Supplementary materials

Palladium-catalyzed 1,2-selective intermolecular arylamination of 1,3-dienes

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1. General Methods

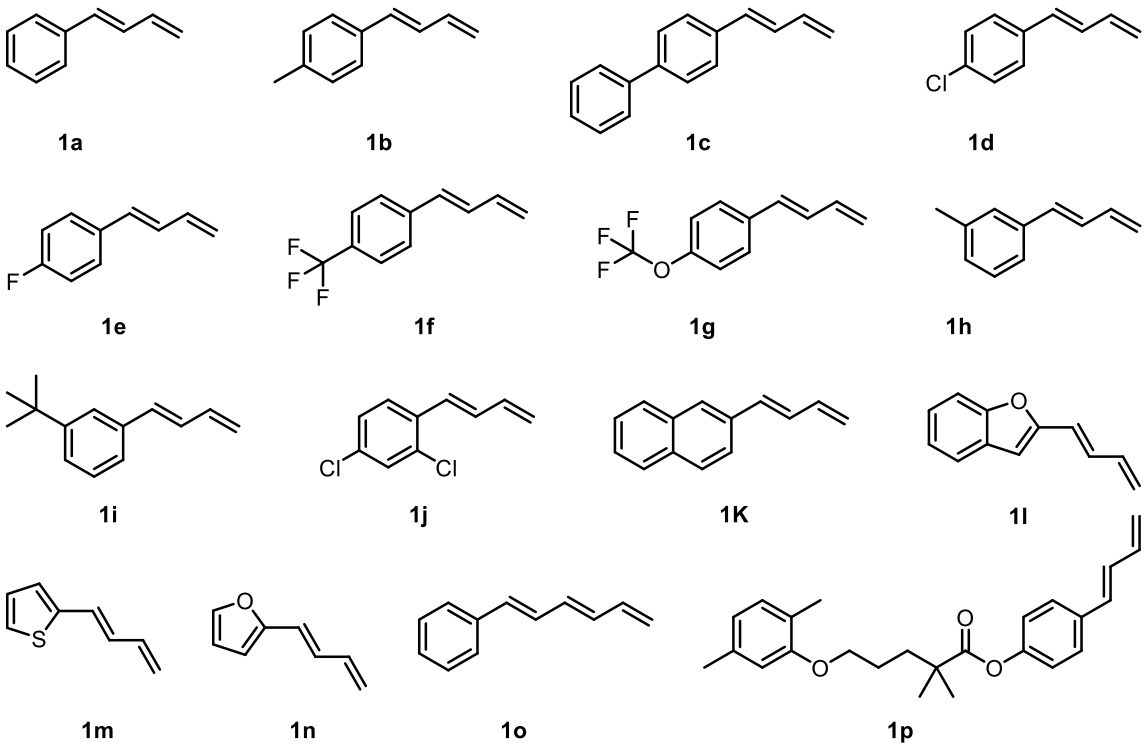
Unless otherwise noted, all of these reactions were carried out under an argon atmosphere. Solvent was freshly distilled prior to use unless otherwise noted. For column chromatography, silica gel (200-300 mesh) was employed. Analytical TLC was performed with silica gel GF 254 plates. Room temperature (r.t.) is 20-25 °C. Commercial reagents were purchased from Innochem, Laajoo, J&Kchemical, Bidepharm, Adamas, Alfa, Aladdin, Leyan, or TCI and used directly without further purification unless otherwise indicated. The trifluoromethanesulfonic acid used in the experiment is a strong acid, please avoid contact with the skin.

Instrumentation.

Deuterated solvents were purchased from Cambridge Isotope Laboratories. ^{1}H NMR spectra were recorded on Bruker AVANCE III 400, 600 and INOVA instruments with 400, 600 frequencies, and ^{13}C NMR spectra were recorded on Bruker AVANCE III 400 and 600 with 101 and 151 MHz frequencies. ^{19}F NMR spectra were recorded on a Bruker AVANCE III 400 spectrometer with a ^{19}F operating frequency of 376 MHz. Chemical shifts(δ) were reported in ppm relative to the residual solvent signal ($CDCl_3$ δ = 7.26 for ^{1}H NMR and δ = 77.0 for ^{13}CNMR). Chemical shifts (ppm) were recorded with tetramethylsilane (TMS) as the internal reference standard. Multiplicities are given as s (singlet), d (doublet), t (triplet), q (quartet), dd (doublet of doublets), td (triplet of doublets) or m (multiplet). High resolution mass spectrometer (HRMS) was obtained using a Q-TOF instrument equipped with an ESI source.

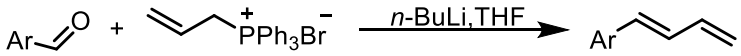
2 Reagents and General Procedures

2.1 Preparation of Dienes



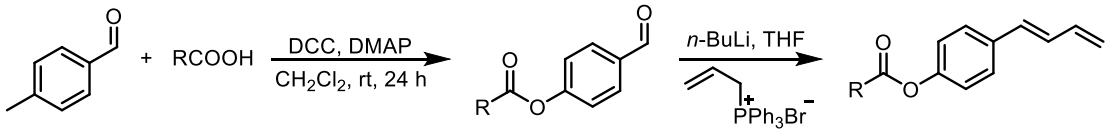
Diene **1o** is commercially available, (**1a**, **1b, 1e**, **1i**, **1j**, **1m**) [1], (**1c**, **1f**, **1h**) [2], (**1d**) [3], (**1g**) [4], (**1k**) [5], (**1l**) [6], (**1n**) [7] and (**1p**) [8] are known compounds and the NMR data were in accordance with that reported in the literatures.

General procedure for synthesis of 1,3-Dienes



To a suspension of allyltriphenylphosphonium bromide (3.57 g, 10 mmol) in THF (50 mL) at 0 °C was added dropwise *n*-BuLi (2.5 M in hexane, 4 mL, 10 mmol). The reaction mixture was stirred for 15 min and aldehyde (8 mmol) was added as solution in THF (10 mL). After 1 h, the solution was warmed to room temperature and stirred for additional 4-7 hours. Subsequently, a saturated solution of NH_4Cl was added and the mixture was extracted with ethyl acetate. The combined organic phases were washed with brine, dried over Na_2SO_4, and the solvents were removed under reduced pressure. The residue was purified by flash column chromatography on silica gel eluting with petroleum ether to afford the desired diene as a colorless liquid.

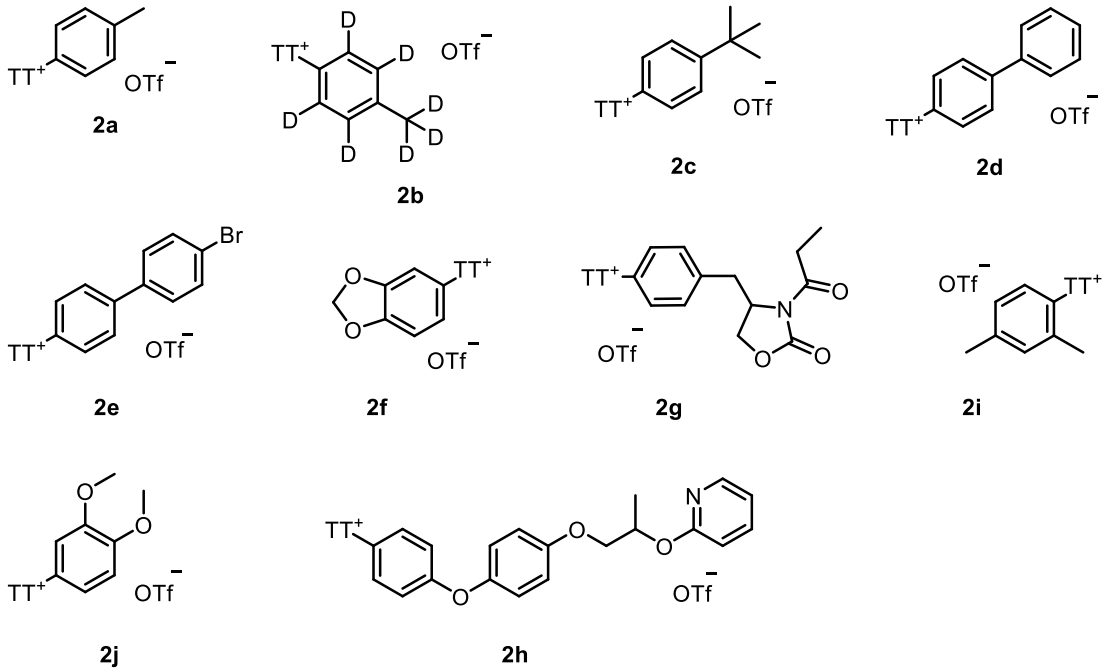
1p was prepared by the following procedure



To a solution of 4-hydroxybenzaldehyde (1.3 g, 10 mmol), acid (1 equiv.), DCC (4.12 g, 2 equiv.), DMAP (320 mg, 0.5 equiv.) was added in CH_2Cl_2 (50 mL) at room temperature for 24 h. Then the reaction mixture was poured into water and the aqueous layer was extracted with CH_2Cl_2 (3×20 mL). The combined organic layers were dried over Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was purified by flash column chromatography (PE: EA = 7:1). The crude product was used for next step to afford product.

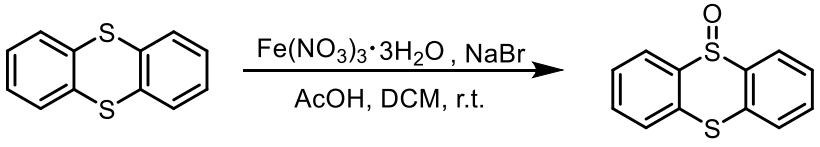
To a suspension of allyltriphenylphosphonium bromide (2.29 g, 6.0 mmol) in anhydrous THF (25.0 mL) at 0 °C was dropwise added a solution of *n*-BuLi in hexane (2.5 M, 2.4 mL, 6.0 mmol) under argon atmosphere. After stirring at the same temperature until all phosphonium bromide dissolved, a solution of enal (5.0 mmol) in anhydrous THF (5.0 mL) was added slowly. The reaction mixture was warmed to room temperature and stirred overnight. The reaction was quenched by a saturated aqueous solution of NH_4Cl and extracted with Et_2O (25 mL × 3). The combined organic layers were washed with brine, dried over anhydrous Na_2SO_4, and concentrated in vacuum. The residue was purified by flash column chromatography on silica gel to afford the target dienes.

2.2 Preparation of Aryl-TT Salts



(**2a**-**2f**) [9], (**2i**) [10], (**2j**, **2h**) [11] are known compounds and the NMR data were in accordance with that reported in the literatures. The preparation of new compounds **2g** and characterization data are provided as follows.

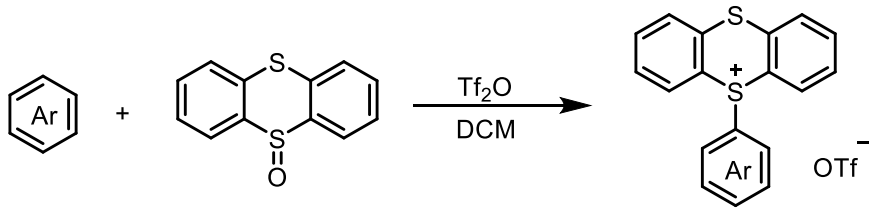
The synthesis method of thiaanthracene oxide



A 100 mL round-bottom flask was charged with thianthrene (21.6 g, 100 mmol, 1.0 equiv.), $Fe(NO_3)_3·9H_2O$ (40.4 g, 100 mmol, 1.0 equiv.) and NaBr (408 mg, 4 mmol, 4.0 mol%). DCM (200

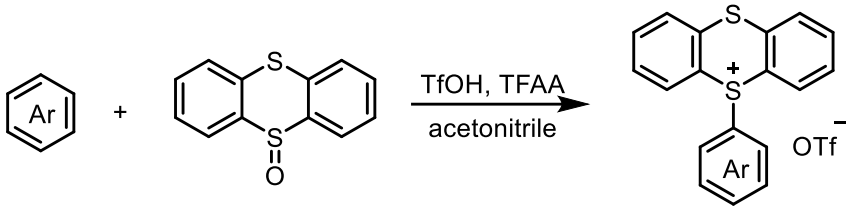
mL), and AcOH (4.0 mL) were then injected. The reaction mixture was stirred at room temperature for a night. After that, the reaction was extracted with DCM and water. The combined organic extract was dried over anhydrous Na_2SO_4, filtered and concentrated under vacuum. The grayish-white solid obtained is thianthrene *S*-oxide.

General procedure for synthesis of Aryl-TT Salts



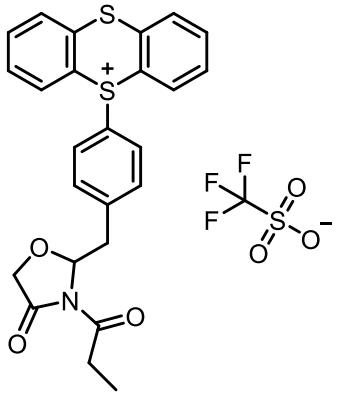
A 50 mL Schlenk tube was charged with arenes (10 mmol, 1.0 equiv.), DCM (25.0 mL) and thianthrene *S*-oxide (10 mmol, 1.0 equiv.), under argon atmosphere. The reaction mixture was then cooled to -40 °C and stirred at this temperature. Tf_2O (12 mmol, 1.2 equiv.) was added dropwise. The reaction mixture was stirred at -40 °C for 30 min, and then allowed to stir at room temperature for 12 h, neutralized by a saturated aqueous $NaHCO_3$ solution, and extracted with DCM. The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated to dryness under reduced pressure. The crude product was purified by crystallization from DCM/Et_2O system or purified by column chromatography on silica gel as a white solid.

2g, 2j was prepared by the following procedure



A 50 mL Schlenk tube was charged with arenes (10 mmol, 1.0 equiv.), acetonitrile (25.0 mL) and thianthrene *S*-oxide (10 mmol, 1.0 equiv.), under argon atmosphere. The reaction mixture was then cooled to -40 °C and stirred at this temperature. Trifluoroacetic anhydride (TFAA, 30.0 mmol, 3.0 equiv.) and trifluoromethanesulfonic acid (TfOH, 15.0 mmol, 1.5 equiv.) were added dropwise. The reaction mixture was stirred at -40 °C for 30 min, and then allowed to stir at room temperature for 12 h, neutralized by a saturated aqueous $NaHCO_3$ solution, and extracted with DCM. The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated to dryness under reduced pressure. The crude product was purified by column chromatography on silica gel as a white solid.

Characterization data of new substrates 2g.



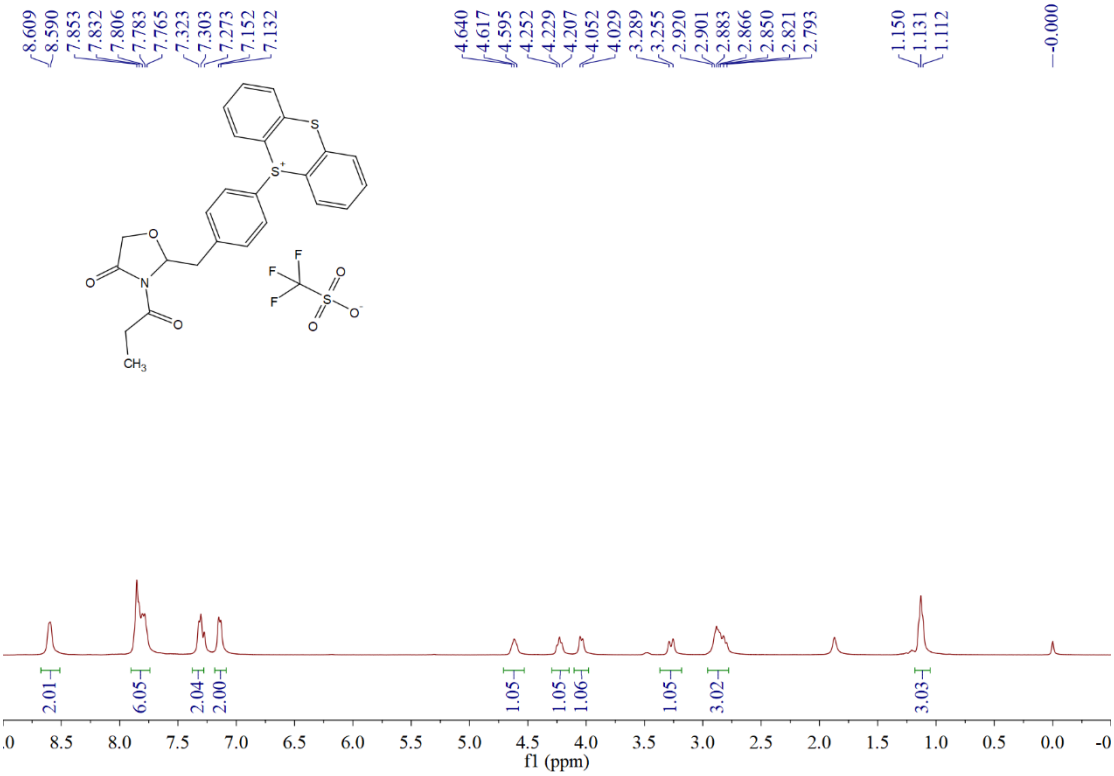
^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.70 – 8.48 (m, 2H), 7.93 – 7.71 (m, 6H), 7.34 – 7.27 (m, 2H), 7.14 (d, *J* = 8.1 Hz, 2H), 4.71 – 4.53 (m, 1H), 4.29 – 4.15 (m, 1H), 4.04 (d, *J* = 9.4 Hz, 1H), 3.27 (d, *J* = 13.7 Hz, 1H), 2.96 – 2.74 (m, 3H), 1.19 – 1.03 (m, 3H).

^{13}C NMR (101 MHz, Chloroform-*d*) δ 173.9, 153.2, 141.6, 136.6, 136.6, 135.4, 134.9, 131.6, 130.3, 130.2, 128.6, 122.7, 118.8, 118.7, 66.2, 54.6, 37.5, 29.1, 8.2.

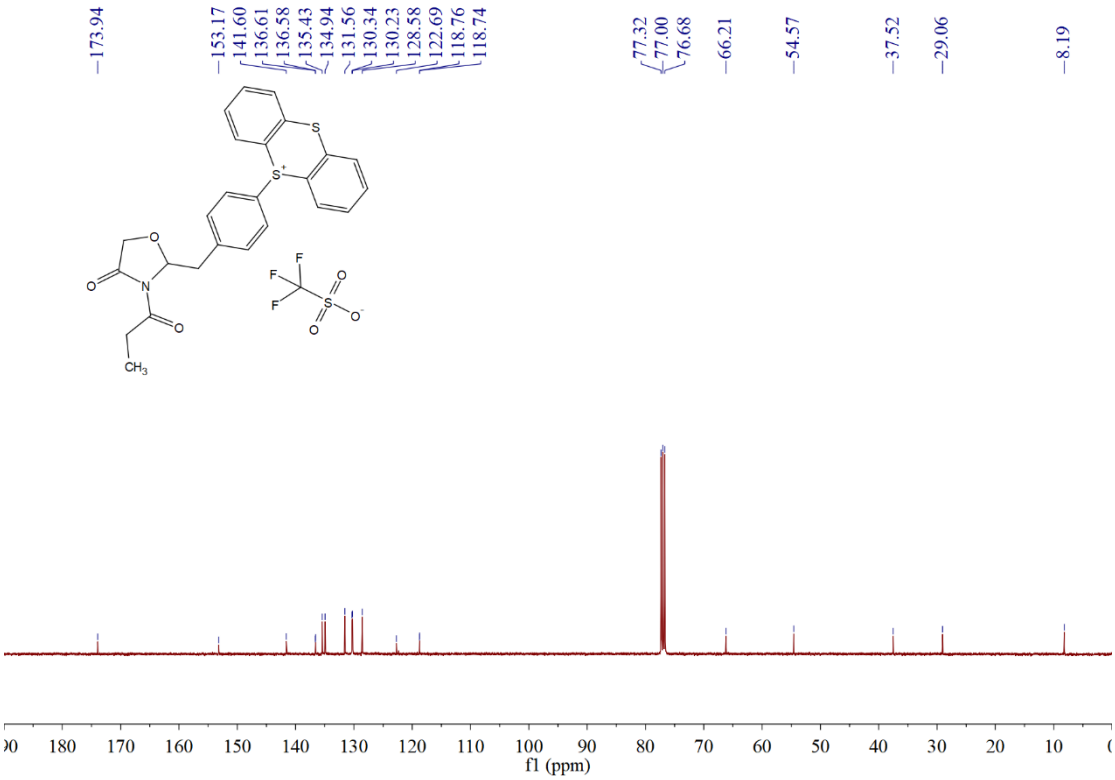
^{19}F NMR (376 MHz, Chloroform-*d*) δ -78.2.

HRMS (ESI) *m/z* calcd. for $C_{25}H_{22}NO_3S_2^+$ [M-OTf]$^+$: 448.1036, found: 448.1030

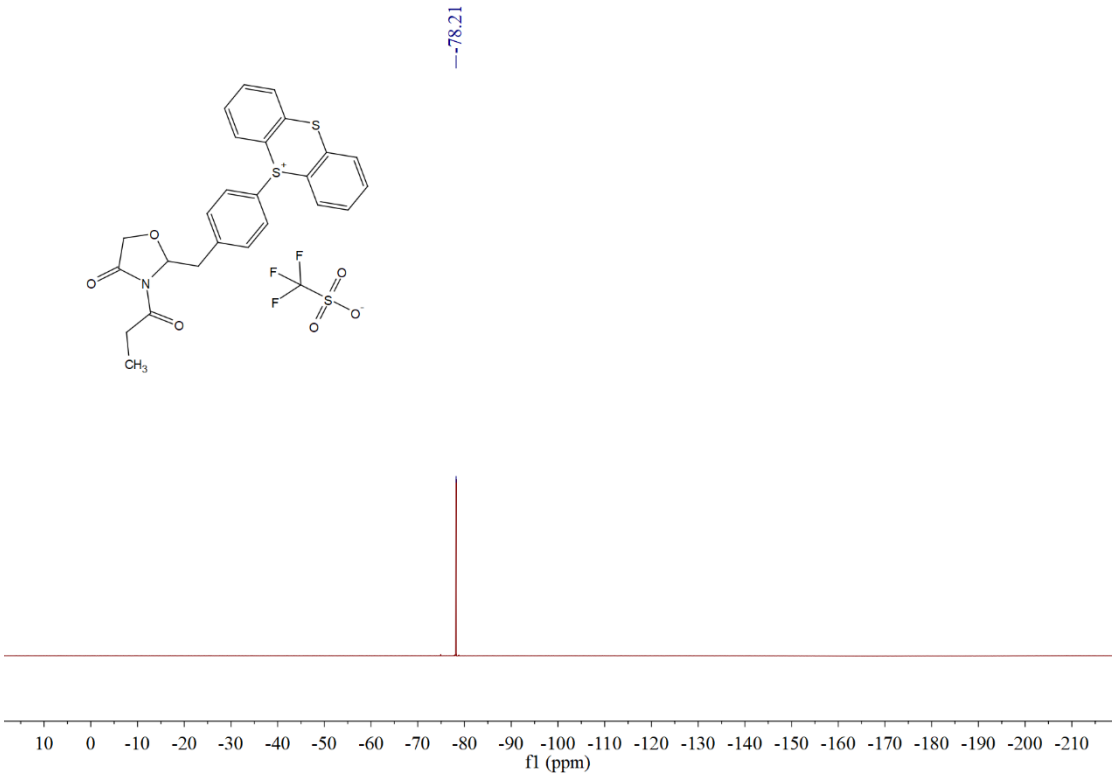
^{1}H NMR (400 MHz, $CDCl_3$) of 2g



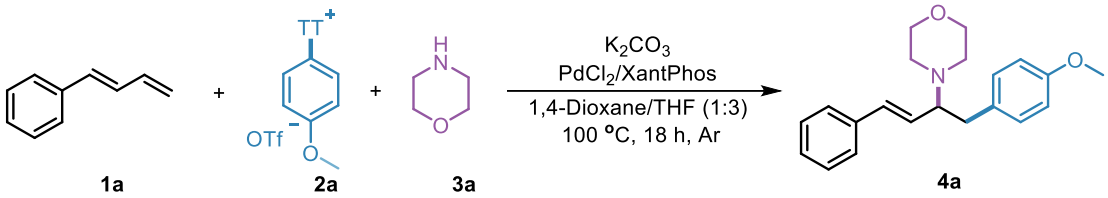
^{13}C NMR (101 MHz, $CDCl_3$) of 2g



^{19}F NMR (376 MHz, $CDCl_3$) of 2g



2.3 Typical procedure for the preparation of products 4a

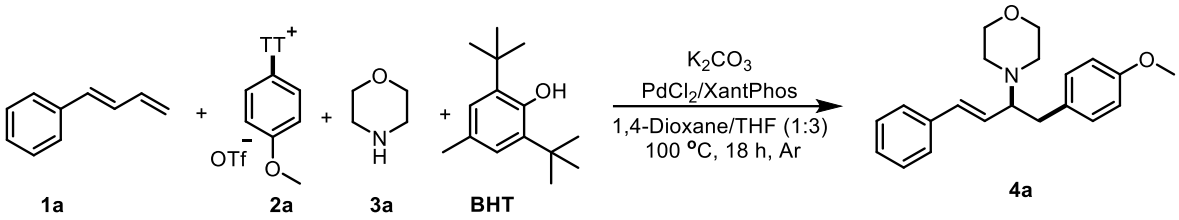


In an oven-dried 20 mL tube, **1a** (0.2 mmol), $PdCl_2$ (10 mol%), XantPhos (20 mol%), K_2CO_3 (2.0 equiv.) were added and charged with argon more than five times (The tube was sealed with tipping plug). 1,4-dioxane (0.5 mL) and THF (1.5 mL), **2a** (0.4 mmol, 2.0 equiv.) and **3a** (0.4 mmol, 2.0 equiv.) were injected into the tube via plastic syringes. Then the white medical adhesive tape was used to reinforce the tipping plug. The resulting light yellow suspension was stirred vigorously at room temperature for 10 minutes before being placed in a preheated oil bath at 100 °C stirring at 550 rpm for 18 h. After the reaction was completed, filter the system first and residue was purified with column chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine to afford the product **4a**.

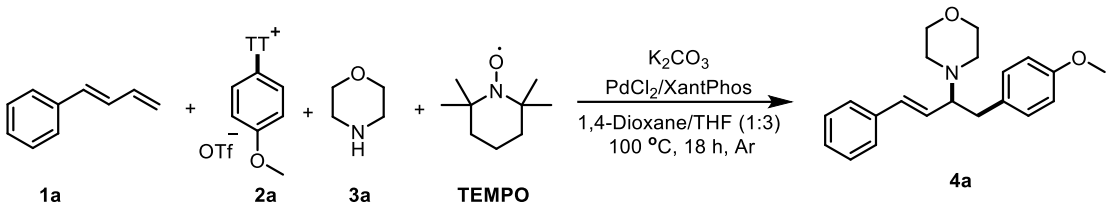
2.4 Gram Scale Synthesis

In a 150 mL pre-dried round bottom flask with stir magneton, **1a** (7.8 mmol), $PdCl_2$ (10 mol%), XantPhos (20 mol%), K_2CO_3 (15.6 mmol, 2.0 equiv.) were added and charged with argon more than five times (The tube was sealed with tipping plug). 1,4-dioxane (19.5 mL) and THF (58.5 mL), **2a** (15.6 mmol, 2.0 equiv.) and **3a** (15.6 mmol, 2.0 equiv.) were injected into the tube via plastic syringes. Then the white medical adhesive tape was used to reinforce the tipping plug. The resulting light yellow suspension was stirred vigorously at room temperature for 10 minutes before being placed in a preheated oil bath at 100 °C stirring at 550 rpm for 18 h. After the reaction was completed, filter the system first and residue was purified with column chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine to afford the product **4a**.

2.5 Operation of free radical inhibition test



In a 20 mL tube, **1a** (0.2 mmol), BHT (0.4 mmol, 2.0 equiv.), $PdCl_2$ (0.02 mmol, 10 mol%), XantPhos (0.04 mmol, 20 mol%), K_2CO_3 (0.4 mmol, 2.0 equiv.) were added and charged with argon more than five times (The tube was sealed with tipping plug). 1,4-dioxane (0.5 mL) and THF (1.5 mL), **2a** (0.4 mmol, 2.0 equiv.), **3a** (0.4 mmol, 2.0 equiv.) was injected into the tube via plastic syringes. Then the white medical adhesive tape was used to reinforce the tipping plug. The resulting light yellow suspension was stirred vigorously at room temperature for 10 minutes before being placed in a preheated oil bath at 100 °C stirring at 550 rpm for 18 h. After the reaction was completed, filter the system first and residue was purified with column chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine to afford the product **4a**.



In a 20 mL tube, **1a** (0.2 mmol), TEMPO (0.4 mmol, 2.0 equiv.), $PdCl_2$ (0.02 mmol, 10 mol%), XantPhos (0.04 mmol, 20 mol%), K_2CO_3 (0.4 mmol, 2.0 equiv.) were added and charged with argon more than five times (The tube was sealed with tipping plug). 1,4-dioxane (0.5 mL) and THF (1.5 mL), **2a** (0.4 mmol, 2.0 equiv.), **3a** (0.4 mmol, 2.0 equiv.) was injected into the tube via plastic syringes. Then the white medical adhesive tape was used to reinforce the tipping plug. The resulting light yellow suspension was stirred vigorously at room temperature for 10 minutes before being placed in a preheated oil bath at 100 °C stirring at 550 rpm for 18 h. After the reaction was completed, filter the system first and residue was purified with column chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine to afford the product **4a**.

3 References

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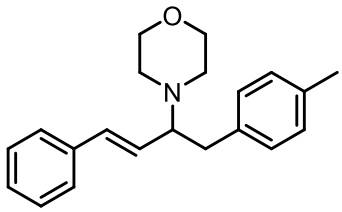
4 Characterization Data of Products



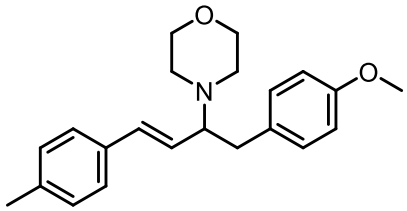
(*E*)-4-(4-phenyl-1-(*p*-tolyl)but-3-en-2-yl)morpholine (4a)

Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 47.3 mg, yield: 77%, colorless oil.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.29 – 7.24 (m, 4H), 7.22 – 7.18 (m, 1H), 7.09 – 6.99 (m, 4H), 6.25 – 6.17 (m, 1H), 6.13 – 6.06 (m, 1H), 3.77 – 3.70 (m, 4H), 3.17 – 3.05 (m, 2H), 2.75 – 2.59 (m, 5H), 2.28 (s, 3H).

^{13}C NMR (101 MHz, Chloroform-*d*) δ 136.8, 135.9, 135.3, 133.0, 129.3, 128.8, 128.6, 128.4, 127.3, 126.2, 69.8, 67.2, 50.5, 37.9, 21.0.

HRMS (ESI) *m/z* calcd. for $C_{21}H_{26}NO$ $[M+H]^+$308.2009, found:308.2003.



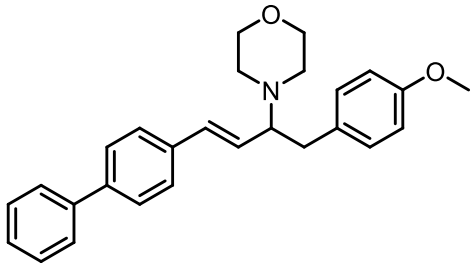
(*E*)-4-(1-(4-methoxyphenyl)-4-(*p*-tolyl)but-3-en-2-yl)morpholine (4b)

Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 50.6 mg, yield: 75%, colorless oil.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.20 – 7.15 (m, 2H), 7.11 – 7.04 (m, 4H), 6.82 – 6.71 (m, 2H), 6.24 – 6.12 (m, 1H), 6.08 – 5.96 (m, 1H), 3.77 – 3.69 (m, 7H), 3.13 – 3.02 (m, 2H), 2.73 – 2.65 (m, 3H), 2.65 – 2.57 (m, 2H), 2.31 (s, 3H).

^{13}C NMR (101 MHz, Chloroform-*d*) δ 157.8, 137.2, 134.1, 133.1, 131.2, 130.5, 129.2, 127.6, 126.2, 113.5, 70.1, 67.3, 55.2, 50.6, 37.7, 21.2.

HRMS (ESI) *m/z* calcd. for $C_{22}H_{28}NO_2$ $[M+H]^+$: 338.2109, found: 338.2115.



(*E*)-4-(4-([1,1'-biphenyl]-4-yl)-1-(4-methoxyphenyl)but-3-en-2-yl)morpholine (4c)

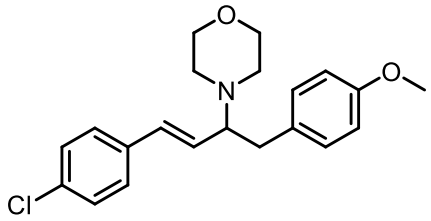
Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 48 mg, yield: 60%, colorless oil.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.60 – 7.56 (m, 2H), 7.52 (d, *J* = 8.3 Hz, 2H), 7.45 – 7.40 (m,

2H), 7.38 – 7.32 (m, 3H), 7.09 (d, *J* = 8.6 Hz, 2H), 6.82 – 6.73 (m, 2H), 6.29 – 6.19 (m, 1H), 6.18 – 6.09 (m, 1H), 3.80 – 3.72 (m, 7H), 3.18 – 3.05 (m, 2H), 2.77 – 2.61 (m, 5H).

^{13}C NMR (101 MHz, Chloroform-*d*) δ 157.8, 140.6, 140.2, 135.8, 132.7, 131.1, 130.4, 128.7, 128.7, 127.3, 127.2, 126.9, 126.7, 113.5, 70.1, 67.3, 55.2, 50.6, 37.6.

HRMS (ESI) *m/z* calcd. for $C_{27}H_{30}NO_2$ $[M+H]^+$: 400.2271, found: 400.2263.



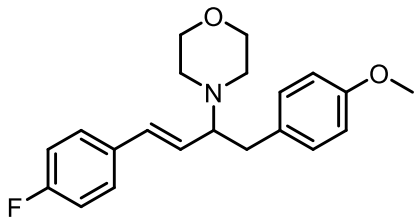
(*E*)-4-(4-(4-chlorophenyl)-1-(4-methoxyphenyl)but-3-en-2-yl)morpholine (4d)

Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 57.3 mg, yield: 80%, colorless oil.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.29 – 7.14 (m, 4H), 7.06 (d, *J* = 8.5 Hz, 2H), 6.78 (d, *J* = 8.5 Hz, 2H), 6.20 – 6.11 (m, 1H), 6.10 – 5.99 (m, 1H), 3.90 – 3.64 (m, 7H), 3.21 – 2.92 (m, 2H), 2.84 – 2.52 (m, 5H).

^{13}C NMR (101 MHz, Chloroform-*d*) δ 157.9, 135.3, 133.0, 131.9, 131.0, 130.4, 129.4, 128.6, 127.4, 113.5, 69.9, 67.2, 55.2, 50.5, 37.4.

HRMS (ESI) *m/z* calcd. for $C_{21}H_{25}ClNO_2$[M+H]$^+$: 358.1568, found: 358.1560.



(*E*)-4-(4-(4-fluorophenyl)-1-(4-methoxyphenyl)but-3-en-2-yl)morpholine (4e)

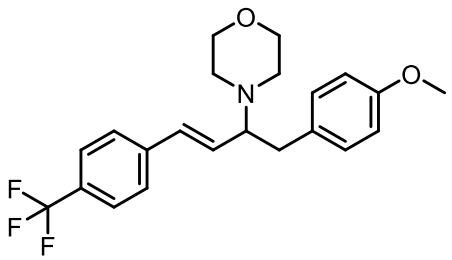
Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 58.7 mg, yield: 86%, colorless oil.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.26 – 7.20 (m, 2H), 7.11 – 7.03 (m, 2H), 7.01 – 6.93 (m, 2H), 6.84 – 6.72 (m, 2H), 6.20 – 6.10 (m, 1H), 6.04 – 5.94 (m, 1H), 3.80 – 3.68 (m, 7H), 3.15 – 3.00 (m, 2H), 2.76 – 2.56 (m, 5H).

^{13}C NMR (101 MHz, Chloroform-*d*) δ 162.2 (d, *J* = 246.5 Hz), 157.8, 133.0, 131.9, 131.1, 130.4, 128.4, 127.7 (d, *J* = 7.9 Hz), 115.4 (d, *J* = 21.5 Hz), 113.5, 69.9, 67.3, 55.2, 50.6, 37.5.

