

Supporting Information

Synthesis of 2-Pyrrolidinone Derivatives *via* N-Heterocyclic Carbene Catalyzed Radical Tandem Cyclization/Coupling Reaction

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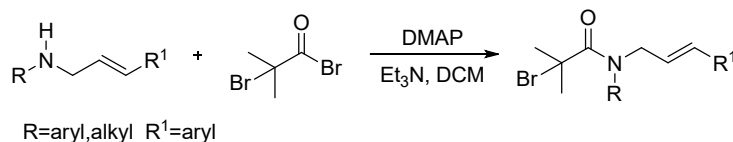
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1. General methods and materials

Unless otherwise mentioned, all reactions were carried out under an atmosphere of argon in dry glassware and were monitored by analytical thin-layer chromatography (TLC), which was visualized by ultraviolet light (254 nm). All solvents were obtained from commercial sources and were purified according to standard procedures. All syntheses and manipulations were carried out under a dry argon atmosphere. Purification of the products was accomplished by flash chromatography using silica gel (200-300 mesh). Melting points were determined in open capillaries and were uncorrected. IR spectra were taken on a FT-IR spectrometer in KBr pellets and reported in cm^{-1} . ^1H NMR spectra were measured on a 400 MHz spectrometer in CDCl_3 (100 MHz, ^{13}C NMR) or $\text{DMSO}-d_6$ with chemical shift (δ) given in ppm relative to TMS as internal standard. Data were reported as follows: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiple), coupling constants (Hz), integration. High-resolution mass spectra (HRMS) were measured with ESI in a positive mode.

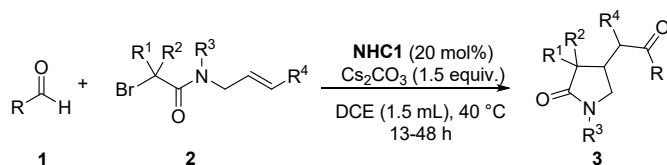
2. General procedures of substrates

Preparation of 2¹.



To a 100 mL flame-dried Schlenk tube charged with the corresponding cinnamyl amine² (5.0 mmol, 1.0 equiv.), Et_3N (1.40 mL, 10.0 mmol, 2.0 equiv.), DMAP (0.5 mmol, 0.1 equiv.) were suspended in DCM (20 mL), cooled to 0 °C, and then 2-bromo acid bromide (7.5 mmol, 1.5 equiv.) was added dropwise and stirred at room temperature for 12 hours. The reaction mixture was washed with NH_4Cl aqueous solution and brine, organic layer was dried with Na_2SO_4 . The reaction mixture was concentrated under reduced pressure, and purified by column chromatography on silica gel (PE/EA=10/1) to give product **2**. All the substrates were prepared according to the above procedure.

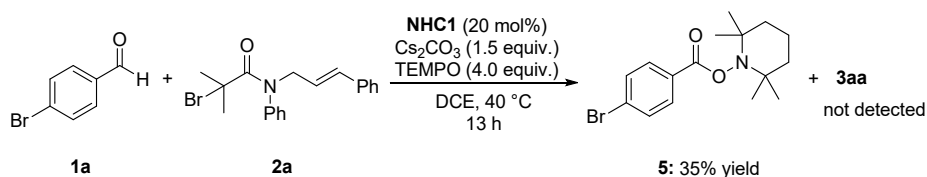
3. General procedures of products



A dried and argon-filled Schlenk tube was charged with aldehydes **1** (0.20 mmol, 1.0 equiv.), α -bromo-N-cinnamylamides **2** (0.30 mmol, 1.5 equiv.), NHC1 (0.04 mmol, 20 mol%), and Cs₂CO₃ (0.30 mmol, 1.5 equiv.) in dry DCE (1.5 mL). The reaction mixture was stirred at 40 °C until the consumption of aldehydes **1** as monitored by TLC. The solvent was removed in vacuo and the residue was purified by chromatography on silica gel using PE/EA (15:1) as eluent to afford the desired products **3**.

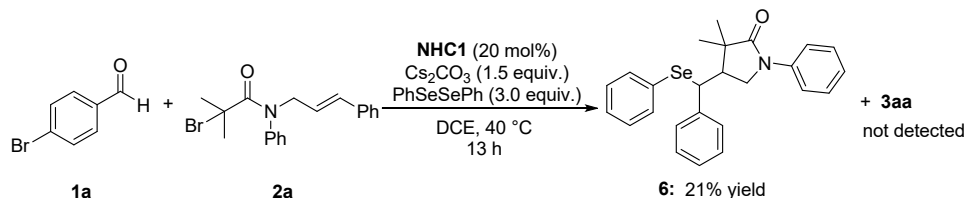
4. Radical trapping experiments

4.1 TEMPO trapping experiment



A dried and argon-filled Schlenk tube was charged with aldehydes **1a** (0.20 mmol, 1.0 equiv.), α -bromo-N-cinnamylamides **2a** (0.30 mmol, 1.5 equiv.), thiazolium salt NHC1 (0.04 mmol, 20 mol%), Cs₂CO₃ (0.30 mmol, 1.5 equiv.) and TEMPO (0.6 mmol, 3.0 equiv.) in dry DCE (1.5 mL). Then the system was stirred at 40 °C for 13 h. The reaction mixture was purified by silica gel column chromatography to afford the adduct **5** (23.8 mg, 35% yield). Instead, the 2-pyrrolidinone derivatives **3aa** was not formed.³

4.2 PhSeSePh trapping experiment

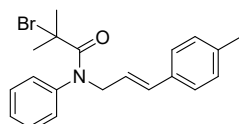


A dried and argon-filled Schlenk tube was charged with aldehydes **1a** (0.20 mmol, 1.0 equiv.), α -bromo-N-cinnamylamides **2a** (0.30 mmol, 1.5 equiv.), thiazolium salt NHC1 (0.04 mmol, 20 mol%), Cs₂CO₃ (0.30 mmol, 1.5 equiv.) and diphenyl diselenide (0.6 mmol, 3.0 equiv.)

in dry DCE (1.5 mL). Then the system was stirred at 40 °C for 13 h. The reaction mixture was purified by silica gel column chromatography to afford the corresponding trapping product **6** (18.5 mg, 21% yield). Instead, the desired product **3aa** was not formed.⁴

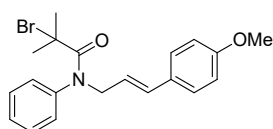
5. Characterization data of substrates

(*E*)-2-bromo-2-methyl-*N*-phenyl-*N*-(3-(*p*-tolyl)allyl)propanamide (**2b**).



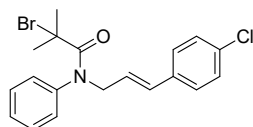
¹H NMR (400 MHz, CDCl₃) δ 7.40 – 7.32 (m, 5H), 7.23 (d, *J* = 7.7 Hz, 2H), 7.10 (d, *J* = 7.7 Hz, 2H), 6.38 – 6.15 (m, 2H), 4.41 (d, *J* = 5.6 Hz, 2H), 2.33 (s, 3H), 1.73 (s, 6H); ¹³C NMR (100 MHz, CDCl₃) δ 169.8, 142.3, 137.6, 133.9, 133.7, 129.9, 129.2, 128.9, 128.3, 126.4, 122.5, 58.3, 56.0, 33.3, 21.2; HRMS (ESI) *m/z* calcd for [M + H]⁺ C₂₀H₂₃BrNO: 372.0958; found: 372.0953.

(*E*)-2-bromo-*N*-(3-(4-methoxyphenyl)allyl)-2-methyl-*N*-phenylpropanamide (**2c**).



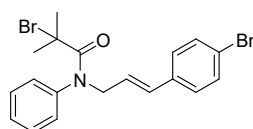
¹H NMR (400 MHz, CDCl₃) δ 7.41 – 7.33 (m, 5H), 7.27 (d, *J* = 8.7 Hz, 2H), 6.83 (d, *J* = 8.4 Hz, 2H), 6.29 (d, *J* = 15.9 Hz, 1H), 6.24 – 6.11 (m, 1H), 4.40 (d, *J* = 6.5 Hz, 2H), 3.79 (s, 3H), 1.73 (s, 6H); ¹³C NMR (100 MHz, CDCl₃) δ 169.8, 159.2, 142.3, 133.2, 129.9, 129.4, 128.9, 128.3, 127.6, 121.2, 113.9, 58.3, 56.1, 55.3, 33.3; HRMS (ESI) *m/z* calcd for [M + H]⁺ C₂₀H₂₃BrNO₂: 388.0907; found: 388.0911.

(*E*)-2-bromo-*N*-(3-(4-chlorophenyl)allyl)-2-methyl-*N*-phenylpropanamide (**2d**).



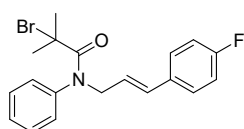
¹H NMR (400 MHz, CDCl₃) δ 7.43 – 7.30 (m, 5H), 7.25 (s, 4H), 6.38 – 6.22 (m, 2H), 4.41 (d, *J* = 4.4 Hz, 2H), 1.72 (s, 6H); ¹³C NMR (100 MHz, CDCl₃) δ 169.8, 142.2, 135.1, 133.2, 132.3, 129.8, 128.9, 128.6, 128.3, 127.6, 124.2, 58.2, 55.8, 33.2; HRMS (ESI) *m/z* calcd for [M + H]⁺ C₁₉H₂₀BrClNO: 392.0411; found: 392.0407.

(*E*)-2-bromo-*N*-(3-(4-bromophenyl)allyl)-2-methyl-*N*-phenylpropanamide (**2e**).



¹H NMR (400 MHz, CDCl₃) δ 7.46 – 7.30 (m, 7H), 7.20 (d, *J* = 8.1 Hz, 2H), 6.38 – 6.19 (m, 2H), 4.40 (d, *J* = 3.8 Hz, 2H), 1.72 (s, 6H); ¹³C NMR (100 MHz, CDCl₃) δ 169.9, 142.3, 135.6, 132.5, 131.6, 129.9, 129.0, 128.4, 128.0, 124.4, 121.5, 58.2, 55.9, 33.3; HRMS (ESI) *m/z* calcd for [M + H]⁺ C₁₉H₂₀Br₂NO: 435.9906.; found: 435.9904.

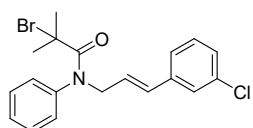
(*E*)-2-bromo-*N*-(3-(4-fluorophenyl)allyl)-2-methyl-*N*-phenylpropanamide (**2f**).



¹H NMR (400 MHz, CDCl₃) δ 7.42 – 7.33 (m, 5H), 7.33 – 7.27 (m, 2H), 6.98 (t, *J* = 8.6 Hz, 2H), 6.33 (d, *J* = 15.9 Hz, 1H), 6.27 – 6.18 (m, 1H),

4.40 (d, $J = 6.4$ Hz, 2H), 1.73 (s, 6H); ^{13}C NMR (100 MHz, CDCl_3) δ 169.8, 162.3 (d, $J_{\text{C-F}} = 245.6$ Hz), 142.3, 132.8 (d, $J_{\text{C-F}} = 3.2$ Hz), 129.9, 129.0, 128.4, 128.0 (d, $J_{\text{C-F}} = 7.9$ Hz), 123.3, 123.2, 115.4 (d, $J_{\text{C-F}} = 21.5$ Hz), 58.2, 55.9, 33.3; ^{19}F NMR (376 MHz, CDCl_3) δ -114.22; HRMS (ESI) m/z calcd for $[\text{M} + \text{H}]^+$ $\text{C}_{19}\text{H}_{20}\text{BrFNO}$: 376.0707; found: 376.0704.

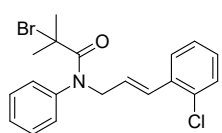
(E)-2-bromo-N-(3-(3-chlorophenyl)allyl)-2-methyl-N-phenylpropanamide (2g).



^1H NMR (400 MHz, CDCl_3) δ 7.42 – 7.33 (m, 5H), 7.32 (s, 1H), 7.25 – 7.17 (m, 3H), 6.37 – 6.27 (m, 2H), 4.41 (d, $J = 4.4$ Hz, 2H), 1.73 (s, 6H); ^{13}C NMR (100 MHz, CDCl_3) δ 169.9, 142.3, 138.5, 134.5, 132.3, 129.8,

129.7, 129.0, 128.4, 127.6, 126.4, 125.2, 124.7, 58.2, 55.8, 33.3; HRMS (ESI) m/z calcd for $[\text{M} + \text{H}]^+$ $\text{C}_{19}\text{H}_{20}\text{BrClNO}$: 392.0411; found: 392.0419.

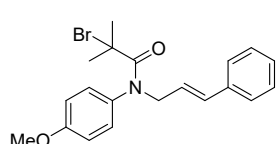
(E)-2-bromo-N-(3-(2-chlorophenyl)allyl)-2-methyl-N-phenylpropanamide (2h).



^1H NMR (400 MHz, CDCl_3) δ 7.52 (d, $J = 7.5$ Hz, 1H), 7.46 – 7.34 (m, 5H), 7.32 (d, $J = 7.7$ Hz, 1H), 7.24 – 7.14 (m, 2H), 6.74 (d, $J = 15.9$ Hz, 1H), 6.35 – 6.24 (m, 1H), 4.46 (d, $J = 6.4$ Hz, 2H), 1.74 (s, 6H); ^{13}C NMR (100 MHz,

CDCl_3) δ 169.9, 142.4, 134.9, 133.0, 129.8, 129.7, 129.6, 129.0, 128.7, 128.4, 127.1, 126.8, 126.6, 58.1, 55.9, 33.3; HRMS (ESI) m/z calcd for $[\text{M} + \text{H}]^+$ $\text{C}_{19}\text{H}_{20}\text{BrClNO}$: 392.0411; found: 392.0413.

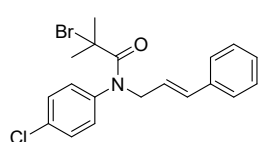
2-bromo-N-cinnamyl-N-(4-methoxyphenyl)-2-methylpropanamide (2i).



^1H NMR (400 MHz, CDCl_3) δ 7.35 (d, $J = 7.4$ Hz, 2H), 7.30 (t, $J = 7.6$ Hz, 2H), 7.27 (d, $J = 6.1$ Hz, 1H), 7.26 – 7.21 (m, 2H), 6.88 (d, $J = 8.7$ Hz, 2H), 6.39 – 6.26 (m, 2H), 4.39 (s, 2H), 3.82 (s, 3H), 1.73 (s, 6H);

^{13}C NMR (100 MHz, CDCl_3) δ 170.1, 159.1, 136.7, 134.9, 133.6, 131.0, 128.5, 127.6, 126.4, 123.6, 113.9, 58.3, 56.1, 55.4, 33.4; HRMS (ESI) m/z calcd for $[\text{M} + \text{H}]^+$ $\text{C}_{20}\text{H}_{23}\text{BrNO}_2$: 388.0907; found: 388.0906.

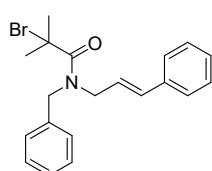
2-bromo-N-(4-chlorophenyl)-N-cinnamyl-2-methylpropanamide (2j).



^1H NMR (400 MHz, CDCl_3) δ 7.36 (t, $J = 8.4$ Hz, 3H), 7.31 (t, $J = 8.1$ Hz, 5H), 7.24 (s, 1H), 6.41 – 6.20 (m, 2H), 4.41 (d, $J = 5.9$ Hz, 2H), 1.76 (s, 6H); ^{13}C NMR (100 MHz, CDCl_3) δ 169.8, 140.8, 136.5, 134.2, 134.1,

131.3, 129.2, 128.6, 127.8, 126.5, 123.2, 57.9, 56.0, 33.3; HRMS (ESI) m/z calcd for $[\text{M} + \text{H}]^+$ $\text{C}_{19}\text{H}_{20}\text{BrClNO}$: 392.0411; found: 392.0411.

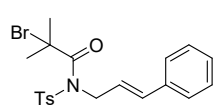
N-benzyl-2-bromo-N-cinnamyl-2-methylpropanamide (2k).



^1H NMR (400 MHz, CDCl_3) δ 7.40 – 7.30 (m, 6H), 7.30 – 7.21 (m, 4H), 6.44 (s, 1H), 6.24 – 6.05 (m, 1H), 5.16 – 3.95 (m, 4H), 2.03 (s, 6H); ^{13}C NMR

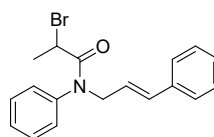
(100 MHz, CDCl₃) δ 170.6, 136.9, 136.3, 133.1, 128.7, 128.6, 127.8, 127.3, 126.4, 124.0, 57.1, 50.4, 48.9, 32.9; **HRMS** (ESI) m/z calcd for [M + H]⁺ C₂₀H₂₃BrNO: 372.0958; found: 372.0962.

2-bromo-*N*-cinnamyl-2-methyl-*N*-tosylpropanamide (2l).



¹H NMR (400 MHz, CDCl₃) δ 7.88 (d, J = 8.0 Hz, 2H), 7.39 – 7.31 (m, 4H), 7.31 – 7.27 (m, 1H), 7.26 – 7.22 (m, 2H), 6.70 (d, J = 16.0 Hz, 1H), 6.29 – 6.21 (m, 1H), 5.10 (d, J = 5.5 Hz, 2H), 2.40 (s, 3H), 1.94 (s, 6H); ¹³C NMR (100 MHz, CDCl₃) δ 170.6, 144.6, 136.2, 136.0, 133.6, 129.2, 129.1, 128.6, 128.1, 126.5, 124.4, 56.9, 50.4, 32.0, 21.6; **HRMS** (ESI) m/z calcd for [M + Na]⁺ C₂₀H₂₂BrNNaO₃S: 458.0396; found: 458.0399.

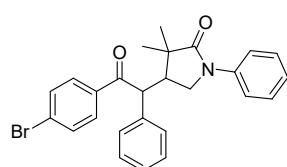
2-bromo-*N*-cinnamyl-*N*-phenylpropanamide (2m).



¹H NMR (400 MHz, CDCl₃) δ 7.46 – 7.37 (m, 3H), 7.33 (t, J = 7.8 Hz, 3H), 7.29 (d, J = 7.5 Hz, 2H), 7.26 – 7.20 (m, 2H), 6.40 (d, J = 15.8 Hz, 1H), 6.32 – 6.19 (m, 1H), 4.51 – 4.37 (m, 2H), 4.23 (q, J = 6.6 Hz, 1H), 1.76 (d, J = 6.6 Hz, 3H); ¹³C NMR (100 MHz, CDCl₃) δ 169.3, 141.2, 136.6, 133.9, 129.8, 128.6, 128.5, 128.3, 127.8, 126.5, 123.4, 52.4, 39.4, 21.7; **HRMS** (ESI) m/z calcd for [M + H]⁺ C₁₈H₁₉BrNO: 344.0645; found: 344.0644.

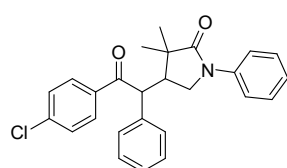
6. Characterization data of products

4-(2-(4-bromophenyl)-2-oxo-1-phenylethyl)-3,3-dimethyl-1-phenylpyrrolidin-2-one (3aa).



White solid (73.8 mg, 80% yield); **mp** 180.3 – 181.6 °C; ¹H NMR (400 MHz, CDCl₃) δ 7.89 (d, J = 8.1 Hz, 2H), 7.66 – 7.54 (m, 4H), 7.43 (d, J = 7.6 Hz, 2H), 7.34 (t, J = 7.5 Hz, 4H), 7.27 (d, J = 9.1 Hz, 1H), 7.12 (t, J = 7.4 Hz, 1H), 4.74 (d, J = 10.7 Hz, 1H), 4.04 (t, J = 8.4 Hz, 1H), 3.37 (t, J = 9.8 Hz, 1H), 3.28 – 3.18 (m, 1H), 1.23 (s, 3H), 0.66 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) δ 196.8, 178.3, 139.3, 135.9, 134.8, 132.0, 130.1, 129.2, 128.7, 128.1, 124.4, 119.7, 53.2, 49.8, 45.7, 44.5, 24.3, 18.9; **IR** (KBr) (ν , cm⁻¹): 3059, 2977, 1698, 1586, 1567, 1494, 1454, 1396; **HRMS** (ESI) m/z calcd for [M + H]⁺ C₂₆H₂₅BrNO₂: 462.1063; found: 462.1055.

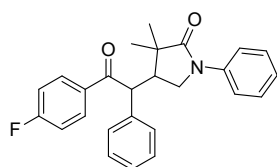
4-(2-(4-chlorophenyl)-2-oxo-1-phenylethyl)-3,3-dimethyl-1-phenylpyrrolidin-2-one (3ba).



White solid (54.5 mg, 65% yield); **mp** 186.8 – 187.4 °C; ¹H NMR (400 MHz, CDCl₃) δ 7.97 (d, J = 8.6 Hz, 2H), 7.61 (d, J = 8.1 Hz, 2H), 7.46 – 7.37 (m, 4H), 7.37 – 7.30 (m, 4H), 7.28 – 7.22 (m, 1H), 7.11 (t, J = 7.4 Hz, 1H), 4.75 (d, J = 10.8 Hz, 1H), 4.09 – 3.98 (m, 1H), 3.37 (t,

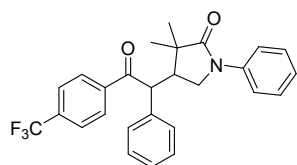
$J = 9.8$ Hz, 1H), 3.28 – 3.17 (m, 1H), 1.23 (s, 3H), 0.66 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 196.6, 178.4, 139.9, 139.3, 135.9, 134.4, 130.1, 129.2, 129.0, 128.7, 128.1, 124.4, 119.7, 53.2, 49.8, 45.8, 44.6, 24.3, 18.9; IR (KBr) (ν , cm^{-1}): 3063, 2980, 1702, 1669, 1589, 1570, 1494, 1455, 1395; HRMS (ESI) m/z calcd for $[\text{M} + \text{H}]^+ \text{C}_{26}\text{H}_{25}\text{ClNO}_2$: 418.1568; found: 418.1563.

4-(2-(4-fluorophenyl)-2-oxo-1-phenylethyl)-3,3-dimethyl-1-phenylpyrrolidin-2-one (3ca).



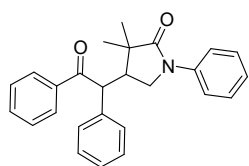
White solid (70.5 mg, 88% yield); mp 187.2 – 187.7 °C; ^1H NMR (400 MHz, CDCl_3) δ 8.10 – 8.03 (m, 2H), 7.61 (d, $J = 8.1$ Hz, 2H), 7.45 (d, $J = 8.1$ Hz, 2H), 7.33 (q, $J = 7.3$ Hz, 4H), 7.27 (d, $J = 7.6$ Hz, 1H), 7.14 – 7.06 (m, 3H), 4.77 (d, $J = 10.8$ Hz, 1H), 4.08 – 4.00 (m, 1H), 3.38 (t, $J = 9.8$ Hz, 1H), 3.29 – 3.16 (m, 1H), 1.23 (s, 3H), 0.66 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 196.3, 178.4, 165.8 (d, $J_{\text{C-F}} = 254.7$ Hz), 139.3, 136.1, 132.5 (d, $J_{\text{C-F}} = 2.8$ Hz), 131.3 (d, $J_{\text{C-F}} = 9.3$ Hz), 129.1, 128.7, 128.0, 124.4, 119.7, 115.9 (d, $J_{\text{C-F}} = 21.8$ Hz), 53.1, 49.8, 45.8, 44.6, 24.3, 18.9; ^{19}F NMR (376 MHz, CDCl_3) δ -104.15; IR (KBr) (ν , cm^{-1}): 3042, 2971, 1703, 1668, 1596, 1494, 1485, 1456, 1393; HRMS (ESI) m/z calcd for $[\text{M} + \text{H}]^+ \text{C}_{26}\text{H}_{25}\text{FNO}_2$: 402.1864; found: 402.1861.

3,3-dimethyl-4-(2-oxo-1-phenyl-2-(4-(trifluoromethyl)phenyl)ethyl)-1-phenylpyrrolidin-2-one (3da).



White solid (41.5 mg, 46% yield); mp 101.4 – 102.8 °C; ^1H NMR (400 MHz, CDCl_3) δ 8.12 (d, $J = 8.1$ Hz, 2H), 7.70 (d, $J = 8.1$ Hz, 2H), 7.61 (d, $J = 8.1$ Hz, 2H), 7.44 (d, $J = 8.2$ Hz, 2H), 7.35 (q, $J = 7.1$ Hz, 4H), 7.29 (d, $J = 7.2$ Hz, 1H), 7.13 (t, $J = 7.4$ Hz, 1H), 4.79 (d, $J = 10.7$ Hz, 1H), 4.06 (t, $J = 8.4$ Hz, 1H), 3.39 (t, $J = 9.8$ Hz, 1H), 3.29 – 3.19 (m, 1H), 1.24 (s, 3H), 0.67 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 196.9, 178.3, 139.3, 138.8, 135.5, 134.6 (q, $J_{\text{C-F}} = 32.6$ Hz), 129.3, 129.2, 129.0, 128.8, 128.3, 125.8 (q, $J_{\text{C-F}} = 3.6$ Hz), 124.5, 123.4 (d, $J_{\text{C-F}} = 280$ Hz), 119.7, 53.7, 49.8, 45.8, 44.6, 24.3, 18.9; ^{19}F NMR (376 MHz, CDCl_3) δ -63.20; IR (KBr) (ν , cm^{-1}): 3060, 2970, 1686, 1598, 1500, 1458, 1403; HRMS (ESI) m/z calcd for $[\text{M} + \text{H}]^+ \text{C}_{27}\text{H}_{25}\text{F}_3\text{NO}_2$: 452.1832; found: 452.1825.

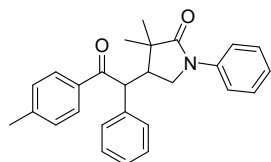
3,3-dimethyl-4-(2-oxo-1,2-diphenylethyl)-1-phenylpyrrolidin-2-one (3ea).



White solid (62.7 mg, 82% yield); mp 202.8 – 203.2 °C; ^1H NMR (400 MHz, CDCl_3) δ 8.04 (d, $J = 7.6$ Hz, 2H), 7.61 (d, $J = 7.9$ Hz, 2H), 7.54 (t, $J = 7.4$ Hz, 1H), 7.45 (q, $J = 7.5, 7.0$ Hz, 4H), 7.37 – 7.30 (m, 4H), 7.28 – 7.25 (m, 1H), 7.11 (t, $J = 7.4$ Hz, 1H), 4.83 (d, $J = 10.8$ Hz, 1H), 4.12 – 3.98 (m, 1H), 3.39 (t, $J = 9.8$ Hz, 1H), 3.32 – 3.20 (m, 1H), 1.24 (s, 3H), 0.67 (s, 3H); ^{13}C NMR

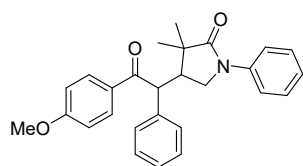
(100 MHz, CDCl₃) δ 197.9, 178.5, 139.4, 136.2, 133.4, 129.3, 129.1, 128.7(5), 128.6(7), 127.9, 124.4, 119.7, 53.1, 49.9, 45.9, 44.6, 24.4, 18.9; **IR** (KBr) (ν , cm⁻¹): 3064, 2964, 1699, 1683, 1668, 1596, 1500, 1484, 1456, 1394; **HRMS** (ESI) m/z calcd for [M + H]⁺ C₂₆H₂₆NO₂: 384.1958; found: 384.1951.

3,3-dimethyl-4-(2-oxo-1-phenyl-2-(*p*-tolyl)ethyl)-1-phenylpyrrolidin-2-one (3fa).



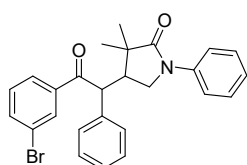
White solid (74.6 mg, 94% yield); **mp** 200.5 – 201.1 °C; **¹H NMR** (400 MHz, CDCl₃) δ 7.95 (d, J = 7.9 Hz, 2H), 7.61 (d, J = 8.1 Hz, 2H), 7.46 (d, J = 7.6 Hz, 2H), 7.32 (t, J = 7.7 Hz, 4H), 7.26 – 7.22 (m, 3H), 7.11 (t, J = 7.4 Hz, 1H), 4.80 (d, J = 10.8 Hz, 1H), 4.03 (t, 1H), 3.37 (t, J = 9.8 Hz, 1H), 3.32 – 3.17 (m, 1H), 2.38 (s, 3H), 1.23 (s, 3H), 0.67 (s, 3H); **¹³C NMR** (100 MHz, CDCl₃) δ 197.5, 178.5, 144.4, 139.4, 136.5, 133.7, 129.4, 129.2, 129.0, 128.8, 128.7, 127.8, 124.3, 119.7, 52.9, 49.9, 45.9, 44.6, 24.4, 21.6, 18.9; **IR** (KBr) (ν , cm⁻¹): 3033, 2979, 1698, 1666, 1604, 1494, 1485, 1456, 1394; **HRMS** (ESI) m/z calcd for [M + H]⁺ C₂₇H₂₈NO₂: 398.2115; found: 398.2114.

4-(2-(4-methoxyphenyl)-2-oxo-1-phenylethyl)-3,3-dimethyl-1-phenylpyrrolidin-2-one (3ga).



White solid (56.2 mg, 68% yield); **mp** 222.3 – 222.8 °C ; **¹H NMR** (400 MHz, CDCl₃) δ 8.04 (d, J = 8.5 Hz, 2H), 7.61 (d, J = 8.1 Hz, 2H), 7.47 (d, J = 7.6 Hz, 2H), 7.32 (t, J = 7.6 Hz, 4H), 7.23 (t, J = 7.4 Hz, 1H), 7.10 (t, J = 7.4 Hz, 1H), 6.91 (d, J = 8.4 Hz, 2H), 4.78 (d, J = 10.8 Hz, 1H), 4.03 (t, J = 8.4 Hz, 1H), 3.84 (s, 3H), 3.37 (t, J = 9.8 Hz, 1H), 3.31 – 3.18 (m, 1H), 1.23 (s, 3H), 0.67 (s, 3H); **¹³C NMR** (100 MHz, CDCl₃) δ 196.4, 178.6, 163.8, 139.4, 136.7, 131.0, 129.1(2), 129.0(7), 128.9(8), 128.7, 127.8, 124.3, 119.7, 113.9, 55.5, 52.6, 49.9, 45.8, 44.6, 24.4, 18.9; **IR** (KBr) (ν , cm⁻¹): 3011, 2973, 1696, 1665, 1599, 1575, 1512, 1494, 1455, 1395; **HRMS** (ESI) m/z calcd for [M + H]⁺ C₂₇H₂₈NO₃: 414.2064; found: 414.2070.

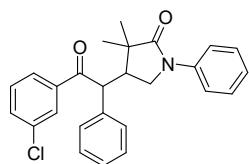
4-(2-(3-bromophenyl)-2-oxo-1-phenylethyl)-3,3-dimethyl-1-phenylpyrrolidin-2-one (3ha).



White solid (36.9 mg, 40% yield); **mp** 161.9 – 162.5 °C; **¹H NMR** (400 MHz, CDCl₃) δ 8.14 (s, 1H), 7.95 (d, J = 7.8 Hz, 1H), 7.65 (d, J = 8.0 Hz, 1H), 7.61 (d, J = 8.1 Hz, 2H), 7.43 (d, J = 7.5 Hz, 2H), 7.38 – 7.31 (m, 4H), 7.31 – 7.26 (m, 2H), 7.12 (t, J = 7.4 Hz, 1H), 4.74 (d, J = 10.8 Hz, 1H), 4.03 (t, J = 8.4 Hz, 1H), 3.38 (t, J = 9.8 Hz, 1H), 3.30 – 3.17 (m, 1H), 1.23 (s, 3H), 0.66 (s, 3H); **¹³C NMR** (100 MHz, CDCl₃) δ 196.5, 178.3, 139.3, 137.8, 136.2, 135.7, 131.7, 130.3, 129.2(3), 129.1(9), 128.8, 128.1, 127.1, 124.4, 123.2, 119.7, 53.4, 49.8, 45.8, 44.6, 24.3, 18.9; **IR**

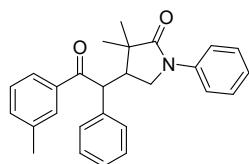
(KBr) (ν , cm^{-1}): 3060, 2970, 1685, 1674, 1598, 1566, 1493, 1468, 1403; **HRMS** (ESI) m/z calcd for $[\text{M} + \text{H}]^+ \text{C}_{26}\text{H}_{25}\text{BrNO}_2$: 462.1063; found: 462.1065.

4-(2-(3-chlorophenyl)-2-oxo-1-phenylethyl)-3,3-dimethyl-1-phenylpyrrolidin-2-one (3ia).



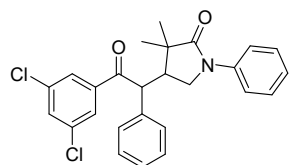
White solid (35.2 mg, 42% yield); **mp** 173.2 – 174.6 °C; **^1H NMR** (400 MHz, CDCl_3) δ 7.98 (s, 1H), 7.91 (d, $J = 7.8$ Hz, 1H), 7.61 (d, $J = 8.6$ Hz, 2H), 7.50 (d, $J = 8.1$ Hz, 1H), 7.44 (d, $J = 7.7$ Hz, 2H), 7.39 (d, $J = 7.8$ Hz, 1H), 7.37 – 7.31 (m, 4H), 7.28 (d, $J = 7.2$ Hz, 1H), 7.12 (t, $J = 7.4$ Hz, 1H), 4.75 (d, $J = 10.7$ Hz, 1H), 4.07 – 3.98 (m, 1H), 3.38 (t, $J = 9.8$ Hz, 1H), 3.28 – 3.18 (m, 1H), 1.24 (s, 3H), 0.66 (s, 3H); **^{13}C NMR** (100 MHz, CDCl_3) δ 196.6, 178.3, 139.3, 137.7, 135.7, 135.1, 133.3, 130.0, 129.2(2), 129.2(0), 128.7, 128.1, 126.7, 124.4, 119.7, 53.4, 49.8, 45.8, 44.6, 24.3, 18.9; **IR** (KBr) (ν , cm^{-1}): 3064, 2965, 1705, 1671, 1597, 1573, 1486, 1460, 1394; **HRMS** (ESI) m/z calcd for $[\text{M} + \text{H}]^+ \text{C}_{26}\text{H}_{25}\text{ClNO}_2$: 418.1568; found: 418.1561.

3,3-dimethyl-4-(2-oxo-1-phenyl-2-(*m*-tolyl)ethyl)-1-phenylpyrrolidin-2-one (3ja).



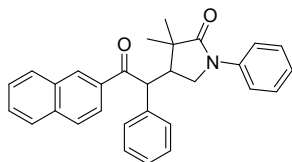
White solid (35.7 mg, 45% yield); **mp** 201.8 – 202.6 °C; **^1H NMR** (400 MHz, CDCl_3) δ 7.87 – 7.81 (m, 2H), 7.61 (d, $J = 8.2$ Hz, 2H), 7.46 (d, $J = 7.5$ Hz, 2H), 7.38 – 7.29 (m, 6H), 7.26 (t, $J = 3.7$ Hz, 1H), 7.11 (t, $J = 7.4$ Hz, 1H), 4.82 (d, $J = 10.8$ Hz, 1H), 4.09 – 3.98 (m, 1H), 3.46 – 3.33 (m, 1H), 3.33 – 3.19 (m, 1H), 2.39 (s, 3H), 1.24 (s, 3H), 0.67 (s, 3H); **^{13}C NMR** (100 MHz, CDCl_3) 198.2, 178.5, 139.4, 138.7, 136.4, 136.3, 134.2, 129.3, 129.2, 129.0, 128.7, 128.6, 127.9, 125.9, 124.4, 119.7, 53.1, 49.9, 45.9, 44.6, 24.4, 21.4, 18.9; **IR** (KBr) (ν , cm^{-1}): 3032, 2965, 1698, 1667, 1601, 1585, 1487, 1460, 1396; **HRMS** (ESI) m/z calcd for $[\text{M} + \text{H}]^+ \text{C}_{27}\text{H}_{28}\text{NO}_2$: 398.2115; found: 398.2113.

4-(2-(3,5-dichlorophenyl)-2-oxo-1-phenylethyl)-3,3-dimethyl-1-phenylpyrrolidin-2-one (3ka).



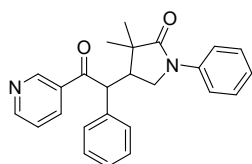
White solid (50.8 mg, 56% yield); **mp** 130.5 – 131.8 °C; **^1H NMR** (400 MHz, CDCl_3) δ 7.85 (s, 2H), 7.61 (d, $J = 8.2$ Hz, 2H), 7.51 (s, 1H), 7.42 (t, $J = 7.6$ Hz, 2H), 7.39 – 7.32 (m, 4H), 7.29 (t, $J = 7.2$ Hz, 1H), 7.13 (t, $J = 7.4$ Hz, 1H), 4.66 (d, $J = 10.8$ Hz, 1H), 4.09 – 3.96 (m, 1H), 3.37 (t, $J = 9.8$ Hz, 1H), 3.28 – 3.16 (m, 1H), 1.24 (s, 3H), 0.65 (s, 3H); **^{13}C NMR** (100 MHz, CDCl_3) δ 195.4, 178.2, 139.3, 138.6, 135.8, 135.2, 133.0, 129.4, 129.2, 128.8, 128.4, 127.1, 124.5, 119.7, 53.7, 49.8, 45.8, 44.6, 24.3, 18.9; **IR** (KBr) (ν , cm^{-1}): 3075, 2968, 1684, 1598, 1567, 1492, 1458, 1417; **HRMS** (ESI) m/z calcd for $[\text{M} + \text{H}]^+ \text{C}_{26}\text{H}_{24}\text{Cl}_2\text{NO}_2$: 452.1179; found: 452.1183.

3,3-dimethyl-4-(2-(naphthalen-2-yl)-2-oxo-1-phenylethyl)-1-phenylpyrrolidin-2-one (3la).



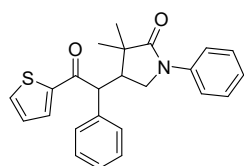
White solid (63.4 mg, 73% yield); **mp** 171.5 – 173.2 °C; **¹H NMR** (400 MHz, CDCl₃) δ 8.58 (s, 1H), 8.06 (d, *J* = 8.6 Hz, 1H), 7.98 (d, *J* = 7.9 Hz, 1H), 7.92 – 7.80 (m, 2H), 7.65 – 7.51 (m, 6H), 7.37 – 7.29 (m, 4H), 7.25 (d, *J* = 7.0 Hz, 1H), 7.11 (t, *J* = 7.4 Hz, 1H), 4.99 (d, *J* = 10.8 Hz, 1H), 4.09 (t, *J* = 8.4 Hz, 1H), 3.44 (t, *J* = 9.8 Hz, 1H), 3.38 – 3.26 (m, 1H), 1.29 (s, 3H), 0.70 (s, 3H); **¹³C NMR** (100 MHz, CDCl₃) δ 197.9, 178.5, 139.4, 136.4, 135.6, 133.6, 132.4, 130.4, 129.7, 129.3, 129.1, 128.8(2), 128.7(5), 128.6(9), 127.9, 127.7, 127.0, 124.4, 124.2, 53.2, 49.9, 45.9, 44.7, 24.4, 19.0; **IR** (KBr) (ν, cm⁻¹): 3060, 2968, 1695, 1663, 1627, 1597, 1491, 1464, 1396; **HRMS** (ESI) *m/z* calcd for [M + Na]⁺ C₃₀H₂₇NNaO₂: 456.1934; found: 456.1937.

3,3-dimethyl-4-(2-oxo-1-phenyl-2-(pyridin-3-yl)ethyl)-1-phenylpyrrolidin-2-one (3ma).



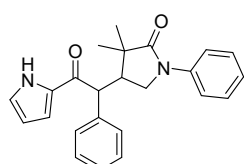
White solid (46.0 mg, 60% yield); **mp** 201.3 – 202.6 °C; **¹H NMR** (400 MHz, CDCl₃) δ 9.28 (s, 1H), 8.73 (d, *J* = 4.8 Hz, 1H), 8.27 (d, *J* = 8.0 Hz, 1H), 7.61 (d, *J* = 8.1 Hz, 2H), 7.45 (d, *J* = 7.4 Hz, 2H), 7.41 – 7.31 (m, 5H), 7.30 – 7.26 (m, 1H), 7.12 (t, *J* = 7.4 Hz, 1H), 4.77 (d, *J* = 10.8 Hz, 1H), 4.07 (t, *J* = 8.5 Hz, 1H), 3.40 (t, *J* = 9.8 Hz, 1H), 3.30 – 3.17 (m, 1H), 1.24 (s, 3H), 0.67 (s, 3H); **¹³C NMR** (100 MHz, CDCl₃) δ 196.7, 178.3, 153.6, 149.9, 139.3, 136.1, 135.3, 131.4, 129.3, 129.2, 128.7, 128.3, 124.4, 123.7, 119.7, 53.8, 49.8, 45.6, 44.5, 24.3, 18.9; **IR** (KBr) (ν, cm⁻¹): 3045, 1691, 1678, 1598, 1586, 1497, 1456, 1418; **HRMS** (ESI) *m/z* calcd for [M + H]⁺ C₂₅H₂₅N₂O₂: 385.1911; found: 385.1907.

