Procedure B**, a screw-capped vial containing aldehyde **7i** (0.50 mmol, 223 mg) and 9*H*-fluoren-9-amine **8** (0.50 mmol, 91 mg) in dry CH_2Cl_2 (5.0 mL) was stirred at 25 °C for 5 h. The mixture was concentrated to give the corresponding *N*-fluorenyl imine (without purification) and was transferred into the glove-box. $PdCl_2$ (5.3 mg, 0.03 mmol, 6 mol %), PCy3 (34 mg, 0.12 mmol, 24 mol %), and THF (6.0 mL) were added into the vial, followed by NaHMDS (96 mg, 0.53 mmol, 1.05 equiv). The vial was sealed with a cap containing a PTFE septum, removed from the glove box, and kept at 25 °C for 16 h. The reaction was worked up following **General Workup Procedure A**. **11i** was obtained as a white solid (209 mg, 0.43 mmol, 85%) in 16:1 *trans:cis* diastereomeric ratio.

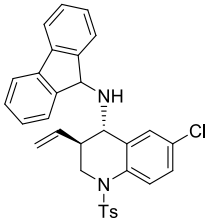
***trans*-diastereomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ**: 7.78 (d, *J* = 8.3 Hz, 1H), 7.71 – 7.63 (m, 4H), 7.57 (d, *J* = 7.4 Hz, 1H), 7.42 – 7.35 (m, 2H), 7.33 – 7.27 (m, 3H), 7.21 – 7.14 (m, 3H), 7.03 (dd, *J* = 7.6, 1.4 Hz, 1H), 6.96 (td, *J* = 7.5, 0.9 Hz, 1H), 5.41 (ddd, *J* = 17.6, 10.1, 7.6 Hz, 1H), 4.96 – 4.87 (m, 2H), 4.77 (s, 1H), 4.14 (dd, *J* = 12.0, 4.4 Hz, 1H), 4.00 (dd, *J* = 12.1, 3.9 Hz, 1H), 3.69 (d, *J* = 4.1 Hz, 1H), 2.57 – 2.49 (m, 1H), 2.29 (s, 3H), 1.40 (br s, 1H); **^{13}C NMR (101 MHz, $CDCl_3$) δ**: 146.5, 145.9, 143.9, 140.7, 140.5, 136.8, 136.8, 136.3, 130.0, 129.9, 129.7, 128.4, 128.4, 128.3, 127.5, 127.4, 127.4, 125.2, 125.2, 124.0, 122.0, 120.2, 120.0, 117.6, 62.1, 56.4, 46.8, 42.5, 21.6; **HRMS (DART-TOF)** calculated for $C_{31}H_{29}N_2O_2S^+$ $[M+H]^+$ m/z 493.1944, found 493.1940.



6-bromo-*N*-(9*H*-fluoren-9-yl)-1-tosyl-3-vinyl-1,2,3,4-tetrahydroquinolin-4-amine (11j). Following the **General Reaction Procedure A**, a mixture of aldehyde **7j** (0.50 mmol, 262 mg) and 9*H*-fluoren-9-amine **8** (0.50 mmol, 91 mg) in dry CH_2Cl_2 (5.0 mL) was stirred at 25 °C for 5h. The mixture was concentrated to give the corresponding *N*-fluorenyl imine (without purification) and was transferred into the glove-box. THF (6.0 mL) was added into the vial, followed by NaHMDS (96 mg, 0.53 mmol, 1.05 equiv). The mixture was stirred for 16 h at 25 °C. The reaction was worked up following **General Workup Procedure A**. At the end of the reaction, the mixture was concentrated, and CH_2Cl_2 (3 mL) was added, followed by $NaBH_4$ (1.5 mmol, 57 mg), and cooled in an ice water bath. AcOH (10 mmol, 0.6 mL) was added slowly for at least 15 minutes while the reaction mixture was rapidly stirred (**CAUTION**: gas evolution). The resulting mixture was warmed to room temperature, and stirred for 1-2 h. The reaction mixture was then cooled in an ice-water bath, and NaOH (10% aq., 5 mL) was added slowly while the reaction mixture was rapidly stirred. The reaction mixture was warmed to room temperature, and stirred for 30 min. The layers were separated, and the aqueous layer was extracted with CH_2Cl_2 (5 mL) twice. The combined organic layers were washed with

brine (5 mL), dried over Na_2SO_4, and concentrated under reduced pressure. Chromatographic purification on silica gel using petroleum ether/ethyl acetate (20/1) as eluents afforded **11j** as a white solid (191 mg, 0.34 mmol, 67%) in 11:1 *trans:cis* diastereomeric ratio. By using **General Reaction Procedure B**, a screw-capped vial containing aldehyde **7j** (0.50 mmol, 262 mg) and 9*H*-fluoren-9-amine **8** (0.50 mmol, 91 mg) in dry CH_2Cl_2 (5.0 mL) was stirred at 25 °C for 5 h. The mixture was concentrated to give the corresponding *N*-fluorenyl imine (without purification) and was transferred into the glove-box. $PdCl_2$ (5.3 mg, 0.03 mmol, 6 mol %), PCy3 (34 mg, 0.12 mmol, 24 mol %), and THF (6.0 mL) were added into the vial, followed by NaHMDS (96 mg, 0.53 mmol, 1.05 equiv). The vial was sealed with a cap containing a PTFE septum, removed from the glove box, and kept at 25 °C for 16 h. The reaction was worked up following **General Workup Procedure A**. **11j** was obtained as a white solid (206 mg, 0.36 mmol, 72%) in 10:1 *trans:cis* diastereomeric ratio.

***trans*-diastereomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ**: 7.73 – 7.61 (m, 5H), 7.53 (d, *J* = 7.3 Hz, 1H), 7.43 – 7.35 (m, 2H), 7.31 (td, *J* = 7.4, 1.1 Hz, 1H), 7.28 – 7.17 (m, 5H), 7.00 (d, *J* = 2.4 Hz, 1H), 5.31 (ddd, *J* = 16.8, 10.8, 7.4 Hz, 1H), 4.93 – 4.83 (m, 2H), 4.72 (s, 1H), 4.08 (dd, *J* = 12.1, 4.6 Hz, 1H), 3.94 (dd, *J* = 12.1, 4.2 Hz, 1H), 3.49 (d, *J* = 4.3 Hz, 1H), 2.52 – 2.43 (m, 1H), 2.31 (s, 3H), 1.38 (br s, 1H); **^{13}C NMR (101 MHz, $CDCl_3$) δ**: 145.8, 145.5, 144.2, 140.7, 140.6, 136.2, 135.7, 132.5, 132.2, 131.2, 129.8, 128.6, 128.5, 127.6, 127.5, 127.4, 125.2, 125.0, 123.7, 120.2, 120.1, 117.9, 116.9, 62.1, 55.7, 46.7, 42.5, 21.7; **HRMS (DART-TOF)** calculated for $C_{31}H_{28}BrN_2O_2S^+$ $[M+H]^+$ m/z 571.1049, found 571.1058.



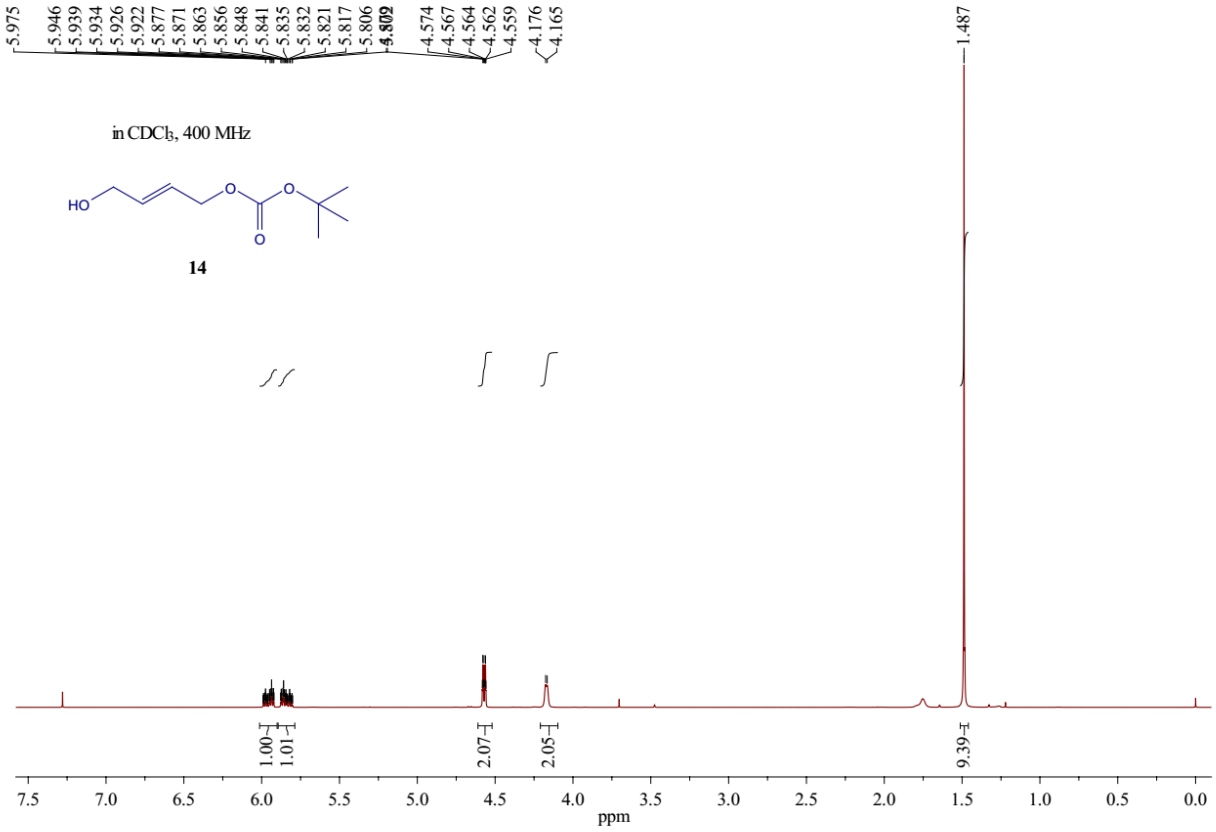
6-chloro-*N*-(9*H*-fluoren-9-yl)-1-tosyl-3-vinyl-1,2,3,4-tetrahydroquinolin-4-amine (11k). Following the **General Reaction Procedure A**, a mixture of aldehyde **7k** (0.50 mmol, 240 mg) and 9*H*-fluoren-9-amine **8** (0.50 mmol, 91 mg) in dry CH_2Cl_2 (5.0 mL) was stirred at 25 °C for 5h. The mixture was concentrated to give the corresponding *N*-fluorenyl imine (without purification) and was transferred into the glove-box. THF (6.0 mL) was added into the vial, followed by NaHMDS (96 mg, 0.53 mmol, 1.05 equiv). The mixture was stirred for 16 h at 25 °C. The reaction was worked up following **General Workup Procedure A**. At the end of the reaction, the mixture was concentrated, and CH_2Cl_2 (3 mL) was added, followed by $NaBH_4$ (1.5 mmol, 57 mg), and cooled in an ice water bath. AcOH (10 mmol, 0.6 mL) was added slowly for at least 15 minutes while the reaction mixture was rapidly stirred (**CAUTION**: gas evolution). The resulting mixture was warmed to room temperature, and stirred for 1-2 h. The reaction mixture was then cooled in an ice-water bath, and NaOH (10% aq., 5 mL) was added slowly while the reaction mixture was rapidly stirred. The reaction mixture was warmed to room temperature, and stirred for 30 min. The layers were separated, and the aqueous layer was extracted with CH_2Cl_2 (5 mL) twice. The combined organic layers were washed with brine (5 mL), dried over Na_2SO_4, and concentrated under reduced pressure. Chromatographic purification on silica gel using

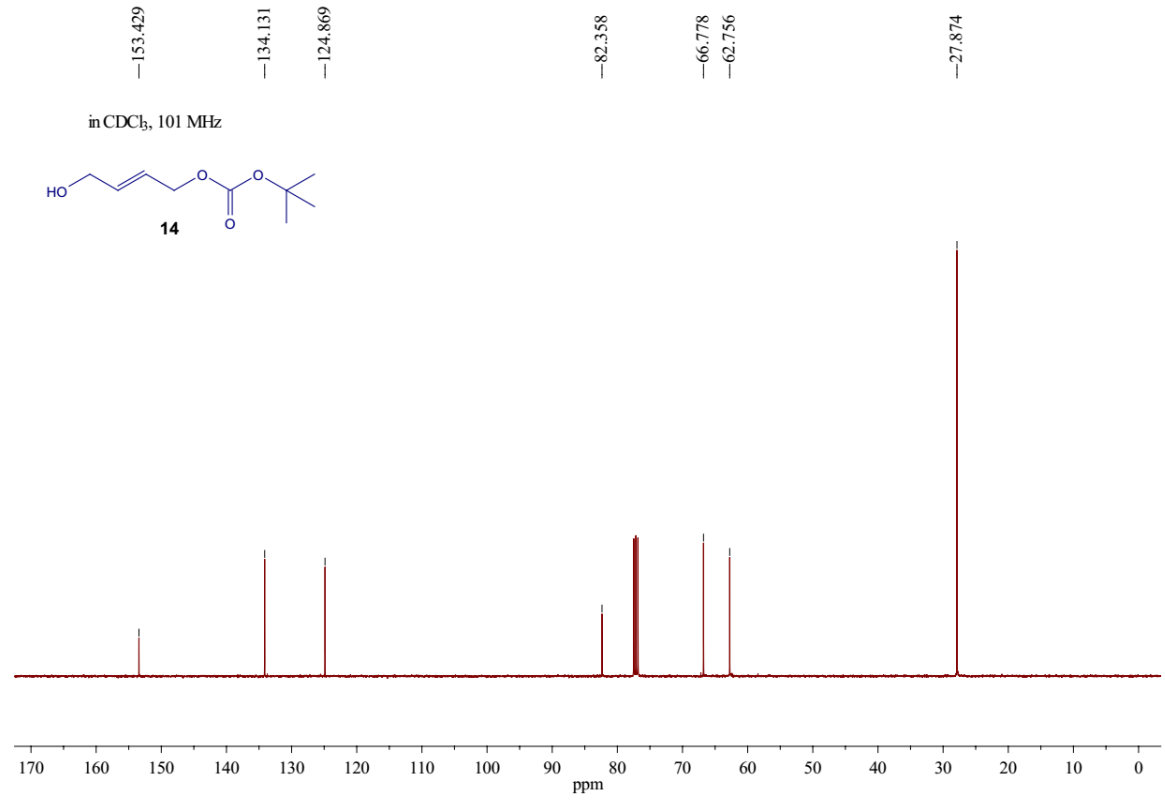
petroleum ether/ethyl acetate (20/1) as eluents afforded **11k** as a white solid (182 mg, 0.35 mmol, 69%) in 11:1 *trans:cis* diastereomeric ratio.

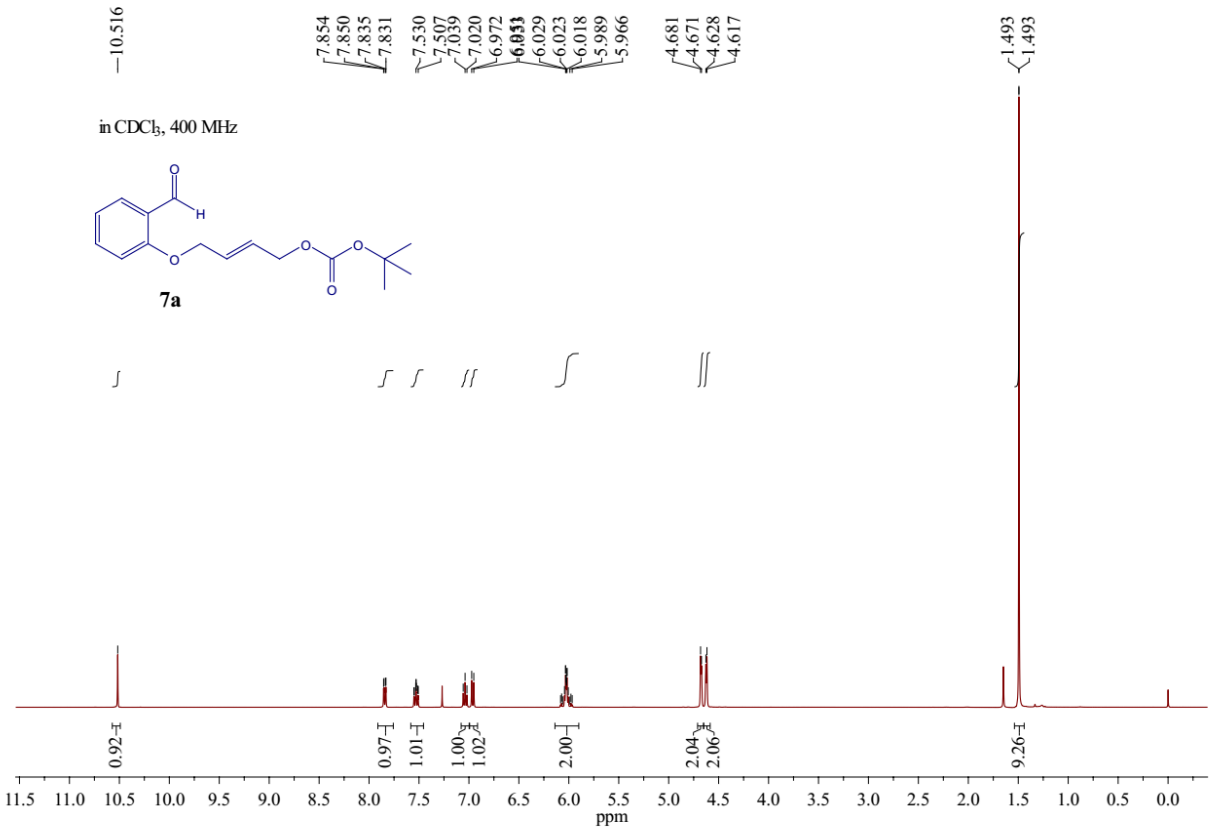
By using **General Reaction Procedure B**, a screw-capped vial containing aldehyde **7k** (0.50 mmol, 240 mg) and 9*H*-fluoren-9-amine **8** (0.50 mmol, 91 mg) in dry CH_2Cl_2 (5.0 mL) was stirred at 25 °C for 5 h. The mixture was concentrated to give the corresponding *N*-fluorenyl imine (without purification) and was transferred into the glove-box. $PdCl_2$ (5.3 mg, 0.03 mmol, 6 mol %), PCy3 (34 mg, 0.12 mmol, 24 mol %), and THF (6.0 mL) were added into the vial, followed by NaHMDS (96 mg, 0.53 mmol, 1.05 equiv). The vial was sealed with a cap containing a PTFE septum, removed from the glove box, and kept at 25 °C for 16 h. The reaction was worked up following **General Workup Procedure A**. **11k** was obtained as a white solid (200 mg, 0.38 mmol, 76%) in 20:1 *trans:cis* diastereomeric ratio.

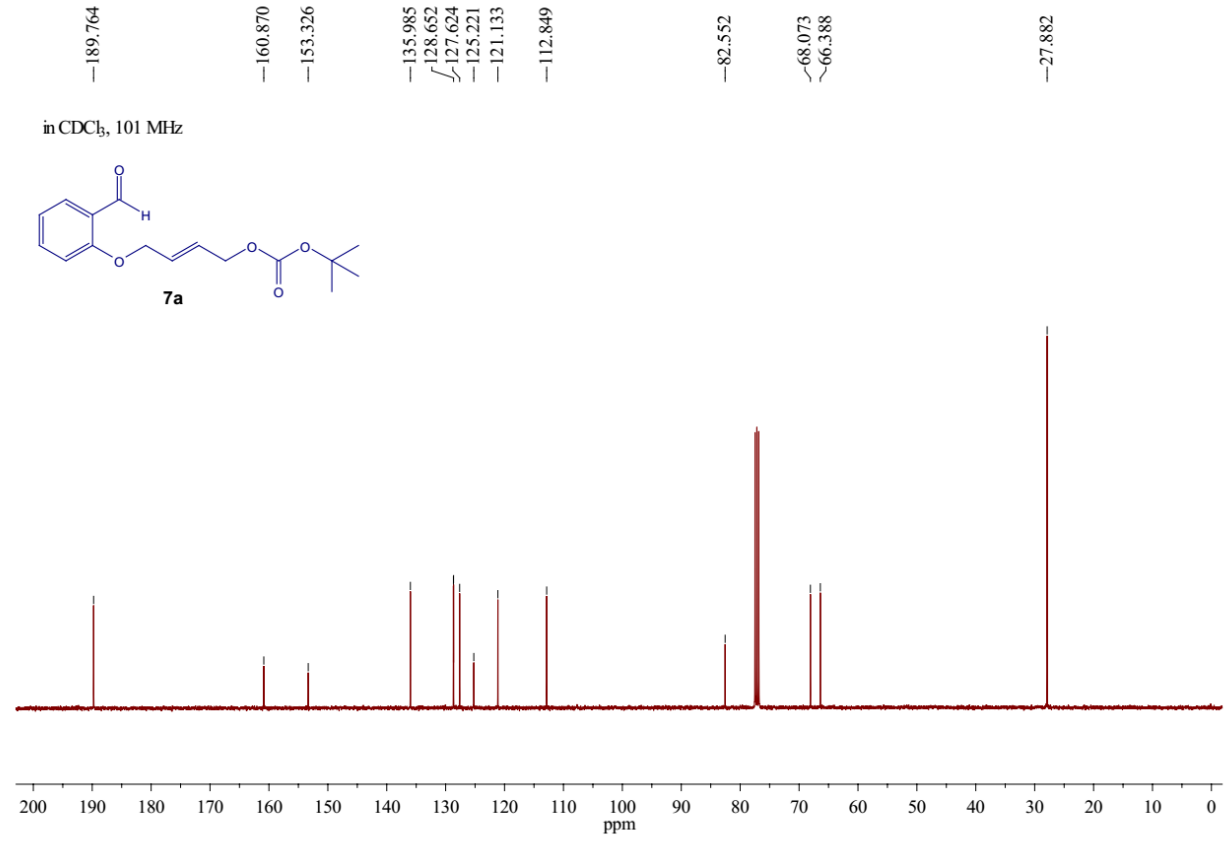
***trans*-diastereomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ**: 7.75 (d, *J* = 8.9 Hz, 1H), 7.69 (d, *J* = 7.5 Hz, 2H), 7.64 (d, *J* = 8.3 Hz, 2H), 7.54 (d, *J* = 7.1 Hz, 1H), 7.39 (dd, *J* = 13.7, 6.5 Hz, 2H), 7.31 (td, *J* = 7.4, 1.1 Hz, 1H), 7.28 – 7.17 (m, 4H), 7.13 (dd, *J* = 8.9, 2.6 Hz, 1H), 6.88 (d, *J* = 2.5 Hz, 1H), 5.32 (ddd, *J* = 16.6, 10.9, 7.5 Hz, 1H), 4.95 – 4.84 (m, 2H), 4.73 (s, 1H), 4.08 (dd, *J* = 12.1, 4.6 Hz, 1H), 3.94 (dd, *J* = 12.1, 3.9 Hz, 1H), 3.51 (d, *J* = 4.4 Hz, 1H), 2.52 – 2.44 (m, 1H), 2.31 (s, 3H), 1.36 (br s, 1H); **^{13}C NMR (101 MHz, $CDCl_3$) δ**: 145.9, 145.5, 144.2, 140.7, 140.5, 136.3, 135.8, 135.2, 132.0, 129.8, 129.5, 129.2, 128.6, 128.5, 128.3, 127.6, 127.5, 127.4, 125.1, 125.0, 123.6, 120.2, 120.1, 117.9, 62.1, 55.8, 46.8, 42.6, 21.7; **HRMS (DART-TOF)** calculated for $C_{31}H_{28}ClN_2O_2S^+$ $[M+H]^+$ m/z 527.1555, found 527.1559.