^{19}F NMR (376 MHz, Chloroform-*d*) δ -114.7.

HRMS (ESI) *m/z* calcd. for $C_{21}H_{25}FNO_2$ $[M+H]^+$: 342.1864, found: 342.1856.



(*E*)-4-(1-(4-methoxyphenyl)-4-(4-(trifluoromethyl)phenyl)but-3-en-2-yl)morpholine (4f)

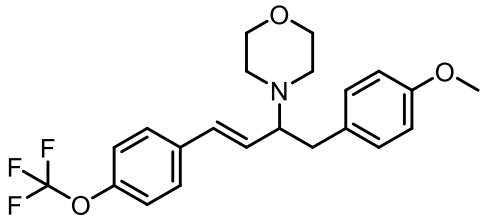
Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 62.7 mg, yield: 80%, colorless oil.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.52 (d, *J* = 8.2 Hz, 2H), 7.35 (d, *J* = 8.1 Hz, 2H), 7.08 – 7.05 (m, 2H), 6.80 – 6.76 (m, 2H), 6.22 – 6.17 (m, 2H), 3.76 – 3.73 (m, 7H), 3.16 – 3.07 (m, 2H), 2.73 – 2.62 (m, 5H).

^{13}C NMR (101 MHz, Chloroform-*d*) δ 157.9, 140.2, 131.8, 131.5, 130.8, 130.4, 129.1 (q, *J* = 32.3 Hz), 126.3, 125.4 (q, *J* = 4.0 Hz), 121.4 (d, *J* = 271.8 Hz), 113.5, 69.8, 67.2, 55.1, 50.5, 37.3.

^{19}F NMR (376 MHz, Chloroform-*d*) δ -62.4.

HRMS (ESI) *m/z* calcd. for $C_{22}H_{25}F_3NO_2$ $[M+H]^+$: 392.1832, found: 392.1824.



(*E*)-4-(1-(4-methoxyphenyl)-4-(4-(trifluoromethoxy)phenyl)but-3-en-2-yl)morpholine (4g)

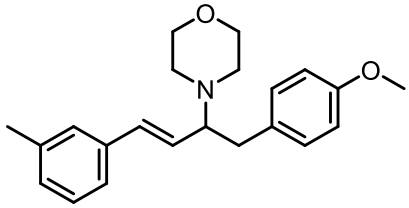
Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 61.1 mg, yield: 75%, colorless oil.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.29 – 7.25 (m, 2H), 7.12 (d, *J* = 8.2 Hz, 2H), 7.07 (d, *J* = 8.6 Hz, 2H), 6.78 (d, *J* = 8.6 Hz, 2H), 6.22 – 6.15 (m, 1H), 6.11 – 6.02 (m, 1H), 3.77 – 3.70 (m, 7H), 3.15 – 3.04 (m, 2H), 2.72 – 2.58 (m, 5H).

^{13}C NMR (101 MHz, Chloroform-*d*) δ 157.8, 148.3 (d, *J* = 2.0 Hz), 135.6, 131.6, 130.9, 130.4, 129.8, 127.4, 121.0, 120.4 (q, *J* = 257.0 Hz), 113.5, 69.8, 67.2, 55.1, 50.5, 37.4.

^{19}F NMR (376 MHz, Chloroform-*d*) δ -57.9.

HRMS (ESI) *m/z* calcd. for $C_{22}H_{25}F_3NO_3$ $[M+H]^+$: 408.1781, found: 408.1795.



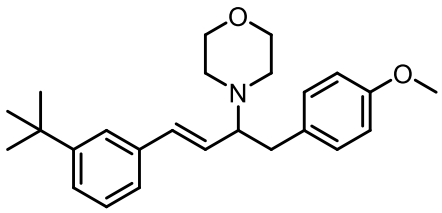
(*E*)-4-(1-(4-methoxyphenyl)-4-(*m*-tolyl)but-3-en-2-yl)morpholine (4h)

Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 50.5 mg, yield: 75%, colorless oil.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.19 – 7.15 (m, 1H), 7.11 – 7.05 (m, 4H), 7.02 (d, *J* = 7.5 Hz, 1H), 6.80 – 6.75 (m, 2H), 6.22 – 6.15 (m, 1H), 6.11 – 6.03 (m, 1H), 3.77 – 3.70 (m, 7H), 3.13 – 3.02 (m, 2H), 2.74 – 2.59 (m, 5H), 2.32 (s, 3H).

^{13}C NMR (101 MHz, Chloroform-*d*) δ 157.8, 138.0, 136.8, 133.2, 131.1, 130.4, 128.3, 128.3, 128.2, 127.0, 123.4, 113.5, 70.0, 67.2, 55.1, 50.5, 37.6, 21.3.

HRMS (ESI) *m/z* calcd. for $C_{22}H_{28}NO_2$ $[M+H]^+$: 338.2115, found: 338.2108.



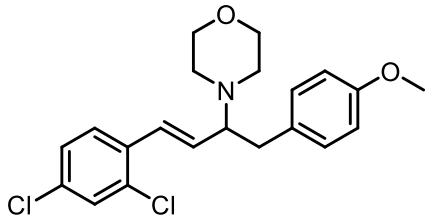
(*E*)-4-(4-(3-(*tert*-butyl)phenyl)-1-(4-methoxyphenyl)but-3-en-2-yl)morpholine (4i)

Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 50.1 mg, yield: 66%, colorless oil.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.31 (d, *J* = 8.1 Hz, 2H), 7.25 – 7.21 (m, 2H), 7.07 (d, *J* = 8.3 Hz, 2H), 6.77 (d, *J* = 8.1 Hz, 2H), 6.23 – 6.14 (m, 1H), 6.13 – 5.97 (m, 1H), 3.78 – 3.70 (m, 7H), 3.13 – 3.02 (m, 2H), 2.74 – 2.58 (m, 5H), 1.30 (s, 9H).

^{13}C NMR (101 MHz, Chloroform-*d*) δ 157.8, 150.5, 134.1, 133.0, 131.2, 130.4, 127.8, 126.0, 125.4, 113.5, 70.0, 67.3, 55.1, 50.6, 37.6, 34.5, 31.3.

HRMS (ESI) *m/z* calcd. for $C_{25}H_{34}NO_2$ $[M+H]^+$: 380.2584, found: 380.2576.



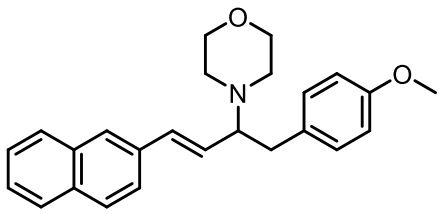
(*E*)-4-(4-(2,4-dichlorophenyl)-1-(4-methoxyphenyl)but-3-en-2-yl)morpholine (4j)

Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 39.2 mg, yield: 50%, colorless oil.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.34 – 7.29 (m, 2H), 7.17 – 7.14 (m, 1H), 7.09 – 7.05 (m, 2H), 6.82 – 6.76 (m, 2H), 6.54 – 6.45 (m, 1H), 6.06 – 5.98 (m, 1H), 3.78 – 3.72 (m, 7H), 3.23 – 3.16 (m, 1H), 3.09 (dd, *J* = 13.4, 4.7 Hz, 1H), 2.74 – 2.61 (m, 5H).

^{13}C NMR (101 MHz, Chloroform-*d*) δ 157.9, 133.7, 133.3, 133.2, 132.2, 130.7, 130.3, 129.2, 128.5, 127.6, 127.1, 113.6, 69.7, 67.2, 55.2, 50.5, 37.2.

HRMS (ESI) *m/z* calcd. for $C_{21}H_{24}Cl_2NO_2$ $[M+H]^+$:392.1171, found: 392.1179.



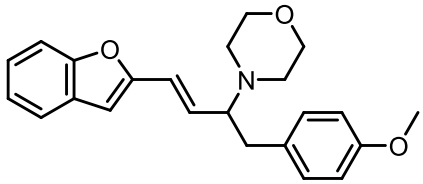
(*E*)-4-(1-(4-methoxyphenyl)-4-(naphthalen-2-yl)but-3-en-2-yl)morpholine (4k)

Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 60.4 mg, yield: 81%, colorless oil.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.80 – 7.72 (m, 3H), 7.59 (s, 1H), 7.54 – 7.49 (m, 1H), 7.45 – 7.38 (m, 2H), 7.09 (d, *J* = 8.5 Hz, 2H), 6.77 (d, *J* = 8.6 Hz, 2H), 6.40 – 6.30 (m, 1H), 6.26 – 6.16 (m, 1H), 3.79 – 3.70 (m, 7H), 3.20 – 3.06 (m, 2H), 2.77 – 2.61 (m, 5H).

^{13}C NMR (101 MHz, Chloroform-*d*) δ 157.7, 134.2, 133.4, 133.2, 132.8, 131.0, 130.4, 128.9, 128.0, 127.8, 127.5, 126.2, 126.0, 125.7, 123.4, 113.4, 70.1, 67.2, 55.1, 50.5, 37.5.

HRMS (ESI) *m/z* calcd. for $C_{25}H_{28}NO_2$ $[M+H]^+$:374.2115, found: 374.2118.



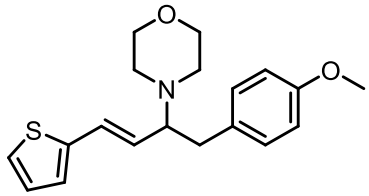
(*E*)-4-(4-(benzofuran-2-yl)-1-(4-methoxyphenyl)but-3-en-2-yl)morpholine (4l)

Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 58.1 mg, yield: 80%, colorless oil.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.47 (d, *J* = 7.7 Hz, 1H), 7.42 (d, *J* = 8.1 Hz, 1H), 7.26 – 7.24 (m, 1H), 7.19 – 7.15 (m, 1H), 7.09 (d, *J* = 8.2 Hz, 2H), 6.84 – 6.72 (m, 2H), 6.43 (s, 1H), 6.40 – 6.33 (m, 1H), 6.17 – 6.10 (m, 1H), 3.78 – 3.70 (m, 7H), 3.19 – 3.05 (m, 2H), 2.75 – 2.62 (m, 5H).

^{13}C NMR (101 MHz, Chloroform-*d*) δ 157.9, 154.6, 154.0, 130.9, 130.8, 130.4, 128.9, 124.4, 122.7, 121.5, 120.8, 113.6, 110.8, 104.1, 69.8, 67.3, 55.2, 50.3, 37.4.

HRMS (ESI) *m/z* calcd. for $C_{23}H_{26}NO_3$ $[M+H]^+$:364.1907, found: 364.1901.



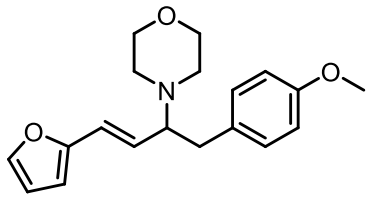
(*E*)-4-(1-(4-methoxyphenyl)-4-(thiophen-2-yl)but-3-en-2-yl)morpholine (4m)

Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 47.4 mg, yield: 72%, colorless oil.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.12 – 7.03 (m, 3H), 6.92 – 6.89 (m, 1H), 6.83 – 6.75 (m, 3H), 6.37 – 6.28 (m, 1H), 5.98 – 5.88 (m, 1H), 3.78 – 3.70 (m, 7H), 3.10 – 3.00 (m, 2H), 2.72 – 2.57 (m, 5H).

^{13}C NMR (101 MHz, Chloroform-*d*) δ 157.8, 141.9, 131.0, 130.3, 128.3, 127.2, 126.2, 125.2, 123.8, 113.5, 69.8, 67.2, 55.1, 50.4, 37.4.

HRMS (ESI) *m/z* calcd. for $C_{19}H_{24}NO_2S$ $[M+H]^+$330.1522, found: 330.1518.



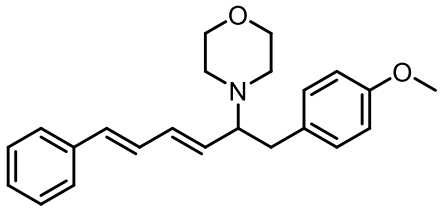
(*E*)-4-(4-(furan-2-yl)-1-(4-methoxyphenyl)but-3-en-2-yl)morpholine (4n)

Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 53.2 mg, yield: 85%, colorless oil.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.33 – 7.28 (m, 1H), 7.08 (d, *J* = 8.6 Hz, 2H), 6.83 – 6.75 (m, 2H), 6.35 – 6.30 (m, 1H), 6.11 (d, *J* = 3.2 Hz, 1H), 6.09 – 5.99 (m, 2H), 3.78 – 3.71 (m, 7H), 3.12 – 3.01 (m, 2H), 2.72 – 2.57 (m, 5H).

^{13}C NMR (101 MHz, Chloroform-*d*) δ 157.8, 152.3, 141.7, 131.1, 130.3, 127.0, 121.5, 113.5, 111.1, 107.4, 69.7, 67.3, 55.1, 50.2, 37.4.

HRMS (ESI) *m/z* calcd. for $C_{19}H_{24}NO_3$[M+H]$^+$314.1751, found: 314.1741.



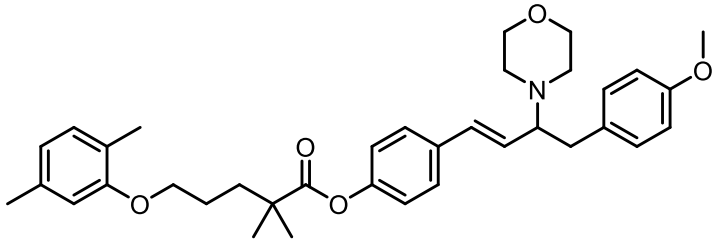
4-((3*E*,5*E*)-1-(4-methoxyphenyl)-6-phenylhexa-3,5-dien-2-yl)morpholine (4o)

Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 60 mg, yield: 86%, colorless oil.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.39 – 7.33 (m, 2H), 7.32 – 7.27 (m, 2H), 7.23 – 7.18 (m, 1H), 7.10 – 7.03 (m, 2H), 6.82 – 6.77 (m, 2H), 6.75 – 6.64 (m, 1H), 6.44 – 6.36 (m, 1H), 6.10 – 5.97 (m, 1H), 5.73 – 5.63 (m, 1H), 3.79 – 3.70 (m, 7H), 3.10 – 2.98 (m, 2H), 2.70 – 2.56 (m, 5H).

^{13}C NMR (101 MHz, Chloroform-*d*) δ 157.8, 137.2, 133.8, 132.7, 131.9, 131.1, 130.4, 128.6, 128.3, 127.4, 126.2, 113.5, 69.7, 67.3, 55.2, 50.4, 37.4.

HRMS (ESI) *m/z* calcd. for $C_{23}H_{28}NO_2$ $[M+H]^+$350.2115, found: 350.2098.



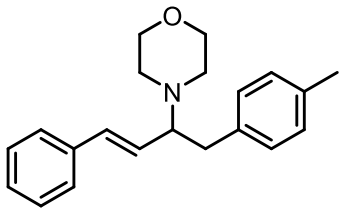
(*E*)-4-(4-(4-methoxyphenyl)-3-morpholinobut-1-en-1-yl)phenyl 2,2-dimethyl-5-(*o*-tolyloxy) pentanoate (4p)

Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 77.1 mg, yield: 67.5%, colorless oil.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.26 – 7.25 (m, 1H), 7.25 – 7.23 (m, 1H), 7.07 – 7.04 (m, 2H), 7.00 (d, *J* = 7.5 Hz, 1H), 6.96 – 6.92 (m, 2H), 6.80 – 6.76 (m, 2H), 6.66 (d, *J* = 7.5 Hz, 1H), 6.62 (s, 1H), 6.20 – 6.14 (m, 1H), 6.07 – 5.99 (m, 1H), 4.00 – 3.95 (m, 2H), 3.77 – 3.72 (m, 7H), 3.12 – 3.04 (m, 2H), 2.72 – 2.60 (m, 5H), 2.30 (s, 3H), 2.17 (s, 3H), 1.89 – 1.83 (m, 4H), 1.36 (s, 6H).

^{13}C NMR (101 MHz, Chloroform-*d*) δ 176.3, 157.8, 156.8, 150.2, 136.5, 134.5, 132.2, 131.0, 130.4, 130.3, 128.8, 127.1, 123.6, 121.5, 120.7, 113.5, 111.9, 70.0, 67.7, 67.3, 55.2, 50.6, 42.4, 37.5, 37.1, 25.3, 25.1, 21.4, 15.8.

HRMS (ESI) *m/z* calcd. for $C_{36}H_{46}NO_5$ $[M+H]^+$572.3370, found:572.3357.



(*E*)-4-(4-phenyl-1-(*p*-tolyl)but-3-en-2-yl)morpholine (5a)

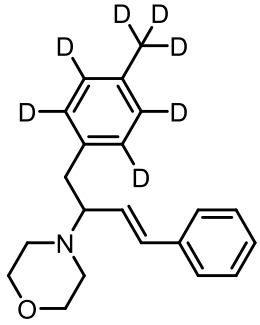
Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 47.3 mg, yield: 77%, colorless oil.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.29 – 7.24 (m, 4H), 7.22 – 7.18 (m, 1H), 7.09 – 6.99 (m, 4H), 6.25 – 6.17 (m, 1H), 6.13 – 6.06 (m, 1H), 3.77 – 3.70 (m, 4H), 3.17 – 3.05 (m, 2H), 2.75 – 2.59 (m,

5H), 2.28 (s, 3H).

^{13}C NMR (101 MHz, Chloroform-*d*) δ 136.8, 135.9, 135.3, 133.0, 129.3, 128.8, 128.6, 128.4, 127.3, 126.2, 69.8, 67.2, 50.5, 37.9, 21.0.

HRMS (ESI) *m/z* calcd. for $C_{21}H_{26}NO$ $[M+H]^+$308.2009, found:308.2003.



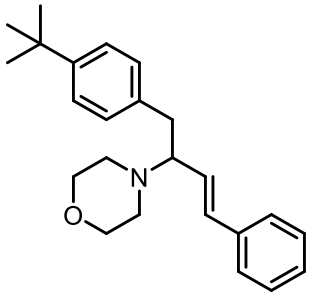
(*E*)-4-(1-(4-(methyl-d_3)phenyl-2,3,5,6-d_4)-4-phenylbut-3-en-2-yl)morpholine (5b)

Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 50.9 mg, yield: 81%, colorless oil.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.28 – 7.19 (m, 5H), 6.26 – 6.17 (m, 1H), 6.14 – 6.06 (m, 1H), 3.77 – 3.70 (m, 4H), 3.17 – 3.03 (m, 2H), 2.76 – 2.59 (m, 5H).

^{13}C NMR (101 MHz, Chloroform-*d*) δ 135.8, 135.0, 133.0, 129.5, 129.1, 128.9, 128.6, 128.4, 128.1, 127.3, 126.2, 69.7, 67.2, 50.5, 37.8.

HRMS (ESI) *m/z* calcd. for $C_{21}H_{19}D_7NO$ $[M+H]^+$315.2448, found:315.2450.



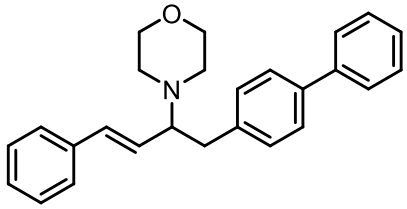
(*E*)-4-(1-(4-(*tert*-butyl)phenyl)-4-phenylbut-3-en-2-yl)morpholine (5c)

Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 60.1 mg, yield: 86%, colorless oil.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.30 – 7.25 (m, 5H), 7.25 – 7.21 (m, 2H), 7.12 – 7.08 (m, 2H), 6.26 – 6.20 (m, 1H), 6.14 – 6.07 (m, 1H), 3.79 – 3.71 (m, 4H), 3.22 – 3.14 (m, 1H), 3.13 – 3.06 (m, 1H), 2.77 – 2.61 (m, 5H), 1.28 (s, 9H).

^{13}C NMR (101 MHz, Chloroform-*d*) δ 148.7, 136.9, 136.0, 133.1, 129.1, 128.6, 128.5, 127.3, 126.2, 125.0, 69.6, 67.3, 50.5, 37.8, 34.3, 31.3.

HRMS (ESI) *m/z* calcd. for $C_{24}H_{32}NO$ $[M+H]^+$350.2478, found:350.2490.



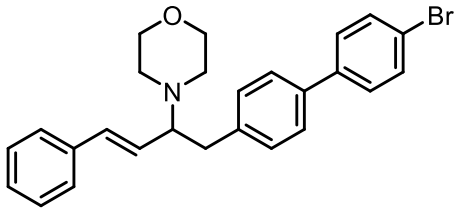
(*E*)-4-(1-([1,1'-biphenyl]-4-yl)-4-phenylbut-3-en-2-yl)morpholine (5d)

Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 38.5 mg, yield: 52%, colorless oil.

^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.56 (d, *J* = 7.6 Hz, 2H), 7.48 (d, *J* = 8.0 Hz, 2H), 7.40 (t, *J* = 7.6 Hz, 2H), 7.33 – 7.16 (m, 8H), 6.33 – 6.19 (m, 1H), 6.18 – 6.07 (m, 1H), 3.80 – 3.70 (m, 4H), 3.24 – 3.12 (m, 2H), 2.85 – 2.77 (m, 1H), 2.77 – 2.58 (m, 4H).

^{13}C NMR (151 MHz, Chloroform-*d*) δ 140.9, 138.8, 138.3, 136.8, 133.3, 129.9, 128.6, 128.5, 128.4, 127.4, 127.0, 126.9, 126.8, 126.2, 69.7, 67.3, 50.5, 38.1.

HRMS (ESI) *m/z* calcd. for $C_{26}H_{28}NO$ $[M+H]^+$370.2165, found:370.2164.



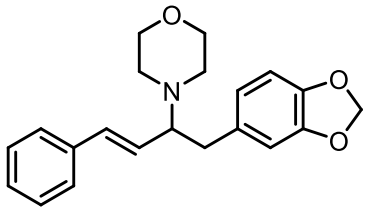
(*E*)-4-(1-(4'-bromo-[1,1'-biphenyl]-4-yl)-4-phenylbut-3-en-2-yl)morpholine (5e)

Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 77.1 mg, yield: 86%, colorless oil.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.54 – 7.50 (m, 2H), 7.45 – 7.40 (m, 4H), 7.30 – 7.21 (m, 7H), 6.31 – 6.20 (m, 1H), 6.18 – 6.07 (m, 1H), 3.80 – 3.71 (m, 4H), 3.25 – 3.11 (m, 2H), 2.89 – 2.78 (m, 1H), 2.78 – 2.56 (m, 4H).

^{13}C NMR (101 MHz, Chloroform-*d*) δ 139.8, 138.8, 137.6, 136.7, 133.3, 131.8, 130.1, 128.5, 128.4, 127.5, 126.6, 126.3, 121.2, 69.7, 67.3, 50.5, 38.1.

HRMS (ESI) *m/z* calcd. for $C_{26}H_{27}BrNO$ $[M+H]^+$448.1271, found:448.1271.



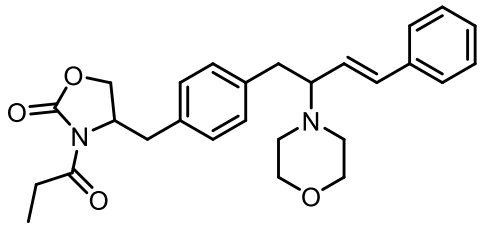
(*E*)-4-(1-(benzo[d][1,3]dioxol-5-yl)-4-phenylbut-3-en-2-yl)morpholine (5f)

Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 43.9 mg, yield: 65%, colorless oil.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.32 – 7.26 (m, 4H), 7.23 – 7.19 (m, 1H), 6.71 – 6.64 (m, 2H), 6.60 (dd, *J* = 7.9, 1.6 Hz, 1H), 6.28 – 6.21 (m, 1H), 6.10 – 6.03 (m, 1H), 5.88 (q, *J* = 1.5 Hz, 2H), 3.75 – 3.70 (m, 4H), 3.14 – 3.01 (m, 2H), 2.71 – 2.59 (m, 5H).

^{13}C NMR (101 MHz, Chloroform-*d*) δ 147.3, 145.7, 136.8, 133.2, 132.8, 128.5, 128.4, 127.4, 126.2, 122.3, 109.7, 107.9, 100.7, 69.8, 67.2, 50.5, 38.1.

HRMS (ESI) *m/z* calcd. for $C_{21}H_{24}NO_3$ $[M+H]^+$338.1751, found:338.1755.



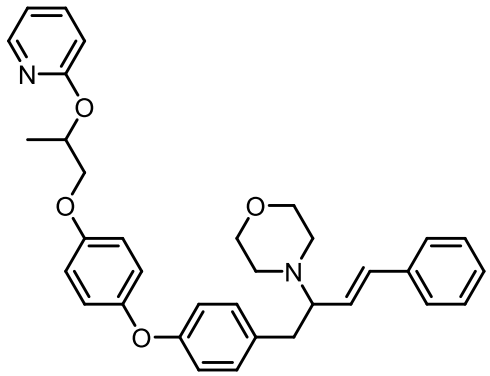
(*E*)-4-(4-(2-morpholino-4-phenylbut-3-en-1-yl)benzyl)-3-propionyloxazolidin-2-one (5g)

Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 49.4 mg, yield: 55%, colorless oil.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.28 – 7.24 (m, 4H), 7.23 – 7.19 (m, 1H), 7.13 (d, *J* = 7.9 Hz, 2H), 7.06 (dd, *J* = 8.1, 2.1 Hz, 2H), 6.21 – 6.12 (m, 1H), 6.10 – 6.02 (m, 1H), 4.64 – 4.56 (m, 1H), 4.11 – 4.04 (m, 2H), 3.78 – 3.68 (m, 4H), 3.24 – 3.18 (m, 1H), 3.17 – 3.07 (m, 2H), 2.96 – 2.86 (m, 2H), 2.78 – 2.59 (m, 6H), 1.21 – 1.14 (m, 3H).

^{13}C NMR (101 MHz, Chloroform-*d*) δ 174.0, 174.0, 153.4, 153.4, 138.3, 136.7, 136.7, 133.2, 132.8, 132.8, 130.0, 129.1, 129.1, 128.4, 128.4, 127.5, 127.4, 126.2, 69.7, 69.7, 67.2, 66.1, 66.0, 55.0, 55.0, 50.5, 38.0, 38.0, 37.4, 37.4, 29.1, 29.1, 8.2, 8.2.

HRMS (ESI) *m/z* calcd. for $C_{27}H_{33}N_2O_4$ $[M+H]^+$449.2435, found:449.2429.



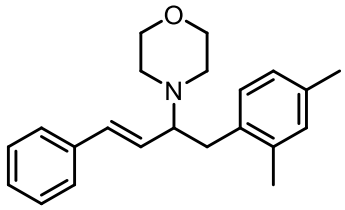
(*E*)-4-(4-phenyl-1-(4-(4-(2-(pyridin-2-yloxy)propoxy)phenoxy)phenyl)but-3-en-2-yl)morpholine (5h)

Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 78.3 mg, yield: 73%, colorless oil.

^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.14 (s, 1H), 7.55 (s, 1H), 7.27 (s, 4H), 7.10 – 7.05 (m, 2H), 6.87 (s, 5H), 6.83 – 6.79 (m, 2H), 6.73 (d, *J* = 8.3 Hz, 1H), 6.24 – 6.16 (m, 1H), 6.10 – 6.03 (m, 1H), 5.58 (s, 1H), 4.18 – 4.14 (m, 1H), 4.07 – 4.02 (m, 1H), 3.74 (s, 4H), 3.15 – 3.06 (m, 2H), 2.74 – 2.60 (m, 5H), 1.59 – 1.36 (m, 4H).

^{13}C NMR (151 MHz, Chloroform-*d*) δ 163.2, 156.6, 155.0, 150.6, 146.8, 138.7, 136.8, 133.3, 130.6, 128.5, 127.5, 126.3, 120.4, 117.6, 116.8, 115.7, 111.7, 71.0, 70.0, 69.3, 67.3, 50.6, 37.7, 17.0.

HRMS (ESI) *m/z* calcd. for $C_{34}H_{37}N_2O_4$ $[M+H]^+$537.2748, found:537.2736

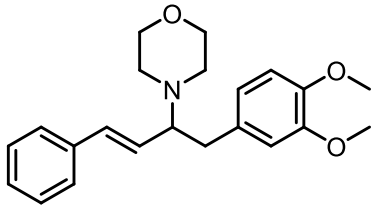


(*E*)-4-(1-(2,4-dimethylphenyl)-4-phenylbut-3-en-2-yl)morpholine (5i)

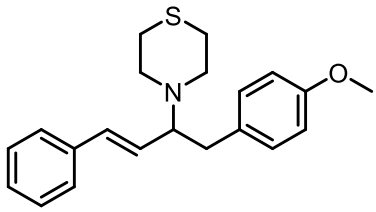
Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 21.9 mg, yield: 34%, colorless oil.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.27 – 7.24 (m, 4H), 7.22 – 7.20 (m, 1H), 6.99 (d, *J* = 7.6 Hz, 1H), 6.91 (s, 1H), 6.87 (d, *J* = 7.6 Hz, 1H), 6.16 – 6.09 (m, 2H), 3.75 (t, *J* = 4.7 Hz, 4H), 3.15 – 3.08 (m, 2H), 2.73 – 2.63 (m, 5H), 2.28 – 2.26 (m, 3H), 2.26 – 2.23 (m, 3H).

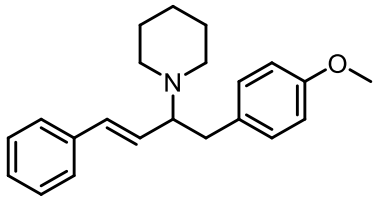
^{13}C NMR (101 MHz, Chloroform-*d*) δ 136.8, 135.9, 135.5, 134.1, 132.8, 130.9, 130.4, 128.7, 128.4, 127.3, 126.3, 126.2, 69.2, 67.2, 50.7, 34.9, 20.9, 19.7.
HRMS (ESI) *m/z* calcd. for $C_{22}H_{28}NO$ $[M+H]^+$322.2165, found:322.2160



(*E*)-4-(1-(3,4-dimethoxyphenyl)-4-phenylbut-3-en-2-yl)morpholine (5j)
Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 57.3 mg, yield: 81%, colorless oil.
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.29 – 7.26 (m, 4H), 7.23 – 7.19 (m, 1H), 6.75 – 6.69 (m, 3H), 6.24 – 6.18 (m, 1H), 6.14 – 6.07 (m, 1H), 3.82 (s, 3H), 3.77 (s, 3H), 3.76 – 3.72 (m, 4H), 3.16 – 3.04 (m, 2H), 2.74 – 2.68 (m, 3H), 2.66 – 2.60 (m, 2H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 148.3, 147.1, 136.7, 133.1, 131.5, 128.4, 128.4, 127.3, 126.1, 121.4, 112.7, 110.7, 69.9, 67.2, 55.7, 55.6, 50.4, 38.0.
HRMS (ESI) *m/z* calcd. for $C_{22}H_{28}NO_3$ $[M+H]^+$354.2064, found:354.2075



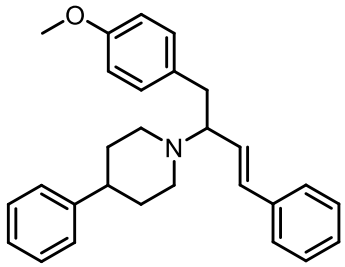
(*E*)-4-(1-(4-methoxyphenyl)-4-phenylbut-3-en-2-yl)thiomorpholine (6a)
Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 44.2 mg, yield: 65%, colorless oil.
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.31 – 7.26 (m, 4H), 7.23 – 7.19 (m, 1H), 7.11 – 7.06 (m, 2H), 6.81 – 6.76 (m, 2H), 6.31 – 6.23 (m, 1H), 6.18 – 6.10 (m, 1H), 3.77 – 3.74 (m, 3H), 3.26 – 3.19 (m, 1H), 3.02 – 2.95 (m, 3H), 2.88 – 2.82 (m, 2H), 2.77 – 2.64 (m, 5H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 157.8, 136.9, 132.7, 131.4, 130.2, 128.4, 128.1, 127.3, 126.2, 113.5, 70.3, 55.1, 51.9, 37.3, 28.4.
HRMS (ESI) *m/z* calcd. for $C_{21}H_{26}NOS$ $[M+H]^+$340.1730, found:340.1718



(*E*)-1-(1-(4-methoxyphenyl)-4-phenylbut-3-en-2-yl)piperidine (6b)
Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 40.5 mg, yield: 63%, colorless oil.
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.30 – 7.25 (m, 4H), 7.21 – 7.18 (m, 1H), 7.08 (d, *J* = 8.2 Hz, 2H), 6.79 – 6.74 (m, 2H), 6.18 – 6.11 (m, 2H), 3.76 – 3.70 (m, 3H), 3.16 – 3.04 (m, 2H), 2.77 – 2.69 (m, 1H), 2.68 – 2.50 (m, 4H), 1.64 – 1.56 (m, 4H), 1.46 – 1.40 (m, 2H).

^{13}C NMR (101 MHz, Chloroform-*d*) δ 157.6, 137.1, 132.5, 131.8, 130.4, 129.0, 128.4, 127.1, 126.2, 113.4, 70.2, 55.1, 50.9, 37.9, 26.4, 24.7.

HRMS (ESI) *m/z* calcd. for $C_{22}H_{28}NO$ $[M+H]^+$322.2165, found:322.2162



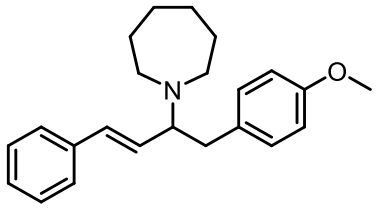
(*E*)-1-(1-(4-methoxyphenyl)-4-phenylbut-3-en-2-yl)-4-phenylpiperidine (6c)

Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 59.7 mg, yield: 75%, colorless oil.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.32 – 7.26 (m, 6H), 7.23 – 7.16 (m, 4H), 7.11 – 7.08 (m, 2H), 6.79 – 6.76 (m, 2H), 6.21 – 6.14 (m, 2H), 3.74 – 3.71 (m, 3H), 3.25 – 3.18 (m, 2H), 3.13 – 3.06 (m, 2H), 2.81 – 2.73 (m, 1H), 2.49 – 2.31 (m, 3H), 1.89 – 1.77 (m, 4H).

^{13}C NMR (101 MHz, Chloroform-*d*) δ 157.7, 146.4, 137.0, 132.8, 131.6, 130.3, 128.7, 128.4, 128.3, 127.2, 126.8, 126.2, 126.0, 113.4, 69.9, 55.1, 52.1, 49.2, 42.9, 38.1, 33.8, 33.8.

HRMS (ESI) *m/z* calcd. For $C_{28}H_{32}NO$ $[M+H]^+$398.2478, found:398.2468.



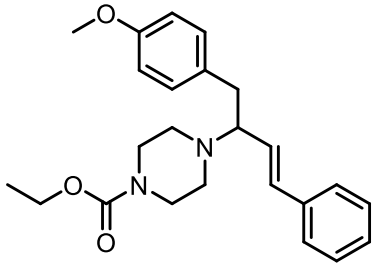
(*E*)-1-(1-(4-methoxyphenyl)-4-phenylbut-3-en-2-yl)azepane (6d)

Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 38.3 mg, yield: 57%, colorless oil.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.30 – 7.27 (m, 3H), 7.22 – 7.17 (m, 1H), 7.14 – 7.08 (m, 2H), 6.82 – 6.72 (m, 2H), 6.28 – 6.21 (m, 1H), 6.20 – 6.13 (m, 1H), 3.78 – 3.73 (m, 3H), 3.40 – 3.31 (m, 1H), 3.02 (dd, *J* = 13.6, 5.1 Hz, 1H), 2.87 – 2.78 (m, 2H), 2.75 – 2.65 (m, 3H), 1.67 – 1.54 (m, 8H).

^{13}C NMR (101 MHz, Chloroform-*d*) δ 157.7, 137.3, 132.0, 131.7, 130.3, 129.3, 128.4, 127.1, 126.2, 113.4, 69.6, 55.1, 52.0, 38.2, 29.3, 27.0.