3,3-dimethyl-4-(2-oxo-1-phenyl-2-(thiophen-2-yl)ethyl)-1-phenylpyrrolidin-2-one (3na).



White solid (58.1 mg, 75% yield); **mp** 207.1 – 208.4 °C; **¹H NMR** (400 MHz, CDCl₃) δ 7.86 (d, *J* = 3.8 Hz, 1H), 7.62 (t, *J* = 7.6 Hz, 3H), 7.48 (d, *J* = 7.6 Hz, 2H), 7.33 (q, *J* = 8.1 Hz, 4H), 7.28 (d, *J* = 7.2 Hz, 1H), 7.15 – 7.08 (m, 2H), 4.60 (d, *J* = 10.9 Hz, 1H), 4.05 (t, *J* = 8.5 Hz, 1H), 3.43 (t, *J* = 9.9 Hz, 1H), 3.30 – 3.18 (m, 1H), 1.21 (s, 3H), 0.68 (s, 3H); **¹³C NMR** (100 MHz, CDCl₃) δ 190.8, 178.4, 143.2, 139.3, 136.4, 134.6, 132.7, 129.1, 129.0, 128.7, 128.4, 128.0, 124.4, 119.7, 54.9, 49.7, 45.6, 44.6, 24.4, 18.8; **IR** (KBr) (ν, cm⁻¹): 3081, 2969, 1697, 1644, 1597, 1500, 1484, 1459, 1413; **HRMS** (ESI) *m/z* calcd for [M + H]⁺ C₂₄H₂₄NO₂S: 390.1522; found: 390.1521.

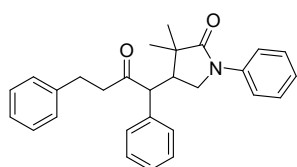
3,3-dimethyl-4-(2-oxo-1-phenyl-2-(1H-pyrrol-2-yl)ethyl)-1-phenylpyrrolidin-2-one (3oa).



White solid (29.6 mg, 40% yield); **mp** 196.2 – 197.7 °C; **¹H NMR** (400 MHz, CDCl₃) δ 9.69 (s, 1H), 7.59 (d, *J* = 8.1 Hz, 2H), 7.48 (d, *J* = 7.5 Hz, 2H), 7.32 (q, *J* = 7.6 Hz, 4H), 7.24 (d, *J* = 7.6 Hz, 1H), 7.14 – 7.07 (m,

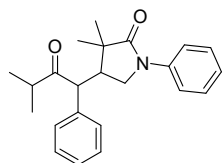
2H), 7.04 (s, 1H), 6.32 – 6.24 (m, 1H), 4.48 (d, $J = 11.2$ Hz, 1H), 3.94 (t, $J = 8.5$ Hz, 1H), 3.44 (t, $J = 9.9$ Hz, 1H), 3.31 – 3.18 (m, 1H), 1.19 (s, 3H), 0.71 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 188.1, 178.5, 139.3, 137.2, 131.1, 128.9, 128.8, 128.7, 127.7, 125.9, 124.3, 119.7, 117.2, 111.1, 53.2, 49.7, 45.3, 44.6, 24.6, 18.8; IR (KBr) (ν , cm^{-1}): 3115, 2965, 1697, 1633, 1598, 1542, 1493, 1457, 1398; HRMS (ESI) m/z calcd for $[\text{M} + \text{H}]^+ \text{C}_{24}\text{H}_{25}\text{N}_2\text{O}_2$: 373.1911; found: 373.1907.

3,3-dimethyl-4-(2-oxo-1,4-diphenylbutyl)-1-phenylpyrrolidin-2-one (3pa).



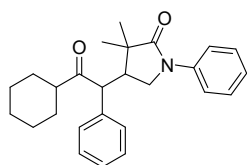
White solid (29.8 mg, 36% yield); mp 162.1 – 163.7 °C; ^1H NMR (400 MHz, CDCl_3) δ 7.59 (d, $J = 8.4$ Hz, 2H), 7.39 – 7.29 (m, 5H), 7.28 – 7.22 (m, 4H), 7.18 (d, $J = 6.9$ Hz, 1H), 7.13 (t, $J = 7.6$ Hz, 1H), 7.08 (d, $J = 7.5$ Hz, 2H), 3.99 – 3.92 (m, 1H), 3.76 (d, $J = 11.0$ Hz, 1H), 3.12 (t, $J = 9.8$ Hz, 1H), 3.06 – 2.95 (m, 1H), 2.95 – 2.83 (m, 1H), 2.81 – 2.68 (m, 3H), 1.03 (s, 3H), 0.61 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 207.7, 178.4, 140.4, 139.4, 135.7, 129.2, 129.1, 128.7, 128.5, 128.3, 128.1, 126.2, 124.3, 59.3, 49.6, 44.4, 44.3, 43.0, 29.9, 24.5, 18.8; IR (KBr) (ν , cm^{-1}): 3060, 2982, 1713, 1691, 1598, 1498, 1489, 1456, 1405; HRMS (ESI) m/z calcd for $[\text{M} + \text{H}]^+ \text{C}_{28}\text{H}_{30}\text{NO}_2$: 412.2271; found: 412.2272.

3,3-dimethyl-4-(3-methyl-2-oxo-1-phenylbutyl)-1-phenylpyrrolidin-2-one (3qa).



White solid (34.9 mg, 50% yield); mp 151.4 – 152.7 °C; ^1H NMR (400 MHz, CDCl_3) δ 7.63 (d, $J = 8.1$ Hz, 2H), 7.40 – 7.29 (m, 7H), 7.13 (t, $J = 7.4$ Hz, 1H), 4.04 (t, $J = 17.0$ Hz, 1H), 3.99 (d, $J = 11.1$ Hz, 1H), 3.28 (t, $J = 9.8$ Hz, 1H), 3.10 – 3.00 (m, 1H), 2.76 – 2.63 (m, 1H), 1.15 (d, $J = 7.1$ Hz, 3H), 1.12 (s, 3H), 0.86 (d, $J = 6.6$ Hz, 3H), 0.63 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 212.3, 178.5, 139.4, 135.9, 129.3, 129.0, 128.8, 128.1, 124.4, 119.8, 57.2, 49.8, 44.5, 44.4, 39.6, 24.4, 19.1, 18.8, 18.1; IR (KBr) (ν , cm^{-1}): 2968, 2930, 1701, 1597, 1558, 1493, 1463, 1393; HRMS (ESI) m/z calcd for $[\text{M} + \text{Na}]^+ \text{C}_{23}\text{H}_{27}\text{NNaO}_2$: 372.1934; found: 372.1910.

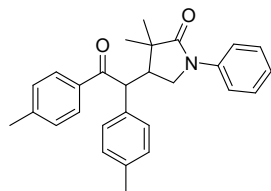
4-(2-cyclohexyl-2-oxo-1-phenylethyl)-3,3-dimethyl-1-phenylpyrrolidin-2-one (3ra).



White solid (59.9 mg, 77% yield); mp 159.1 – 161.0 °C; ^1H NMR (400 MHz, CDCl_3) δ 7.62 (d, $J = 8.1$ Hz, 2H), 7.40 – 7.28 (m, 7H), 7.13 (t, $J = 7.4$ Hz, 1H), 4.04 – 3.95 (m, 2H), 3.26 (t, $J = 9.8$ Hz, 1H), 3.10 – 2.98 (m, 1H), 2.50 – 2.34 (m, 1H), 1.99 – 1.90 (m, 1H), 1.87 – 1.76 (m, 1H), 1.64 (d, $J = 11.3$ Hz, 2H), 1.40 – 1.14 (m, 5H), 1.11 (s, 3H), 1.10 – 1.01 (m, 1H), 0.62 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 211.4, 178.5, 139.4, 135.7, 129.3, 129.0, 128.7, 128.0, 124.4, 119.8, 57.1, 49.9, 49.8, 44.6, 44.4, 29.4, 28.1, 25.9, 25.6, 25.0, 24.4, 18.8; IR (KBr) (ν , cm^{-1}): 2966,

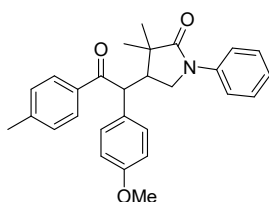
2929, 1711, 1684, 1598, 1505, 1491, 1459, 1404; **HRMS** (ESI) m/z calcd for $[M + Na]^+$ $C_{26}H_{31}NNaO_2$: 412.2247; found: 412.2235.

3,3-dimethyl-4-(2-oxo-1,2-di-*p*-tolylethyl)-1-phenylpyrrolidin-2-one (3fb).



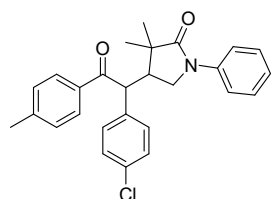
White solid (73.2 mg, 89% yield); **mp** 168.0 – 168.7 °C; **¹H NMR** (400 MHz, $CDCl_3$) δ 7.94 (d, $J = 7.9$ Hz, 2H), 7.60 (d, $J = 8.1$ Hz, 2H), 7.31 (q, $J = 7.8$ Hz, 4H), 7.21 (d, $J = 7.9$ Hz, 2H), 7.14 – 7.07 (m, 3H), 4.77 (d, $J = 10.8$ Hz, 1H), 4.02 (t, $J = 8.5$ Hz, 1H), 3.36 (t, $J = 9.9$ Hz, 1H), 3.27 – 3.18 (m, 1H), 2.35 (s, 3H), 2.27 (s, 3H), 1.23 (s, 3H), 0.69 (s, 3H); **¹³C NMR** (100 MHz, $CDCl_3$) δ 197.5, 178.6, 144.2, 139.4, 137.5, 133.6, 133.3, 129.6, 129.3, 129.0, 128.8, 128.6, 124.2, 119.8, 119.6, 52.4, 49.8, 45.6, 44.6, 24.4, 21.5, 21.0, 18.8; **IR** (KBr) (ν , cm^{-1}): 3027, 2971, 1691, 1666, 1603, 1571, 1493, 1485, 1458, 1396, 782, 690; **HRMS** (ESI) m/z calcd for $[M + H]^+$ $C_{28}H_{30}NO_2$: 412.2271; found: 412.2262.

4-(1-(4-methoxyphenyl)-2-oxo-2-(*p*-tolyl)ethyl)-3,3-dimethyl-1-phenylpyrrolidin-2-one (3fc).



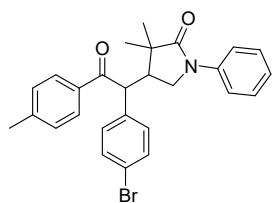
White solid (60.4 mg, 71% yield); **mp** 173.2 – 174.9 °C; **¹H NMR** (400 MHz, $CDCl_3$) δ 7.93 (d, $J = 7.9$ Hz, 2H), 7.60 (d, $J = 8.1$ Hz, 2H), 7.41 – 7.29 (m, 4H), 7.23 (d, $J = 8.0$ Hz, 2H), 7.10 (t, $J = 7.4$ Hz, 1H), 6.85 (d, $J = 8.3$ Hz, 2H), 4.74 (d, $J = 10.9$ Hz, 1H), 4.12 – 3.94 (m, 1H), 3.76 (s, 3H), 3.36 (t, $J = 9.9$ Hz, 1H), 3.28 – 3.13 (m, 1H), 2.38 (s, 3H), 1.22 (s, 3H), 0.71 (s, 3H); **¹³C NMR** (100 MHz, $CDCl_3$) δ 197.7, 178.6, 159.1, 144.3, 139.5, 133.7, 130.2, 129.4, 128.8, 128.7, 128.3, 124.3, 119.7, 114.4, 55.2, 52.0, 49.9, 45.7, 44.6, 24.5, 21.6, 18.9; **IR** (KBr) (ν , cm^{-1}): 3032, 2969, 1684, 1673, 1607, 1510, 1463, 1406; **HRMS** (ESI) m/z calcd for $[M + K]^+$ $C_{28}H_{29}KNO_3$: 466.1779; found: 466.1761.

4-(1-(4-chlorophenyl)-2-oxo-2-(*p*-tolyl)ethyl)-3,3-dimethyl-1-phenylpyrrolidin-2-one (3fd).



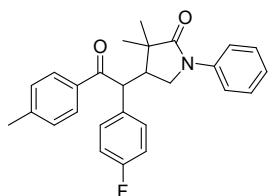
White solid (74.6 mg, 90% yield); **mp** 197.5 – 198.3 °C; **¹H NMR** (400 MHz, $CDCl_3$) δ 7.91 (d, $J = 8.0$ Hz, 2H), 7.59 (d, $J = 8.2$ Hz, 2H), 7.41 (d, $J = 8.3$ Hz, 2H), 7.35 – 7.29 (m, 4H), 7.25 (d, $J = 7.5$ Hz, 2H), 7.11 (t, $J = 7.4$ Hz, 1H), 4.79 (d, $J = 10.9$ Hz, 1H), 4.07 – 3.96 (m, 1H), 3.37 (t, $J = 9.9$ Hz, 1H), 3.26 – 3.15 (m, 1H), 2.39 (s, 3H), 1.22 (s, 3H), 0.72 (s, 3H); **¹³C NMR** (100 MHz, $CDCl_3$) δ 197.3, 178.2, 144.8, 139.3, 135.1, 133.8, 133.5, 130.5, 129.6, 129.3, 128.8, 124.4, 119.7, 52.1, 49.7, 45.9, 44.6, 24.7, 21.6, 19.0; **IR** (KBr) (ν , cm^{-1}): 3064, 2968, 1690, 1674, 1599, 1501, 1489, 1458, 1400; **HRMS** (ESI) m/z calcd for $[M + H]^+$ $C_{27}H_{27}ClNO_2$: 432.1725; found: 432.1720.

4-(1-(4-bromophenyl)-2-oxo-2-(*p*-tolyl)ethyl)-3,3-dimethyl-1-phenylpyrrolidin-2-one (3fe).



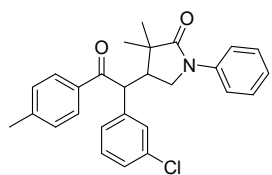
White solid (87.6 mg, 92% yield); **mp** 209.7 – 210.7 °C; **¹H NMR** (400 MHz, CDCl₃) δ 7.94 (d, J = 7.9 Hz, 2H), 7.60 (d, J = 8.1 Hz, 2H), 7.31 (q, J = 7.8 Hz, 4H), 7.21 (d, J = 7.9 Hz, 2H), 7.11 (d, J = 7.4 Hz, 2H), 7.08 (d, J = 7.2 Hz, 1H), 4.77 (d, J = 10.8 Hz, 1H), 4.02 (t, J = 8.5 Hz, 1H), 3.36 (t, J = 9.9 Hz, 1H), 3.28 – 3.12 (m, 1H), 2.35 (s, 3H), 2.27 (s, 3H), 1.23 (s, 3H), 0.69 (s, 3H); **¹³C NMR** (100 MHz, CDCl₃) δ 197.1, 178.2, 144.7, 139.3, 135.6, 133.4, 132.2, 130.7, 129.5, 128.7, 124.4, 121.9, 119.7, 52.1, 49.7, 45.8, 44.5, 24.7, 21.6, 19.0; **IR** (KBr) (ν , cm⁻¹): 3062, 2968, 1690, 1674, 1607, 1598, 1573, 1500, 1458, 1399; **HRMS** (ESI) m/z calcd for [M + H]⁺ C₂₇H₂₇BrNO₂: 476.1220; found: 476.1214.

4-(1-(4-fluorophenyl)-2-oxo-2-(*p*-tolyl)ethyl)-3,3-dimethyl-1-phenylpyrrolidin-2-one (3ff).



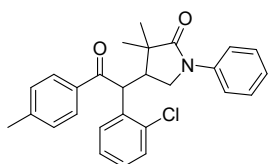
White solid (76.7 mg, 92% yield); **mp** 146.5 – 147.8 °C; **¹H NMR** (400 MHz, CDCl₃) δ 7.92 (d, J = 7.7 Hz, 2H), 7.59 (d, J = 8.2 Hz, 2H), 7.47 – 7.40 (m, 2H), 7.32 (t, J = 7.5 Hz, 2H), 7.25 (d, J = 7.1 Hz, 2H), 7.11 (t, J = 7.4 Hz, 1H), 7.03 (t, J = 8.2 Hz, 2H), 4.80 (d, J = 10.9 Hz, 1H), 4.05 – 3.96 (m, 1H), 3.36 (t, J = 9.9 Hz, 1H), 3.26 – 3.16 (m, 1H), 2.39 (s, 3H), 1.22 (s, 3H), 0.71 (s, 3H); **¹³C NMR** (100 MHz, CDCl₃) δ 197.5, 178.3, 162.2 (d, J_{C-F} = 246.3 Hz), 144.7, 139.3, 133.5, 132.3 (d, J_{C-F} = 3.2 Hz), 130.7 (d, J_{C-F} = 8.0 Hz), 129.5, 128.8, 124.4, 119.7, 116.0 (d, J_{C-F} = 21.4 Hz), 51.9, 49.7, 45.9, 44.6, 24.6, 21.6, 19.0; **¹⁹F NMR** (376 MHz, CDCl₃) δ -113.87; **IR** (KBr) (ν , cm⁻¹): 3058, 1701, 1671, 1605, 1573, 1493, 1461, 1395; **HRMS** (ESI) m/z calcd for [M + H]⁺ C₂₇H₂₇FNO₂: 416.2020; found: 416.2016.

4-(1-(3-chlorophenyl)-2-oxo-2-(*p*-tolyl)ethyl)-3,3-dimethyl-1-phenylpyrrolidin-2-one (3fg).



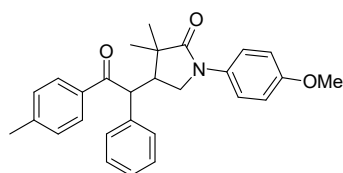
White solid (73.2 mg, 85% yield); **mp** 204.7 – 205.6 °C; **¹H NMR** (400 MHz, CDCl₃) δ 7.93 (d, J = 8.0 Hz, 2H), 7.59 (d, J = 8.3 Hz, 2H), 7.47 (s, 1H), 7.37 (d, J = 7.2 Hz, 1H), 7.32 (t, J = 7.8 Hz, 2H), 7.29 – 7.23 (m, 4H), 7.11 (t, J = 7.4 Hz, 1H), 4.79 (d, J = 10.8 Hz, 1H), 4.00 (s, 1H), 3.37 (t, J = 9.8 Hz, 1H), 3.30 – 3.13 (m, 1H), 2.39 (s, 3H), 1.23 (s, 3H), 0.73 (s, 3H); **¹³C NMR** (100 MHz, CDCl₃) δ 197.1, 178.2, 144.8, 139.3, 138.6, 134.8, 133.5, 130.2, 129.6, 129.2, 128.7(8), 128.7(5), 128.1, 127.4, 124.4, 119.8, 52.3, 49.7, 46.0, 44.6, 24.6, 21.6, 19.0; **IR** (KBr) (ν , cm⁻¹): 3058, 1701, 1671, 1605, 1573, 1493, 1461, 1395; **HRMS** (ESI) m/z calcd for [M + H]⁺ C₂₇H₂₇ClNO₂: 432.1725; found: 432.1719.

4-(1-(2-chlorophenyl)-2-oxo-2-(*p*-tolyl)ethyl)-3,3-dimethyl-1-phenylpyrrolidin-2-one (3fh).



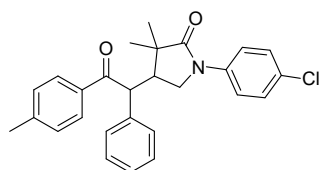
White solid (70.8 mg, 82% yield); **mp** 178.6 – 179.4 °C; **¹H NMR** (400 MHz, CDCl₃) δ 8.05 (d, *J* = 7.6 Hz, 2H), 7.63 (d, *J* = 7.7 Hz, 1H), 7.58 (d, *J* = 8.1 Hz, 2H), 7.38 (d, *J* = 7.4 Hz, 1H), 7.32 (t, *J* = 7.9 Hz, 2H), 7.27 (d, *J* = 7.9 Hz, 2H), 7.23 (s, 1H), 7.19 (t, *J* = 6.9 Hz, 1H), 7.11 (t, *J* = 7.4 Hz, 1H), 5.33 (d, *J* = 10.4 Hz, 1H), 3.93 (t, *J* = 8.4 Hz, 1H), 3.49 (t, *J* = 9.8 Hz, 1H), 3.36 – 3.19 (m, 1H), 2.40 (s, 3H), 1.24 (s, 3H), 0.76 (s, 3H); **¹³C NMR** (100 MHz, CDCl₃) δ 198.3, 178.4, 144.9, 139.4, 134.1, 133.9, 130.6, 130.4, 129.5, 129.1, 128.9, 128.7, 127.4, 124.4, 119.8, 49.6, 47.4, 47.2, 44.8, 24.6, 21.6, 19.9; **IR** (KBr) (ν, cm⁻¹): 3065, 1694, 1663, 1604, 1571, 1503, 1459, 1398; **HRMS** (ESI) *m/z* calcd for [M + H]⁺ C₂₇H₂₇ClNO₂: 432.1725; found: 432.1719.

1-(4-methoxyphenyl)-3,3-dimethyl-4-(2-oxo-1-phenyl-2-(p-tolyl)ethyl)pyrrolidin-2-one (3fi).



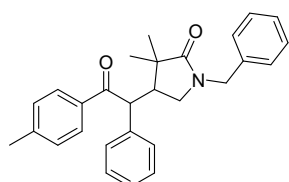
White solid (44.5 mg, 52% yield); **mp** 199.9 – 201.7 °C; **¹H NMR** (400 MHz, CDCl₃) δ 7.94 (d, *J* = 7.9 Hz, 2H), 7.52 – 7.44 (m, 4H), 7.31 (t, *J* = 7.5 Hz, 2H), 7.24 (t, *J* = 6.8 Hz, 3H), 6.85 (d, *J* = 8.6 Hz, 2H), 4.80 (d, *J* = 10.7 Hz, 1H), 3.98 (t, *J* = 8.3 Hz, 1H), 3.77 (s, 3H), 3.34 (t, *J* = 9.8 Hz, 1H), 3.28 – 3.20 (m, 1H), 2.37 (s, 3H), 1.22 (s, 3H), 0.66 (s, 3H); **¹³C NMR** (100 MHz, CDCl₃) δ 197.6, 178.1, 156.3, 144.4, 136.5, 133.6, 132.6, 129.4, 129.2, 129.0, 128.8, 127.8, 121.4, 113.9, 55.4, 52.8, 50.2, 45.9, 44.4, 24.4, 21.6, 18.9; **IR** (KBr) (ν, cm⁻¹): 2966, 1691, 1666, 1603, 1514, 1496, 1456, 1404; **HRMS** (ESI) *m/z* calcd for [M + H]⁺ C₂₈H₃₀NO₃: 428.2220; found: 428.2213.

1-(4-chlorophenyl)-3,3-dimethyl-4-(2-oxo-1-phenyl-2-(p-tolyl)ethyl)pyrrolidin-2-one (3fj).



White solid (31.6 mg, 37% yield); **mp** 236.7 – 237.2 °C; **¹H NMR** (400 MHz, CDCl₃) δ 7.94 (d, *J* = 7.9 Hz, 2H), 7.57 (d, *J* = 8.6 Hz, 2H), 7.45 (d, *J* = 7.6 Hz, 2H), 7.32 (t, *J* = 7.5 Hz, 2H), 7.29 (s, 1H), 7.27 – 7.21 (m, 4H), 4.79 (d, *J* = 10.7 Hz, 1H), 4.05 – 3.97 (m, 1H), 3.34 (t, *J* = 9.7 Hz, 1H), 3.30 – 3.18 (m, 1H), 2.38 (s, 3H), 1.23 (s, 3H), 0.66 (s, 3H); **¹³C NMR** (100 MHz, CDCl₃) δ 197.4, 178.6, 144.5, 137.9, 136.3, 133.5, 129.4, 129.3, 129.2, 129.0, 128.8, 128.7, 127.9, 120.7, 52.8, 49.8, 45.7, 44.6, 24.3, 21.6, 18.9; **IR** (KBr) (ν, cm⁻¹): 3068, 1698, 1666, 1602, 1570, 1494, 1452, 1419; **HRMS** (ESI) *m/z* calcd for [M + H]⁺ C₂₇H₂₇ClNO₂: 432.1725; found: 432.1724.

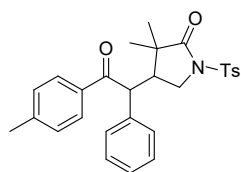
1-benzyl-3,3-dimethyl-4-(2-oxo-1-phenyl-2-(p-tolyl)ethyl)pyrrolidin-2-one (3fk).



White solid (70.0 mg, 85% yield); **mp** 193.4 – 197.5 °C; **¹H NMR** (400 MHz, CDCl₃) δ 7.90 (d, *J* = 7.9 Hz, 2H), 7.47 (d, *J* = 7.6 Hz, 2H),

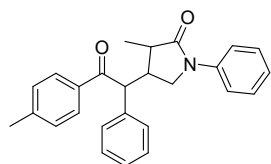
7.39 – 7.31 (m, 5H), 7.30 (d, $J = 8.9$ Hz, 1H), 7.26 – 7.21 (m, 4H), 4.77 – 4.67 (m, 2H), 4.29 (d, $J = 14.6$ Hz, 1H), 3.50 (t, $J = 8.7$ Hz, 1H), 3.25 – 3.10 (m, 1H), 2.79 (t, $J = 9.8$ Hz, 1H), 2.39 (s, 3H), 1.21 (s, 3H), 0.68 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 197.5, 179.3, 144.3, 136.6, 136.5, 133.6, 129.3, 129.2, 128.9, 128.7(1), 128.6(6), 128.0, 127.7, 127.5, 52.8, 48.4, 46.6, 46.5, 43.2, 24.2, 21.5, 18.8; IR (KBr) (ν , cm^{-1}): 3063, 3038, 1678, 1667, 1604, 1491, 1456, 1411; HRMS (ESI) m/z calcd for $[\text{M} + \text{H}]^+$ $\text{C}_{28}\text{H}_{30}\text{NO}_2$: 412.2271; found: 412.2268.

3,3-dimethyl-4-(2-oxo-1-phenyl-2-(*p*-tolyl)ethyl)-1-tosylpyrrolidin-2-one (3fl).



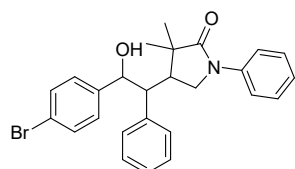
White solid (19.0 mg, 20% yield); mp 235.5 – 243.4 °C; ^1H NMR (400 MHz, CDCl_3) δ 7.90 (t, $J = 8.4$ Hz, 4H), 7.37 (d, $J = 7.6$ Hz, 2H), 7.35 – 7.31 (m, 2H), 7.29 (t, $J = 7.4$ Hz, 2H), 7.22 (d, $J = 7.7$ Hz, 3H), 4.64 (d, $J = 10.8$ Hz, 1H), 4.22 – 4.15 (m, 1H), 3.27 (t, $J = 10.2$ Hz, 1H), 3.14 – 3.05 (m, 1H), 2.44 (s, 3H), 2.37 (s, 3H), 1.06 (s, 3H), 0.47 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 196.7, 177.8, 145.1, 144.6, 135.9, 135.2, 133.4, 129.7, 129.4, 129.1, 129.0, 128.8, 128.0, 52.6, 48.1, 45.6, 44.8, 23.3, 21.7, 21.6, 18.3; IR (KBr) (ν , cm^{-1}): 2048, 1726, 1671, 1607, 1493, 1455, 1410; HRMS (ESI) m/z calcd for $[\text{M} + \text{H}]^+$ $\text{C}_{28}\text{H}_{30}\text{NO}_4\text{S}$: 476.1890; found: 476.1884.

3-methyl-4-(2-oxo-1-phenyl-2-(*p*-tolyl)ethyl)-1-phenylpyrrolidin-2-one (3fm).



White solid (38.4 mg, 50% yield); mp 196.8 – 198.3 °C; ^1H NMR (400 MHz, CDCl_3) δ 7.88 (d, $J = 7.9$ Hz, 2H), 7.61 (d, $J = 8.1$ Hz, 2H), 7.38 – 7.29 (m, 6H), 7.29 – 7.26 (m, 1H), 7.19 (d, $J = 7.9$ Hz, 2H), 7.12 (t, $J = 7.4$ Hz, 1H), 4.57 (d, $J = 10.5$ Hz, 1H), 4.21 – 4.12 (m, 1H), 3.44 – 3.34 (m, 1H), 3.06 – 2.96 (m, 1H), 2.54 – 2.43 (m, 1H), 2.35 (s, 3H), 0.72 (d, $J = 7.1$ Hz, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 197.8, 175.8, 144.3, 139.3, 136.9, 133.6, 129.4, 129.0, 128.8, 128.5, 127.9, 124.5, 119.8, 58.9, 52.2, 42.6, 42.4, 21.6, 16.6; IR (KBr) (ν , cm^{-1}): 2968, 1694, 1666, 1605, 1495, 1480, 1453, 1394; HRMS (ESI) m/z calcd for $[\text{M} + \text{H}]^+$ $\text{C}_{26}\text{H}_{26}\text{NO}_2$: 384.1958; found: 384.1955.

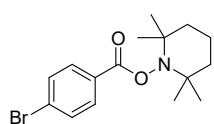
4-(2-(4-bromophenyl)-2-hydroxy-1-phenylethyl)-3,3-dimethyl-1-phenylpyrrolidin-2-one (4).



White solid; mp 232.5 – 235.9 °C; ^1H NMR (400 MHz, CDCl_3) δ 7.66 (d, $J = 8.1$ Hz, 2H), 7.38 (t, $J = 7.9$ Hz, 2H), 7.27 (d, $J = 7.9$ Hz, 2H), 7.24 – 7.12 (m, 4H), 7.02 (d, $J = 6.2$ Hz, 2H), 6.75 (d, $J = 8.2$ Hz, 2H), 5.01 (t, $J = 3.2$ Hz, 1H), 4.11 (t, $J = 8.3$ Hz, 1H), 3.74 (t, $J = 9.8$ Hz, 1H), 3.15 – 3.03 (m, 1H), 2.92 – 2.81 (m, 1H), 2.21 (d, $J = 4.0$ Hz, 1H), 0.98 (s, 3H), 0.66 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 179.0, 141.7, 139.5, 136.8, 130.9, 130.3, 128.8, 127.8, 127.6,

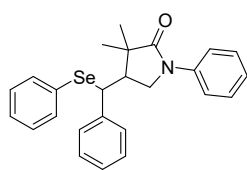
127.2, 124.5, 121.1, 119.9, 74.2, 52.8, 50.3, 44.9, 43.9, 24.9, 18.5; **IR** (KBr) (ν , cm^{-1}): 3069, 3031, 1670, 1594, 1500, 1497, 1454, 1420; **HRMS** (ESI) m/z calcd for $[\text{M} + \text{H}]^+$ $\text{C}_{26}\text{H}_{27}\text{BrNO}_2$: 464.1220; found: 464.1206.

2,2,6,6-tetramethylpiperidin-1-yl 4-bromobenzoate (5).³



¹H NMR (400 MHz, CDCl_3) δ 7.93 (d, $J = 8.5$ Hz, 2H), 7.60 (d, $J = 8.4$ Hz, 2H), 1.83 – 1.66 (m, 3H), 1.65 – 1.53 (m, 3H), 1.50 – 1.42 (m, 1H), 1.26 (s, 6H), 1.11 (s, 6H); **¹³C NMR** (100 MHz, CDCl_3) δ 165.7, 131.8, 131.1, 128.6, 127.9, 60.5, 39.0, 31.9, 20.8, 16.9.

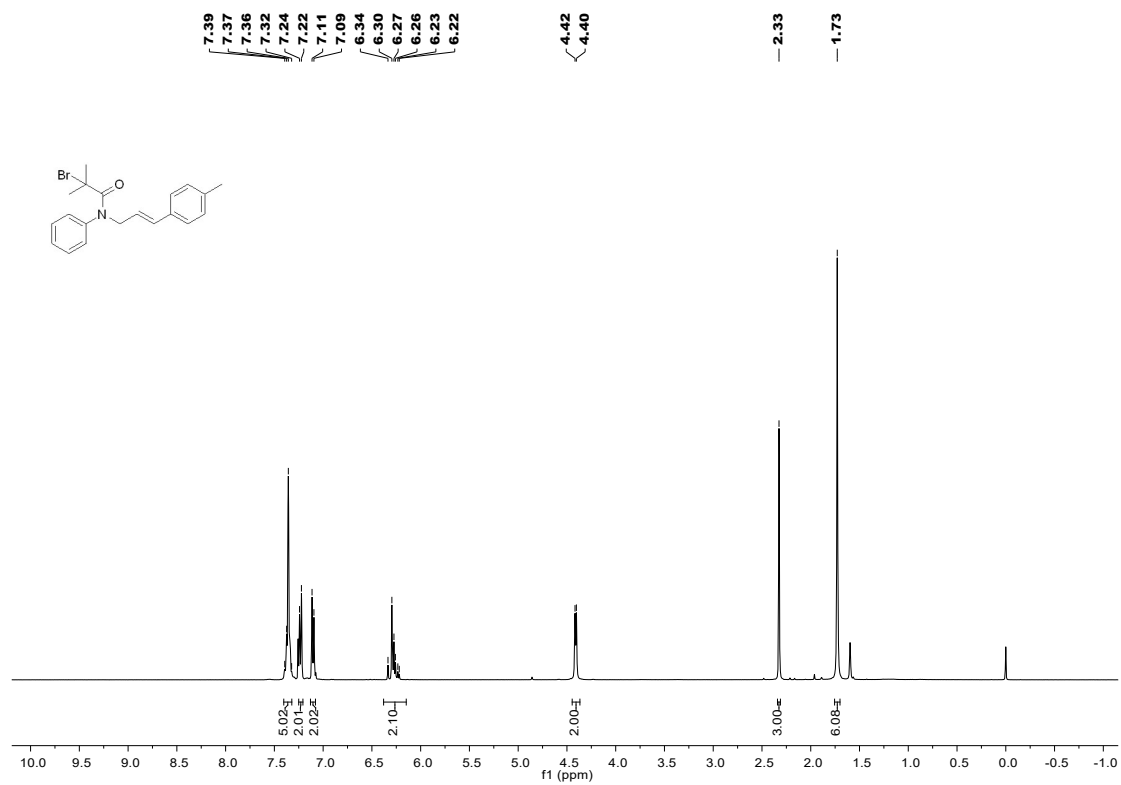
3,3-dimethyl-1-phenyl-4-(phenyl(phenylselanyl)methyl)pyrrolidin-2-one (6).



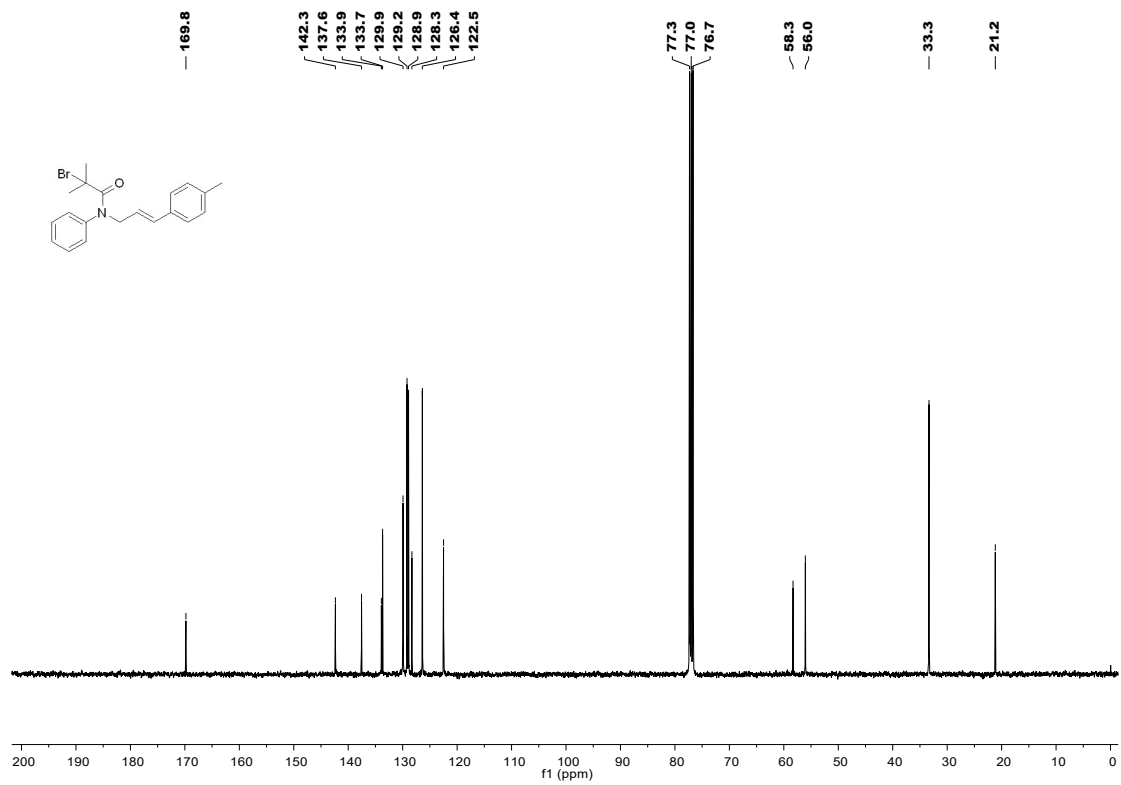
White solid (18.5 mg, 21% yield); **mp** 131.4 – 131.8 °C; **¹H NMR** (400 MHz, CDCl_3) δ 7.66 (d, $J = 8.2$ Hz, 2H), 7.39 (t, $J = 7.7$ Hz, 2H), 7.32 (d, $J = 7.8$ Hz, 2H), 7.29 – 7.26 (m, 1H), 7.25 – 7.13 (m, 6H), 7.10 (d, $J = 7.0$ Hz, 2H), 4.30 (d, $J = 11.9$ Hz, 1H), 4.20 – 4.13 (m, 1H), 3.66 (t, $J = 10.2$ Hz, 1H), 3.05 – 2.94 (m, 1H), 1.02 (s, 3H), 0.73 (s, 3H); **¹³C NMR** (100 MHz, CDCl_3) δ 178.4, 140.9, 139.4, 136.2, 128.9, 128.8, 128.4, 128.3, 128.2(1), 128.1(8), 127.4, 124.4, 119.7, 51.6, 50.2, 47.7, 45.9, 24.8, 18.5; **IR** (KBr) (ν , cm^{-1}): 3070, 2966, 1686, 1596, 1578, 1493, 1438, 1405; **HRMS** (ESI) m/z calcd for $[\text{M} + \text{H}]^+$ $\text{C}_{25}\text{H}_{26}\text{NOSe}$: 436.1174; found: 436.1171.