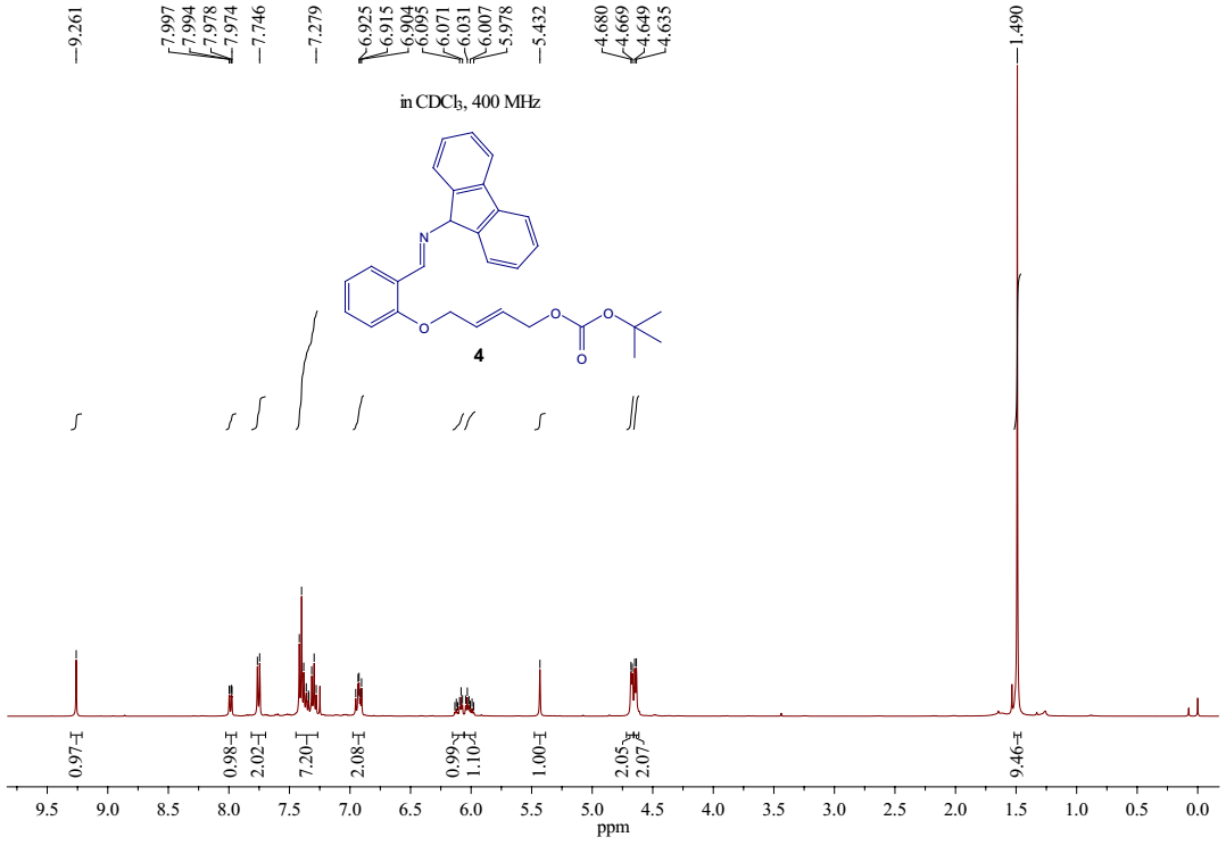
NMR Spectra

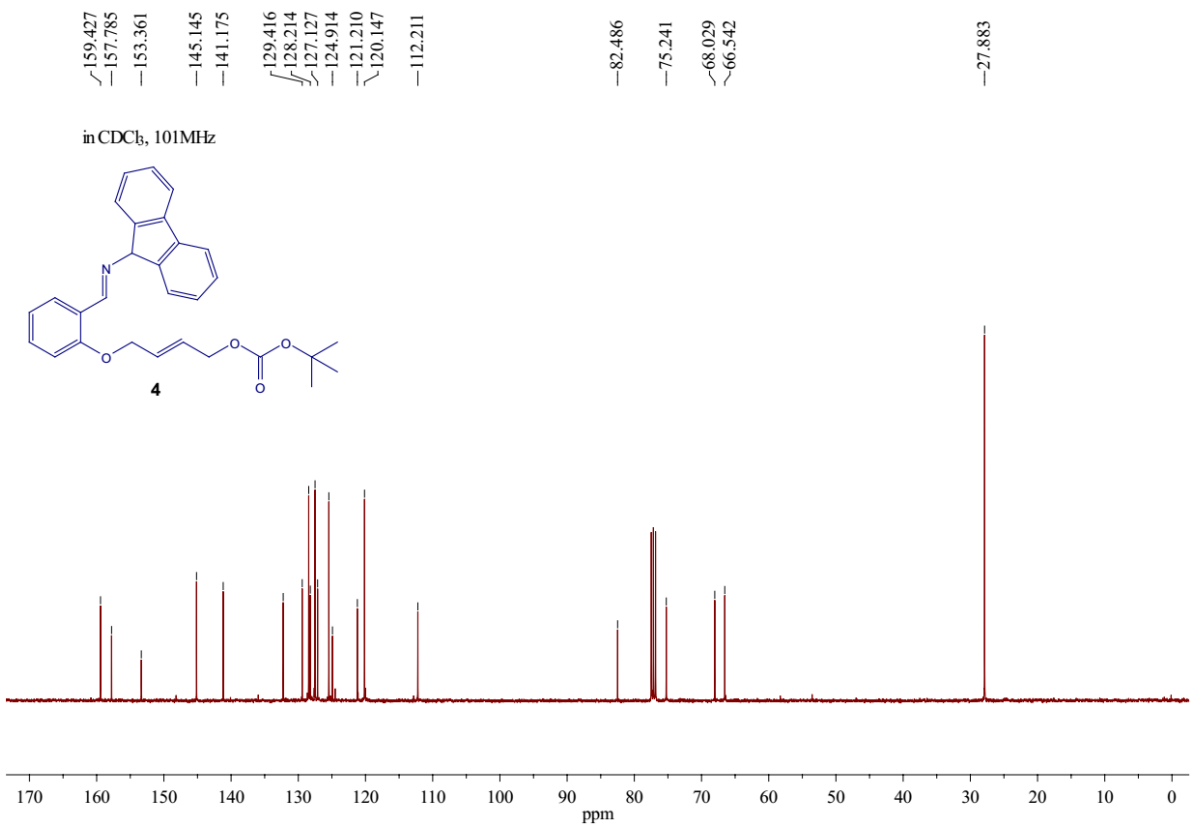

5.975
5.946
5.939
5.934
5.926
5.922
5.877
5.871
5.863
5.856
5.848
5.841
5.835
5.832
5.821
5.817
5.806
4.574
4.567
4.564
4.562
4.559
4.176
4.165
1.487
in CDCl3, 400 MHz
HO
O
O
O
14
1.00
1.01
2.07
2.05
9.39
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm

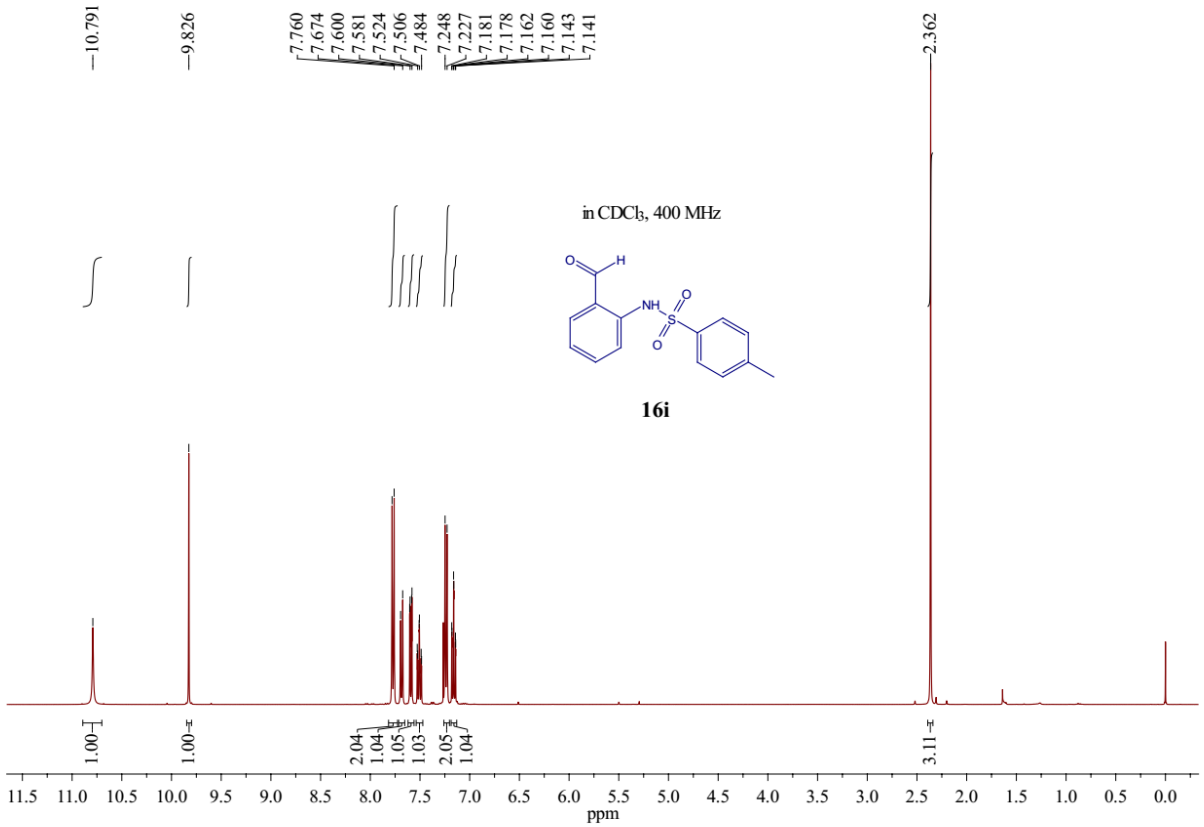

153.429
134.131
124.869
82.358
66.778
62.756
27.874
in CDCl3, 101 MHz
HO
O
O
O
14
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

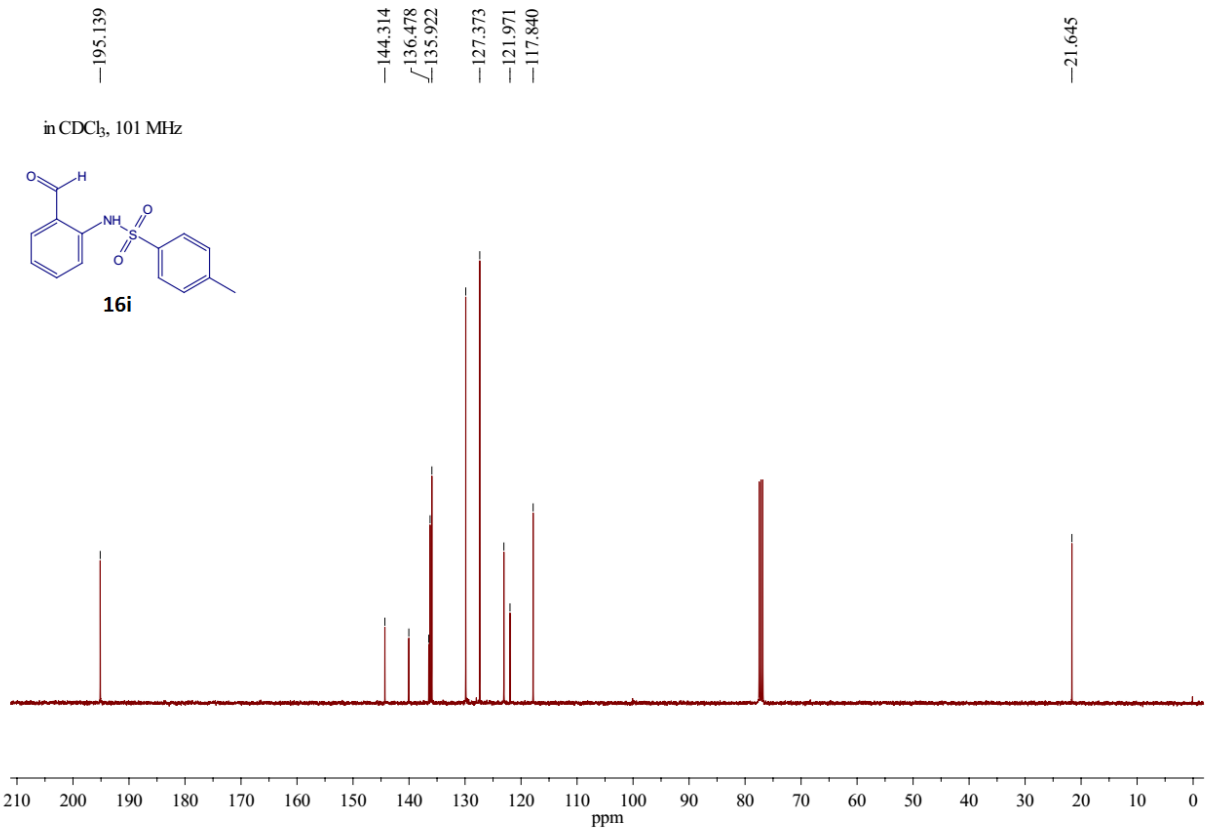

10.516
7.854
7.850
7.835
7.831
7.530
7.507
7.039
7.020
6.972
6.029
6.023
6.018
5.989
5.966
4.681
4.671
4.628
4.617
1.493
1.493
in CDCl3, 400 MHz
7a
0.92
0.97
1.01
1.00
1.02
2.00
2.04
2.06
9.26
ppm

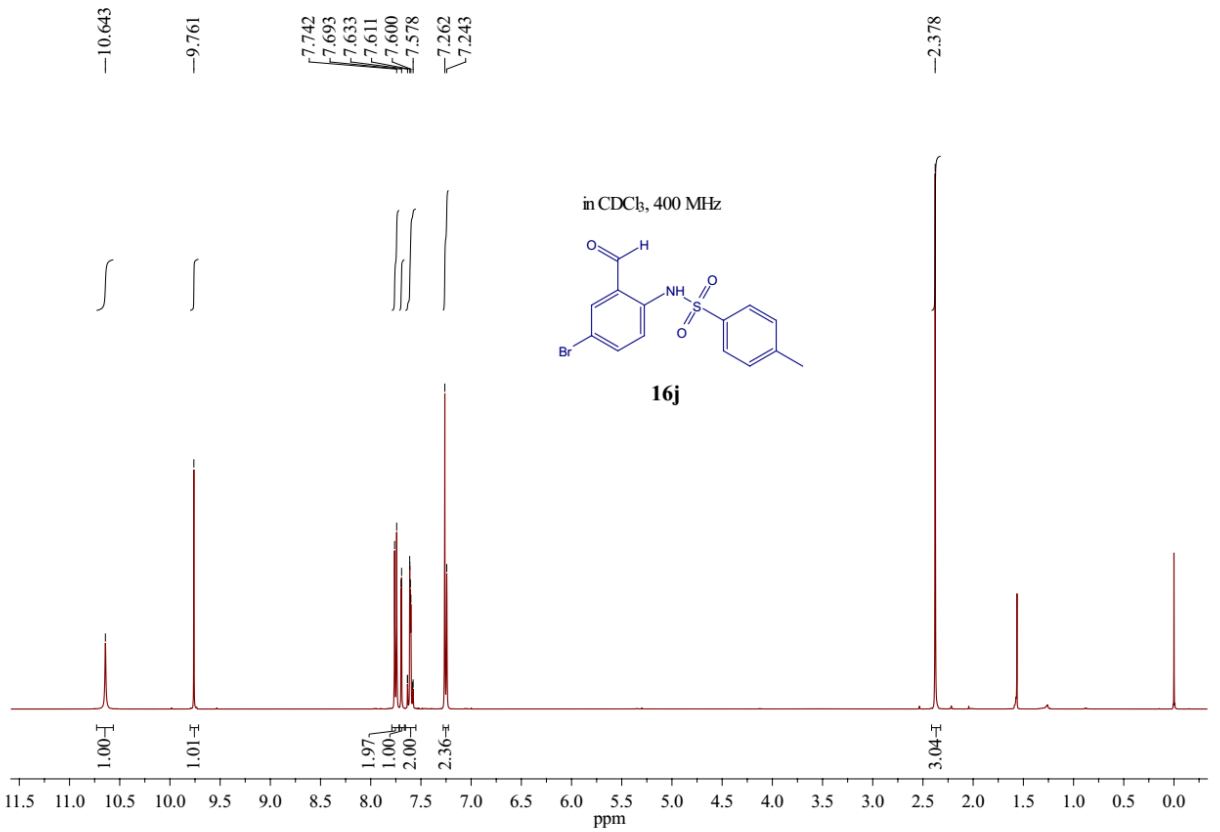

189.764
160.870
153.326
135.985
128.652
127.624
125.221
121.133
112.849
82.552
68.073
66.388
27.882
in CDCl3, 101 MHz
7a
ppm

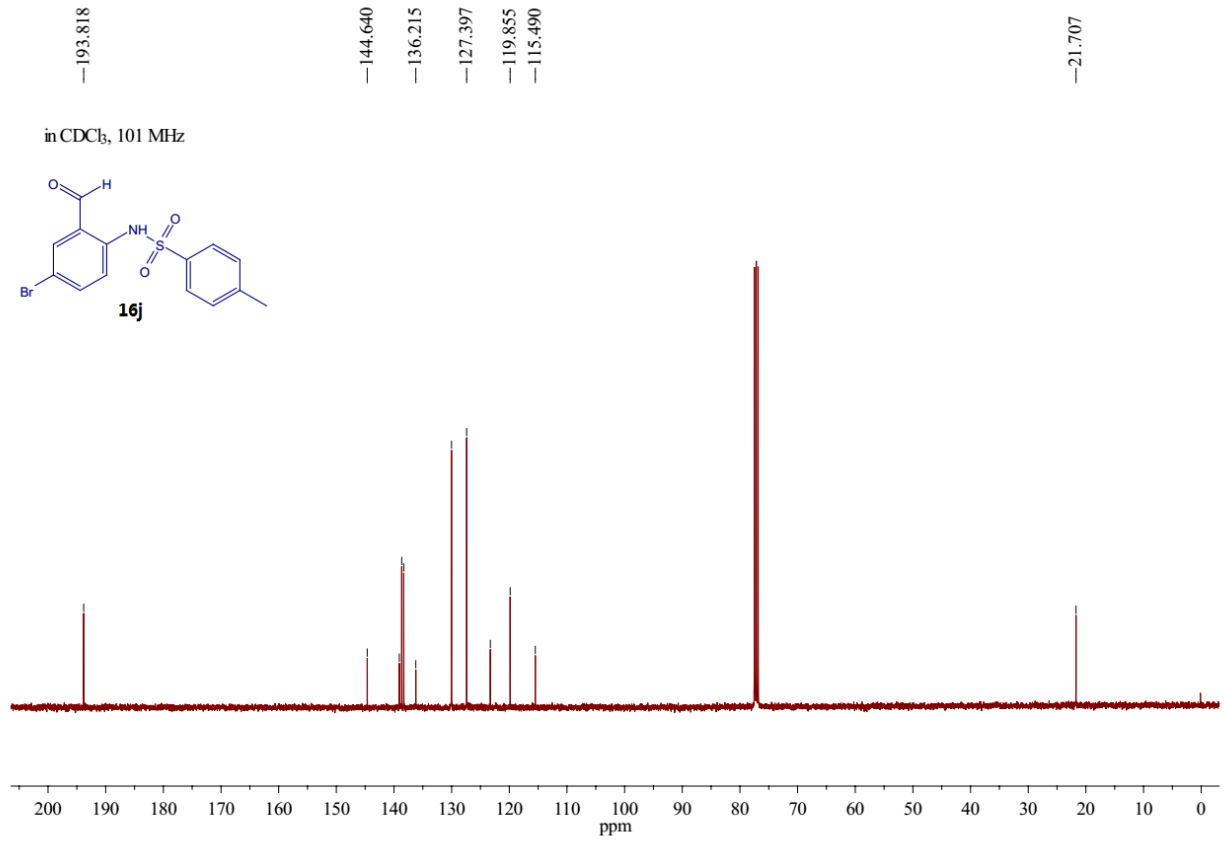

9.261
7.997
7.994
7.978
7.974
7.746
7.279
6.925
6.915
6.904
6.095
6.071
6.031
6.007
5.978
5.432
4.680
4.669
4.649
4.635
1.490
in CDCl3, 400 MHz
4
0.97
0.98
2.02
7.20
2.08
0.99
1.10
1.00
2.05
2.07
9.46
ppm

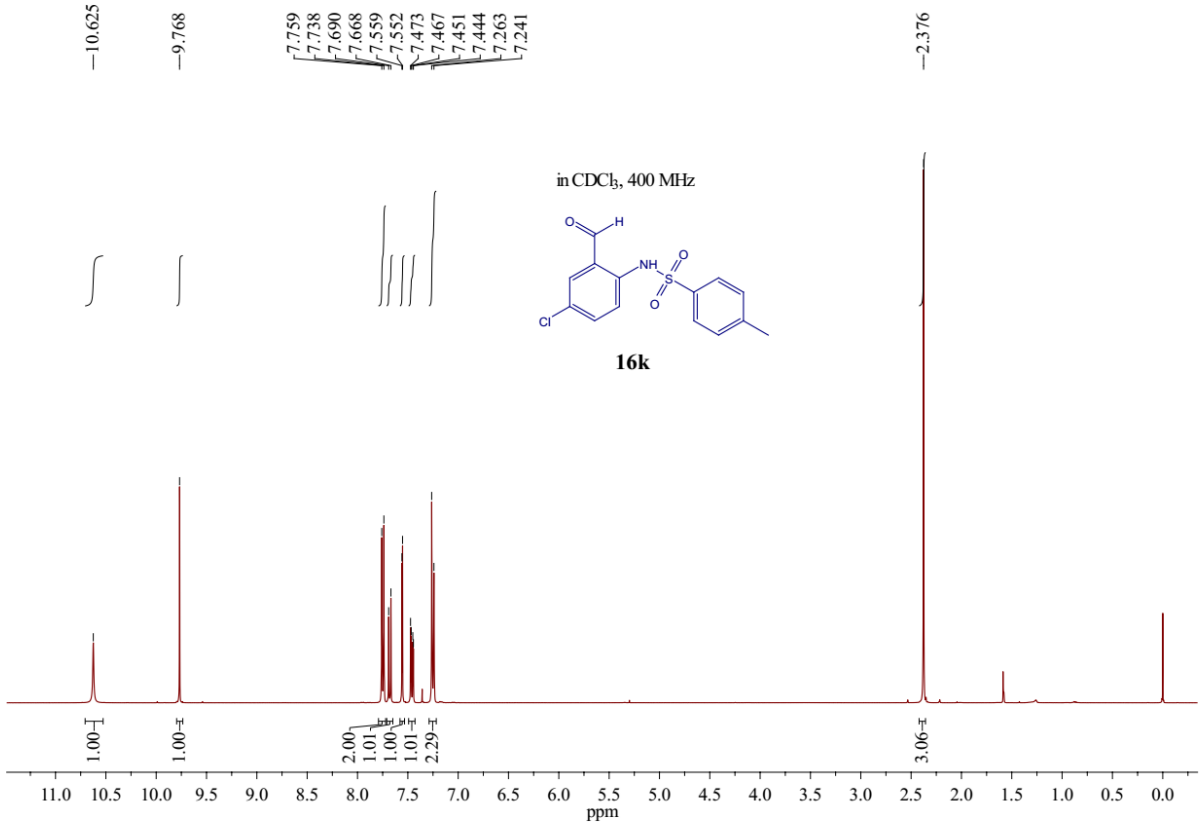

159.427
157.785
153.361
145.145
141.175
129.416
128.214
127.127
124.914
121.210
120.147
112.211
82.486
75.241
68.029
66.542
27.883
in CDCl3, 101MHz
4
ppm

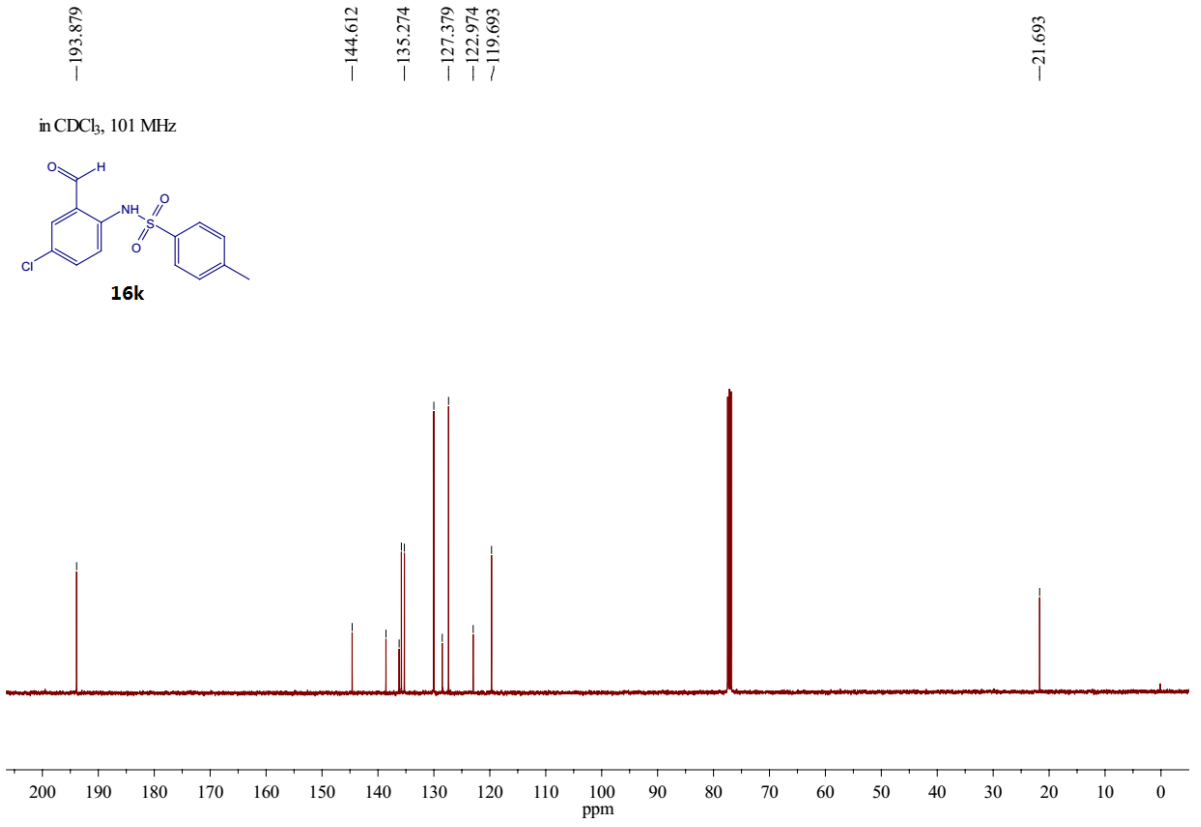

10.791
9.826
7.760
7.674
7.600
7.581
7.524
7.506
7.484
7.248
7.227
7.181
7.178
7.162
7.160
7.143
7.141
2.362
in CDCl3, 400 MHz
16i
1.00
1.00
2.04
1.04
1.05
1.03
2.05
1.04
3.11
ppm

