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Supporting information

Solvent Strategy for Unleashing Lewis Acidity of Titanocene Dichloride for Rapid Mannich Reactions

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Contents

1. General procedures

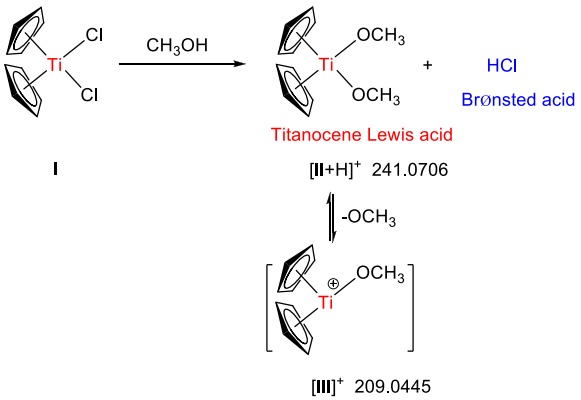
^{1}H and ^{13}C NMR spectra were recorded on a Bruker EQUINX55 (400 MHz for ^{1}H; 101 MHz for ^{13}C) spectrometer in $CDCl_3$. For ^{1}H NMR, tetramethylsilane (TMS) served as internal standard ($\delta = 0$) and ^{1}H NMR chemical shifts are reported in ppm downfield of tetramethylsilane and referenced to residual solvent peak ($CDCl_3$ at 7.26 ppm) unless otherwise noted. The data are reported as follows: chemical shift, integration, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet and m = multiplet), and coupling constant in Hz. For ^{13}C NMR, $CDCl_3$ was used as internal standard ($\delta = 77.0$) and spectra were obtained with complete proton decoupling. Infrared (IR) spectra were obtained using a Thermo Electron Nicolet 380 FT-IR spectrometer and reported as wavenumbers (cm^{-1}). Column chromatography was performed on silica gel (230-400 mesh) and analytical thin layer chromatography was carried out using 250 μm commercial silica gel plates. Visualization of the developed chromatogram was performed by UV absorbance and stained with an iodine vapor.

2. Typical procedures for three-component Mannich reactions

A nitrogen flushed 10 mL test tube, equipped with a magnetic stirrer and a septum, was charged with methanol (0.5 mL), benzaldehyde (1.0 mmol), aniline (1.0 mmol), and the aromatic/ aliphatic ketone (2.0 mmol) in one portion. Cp_2TiCl_2 (0.01 mmol) was added at 25 ℃ and stirred until the reaction was completed as indicated by TLC. Upon completion of the reaction, the reaction mixture was quenched with distilled water (5.0 mL). The aqueous phase was extracted with ether (3×5 mL), dried over Na_2SO_4 and concentrated in vacuo to give desired products. The crude product was purified by flash column chromatography on neutral silica gel (ethyl acetate: n-hexane).

3. NMR experiments

The interplay of Cp_2TiCl_2 and methanol was investigated by ^{1}H NMR in mechanistic scenario (Figure S1). A general procedure was as follows: Cp_2TiCl_2 (10 μmol) was placed in CD_3OD (0.5mL) and the solution was detected immediately as observed by ^{1}H NMR spectroscopy. The mixture was allowed to stand for 1 h and was conducted by ^{1}H NMR spectroscopy as confirmed by ^{1}H NMR spectroscopy. After 1.0 equiv. of aniline was added in the above solution, one new Cp protons singlet appeared at δ 6.70 ppm. Titanocene chloride (**I**) was consumed gradually in CD_3OD in the presence of base and formed new titanocene species $Cp_2Ti(OCH_3)_2$ (**II**) (Scheme S1).



Scheme S1. The coordination of Cp_2TiCl_2 with CH_3OH unleashed Lewis acidity and Brønsted acidity by ^1H NMR and ESI-MS.

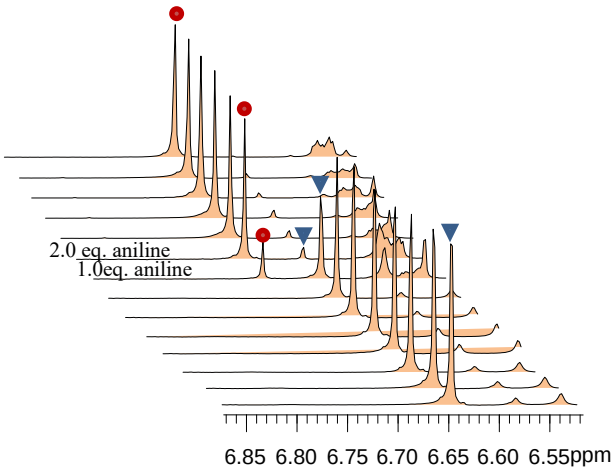


Figure S1. Partial 400MHz ^1H NMR spectra (CD_3OD) of a solution containing Cp_2TiCl_2 with addition of aniline.