7. NMR spectrum

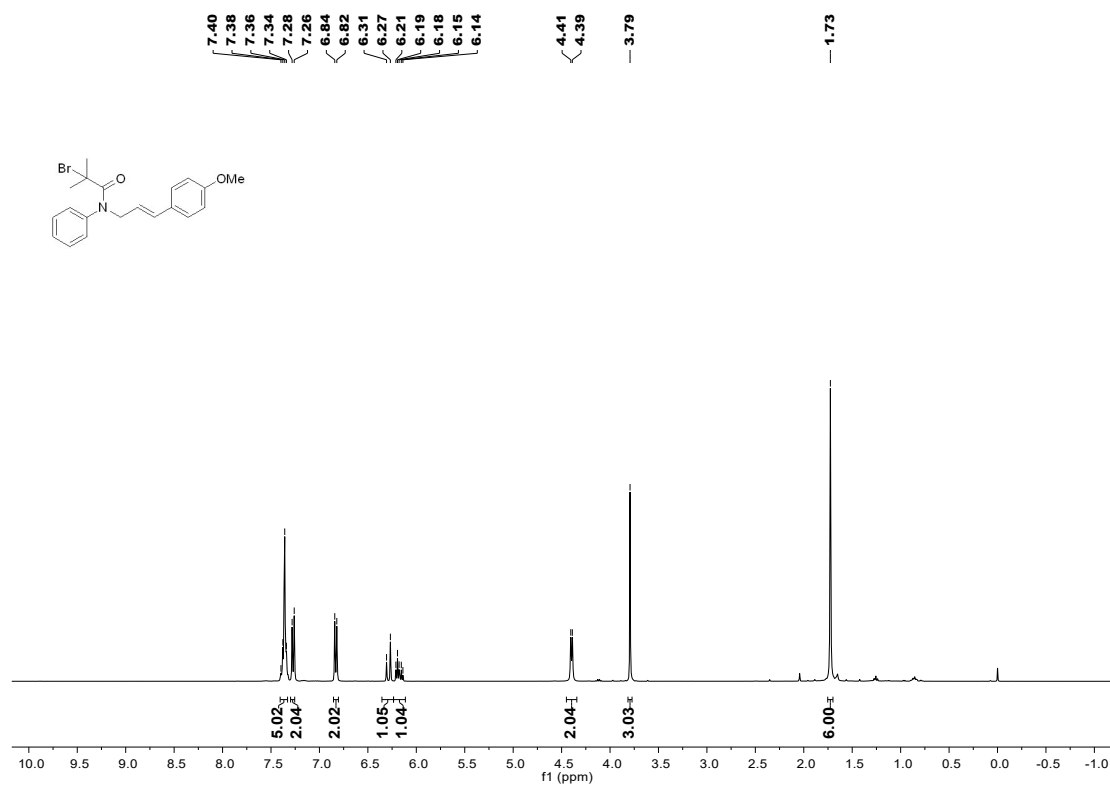
¹H NMR spectrum of compound (2b)



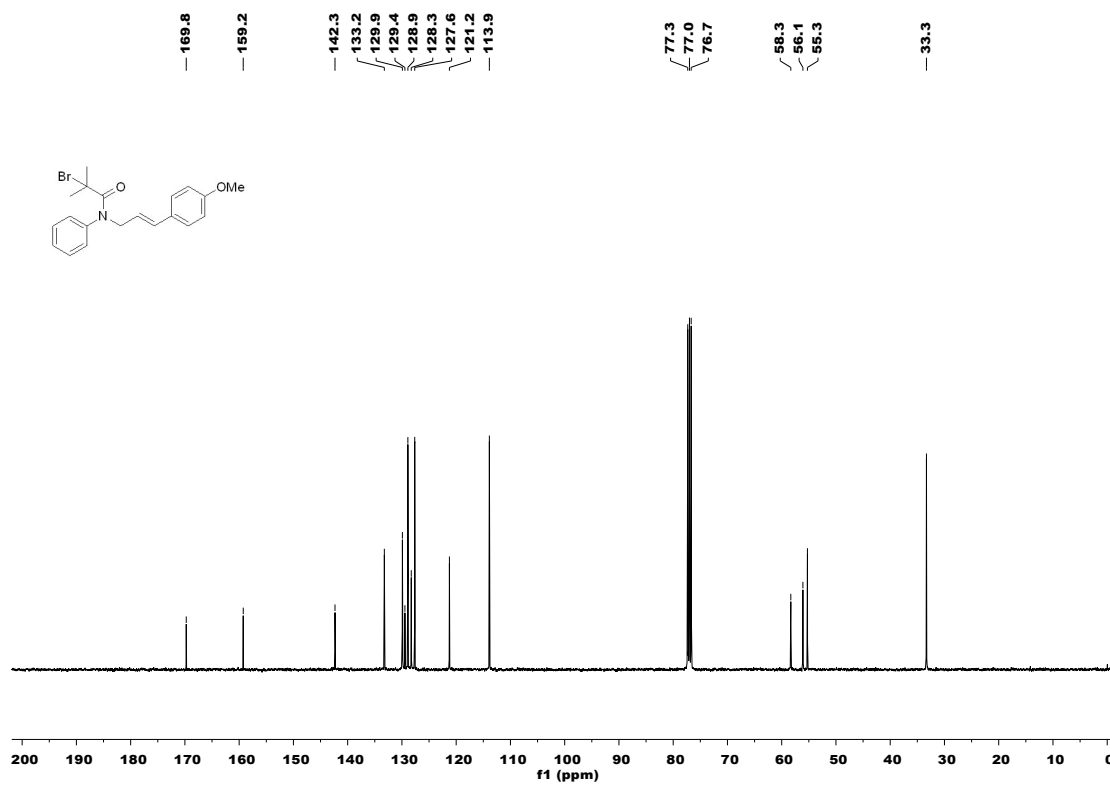
¹³C NMR spectrum of compound **(2b)**



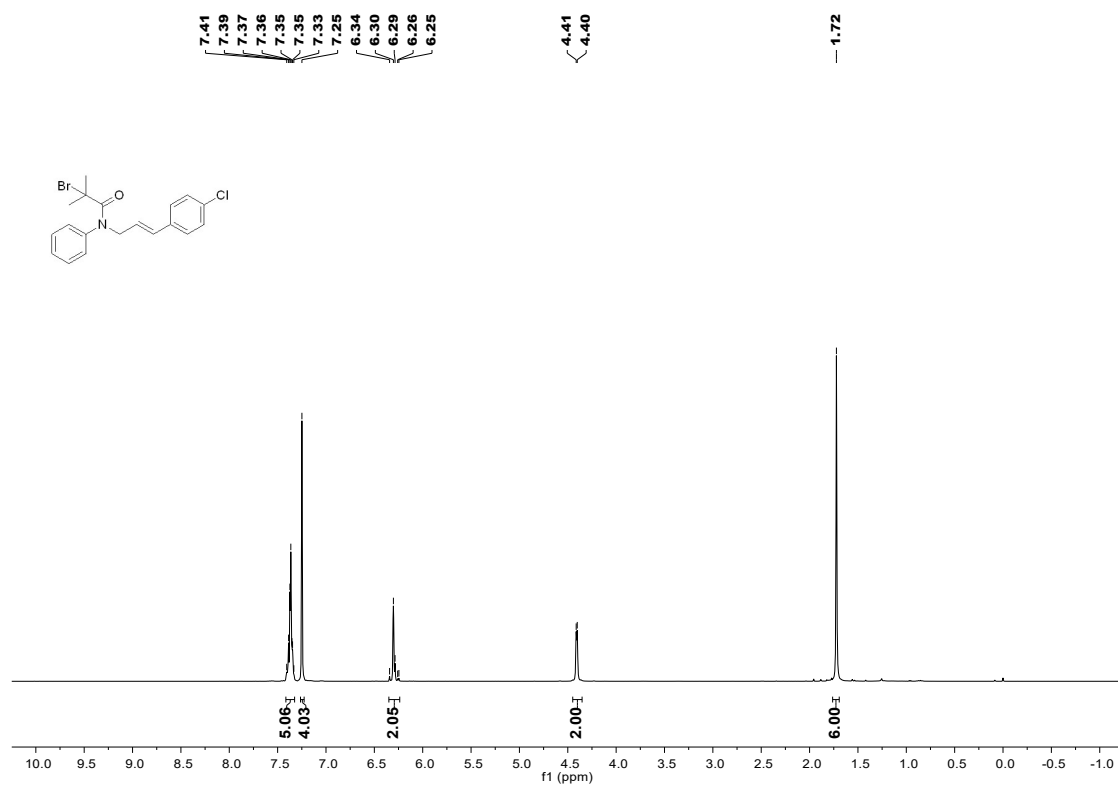
¹H NMR spectrum of compound (2c)



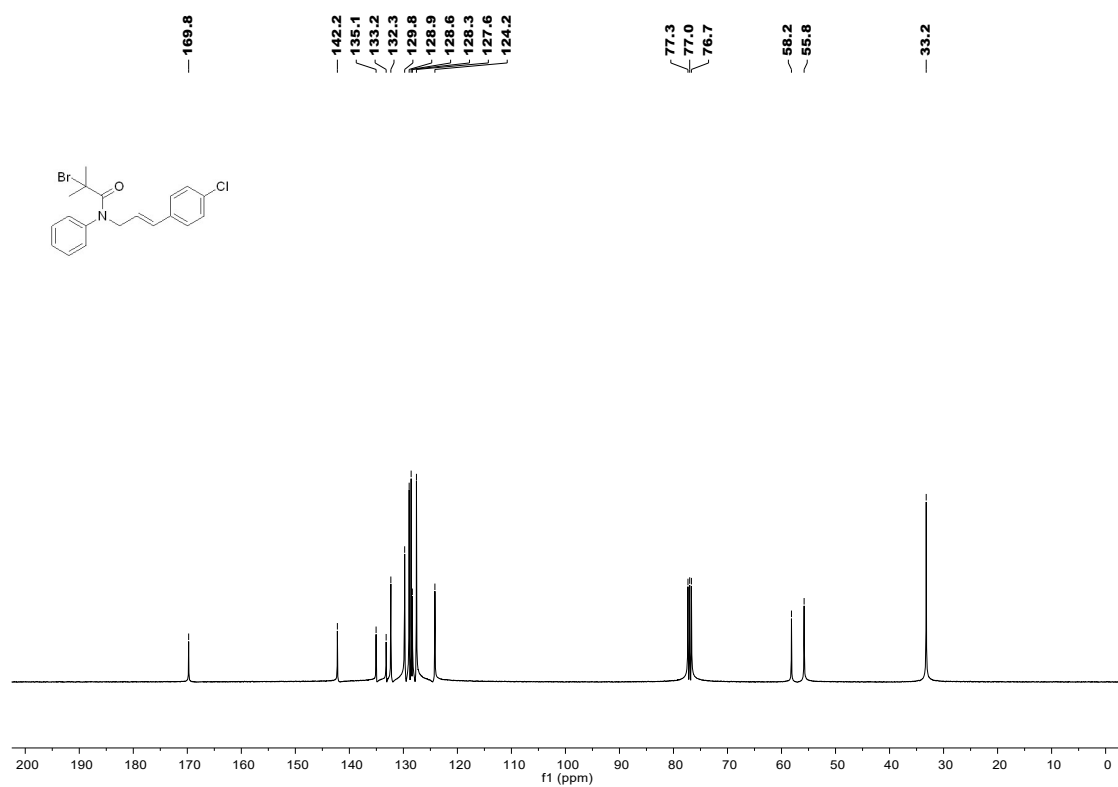
¹³C NMR spectrum of compound (2c)



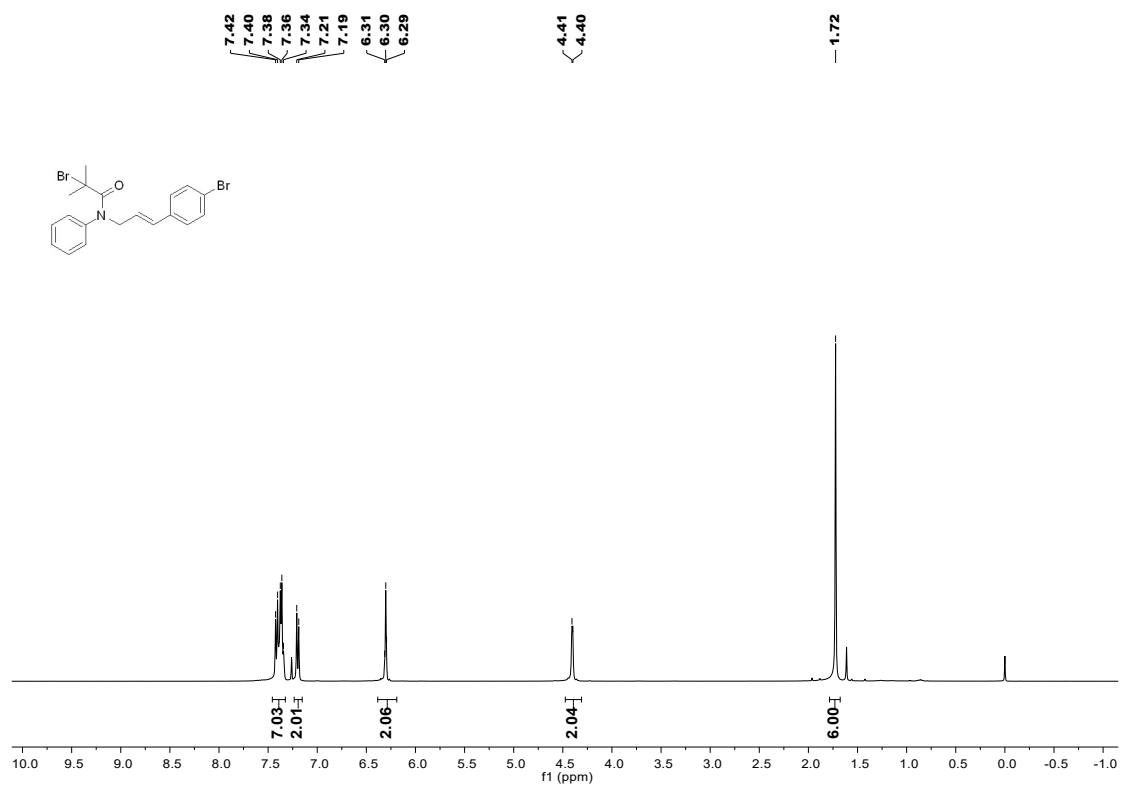
¹H NMR spectrum of compound (2d)



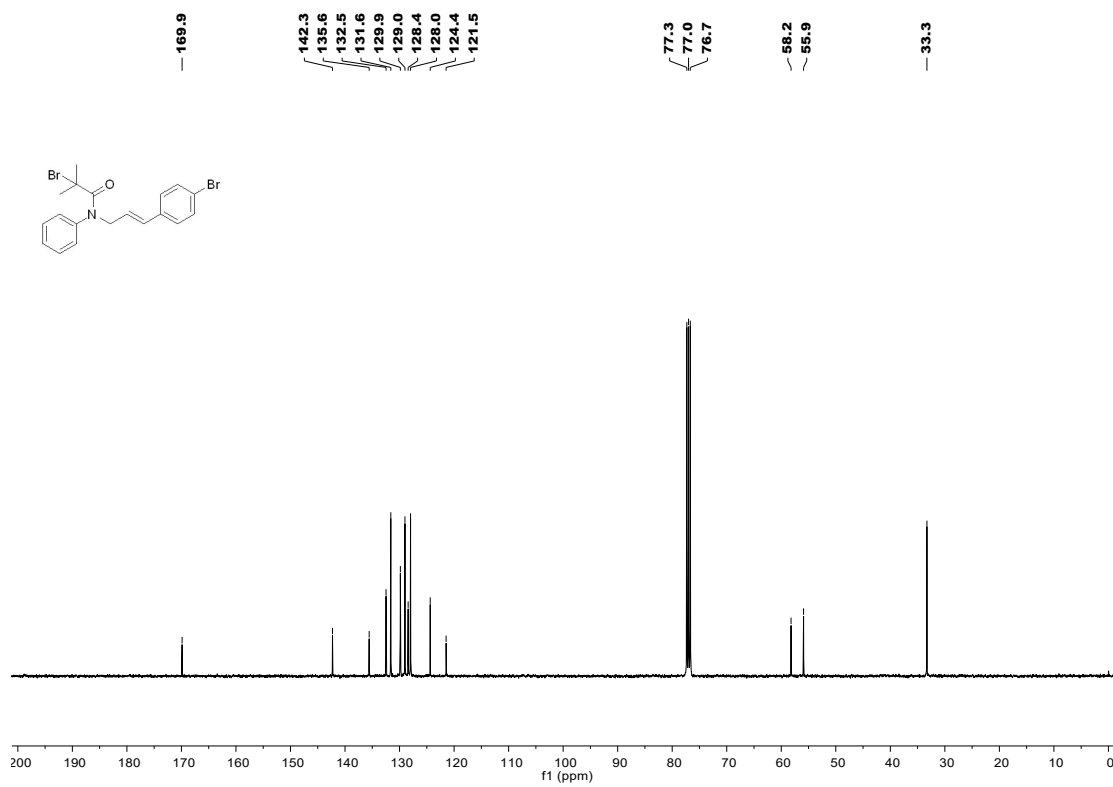
¹³C NMR spectrum of compound (2d)



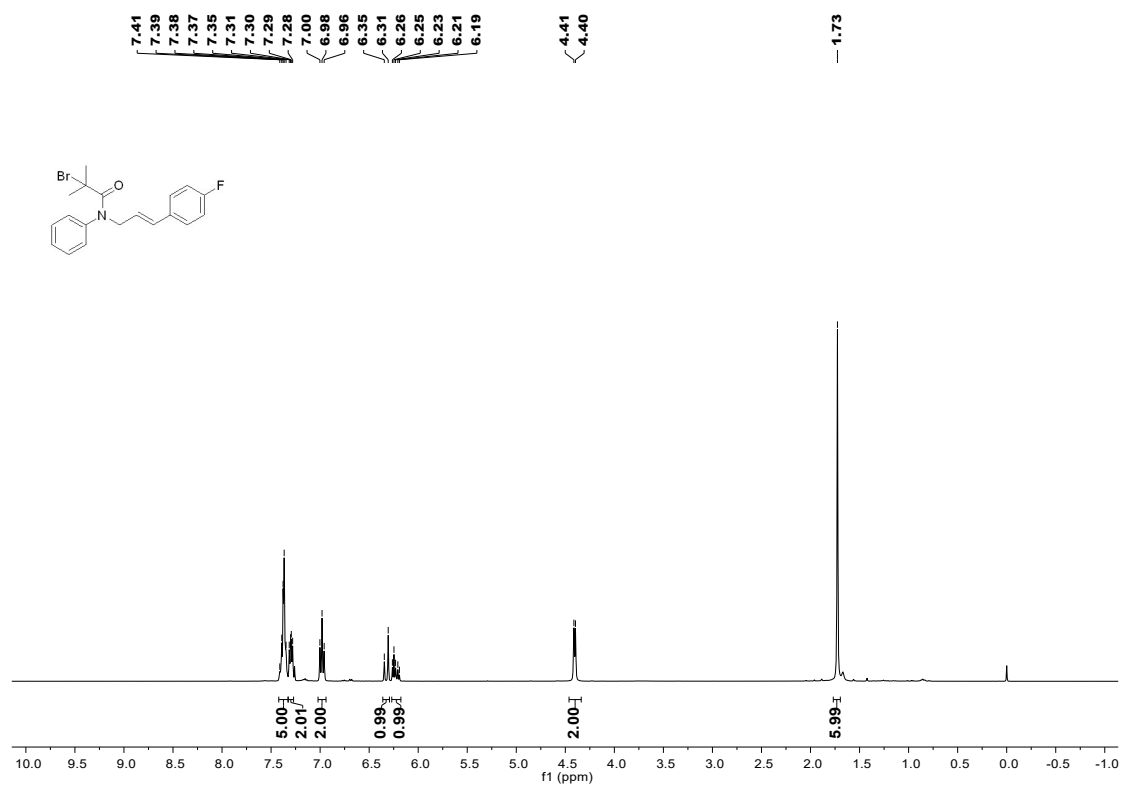
¹H NMR spectrum of compound (2e)



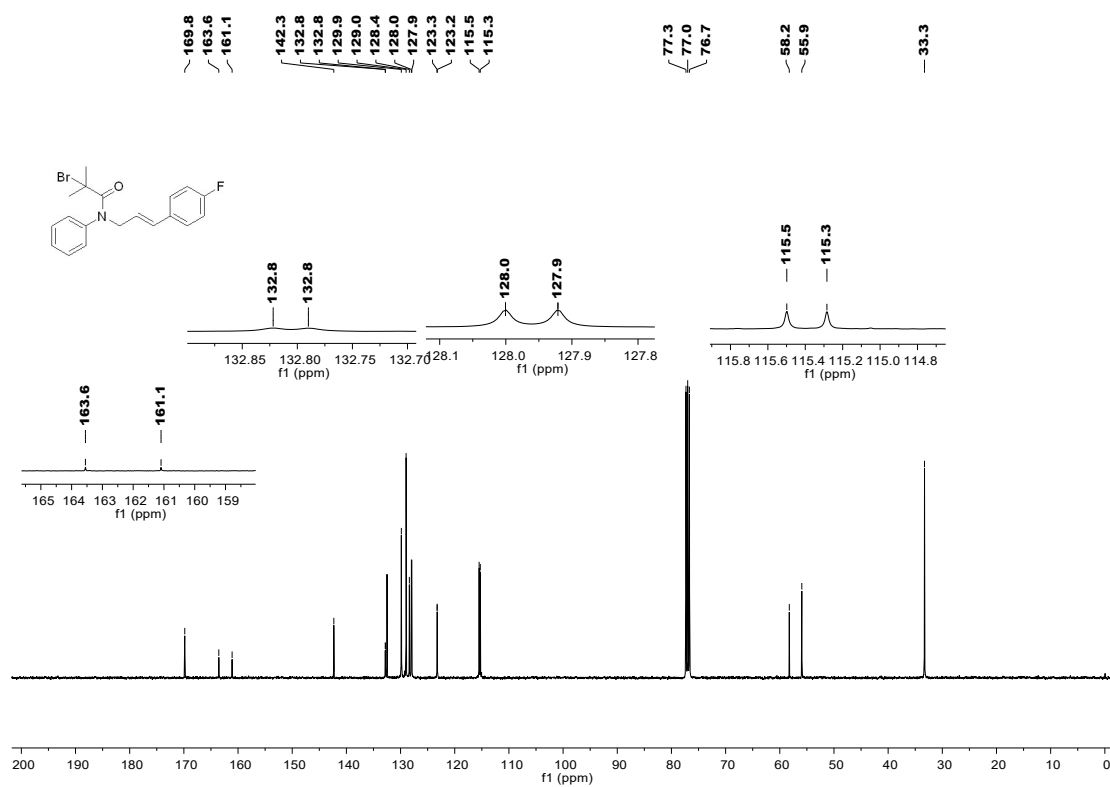
¹³C NMR spectrum of compound (2e)



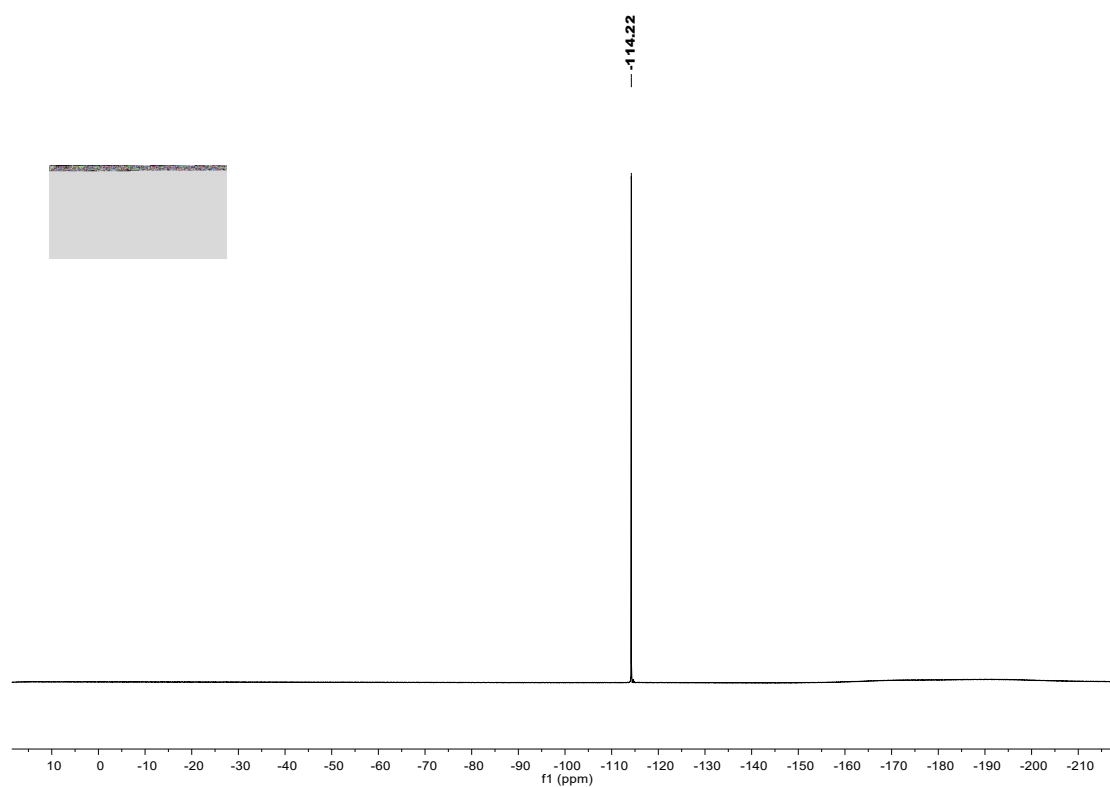
¹H NMR spectrum of compound (2f)



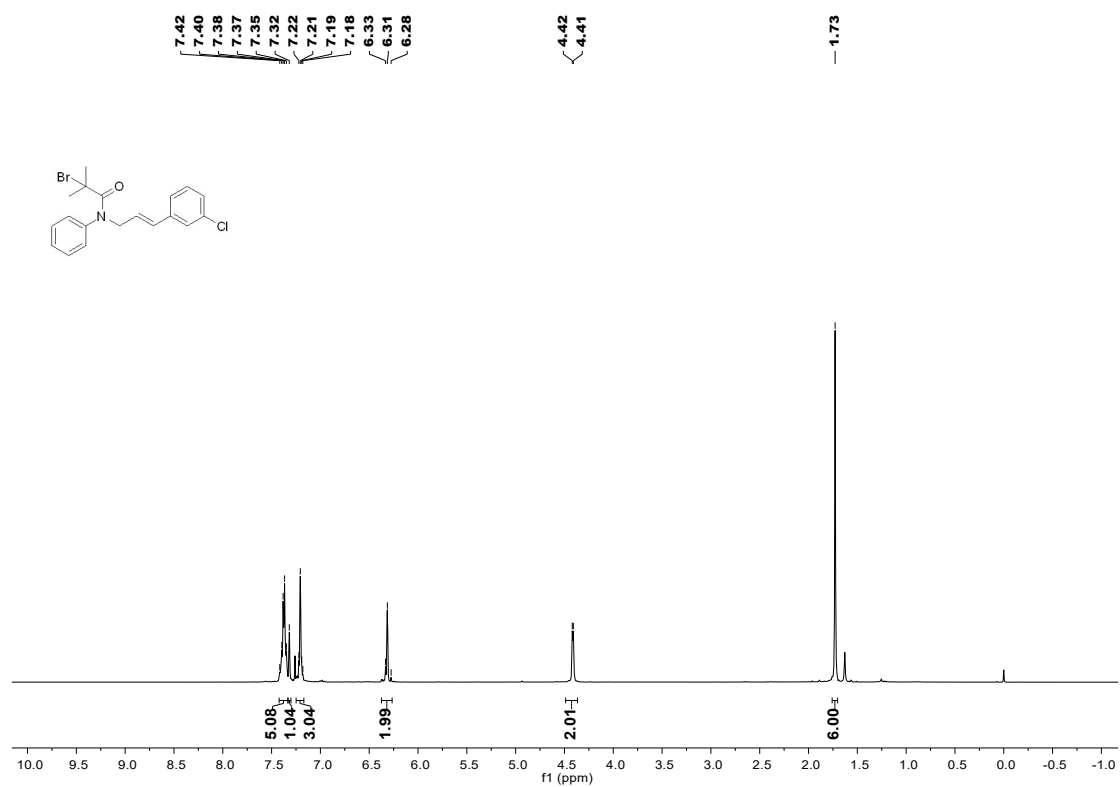
¹³C NMR spectrum of compound (2f)



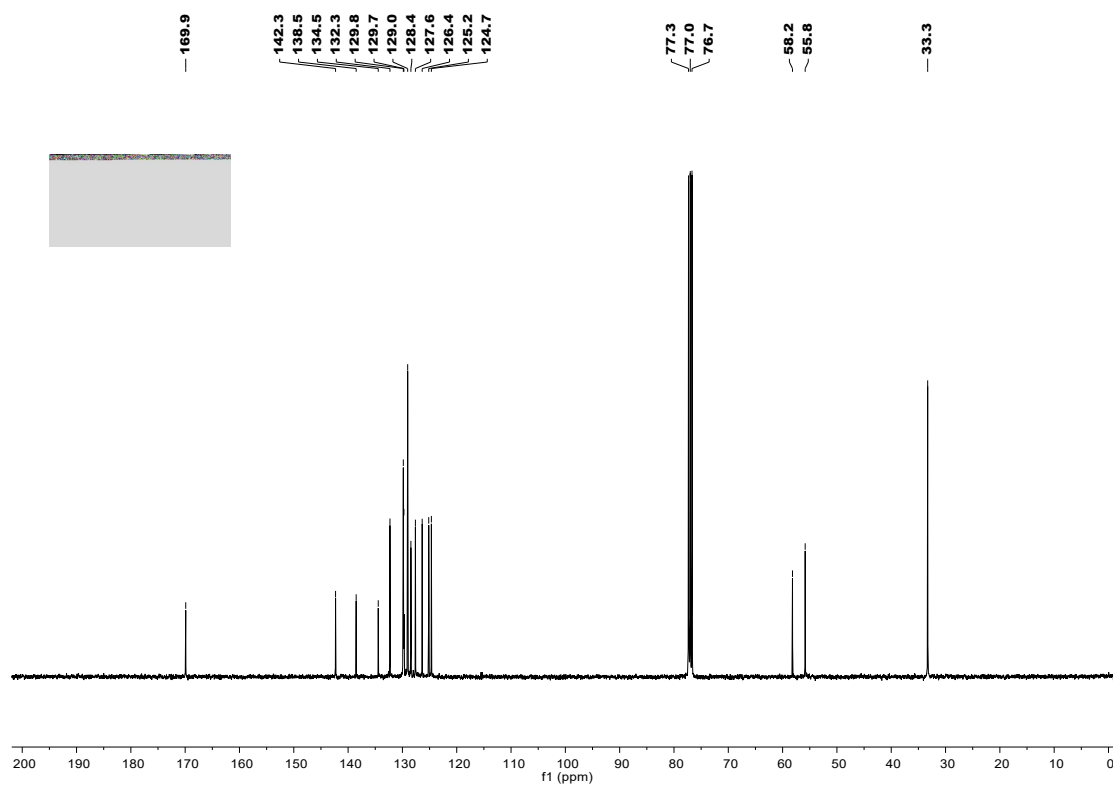
^{19}F NMR spectrum of compound (2f)



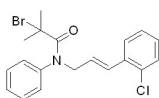
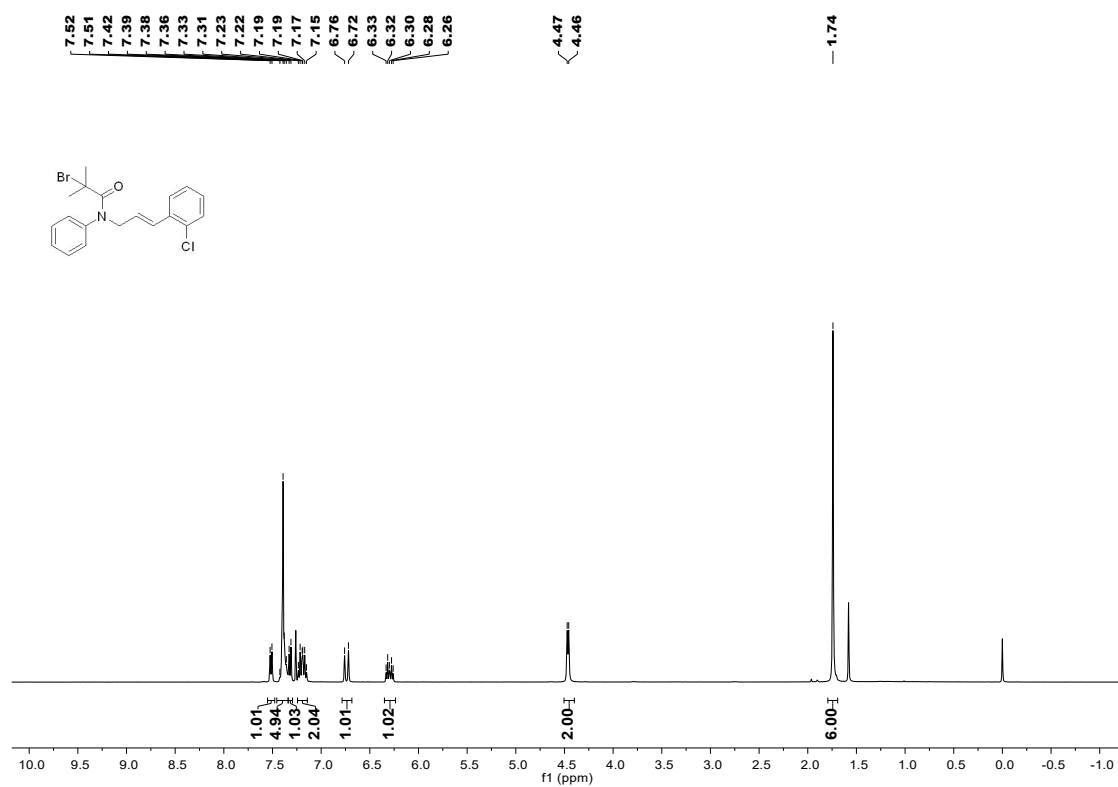
^1H NMR spectrum of compound (2g)



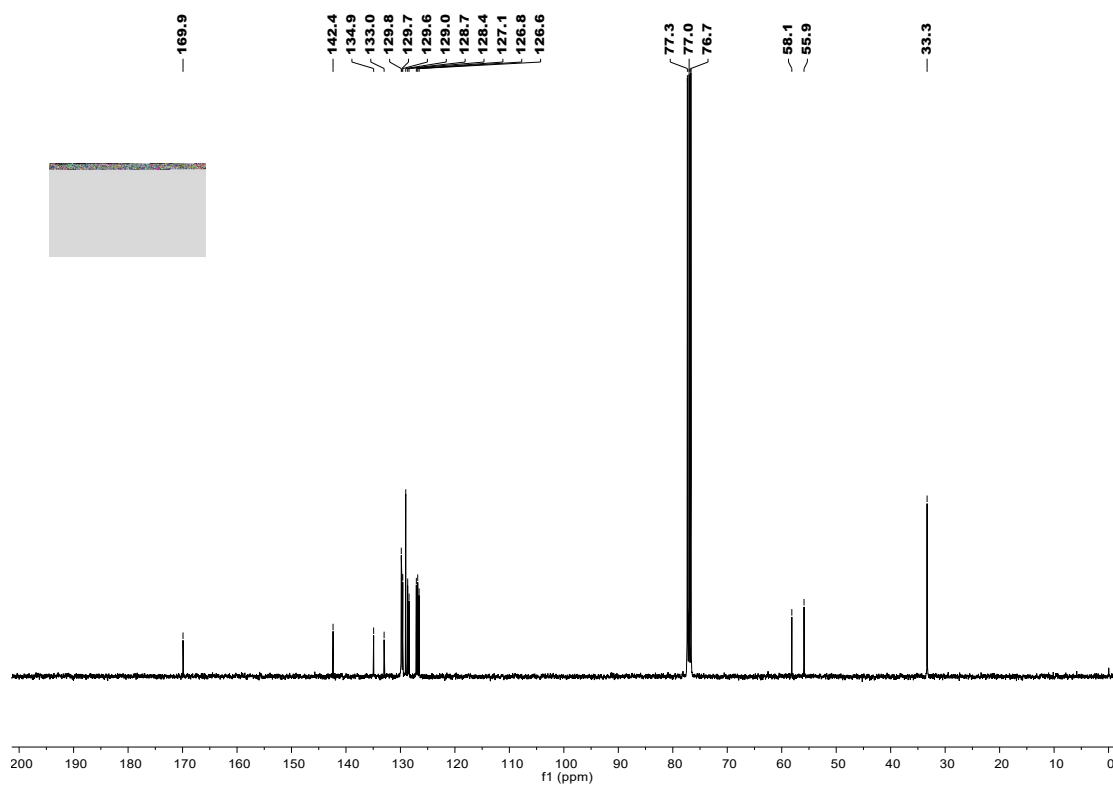
¹³C NMR spectrum of compound (2g)



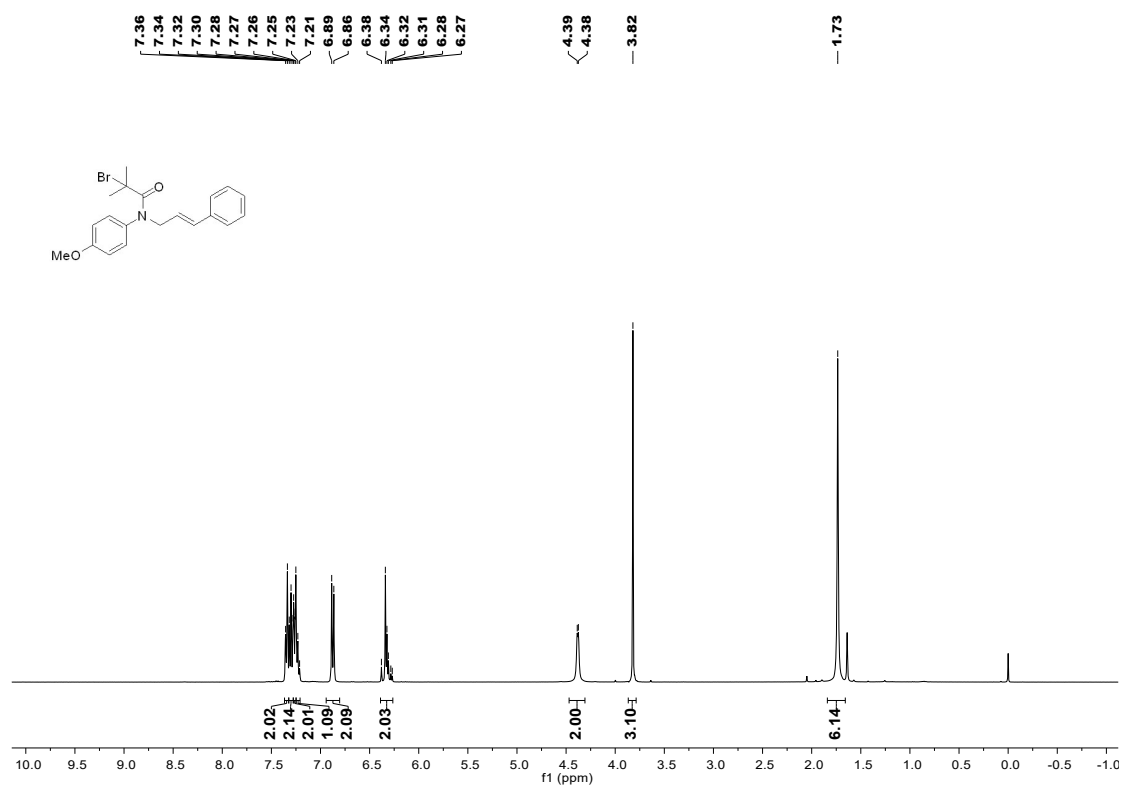
¹H NMR spectrum of compound (2h)



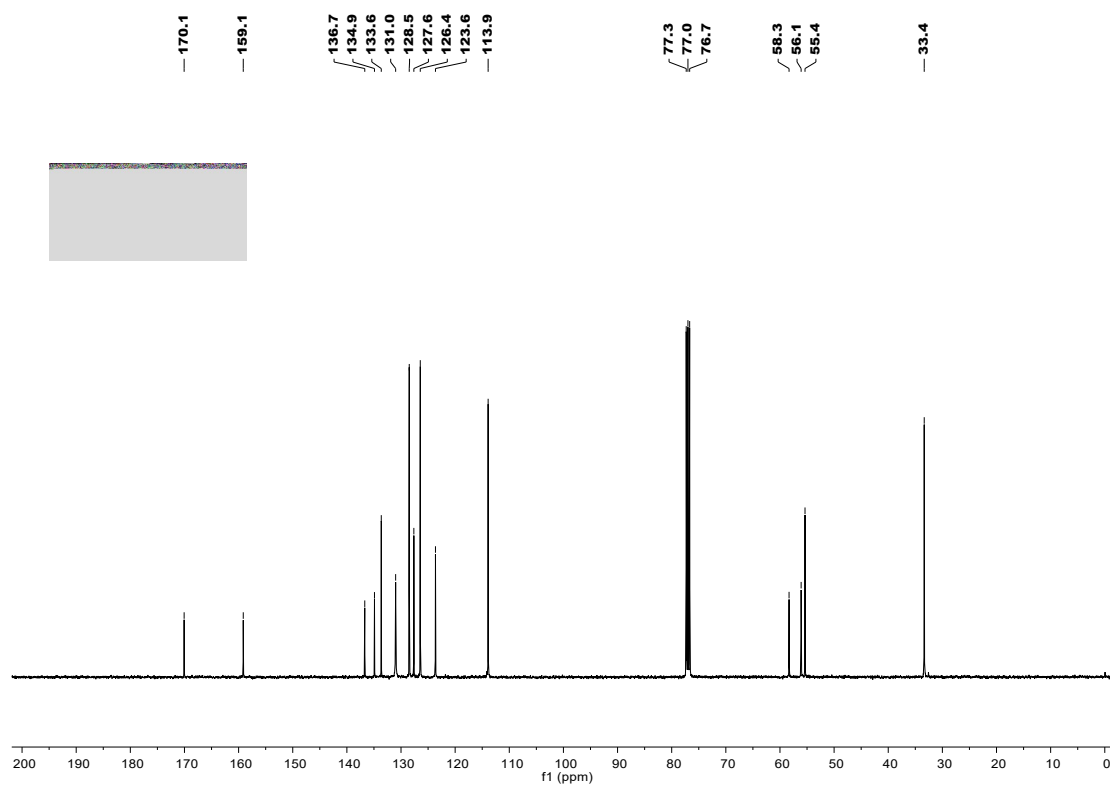
¹³C NMR spectrum of compound (2h)