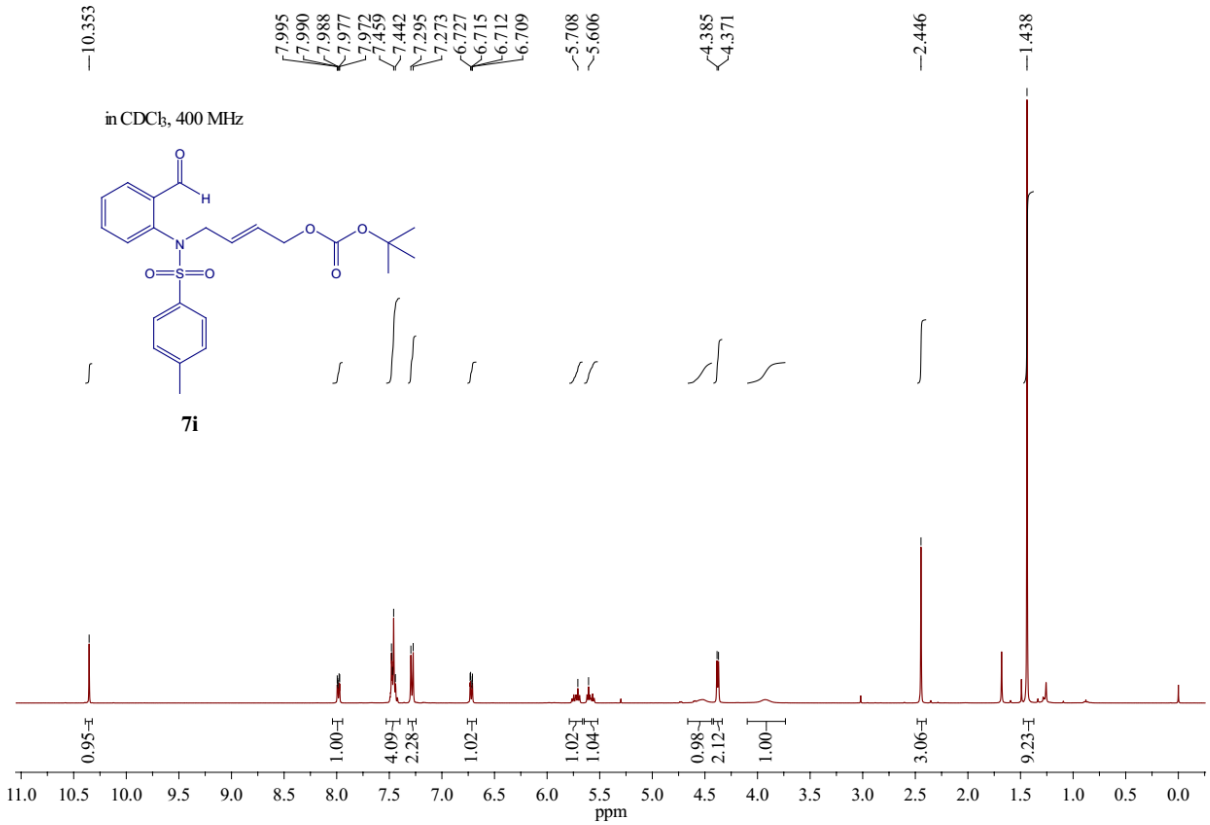

195.139
144.314
136.478
135.922
127.373
121.971
117.840
21.645
in CDCl3, 101 MHz
16i
ppm

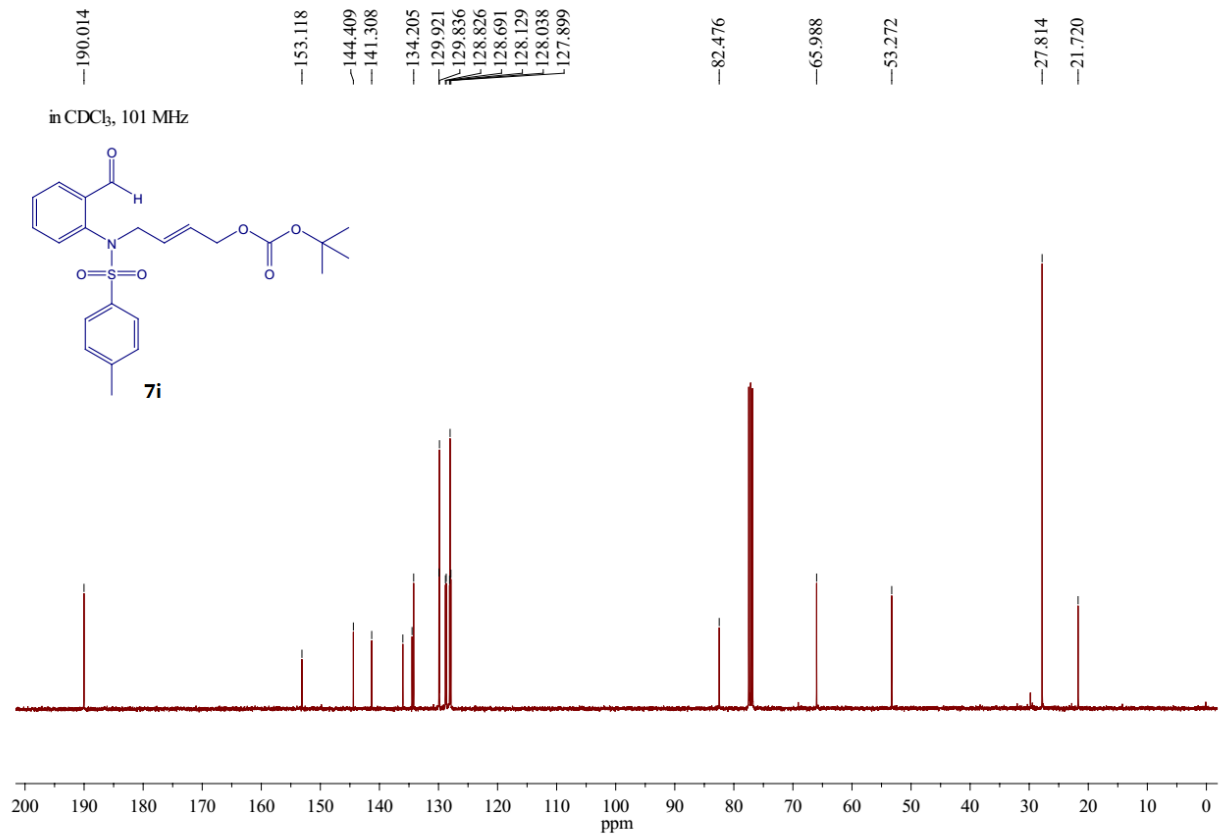

10.643
9.761
7.742
7.693
7.633
7.611
7.600
7.578
7.262
7.243
2.378
in CDCl3, 400 MHz
16j
1.00
1.01
1.97
1.00
2.00
2.36
3.04
ppm

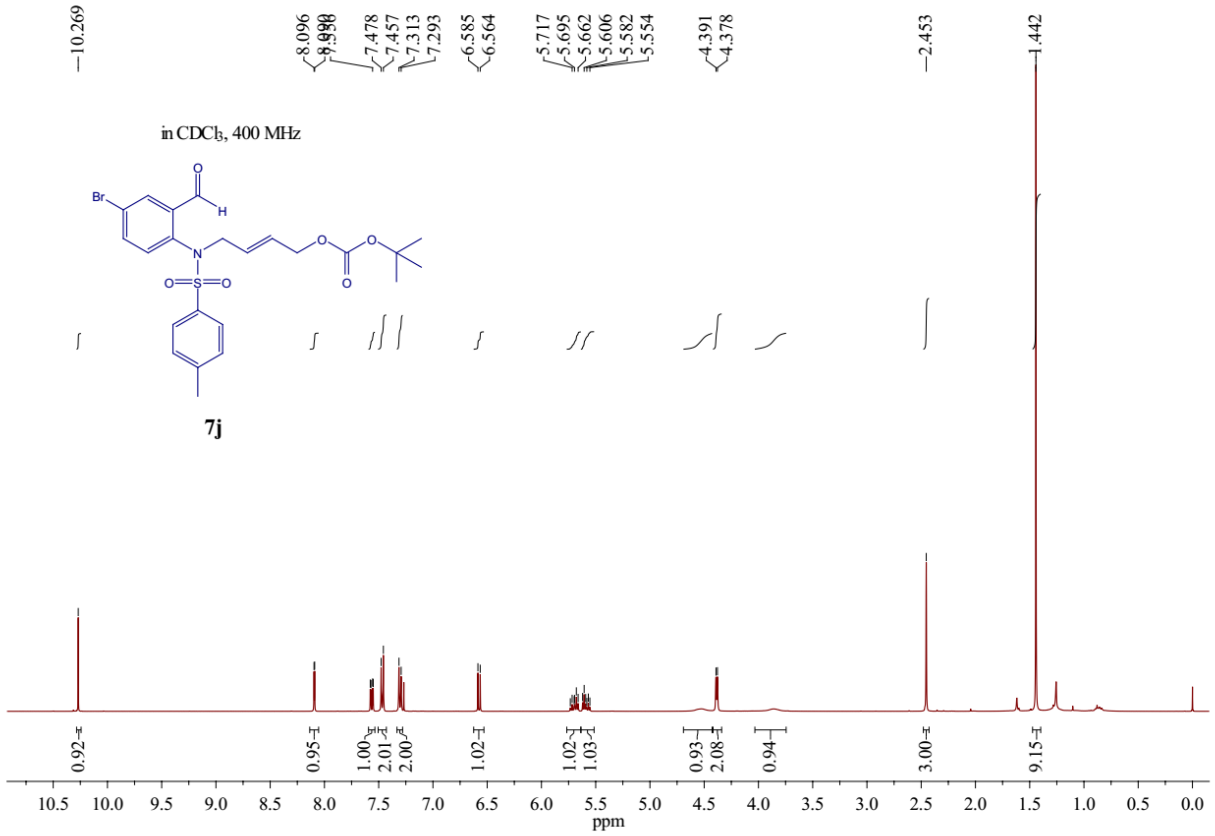

193.818
144.640
136.215
127.397
119.855
115.490
21.707
in CDCl3, 101 MHz
16j
ppm

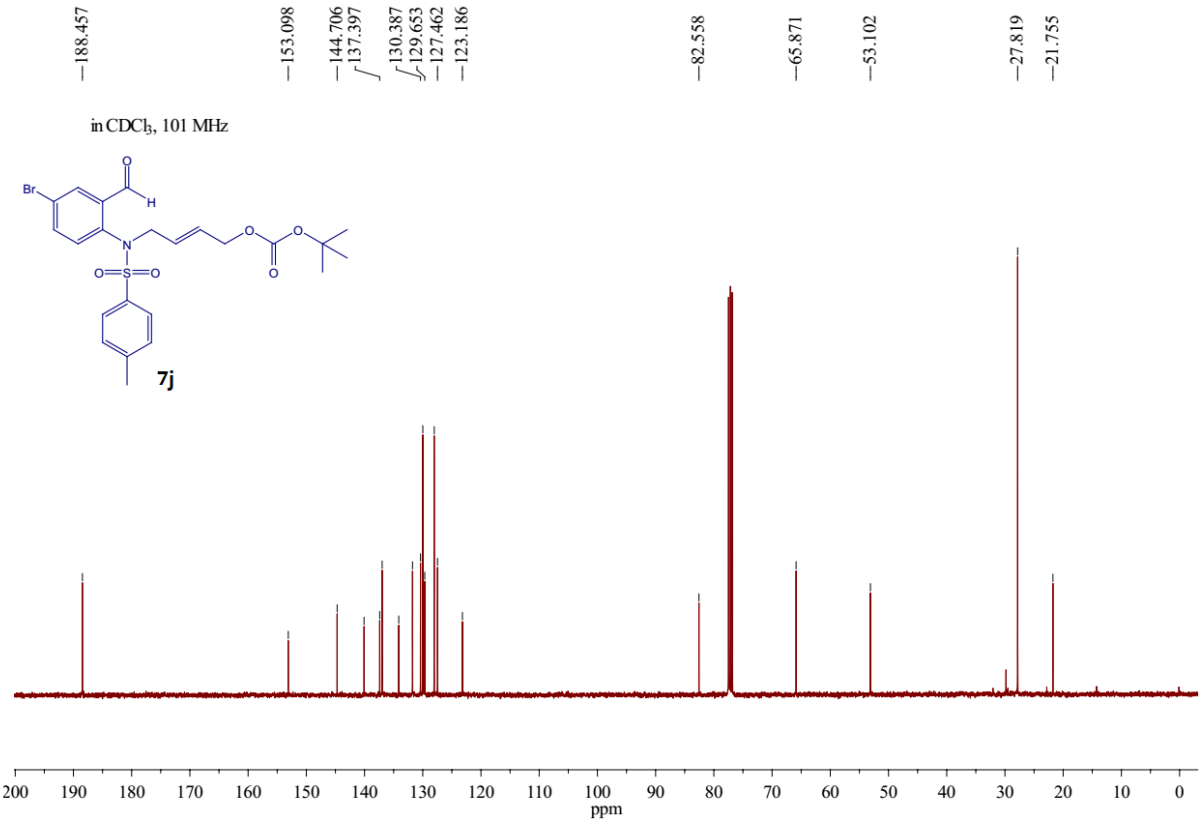

10.625
9.768
7.759
7.738
7.690
7.668
7.559
7.552
7.473
7.467
7.451
7.444
7.263
7.241
2.376
in CDCl3, 400 MHz
16k
1.00
1.00
2.00
1.01
1.00
1.01
2.29
3.06
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
ppm

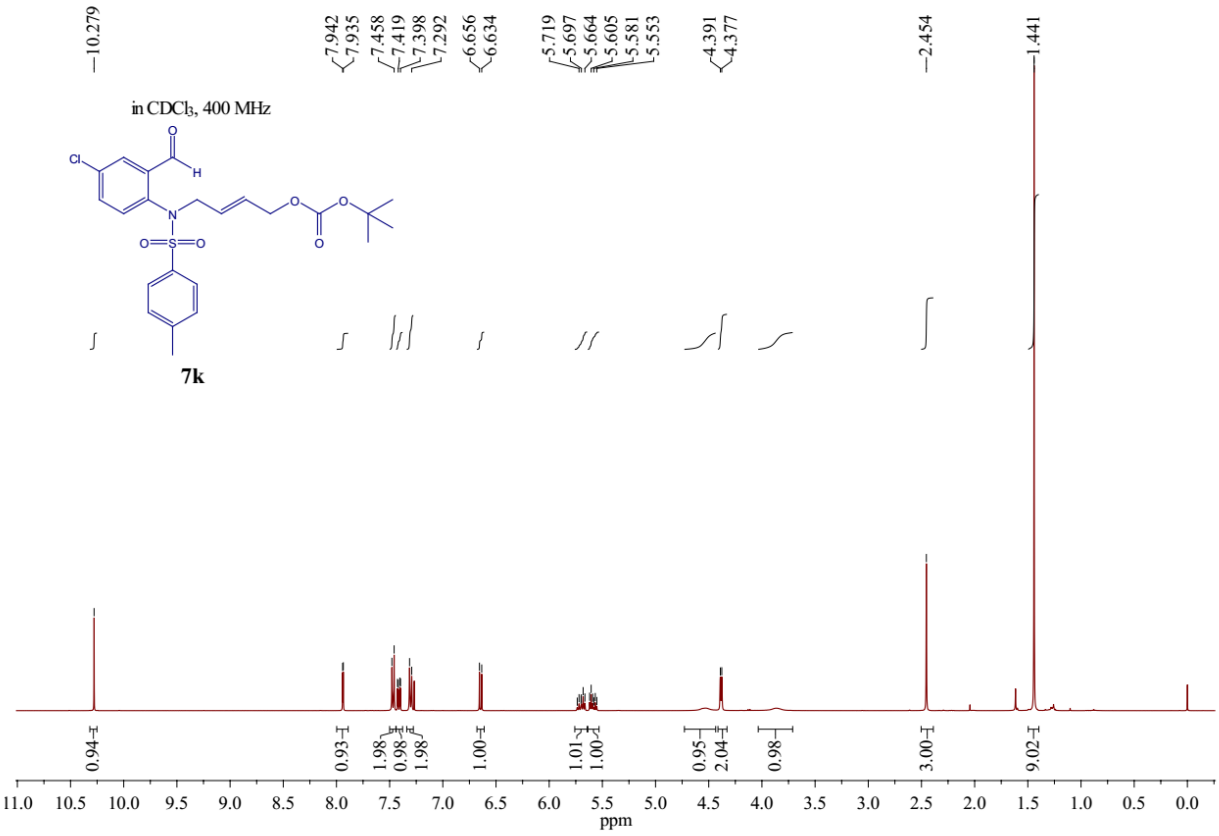

193.879
144.612
135.274
127.379
122.974
119.693
21.693
in CDCl3, 101 MHz
16k
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
ppm

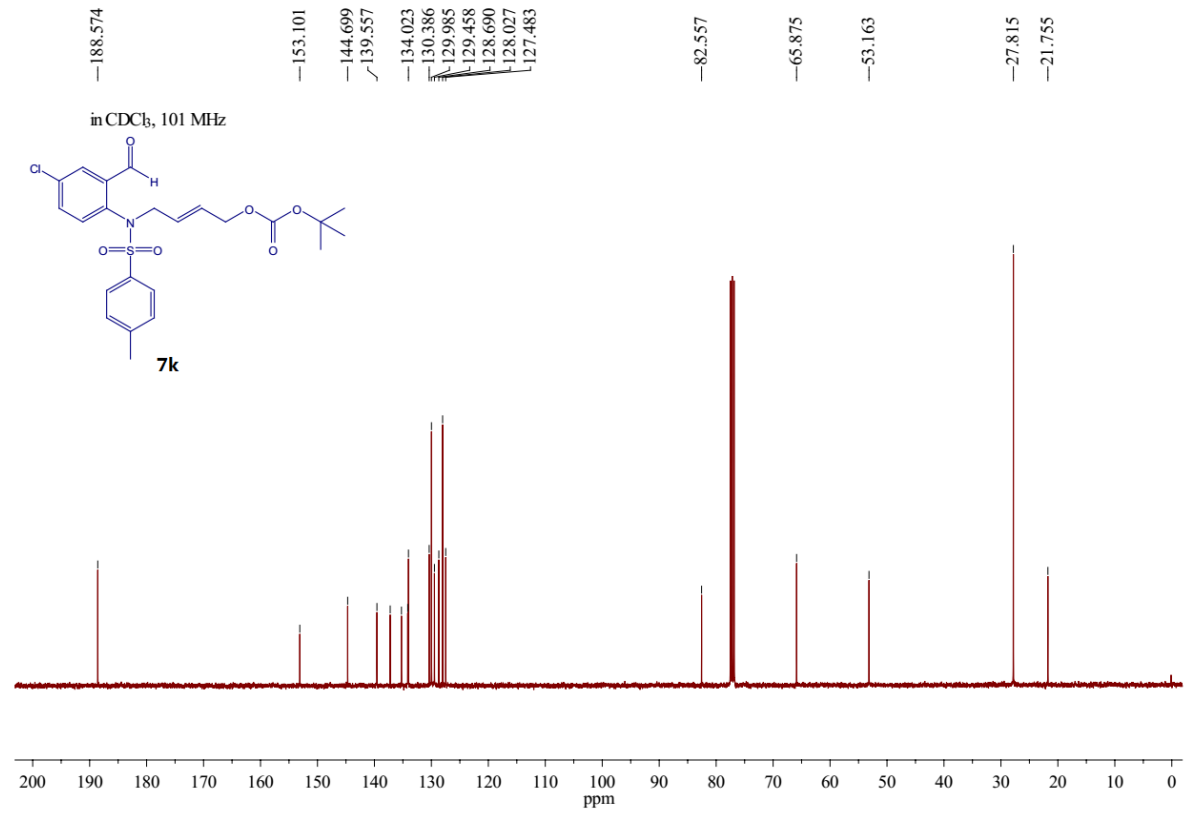

10.353
7.995
7.990
7.988
7.977
7.972
7.459
7.442
7.295
7.273
6.727
6.715
6.712
6.709
5.708
5.606
4.385
4.371
2.446
1.438
in CDCl3, 400 MHz
7i
0.95
1.00
4.09
2.28
1.02
1.02
1.04
0.98
2.12
1.00
3.06
9.23
ppm

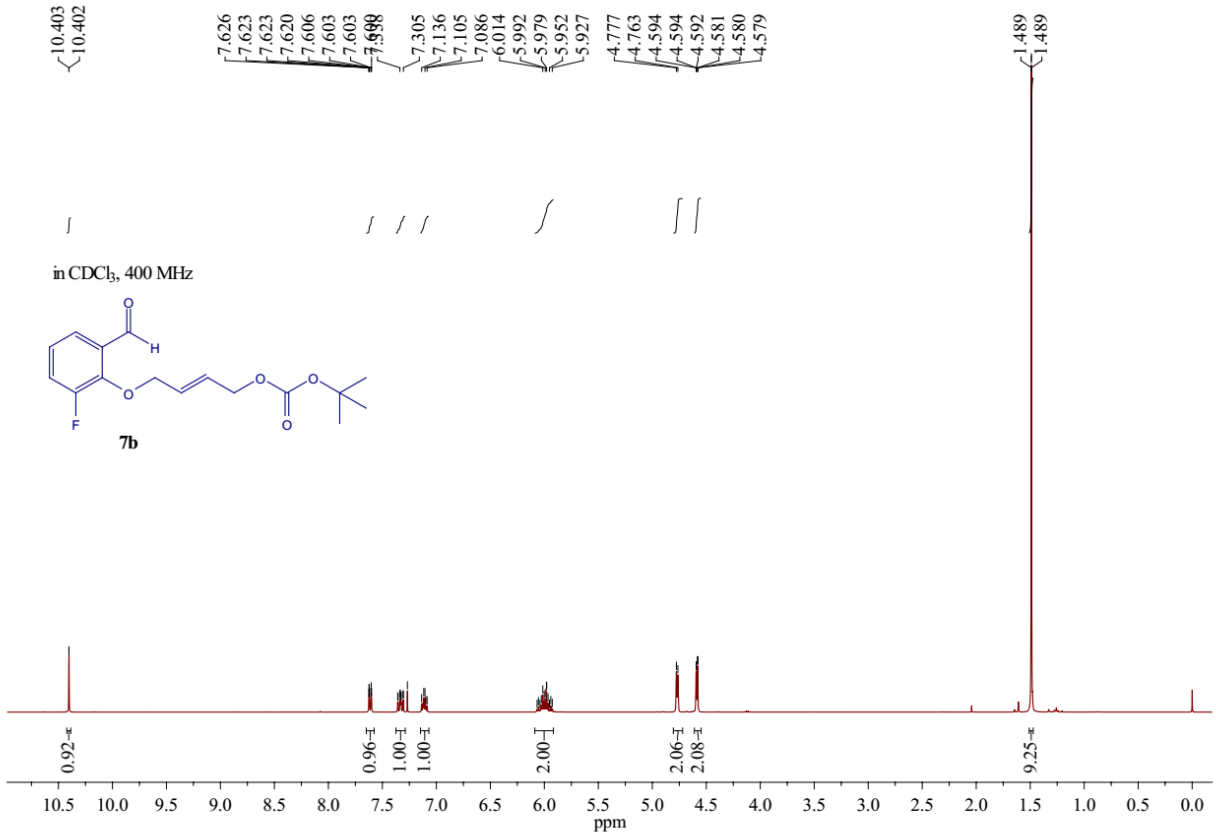

190.014
153.118
144.409
141.308
134.205
129.921
129.836
128.826
128.691
128.129
128.038
127.899
82.476
65.988
53.272
27.814
21.720
in CDCl3, 101 MHz
7i
ppm

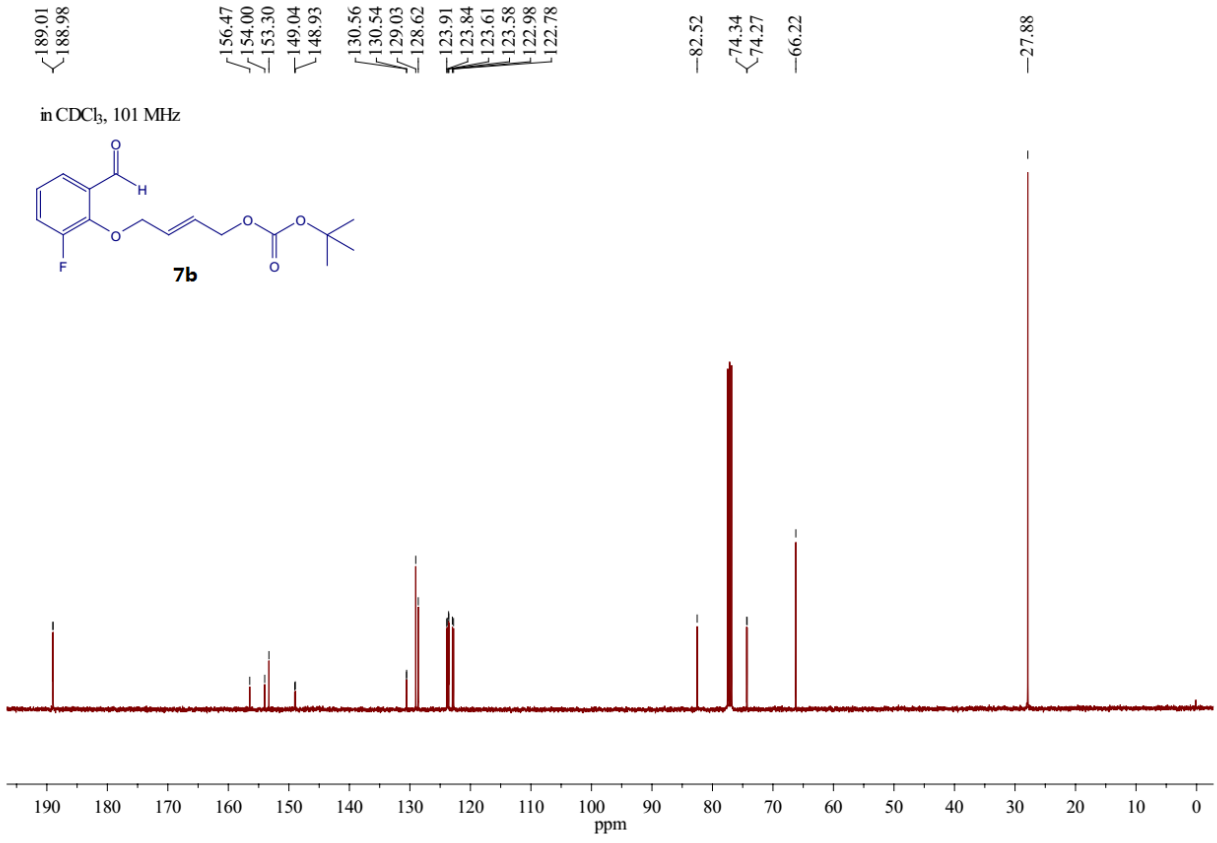

10.269
8.096
8.098
7.478
7.457
7.313
7.293
6.585
6.564
5.717
5.695
5.662
5.606
5.582
5.554
4.391
4.378
2.453
1.442
in CDCl3, 400 MHz
7j
0.92
0.95
1.00
2.01
2.00
1.02
1.02
1.03
0.93
2.08
0.94
3.00
9.15
ppm