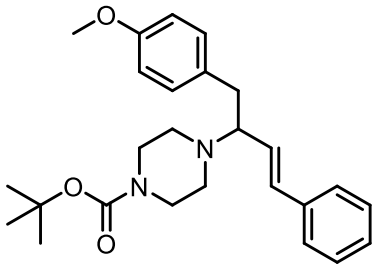
HRMS (ESI) *m/z* calcd. for $C_{23}H_{30}NO$ $[M+H]^+$336.2322, found:336.2313



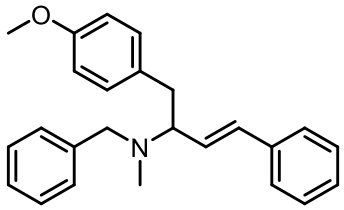
ethyl (*E*)-4-(1-(4-methoxyphenyl)-4-phenylbut-3-en-2-yl)piperazine-1-carboxylate (6e)

Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 39.5 mg, yield: 50%, colorless oil.

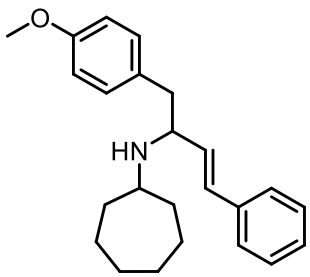
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.30 – 7.25 (m, 4H), 7.23 – 7.18 (m, 1H), 7.08 (d, *J* = 8.6 Hz, 2H), 6.78 (d, *J* = 8.6 Hz, 2H), 6.25 – 6.18 (m, 1H), 6.13 – 6.04 (m, 1H), 4.12 (q, *J* = 7.1 Hz, 2H), 3.75 (s, 3H), 3.52 – 3.46 (m, 3H), 3.23 – 3.16 (m, 1H), 3.04 (dd, *J* = 13.5, 4.8 Hz, 1H), 2.76 – 2.71 (m, 1H), 2.70 – 2.51 (m, 4H), 1.33 – 1.14 (m, 4H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 157.8, 155.3, 136.7, 133.1, 131.1, 130.3, 128.4, 128.1, 127.4, 126.2, 113.5, 69.5, 61.2, 55.1, 37.7, 14.6.
HRMS (ESI) *m/z* calcd. For $C_{24}H_{31}N_2O_3$ $[M+H]^+$395.2329, found:395.2321



***tert*-butyl (*E*)-4-(1-(4-methoxyphenyl)-4-phenylbut-3-en-2-yl)piperazine-1-carboxylate (6f)**
Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 42.3 mg, yield: 50%, colorless oil.
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.29 – 7.25 (m, 4H), 7.23 – 7.19 (m, 1H), 7.10 – 7.06 (m, 2H), 6.80 – 6.76 (m, 2H), 6.25 – 6.17 (m, 1H), 6.14 – 6.02 (m, 1H), 3.78 – 3.74 (m, 3H), 3.50 – 3.39 (m, 4H), 3.22 – 3.15 (m, 1H), 3.04 (dd, *J* = 13.5, 4.6 Hz, 1H), 2.77 – 2.70 (m, 1H), 2.69 – 2.51 (m, 4H), 1.46 – 1.43 (m, 9H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 157.8, 154.6, 136.8, 133.1, 131.2, 130.3, 128.5, 128.2, 127.4, 126.2, 113.5, 79.5, 69.5, 55.1, 49.6, 44.3, 43.4, 37.8, 28.4.
HRMS (ESI) *m/z* calcd. For $C_{26}H_{35}N_2O_3$ $[M+H]^+$423.2642, found:423.2643



(*E*)-N-benzyl-1-(4-methoxyphenyl)-N-methyl-4-phenylbut-3-en-2-amine (6g)
Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 39.4 mg, yield: 55%, colorless oil.
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.37 – 7.31 (m, 3H), 7.31 – 7.28 (m, 2H), 7.27 – 7.25 (m, 2H), 7.24 – 7.21 (m, 2H), 7.21 – 7.16 (m, 1H), 7.09 (d, *J* = 8.3 Hz, 2H), 6.80 (d, *J* = 8.1 Hz, 2H), 6.36 – 6.17 (m, 2H), 3.81 – 3.74 (m, 4H), 3.53 (d, *J* = 13.4 Hz, 1H), 3.42 – 3.34 (m, 1H), 3.06 (dd, *J* = 13.6, 6.0 Hz, 1H), 2.80 (dd, *J* = 13.6, 8.3 Hz, 1H), 2.29 (s, 3H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 157.7, 139.8, 137.1, 132.8, 131.7, 130.3, 128.7, 128.5, 128.1, 128.0, 127.3, 126.7, 126.3, 113.5, 67.0, 58.2, 55.2, 38.1, 37.7.
HRMS (ESI) *m/z* calcd. For $C_{25}H_{28}NO$ $[M+H]^+$358.2165, found:358.2158



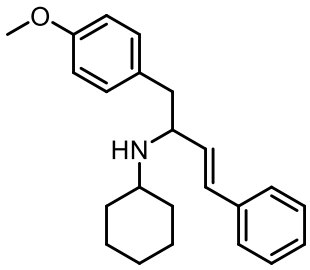
(*E*)-*N*-(1-(4-methoxyphenyl)-4-phenylbut-3-en-2-yl)cycloheptanamine (6h)

Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 45.5 mg, yield: 65%, colorless oil.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.38 – 7.34 (m, 2H), 7.32 – 7.29 (m, 2H), 7.26 – 7.17 (m, 2H), 7.16 – 7.10 (m, 2H), 6.85 – 6.80 (m, 2H), 6.43 – 6.36 (m, 1H), 6.11 – 6.00 (m, 1H), 3.79 – 3.76 (m, 3H), 3.56 – 3.44 (m, 1H), 2.79 – 2.74 (m, 1H), 2.72 – 2.66 (m, 1H), 1.78 – 1.71 (m, 1H), 1.53 – 1.24 (m, 12H).

^{13}C NMR (101 MHz, Chloroform-*d*) δ 158.0, 137.2, 133.5, 130.5, 130.4, 130.3, 128.5, 127.2, 126.2, 113.7, 59.4, 55.3, 55.2, 42.1, 36.4, 33.2, 28.3, 28.1, 24.4, 23.9.

HRMS (ESI) *m/z* calcd. For $C_{24}H_{32}NO$ $[M+H]^+$350.2478, found:350.2473



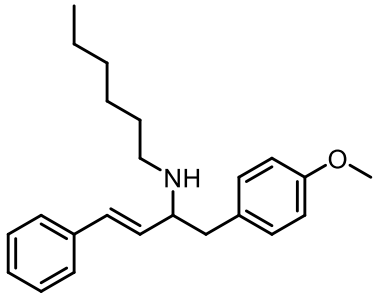
(*E*)-N-(1-(4-methoxyphenyl)-4-phenylbut-3-en-2-yl)cyclohexanamine (6i)

Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine. 44.3 mg, yield: 66%, colorless oil.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.39 – 7.34 (m, 2H), 7.31 (t, *J* = 7.5 Hz, 2H), 7.24 – 7.20 (m, 1H), 7.14 (d, *J* = 8.5 Hz, 2H), 6.86 – 6.81 (m, 2H), 6.46 – 6.37 (m, 1H), 6.13 – 6.04 (m, 1H), 3.79 (s, 3H), 3.63 – 3.57 (m, 1H), 2.83 – 2.70 (m, 2H), 2.49 – 2.41 (m, 1H), 1.83 (dd, *J* = 30.8, 12.6 Hz, 2H), 1.63 – 1.54 (m, 2H), 1.31 – 0.96 (m, 6H), 0.85 – 0.75 (m, 1H).

^{13}C NMR (101 MHz, Chloroform-*d*) δ 158.1, 137.2, 133.6, 130.5, 130.3, 128.5, 127.2, 126.2, 113.7, 59.0, 55.2, 53.4, 42.1, 34.8, 32.8, 26.1, 25.2, 24.9.

HRMS (ESI) *m/z* calcd. For $C_{23}H_{30}NO$ $[M+H]^+$336.2322, found:336.2316.



(*E*)-*N*-(1-(4-methoxyphenyl)-4-phenylbut-3-en-2-yl)hexan-1-amine (6j)

Purified by chromatography on silica gel, eluting with petroleum ether/ethyl acetate/triethylamine.

40.5 mg, yield: 60%, colorless oil.

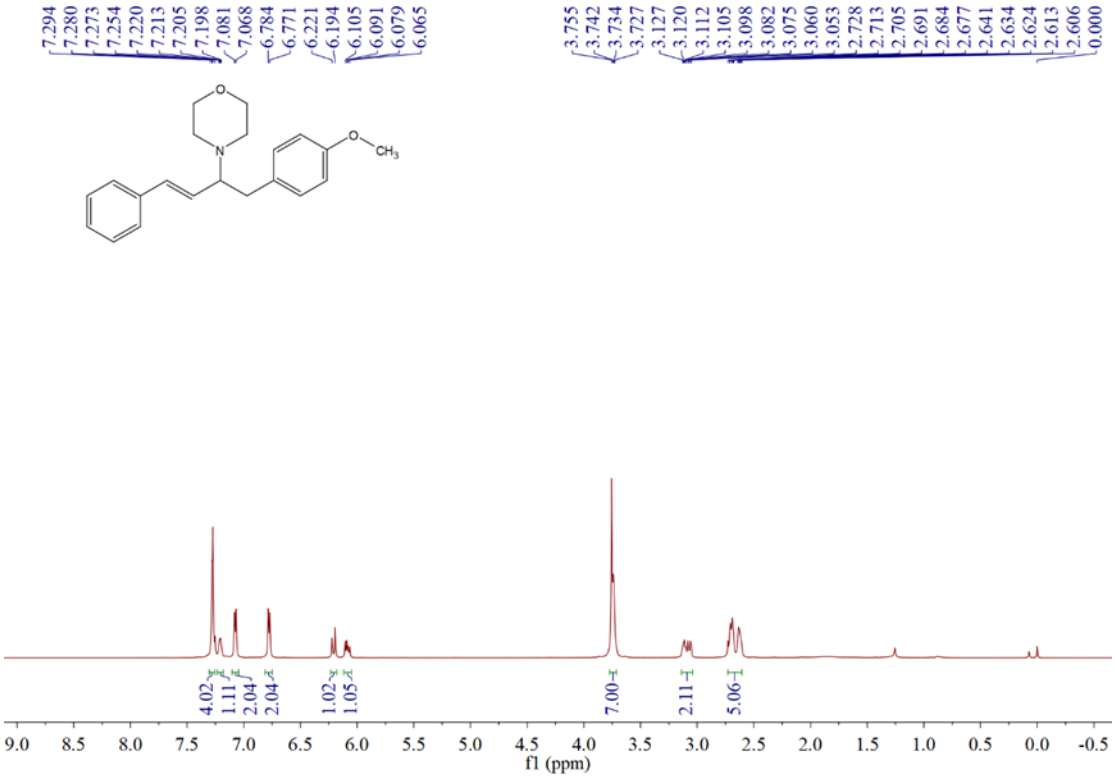
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.39 – 7.35 (m, 2H), 7.31 (t, *J* = 7.5 Hz, 2H), 7.24 – 7.20 (m, 1H), 7.17 – 7.11 (m, 2H), 6.87 – 6.80 (m, 2H), 6.49 – 6.42 (m, 1H), 6.13 – 6.02 (m, 1H), 3.83 – 3.76 (m, 3H), 3.42 – 3.33 (m, 1H), 2.86 – 2.73 (m, 2H), 2.67 – 2.59 (m, 1H), 2.47 – 2.39 (m, 1H), 1.46 – 1.33 (m, 3H), 1.25 – 1.14 (m, 6H), 0.84 (t, *J* = 6.9 Hz, 3H).

^{13}C NMR (101 MHz, Chloroform-*d*) δ 158.1, 137.1, 133.0, 130.8, 130.4, 130.3, 128.5, 127.2, 126.2, 113.8, 62.6, 55.2, 47.7, 41.9, 31.7, 29.9, 26.9, 22.6, 14.0.

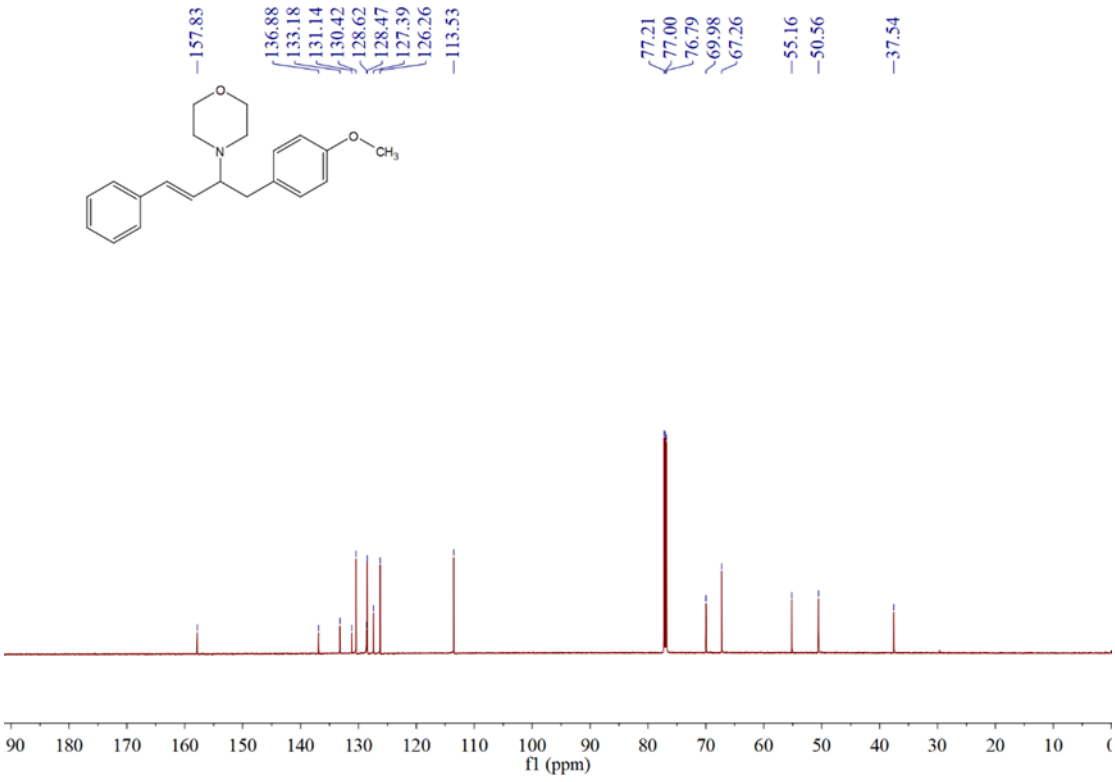
HRMS (ESI) *m/z* calcd. For $C_{23}H_{32}NO$ $[M+H]^{+}$338.2478, found:338.2474.

5 NMR Spectroscopic

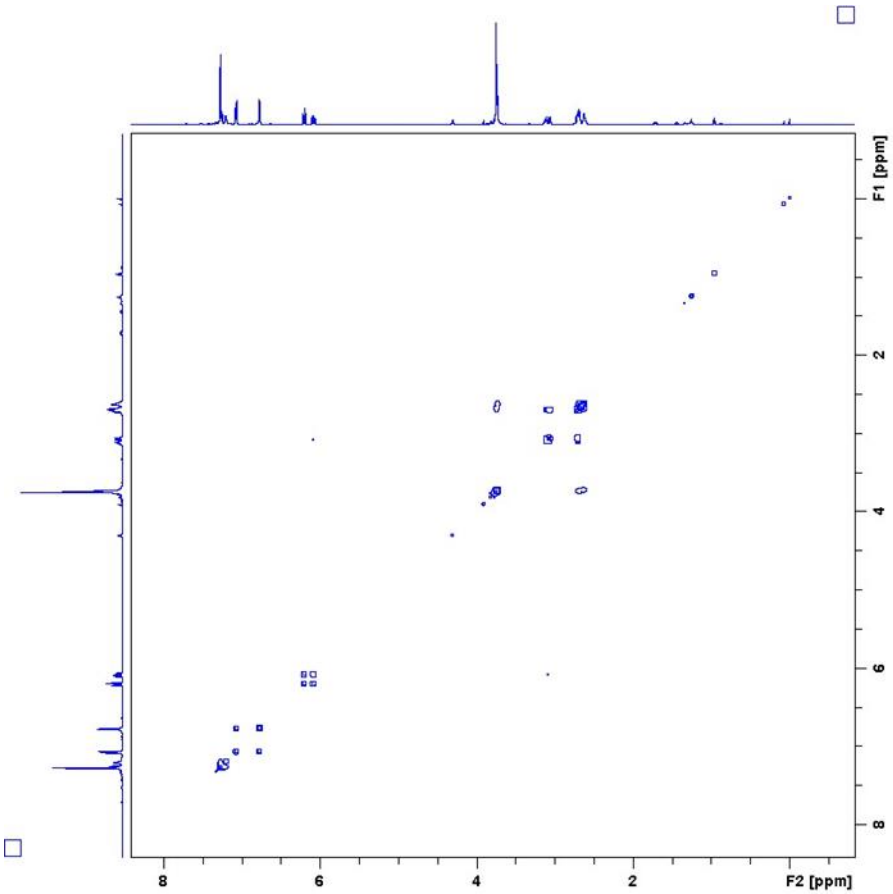
^{1}H NMR (400 MHz, $CDCl_3$) of 4a



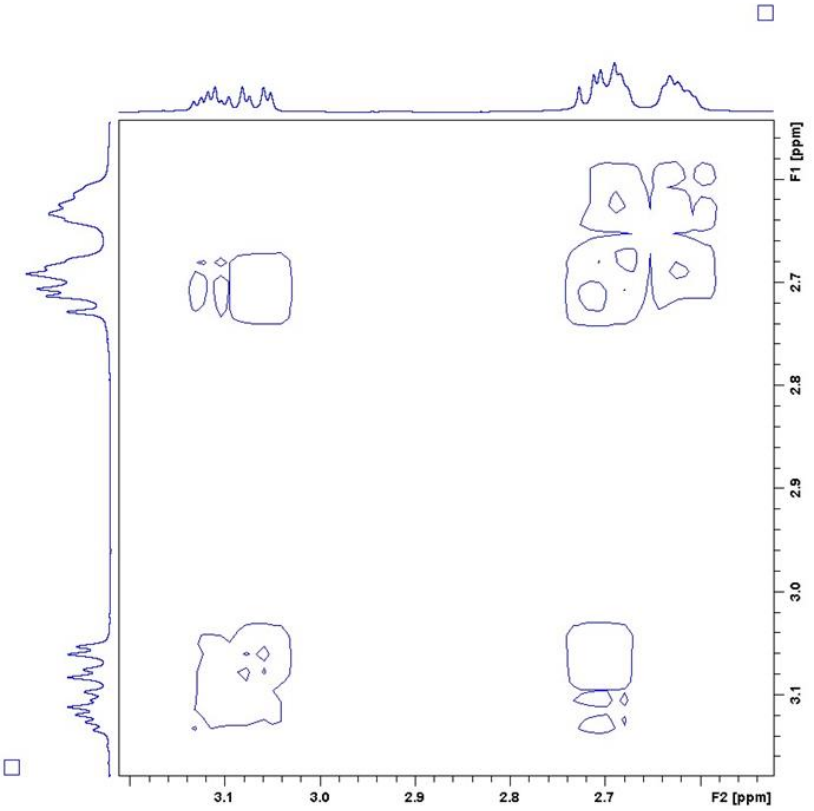
^{13}C NMR (101 MHz, $CDCl_3$) of 4a



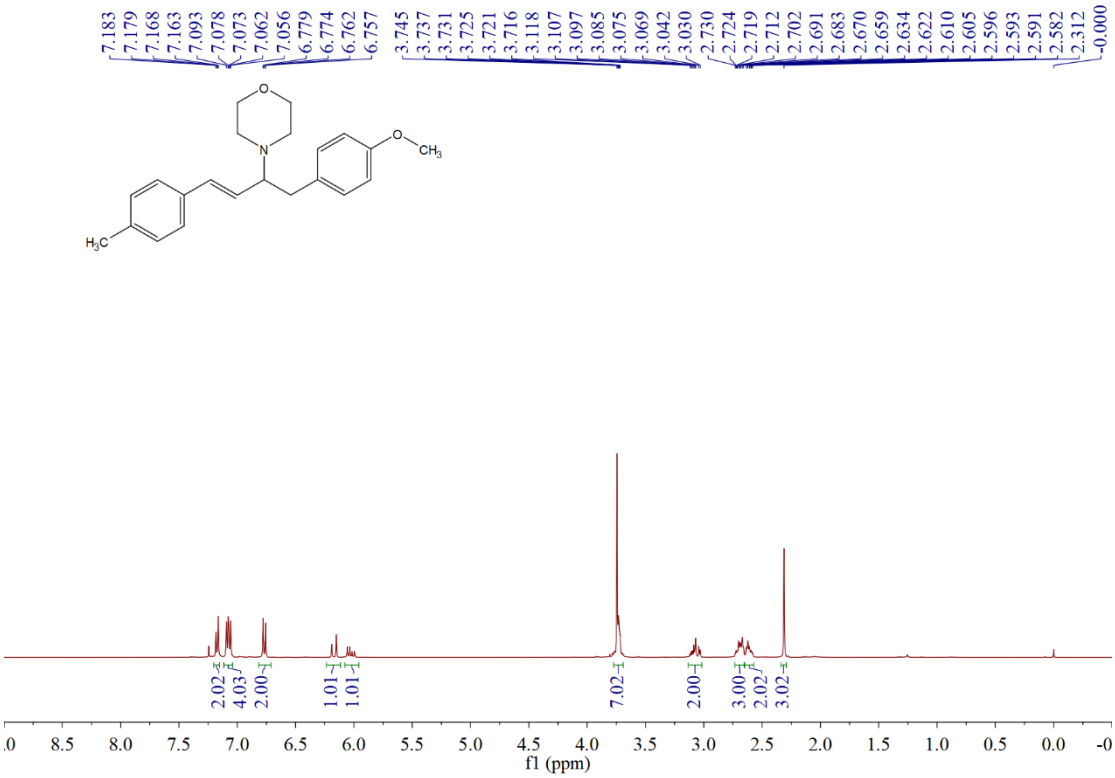
^{1}H-^{1}H COSY NMR of 4a, 600 MHz, $CDCl_3$



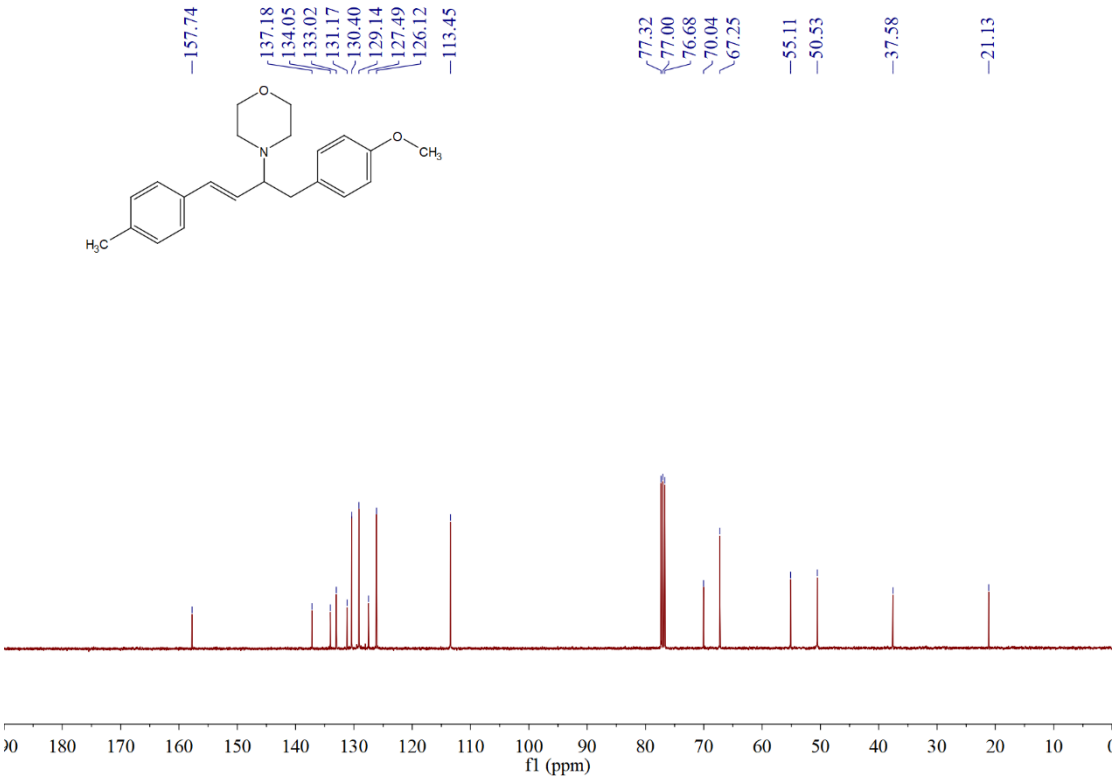
^{1}H-^{1}H COSY NMR of 4a, 600 MHz, $CDCl_3$ -- Expand 1