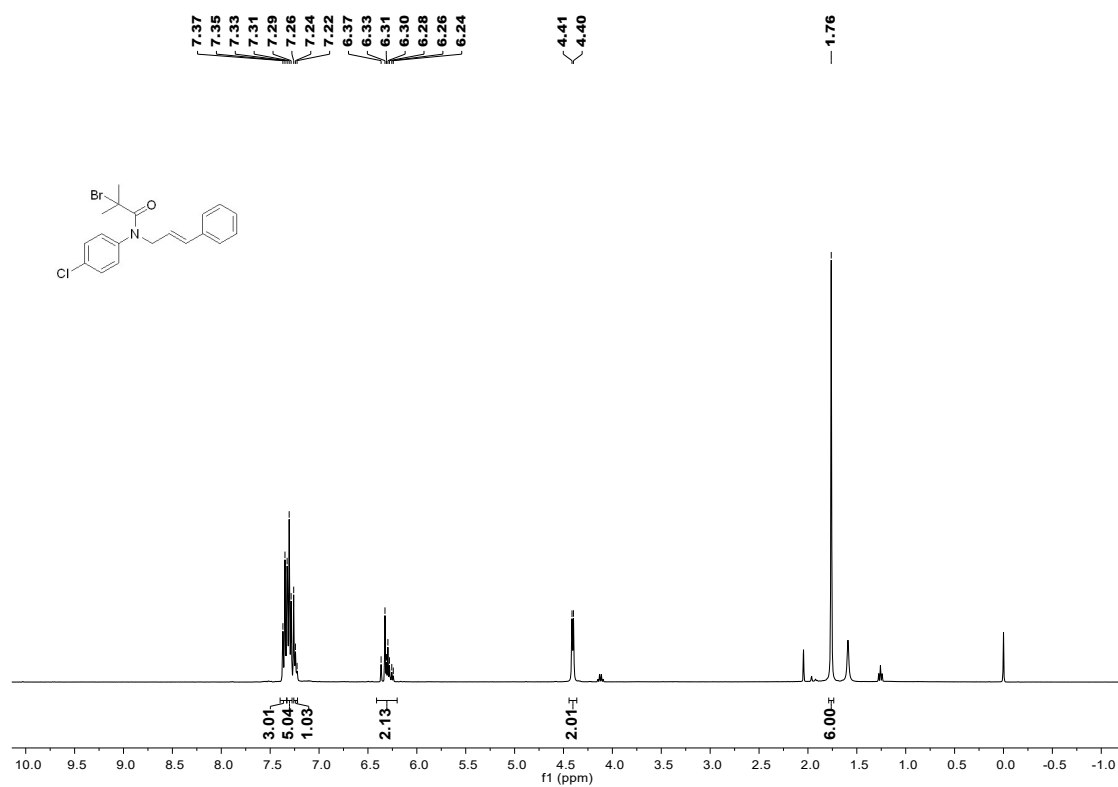
¹H NMR spectrum of compound (2i)



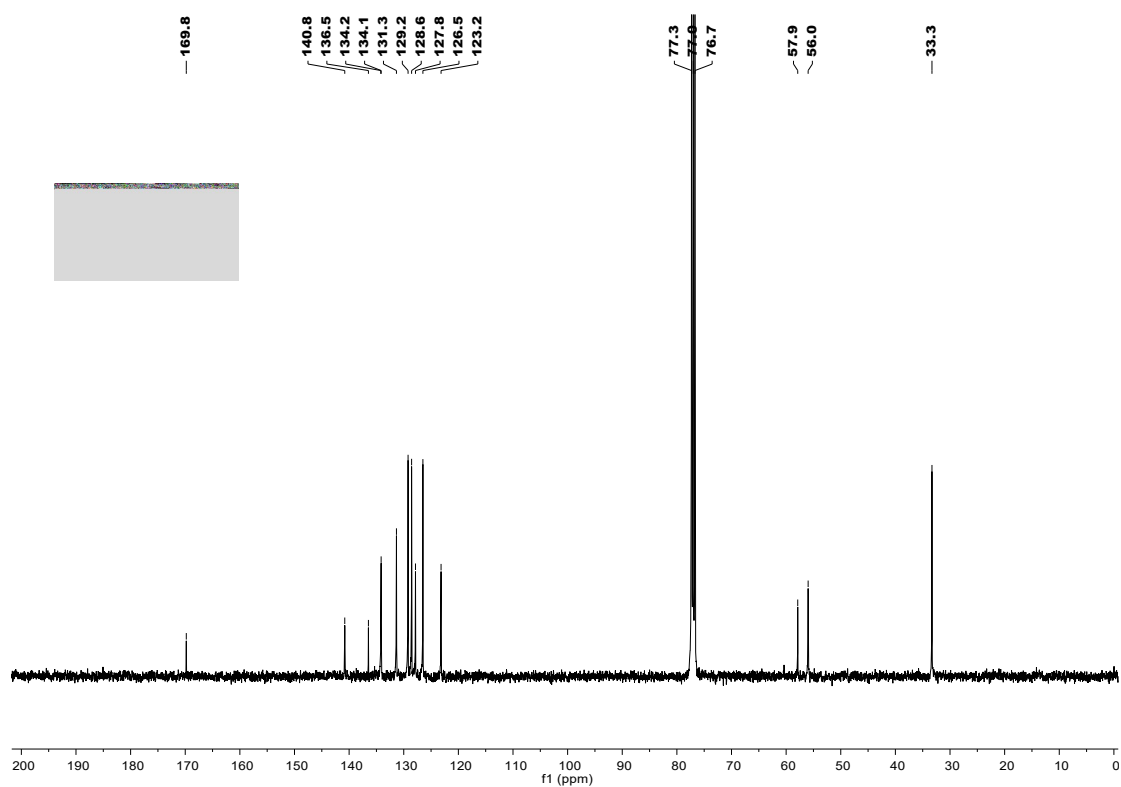
¹³C NMR spectrum of compound (2i)



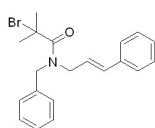
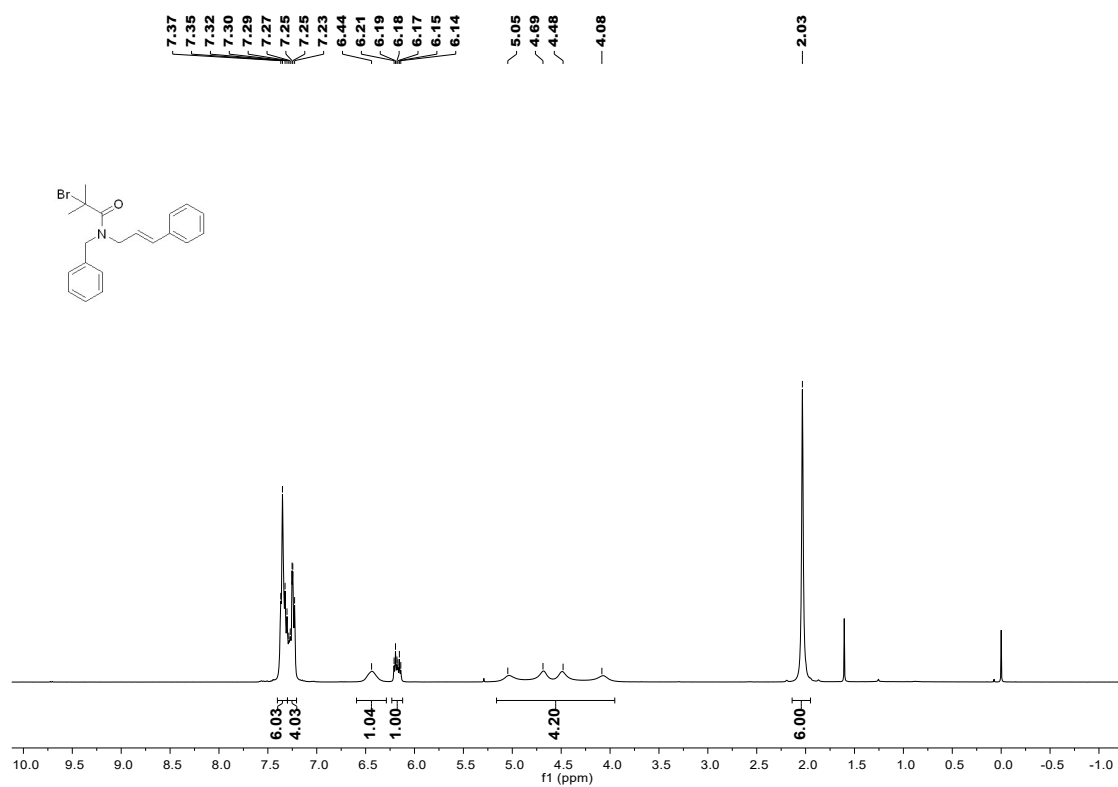
¹H NMR spectrum of compound (2j)



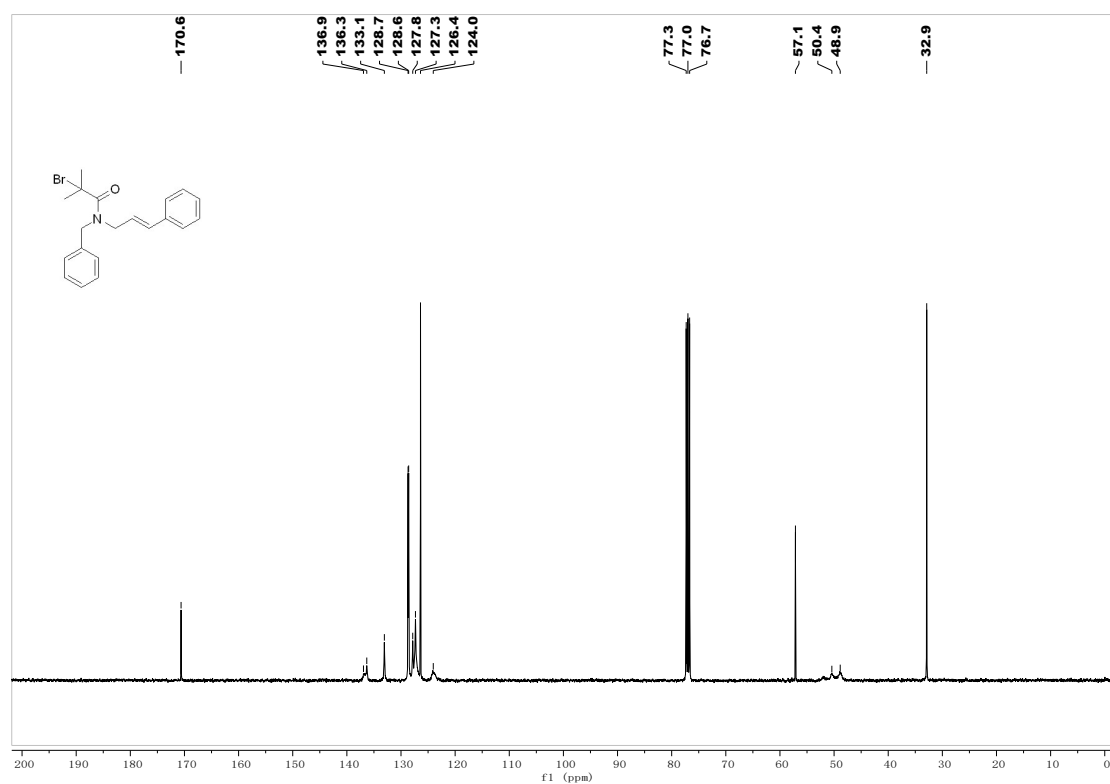
¹³C NMR spectrum of compound (2j)



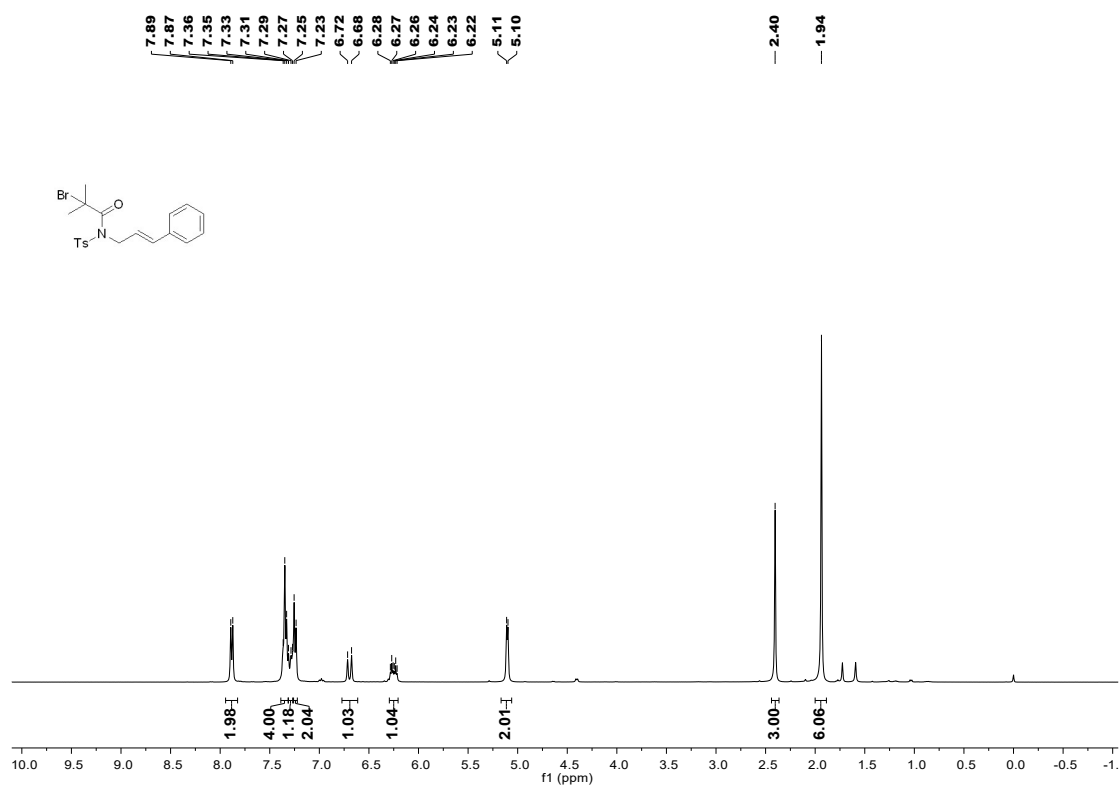
¹H NMR spectrum of compound (2k)



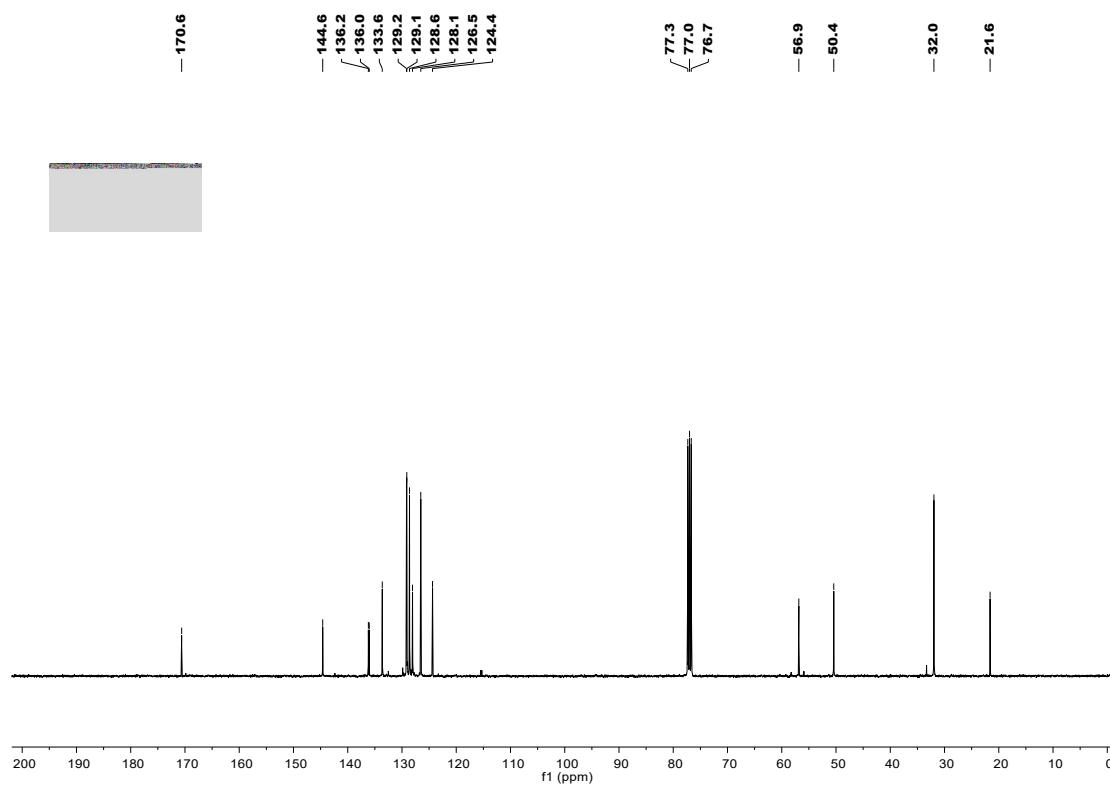
¹³C NMR spectrum of compound (2k)



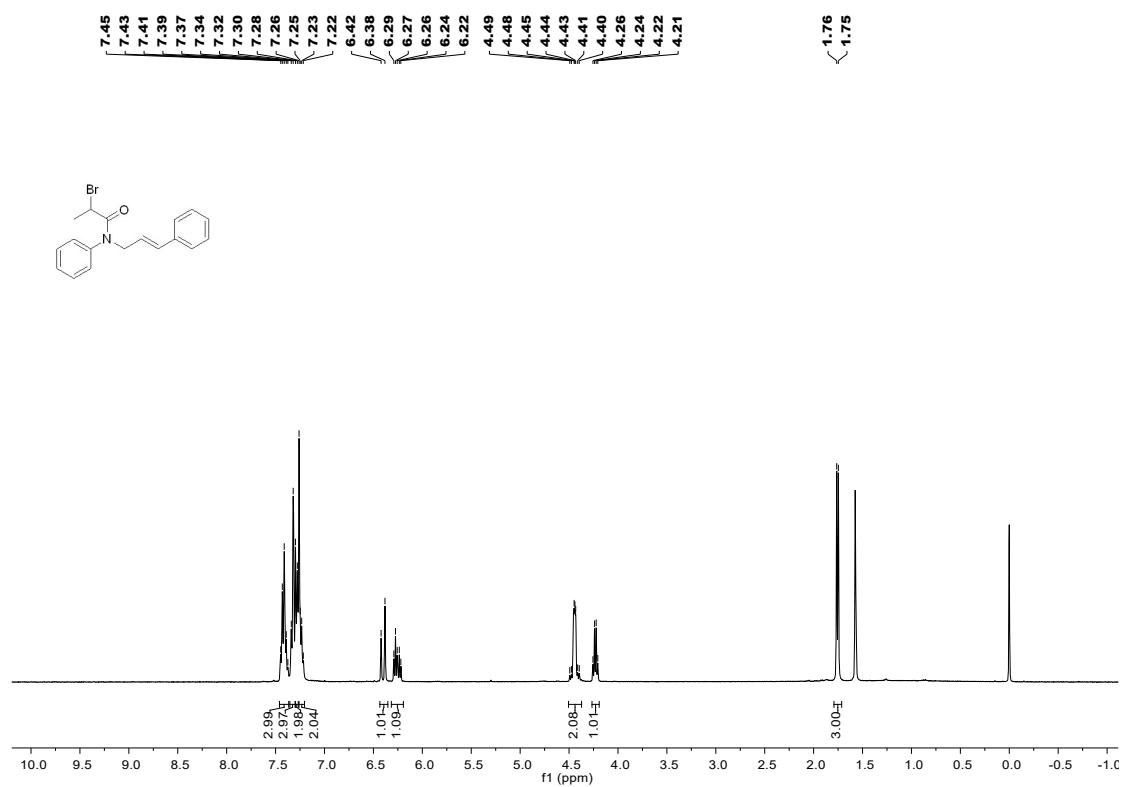
¹H NMR spectrum of compound (2l)



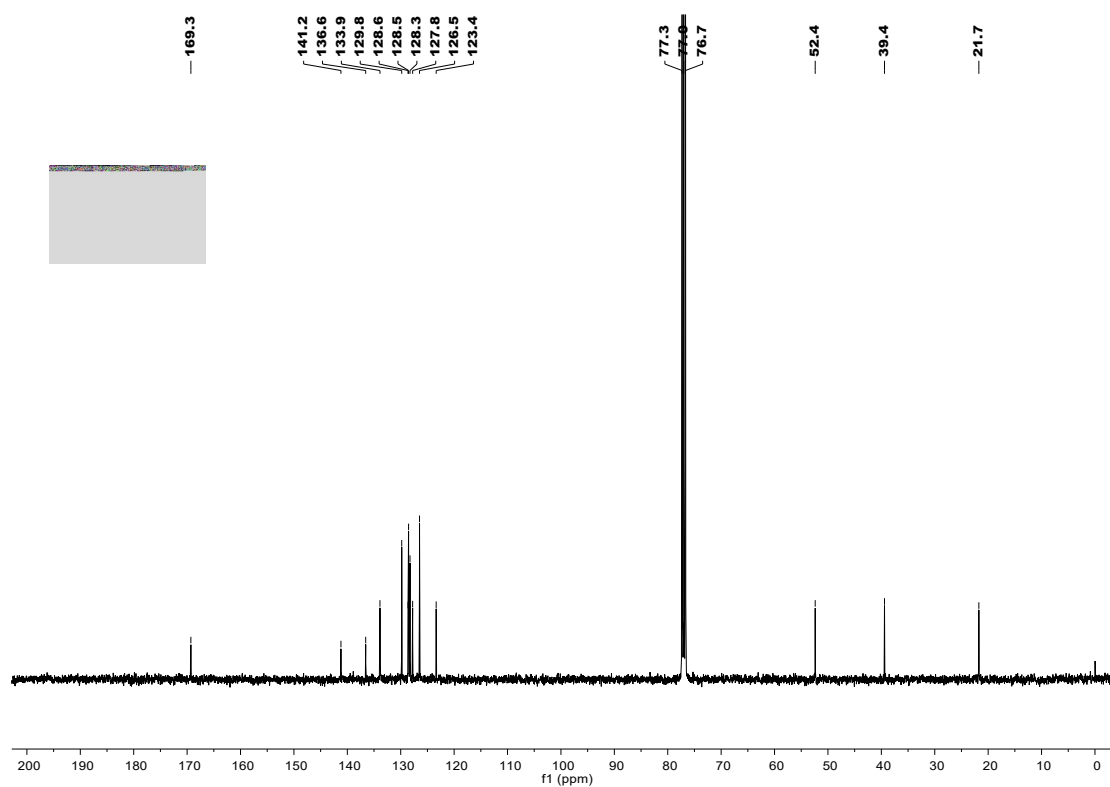
¹³C NMR spectrum of compound (2l)



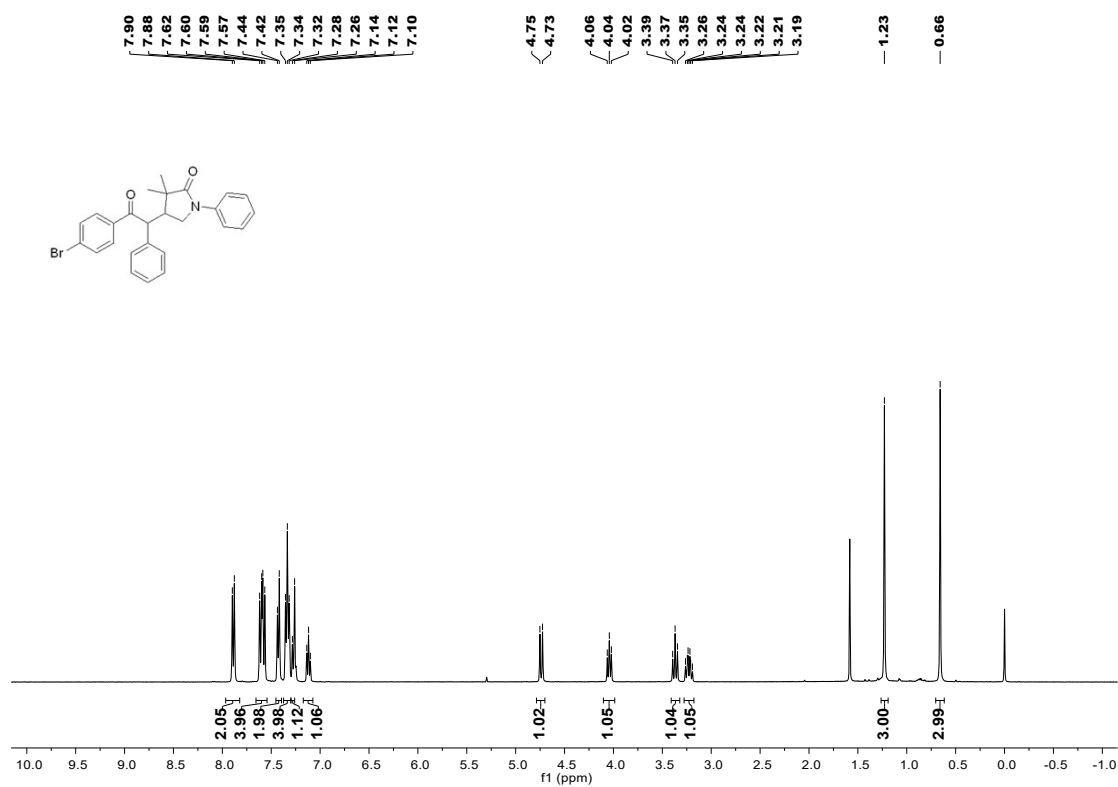
¹H NMR spectrum of compound (2m)



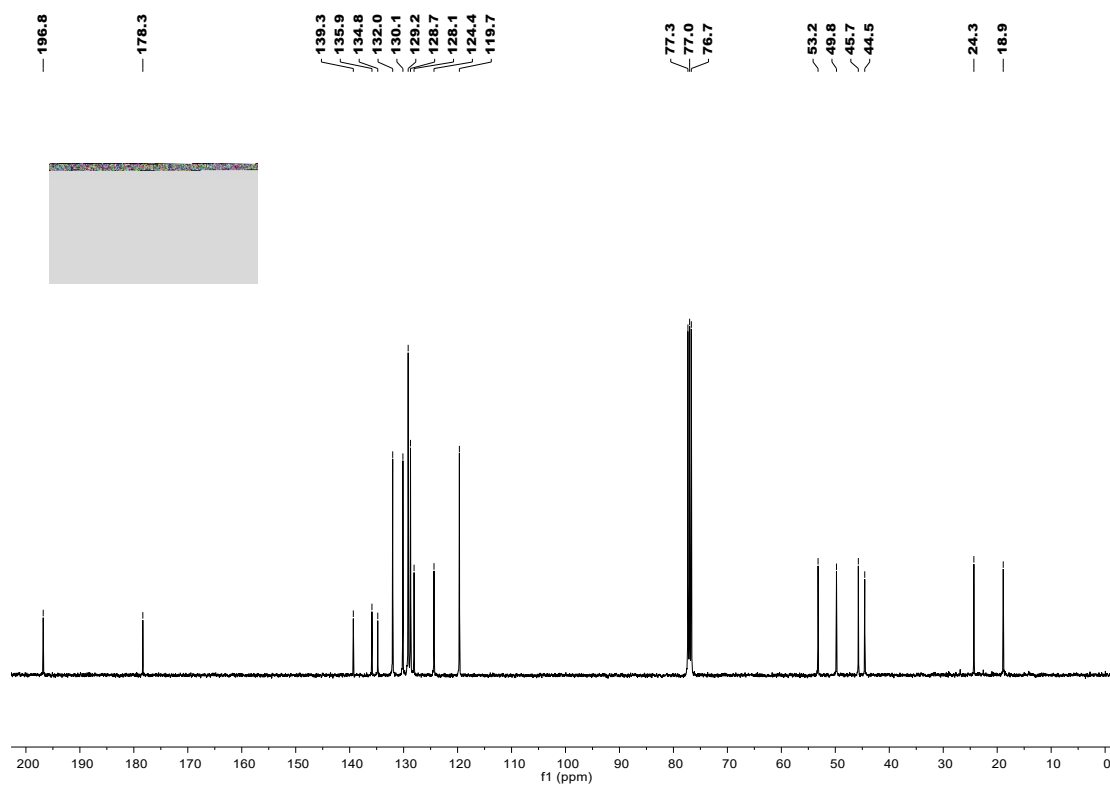
¹³C NMR spectrum of compound (2m)



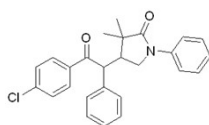
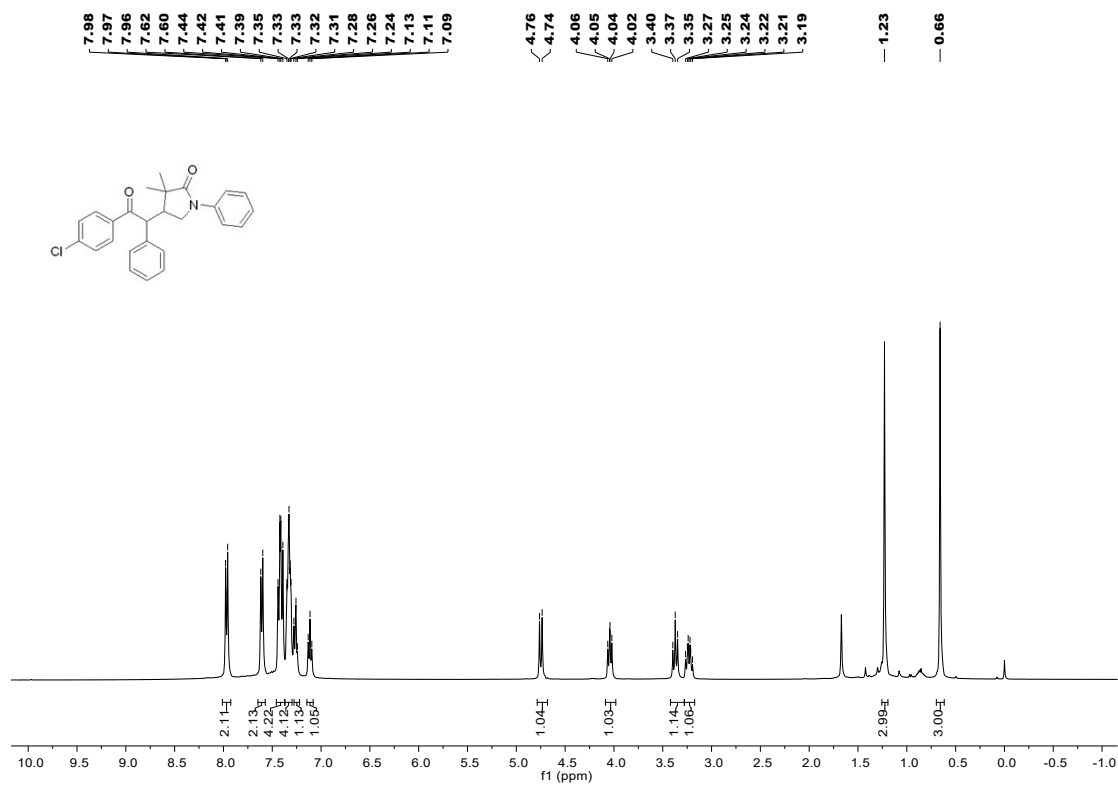
¹H NMR spectrum of compound (3aa)



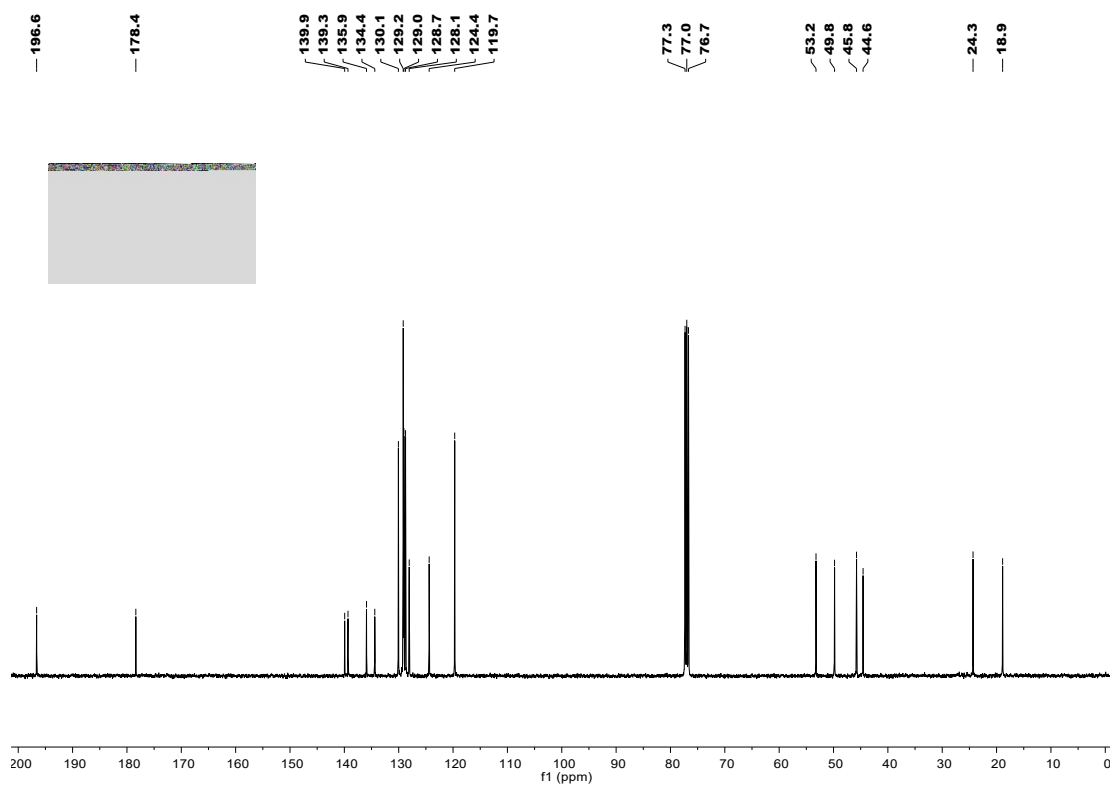
¹³C NMR spectrum of compound (3aa)



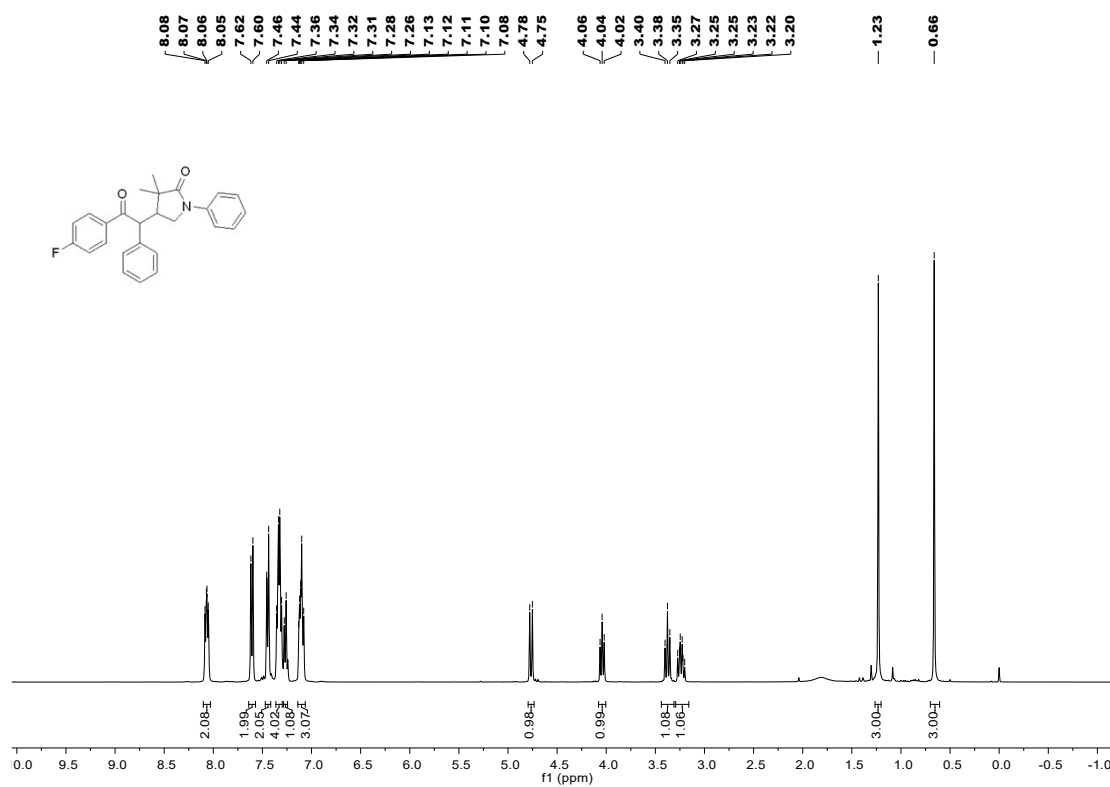
¹H NMR spectrum of compound (3ba)



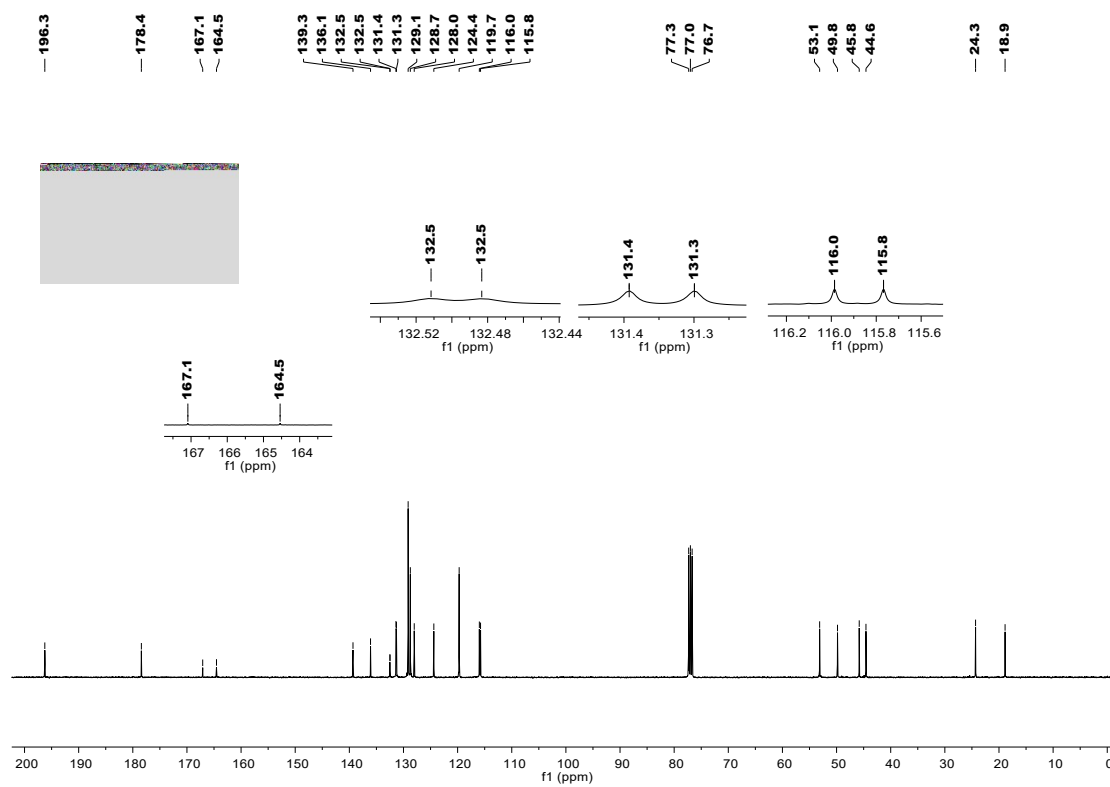
¹³C NMR spectrum of compound (3ba)