188.457
153.098
144.706
137.397
130.387
129.653
127.462
123.186
82.558
65.871
53.102
27.819
21.755
in CDCl3, 101 MHz
7j
ppm

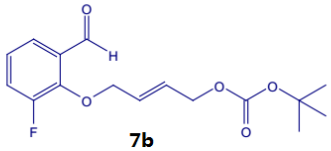

10.279
7.942
7.935
7.458
7.419
7.398
7.292
6.656
6.634
5.719
5.697
5.664
5.605
5.581
5.553
4.391
4.377
2.454
1.441
in CDCl3, 400 MHz
7k
0.94
0.93
1.98
0.98
1.98
1.00
1.01
1.00
0.95
2.04
0.98
3.00
9.02
ppm


188.574
153.101
144.699
139.557
134.023
130.386
129.985
129.458
128.690
128.027
127.483
82.557
65.875
53.163
27.815
21.755
in CDCl3, 101 MHz
7k
ppm

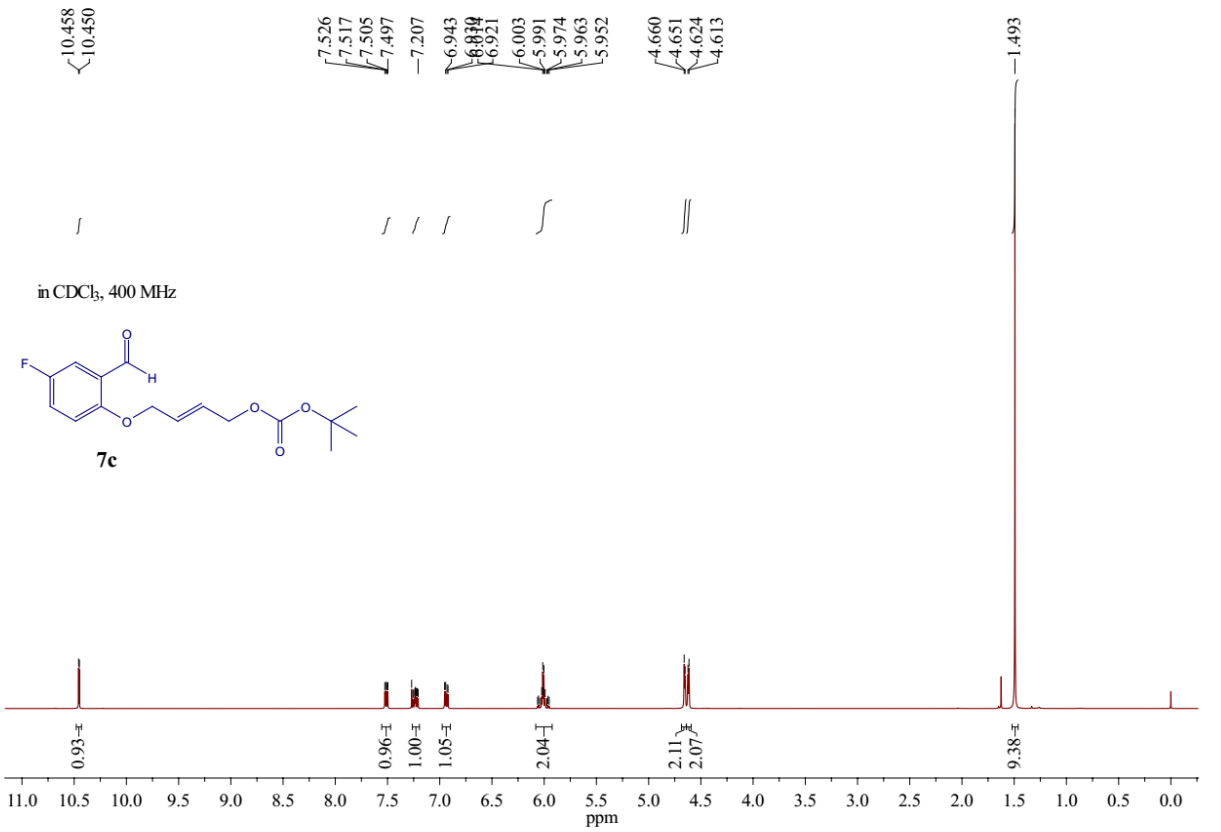

10.403
10.402
7.626
7.623
7.623
7.620
7.606
7.603
7.603
7.598
7.305
7.136
7.105
7.086
6.014
5.992
5.979
5.952
5.927
4.777
4.763
4.594
4.594
4.592
4.581
4.580
4.579
1.489
1.489
in CDCl3, 400 MHz
7b
0.92
0.96
1.00
1.00
2.00
2.06
2.08
9.25
ppm


189.01
188.98
156.47
154.00
153.30
149.04
148.93
130.56
130.54
129.03
128.62
123.91
123.84
123.61
123.58
122.98
122.78
82.52
74.34
74.27
66.22
27.88
in CDCl3, 101 MHz
7b
ppm

in $CDCl_3$, 376 MHz

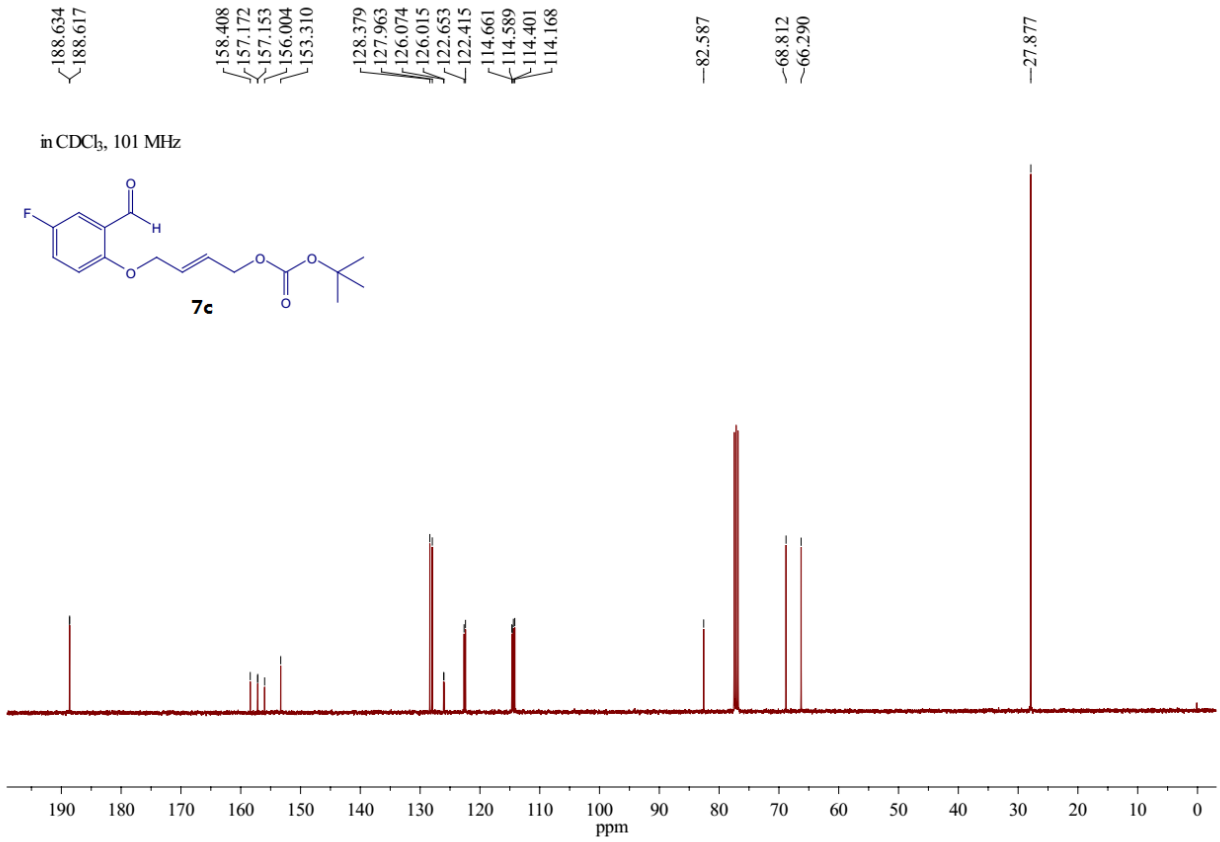


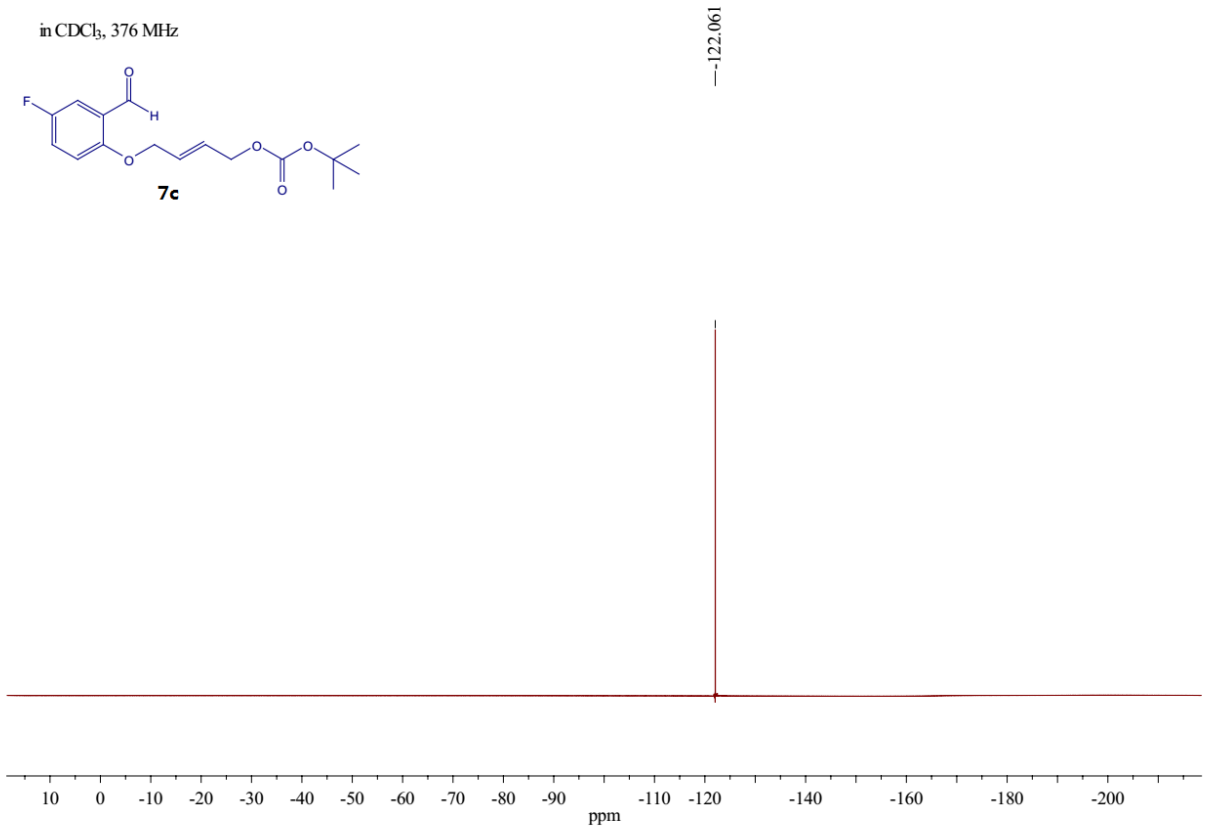
7b

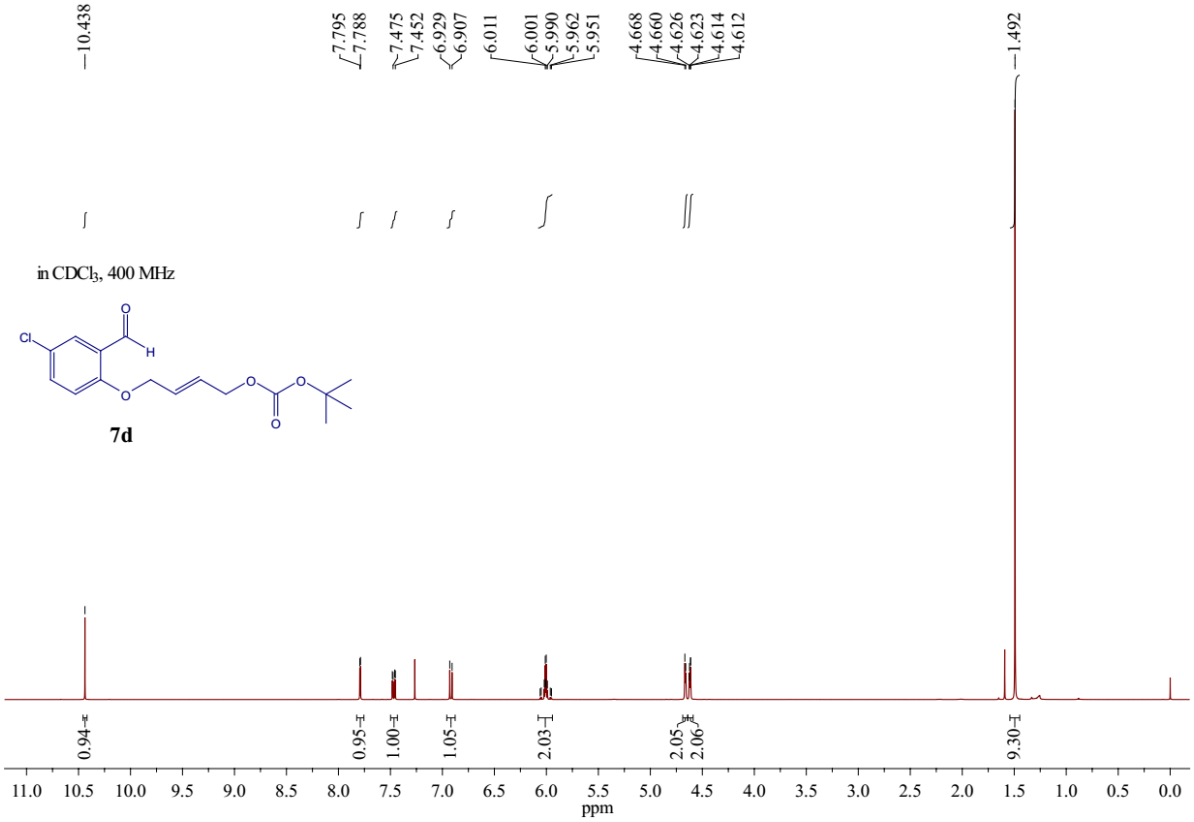


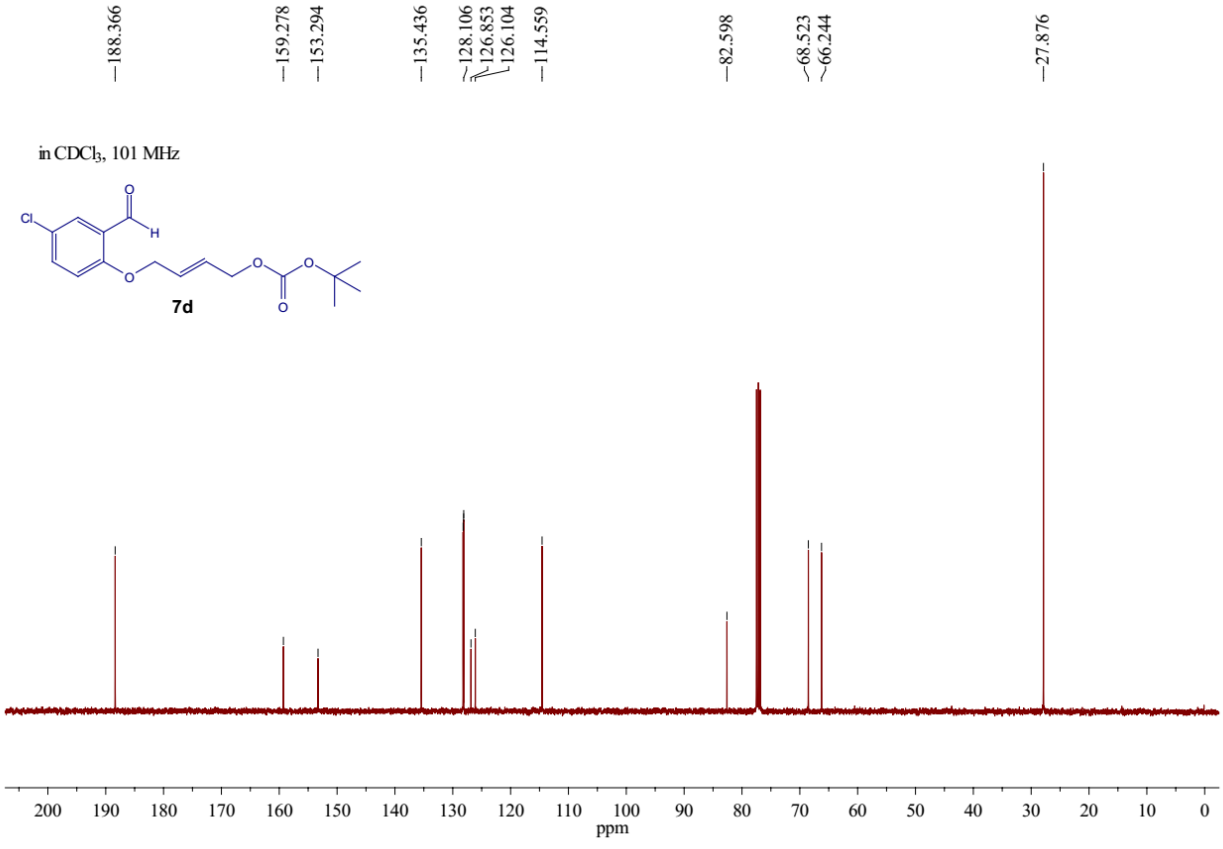
in $CDCl_3$, 400 MHz

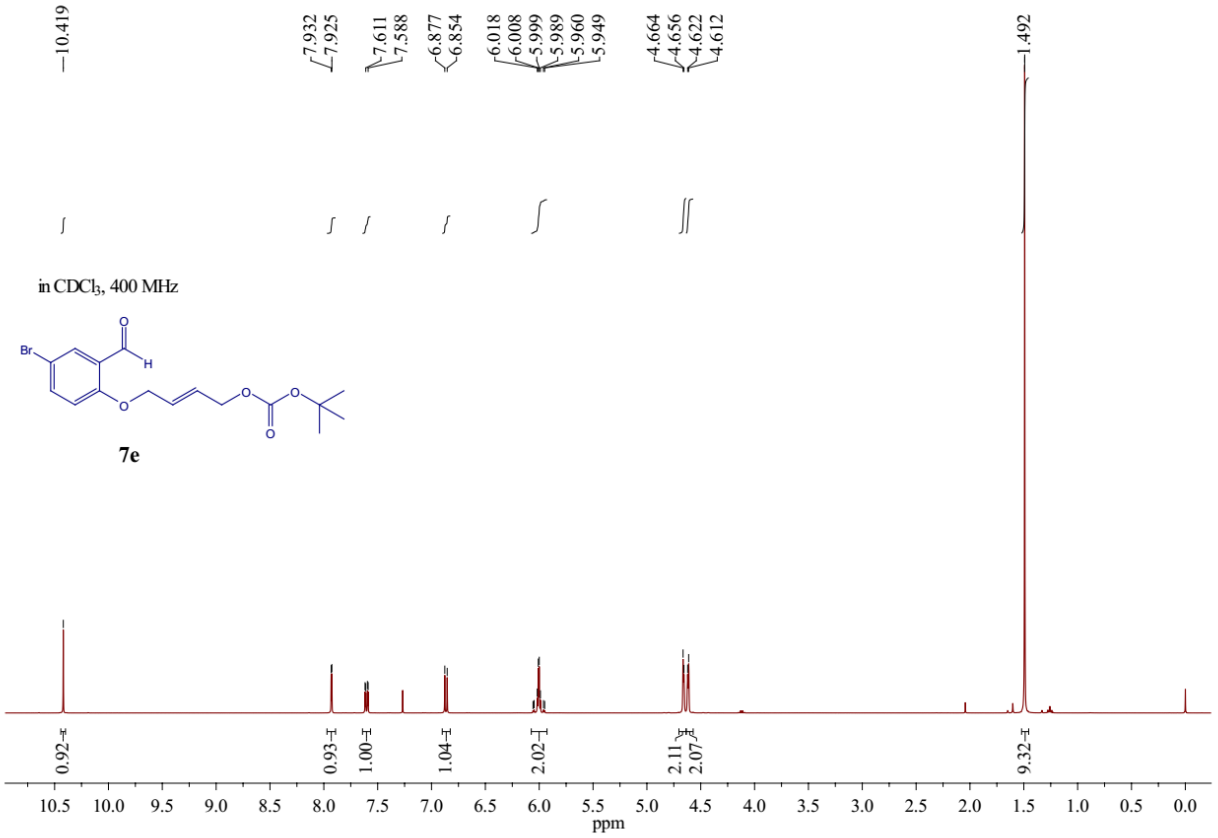
7c

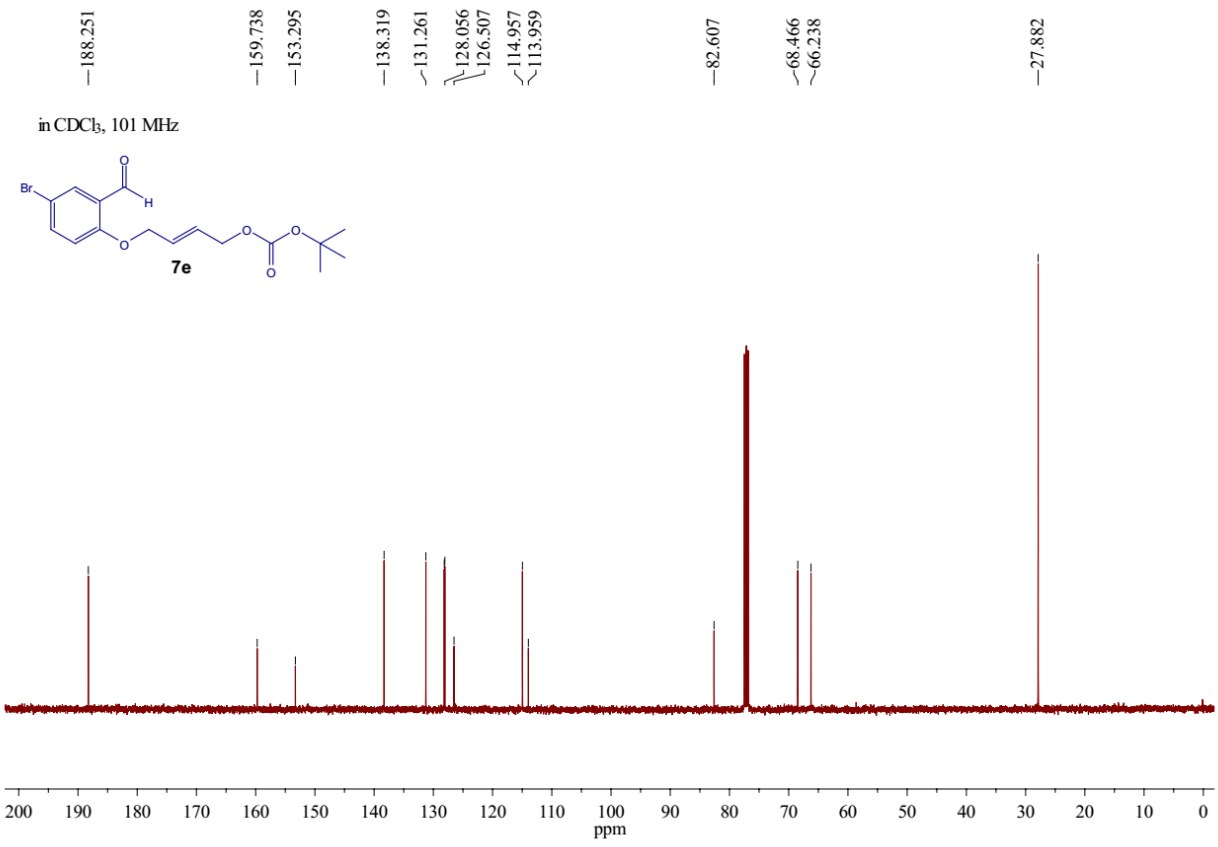

188.634
188.617
158.408
157.172
157.153
156.004
153.310
128.379
127.963
126.074
126.015
122.653
122.415
114.661
114.589
114.401
114.168
82.587
68.812
66.290
27.877
in CDCl3, 101 MHz
F
O
H
O
O
O
O
7c
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
ppm