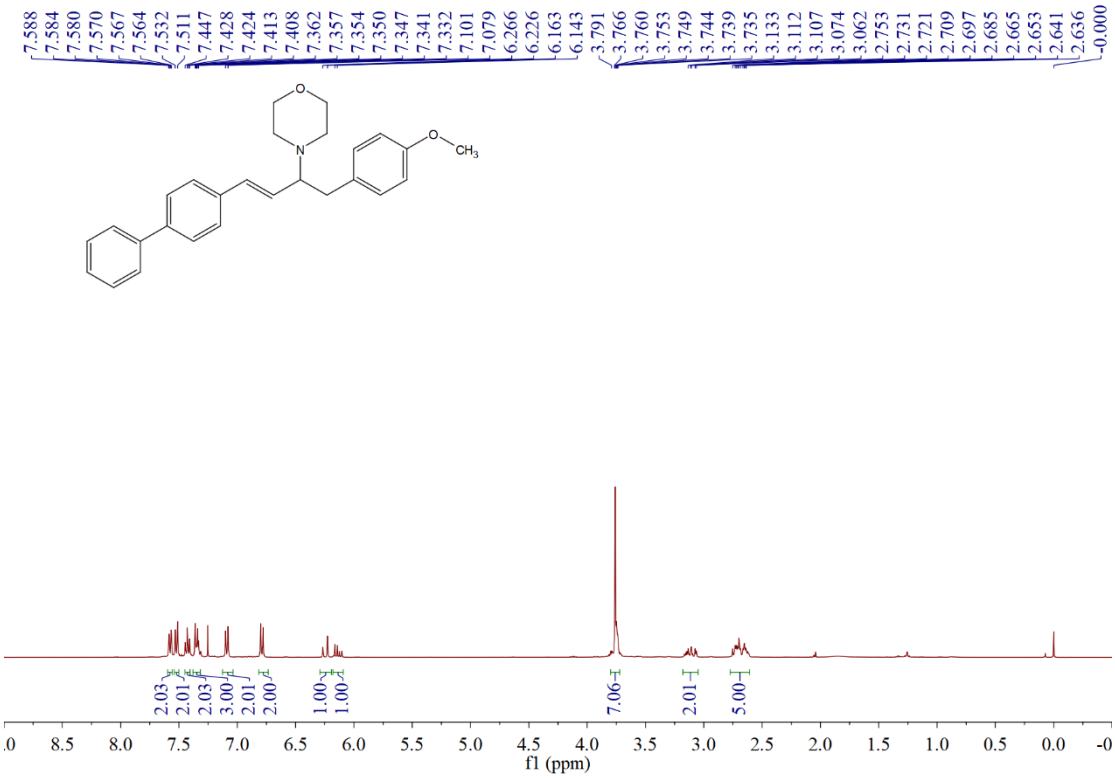
^{1}H NMR (400 MHz, $CDCl_3$) of 4b



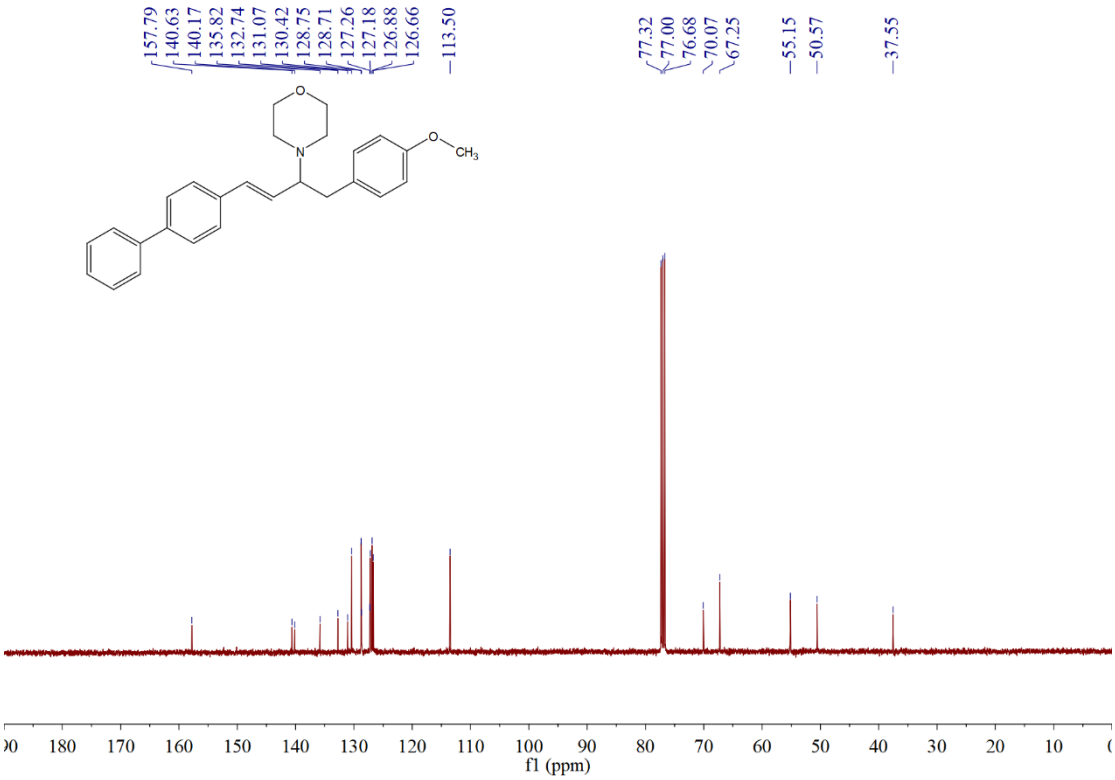
^{13}C NMR (101 MHz, $CDCl_3$) of 4b



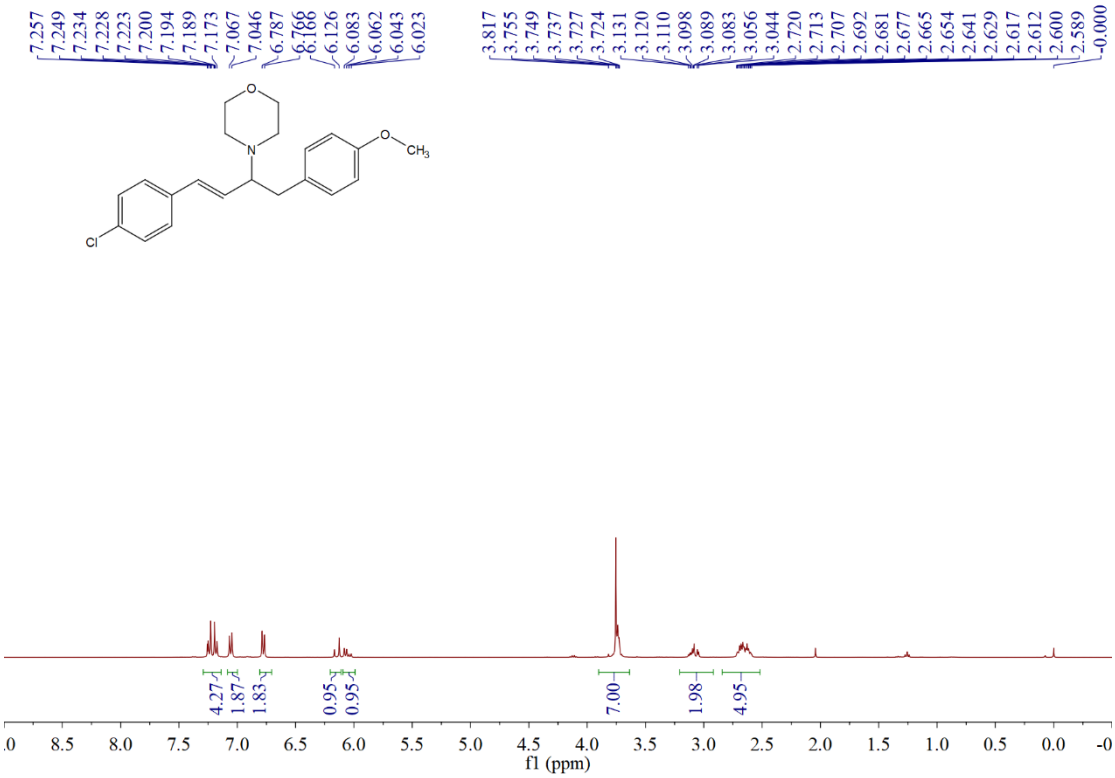
^{1}H NMR (400 MHz, $CDCl_3$) of 4c



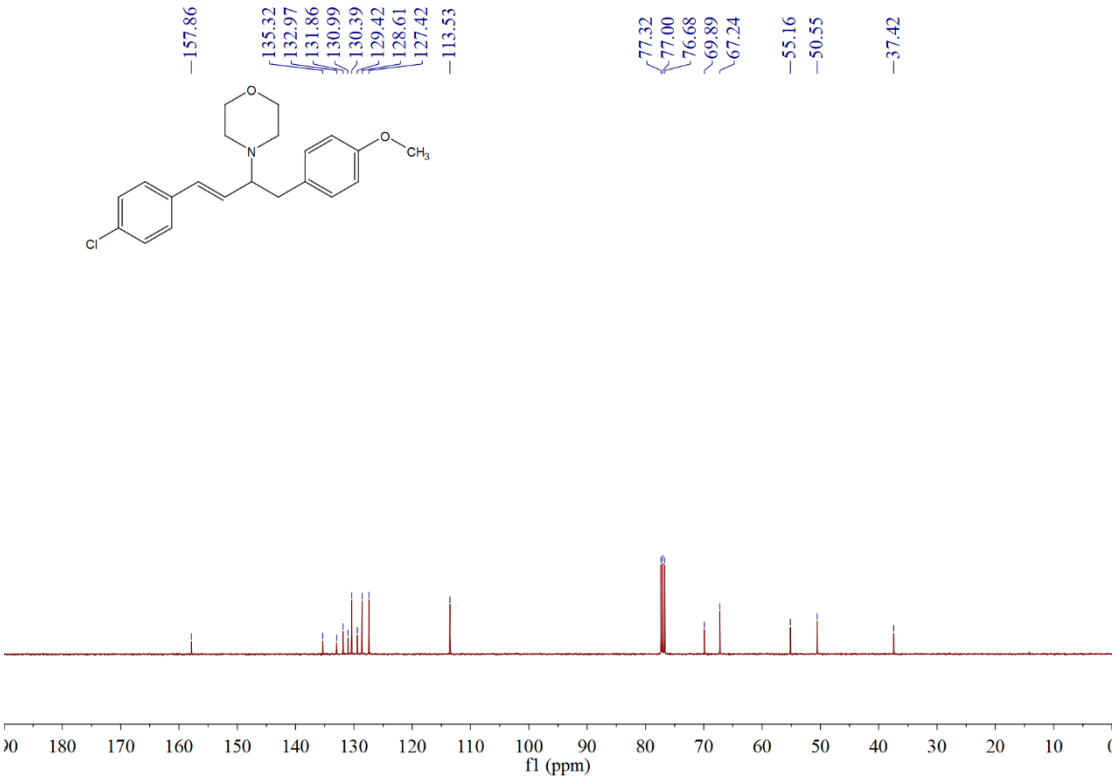
^{13}C NMR (101 MHz, $CDCl_3$) of 4c



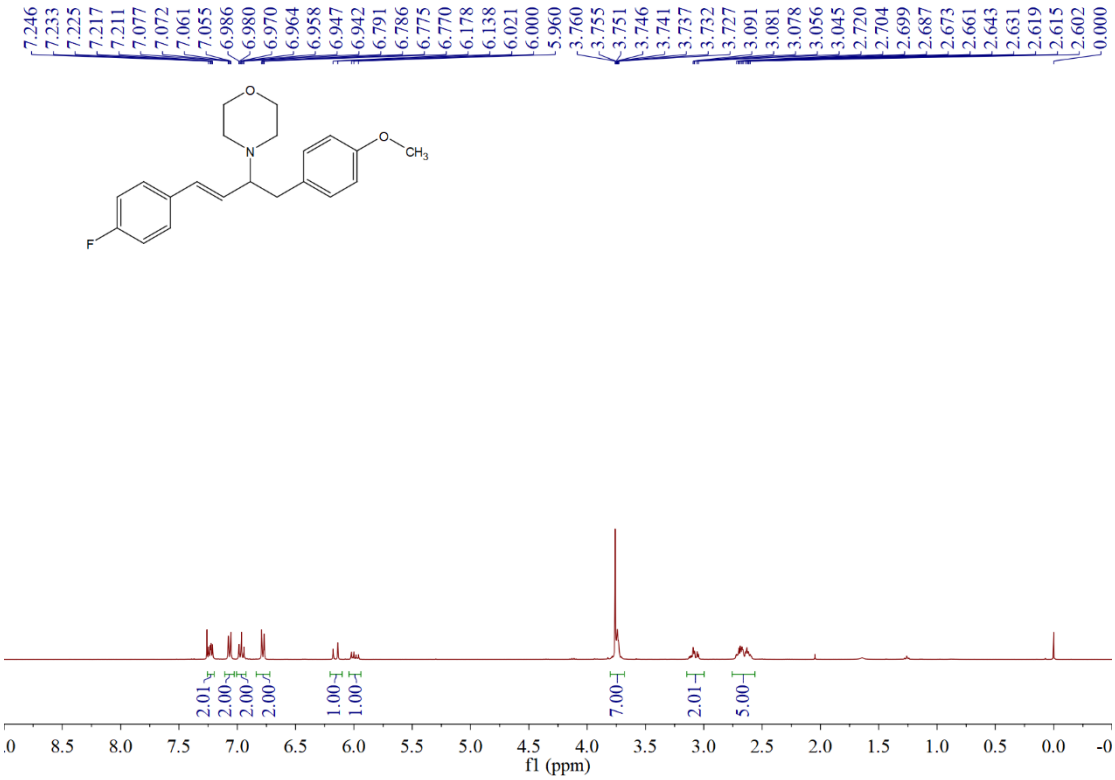
^{1}H NMR (400 MHz, $CDCl_3$) of 4d



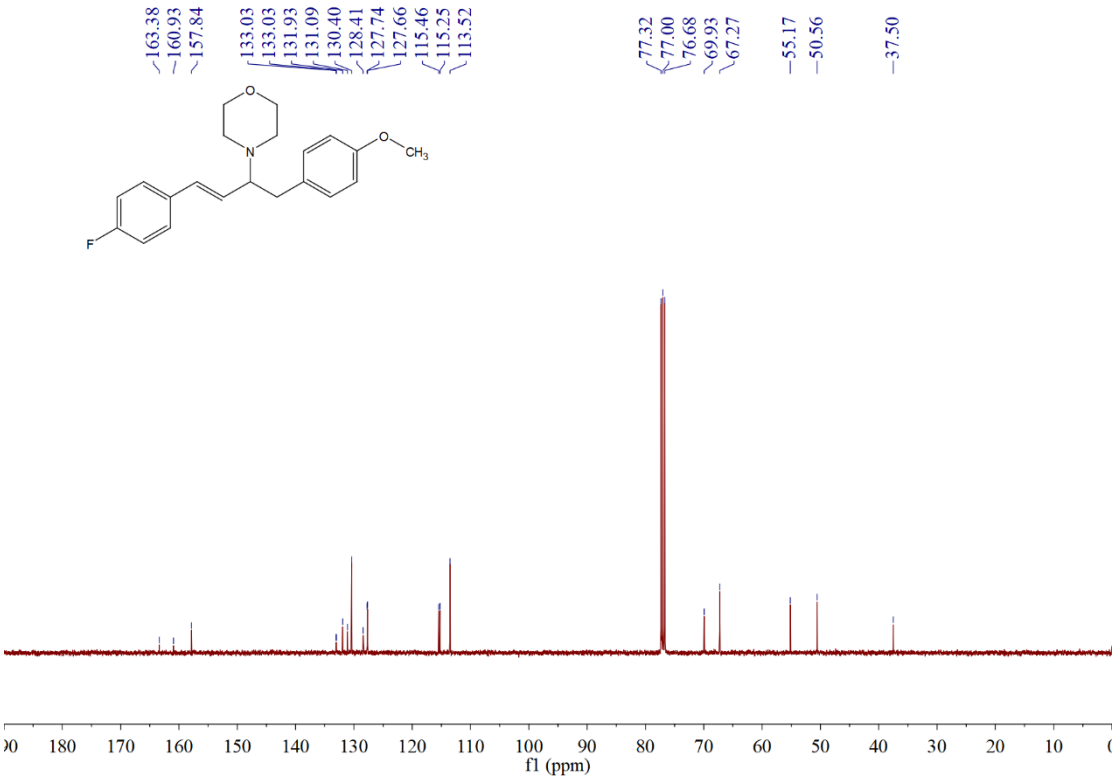
^{13}C NMR (101 MHz, $CDCl_3$) of 4d



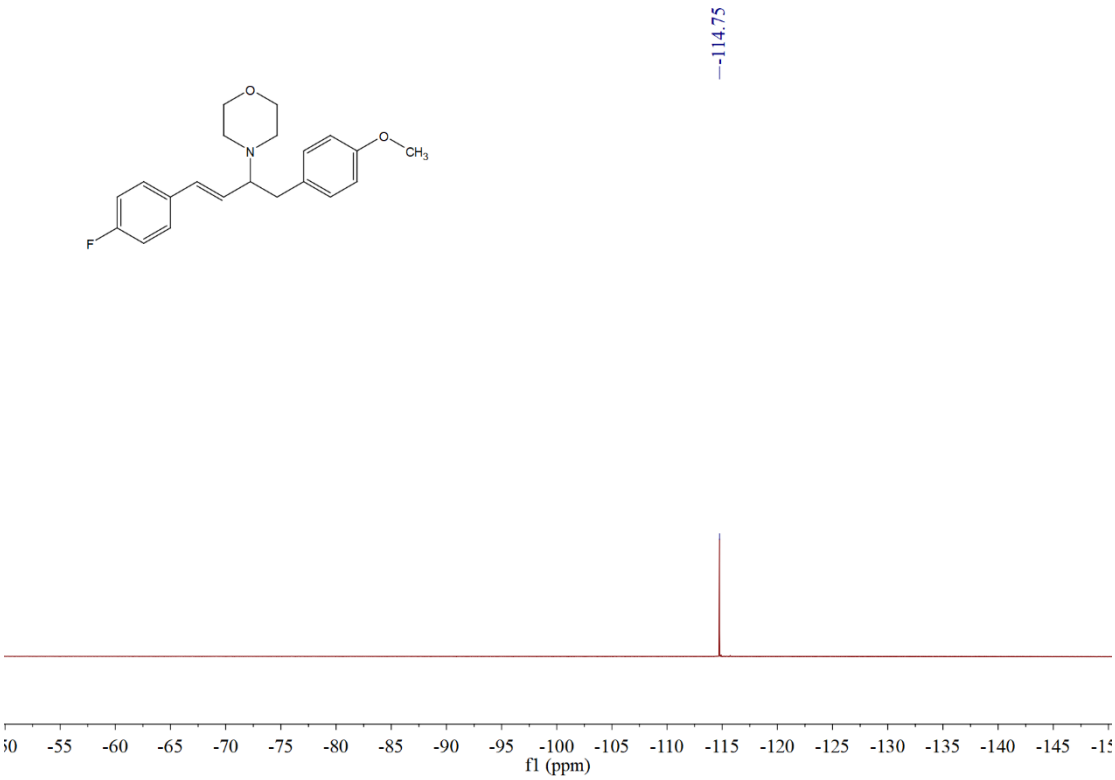
^{1}H NMR (400 MHz, $CDCl_3$) of 4e



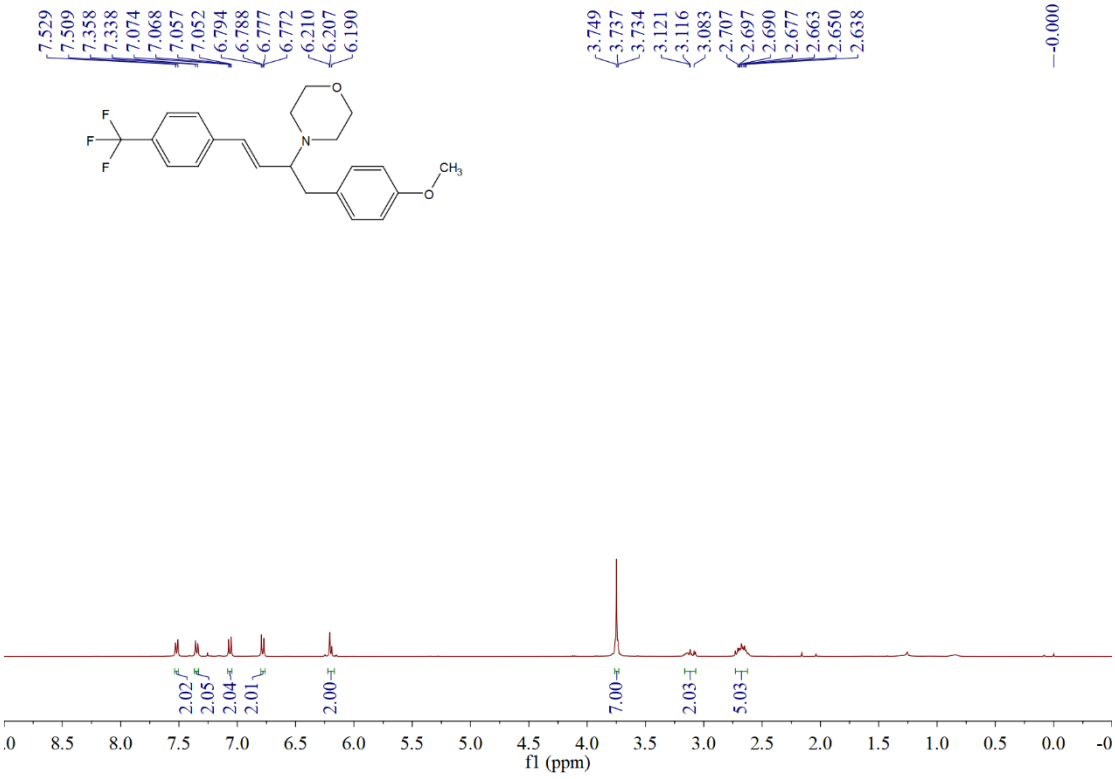
^{13}C NMR (101 MHz, $CDCl_3$) of 4e



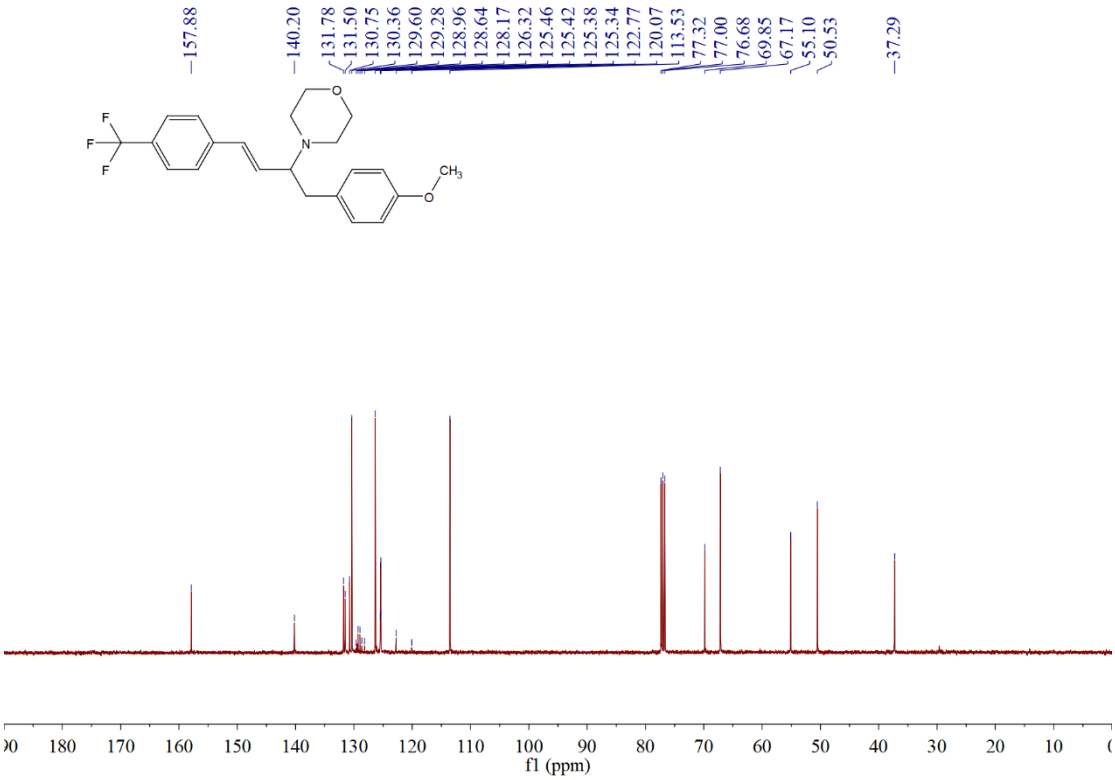
^{19}F NMR (376 MHz, $CDCl_3$) of 4e



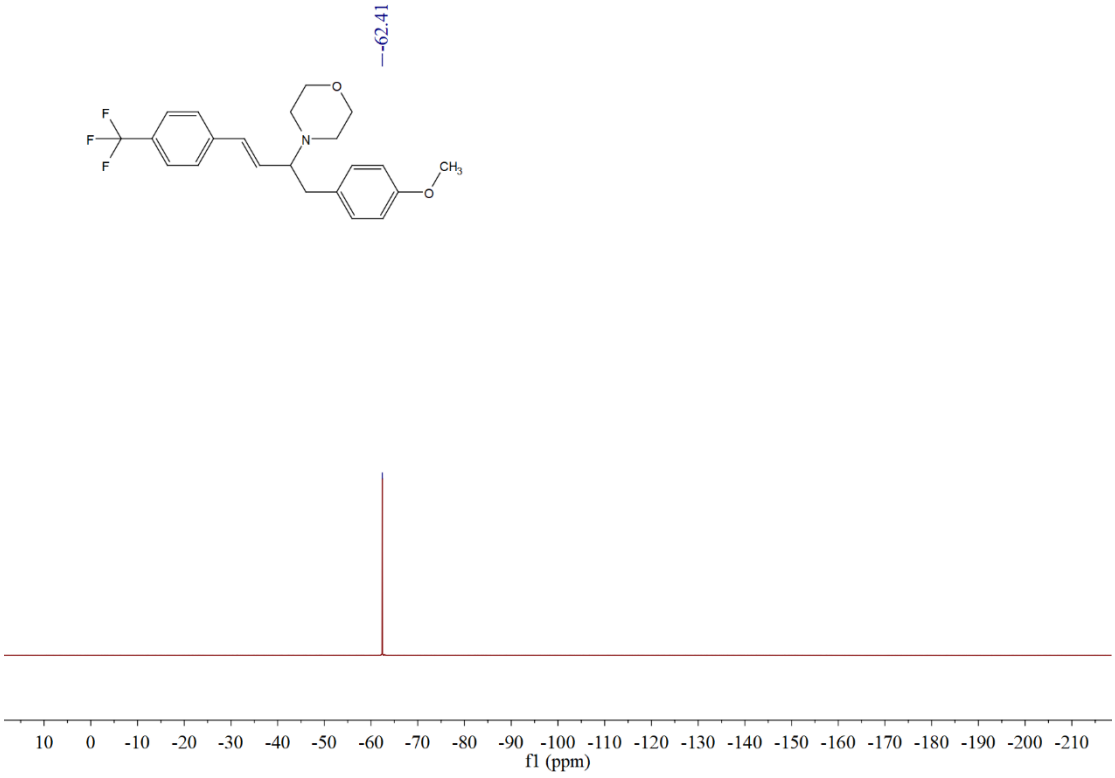
^{1}H NMR (400 MHz, $CDCl_3$) of 4f



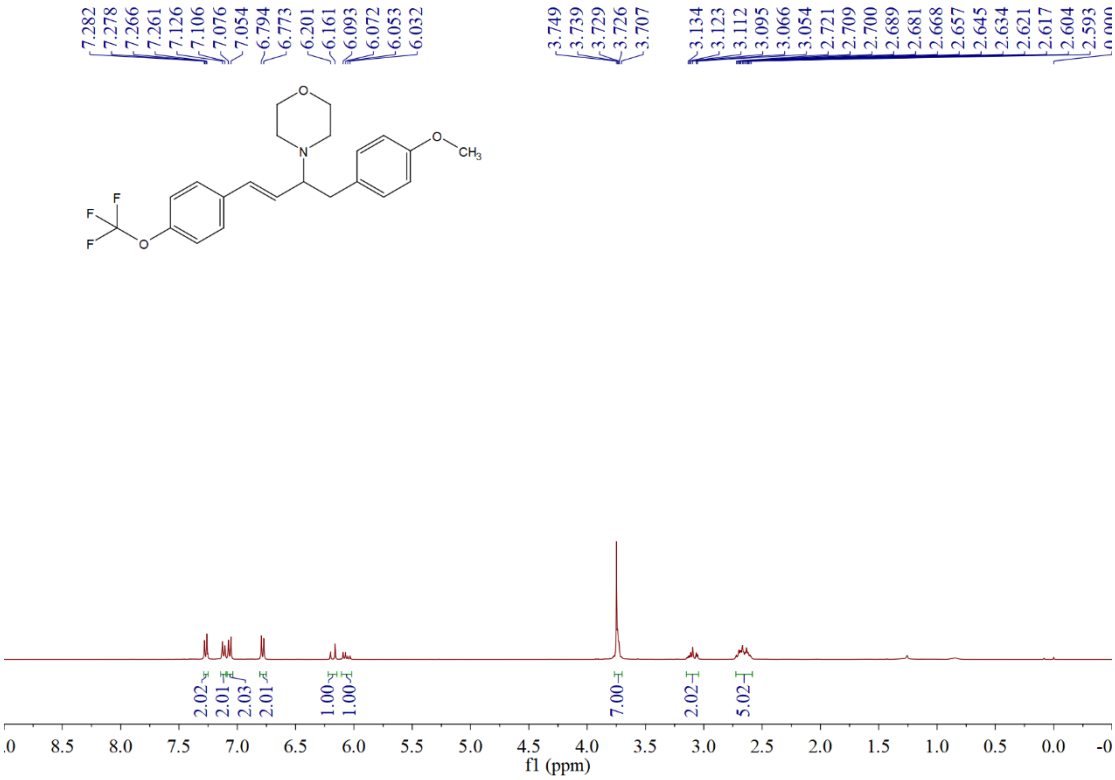
^{13}C NMR (101 MHz, $CDCl_3$) of 4f



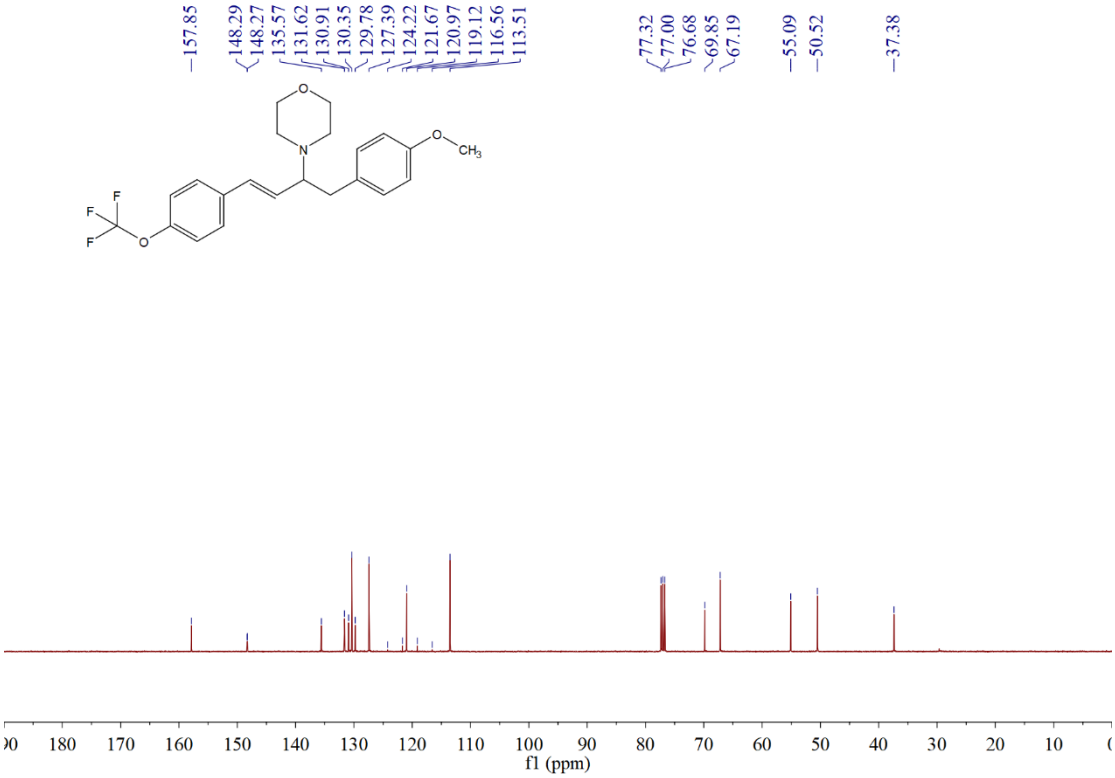
^{19}F NMR (376 MHz, $CDCl_3$) of 4f



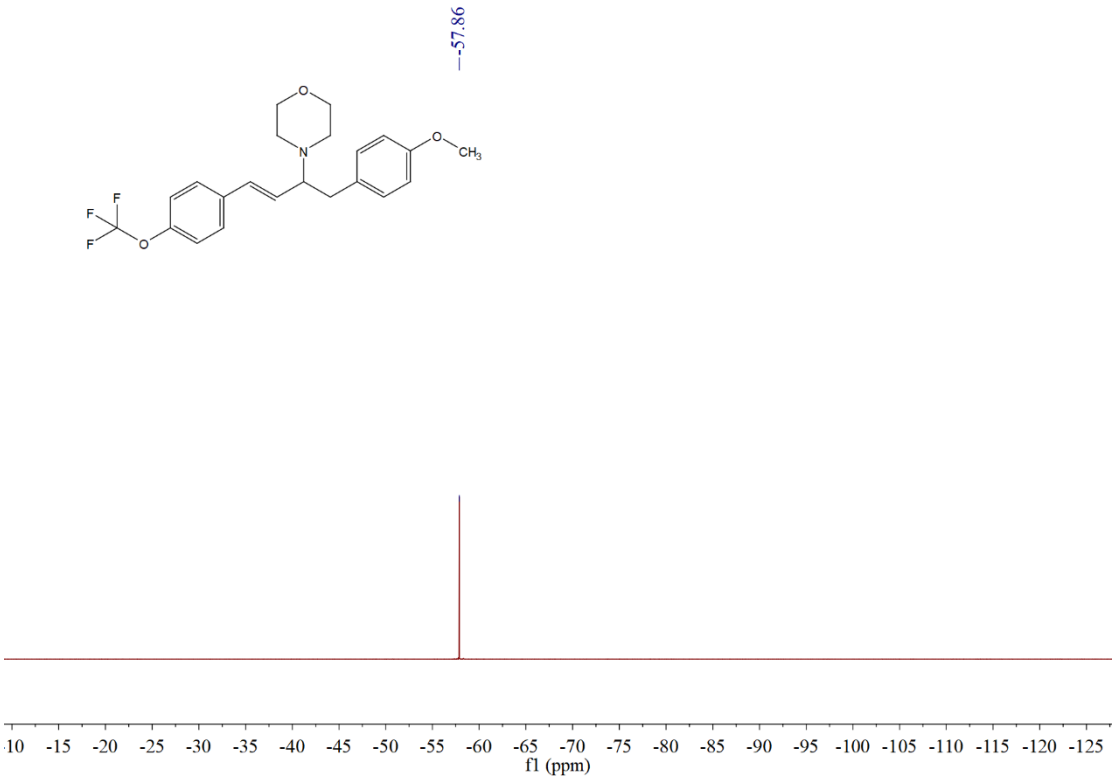
^{1}H NMR (400 MHz, $CDCl_3$) of 4g



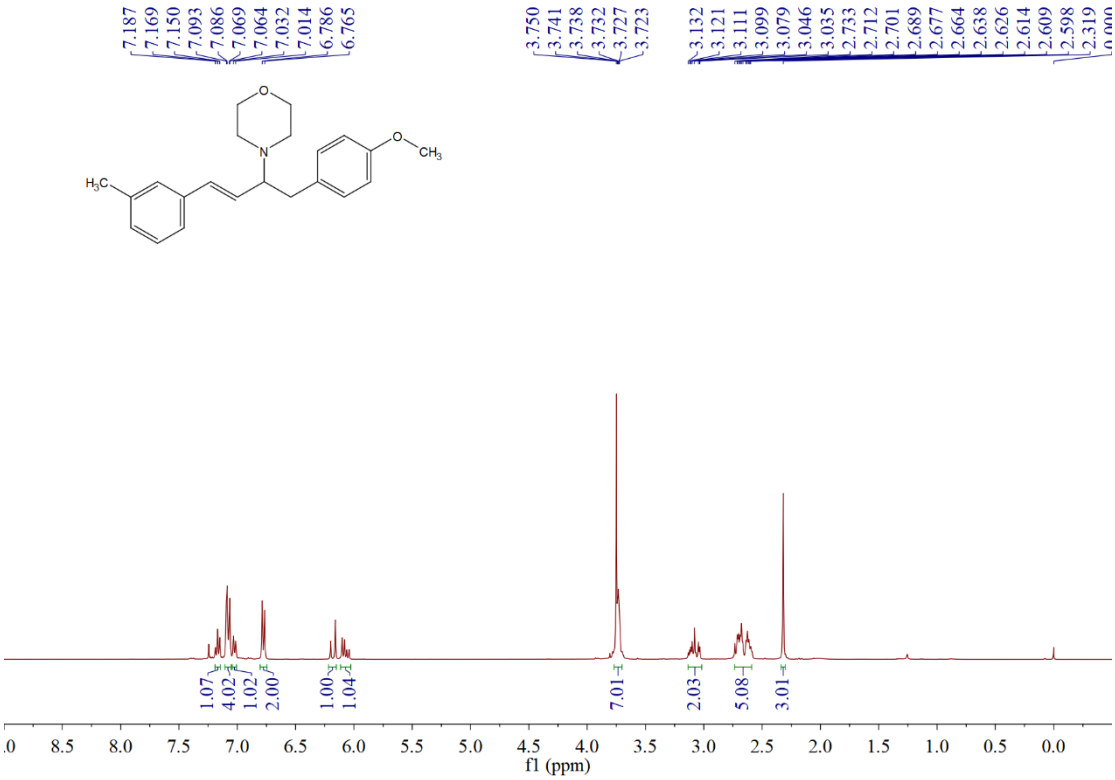
^{13}C NMR (101 MHz, $CDCl_3$) of 4g



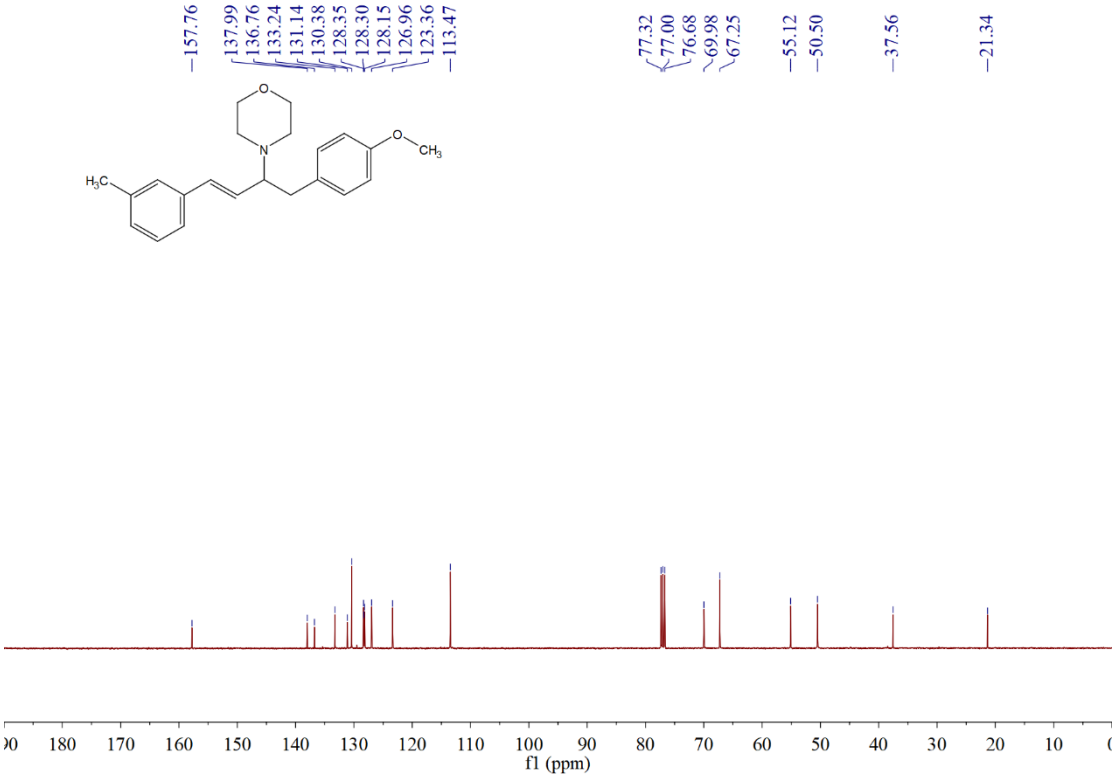