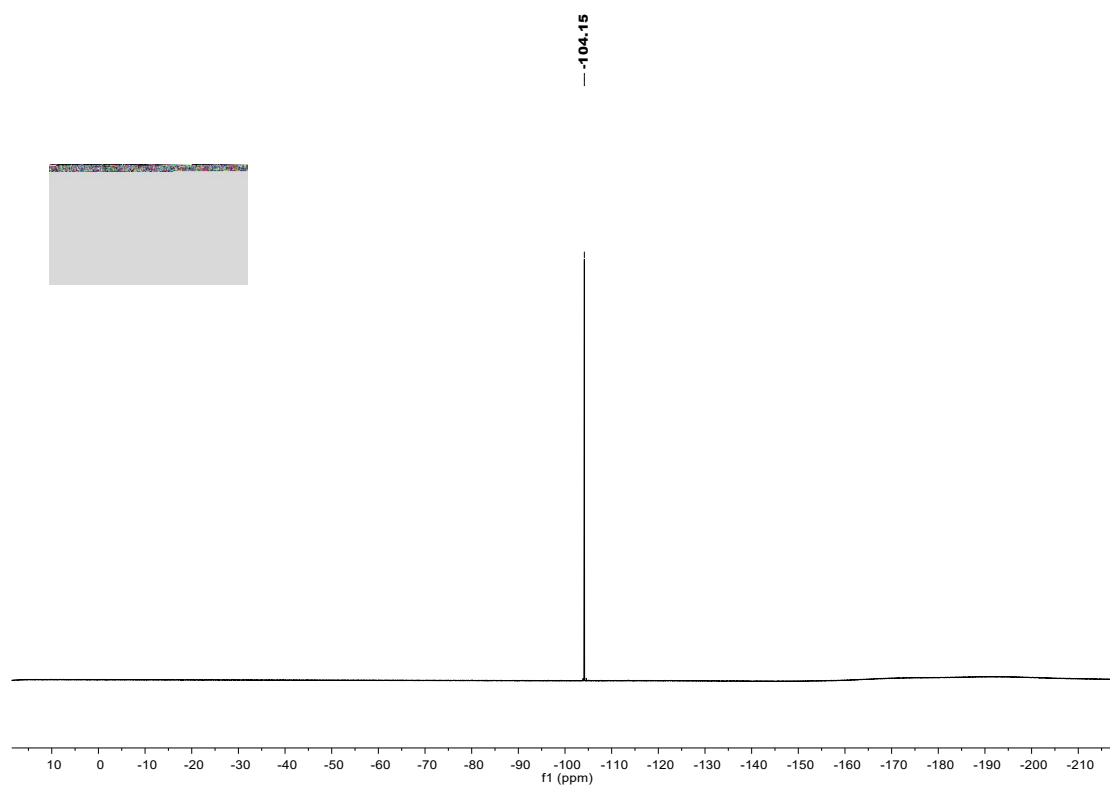
¹H NMR spectrum of compound (3ca)



¹³C NMR spectrum of compound (3ca)

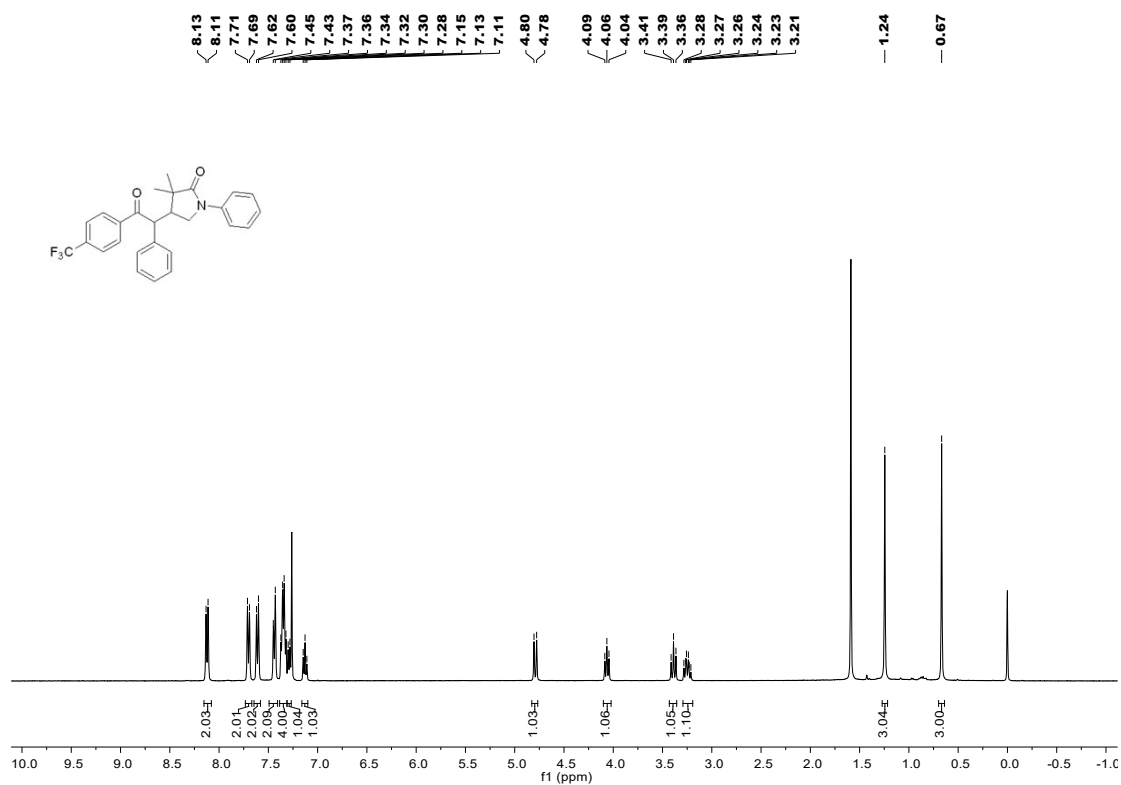


¹⁹F NMR spectrum of compound (3ca)

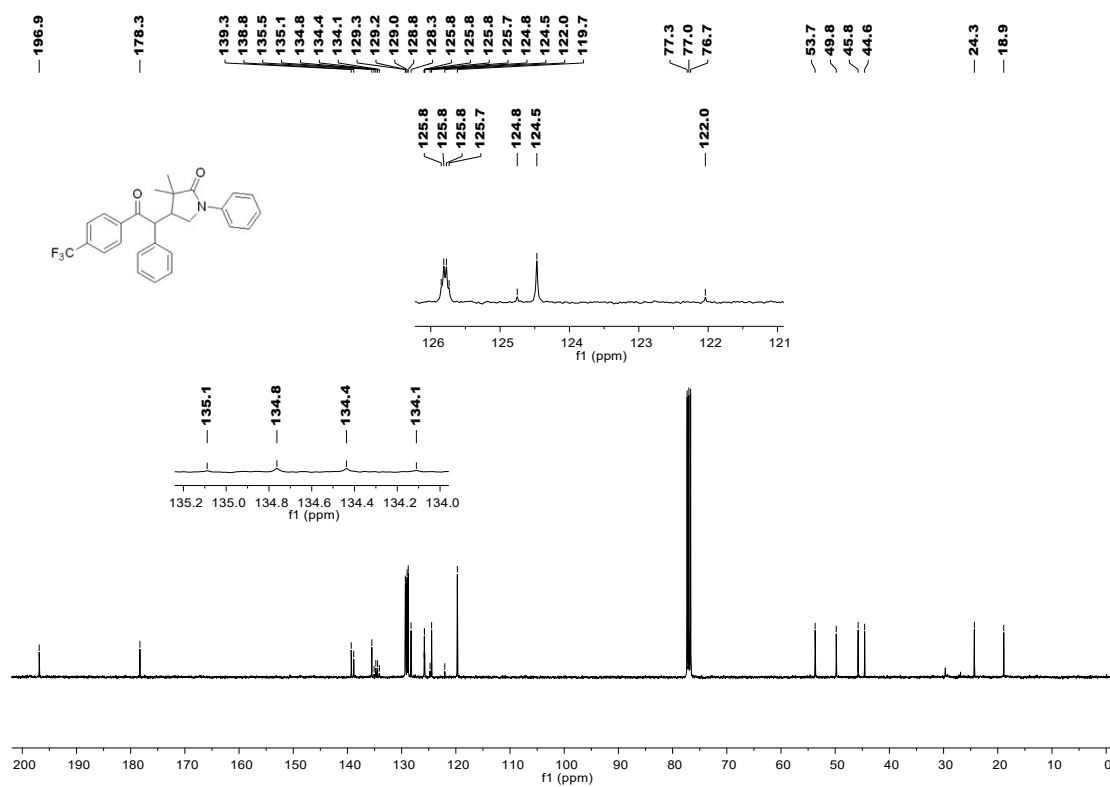


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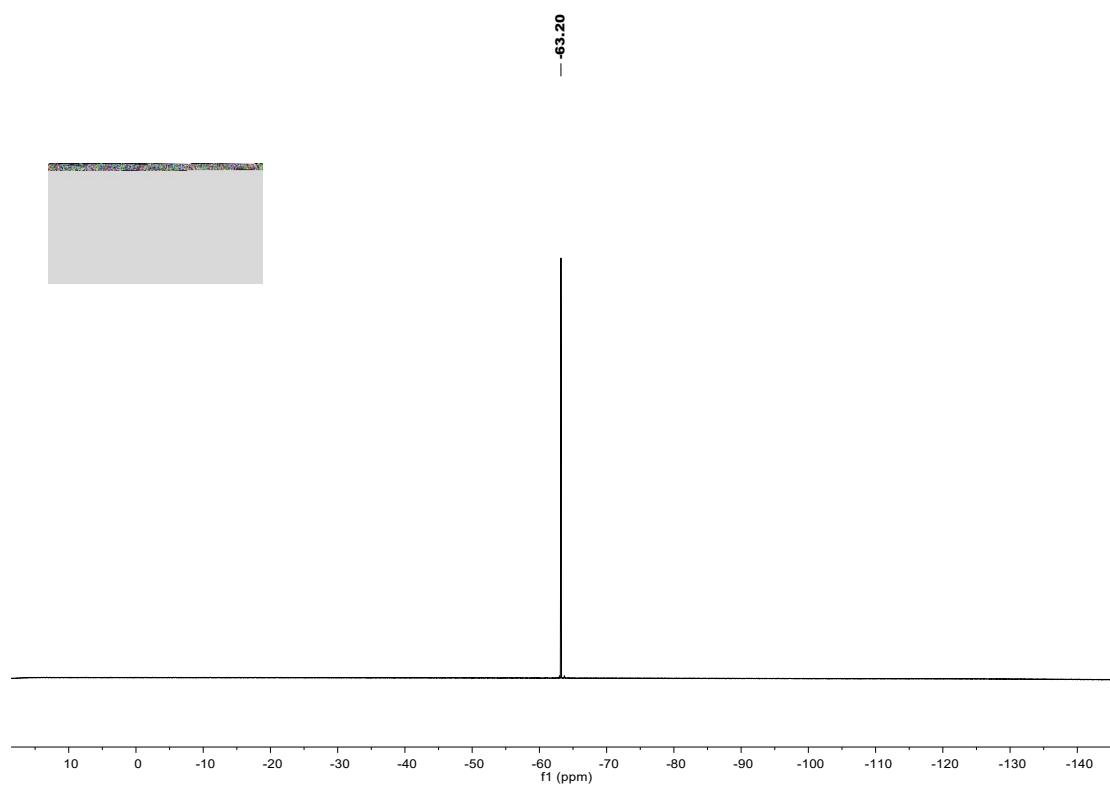
¹H NMR spectrum of compound (3da)



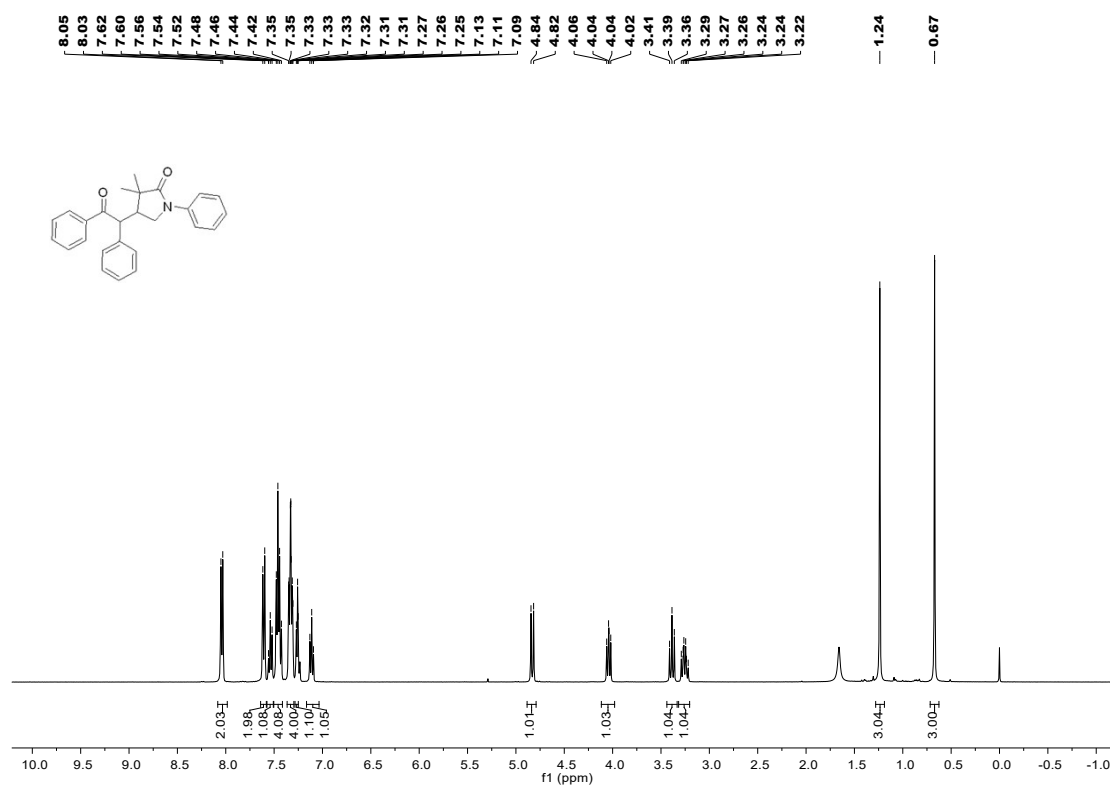
¹³C NMR spectrum of compound (3da)



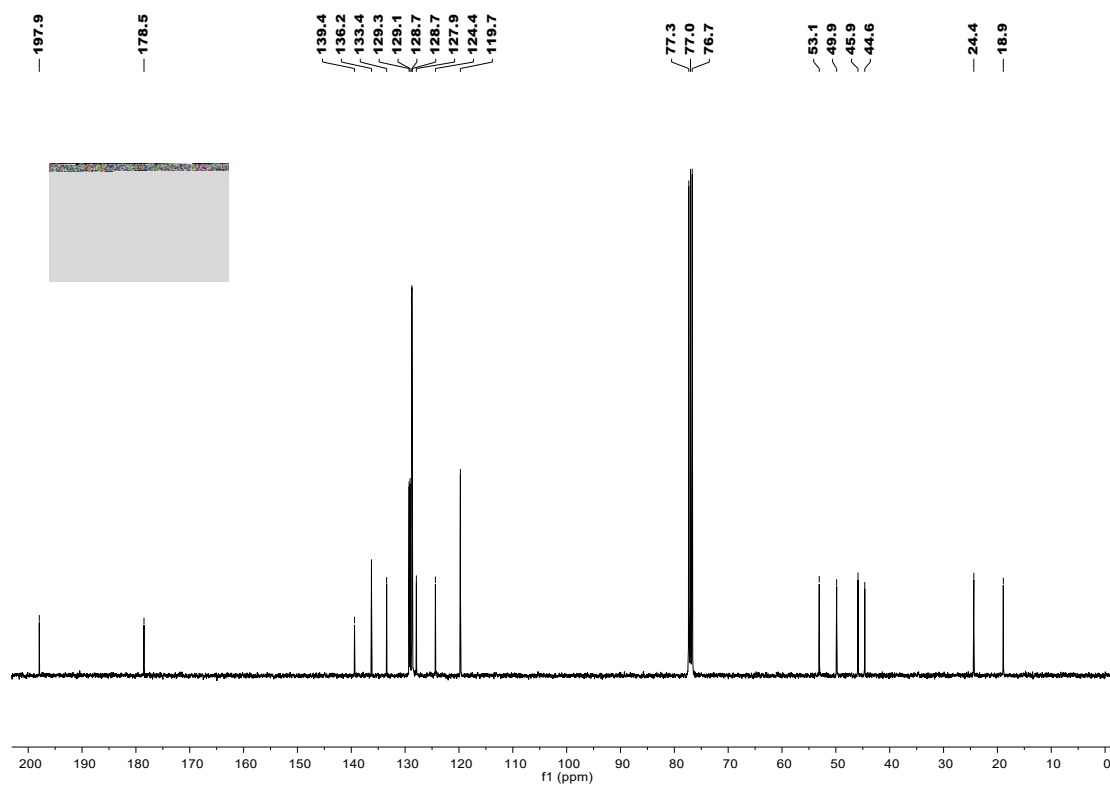
¹⁹F NMR spectrum of compound (3da)



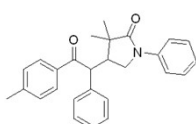
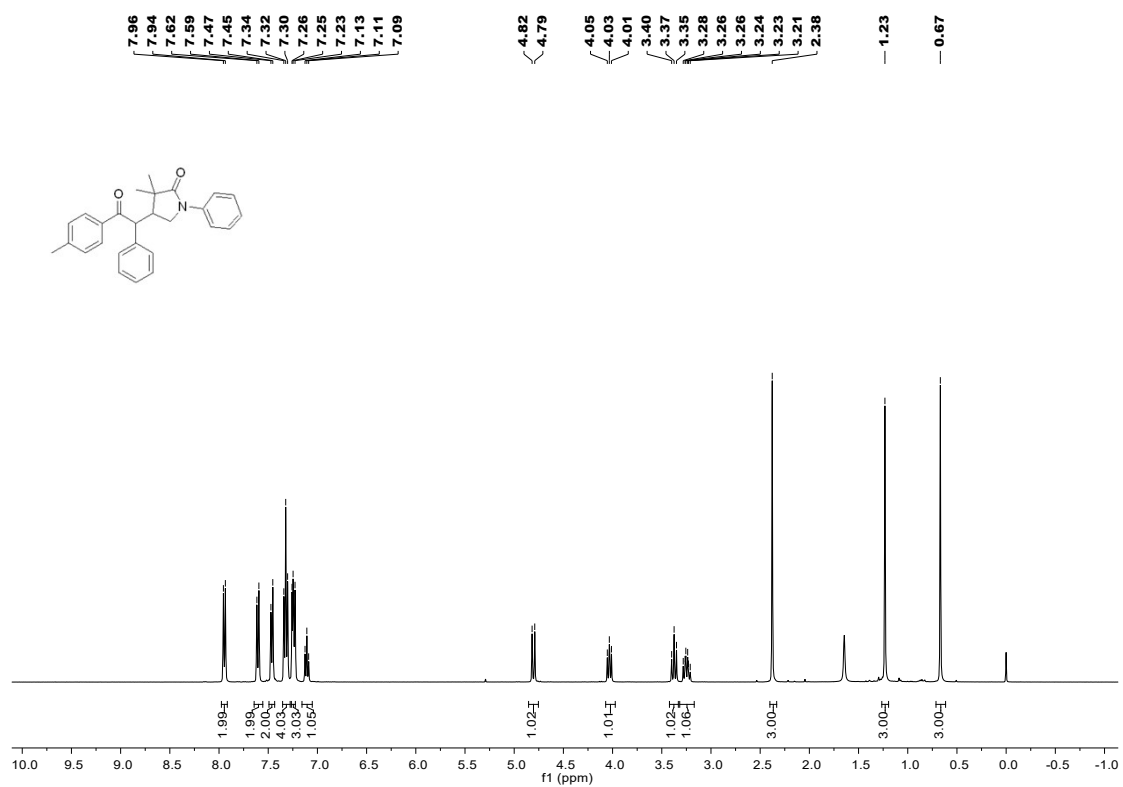
¹H NMR spectrum of compound (3ea)



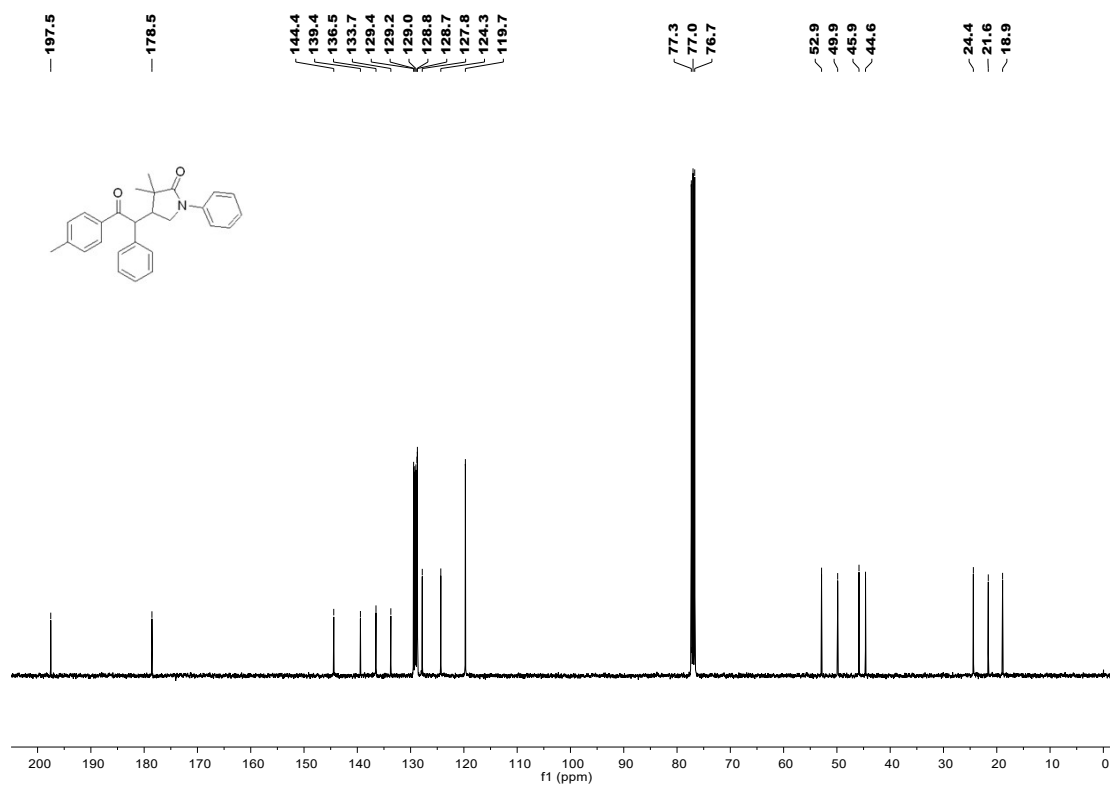
¹³C NMR spectrum of compound (3ea)



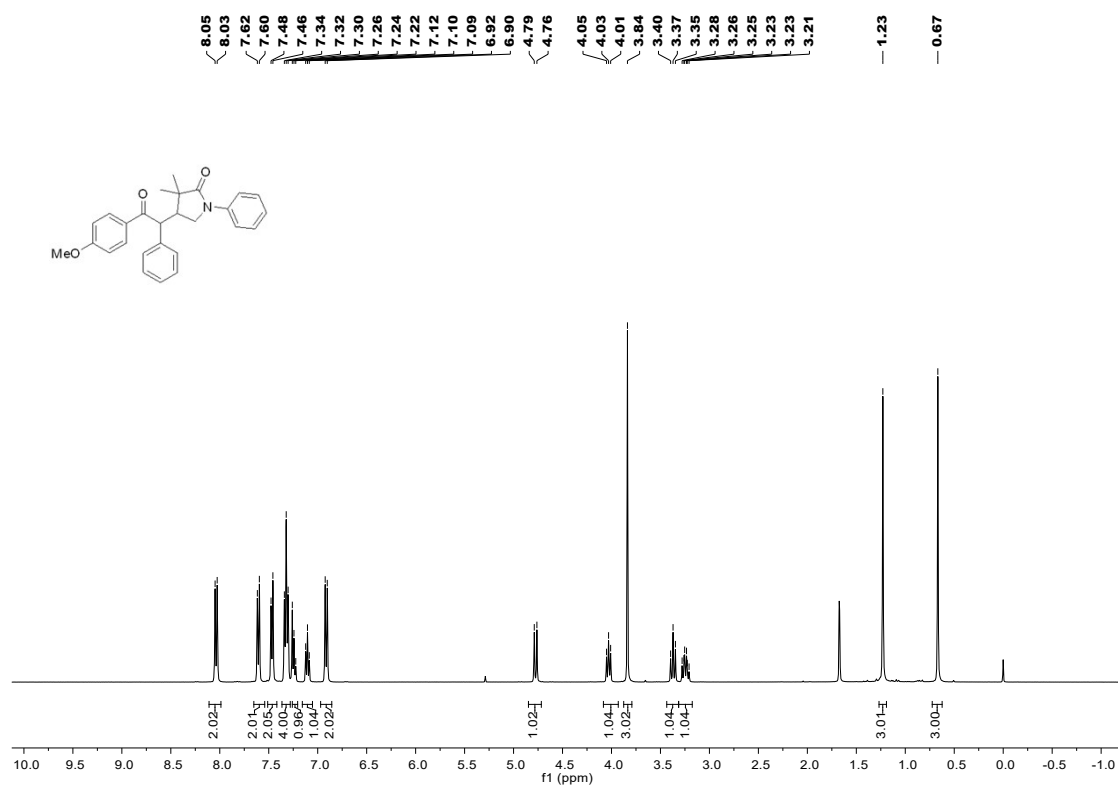
¹H NMR spectrum of compound (3fa)



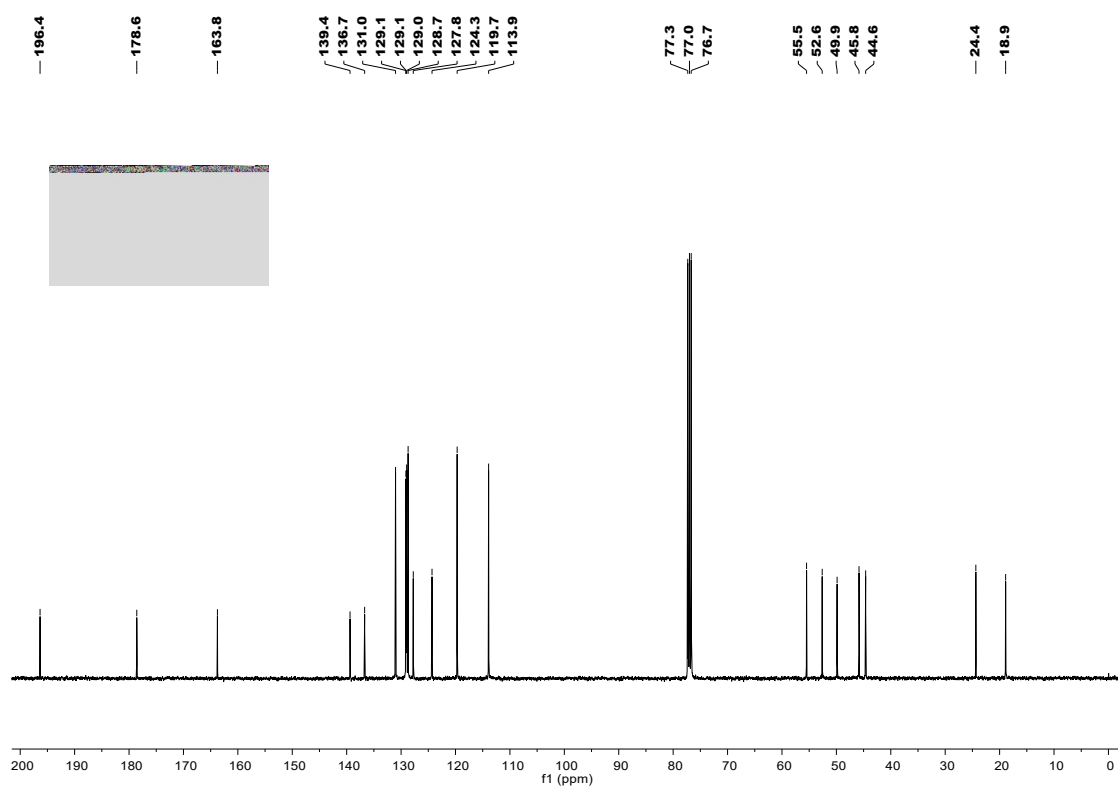
¹³C NMR spectrum of compound (3fa)



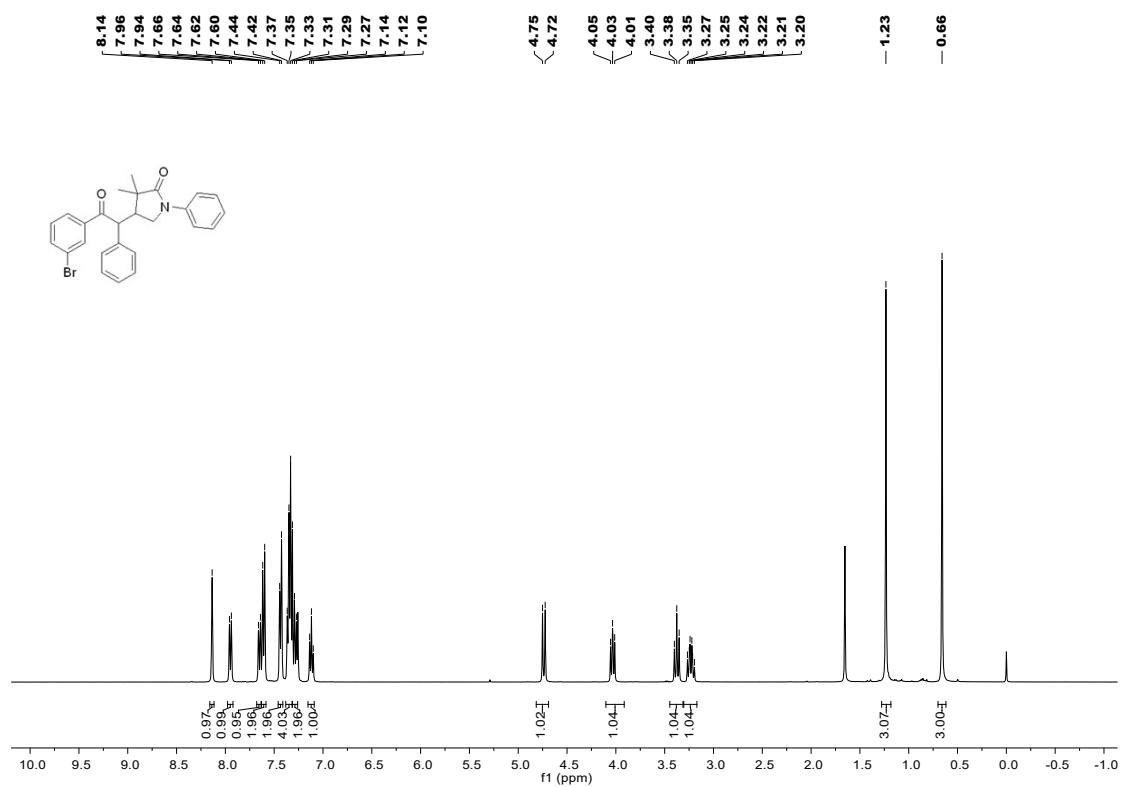
¹H NMR spectrum of compound (3ga)



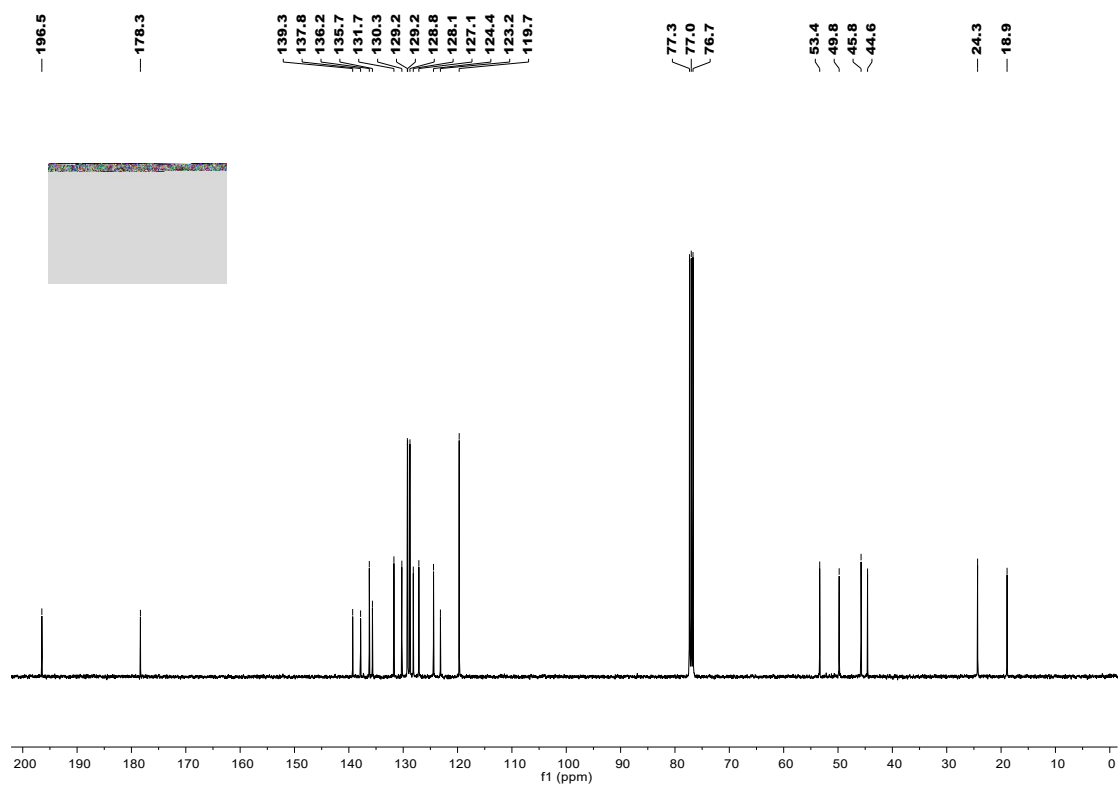
¹³C NMR spectrum of compound (3ga)



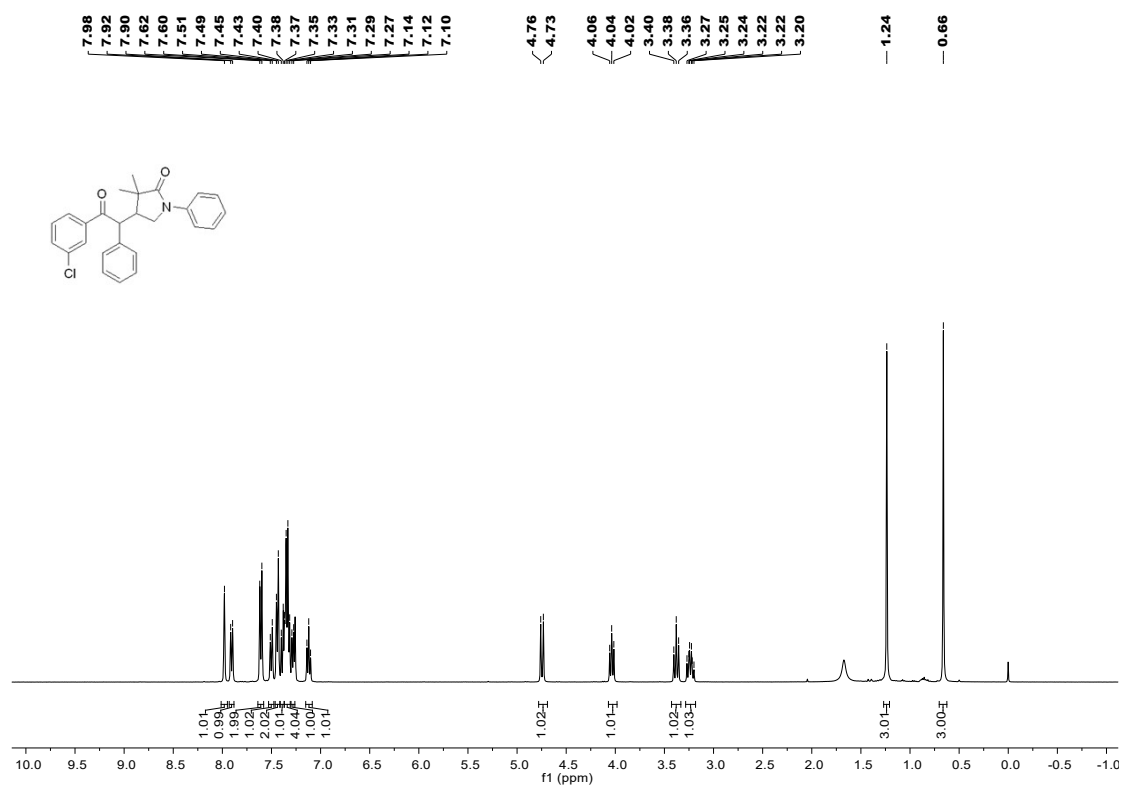
¹H NMR spectrum of compound (3ha)



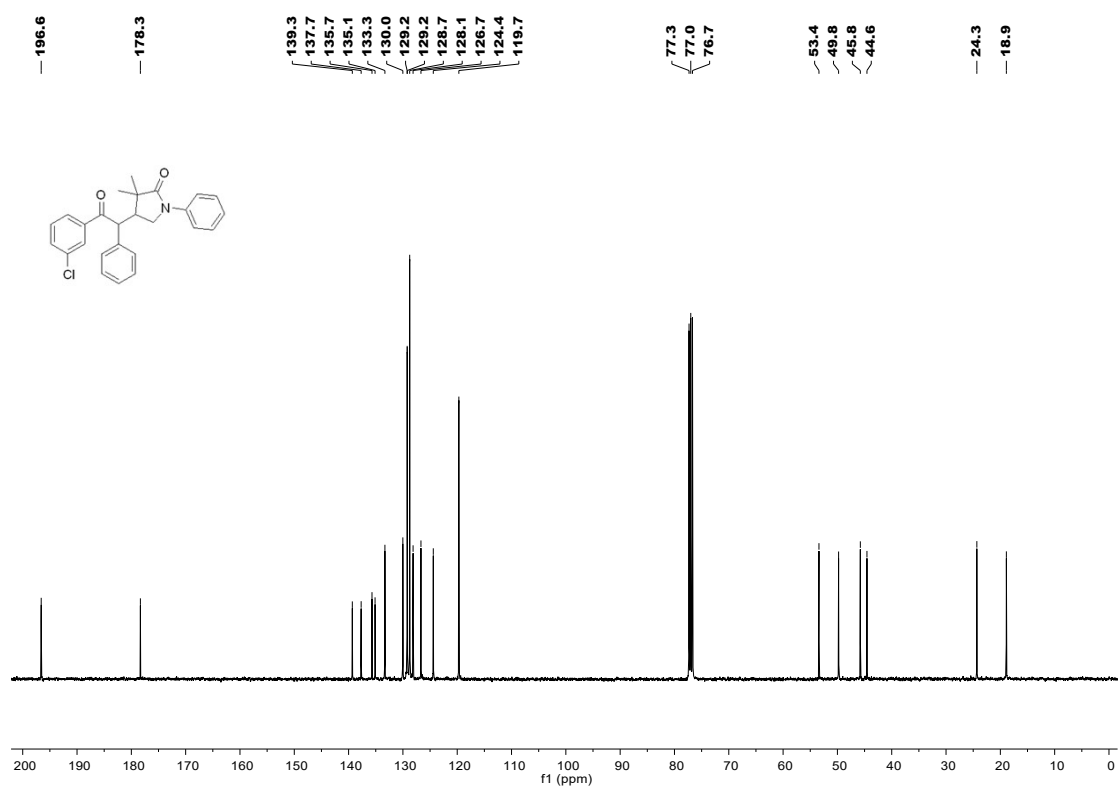
¹³C NMR spectrum of compound (3ha)