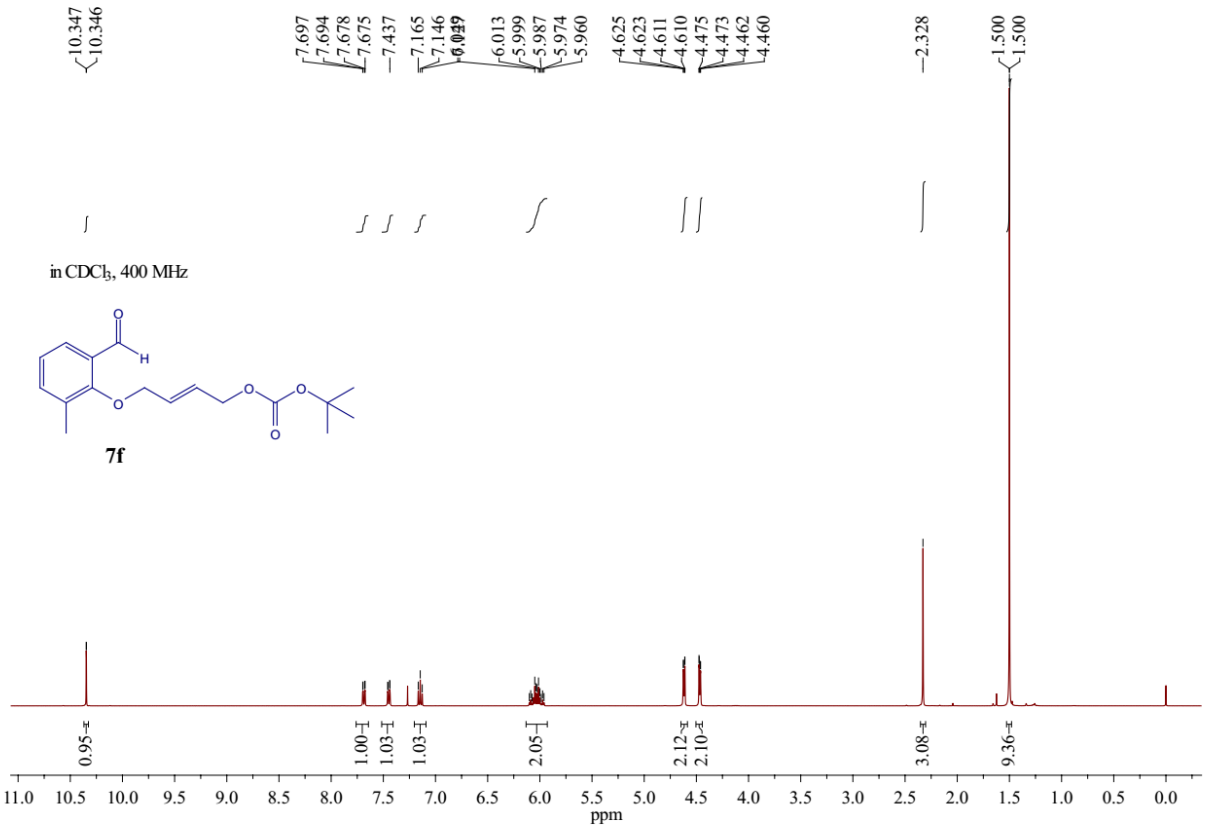

in CDCl3, 376 MHz
-122.061
F
O
H
O
O
O
O
7c
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -110 -120 -140 -160 -180 -200
ppm

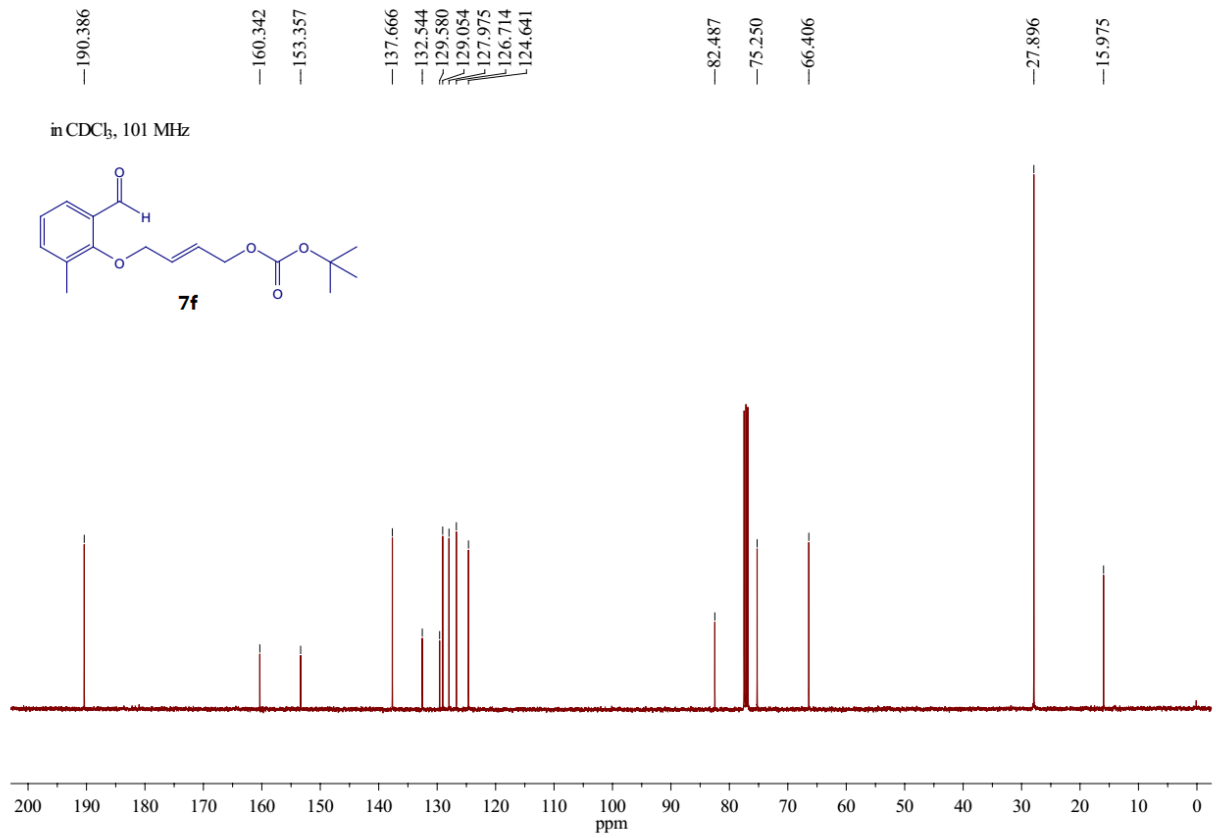

10.438
7.795
7.788
7.475
7.452
6.929
6.907
6.011
6.001
5.990
5.962
5.951
4.668
4.660
4.626
4.623
4.614
4.612
1.492
in CDCl3, 400 MHz
Cl
O
H
O
O
O
O
7d
0.94
0.95
1.00
1.05
2.03
2.05
2.06
9.30
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
ppm

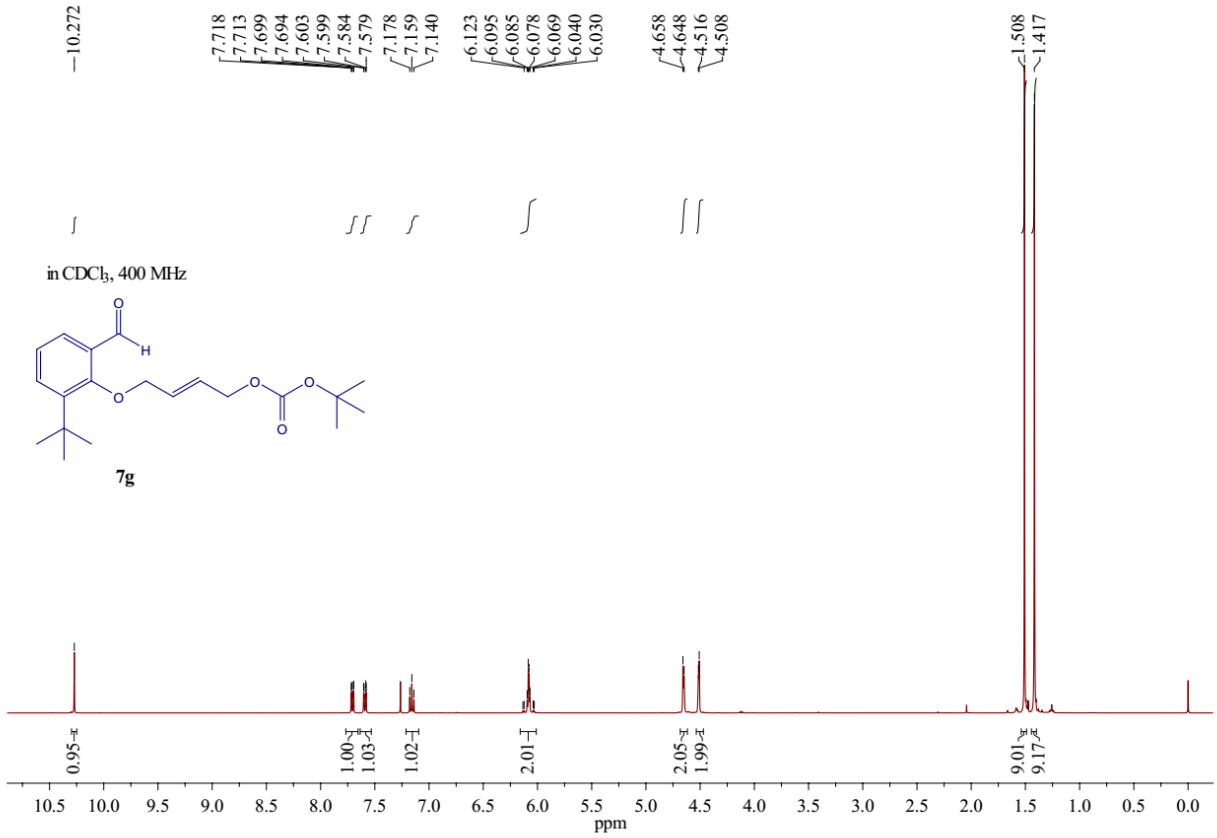

188.366
159.278
153.294
135.436
128.106
126.853
126.104
114.559
82.598
68.523
66.244
27.876
in CDCl3, 101 MHz
Cl
O
H
O
O
O
O
7d
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
ppm

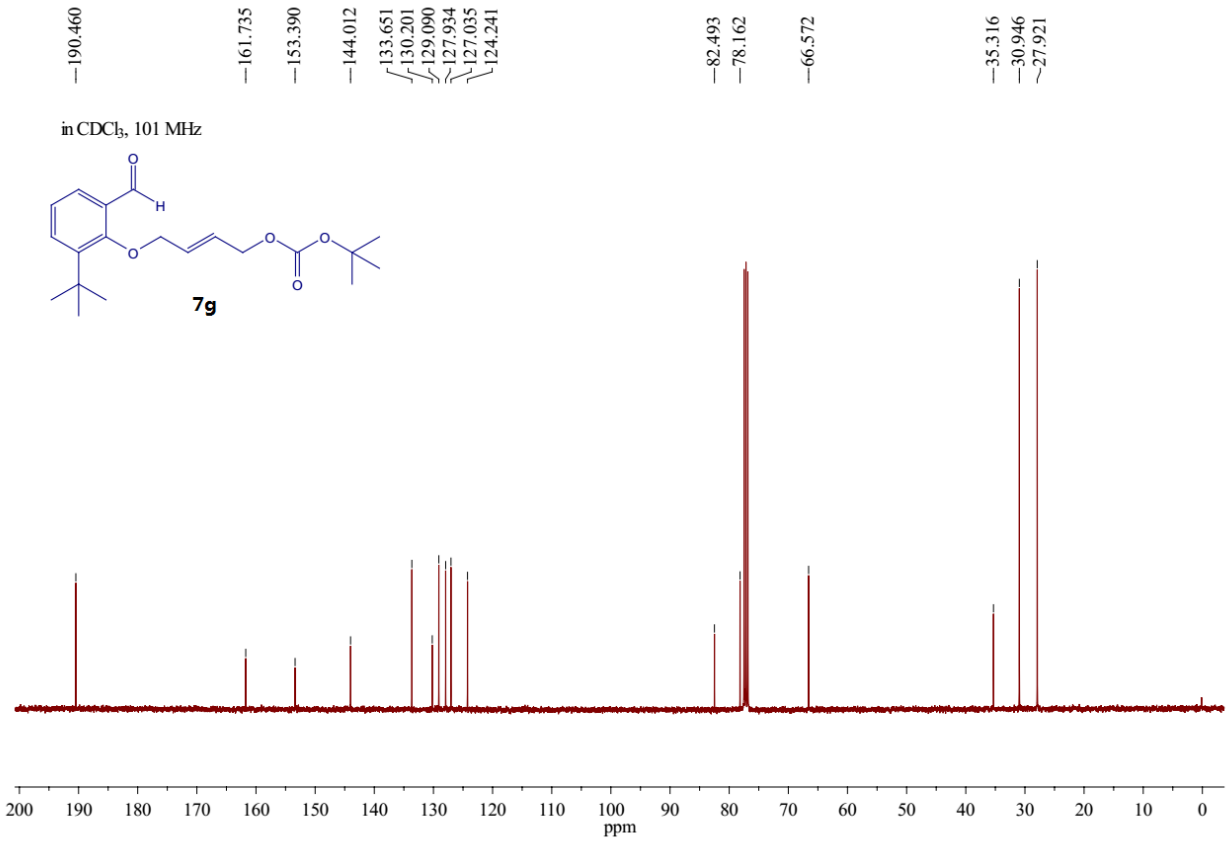

10.419
7.932
7.925
7.611
7.588
6.877
6.854
6.018
6.008
5.999
5.989
5.960
5.949
4.664
4.656
4.622
4.612
1.492
in CDCl3, 400 MHz
Br
O
H
O
O
O
O
7e
0.92
0.93
1.00
1.04
2.02
2.11
2.07
9.32
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
ppm

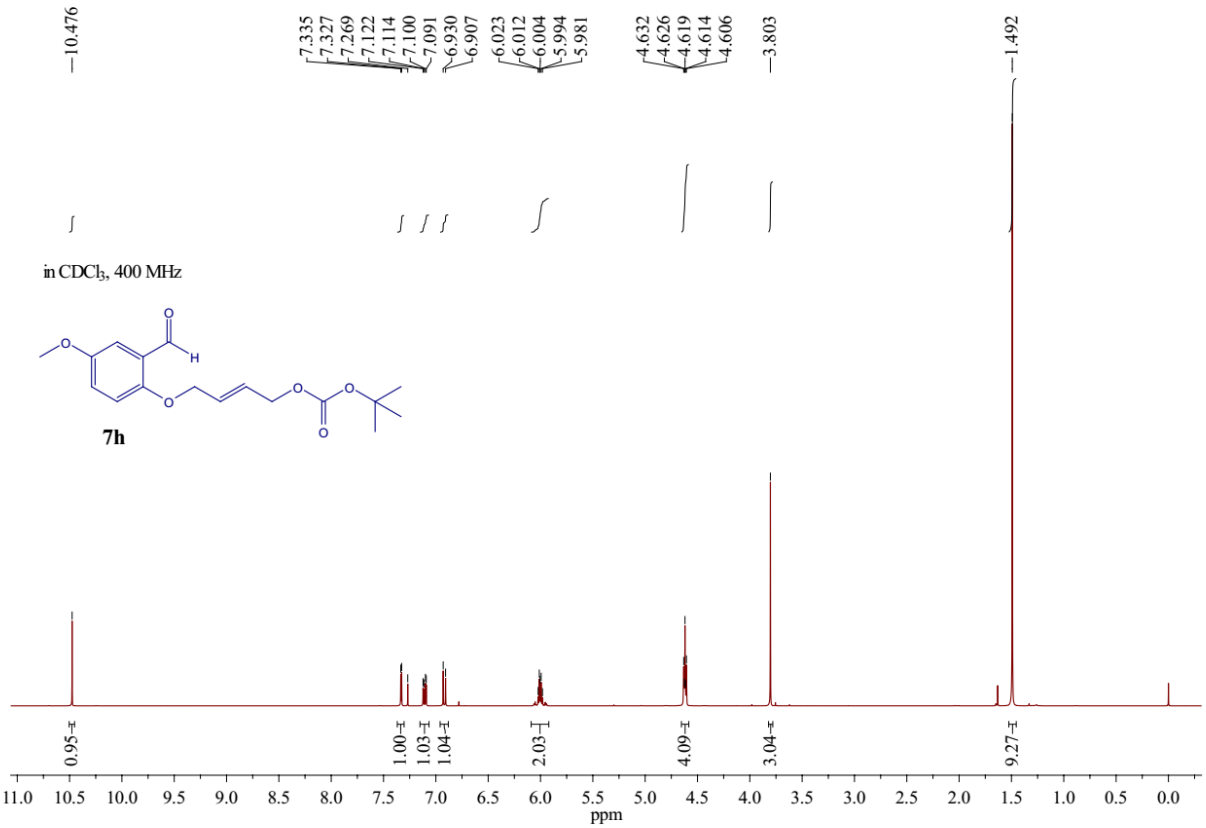

188.251
159.738
153.295
138.319
131.261
128.056
126.507
114.957
113.959
82.607
68.466
66.238
27.882
in CDCl3, 101 MHz
Br
O
H
O
O
O
O
7e
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
ppm

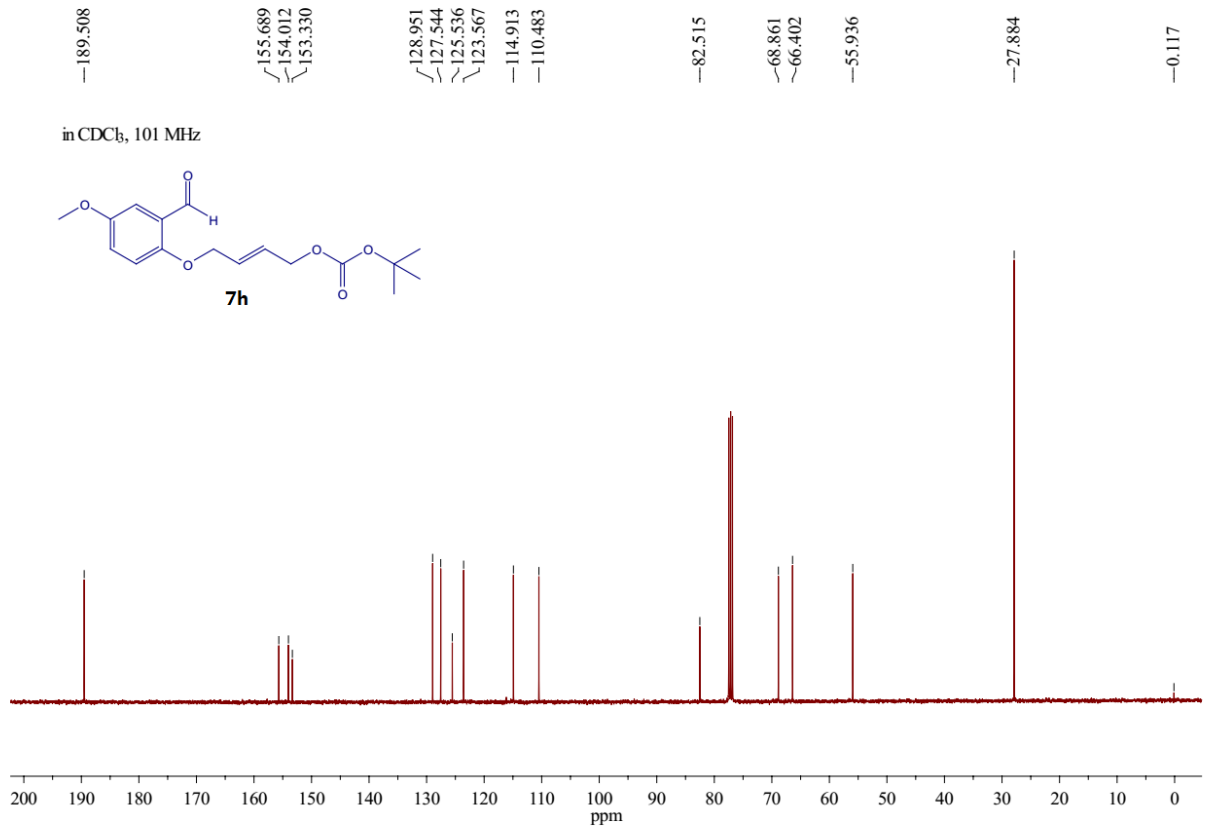

10.347
10.346
7.697
7.694
7.678
7.675
7.437
7.165
7.146
6.013
5.999
5.987
5.974
5.960
4.625
4.623
4.611
4.610
4.475
4.473
4.462
4.460
2.328
1.500
1.500
in CDCl3, 400 MHz
7f
0.95
1.00
1.03
1.03
2.05
2.12
2.10
3.08
9.36
ppm

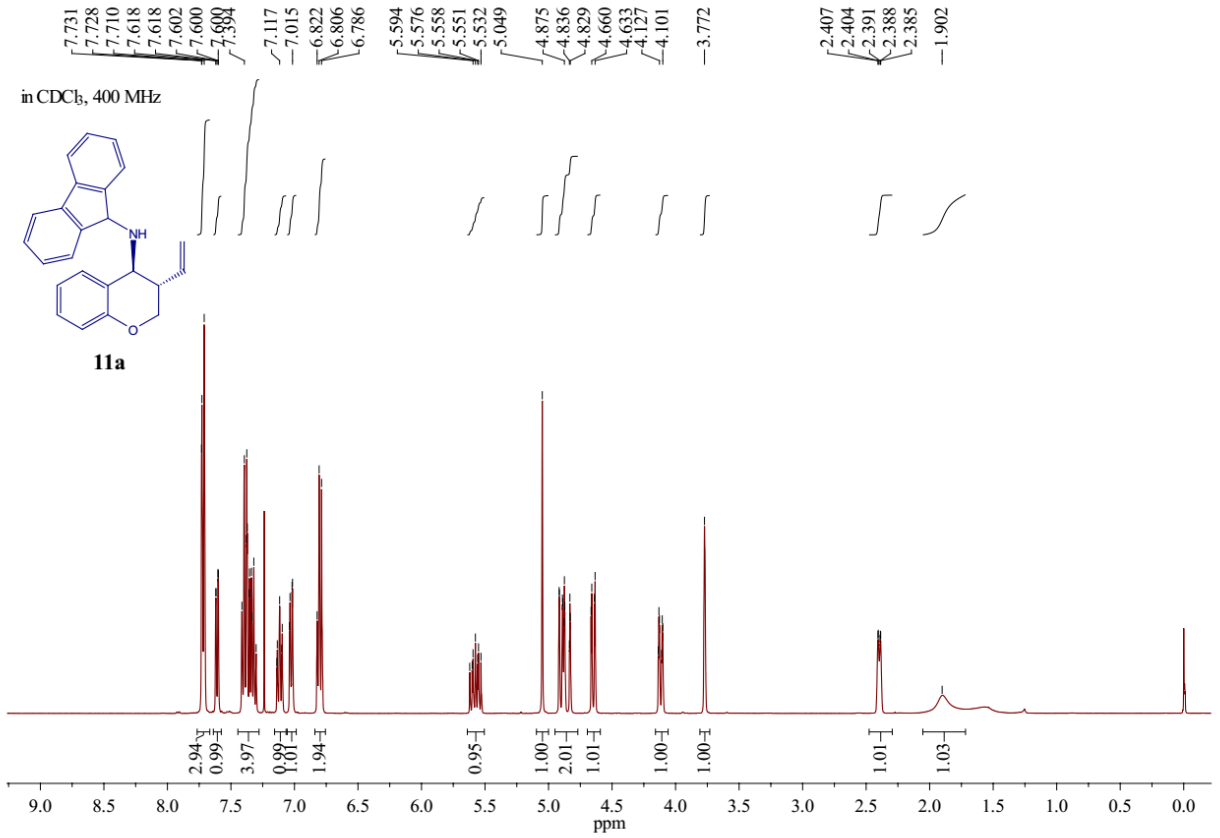

190.386
160.342
153.357
137.666
132.544
129.580
129.054
127.975
126.714
124.641
82.487
75.250
66.406
27.896
15.975
in CDCl3, 101 MHz
7f
ppm