^{19}F NMR (376 MHz, $CDCl_3$) of 4g



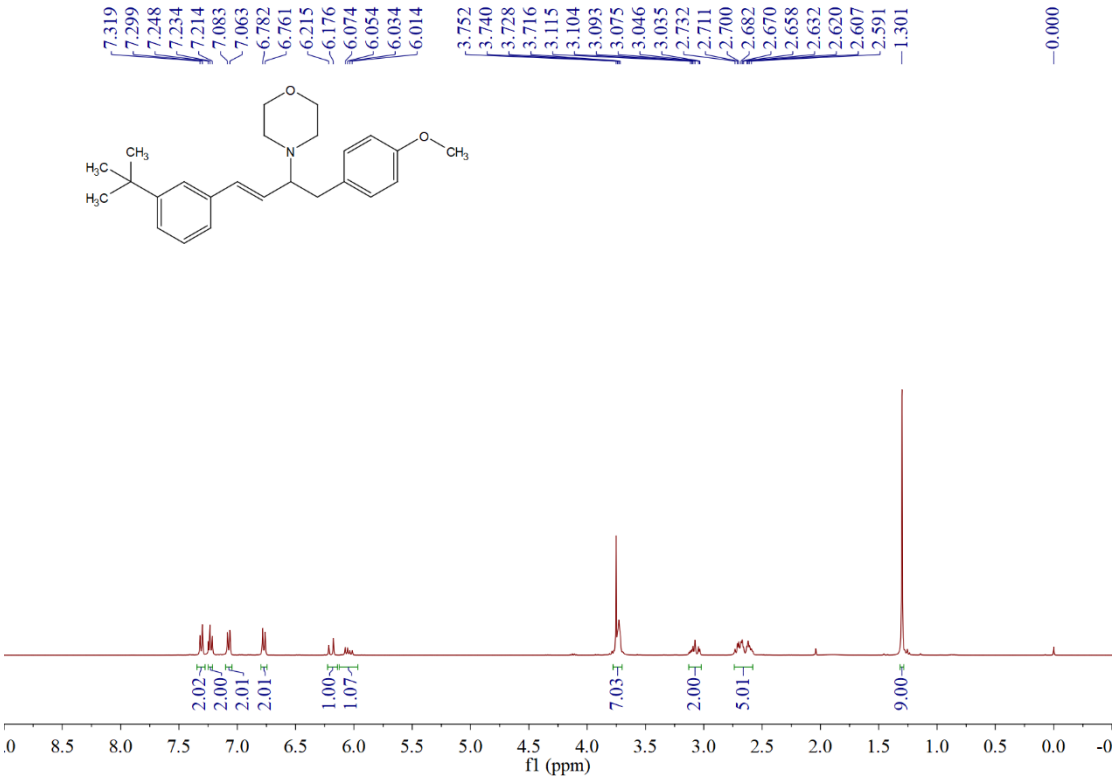
^{1}H NMR (400 MHz, $CDCl_3$) of 4h



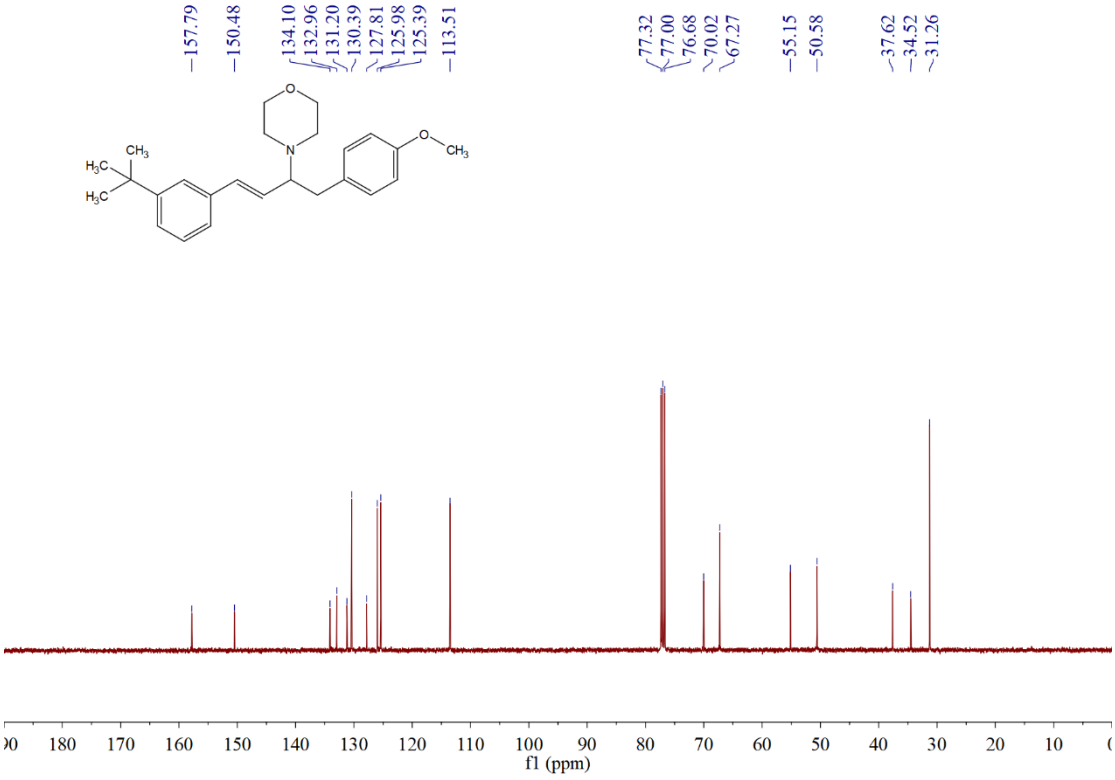
^{13}C NMR (101 MHz, $CDCl_3$) of 4h



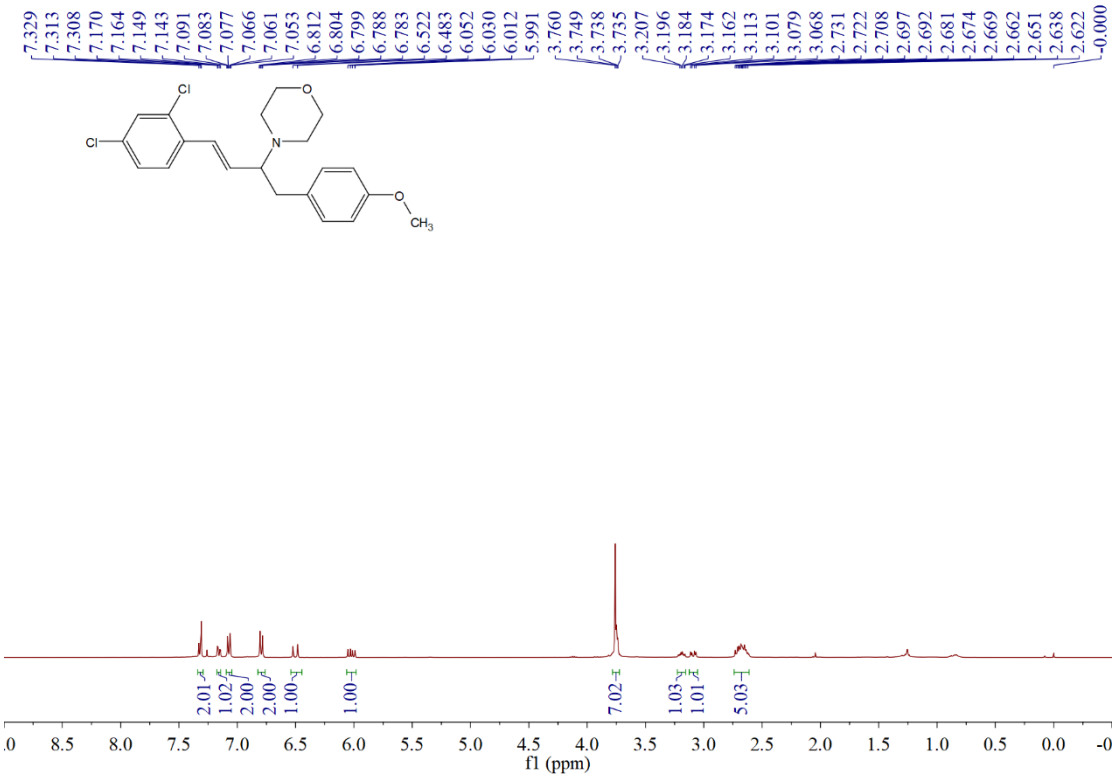
^{1}H NMR (400 MHz, $CDCl_3$) of 4i



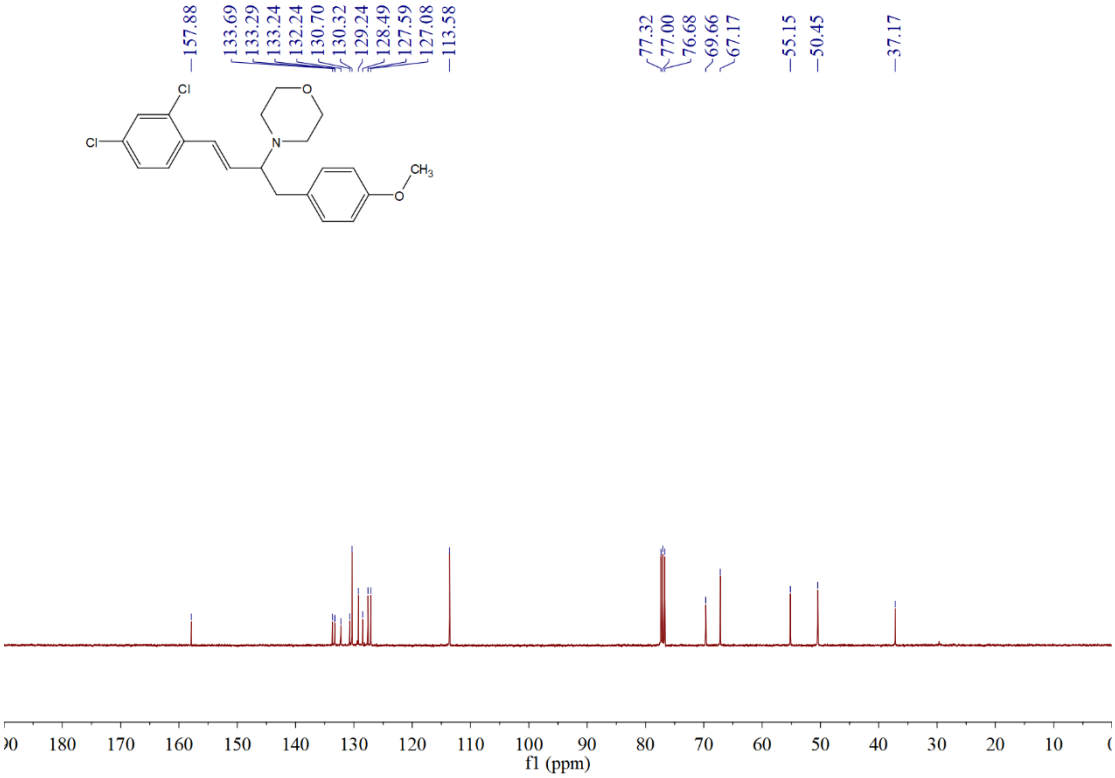
^{13}C NMR (101 MHz, $CDCl_3$) of 4i



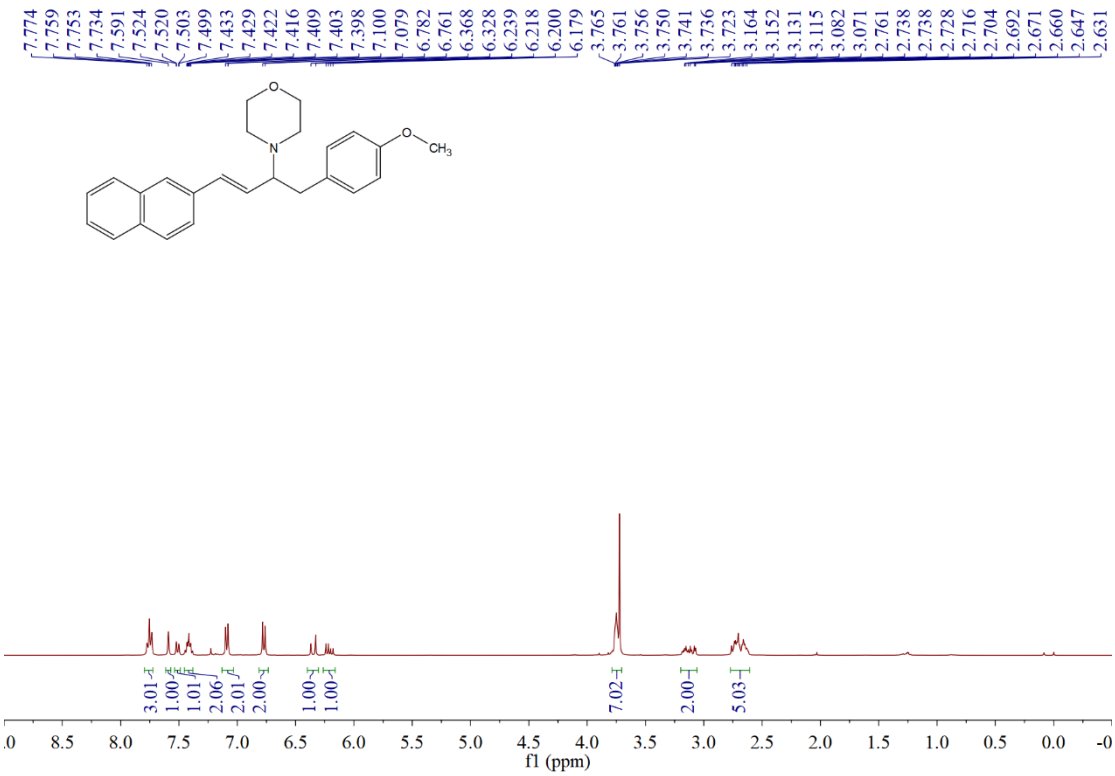
^{1}H NMR (400 MHz, $CDCl_3$) of 4j



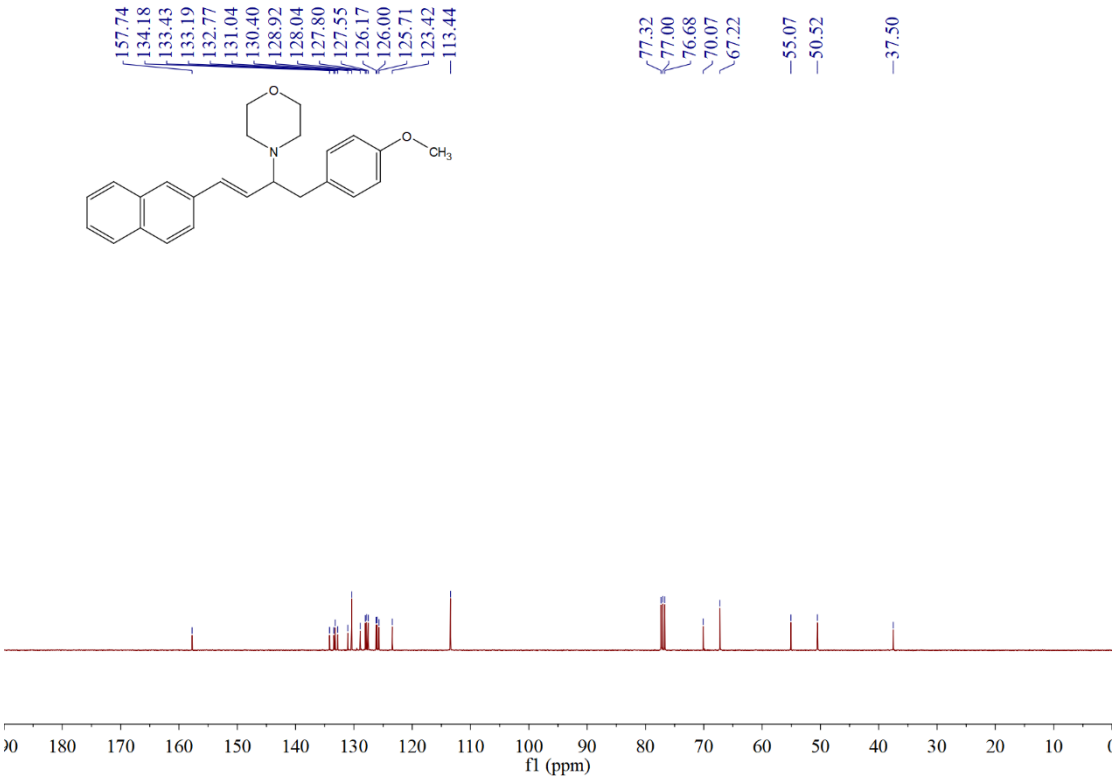
^{13}C NMR (101 MHz, $CDCl_3$) of 4j



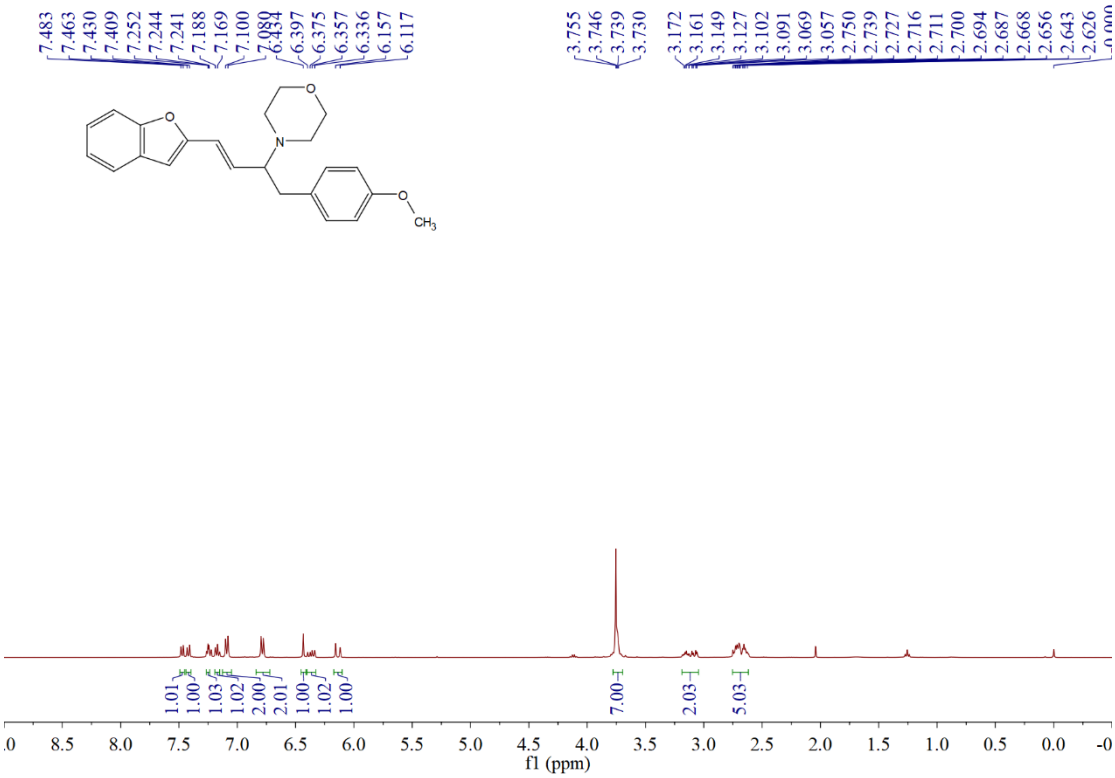
^{1}H NMR (400 MHz, $CDCl_3$) of 4k



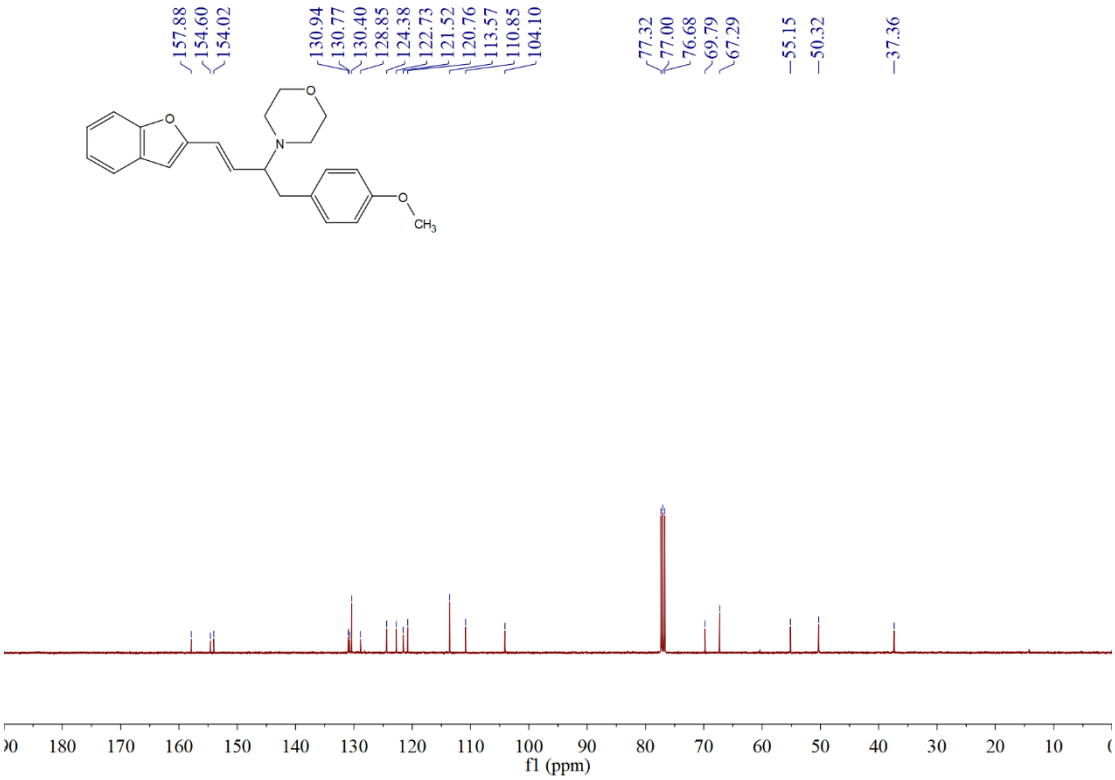
^{13}C NMR (101 MHz, $CDCl_3$) of 4k



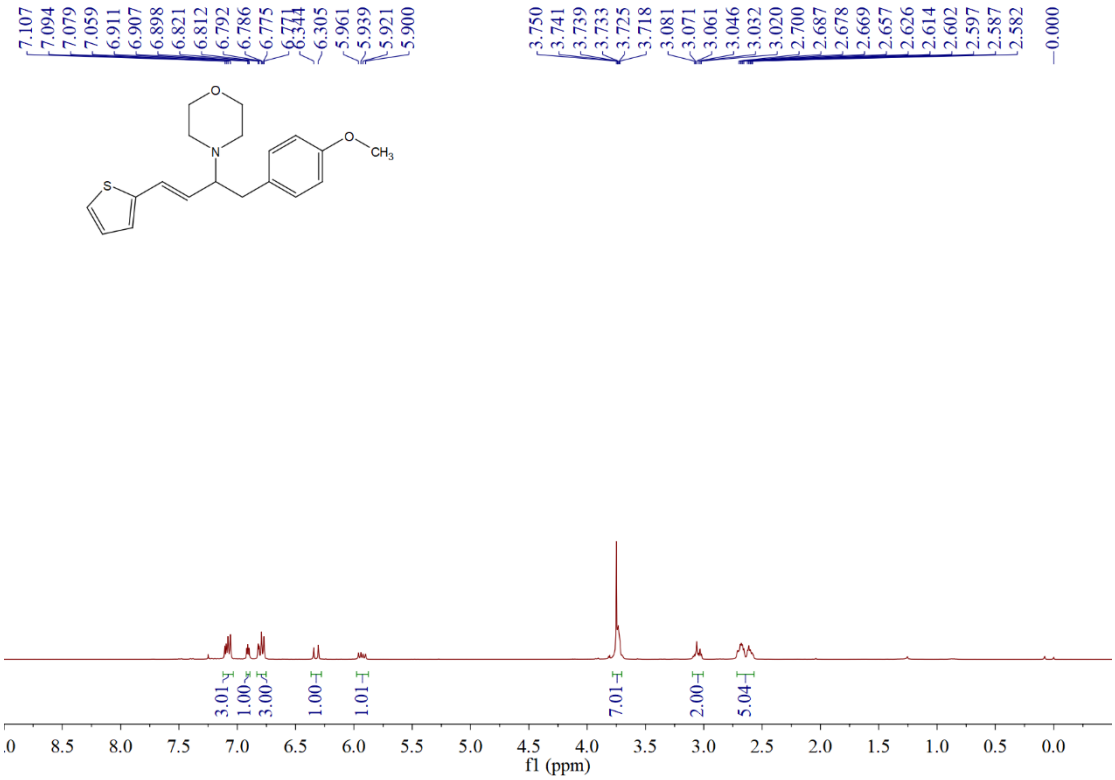
^{1}H NMR (400 MHz, $CDCl_3$) of 4l



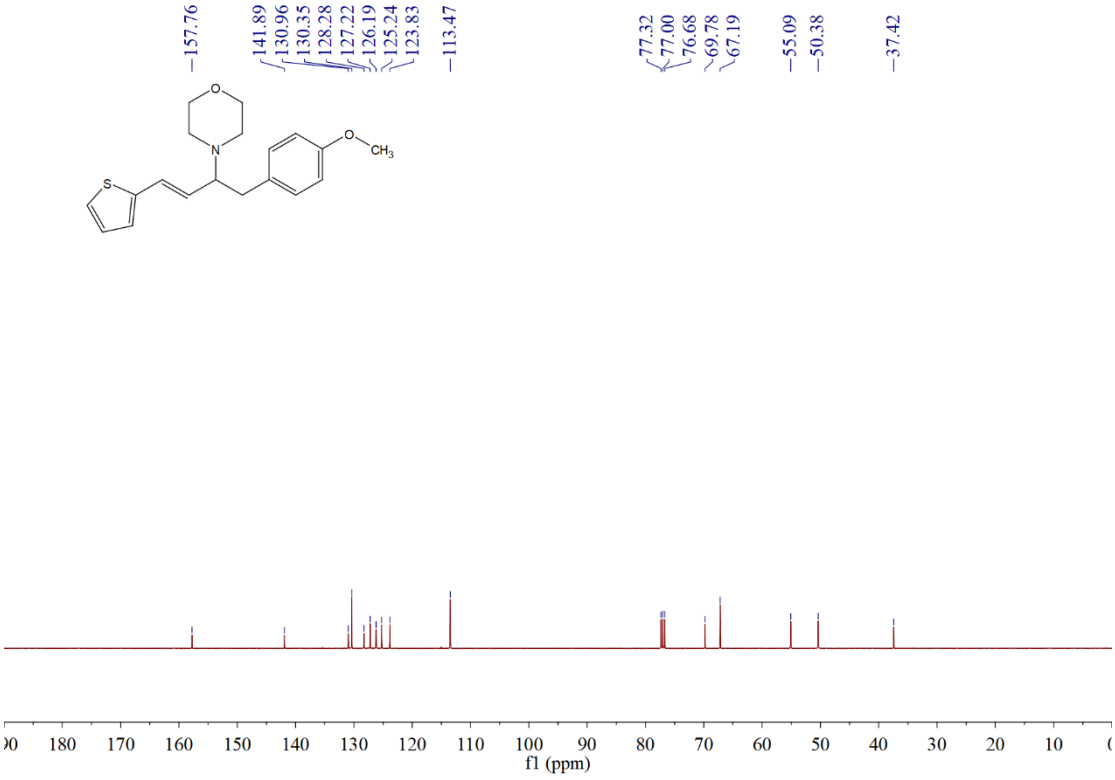
^{13}C NMR (101 MHz, $CDCl_3$) of 4l



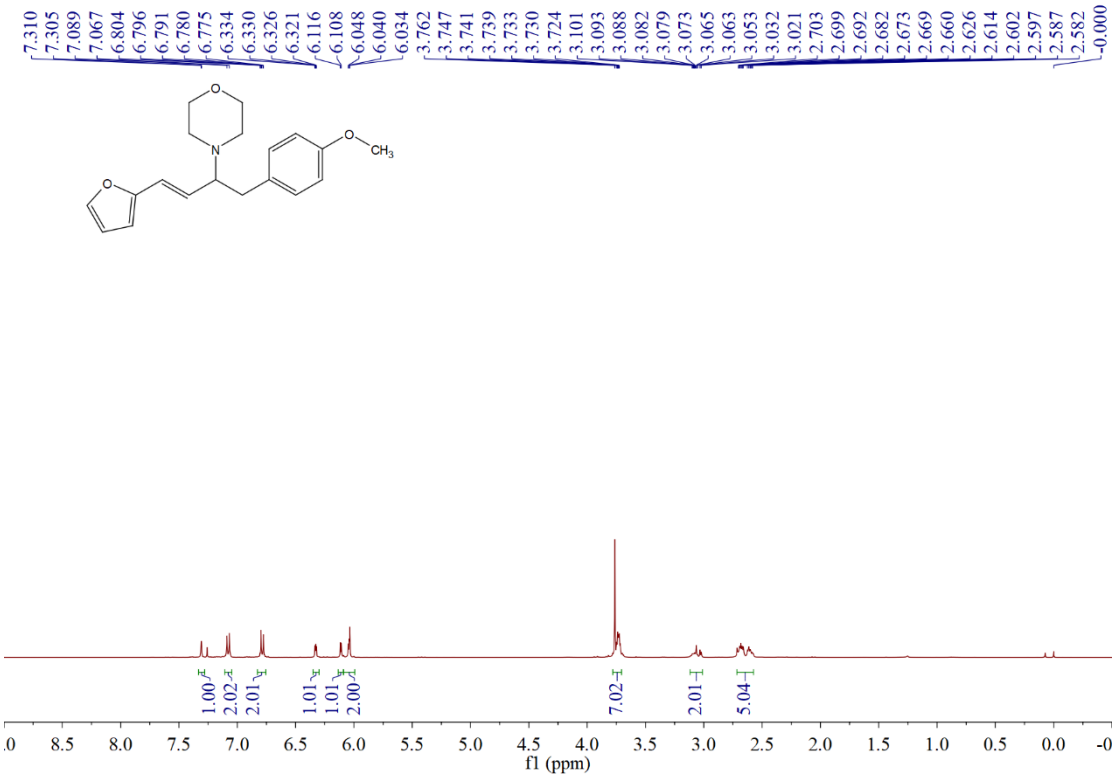
^{1}H NMR (400 MHz, $CDCl_3$) of 4m



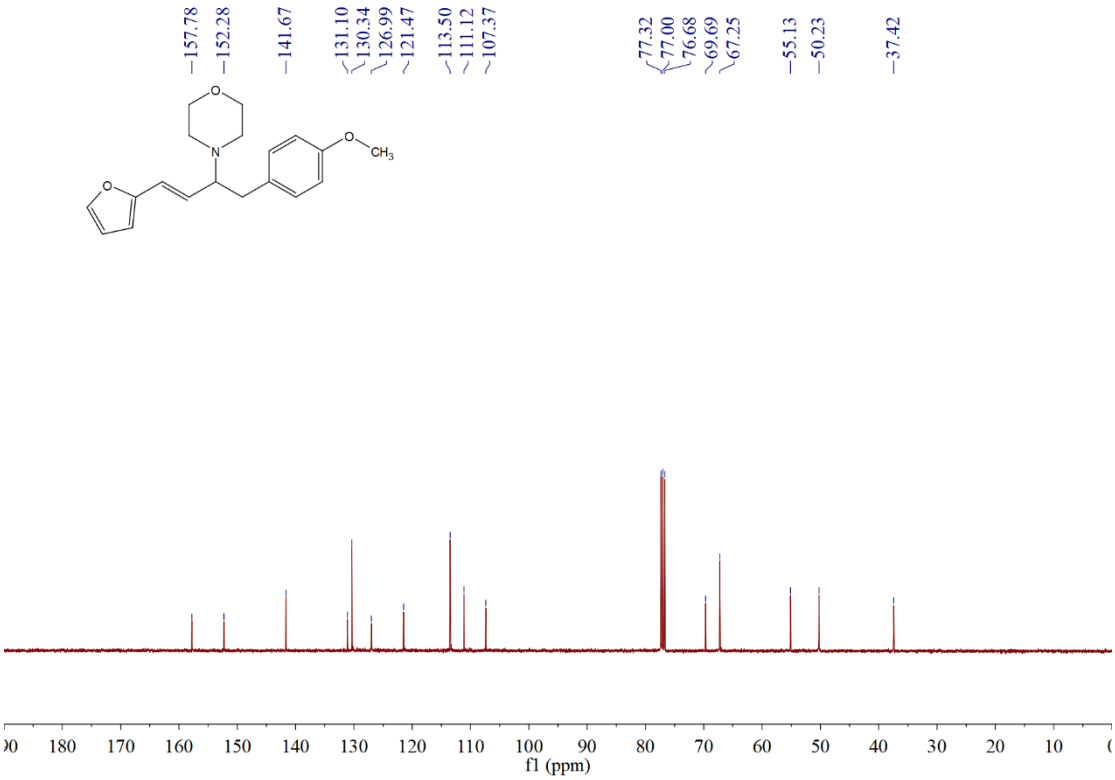
^{13}C NMR (101 MHz, $CDCl_3$) of 4m



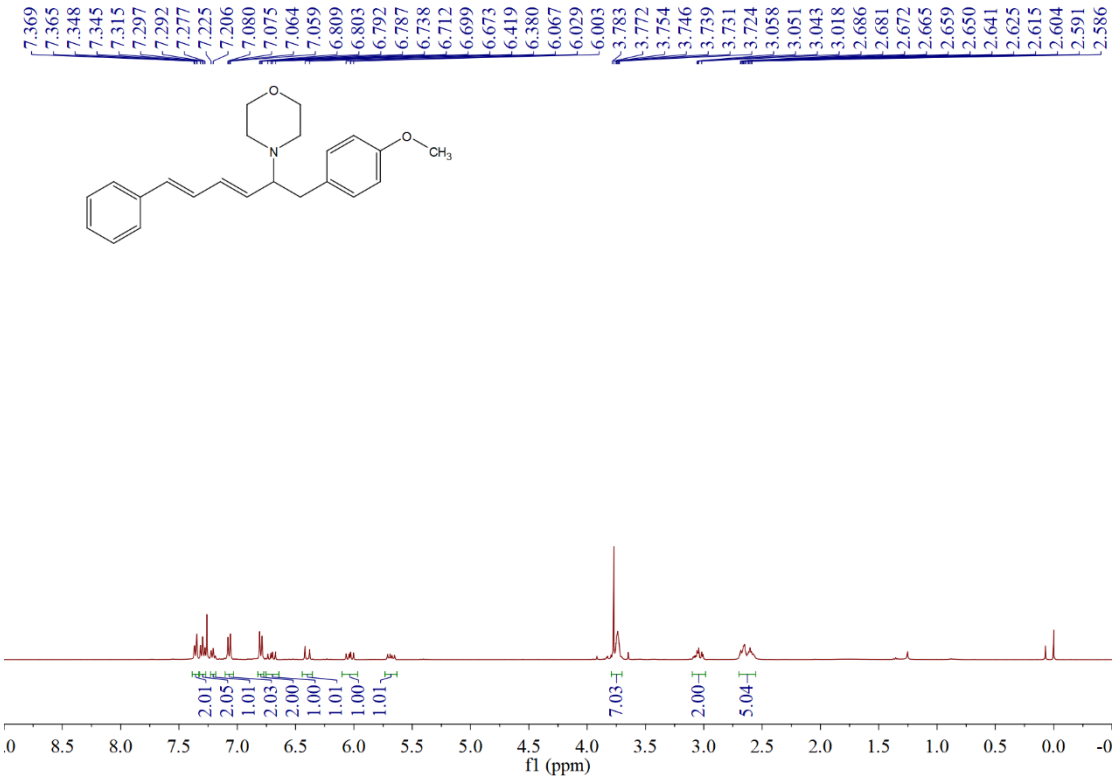
^{1}H NMR (400 MHz, $CDCl_3$) of 4n



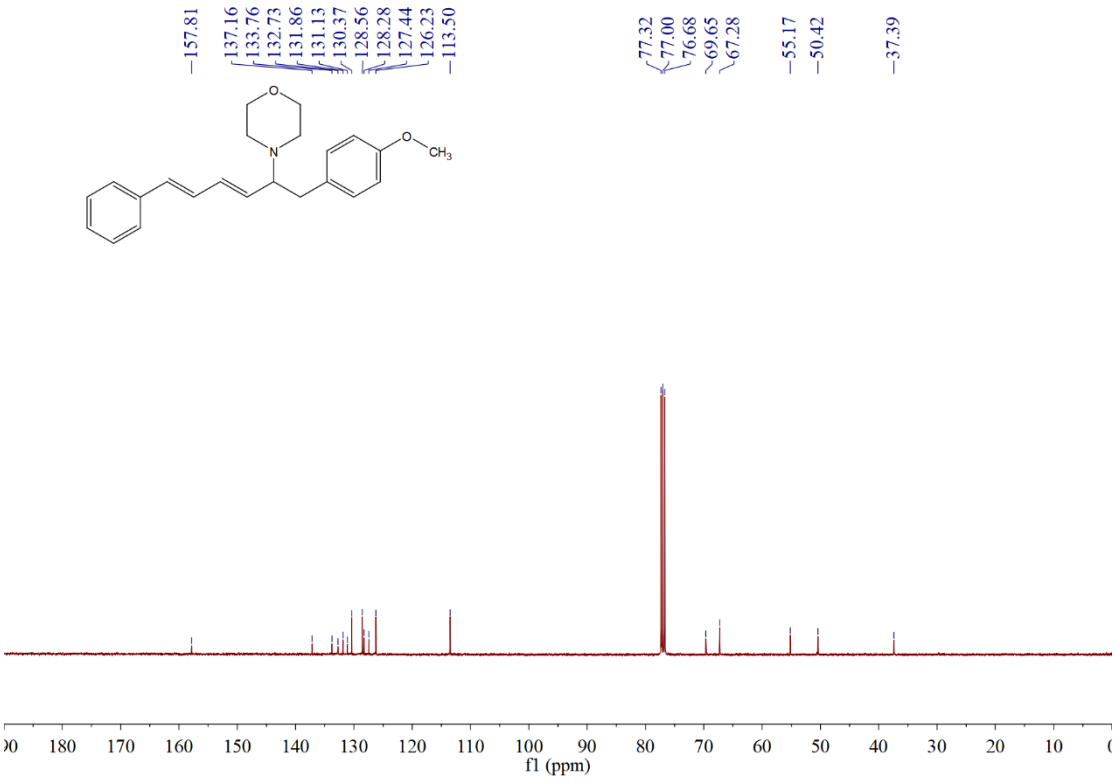