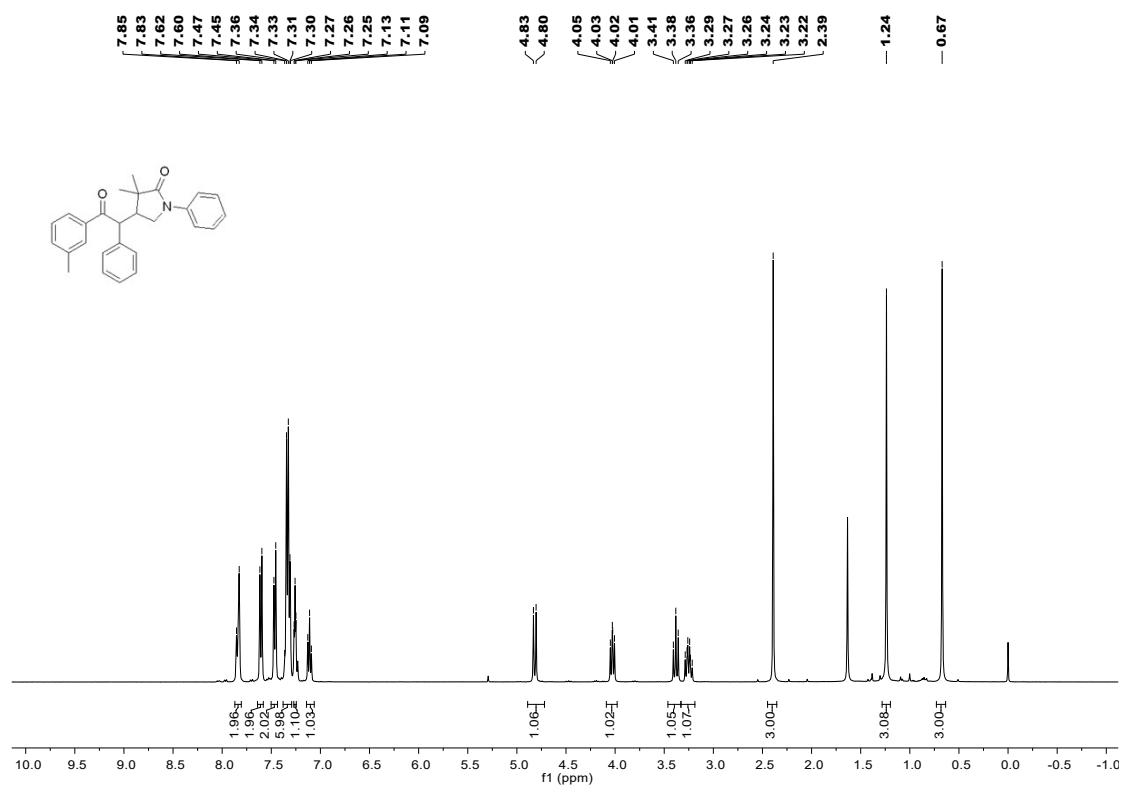
¹H NMR spectrum of compound (3ia)



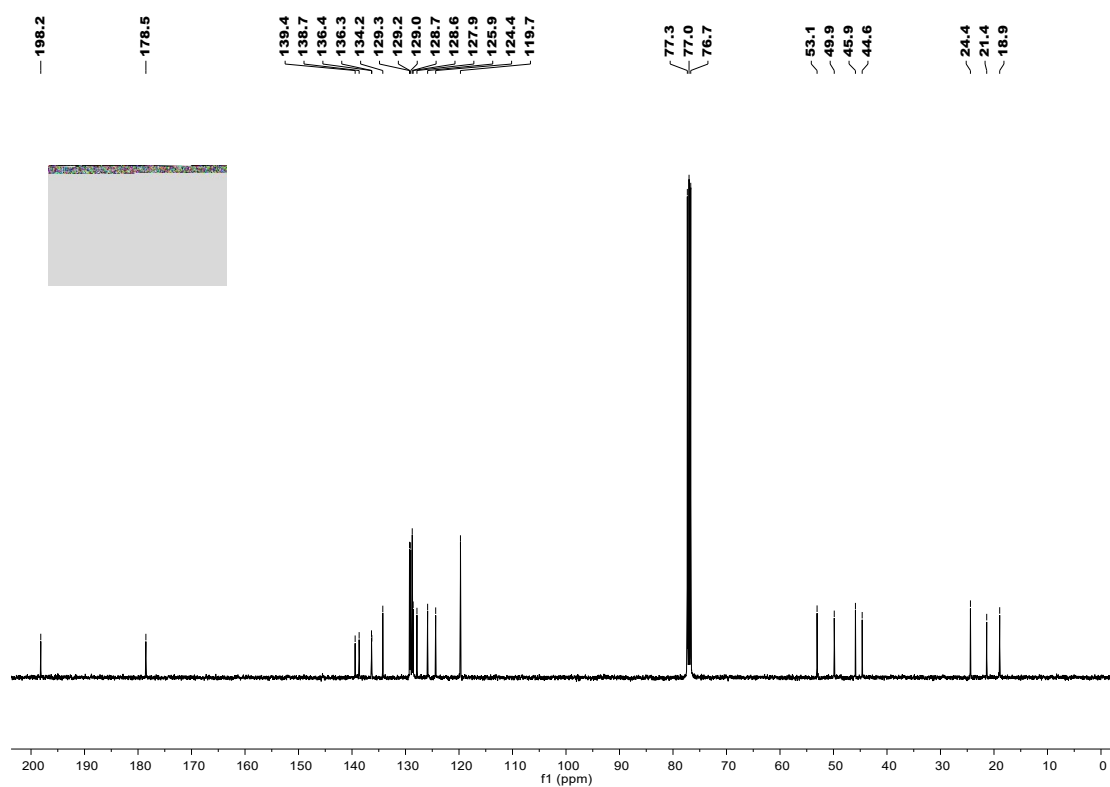
¹³C NMR spectrum of compound (3ia)



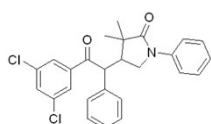
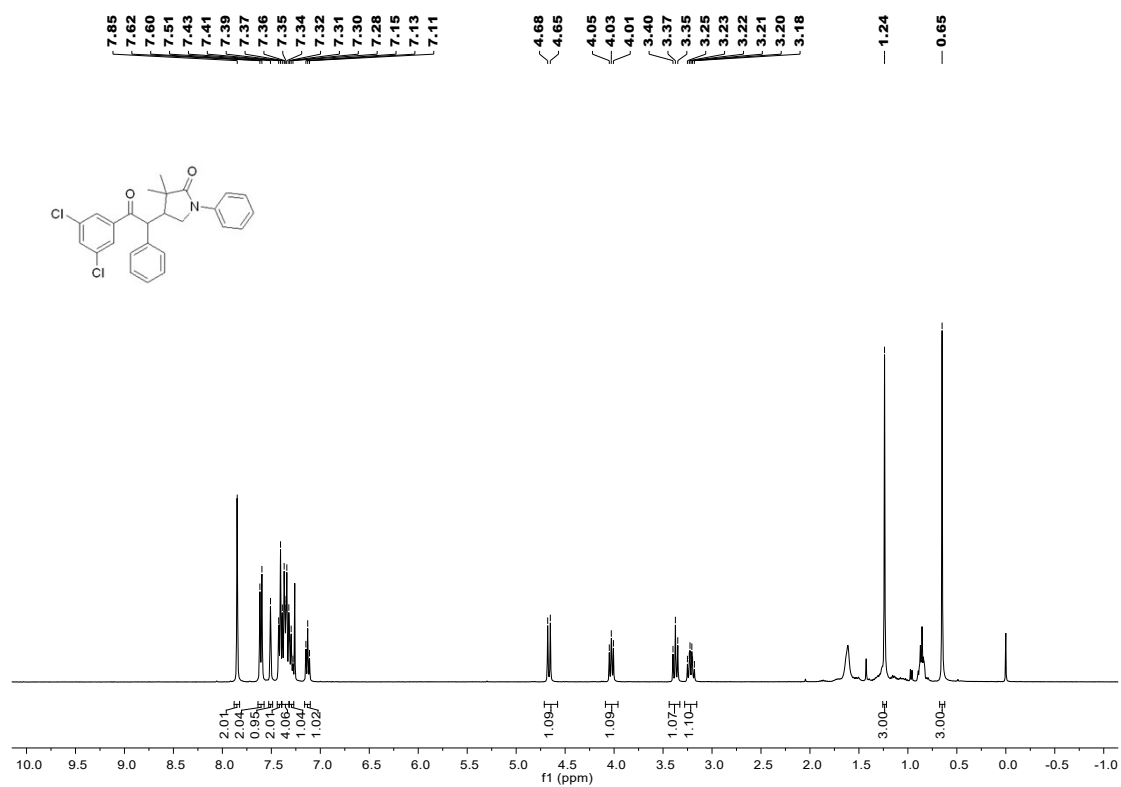
¹H NMR spectrum of compound (3ja)



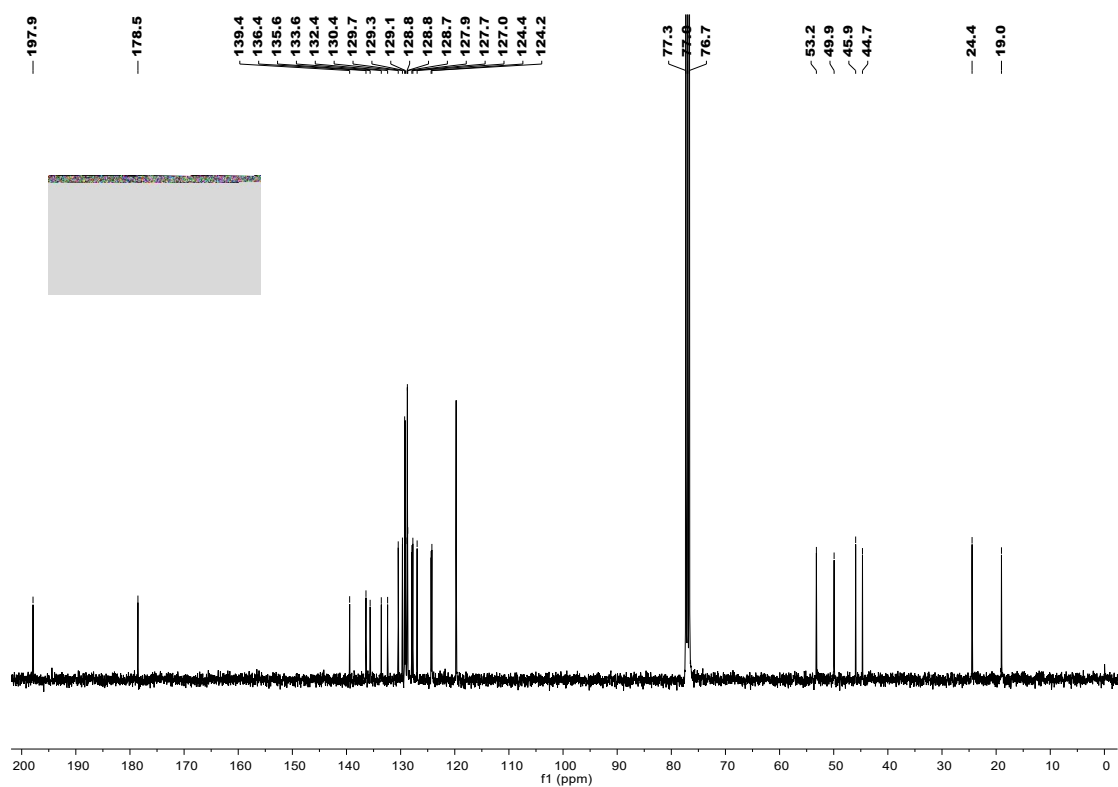
¹³C NMR spectrum of compound (3ja)



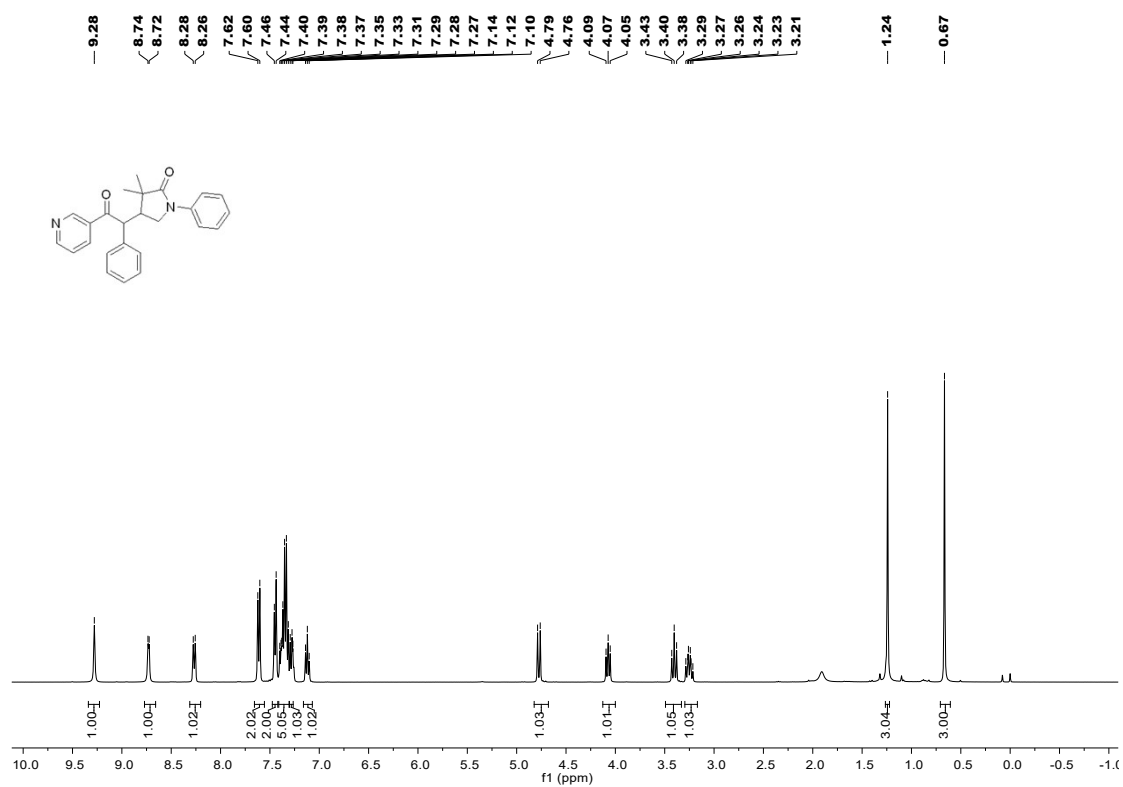
¹H NMR spectrum of compound (3ka)



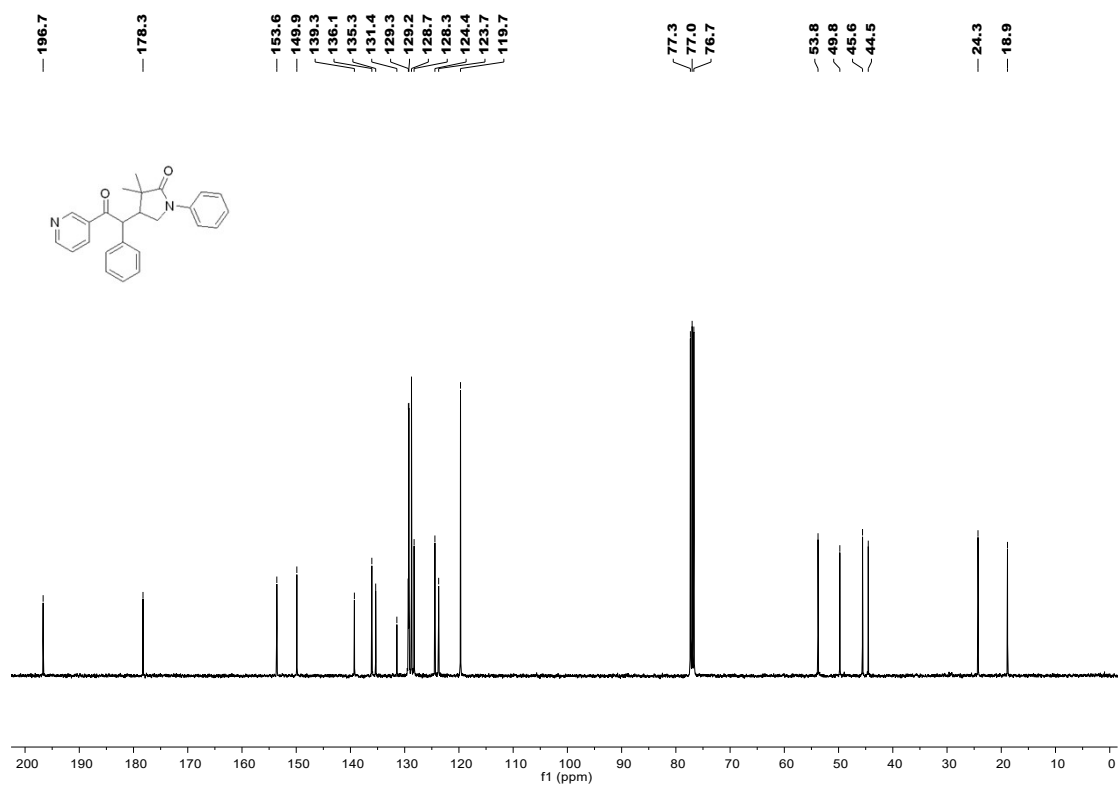
¹³C NMR spectrum of compound (3la)



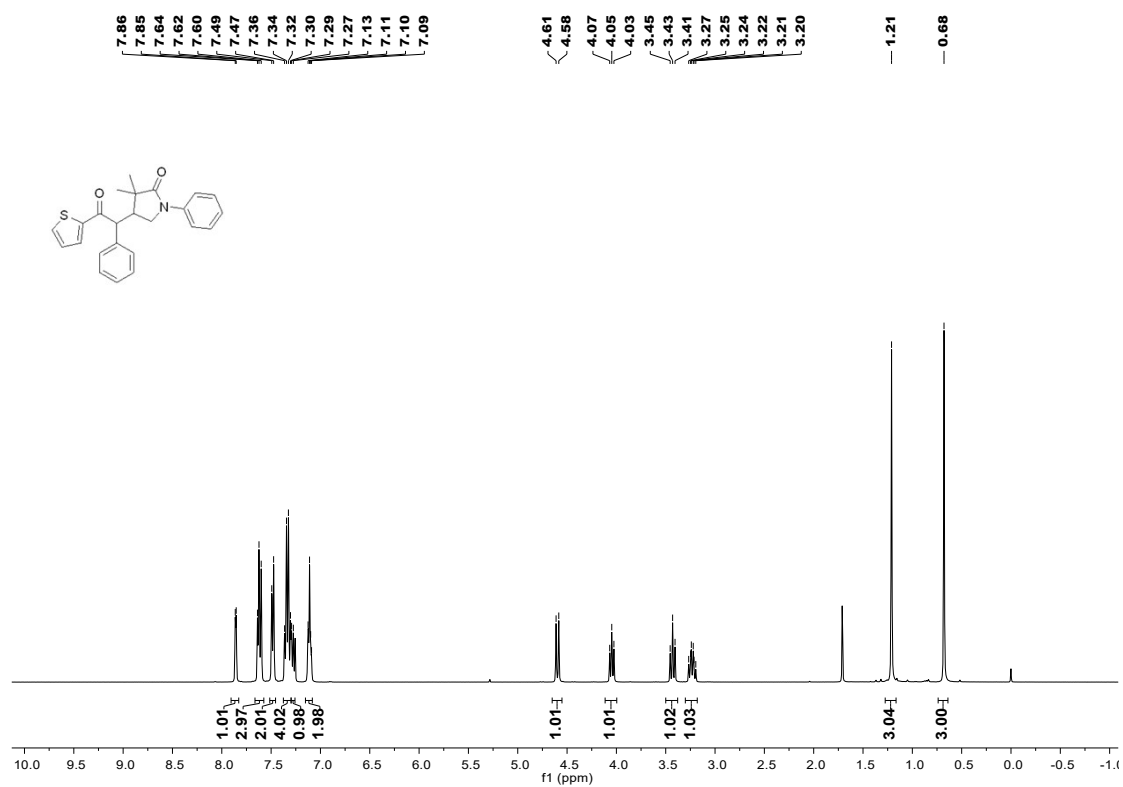
¹H NMR spectrum of compound (3ma)



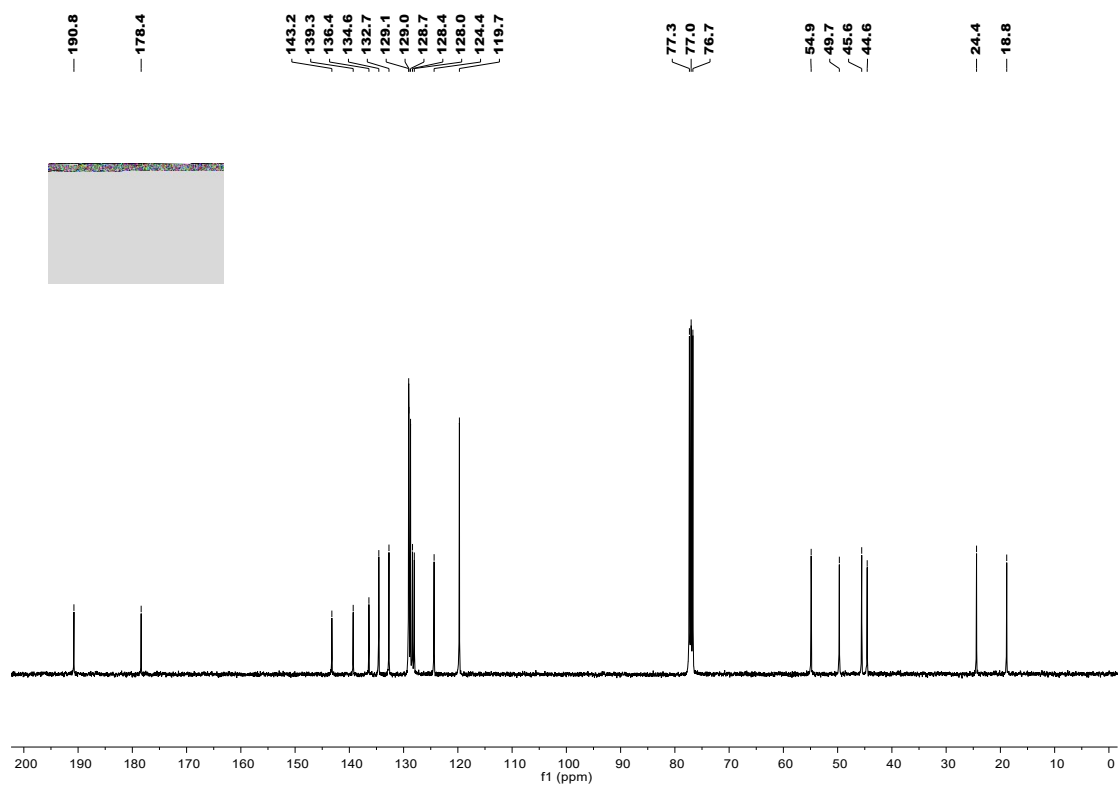
¹³C NMR spectrum of compound (3ma)



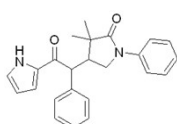
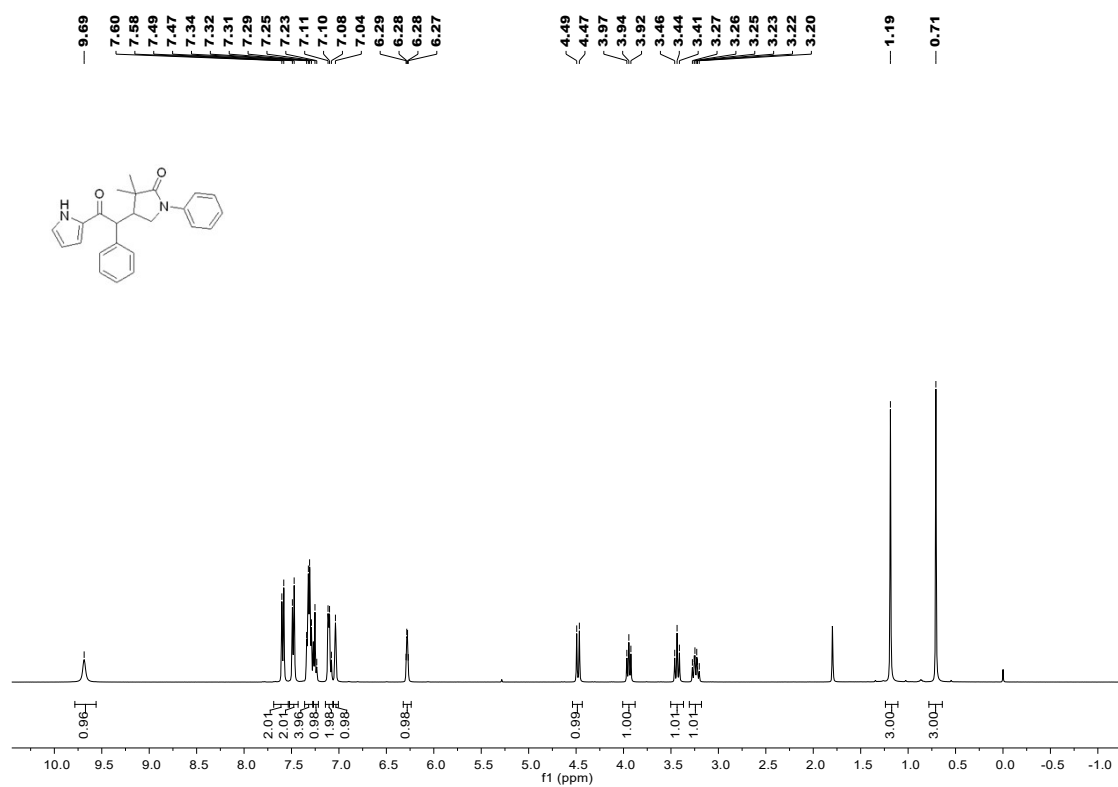
¹H NMR spectrum of compound (3na)



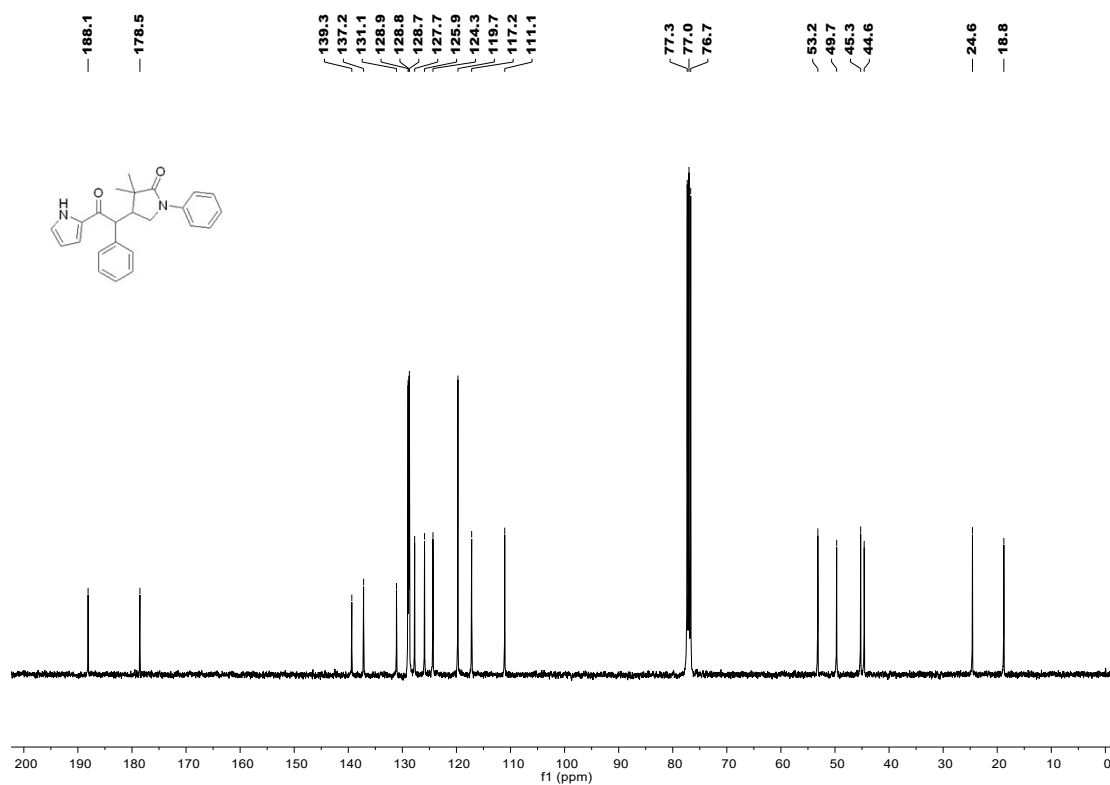
^{13}C NMR spectrum of compound (**3na**)



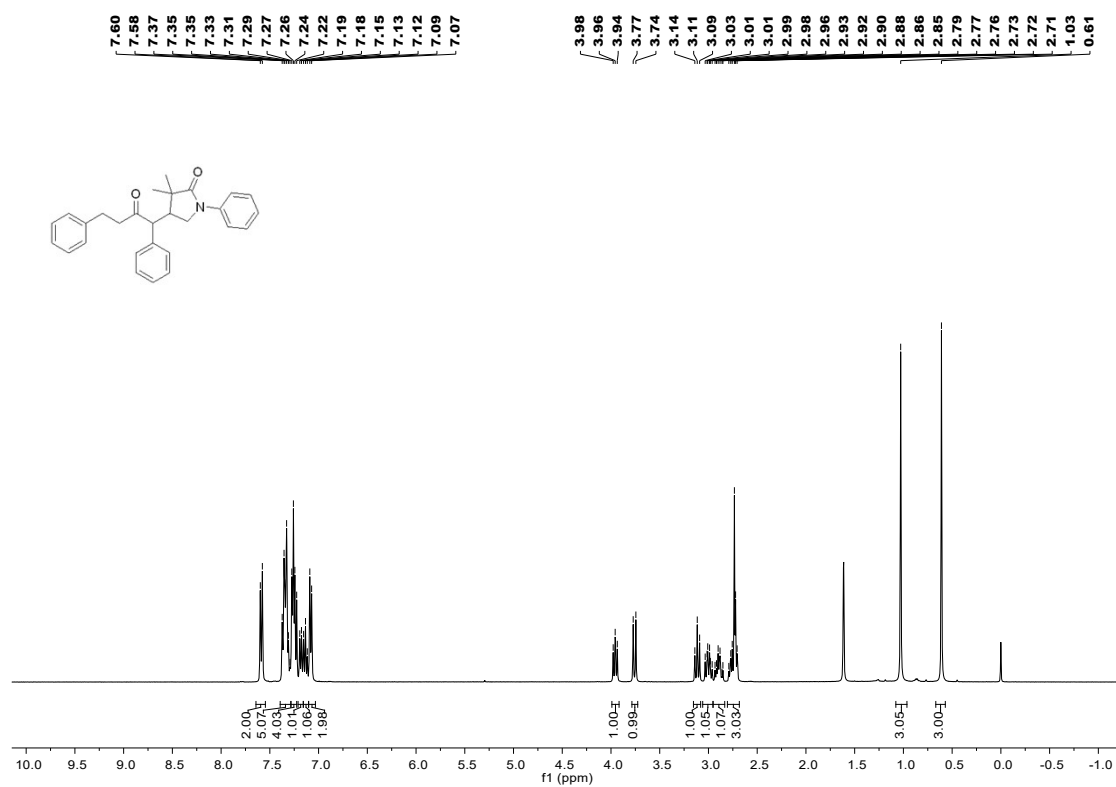
^1H NMR spectrum of compound (**3oa**)



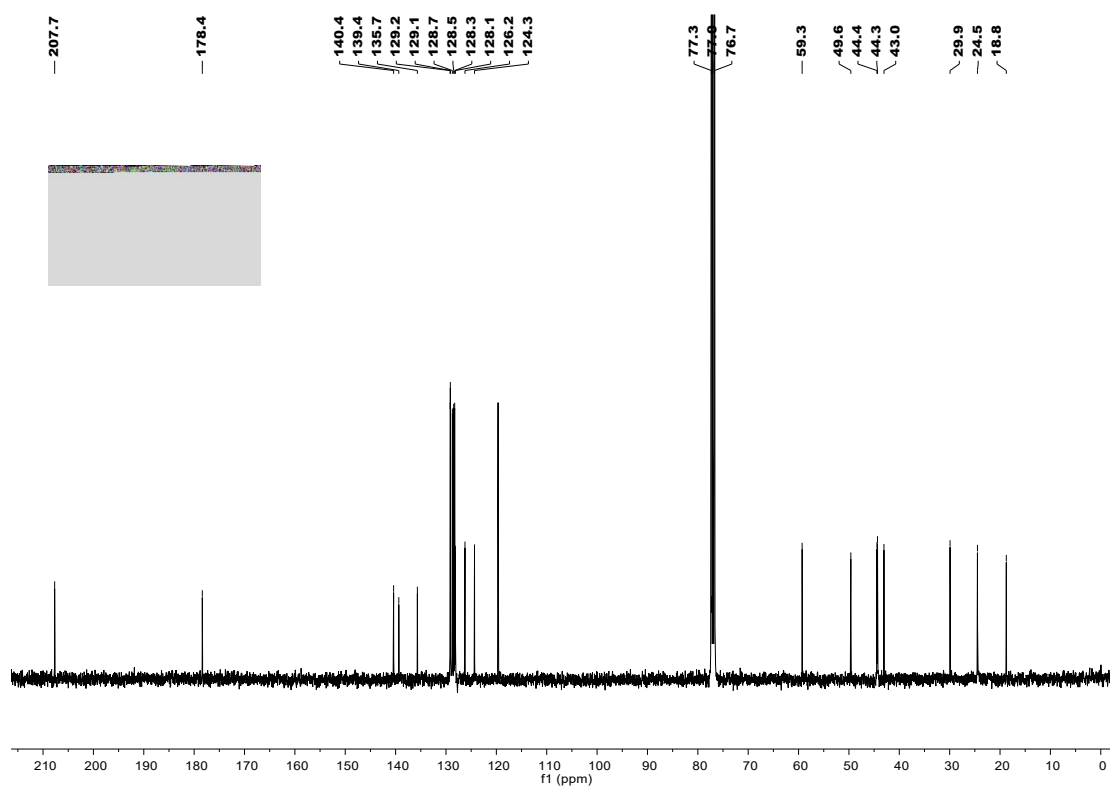
¹³C NMR spectrum of compound (30a)



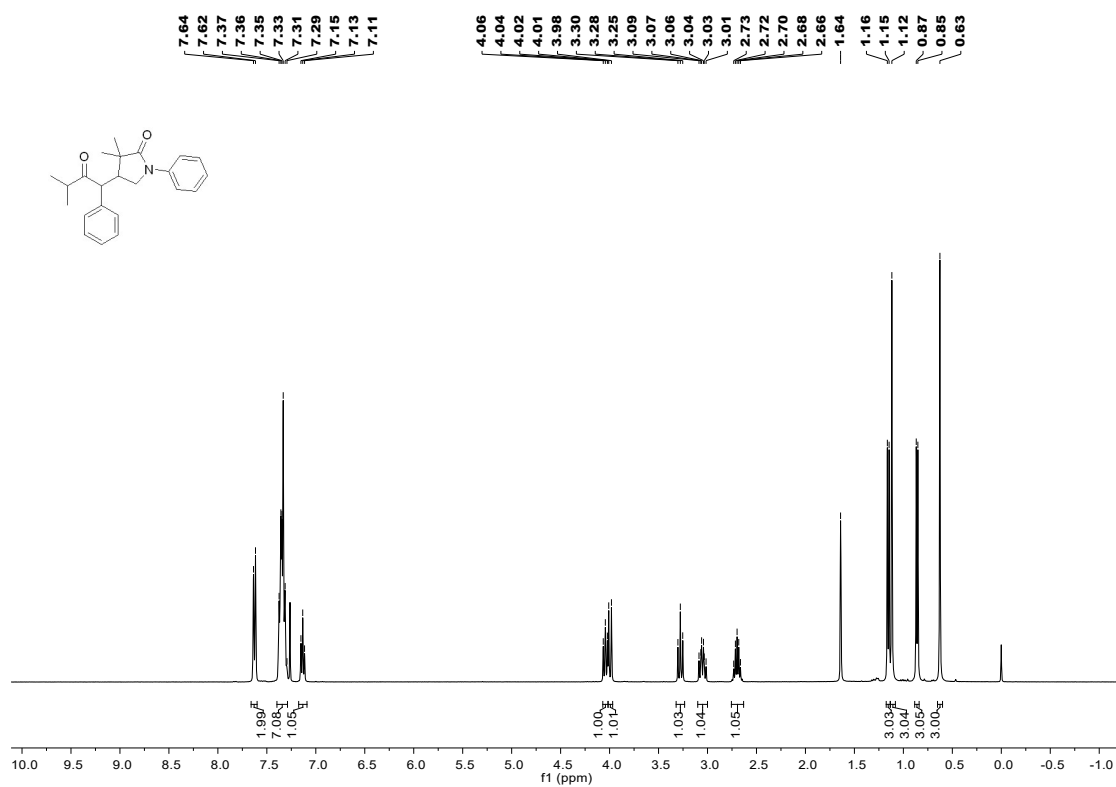
¹H NMR spectrum of compound (3pa)



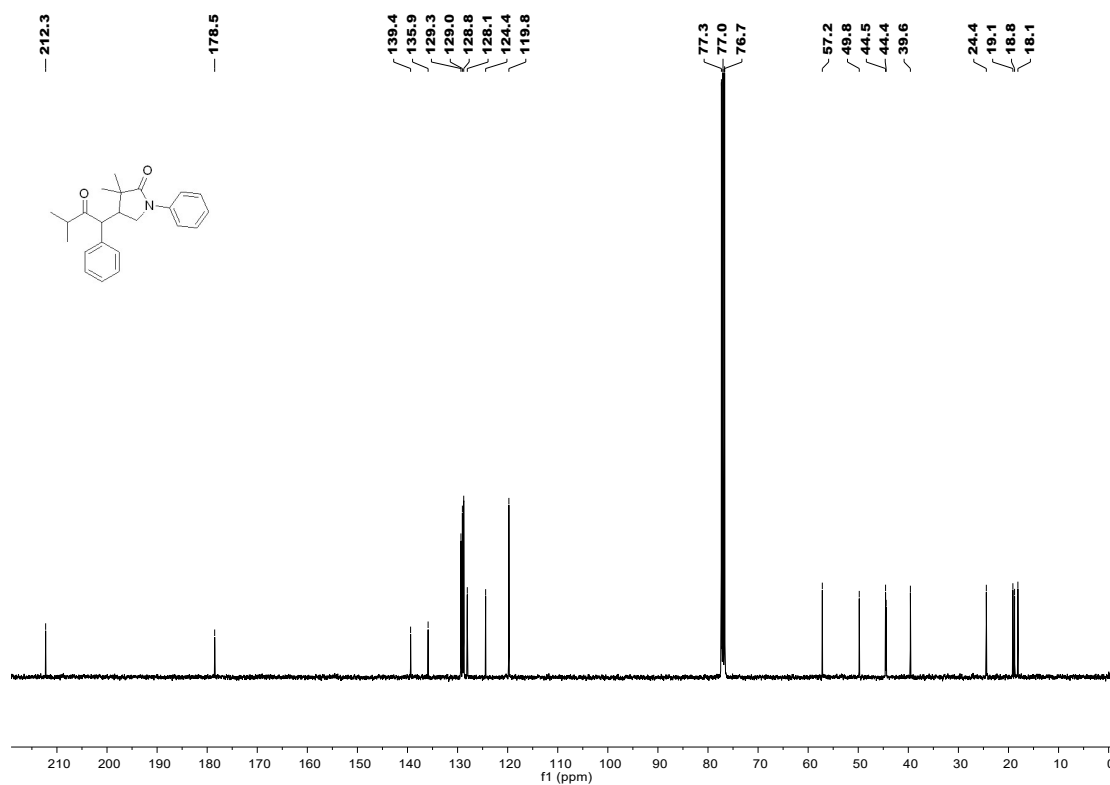
¹³C NMR spectrum of compound (3pa)