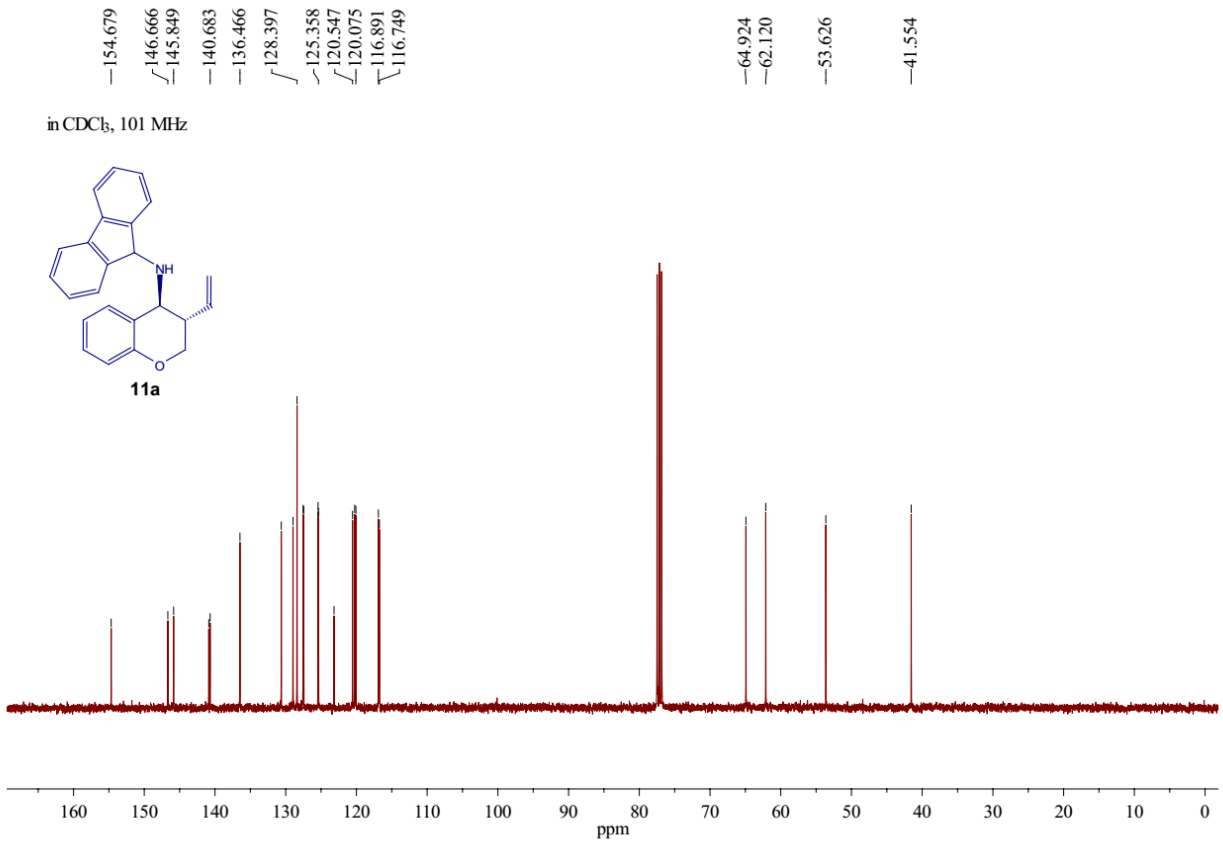

10.272
7.718
7.713
7.699
7.694
7.603
7.599
7.584
7.579
7.178
7.159
7.140
6.123
6.095
6.085
6.078
6.069
6.040
6.030
4.658
4.648
4.516
4.508
1.508
1.417
in CDCl3, 400 MHz
7g
0.95
1.00
1.03
1.02
2.01
2.05
1.99
9.01
9.17
ppm

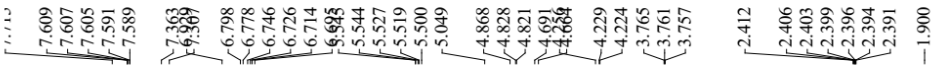

190.460
161.735
153.390
144.012
133.651
130.201
129.090
127.934
127.035
124.241
82.493
78.162
66.572
35.316
30.946
27.921
in CDCl3, 101 MHz
7g
ppm


10.476
7.335
7.327
7.269
7.122
7.114
7.100
7.091
6.930
6.907
6.023
6.012
6.004
5.994
5.981
4.632
4.626
4.619
4.614
4.606
3.803
1.492
in CDCl3, 400 MHz
7h
0.95
1.00
1.03
1.04
2.03
4.09
3.04
9.27
ppm

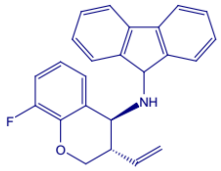

189.508
155.689
154.012
153.330
128.951
127.544
125.536
123.567
114.913
110.483
82.515
68.861
66.402
55.936
27.884
0.117
in CDCl3, 101 MHz
7h
ppm


7.731
7.728
7.710
7.618
7.618
7.602
7.600
7.600
7.394
7.117
7.015
6.822
6.806
6.786
5.594
5.576
5.558
5.551
5.532
5.049
4.875
4.836
4.829
4.660
4.633
4.127
4.101
3.772
2.407
2.404
2.391
2.388
2.385
1.902
in CDCl3, 400 MHz
NH
O
11a
2.94
0.99
3.97
0.99
1.01
1.94
0.95
1.00
2.01
1.01
1.00
1.00
1.01
1.03
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
ppm

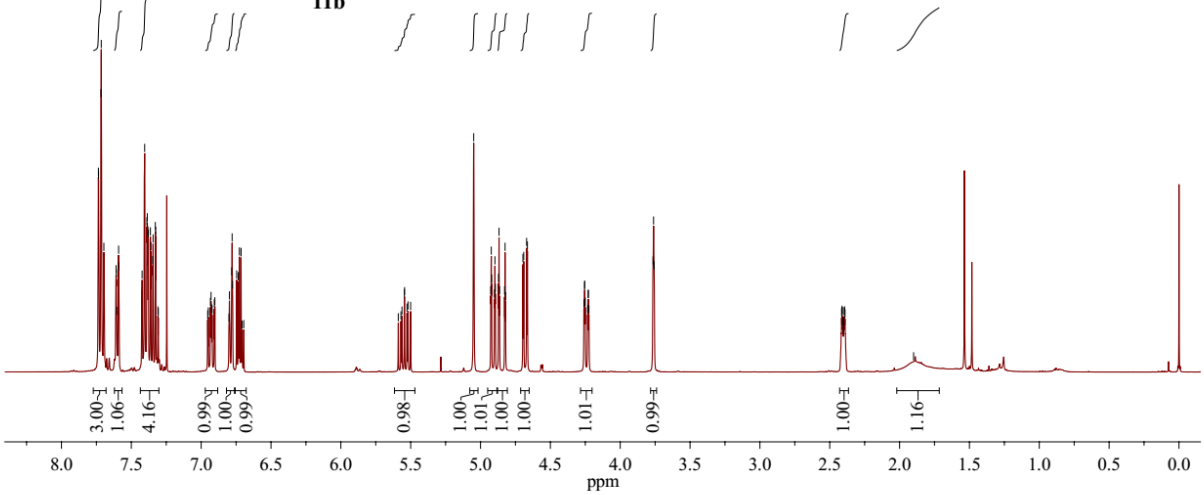

154.679
146.666
145.849
140.683
136.466
128.397
125.358
120.547
120.075
116.891
116.749
64.924
62.120
53.626
41.554
in CDCl3, 101 MHz
NH
O
11a
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm



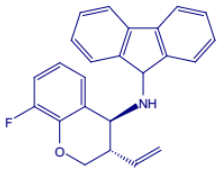
in $CDCl_3$, 400 MHz



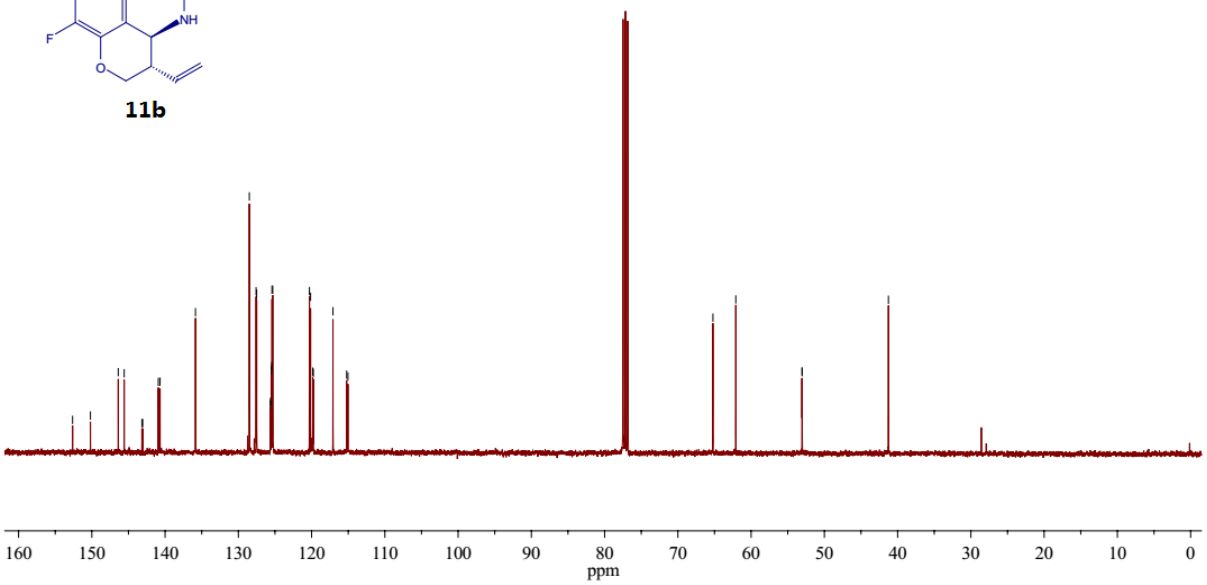
11b



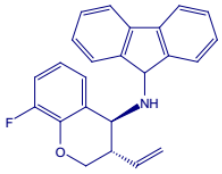
in $CDCl_3$, 101 MHz



11b

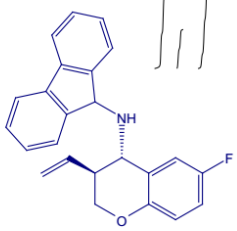


in $CDCl_3$,376 MHz

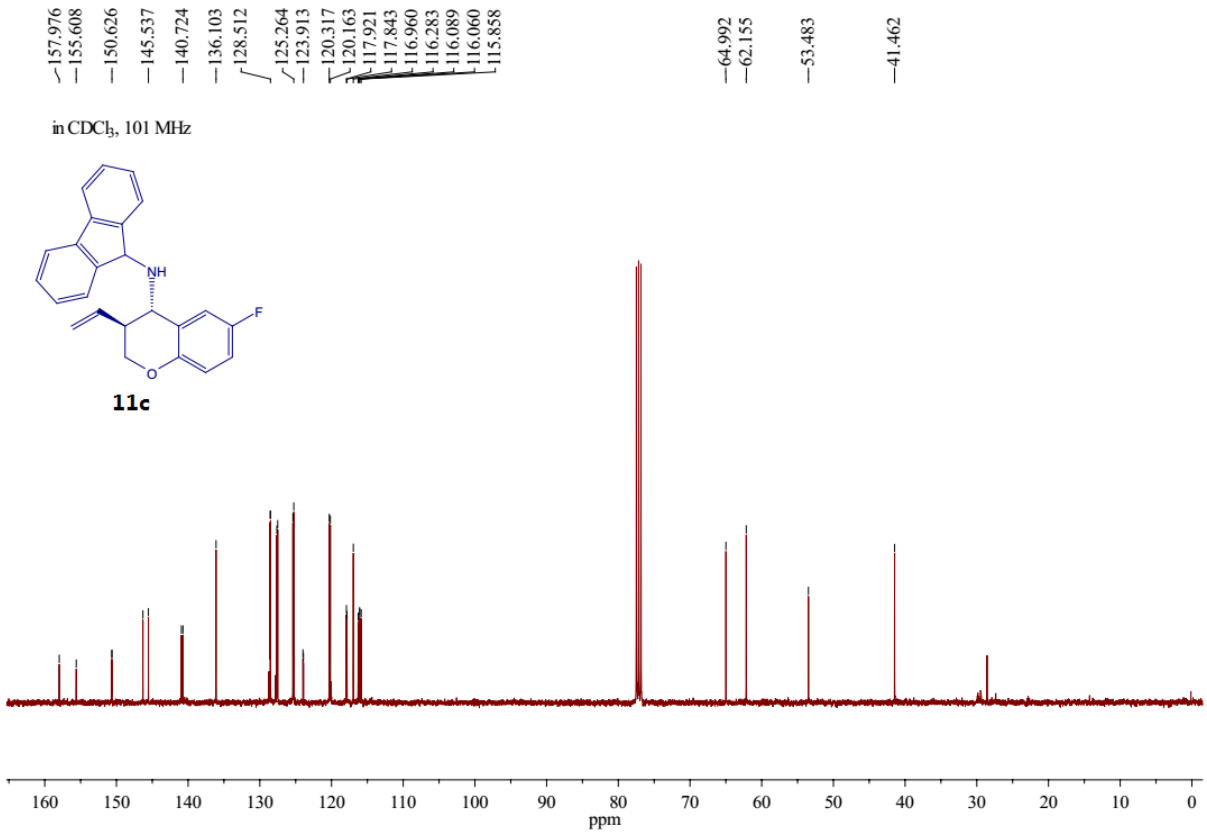


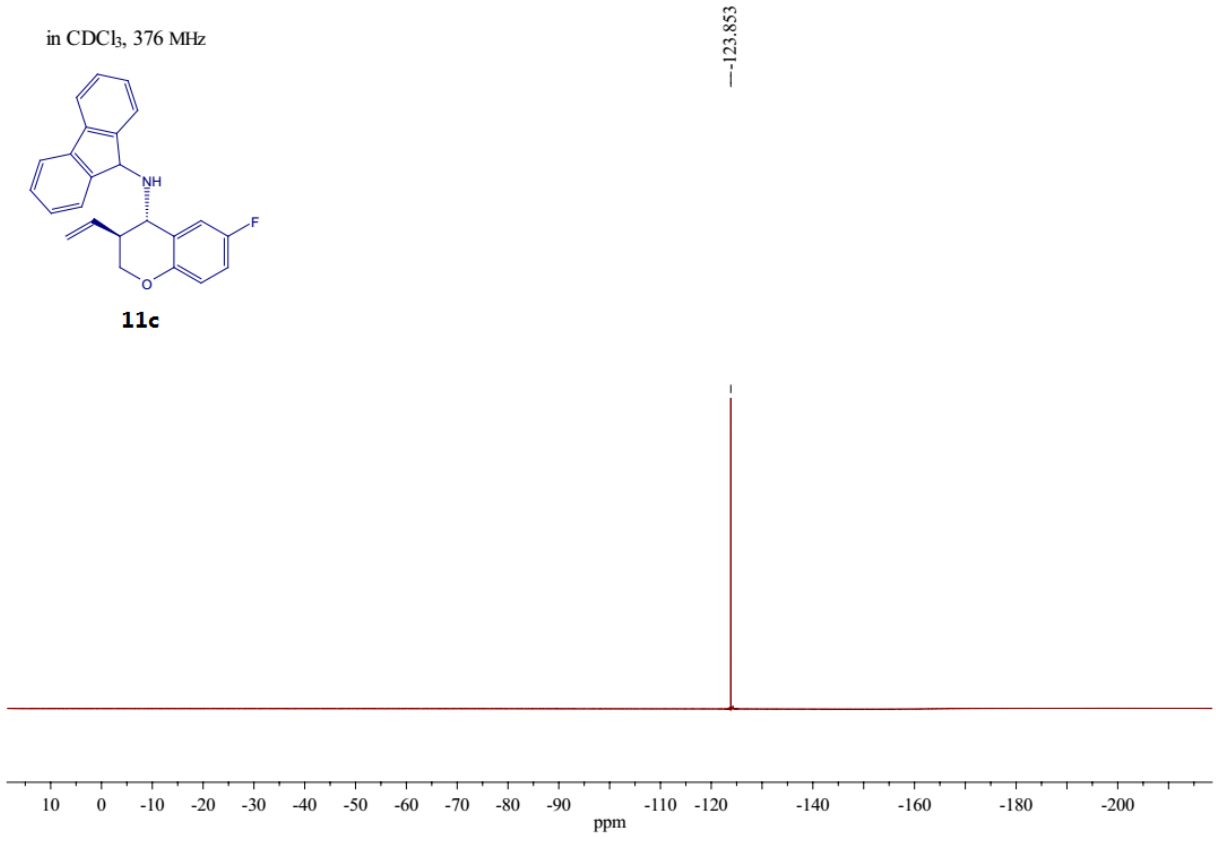
11b

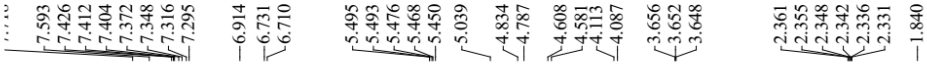
in $CDCl_3$, 400 MHz



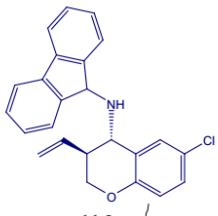
11c


157.976
155.608
150.626
145.537
140.724
136.103
128.512
125.264
123.913
120.317
120.163
117.921
117.843
116.960
116.283
116.089
116.060
115.858
64.992
62.155
53.483
41.462
in CDCl3, 101 MHz
NH
F
O
11c
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

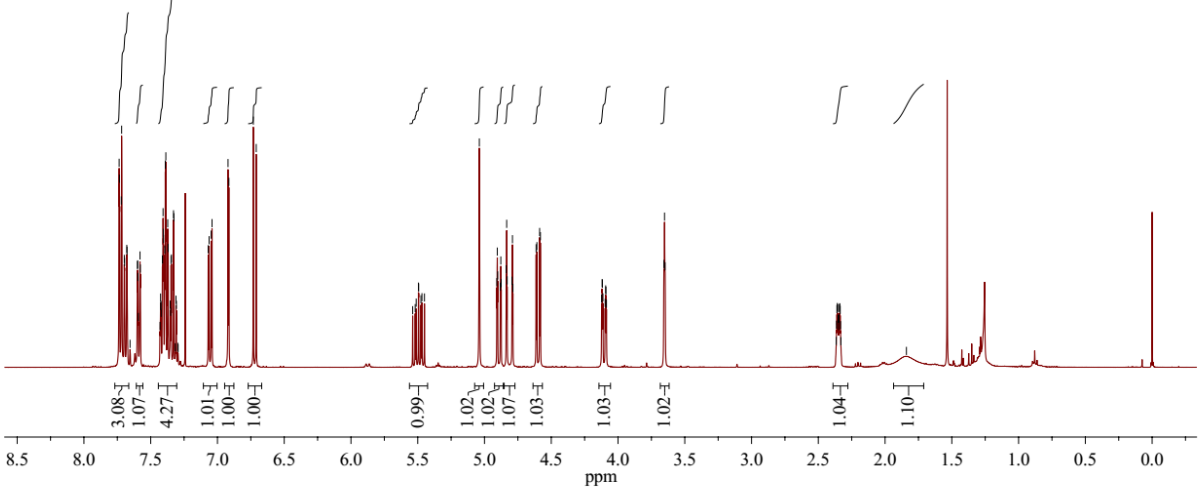

in CDCl3, 376 MHz
-123.853
NH
F
O
11c
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-110
-120
-140
-160
-180
-200
ppm