^{13}C NMR (101 MHz, $CDCl_3$) of 4n



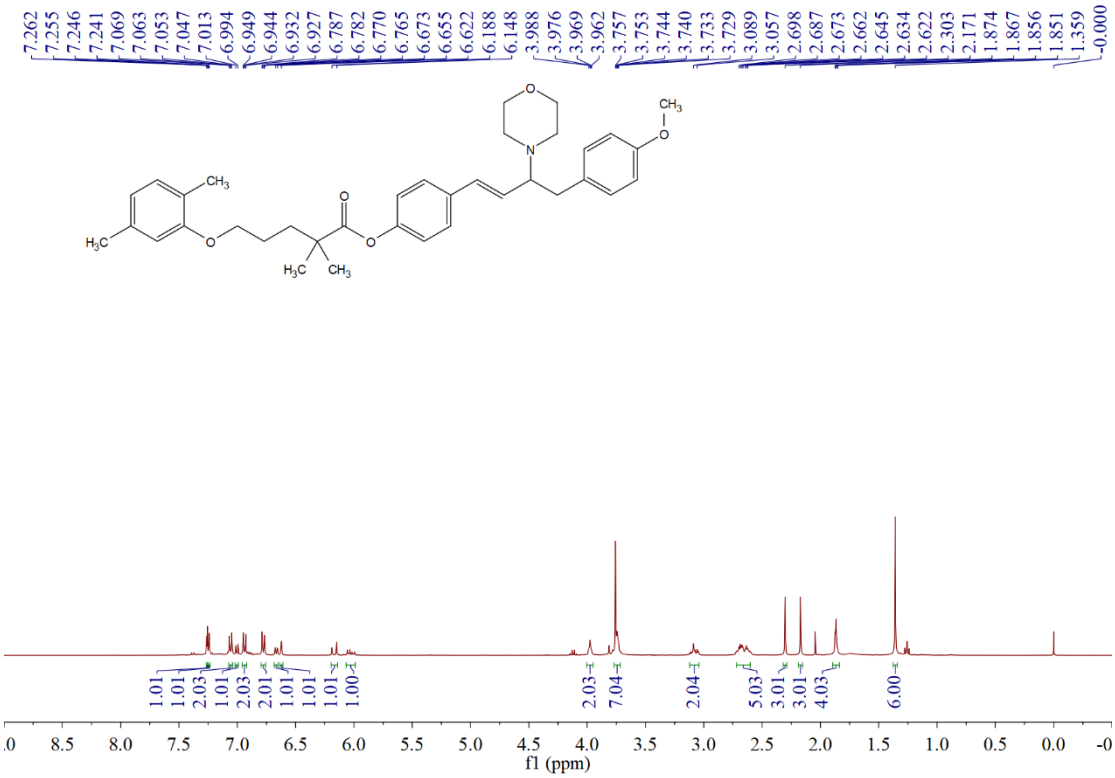
^{1}H NMR (400 MHz, $CDCl_3$) of 4o



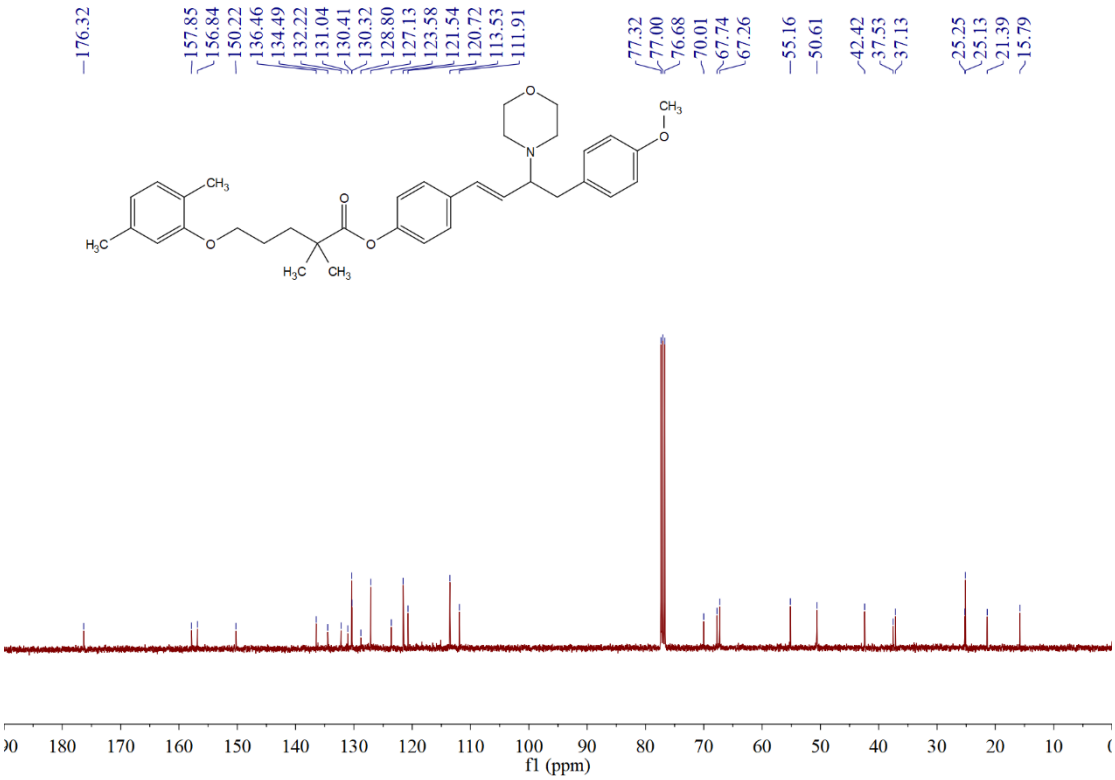
^{13}C NMR (101 MHz, $CDCl_3$) of 4o



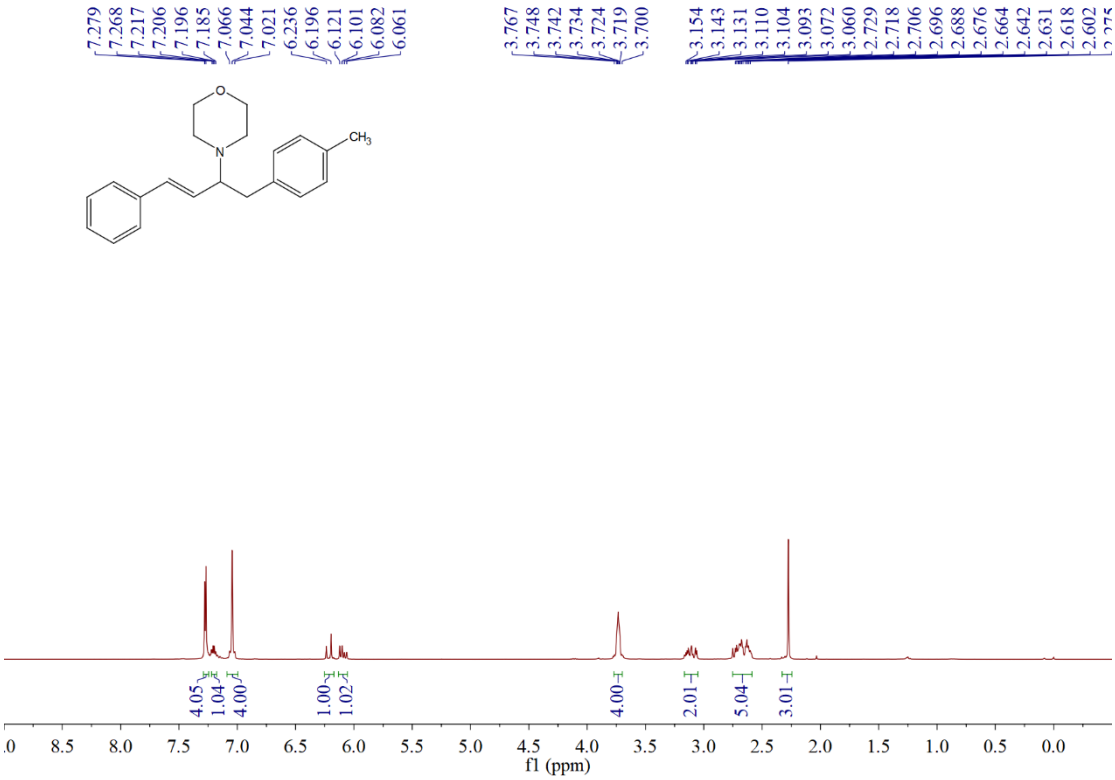
^{1}H NMR (400 MHz, $CDCl_3$) of 4p



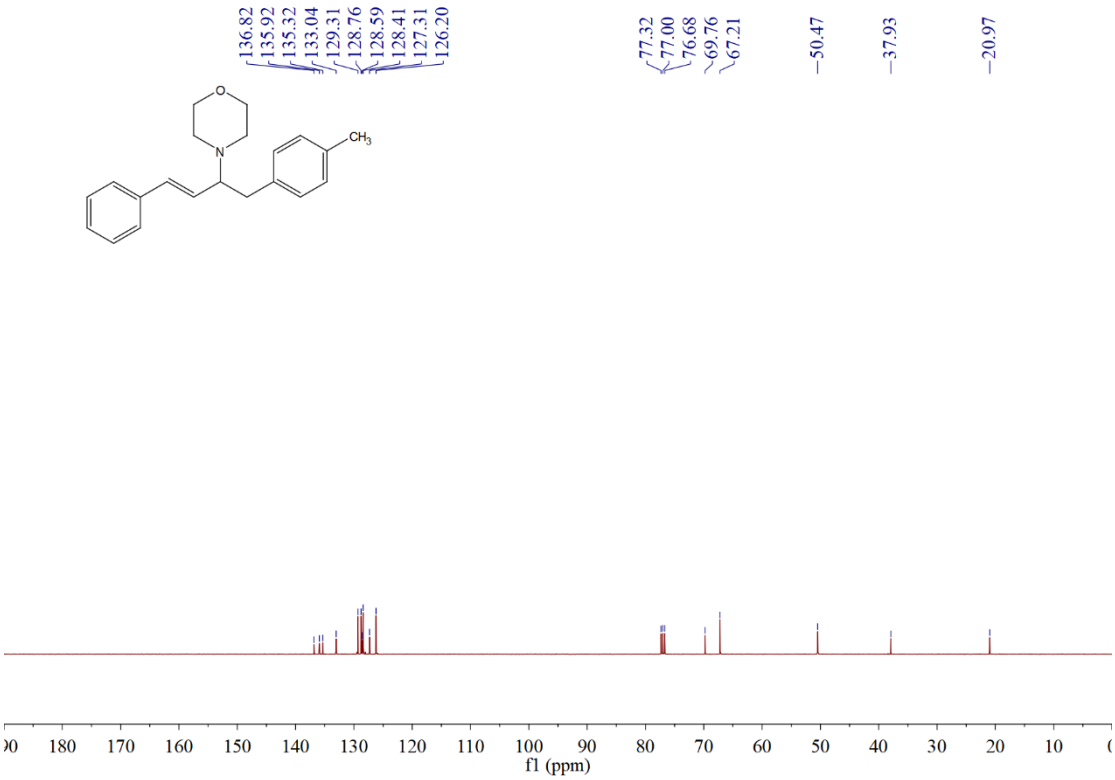
^{13}C NMR (101 MHz, $CDCl_3$) of 4p



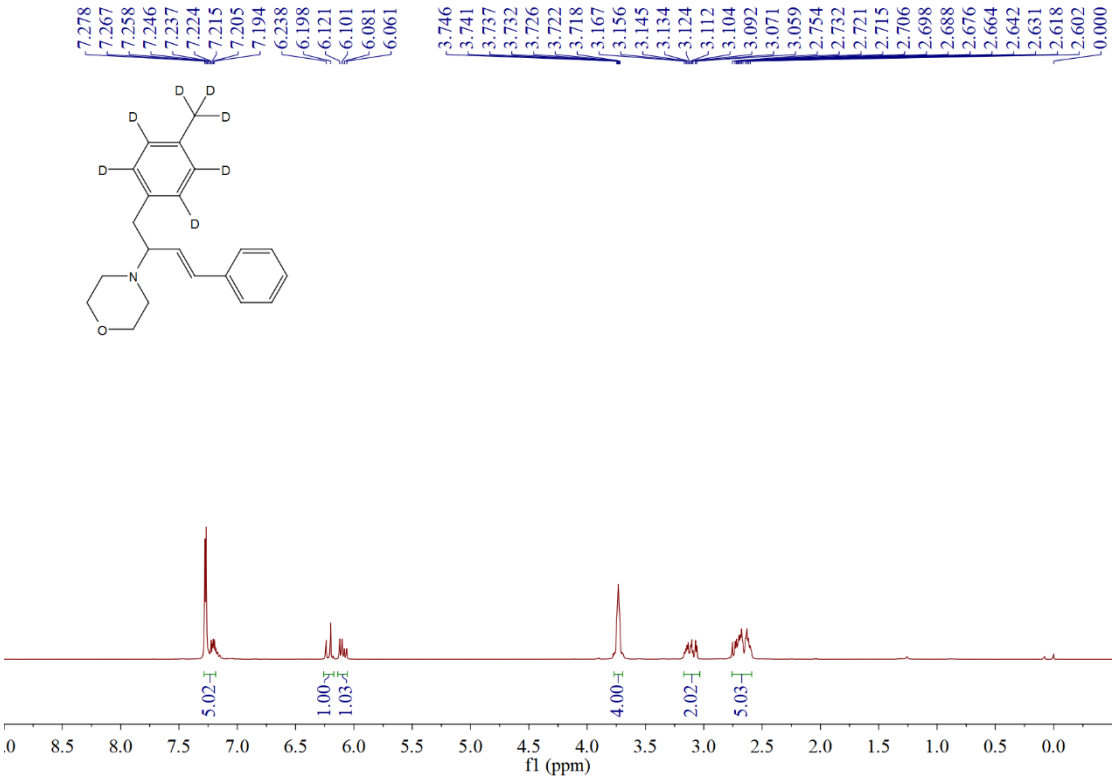
^{1}H NMR (400 MHz, $CDCl_3$) of 5a



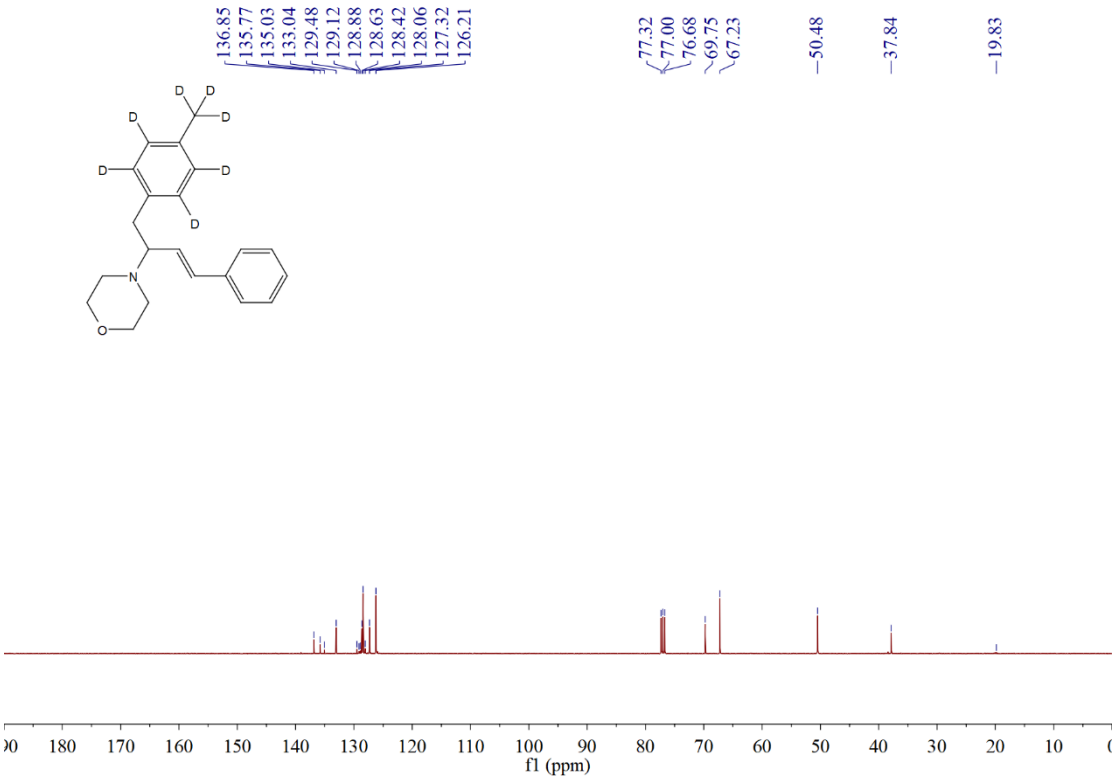
^{13}C NMR (101 MHz, $CDCl_3$) of 5a



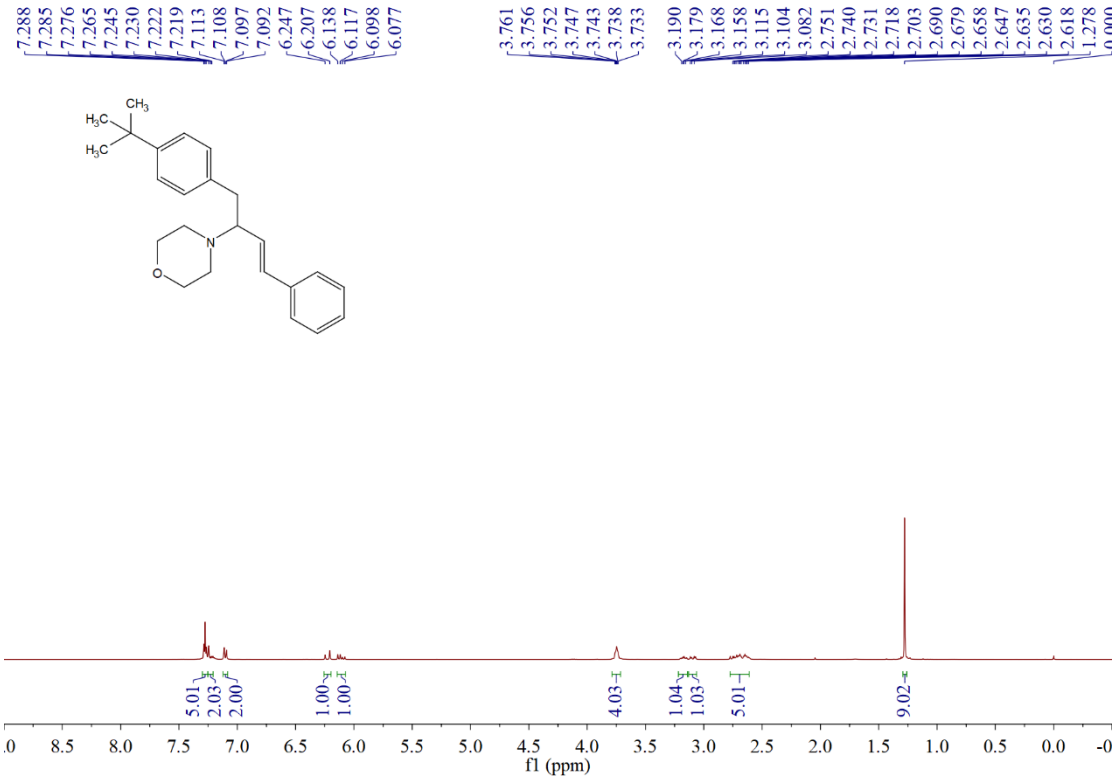
^{1}H NMR (400 MHz, $CDCl_3$) of 5b



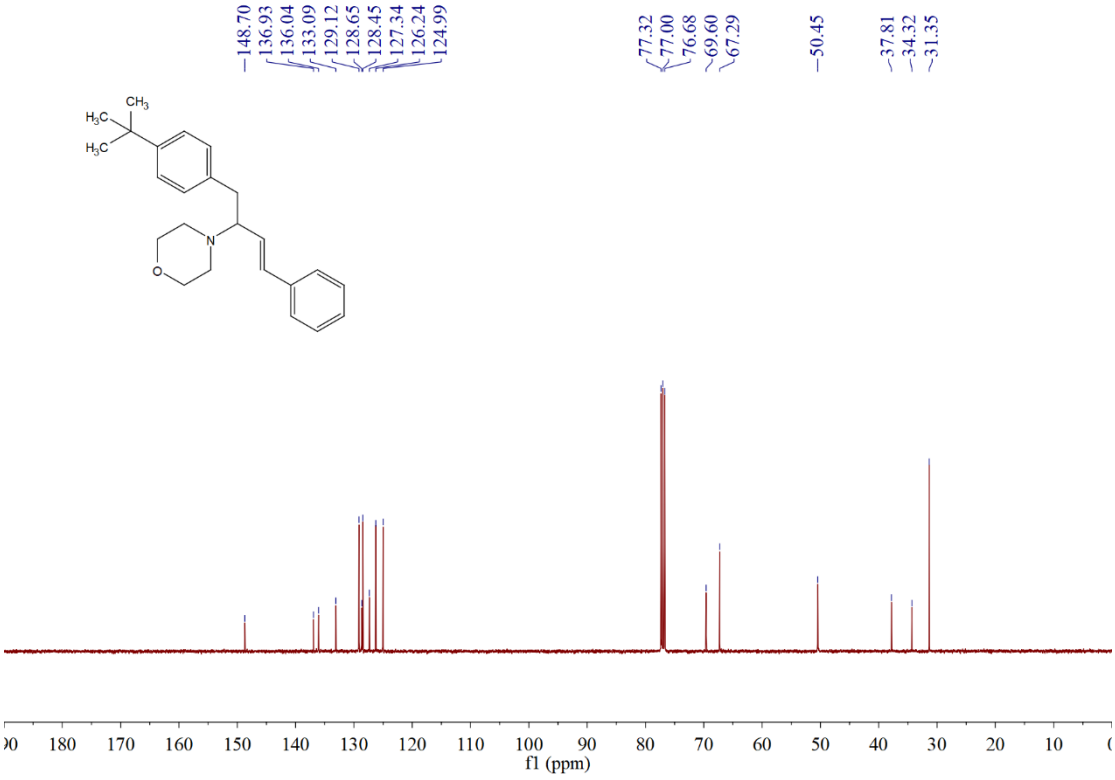
^{13}C NMR (101 MHz, $CDCl_3$) of 5b



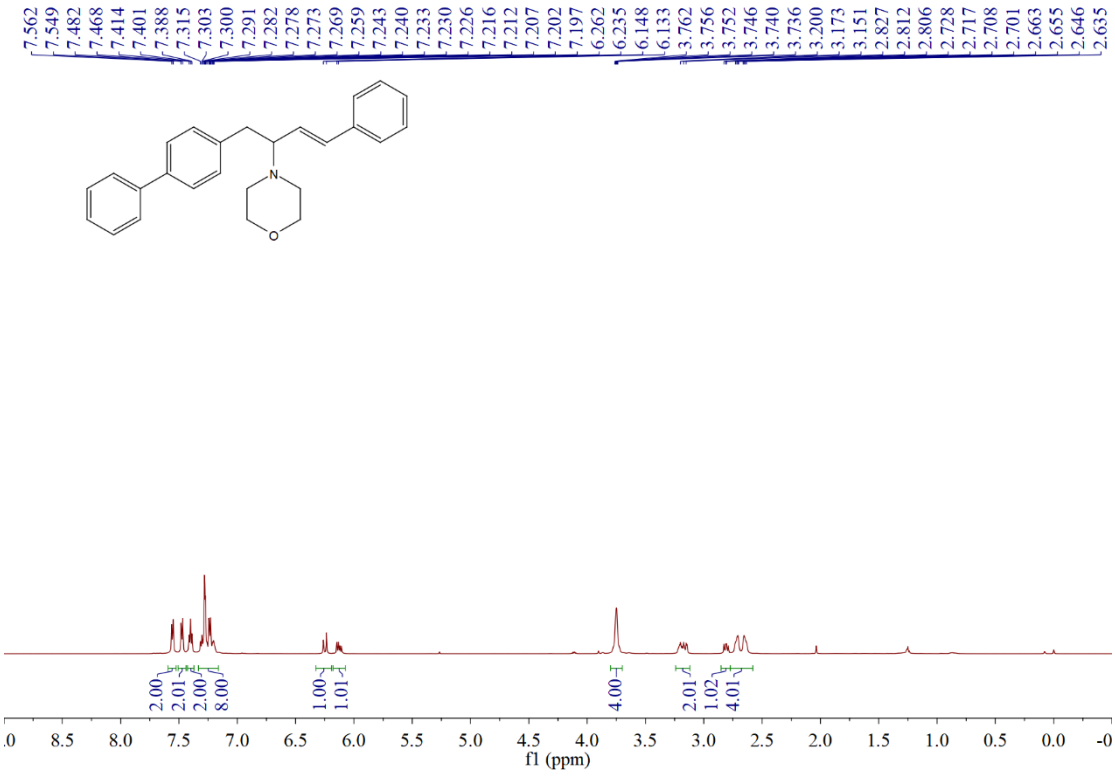
^{1}H NMR (400 MHz, $CDCl_3$) of 5c



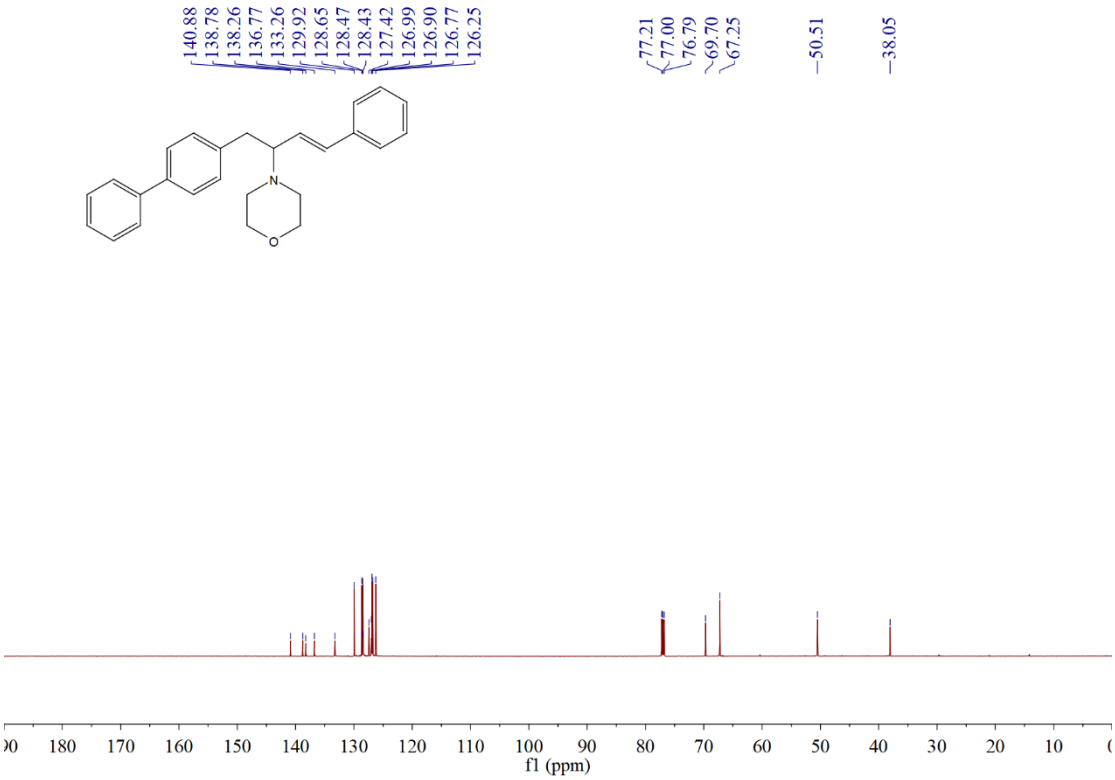
^{13}C NMR (101 MHz, $CDCl_3$) of 5c



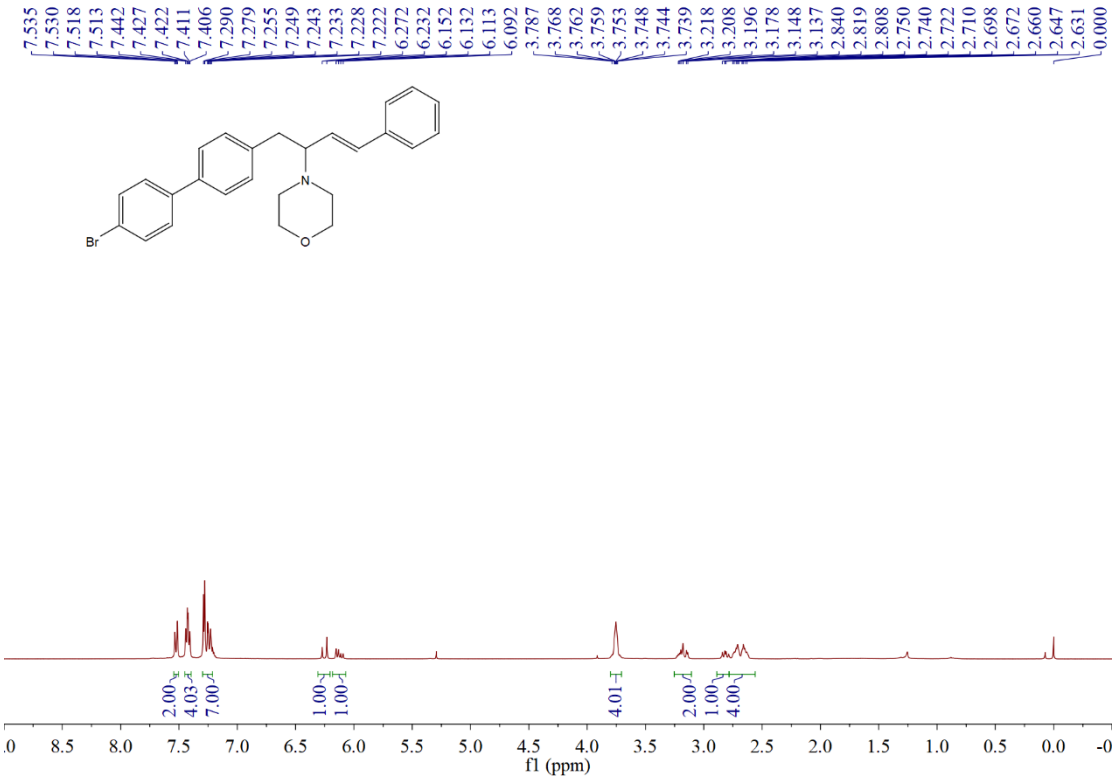
^{1}H NMR (400 MHz, $CDCl_3$) of 5d



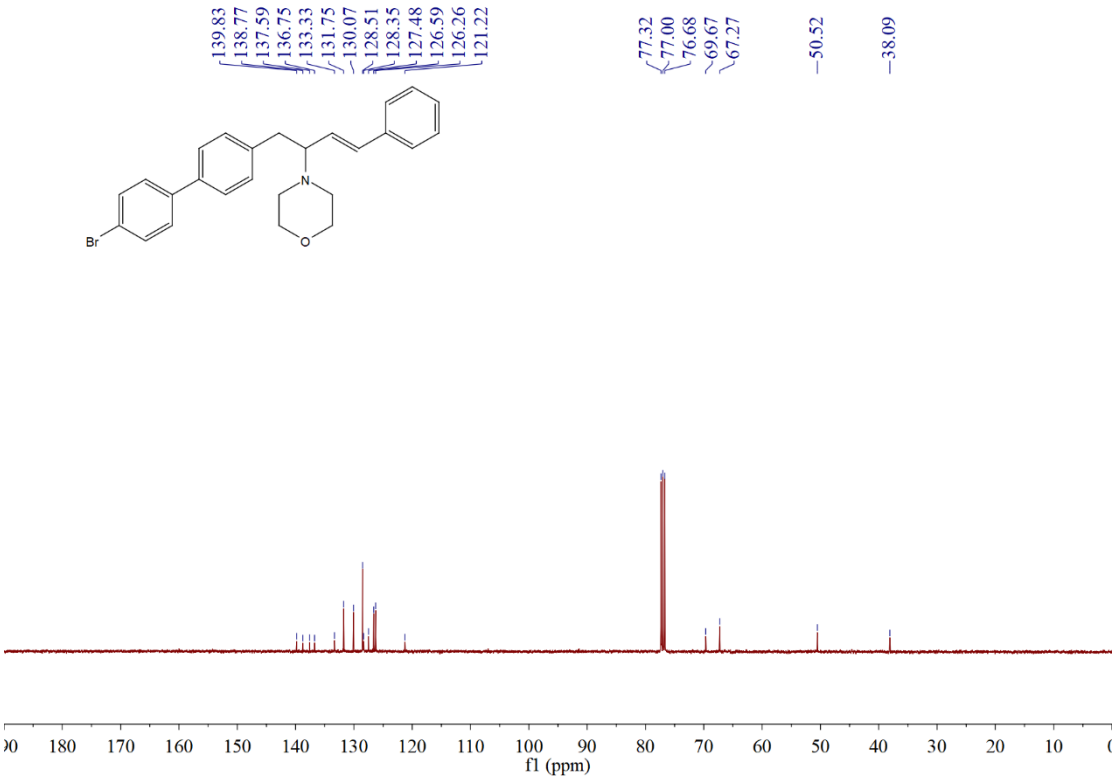
^{13}C NMR (101 MHz, $CDCl_3$) of 5d



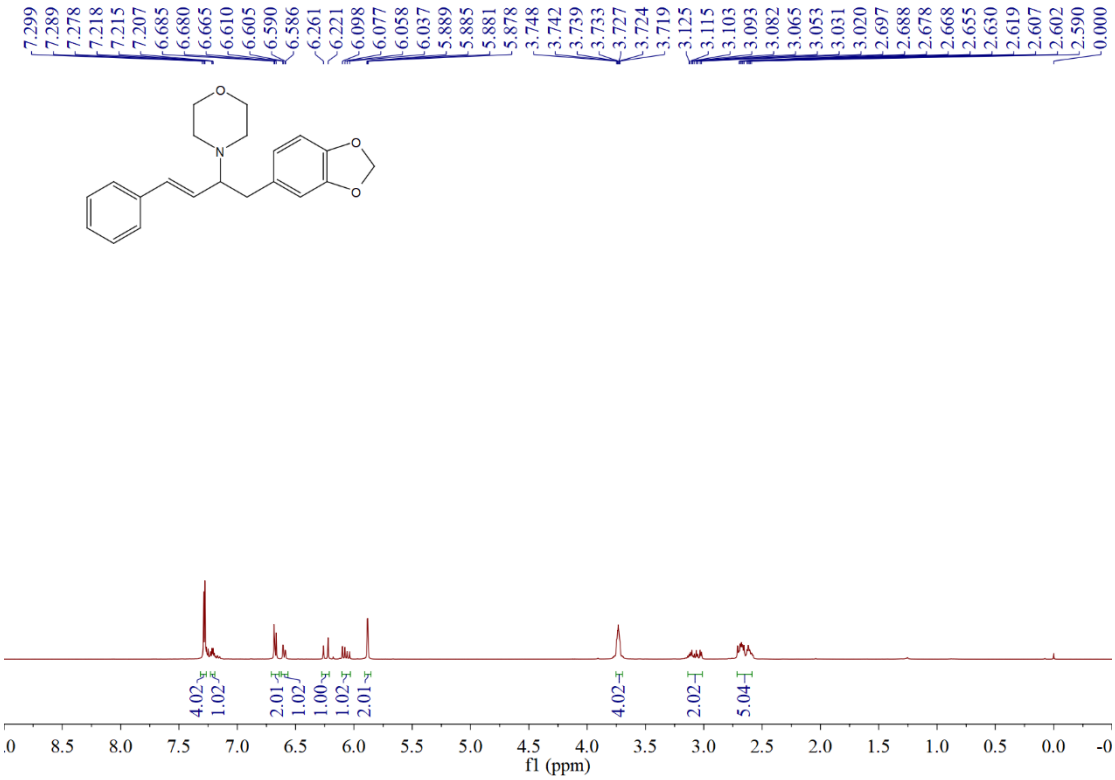
^{1}H NMR (400 MHz, $CDCl_3$) of 5e



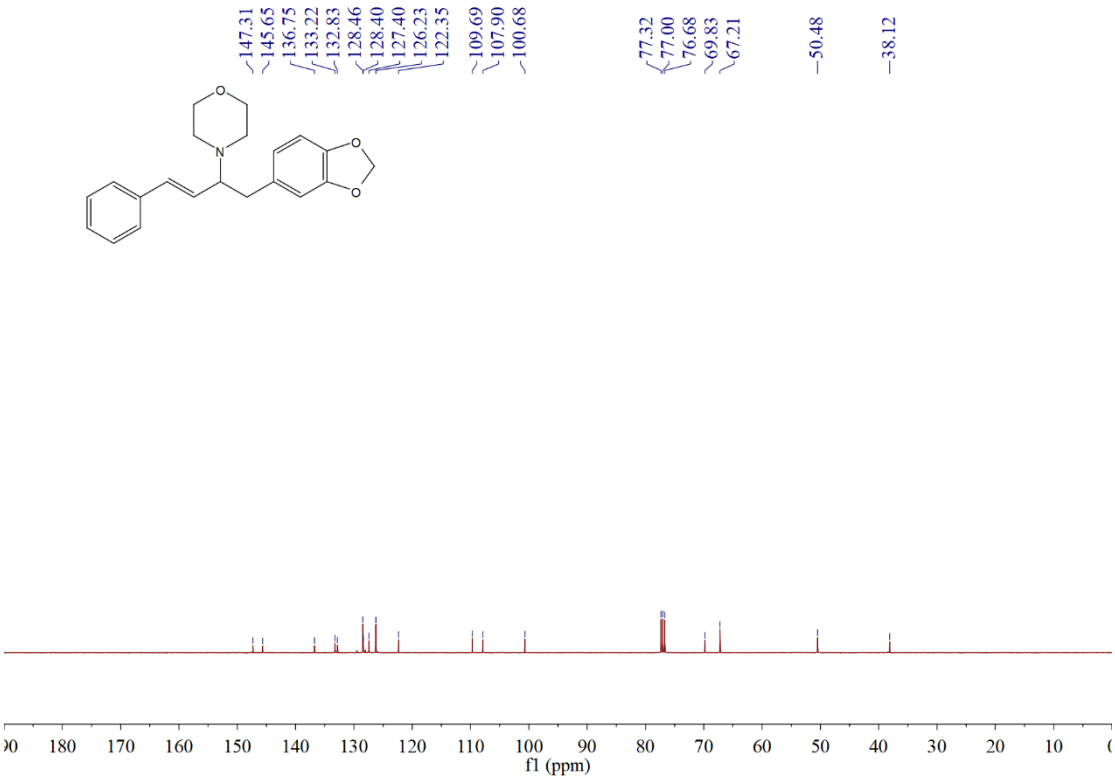
^{13}C NMR (101 MHz, $CDCl_3$) of 5e