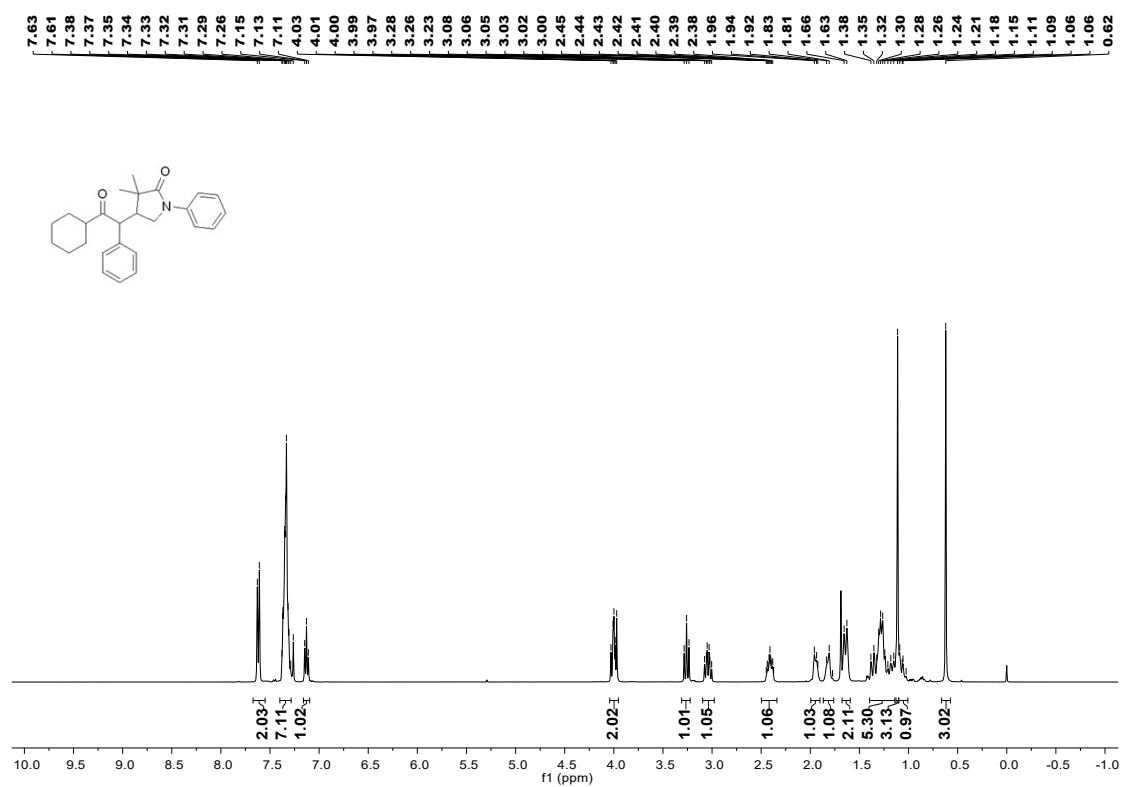
¹H NMR spectrum of compound (3qa)



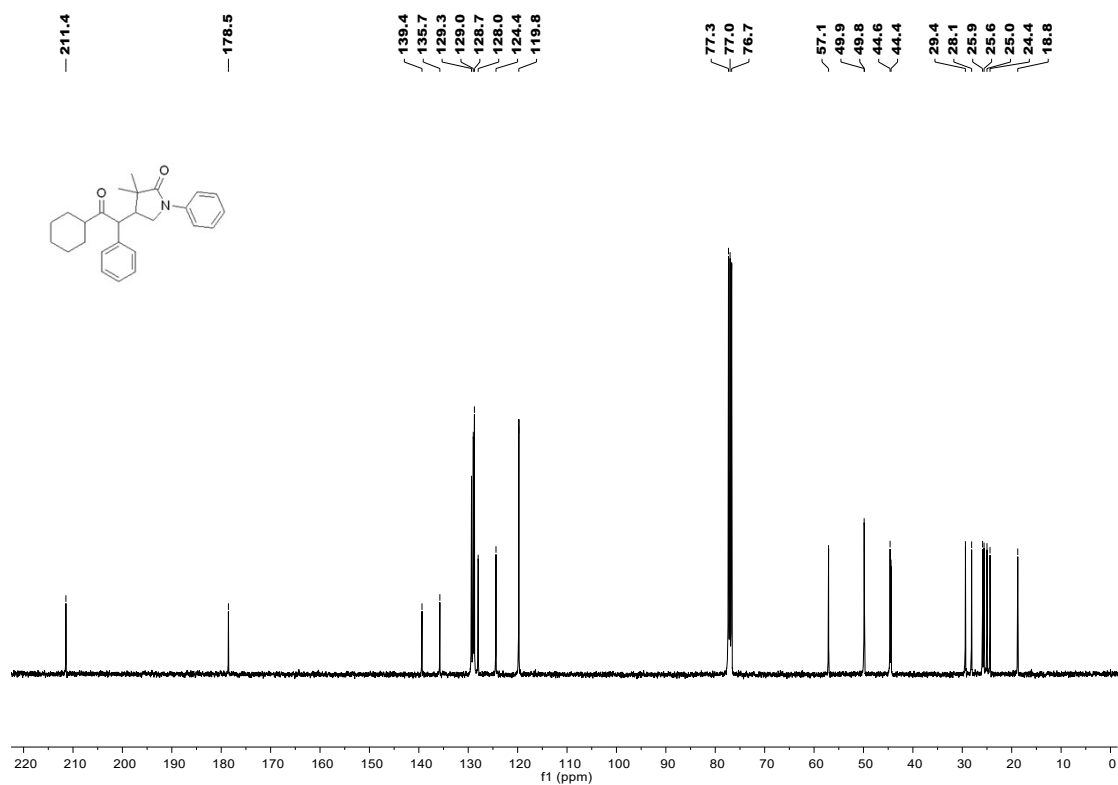
¹³C NMR spectrum of compound (3qa)



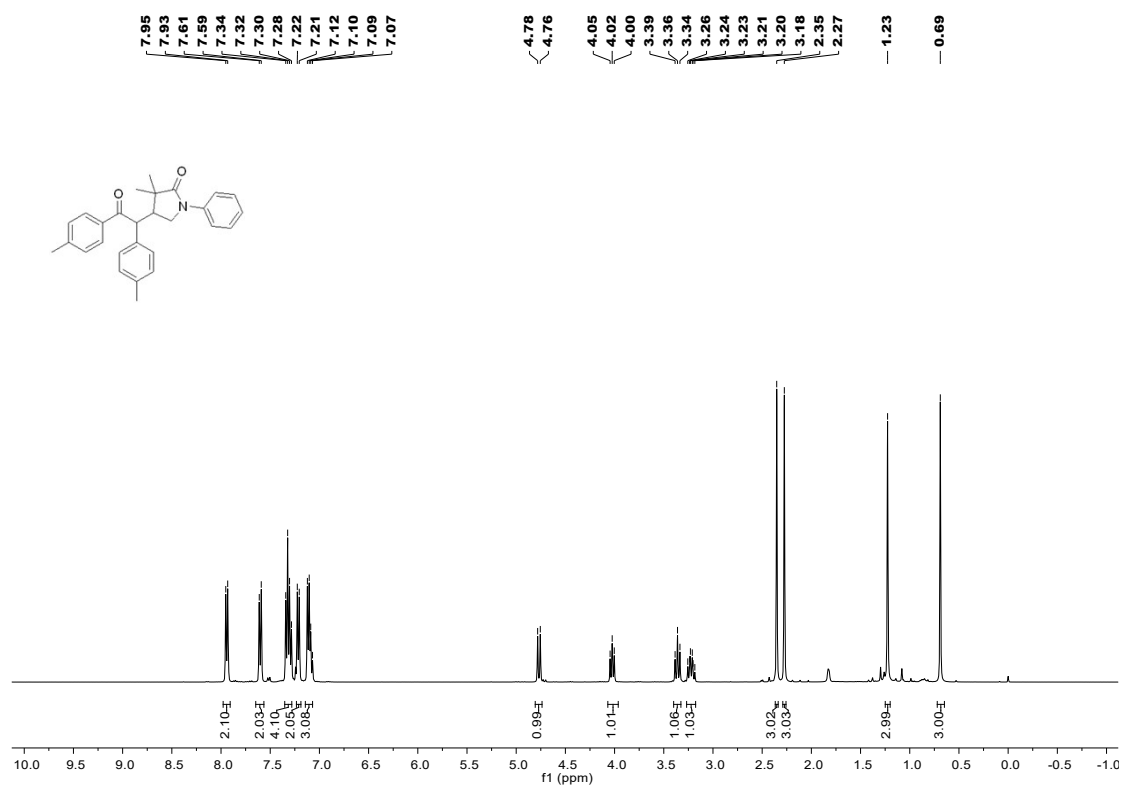
¹H NMR spectrum of compound (3ra)



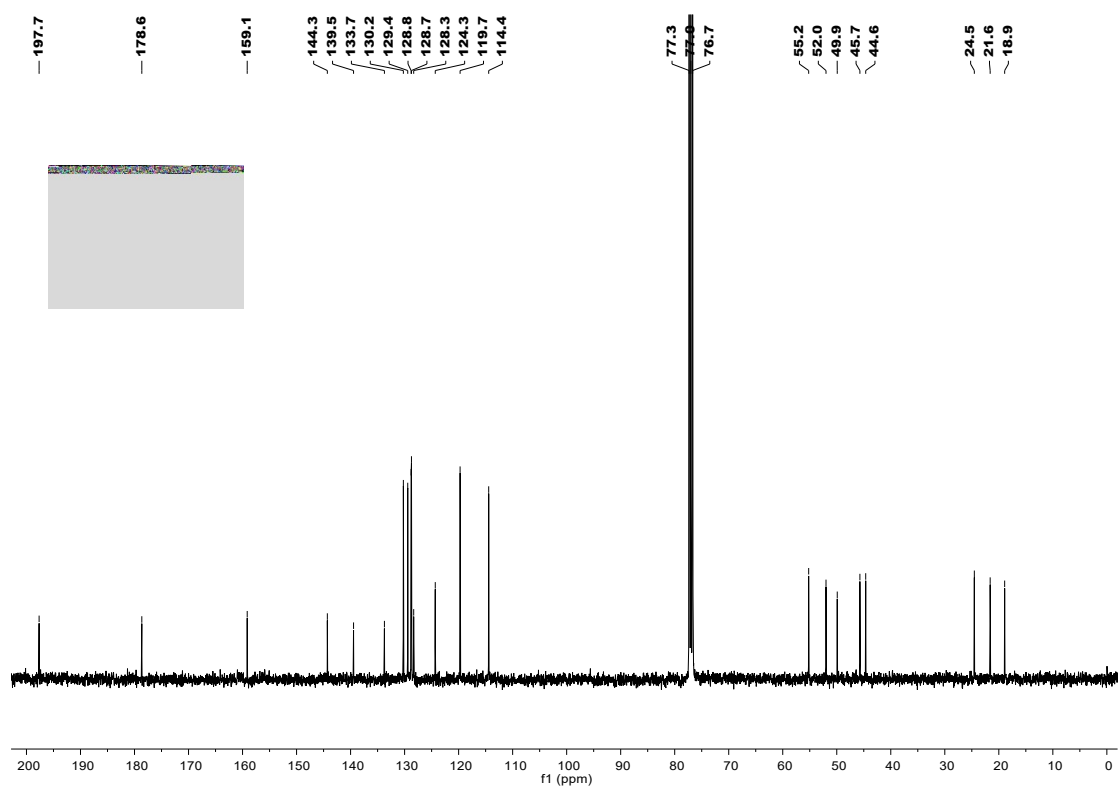
¹³C NMR spectrum of compound (3ra)



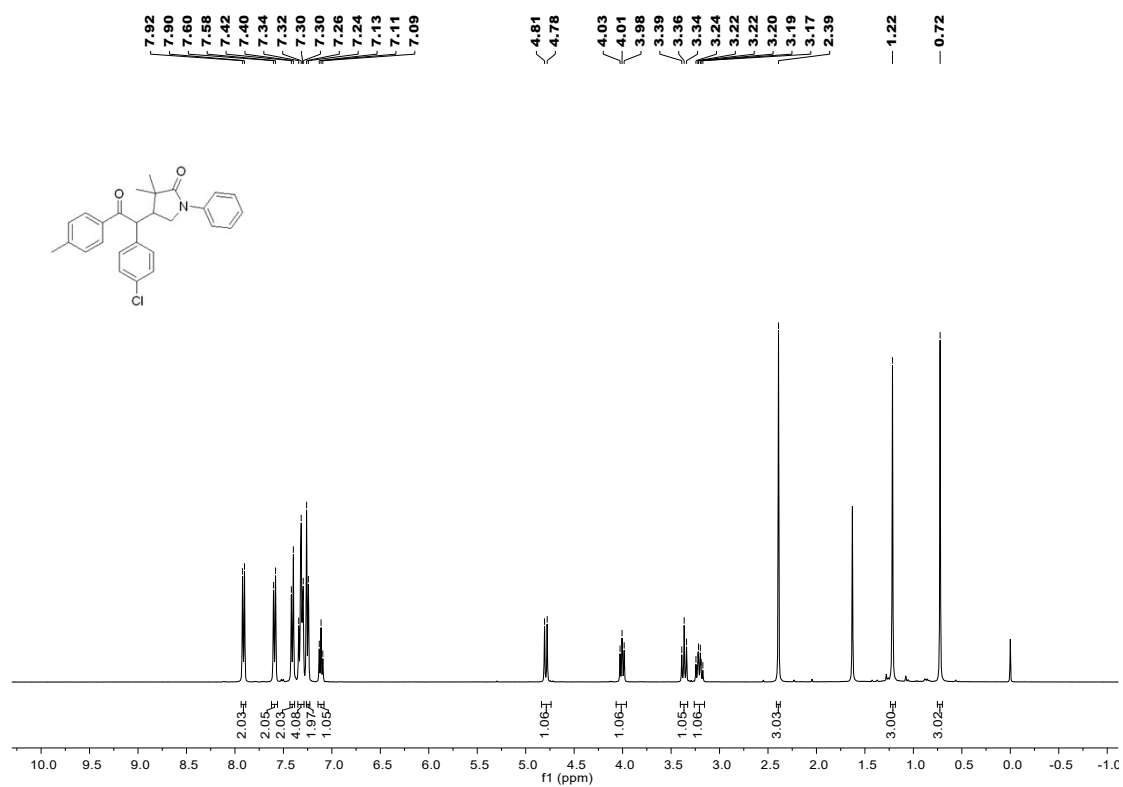
¹H NMR spectrum of compound (3fb)



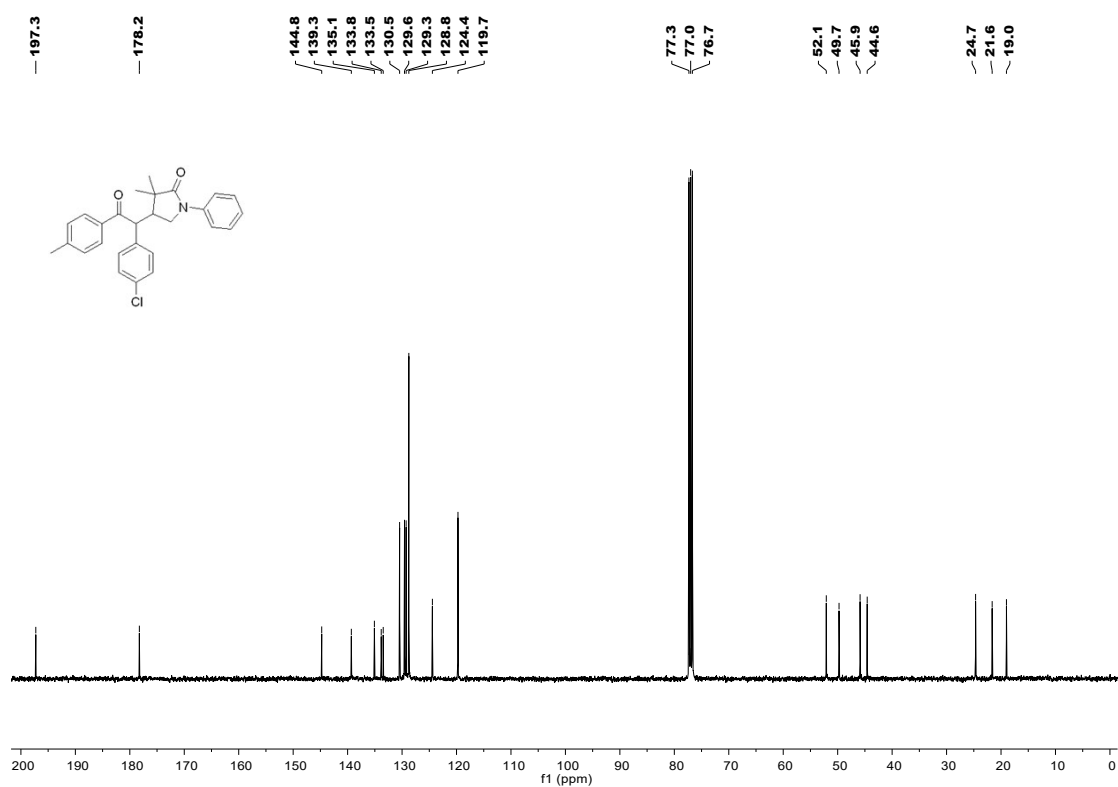
¹³C NMR spectrum of compound (3fc)



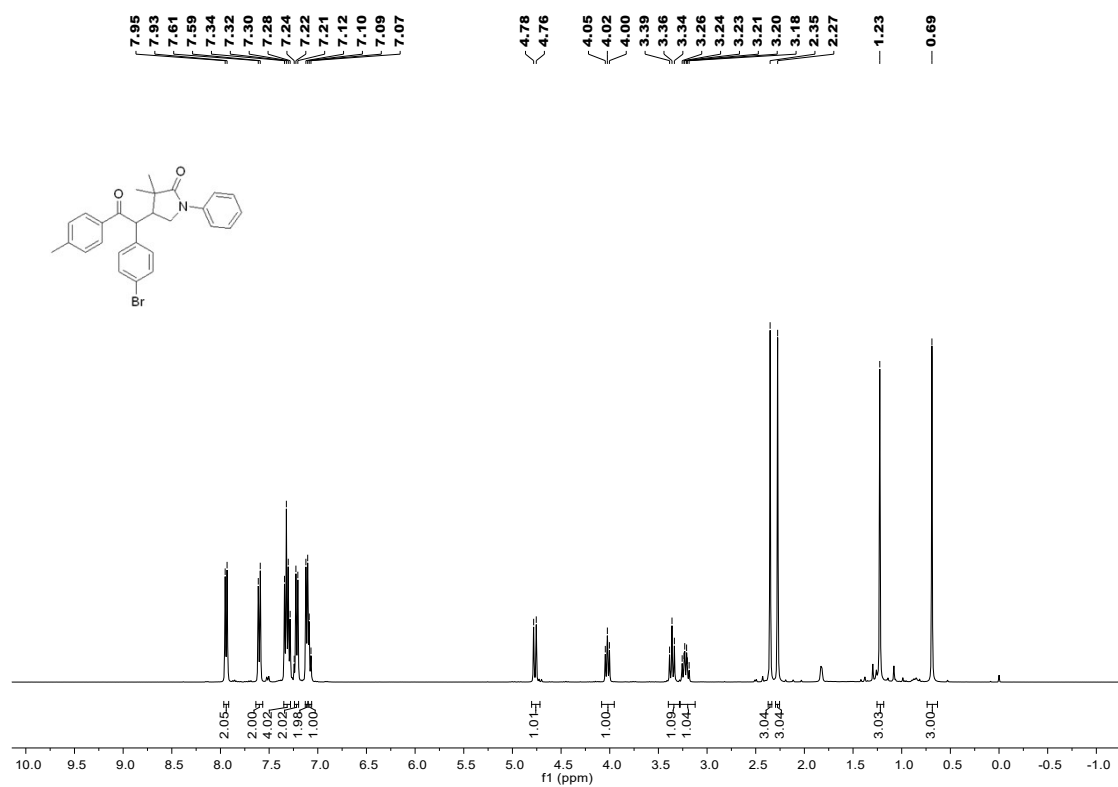
¹H NMR spectrum of compound (3fd)



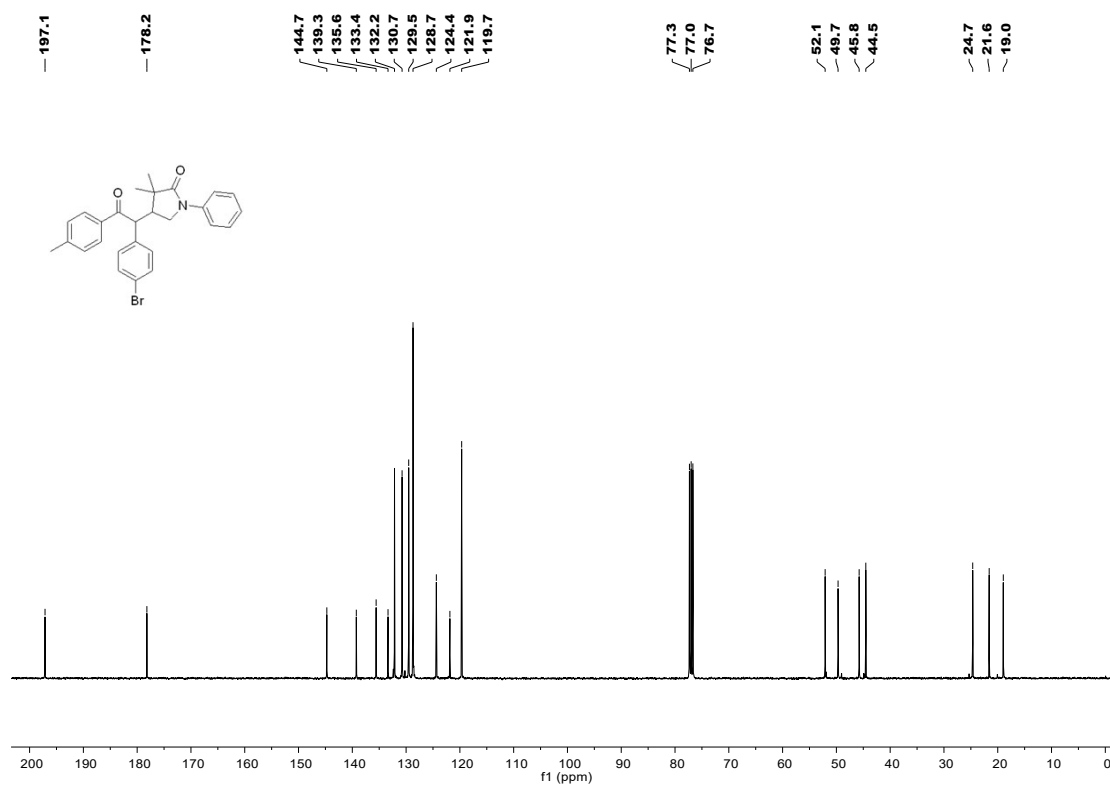
¹³C NMR spectrum of compound (3fd)



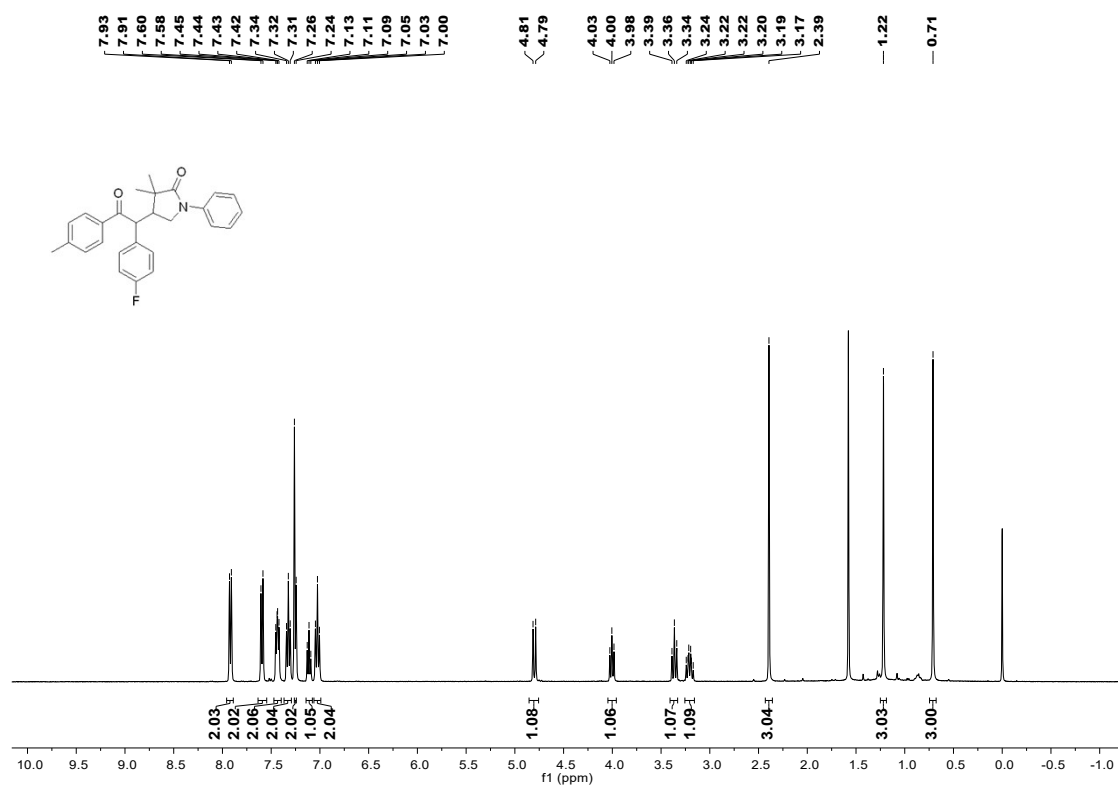
¹H NMR spectrum of compound (3fe)



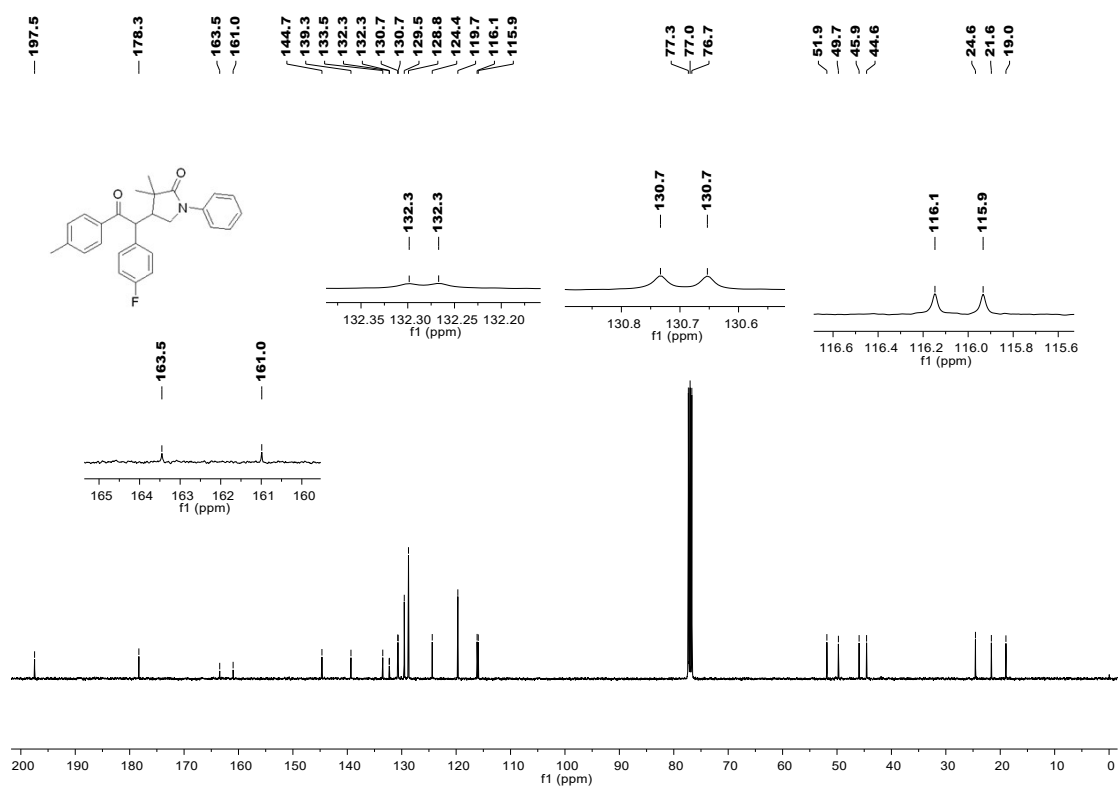
¹³C NMR spectrum of compound (3fe)



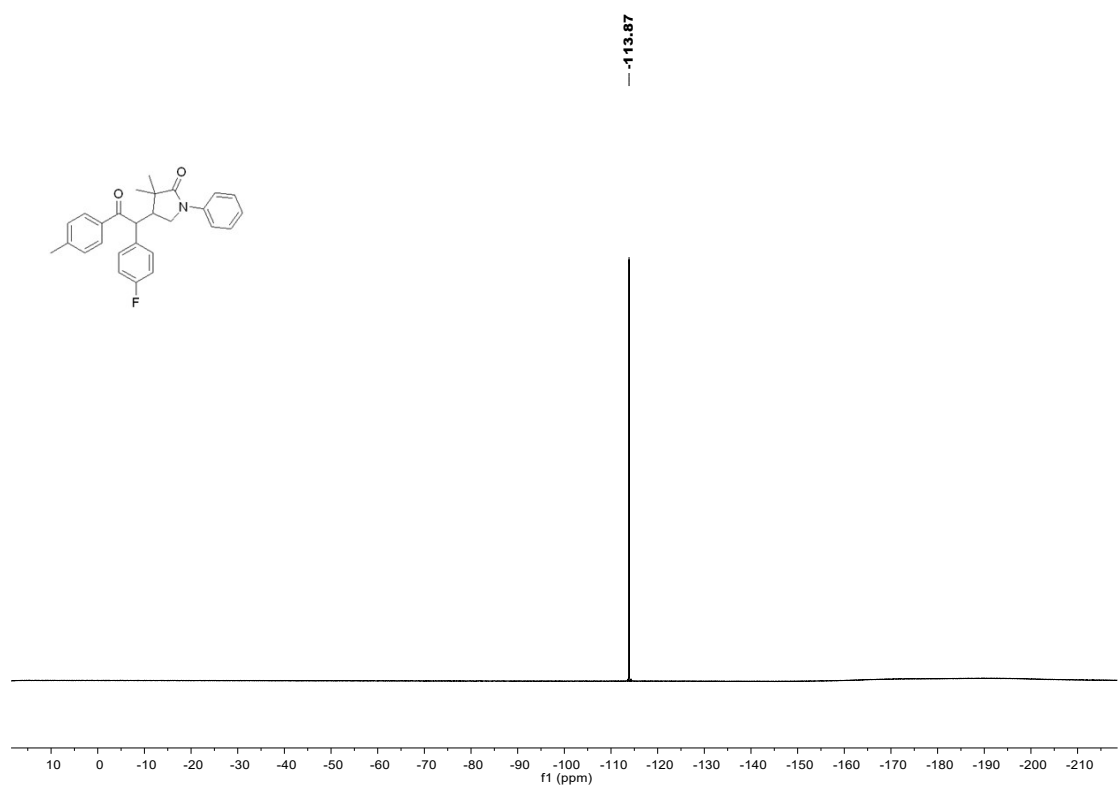
¹H NMR spectrum of compound (3ff)



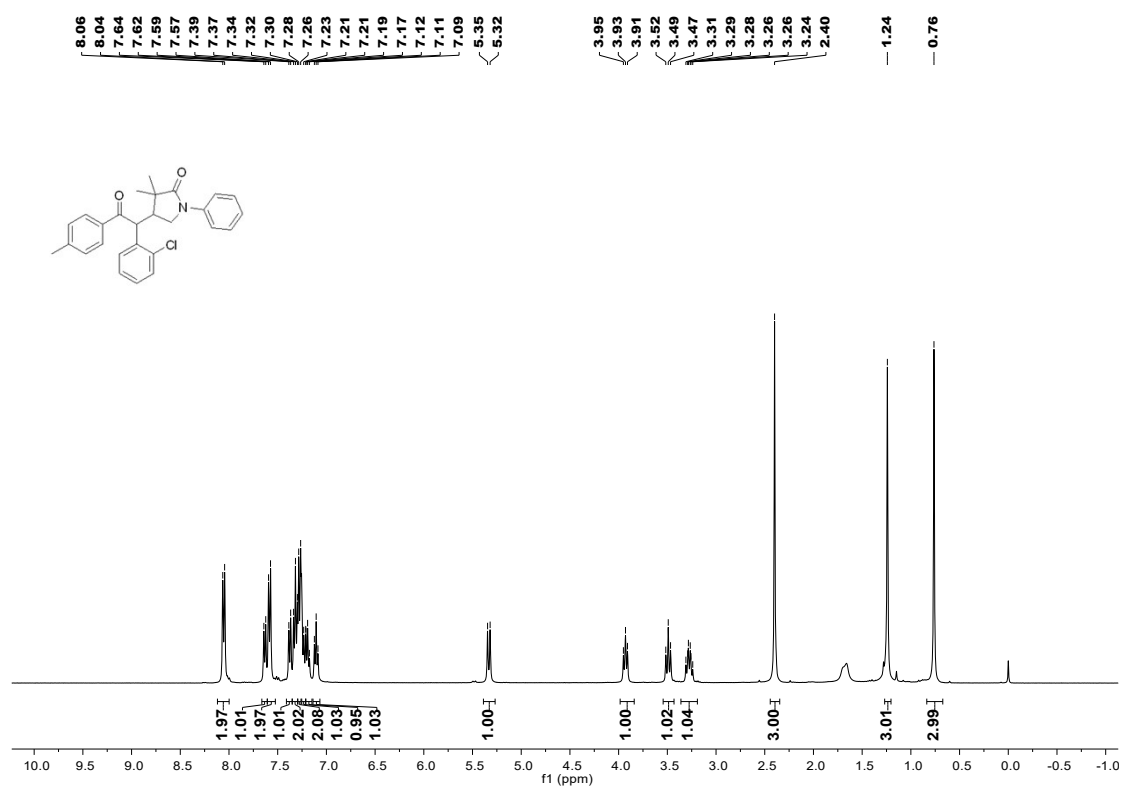
¹³C NMR spectrum of compound (3ff)



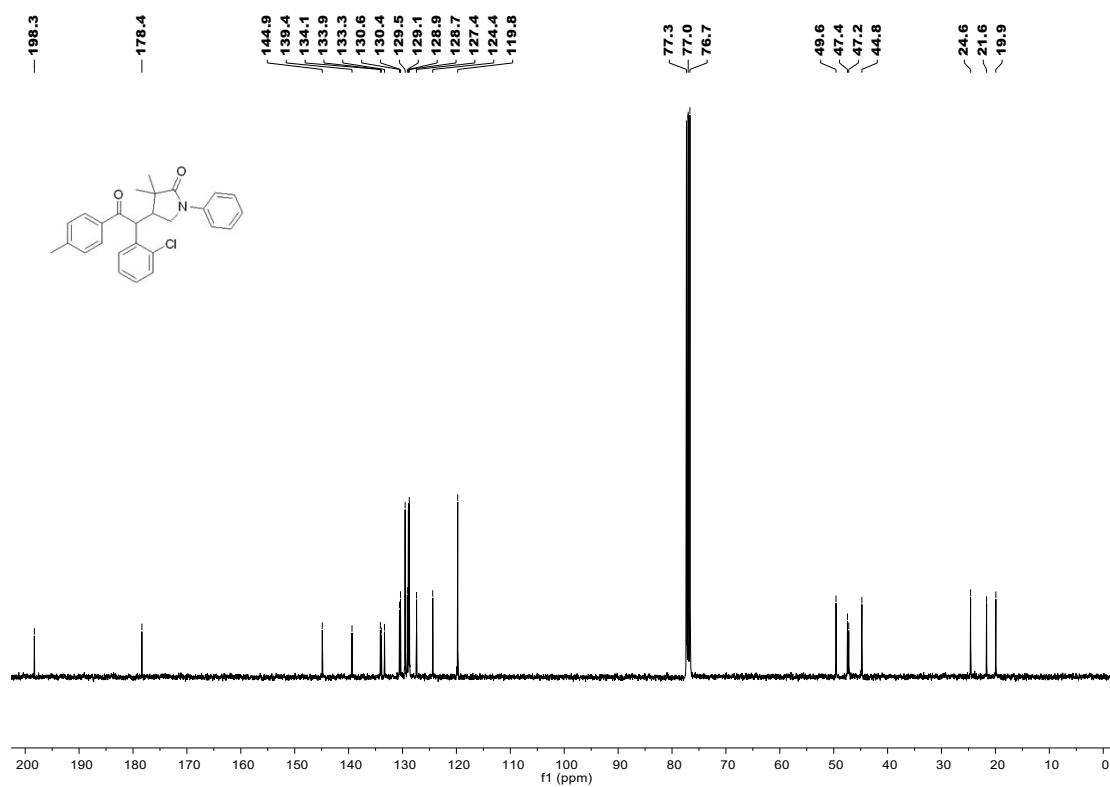
¹⁹F NMR spectrum of compound (3ff)



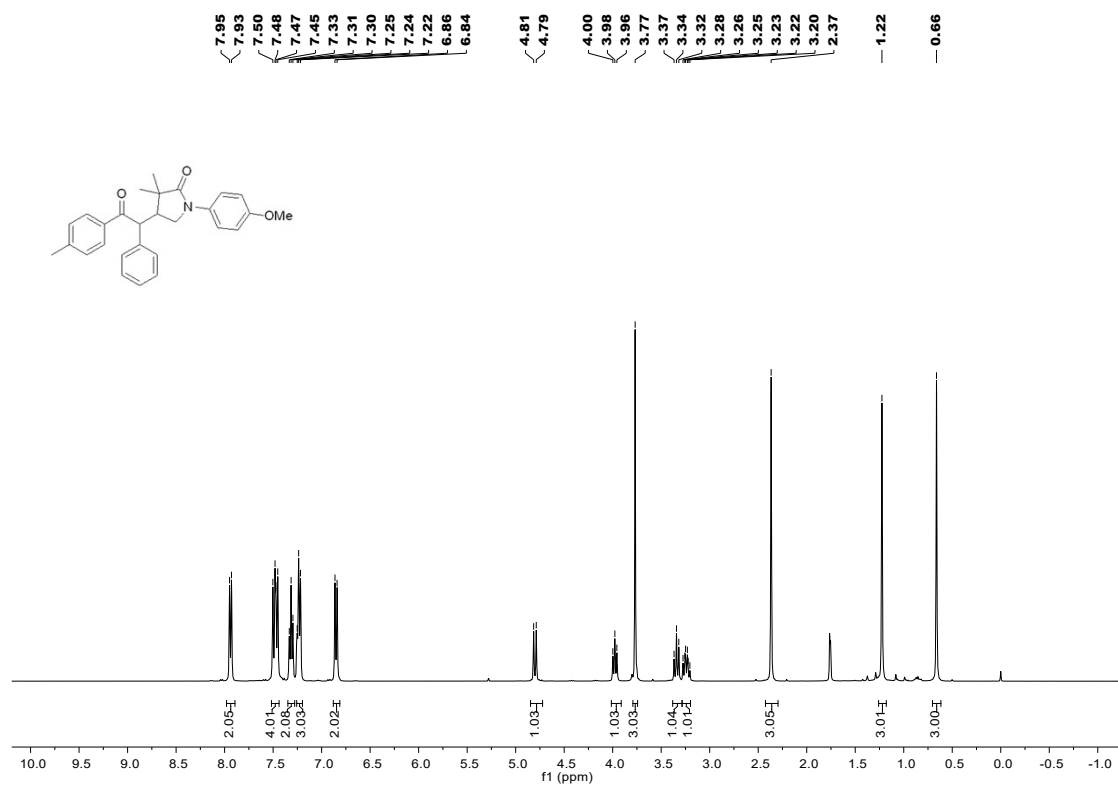
¹H NMR spectrum of compound (3fh)



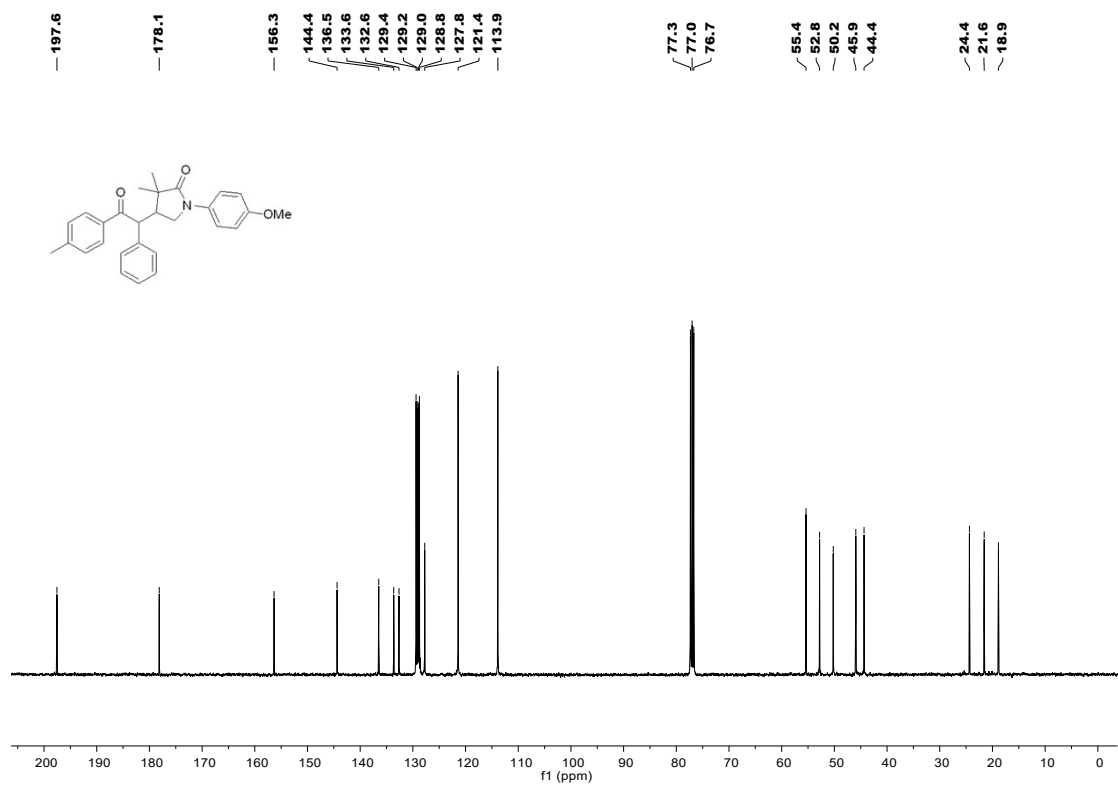
¹³C NMR spectrum of compound (3fh)