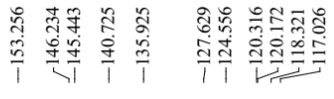


in $CDCl_3$, 400 MHz

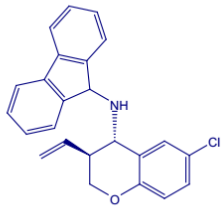


11d

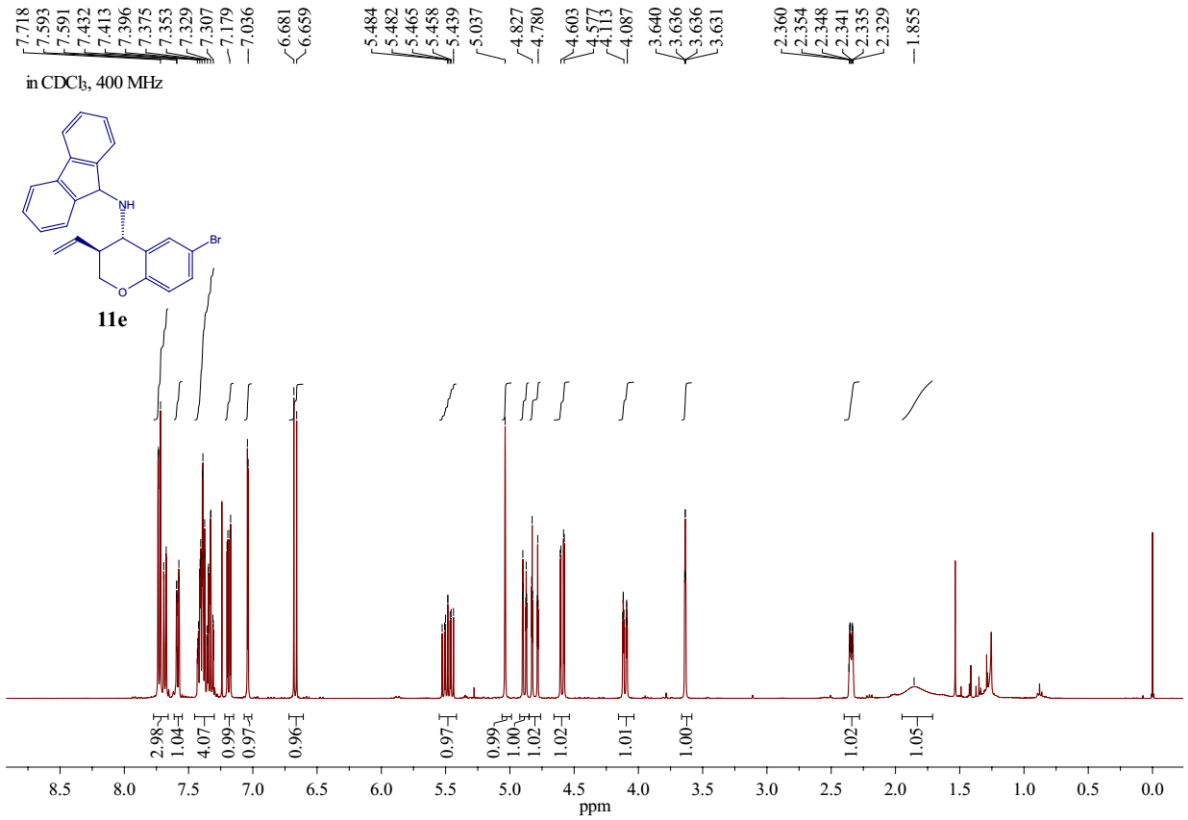


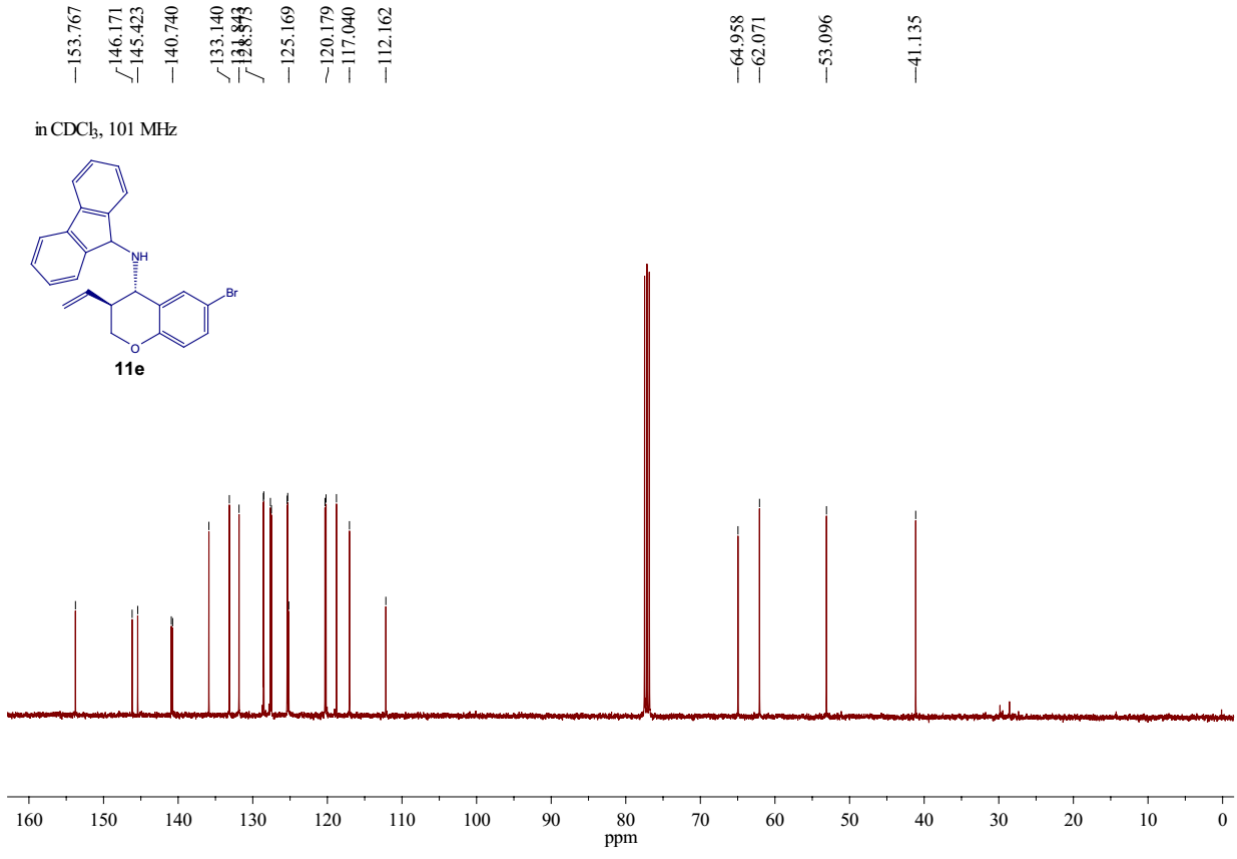


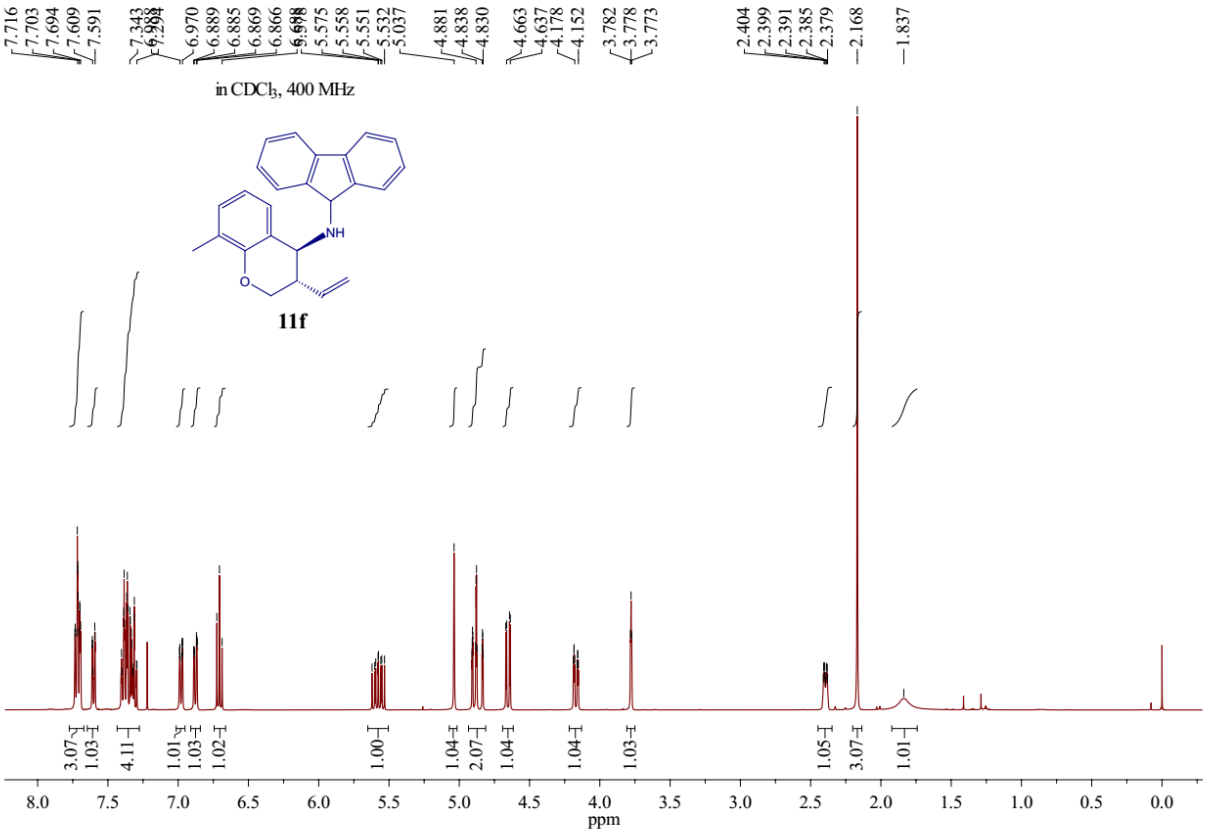
in $CDCl_3$, 101 MHz

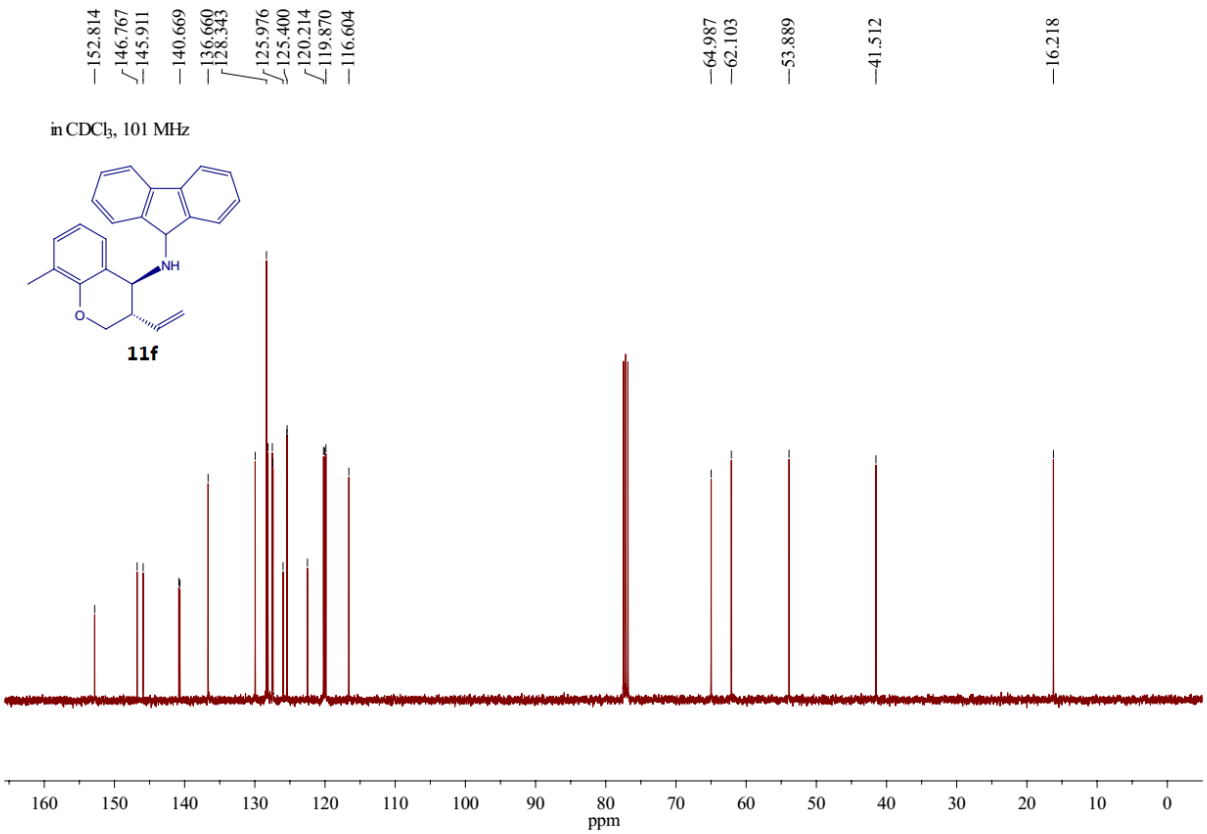


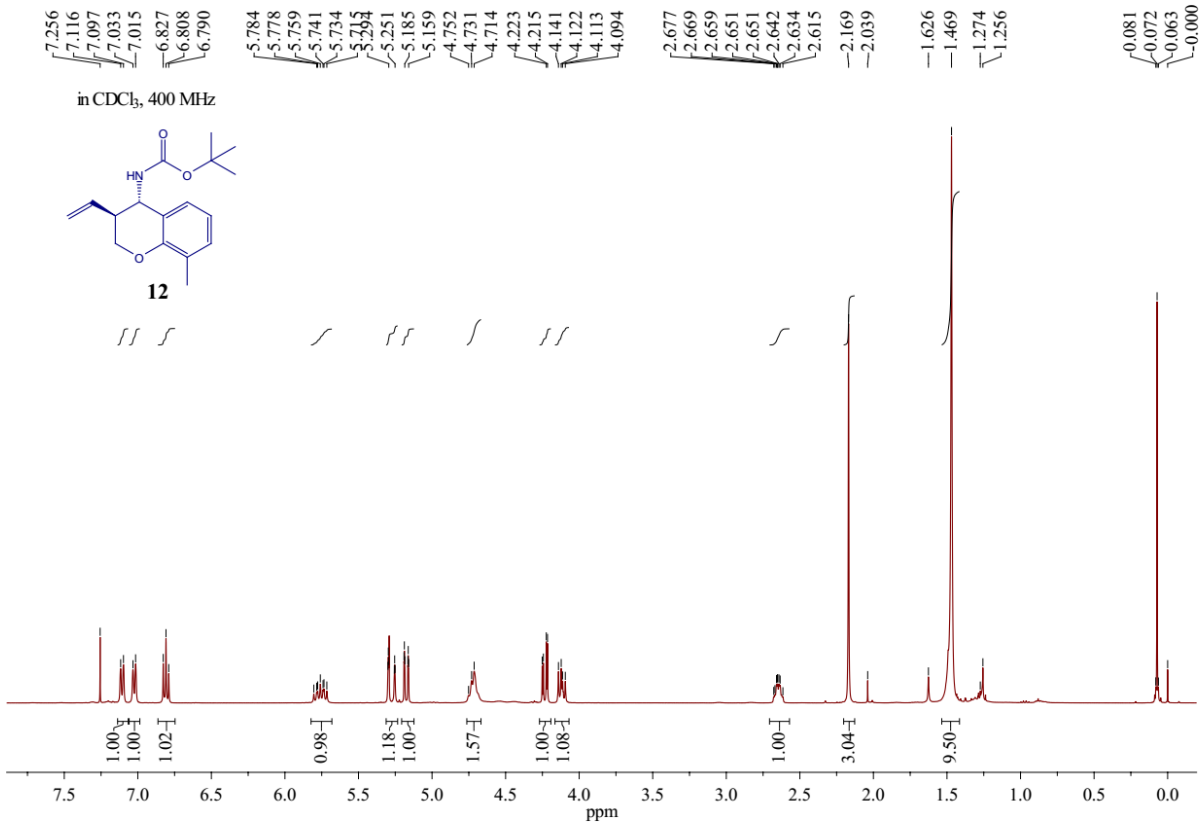
11d

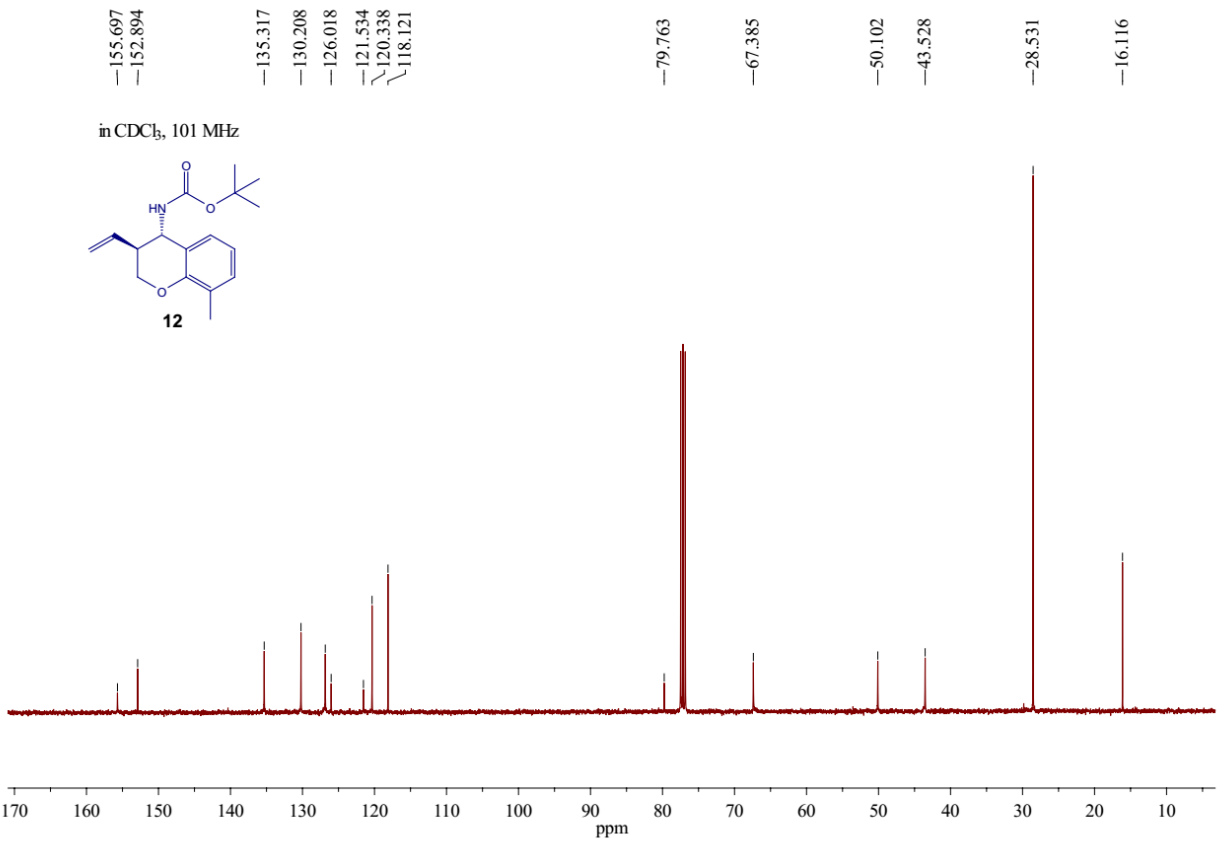

7.718
7.593
7.591
7.432
7.413
7.396
7.375
7.353
7.329
7.307
7.179
7.036
6.681
6.659
5.484
5.482
5.465
5.458
5.439
5.037
4.827
4.780
4.603
4.577
4.113
4.087
3.640
3.636
3.636
3.631
2.360
2.354
2.348
2.341
2.335
2.329
1.855
in CDCl3, 400 MHz
NH
Br
O
11e
2.98
1.04
4.07
0.99
0.97
0.96
0.97
0.99
1.00
1.02
1.02
1.01
1.00
1.02
1.05
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
ppm

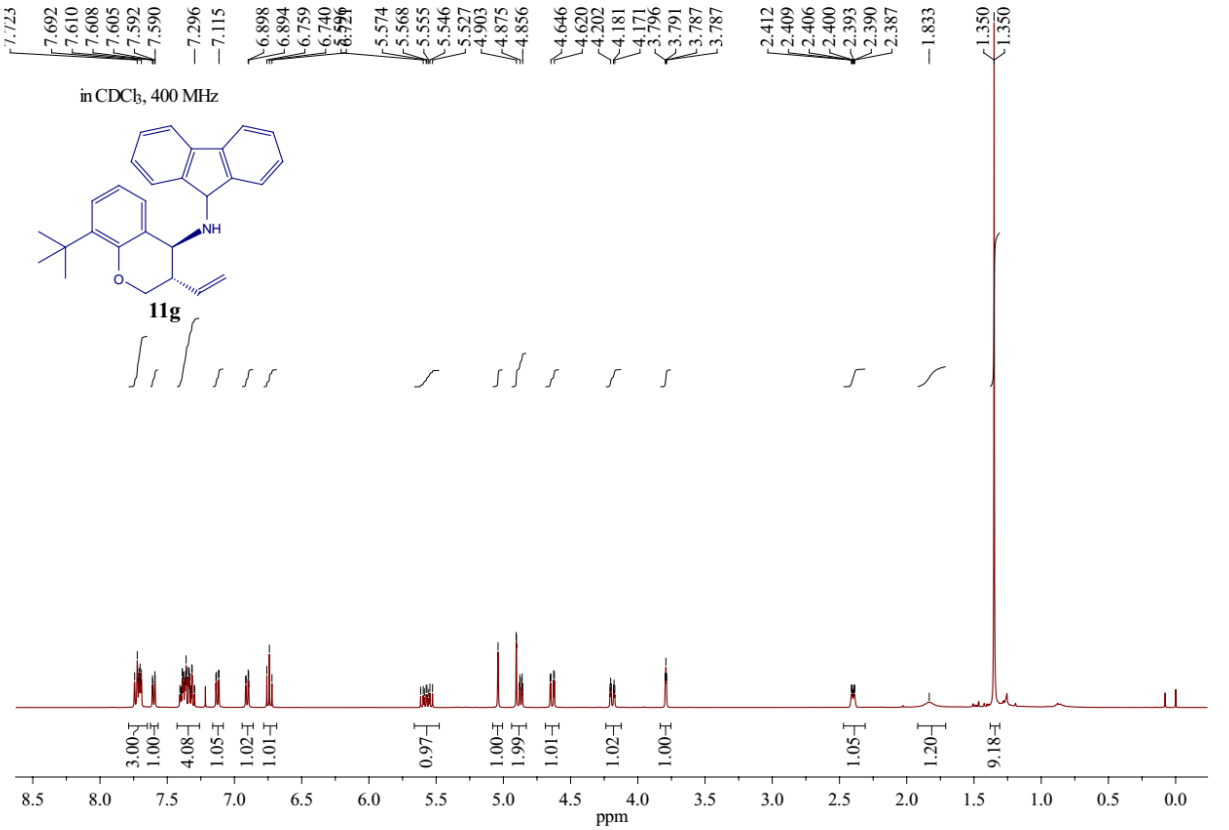

153.767
146.171
145.423
140.740
133.140
131.843
128.873
125.169
120.179
117.040
112.162
64.958
62.071
53.096
41.135
in CDCl3, 101 MHz
NH
Br
O
11e
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

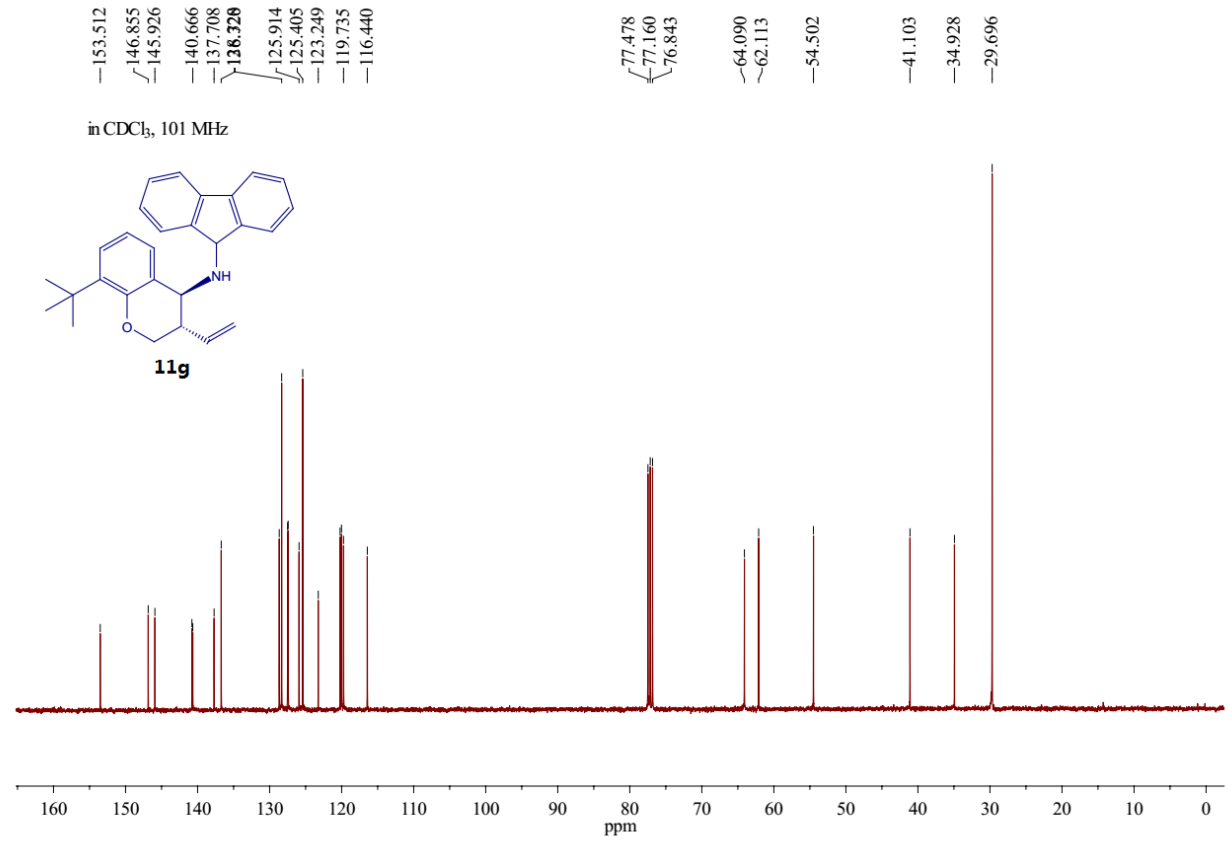

7.716
7.703
7.694
7.609
7.591
7.343
6.970
6.889
6.885
6.869
6.866
5.575
5.558
5.551
5.532
5.037
4.881
4.838
4.830
4.663
4.637
4.178
4.152
3.782
3.778
3.773
2.404
2.399
2.391
2.385
2.379
2.168
1.837
in CDCl3, 400 MHz
NH
O
11f
3.07
1.03
4.11
1.01
1.03
1.02
1.00
1.04
2.07
1.04
1.04
1.03
1.05
3.07
1.01
8.0
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
ppm

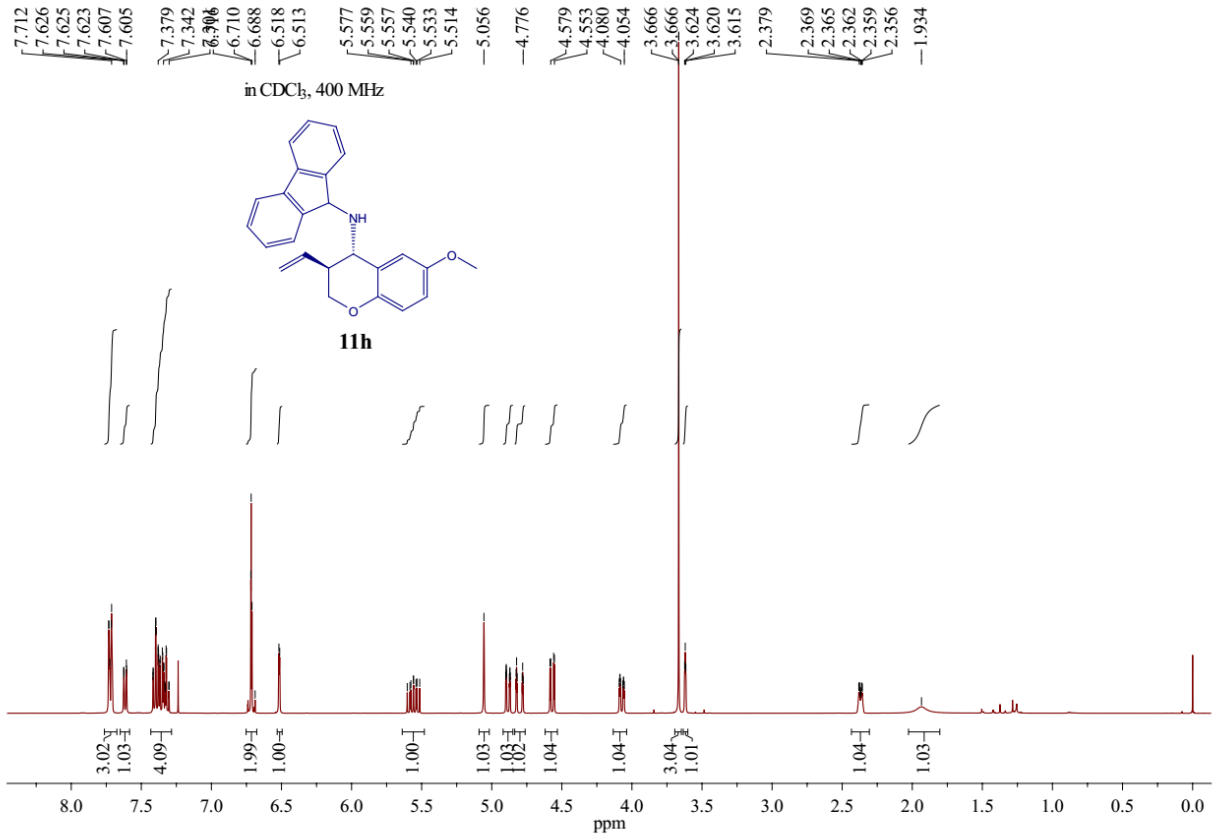

152.814
146.767
145.911
140.669
136.660
128.343
125.976
125.400
120.214
119.870
116.604
64.987
62.103
53.889
41.512
16.218
in CDCl3, 101 MHz
NH
O
11f
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

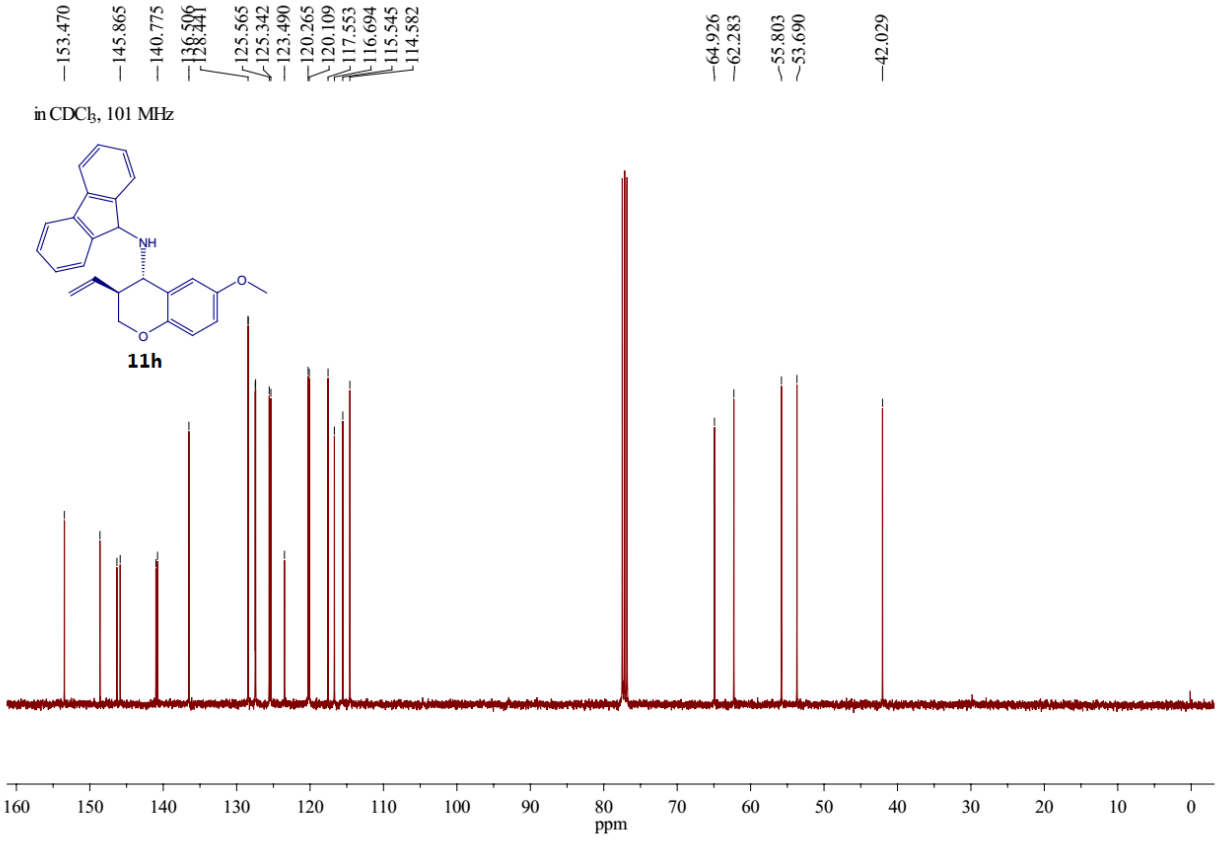

7.256
7.116
7.097
7.033
7.015
6.827
6.808
6.790
5.784
5.778
5.759
5.741
5.734
5.251
5.185
5.159
4.752
4.731
4.714
4.223
4.215
4.141
4.122
4.113
4.094
2.677
2.669
2.659
2.651
2.642
2.634
2.615
2.169
2.039
1.626
1.469
1.274
1.256
0.081
0.072
0.063
0.000
in CDCl3, 400 MHz
HN
O
O
O
12
1.00
1.00
1.02
0.98
1.18
1.00
1.57
1.00
1.08
1.00
3.04
9.50
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
ppm