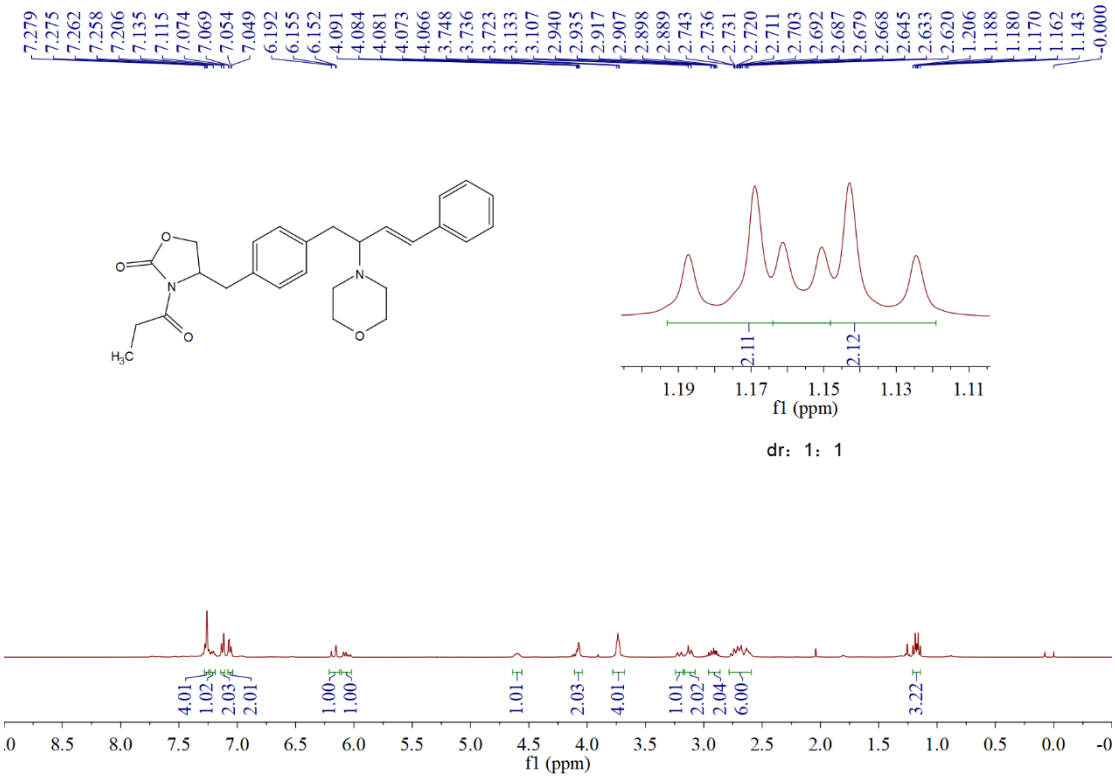
^{1}H NMR (400 MHz, $CDCl_3$) of 5f



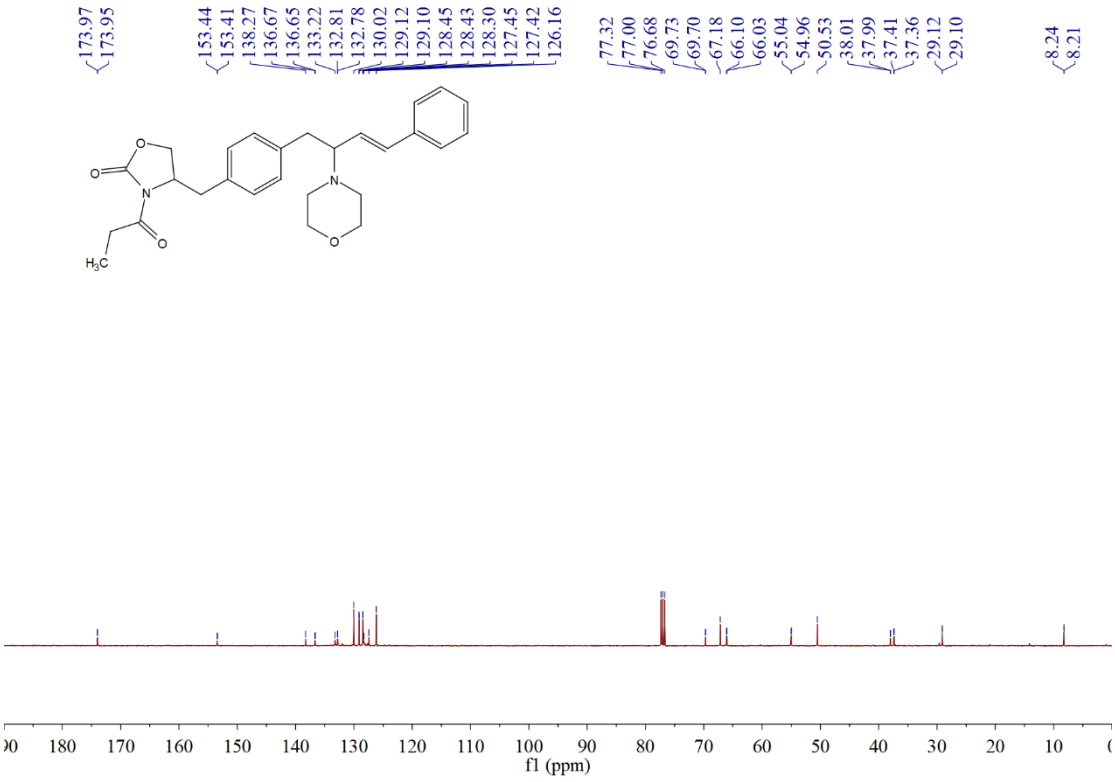
^{13}C NMR (101 MHz, $CDCl_3$) of 5f



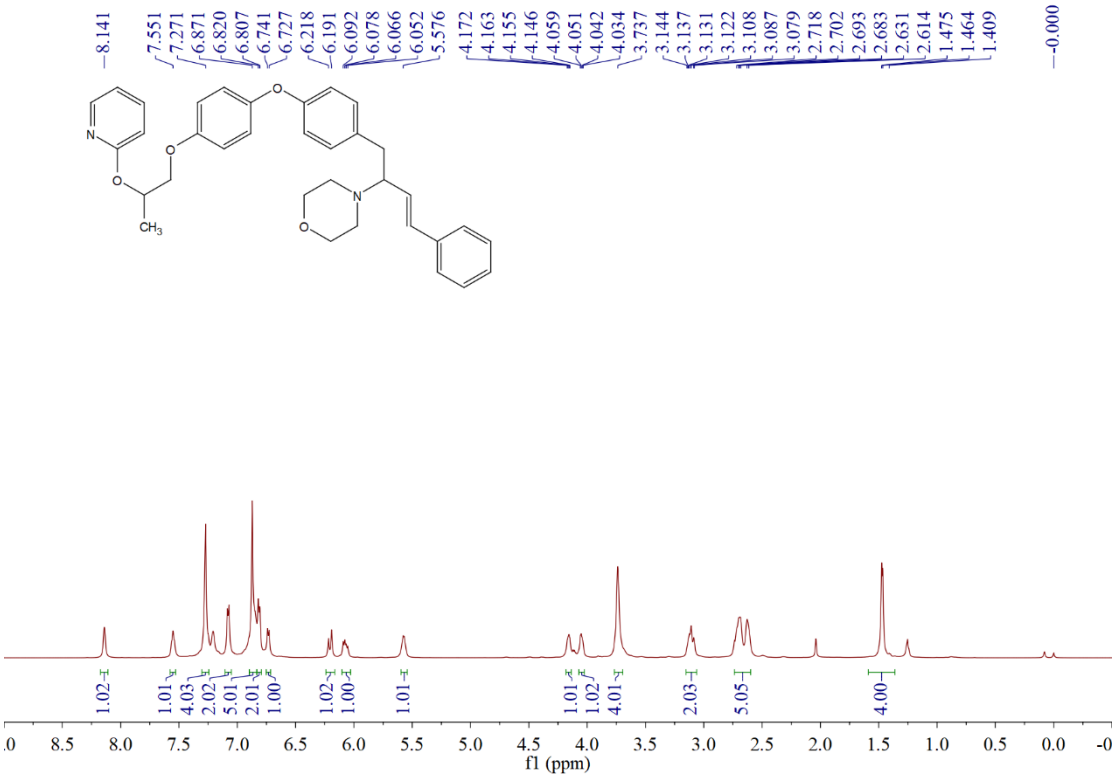
^{1}H NMR (400 MHz, $CDCl_3$) of 5g



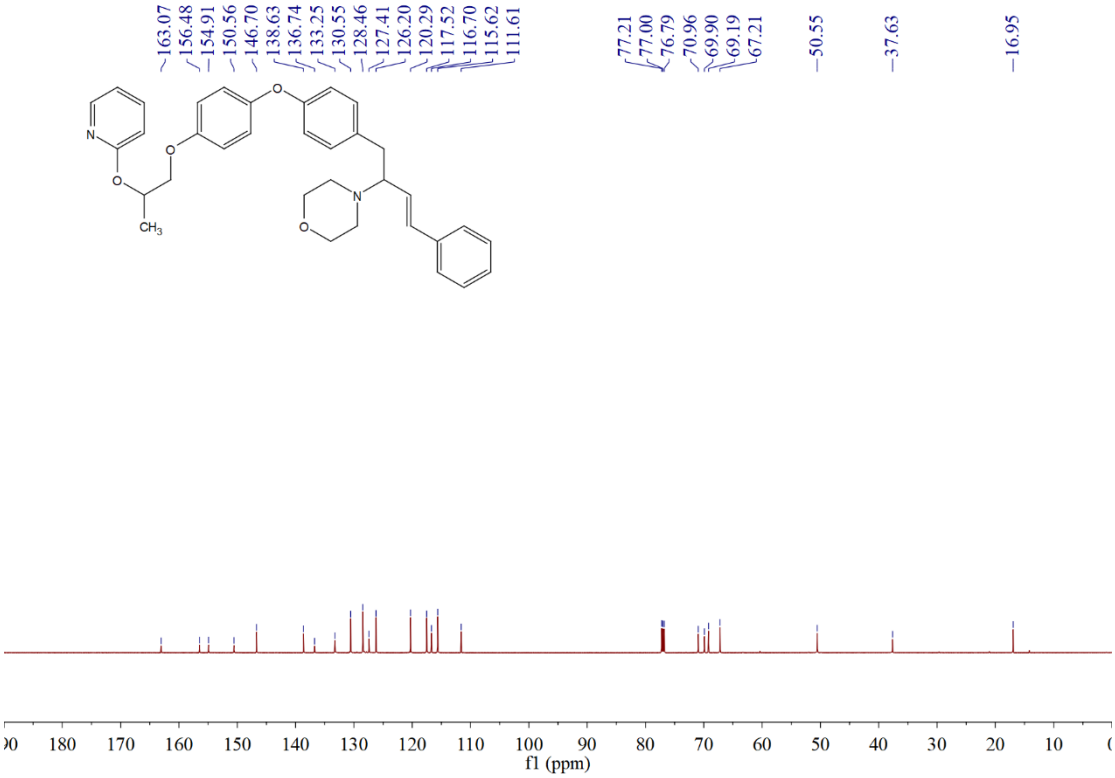
^{13}C NMR (101 MHz, $CDCl_3$) of 5g



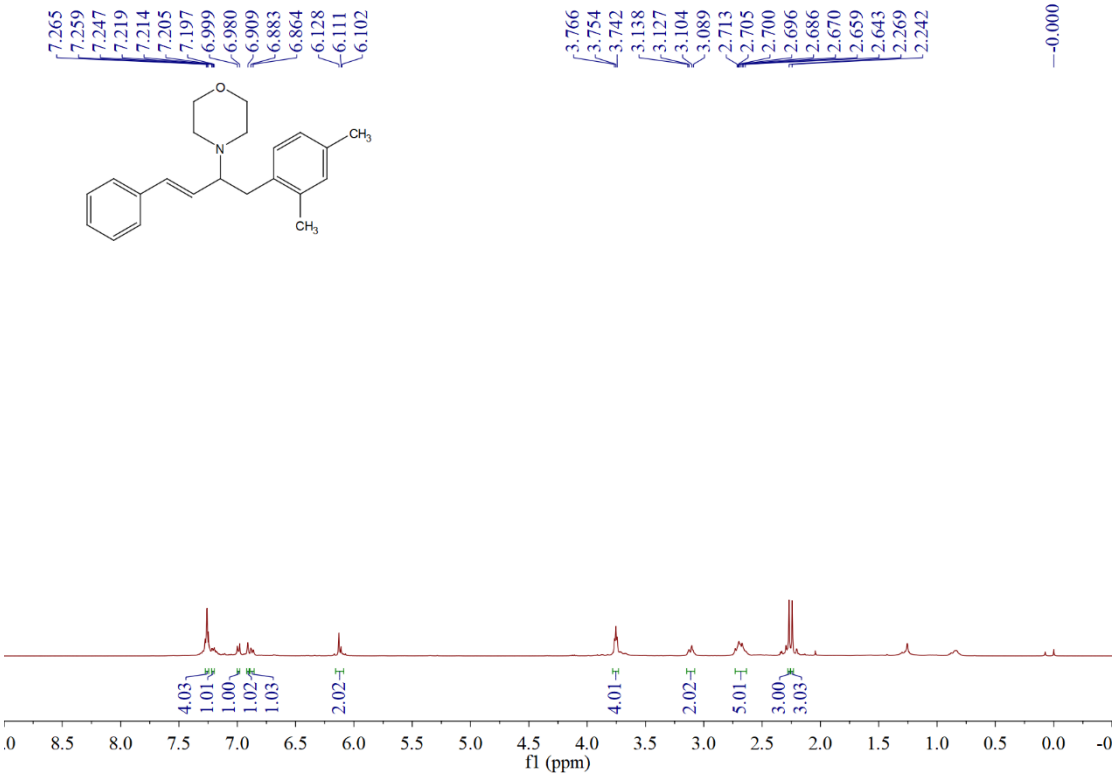
^{1}H NMR (600 MHz, $CDCl_3$) of 5h



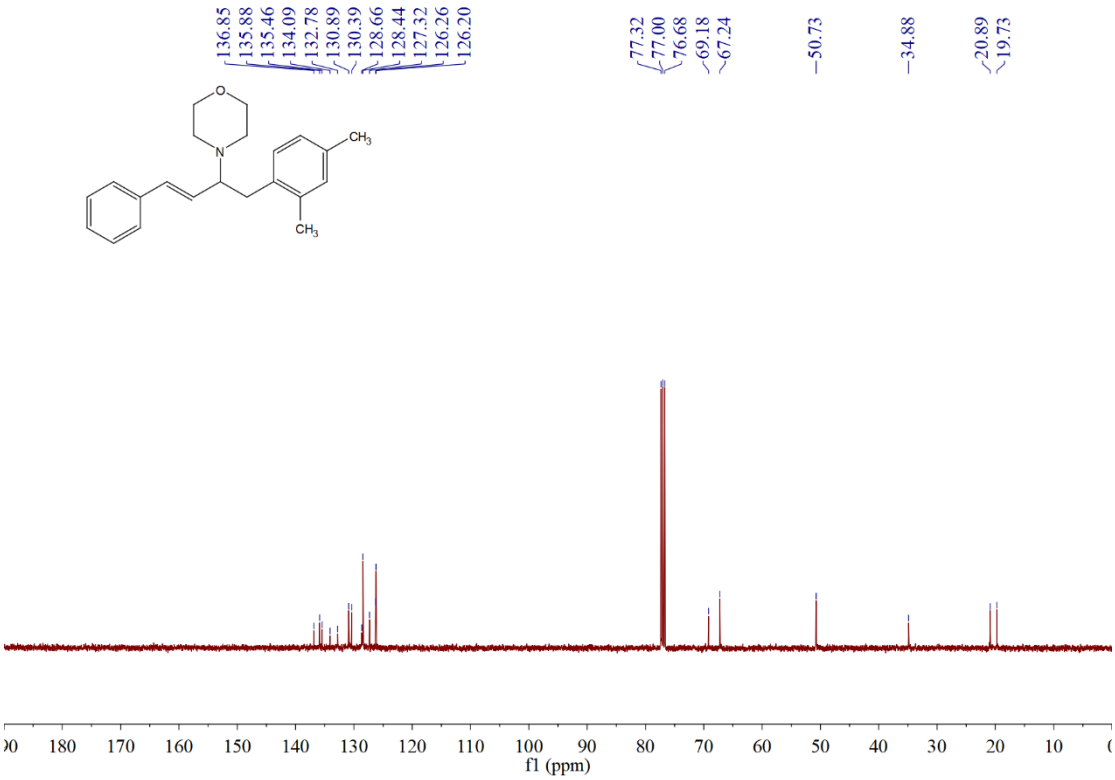
^{13}C NMR (151 MHz, $CDCl_3$) of 5h



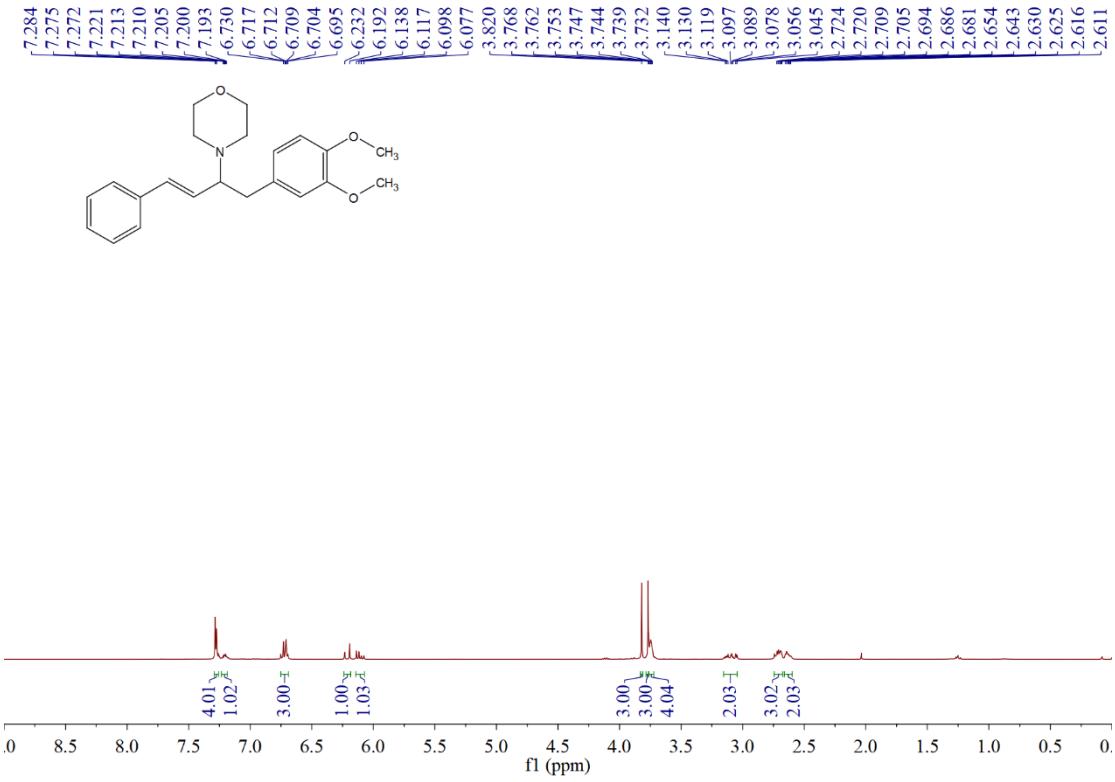
^{1}H NMR (400 MHz, $CDCl_3$) of 5i



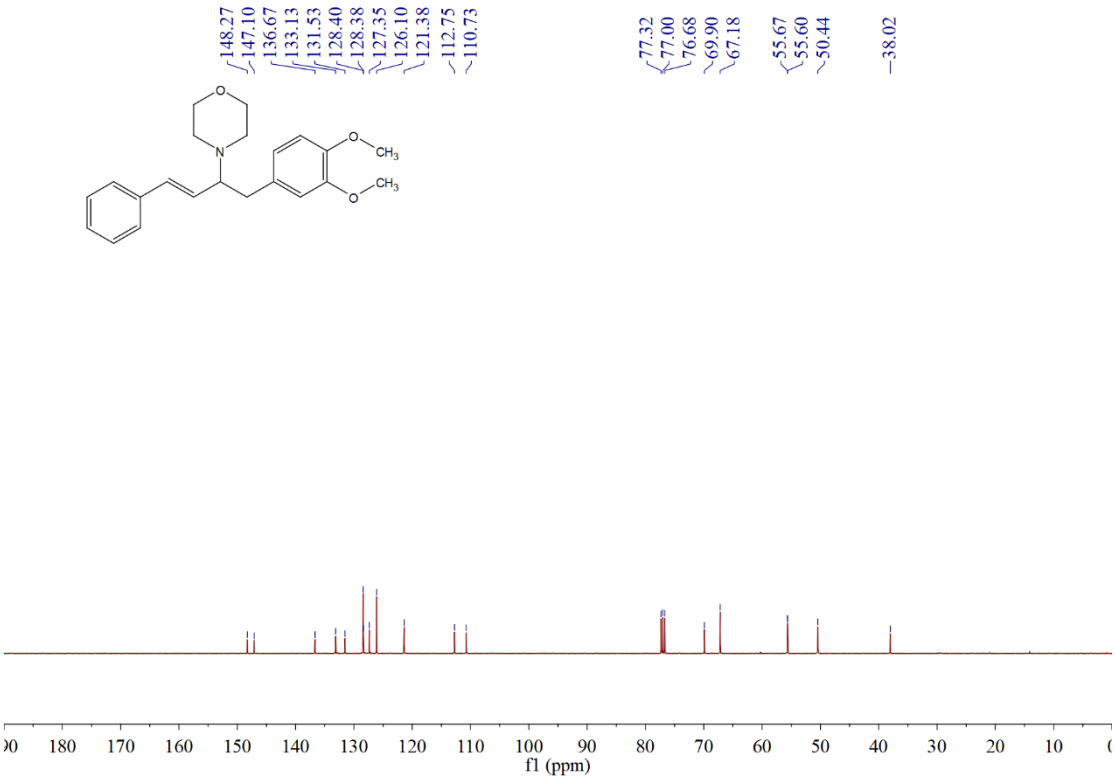
^{13}C NMR (101 MHz, $CDCl_3$) of 5i



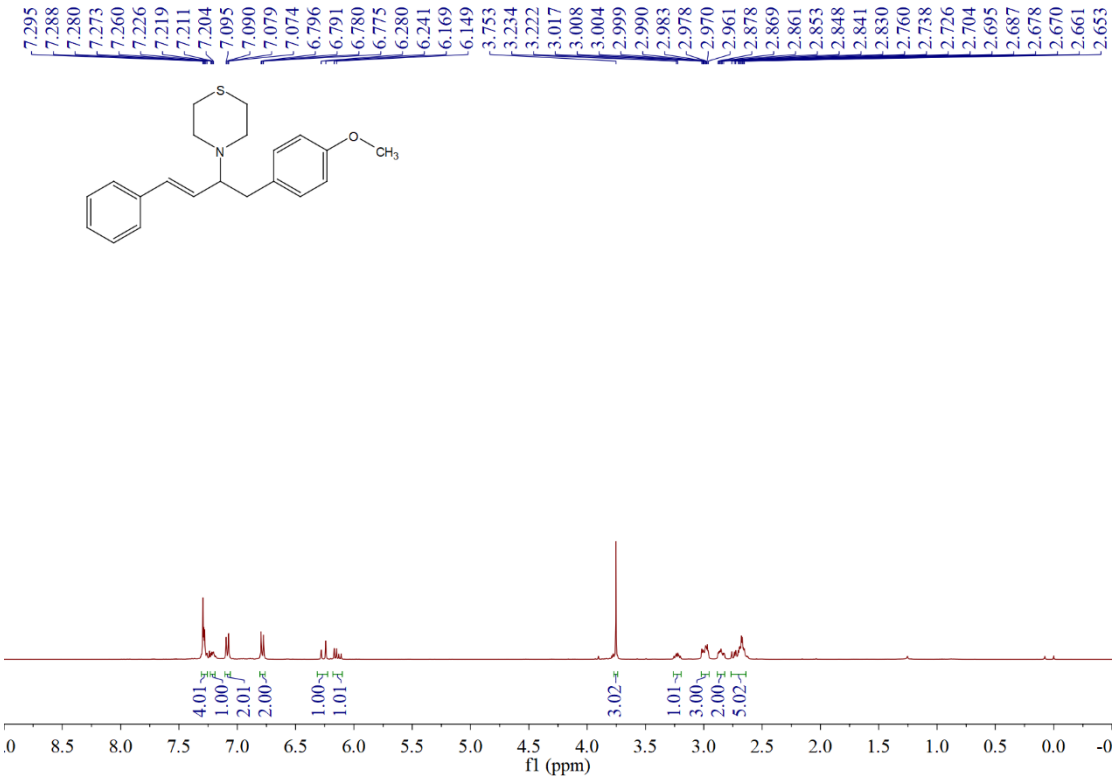
^{1}H NMR (400 MHz, $CDCl_3$) of 5j



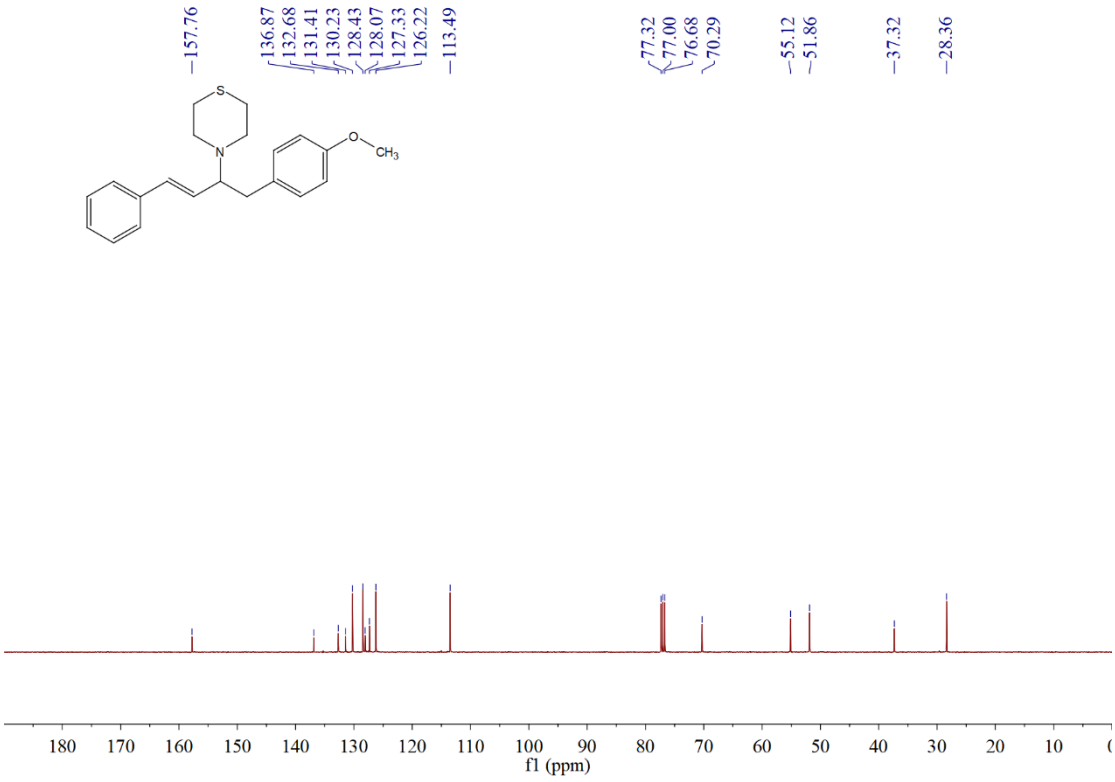
^{13}C NMR (101 MHz, $CDCl_3$) of 5j



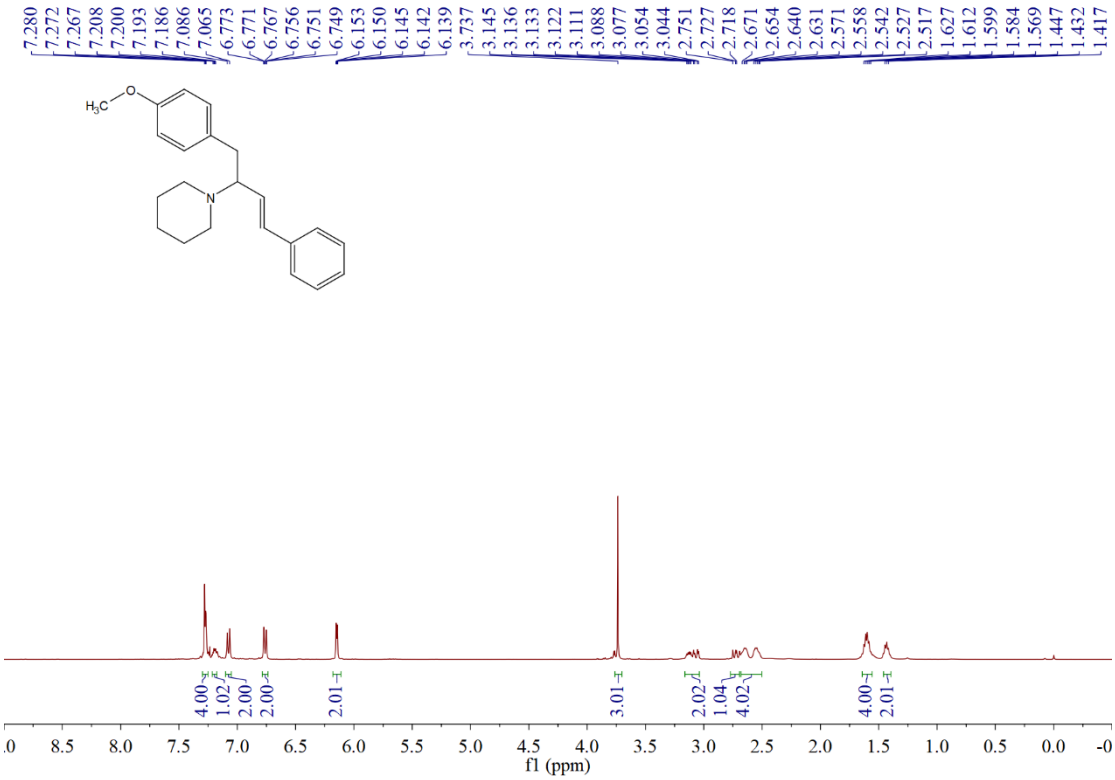
^{1}H NMR (400 MHz, $CDCl_3$) of 6a



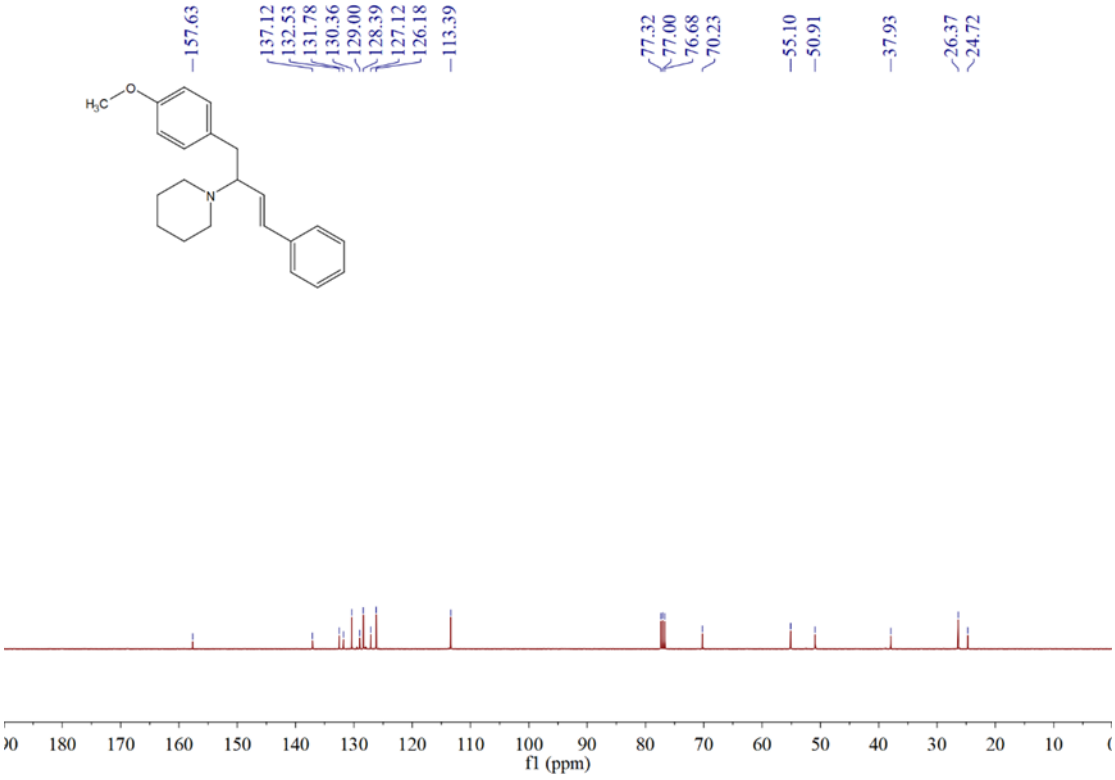
^{13}C NMR (101 MHz, $CDCl_3$) of 6a



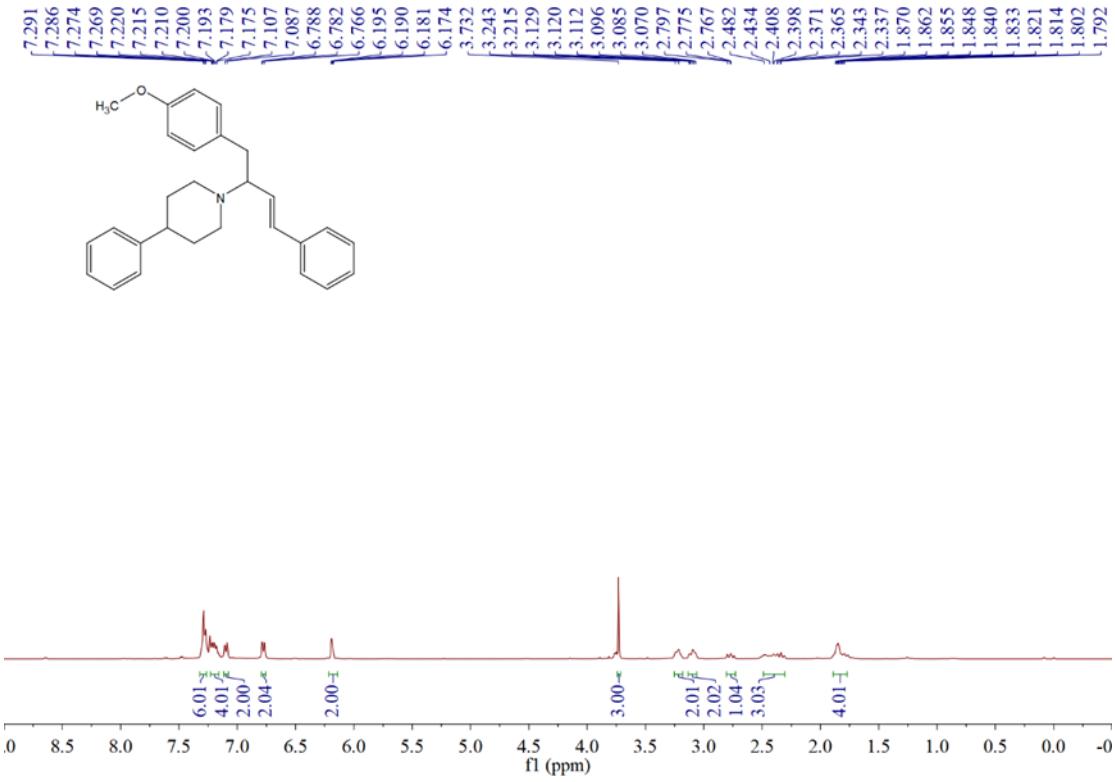
^{1}H NMR (400 MHz, $CDCl_3$) of 6b



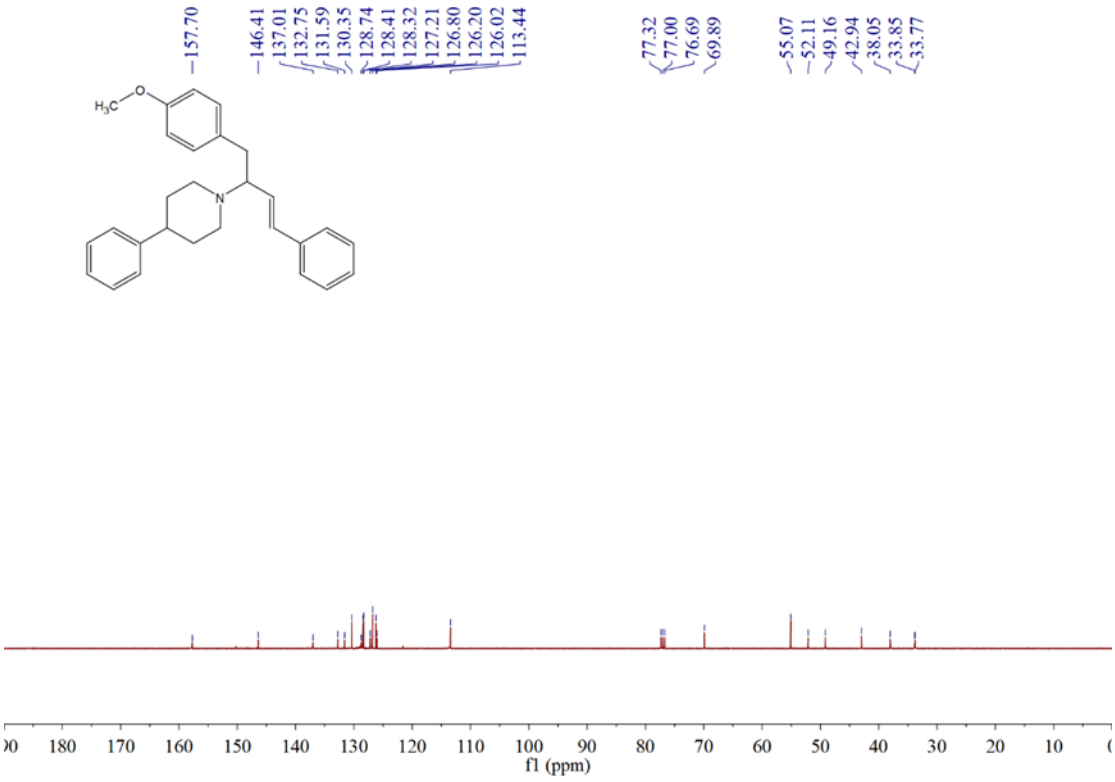
^{13}C NMR (101 MHz, $CDCl_3$) of 6b