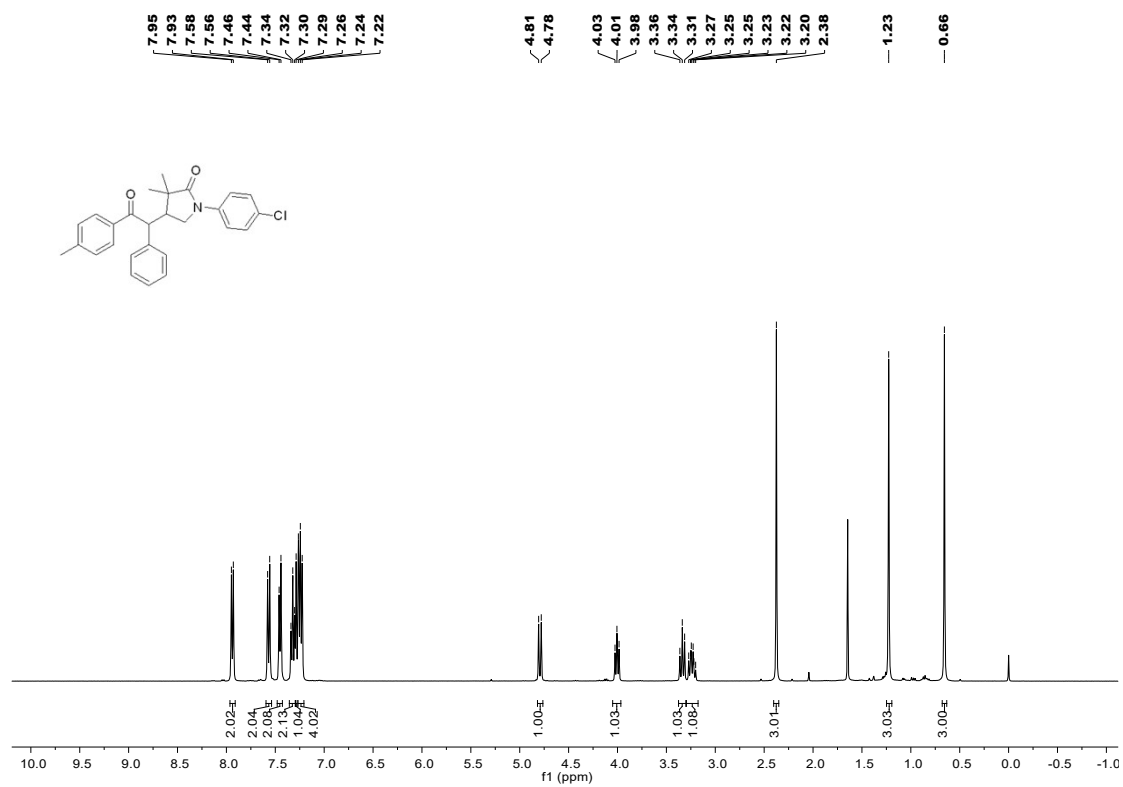
¹H NMR spectrum of compound (3fi)



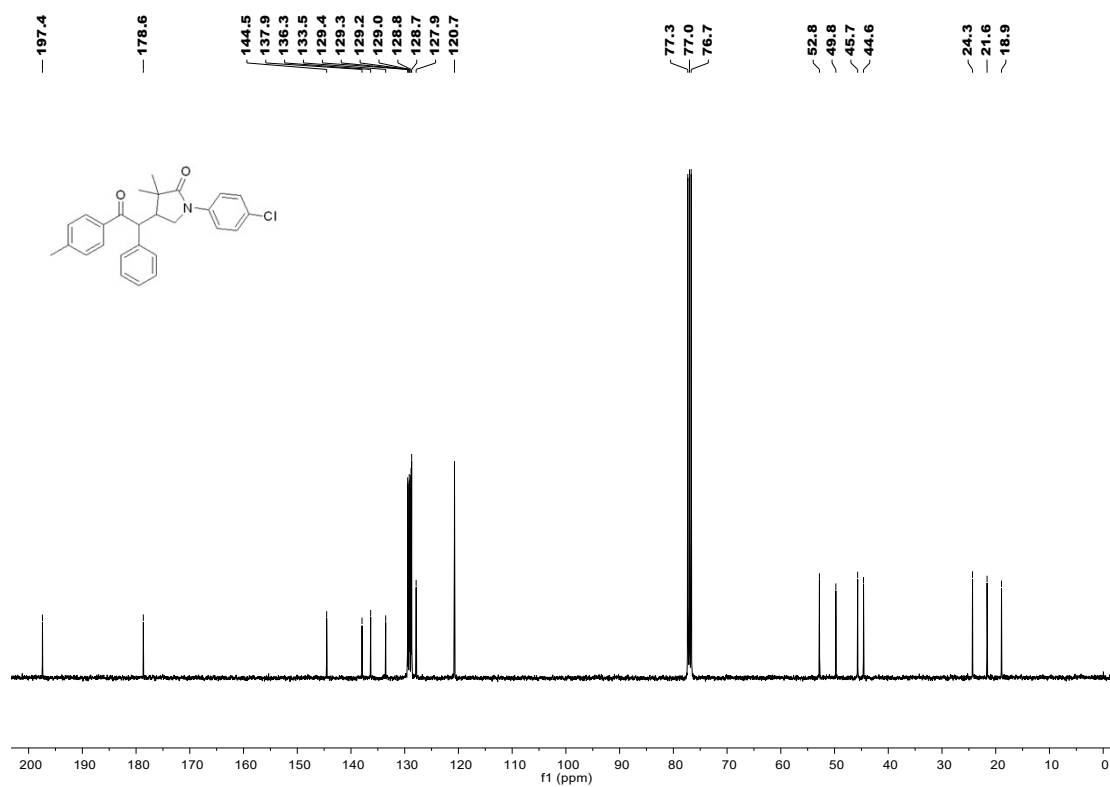
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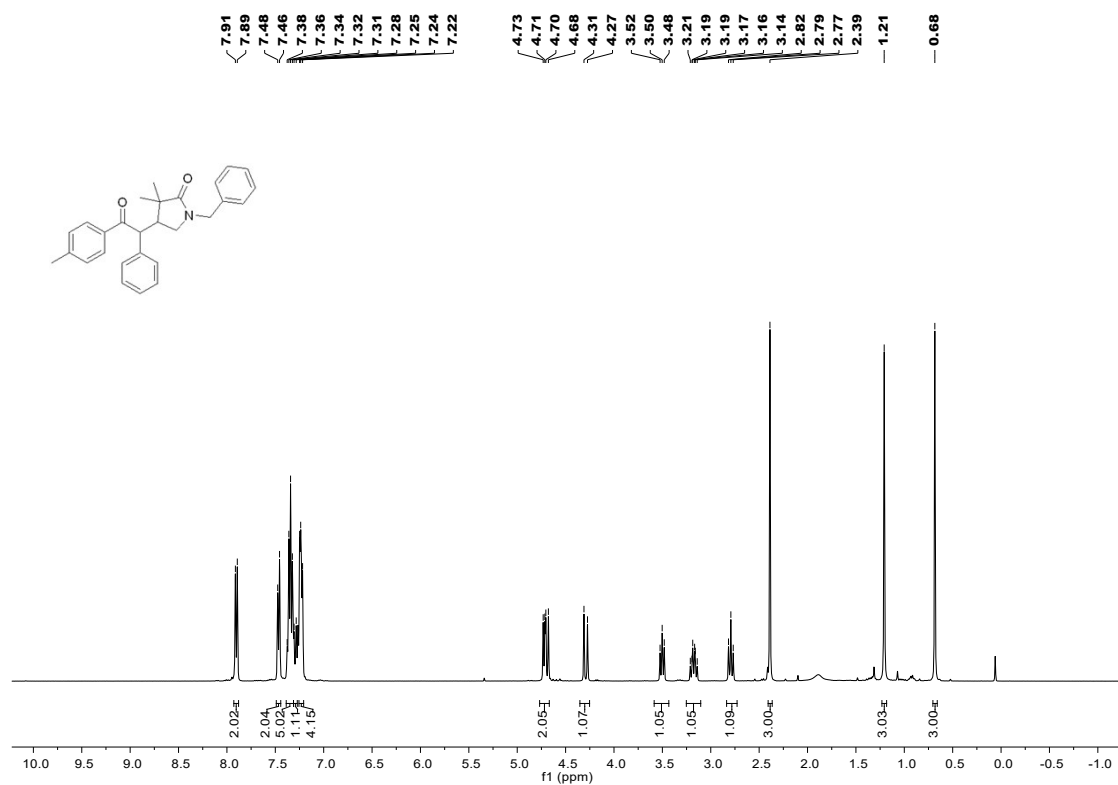
¹H NMR spectrum of compound (3fj)



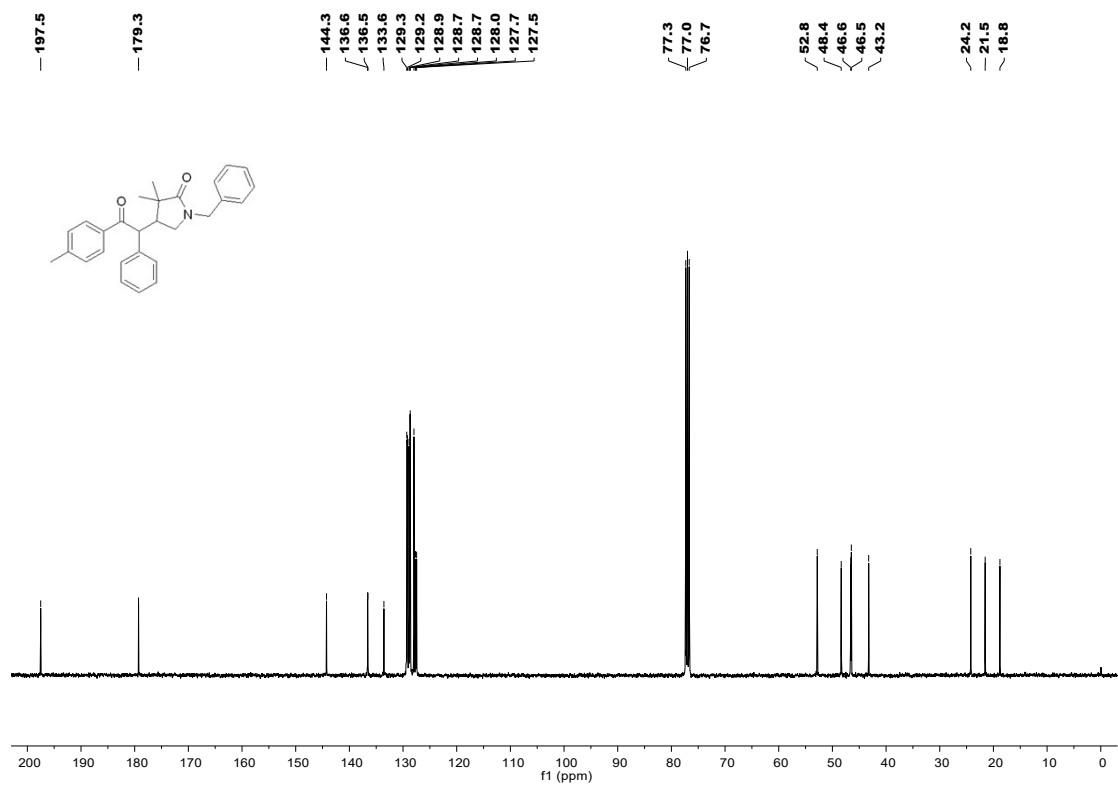
¹³C NMR spectrum of compound (3fj)



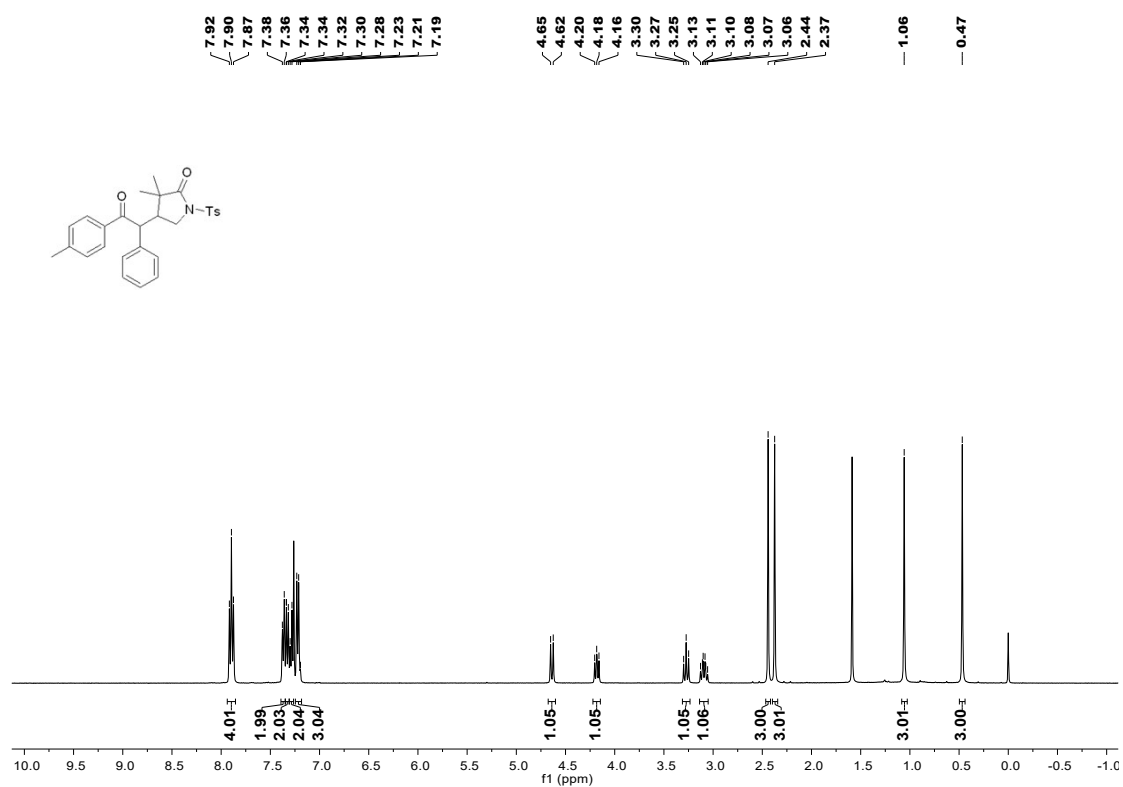
¹H NMR spectrum of compound (3fk)



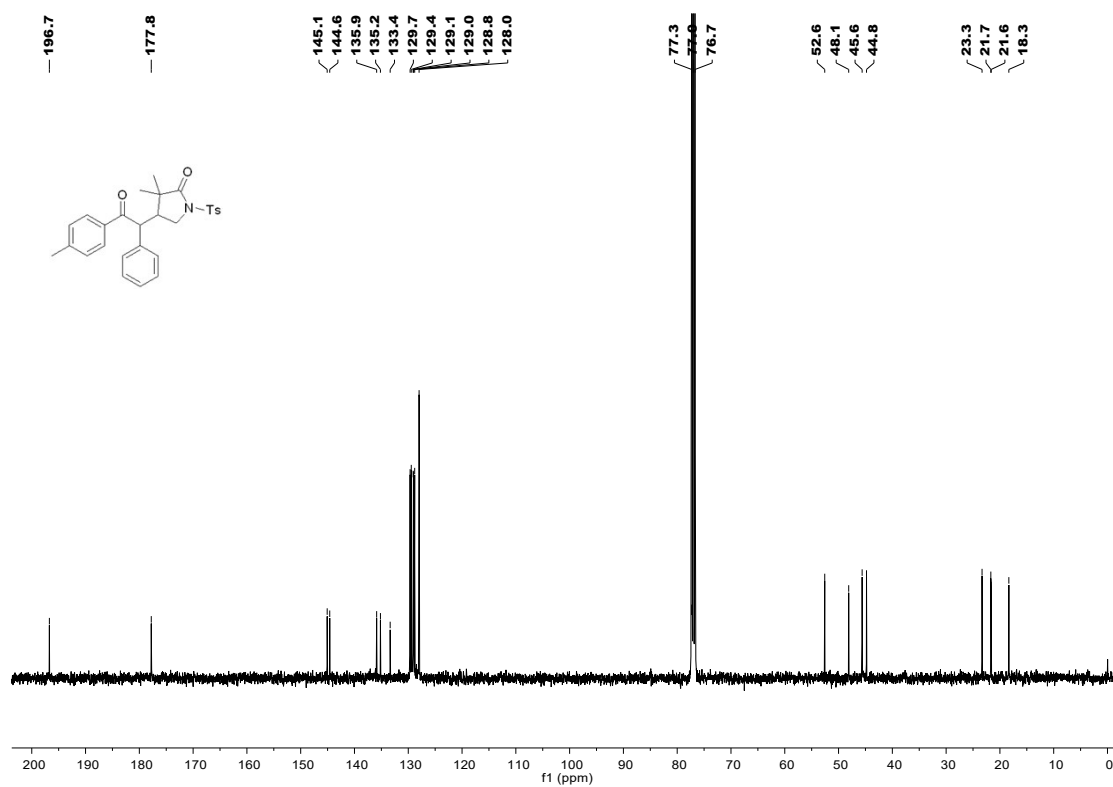
¹³C NMR spectrum of compound (3fk)



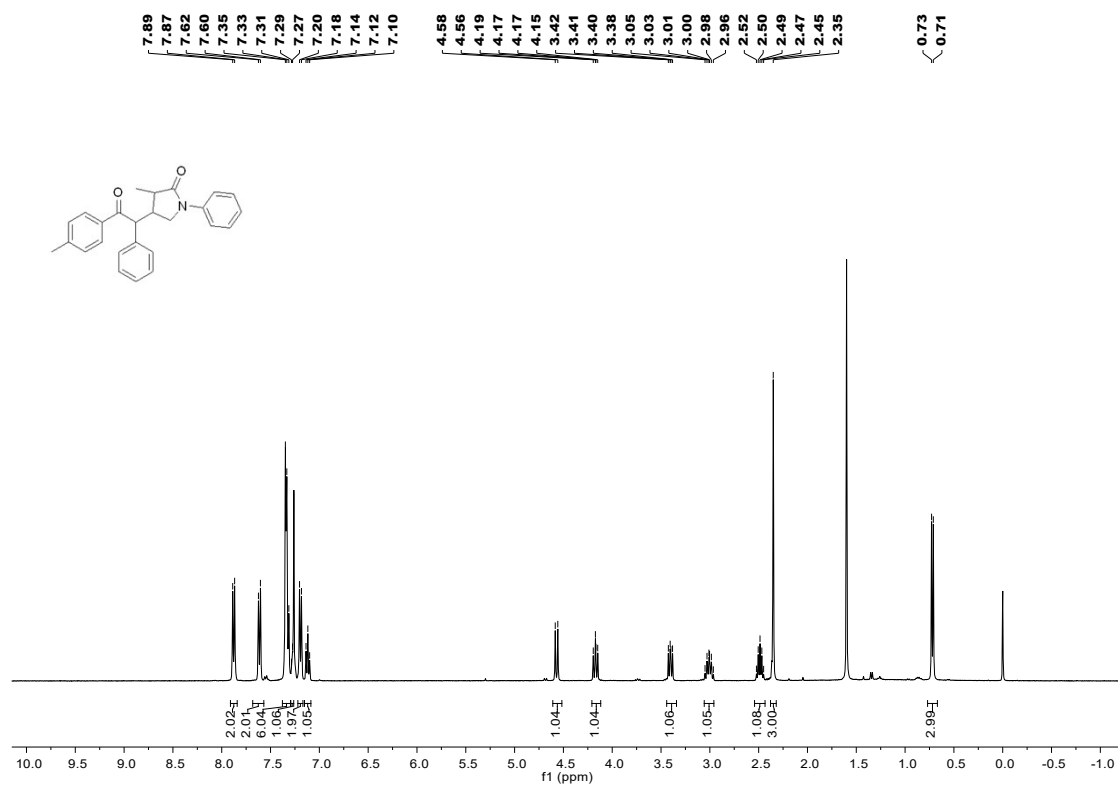
¹H NMR spectrum of compound (3fl)



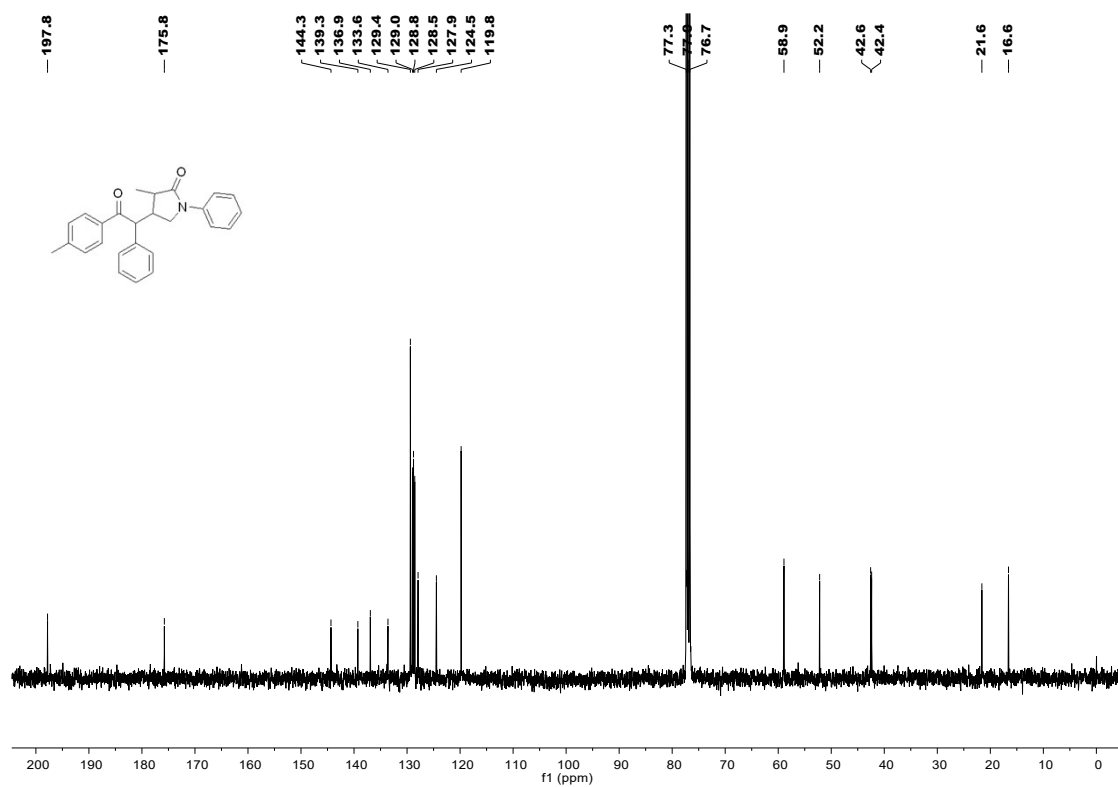
¹³C NMR spectrum of compound (3fl)



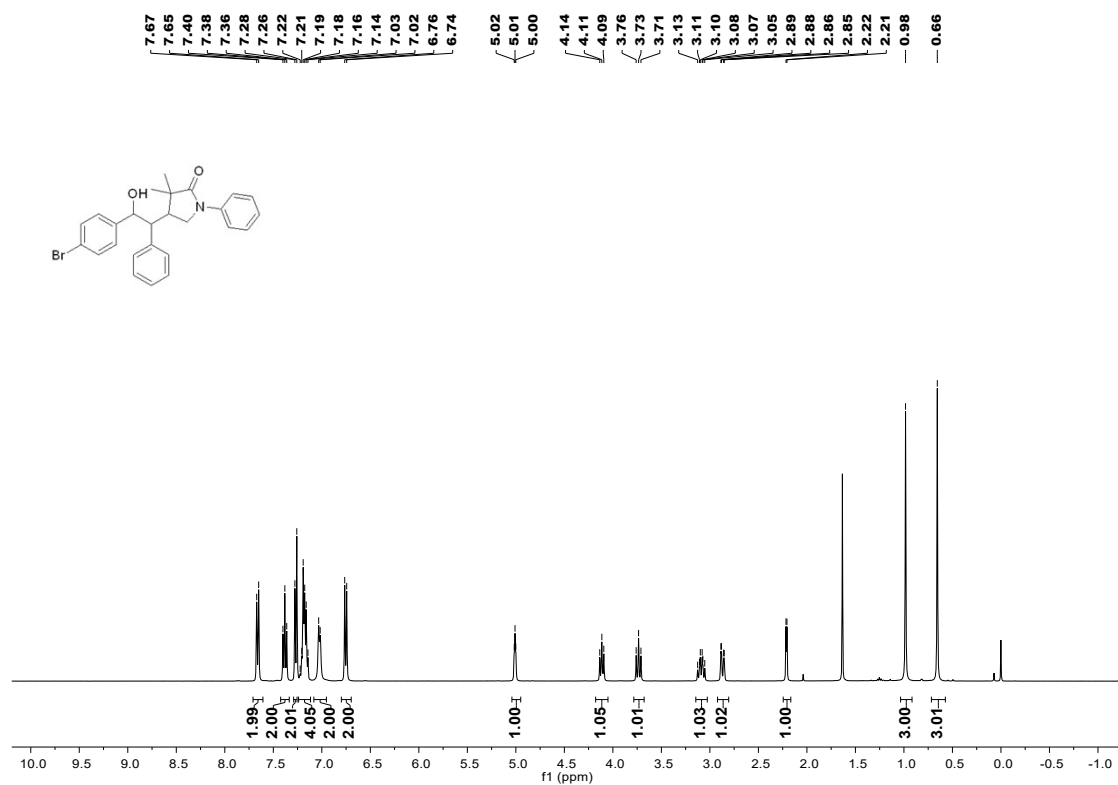
¹H NMR spectrum of compound (3fm)



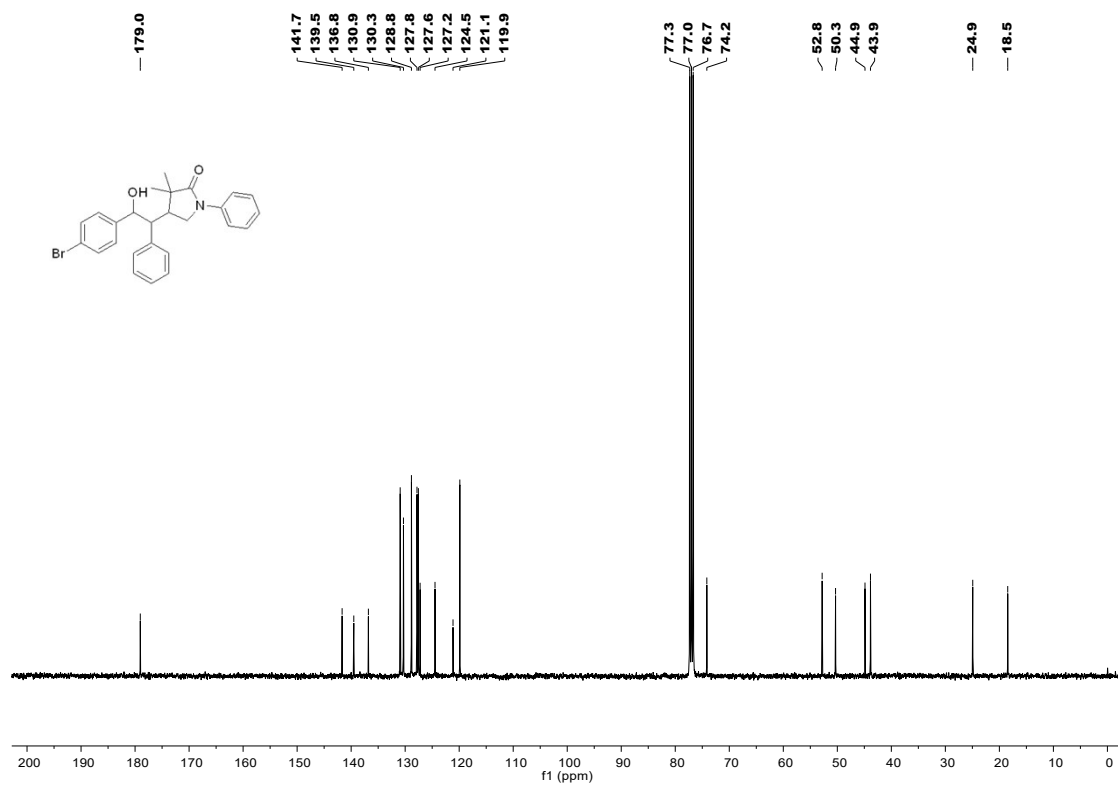
¹³C NMR spectrum of compound (3fm)



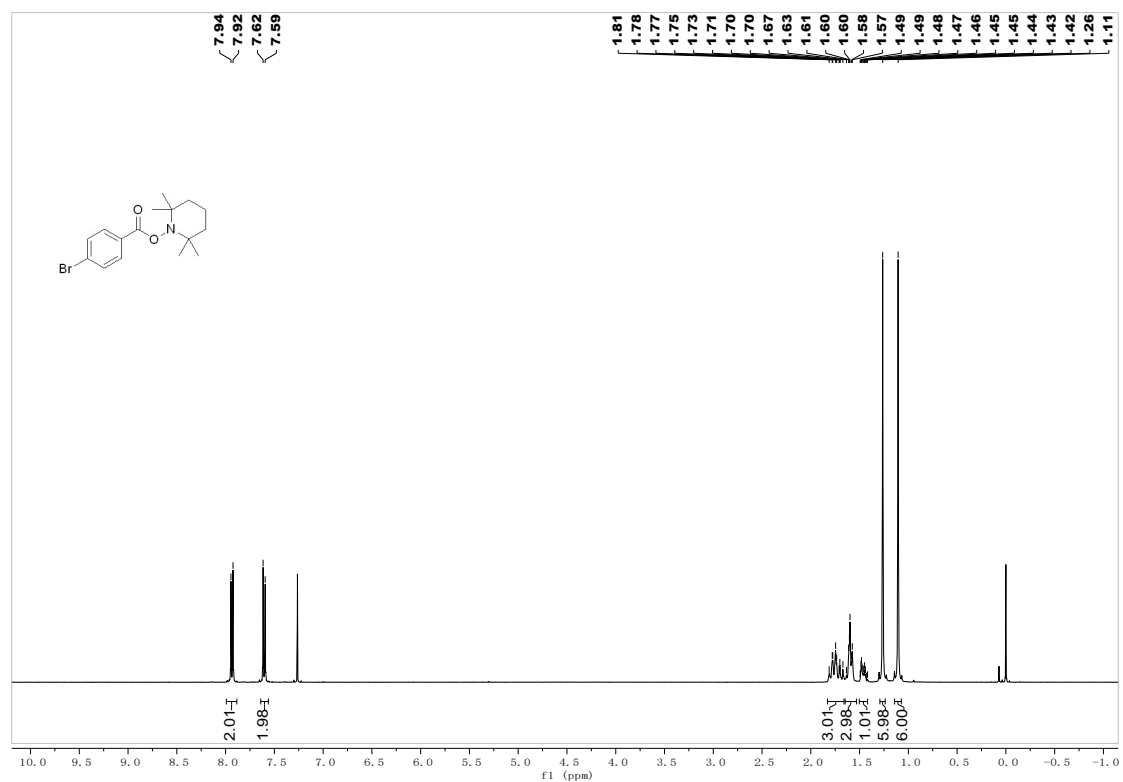
¹H NMR spectrum of compound (4)



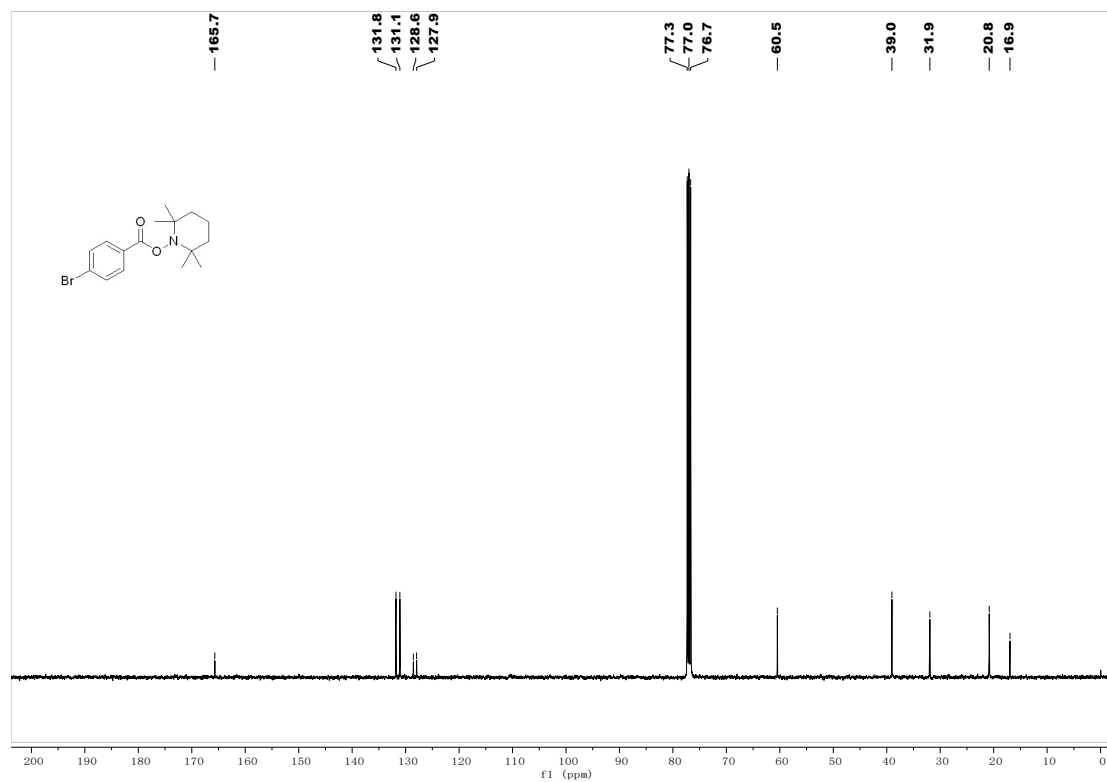
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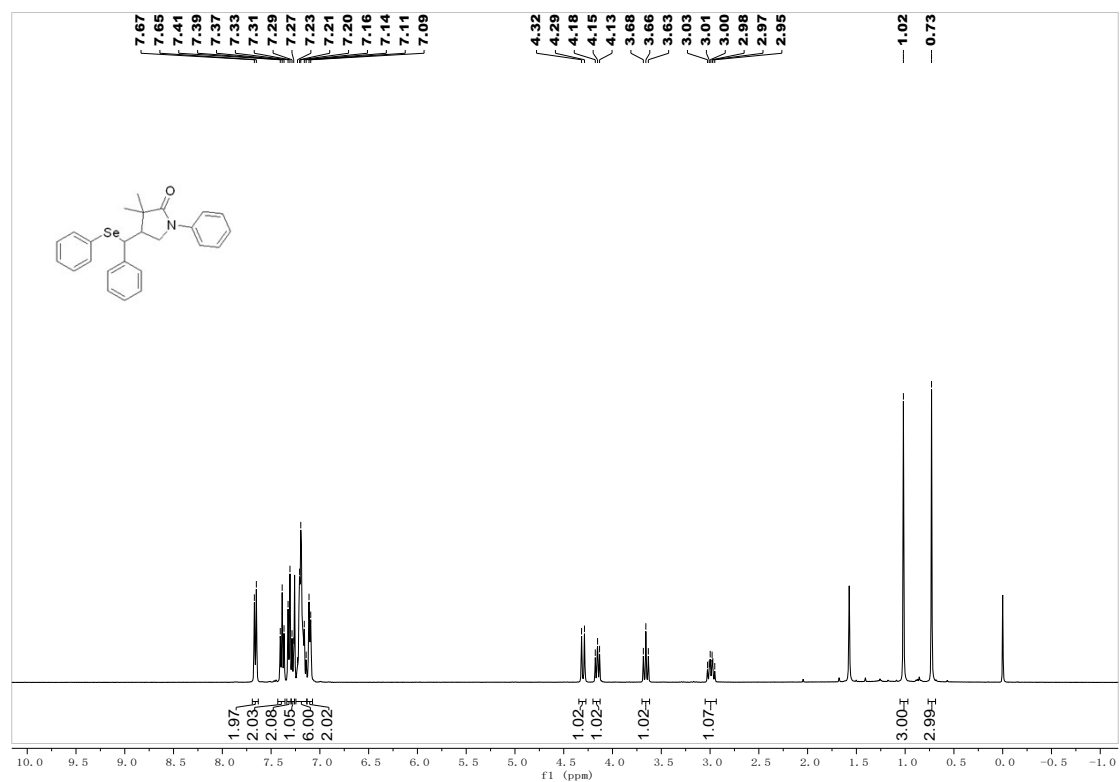
¹H NMR spectrum of compound (5)



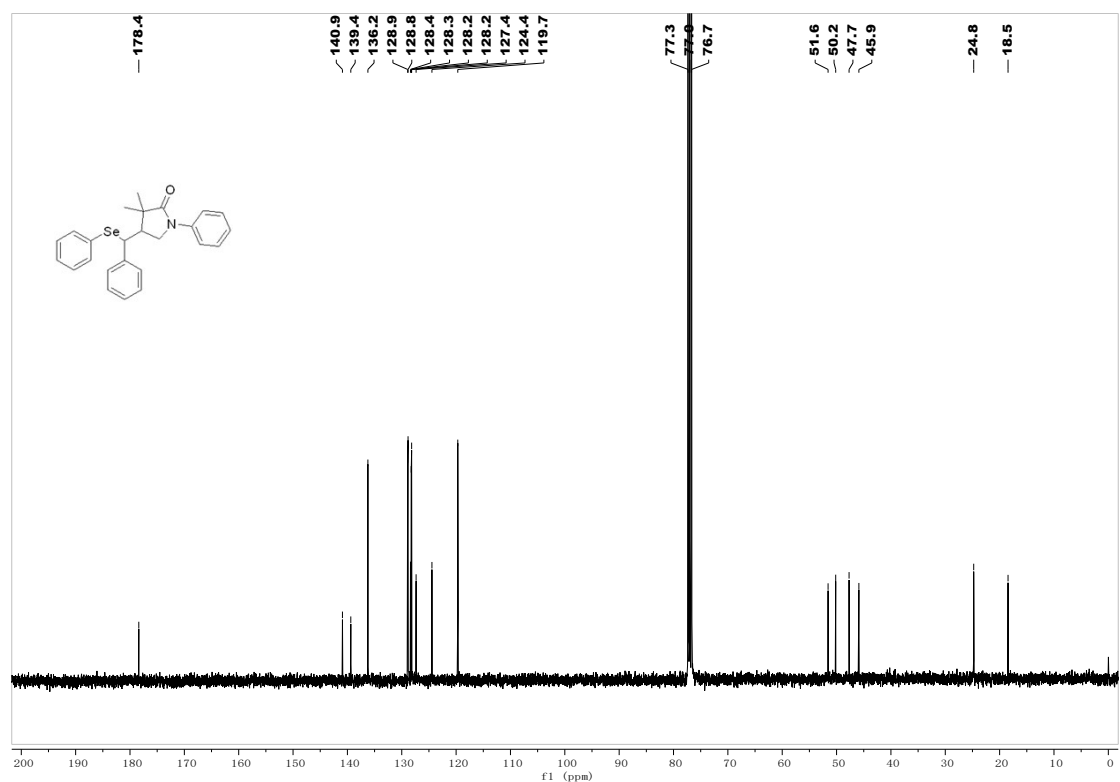
¹³C NMR spectrum of compound (5)



¹H NMR spectrum of compound (6)



¹³C NMR spectrum of compound (6)



8. References

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