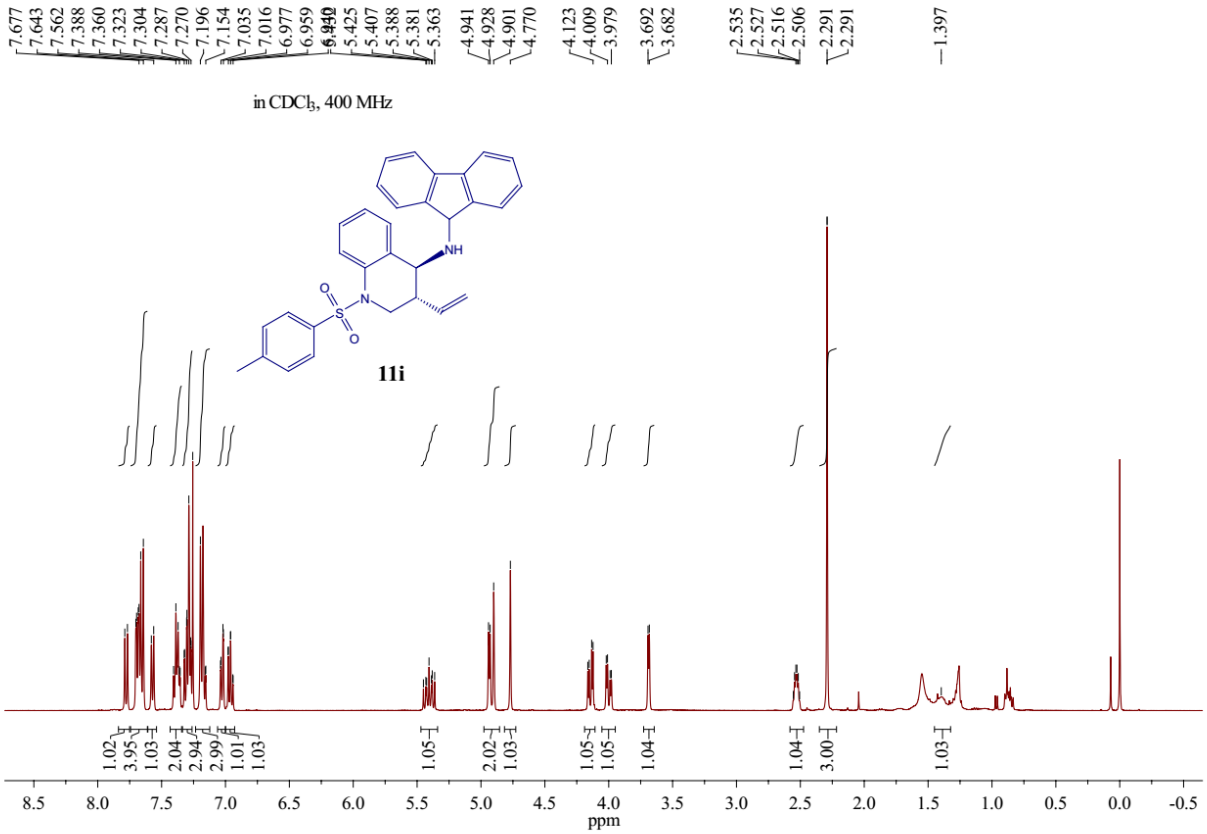

155.697
152.894
135.317
130.208
126.018
121.534
120.338
118.121
79.763
67.385
50.102
43.528
28.531
16.116
in CDCl3, 101 MHz
HN
O
O
O
12
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

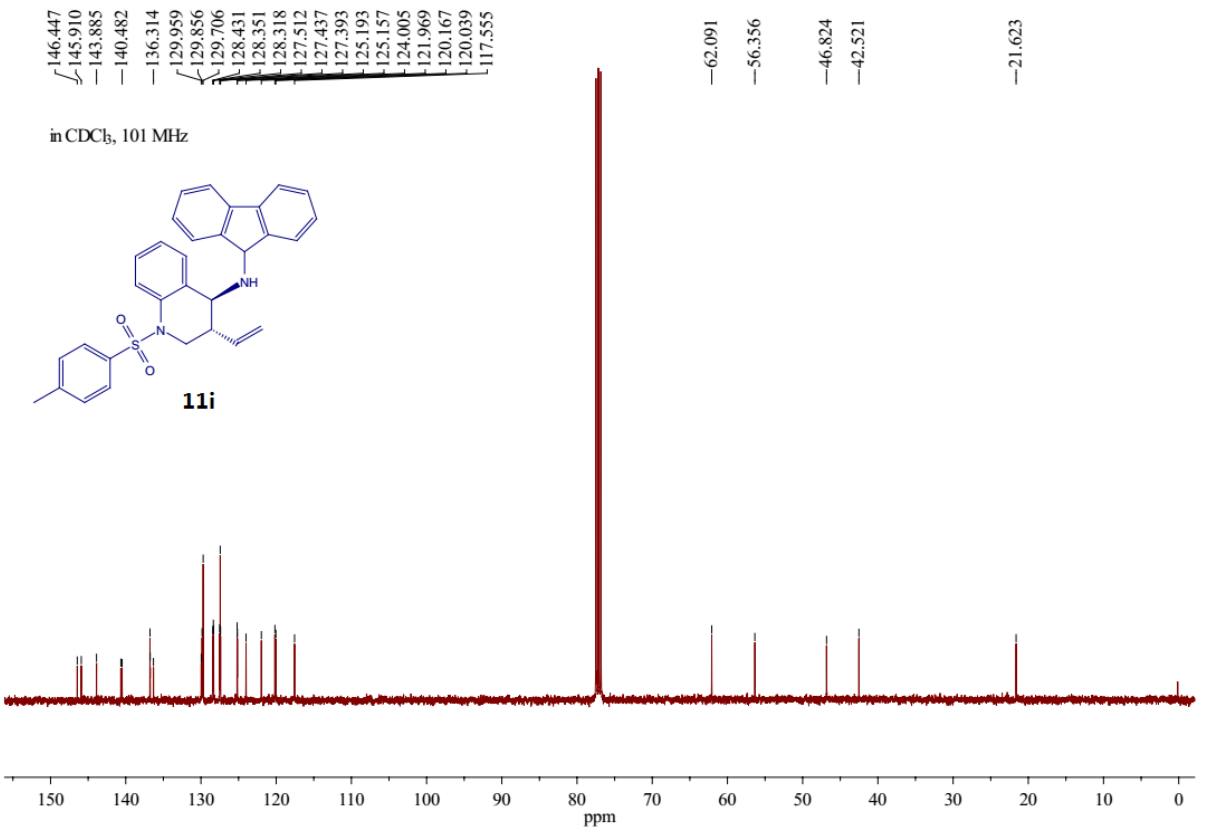

7.723
7.692
7.610
7.608
7.605
7.592
7.590
7.296
7.115
6.898
6.894
6.759
6.740
5.574
5.568
5.555
5.546
5.527
4.903
4.875
4.856
4.646
4.620
4.202
4.181
4.171
3.796
3.791
3.787
3.787
2.412
2.409
2.406
2.400
2.393
2.390
2.387
1.833
1.350
1.350
in CDCl3, 400 MHz
NH
O
11g
3.00
1.00
4.08
1.05
1.02
1.01
0.97
1.00
1.99
1.01
1.02
1.00
1.05
1.20
9.18
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
ppm

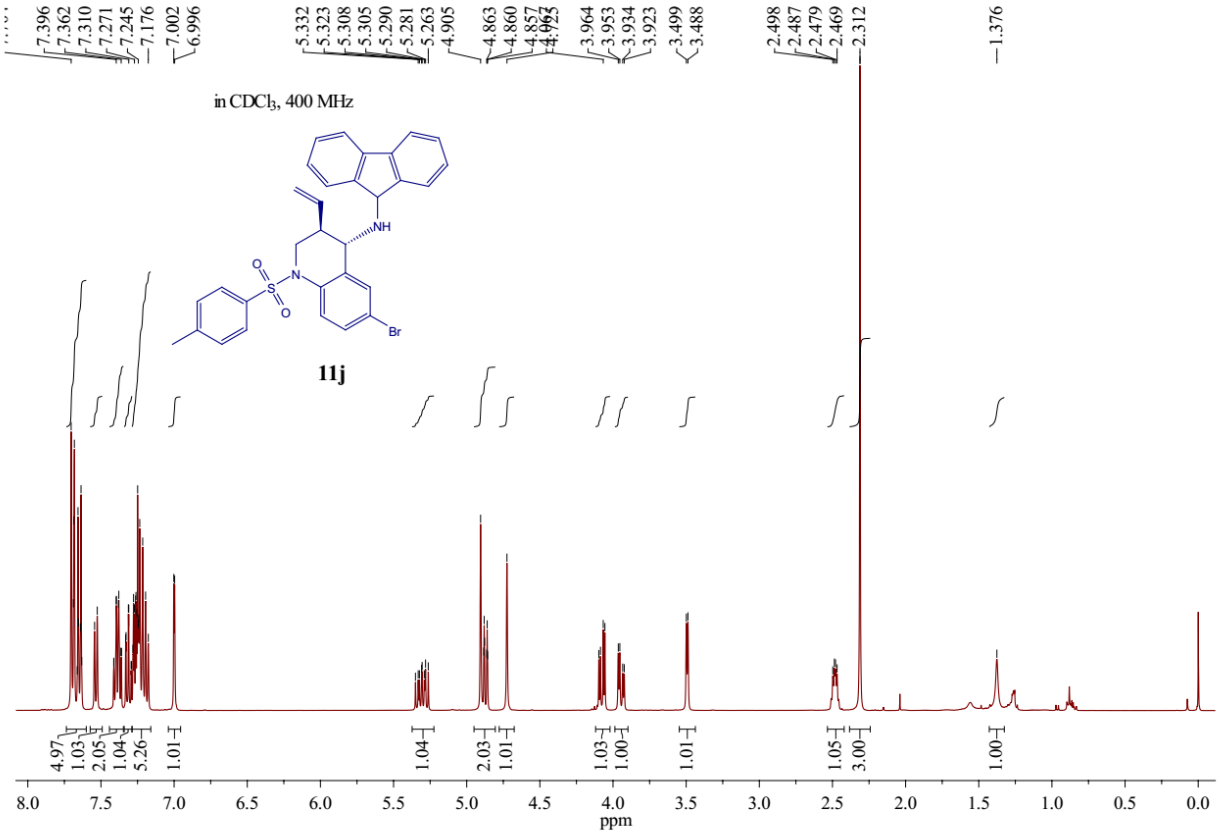

153.512
146.855
145.926
140.666
137.708
125.914
125.405
123.249
119.735
116.440
77.478
77.160
76.843
64.090
62.113
54.502
41.103
34.928
29.696
in CDCl3, 101 MHz
NH
O
11g
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

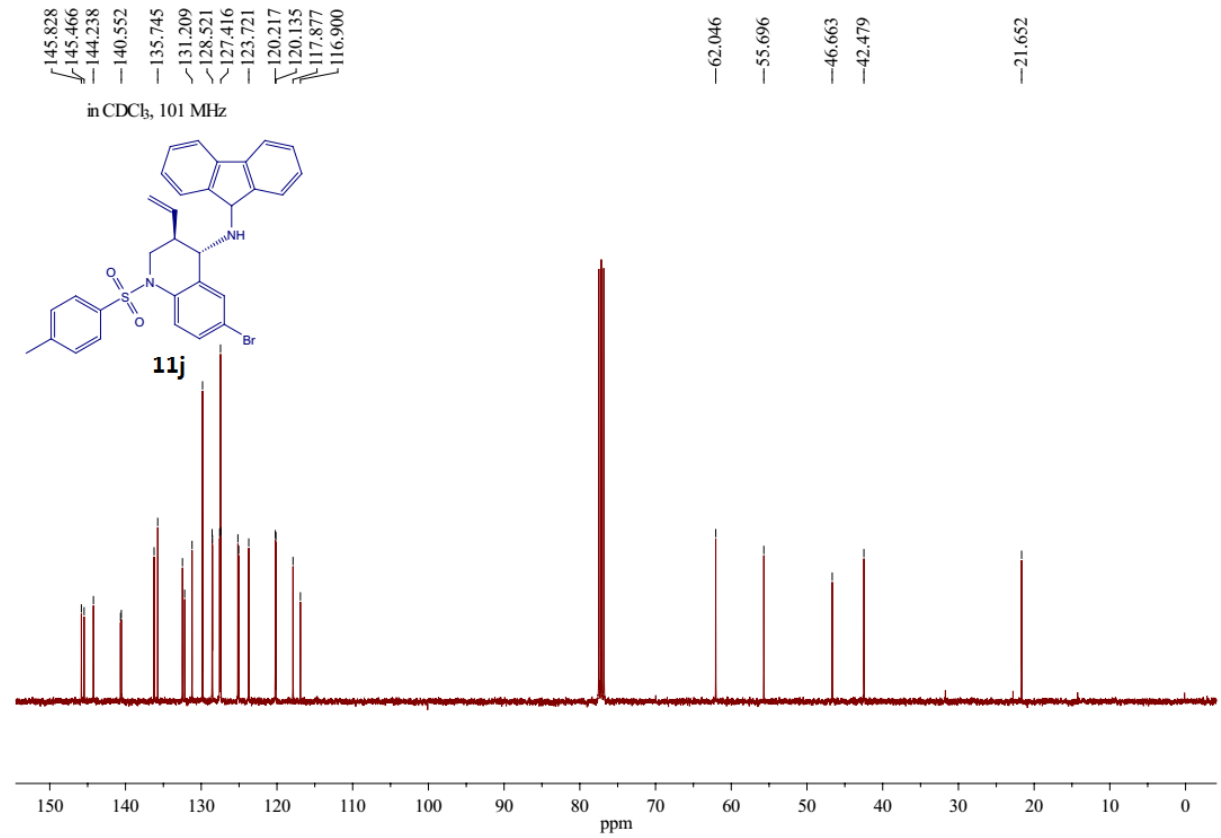

7.712
7.626
7.625
7.623
7.607
7.605
7.379
7.342
6.710
6.688
6.518
6.513
5.577
5.559
5.557
5.540
5.533
5.514
5.056
4.776
4.579
4.553
4.080
4.054
3.666
3.624
3.620
3.615
2.379
2.369
2.365
2.362
2.359
2.356
1.934
in CDCl3, 400 MHz
NH
O
O
11h
3.02
1.03
4.09
1.99
1.00
1.00
1.03
1.03
1.02
1.04
1.04
3.04
1.01
1.04
1.03
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
ppm

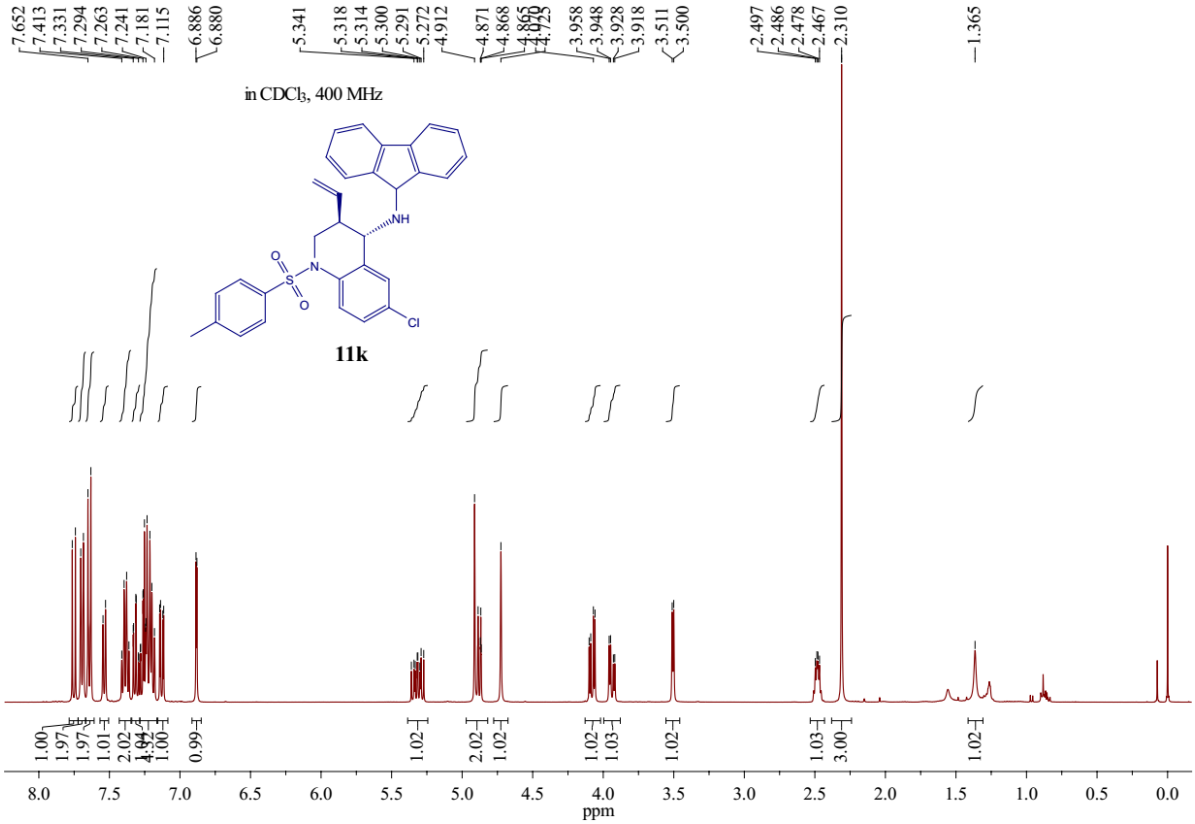

153.470
145.865
140.775
136.506
128.441
125.565
125.342
123.490
120.265
120.109
117.553
116.694
115.545
114.582
64.926
62.283
55.803
53.690
42.029
in CDCl3, 101 MHz
NH
O
O
11h
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

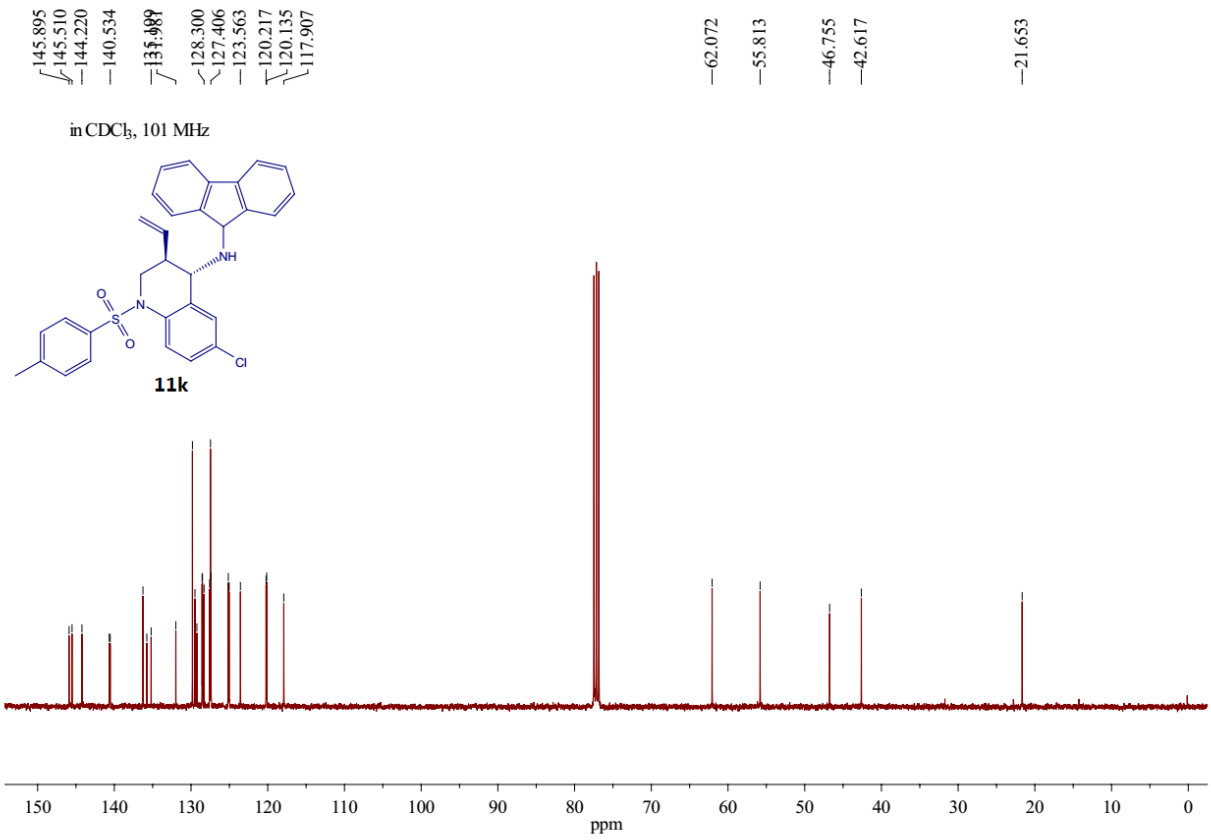

7.677
7.643
7.562
7.388
7.360
7.323
7.304
7.287
7.270
7.196
7.154
7.035
7.016
6.977
6.959
5.425
5.407
5.388
5.381
5.363
4.941
4.928
4.901
4.770
4.123
4.009
3.979
3.692
3.682
2.535
2.527
2.516
2.506
2.291
2.291
1.397
in CDCl3, 400 MHz
NH
O
S
O
N
11i
1.02
3.95
1.03
2.04
2.94
2.99
1.01
1.03
1.05
2.02
1.03
1.05
1.05
1.04
1.04
3.00
1.03
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
-0.5
ppm


146.447
145.910
143.885
140.482
136.314
129.959
129.856
129.706
128.431
128.351
128.318
127.512
127.437
127.393
125.193
125.157
124.005
121.969
120.167
120.039
117.555
62.091
56.356
46.824
42.521
21.623
in CDCl3, 101 MHz
NH
O
S
O
N
11i
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm


7.396
7.362
7.310
7.271
7.245
7.176
7.002
6.996
5.332
5.323
5.308
5.305
5.290
5.281
5.263
4.905
4.863
4.860
4.857
3.964
3.953
3.934
3.923
3.499
3.488
2.498
2.487
2.479
2.469
2.312
1.376
in CDCl3, 400 MHz
NH
O
S
O
N
Br
11j
4.97
1.03
2.05
1.04
5.26
1.01
1.04
2.03
1.01
1.03
1.00
1.01
1.05
3.00
1.00
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
ppm


145.828
145.466
144.238
140.552
135.745
131.209
128.521
127.416
123.721
120.217
120.135
117.877
116.900
62.046
55.696
46.663
42.479
21.652
in CDCl3, 101 MHz
NH
O
S
O
N
Br
11j
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm


7.652
7.413
7.331
7.294
7.263
7.241
7.181
7.115
6.886
6.880
5.341
5.318
5.314
5.300
5.291
5.272
4.912
4.871
4.868
3.958
3.948
3.928
3.918
3.511
3.500
2.497
2.486
2.478
2.467
2.310
1.365
in CDCl3, 400 MHz
NH
O
S
O
N
Cl
11k
1.00
1.97
1.97
1.01
2.02
4.94
1.00
0.99
1.02
2.02
1.02
1.02
1.03
1.02
1.03
3.00
1.02
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
ppm


145.895
145.510
144.220
140.534
128.300
127.406
123.563
120.217
120.135
117.907
62.072
55.813
46.755
42.617
21.653
in CDCl3, 101 MHz
NH
O
S
O
N
Cl
11k
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

References

1. (a) Y. Zhu and S. L. Buchwald, *J. Am. Chem. Soc.*, 2014, **136**, 4500-4503; (b) J. Liu, C.-G. Cao, H.-B. Sun, X. Zhang and D. Niu, *J. Am. Chem. Soc.*, 2016, **138**, 13103-13106.
2. (a) Y.-T. Lee, Y.-J. Jang, S.-e. Syu, S.-C. Chou, C.-J. Lee and W. Lin, *Chem. Commun.*, 2012, **48**, 8135-8137; (b) Z. Gao, C. Wang, C. Yuan, L. Zhou, Y. Xiao and H. Guo, *Chem. Commun.*, 2015, **51**, 12653-12656.