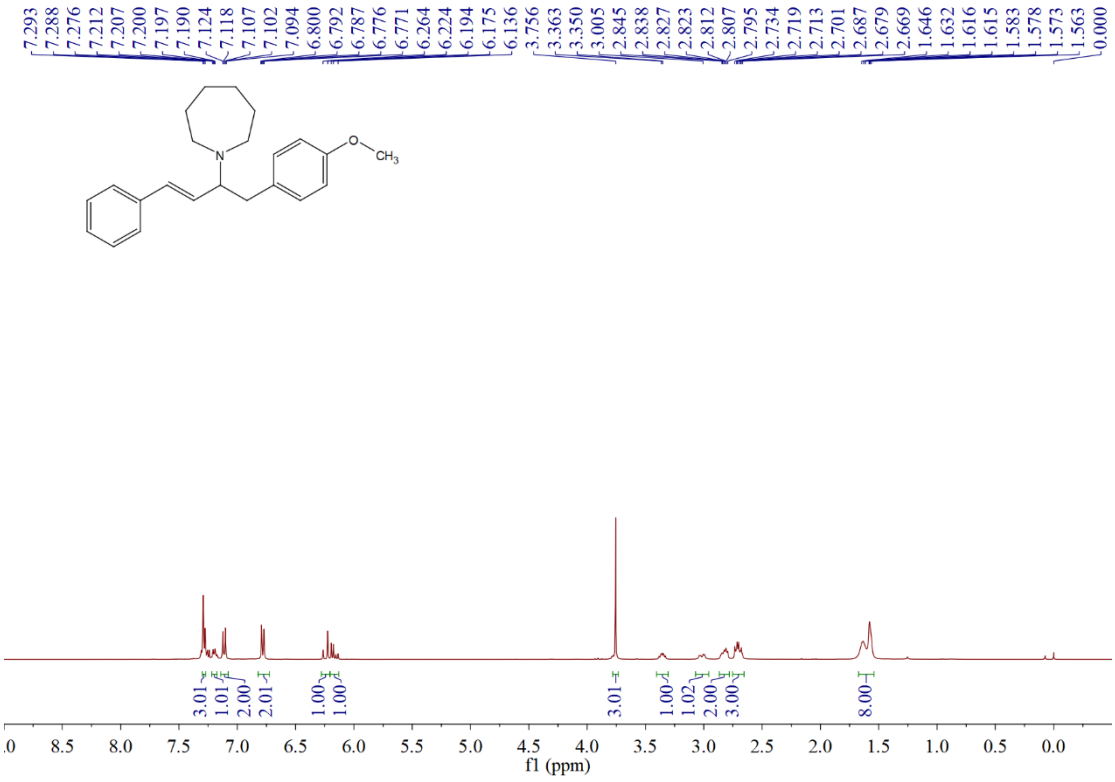
^{1}H NMR (400 MHz, $CDCl_3$) of 6c



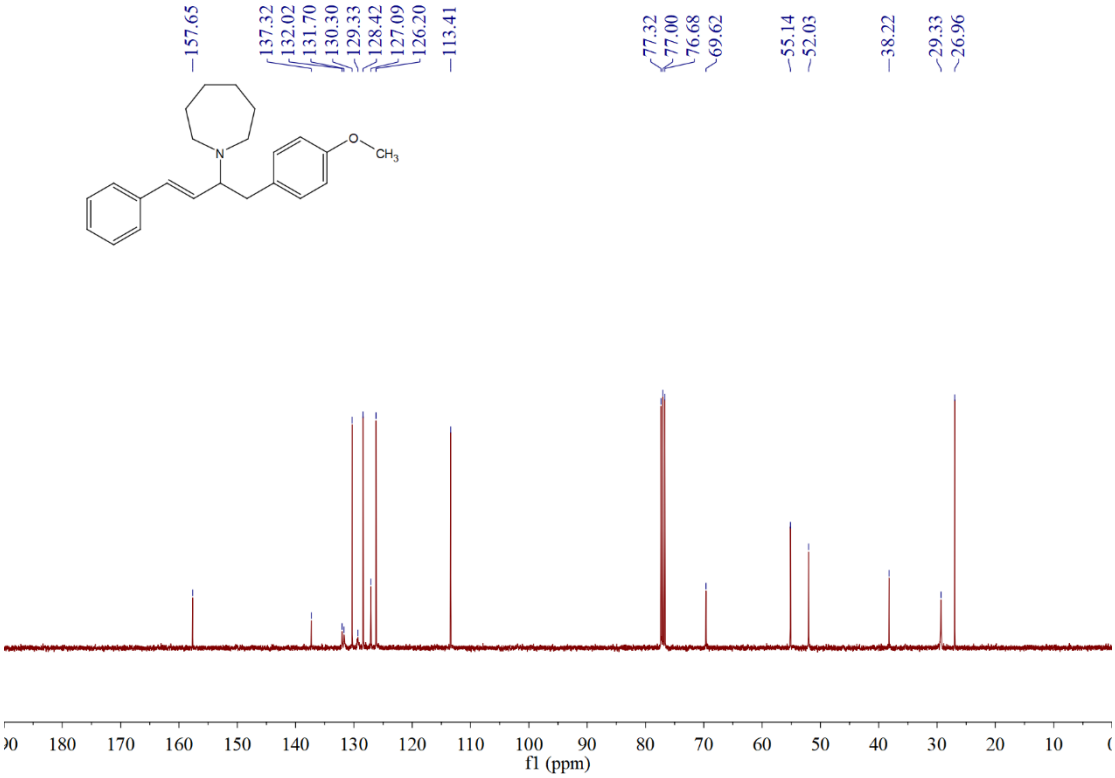
^{13}C NMR (101 MHz, $CDCl_3$) of 6c



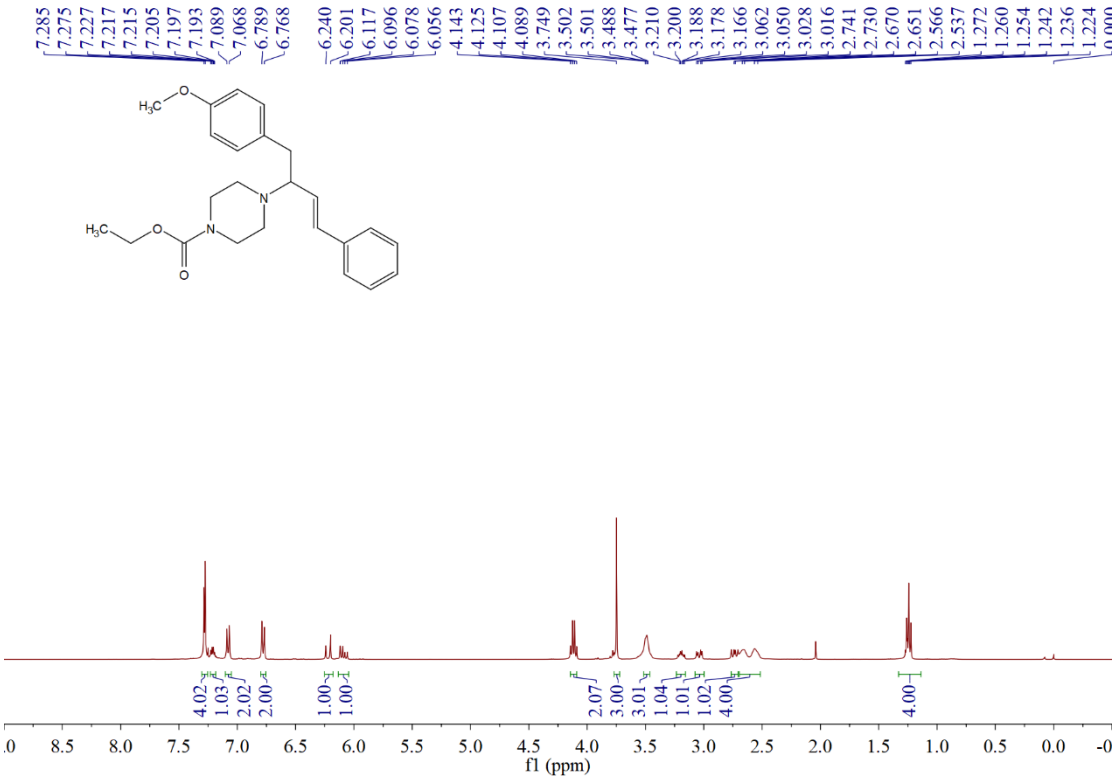
^{1}H NMR (400 MHz, $CDCl_3$) of 6d



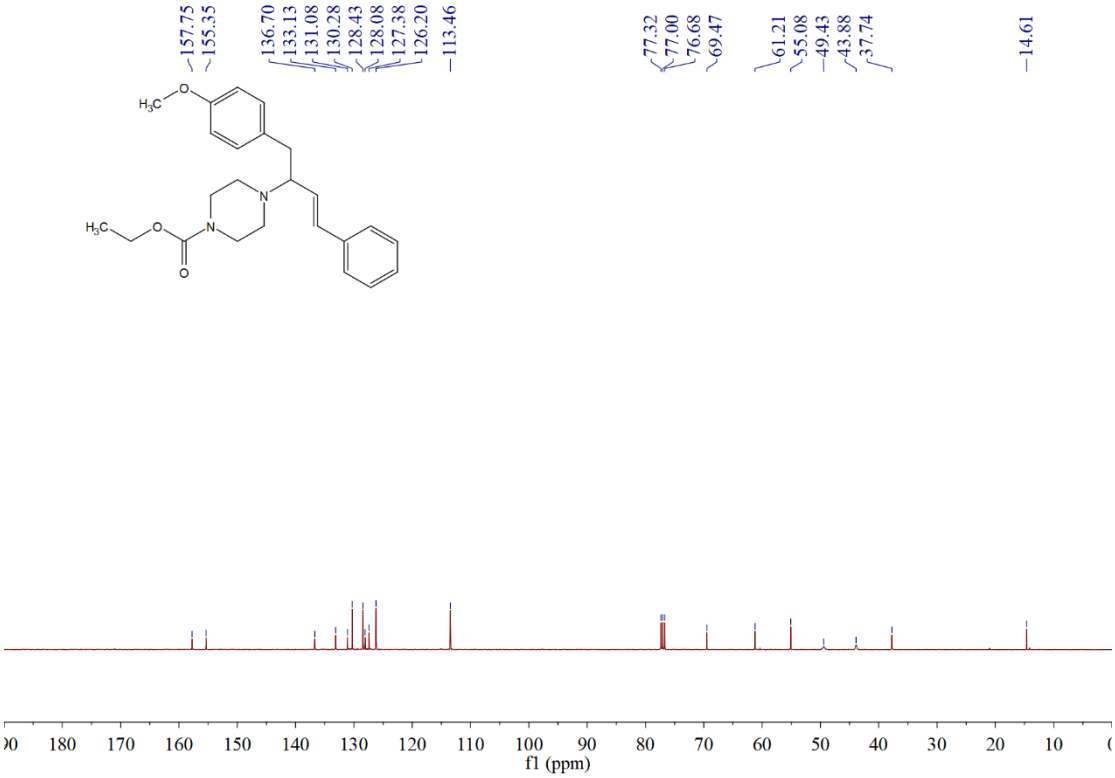
^{13}C NMR (101 MHz, $CDCl_3$) of 6d



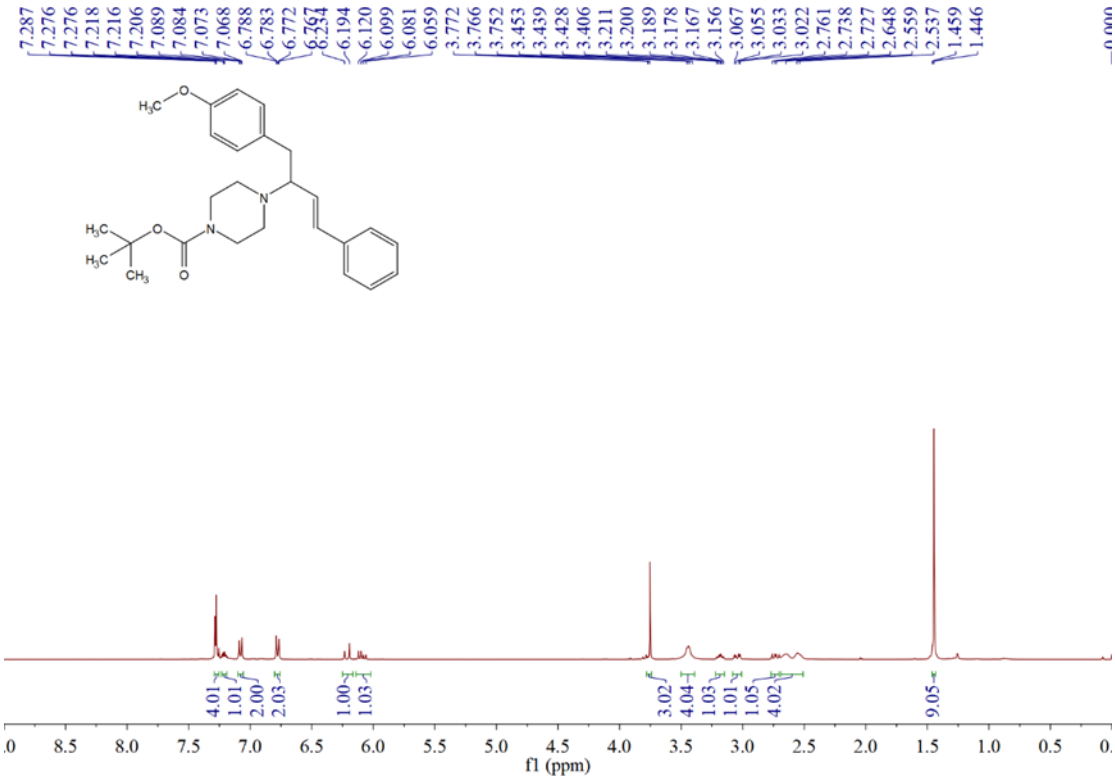
^{1}H NMR (400 MHz, $CDCl_3$) of 6e



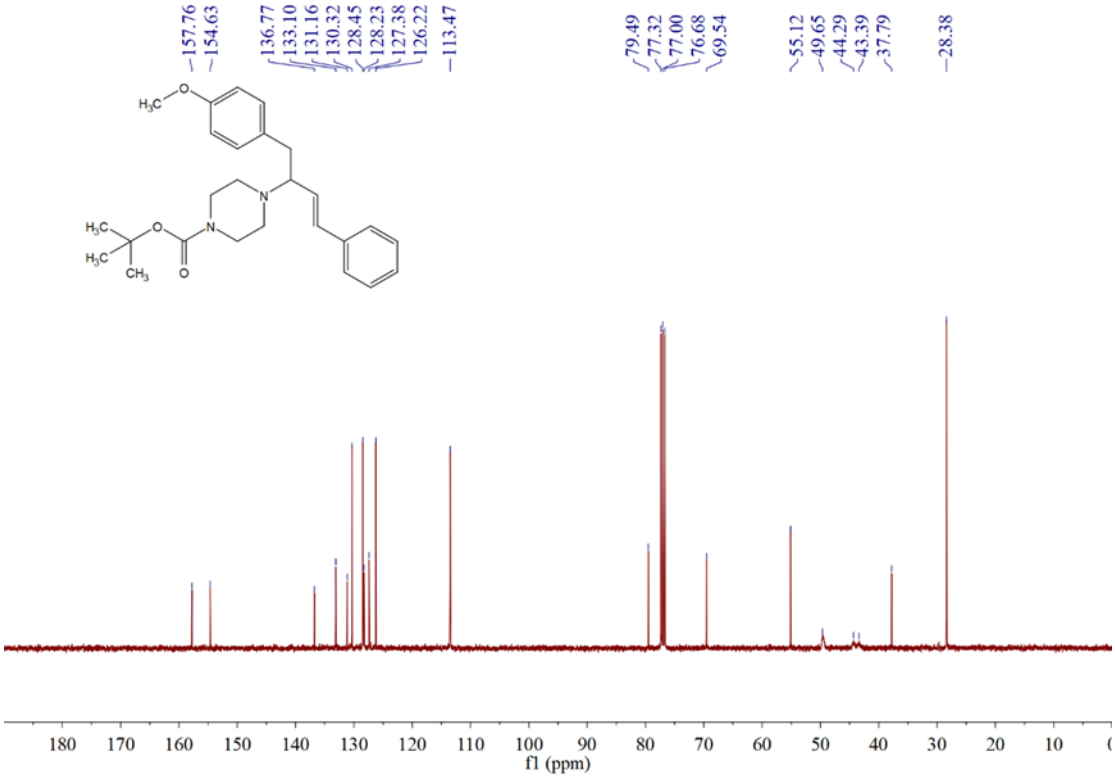
^{13}C NMR (101 MHz, $CDCl_3$) of 6e



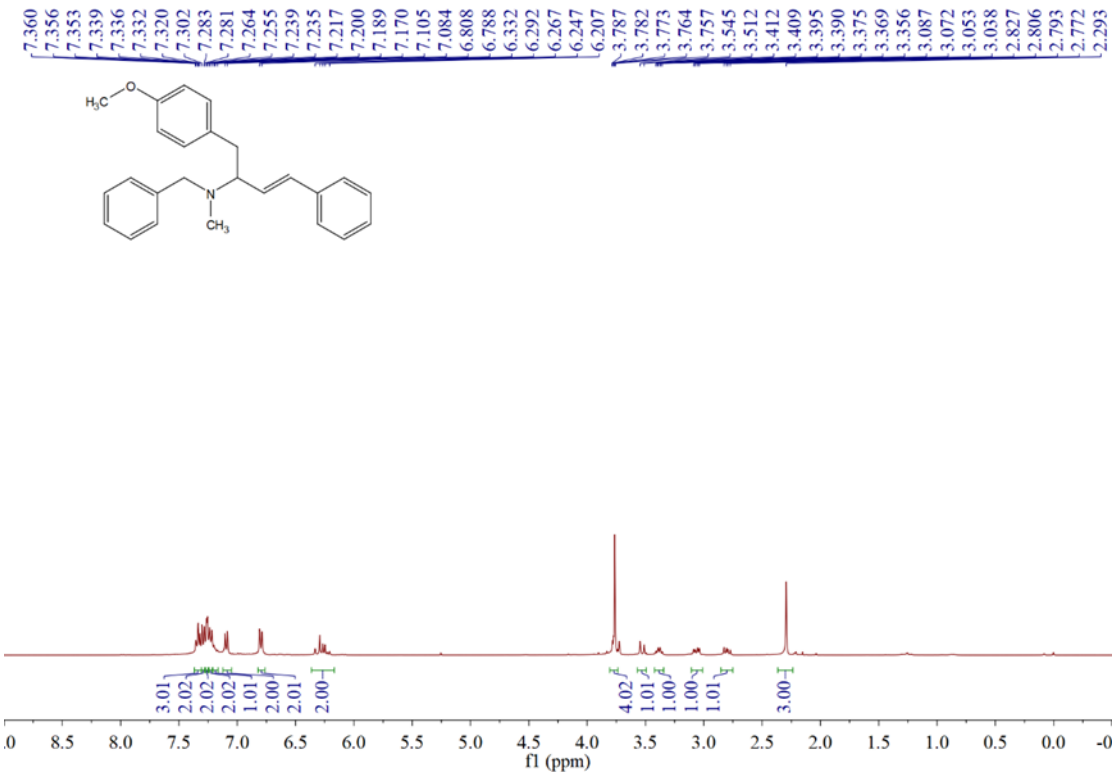
^{1}H NMR (400 MHz, $CDCl_3$) of 6f



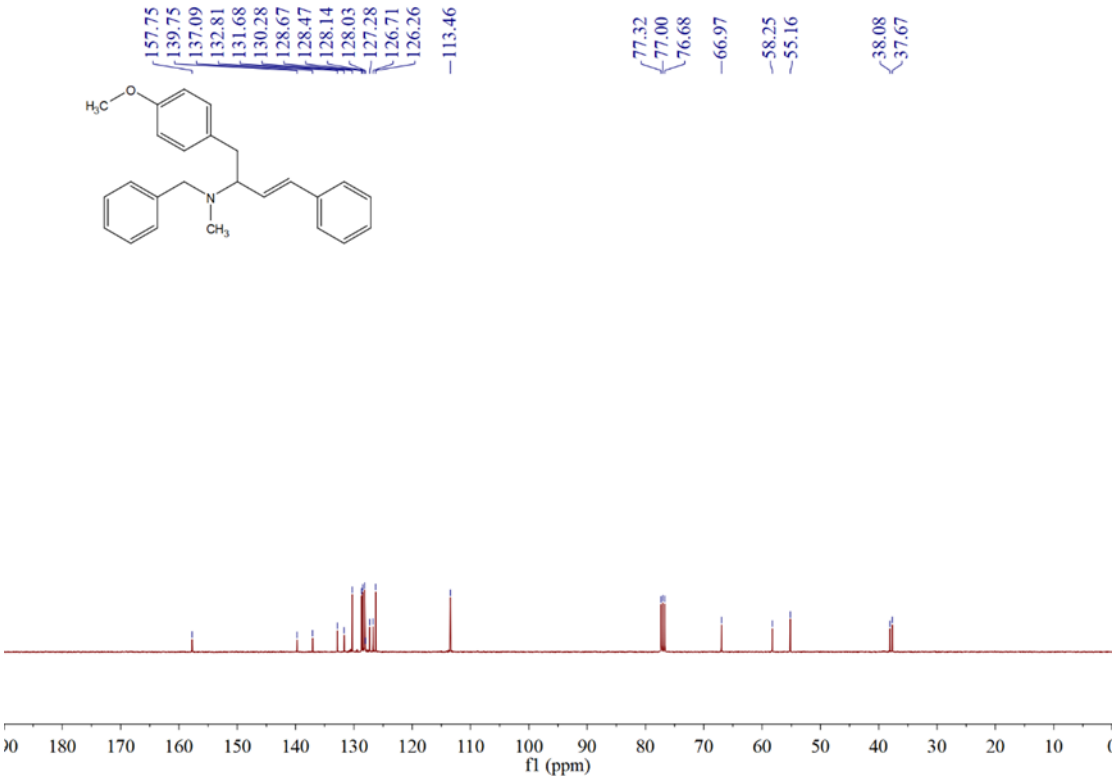
^{13}C NMR (101 MHz, $CDCl_3$) of 6f



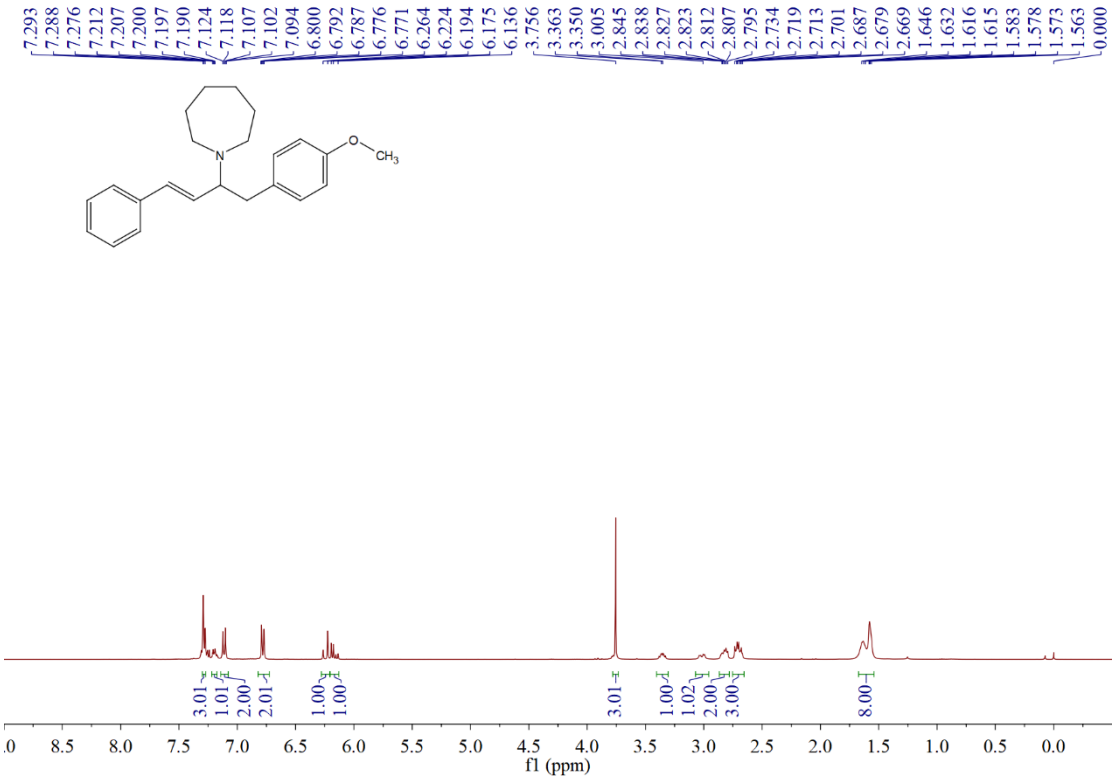
^{1}H NMR (400 MHz, $CDCl_3$) of 6g



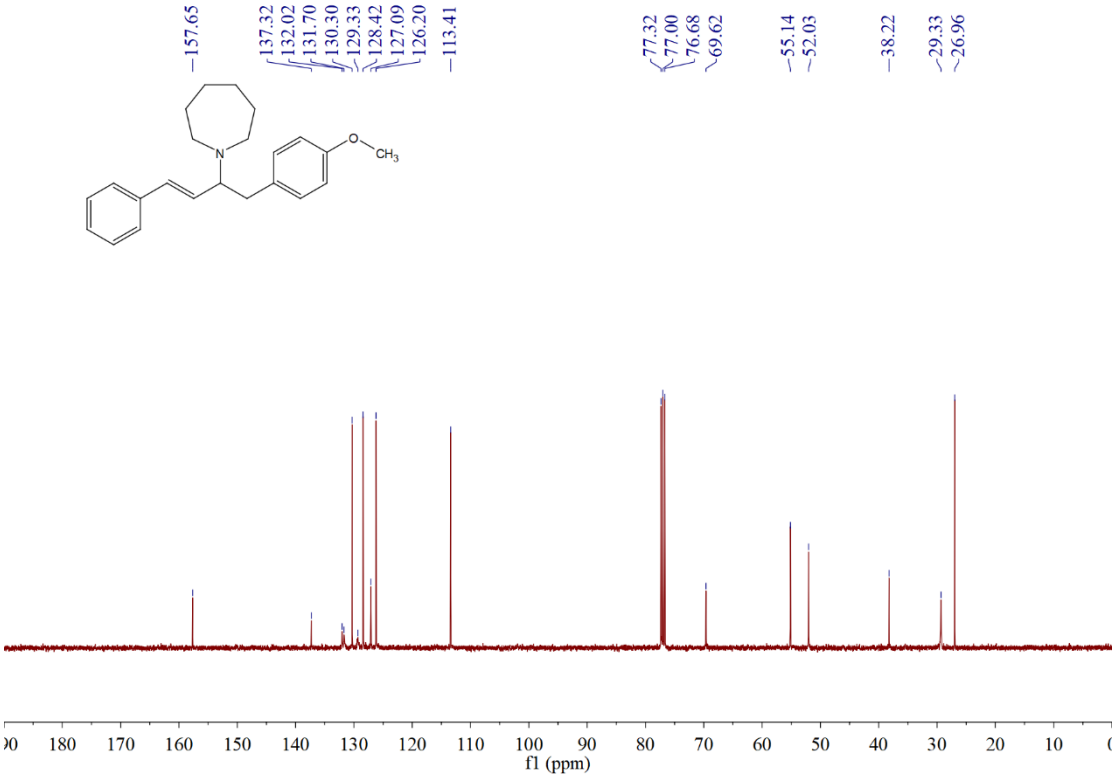
^{13}C NMR (101 MHz, $CDCl_3$) of 6g



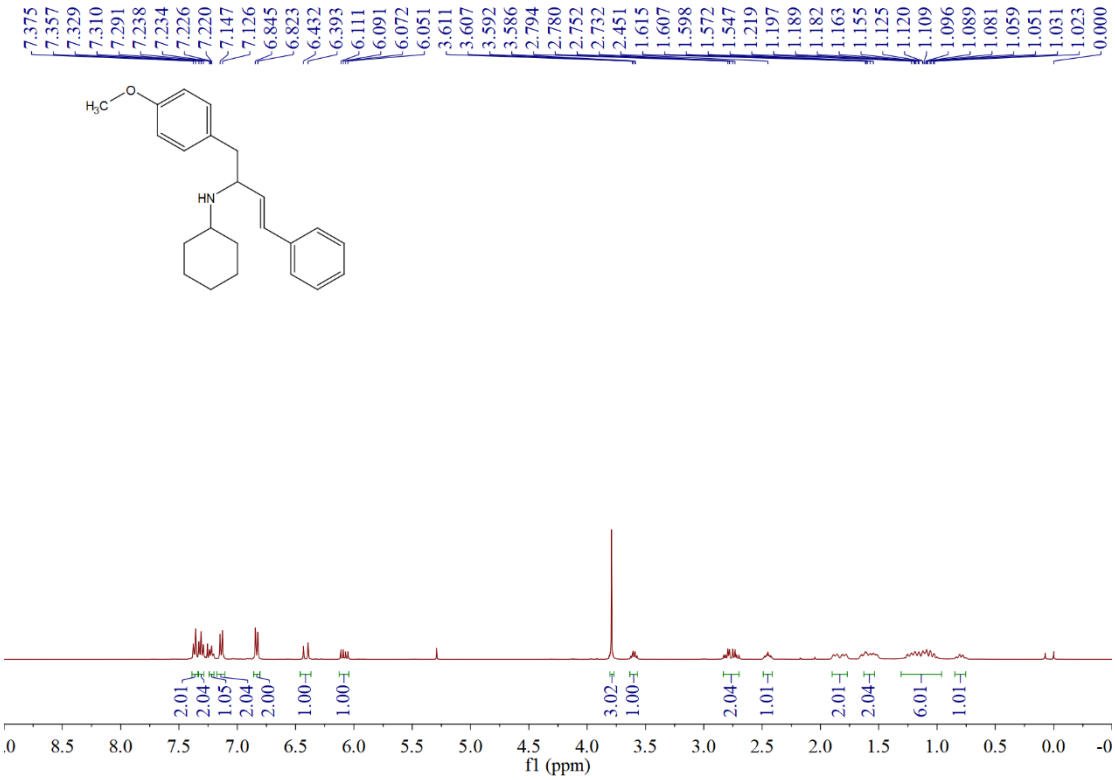
^{1}H NMR (400 MHz, $CDCl_3$) of 6h



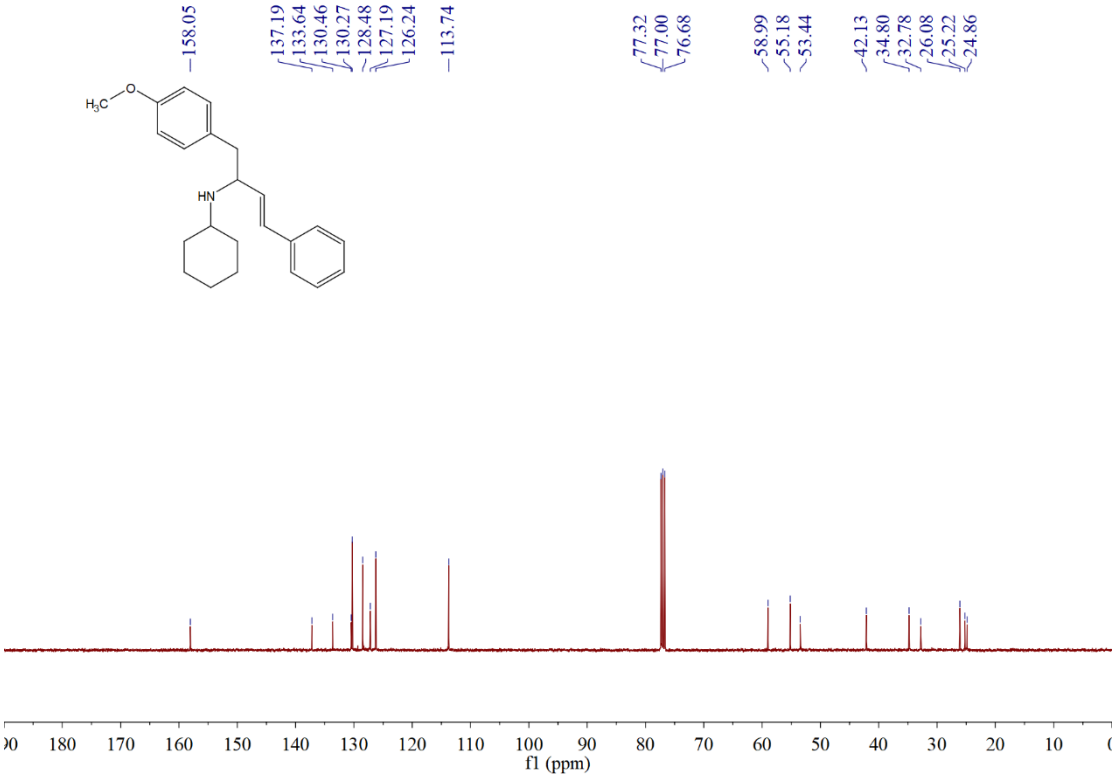
^{13}C NMR (101 MHz, $CDCl_3$) of 6h



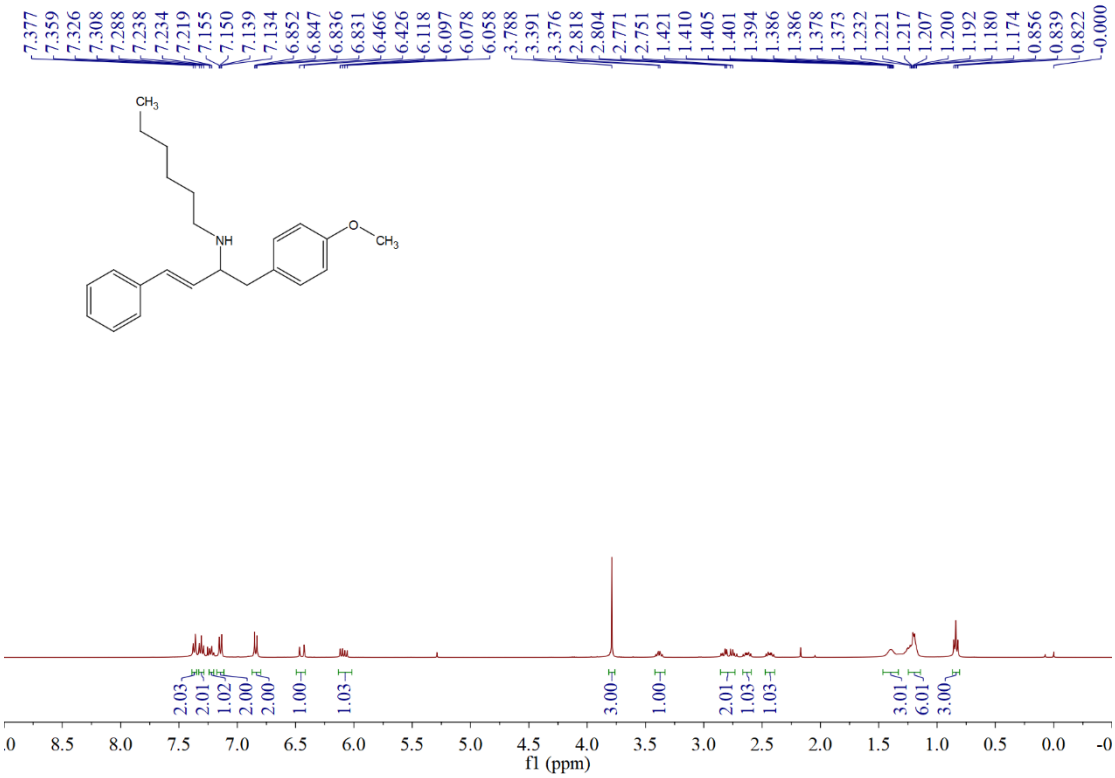
^{1}H NMR (400 MHz, $CDCl_3$) of 6i



^{13}C NMR (101 MHz, $CDCl_3$) of 6i



^{1}H NMR (400 MHz, $CDCl_3$) of 6j



^{13}C NMR (101 MHz, $CDCl_3$) of 6j