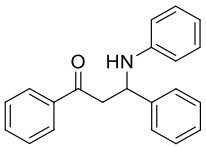
▼ 6.64 ppm **I** $[Cp_2TiCl_2]$; ● 6.70 ppm **II** $[Cp_2Ti(OCH_3)_2]$

4. Spectrometric analysis

Mass spectrometric measurements were performed in a Bruker EVOQ tandem mass spectrometer. As a general rule, scan mode was Q1MS, positive ion mode (otherwise indicated), tube lens potential was optimized in each case or for a series of measurements that required equal conditions, a time span of 1 minute was used to collect spectra and average them. The tube lens potential was adjusted in a way that the most interest ions had almost no attenuation (around 70 V).

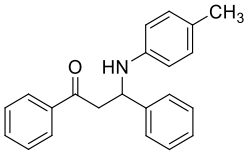
For CID experiments, the cations of interest were mass-selected using the first quadrupole (Q1) and interacted with argon in the T-wave collision cell at variable collision energies (Elaboratory= 3-15 eV). The ionic products of fragmentation were analyzed with the time-of-flight analyzer. The isolation width was 1Da and the most abundant isotopomer was mass-selected in the first quadrupole analyzer.

5. Characterization data of products



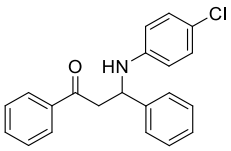
4a

1,3-Diphenyl-3-(*N*-phenylamino)propan-1-one (4a): Yield, 95%; white solid; mp 170-172 ℃; *R*f 0.51 (hexane/ethyl acetate = 4:1); IR (KBr): 3383, 1669; HRMS (ESI) *m/z* 302.1498 [$C_{21}H_{19}NO$ (M+1) requires 302.1545]; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.89-7.91 (m, 2H), 7.56 (dd, *J* = 10.5, 4.3, 1H), 7.45 (dd, *J* = 10.5, 4.5, 4H), 7.32 (t, *J* = 7.5, 2H), 7.23 (t, *J* = 7.3, 1H), 7.06-7.09 (m, 2H), 6.68 (t, *J* = 7.3, 1H), 6.56-6.59 (m, 2H), 5.02 (dd, *J* = 7.4, 5.4, 1H), 3.48 (qd, *J* = 16.1, 6.4, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 198.26, 146.78, 142.81, 136.76, 133.40, 129.11, 128.82, 128.69, 128.20, 127.39, 126.43, 118.02, 114.04, 55.03, 46.21.



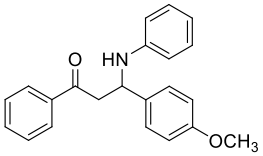
4b

3-[*N*-(4-Methylphenylamino)]-1,3-diphenylpropan-1-one (4b): Yield, 95%; white solid; mp 125-126 ℃; *R*f 0.45 (hexane/ethyl acetate = 4:1); IR (KBr): 3376, 1674; HRMS (ESI) *m/z* 316.1689 [$C_{22}H_{21}NO$ (M+1) requires 316.1701]; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.90 (d, *J* = 8.1 Hz, 2H), 7.54 (d, *J* = 7.3 Hz, 1H), 7.43 (m, 4H), 7.31 (t, *J* = 7.5 Hz, 2H), 7.24 (m, 1H), 6.89 (d, *J* = 8.1 Hz, 2H), 6.48 (d, *J* = 8.2 Hz, 2H), 4.97 (m, 1H), 4.40 (s, 1H), 3.45 (ddd, *J* = 23.7, 16.1, 6.4 Hz, 2H), 2.17 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 198.32, 144.71, 143.17, 136.80, 133.34, 129.59, 128.78, 128.66, 128.19, 127.28, 127.00, 126.39, 114.03, 55.11, 46.36, 20.33.



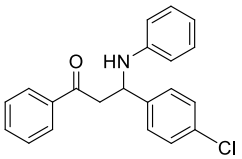
4c

3-[*N*-(4-chlorophenylamino)]-1,3-diphenylpropan-1-one (4c): Yield, 85%; yellowish solid; mp 167-168 ℃; *R*f 0.40 (hexane/ethyl acetate = 4:1); IR (KBr): 3370, 1665; HRMS (ESI) *m/z* 336.1140 [$C_{21}H_{18}ClNO$ (M+1) requires 336.1155]; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.90 (d, *J* = 7.8, 2H), 7.56 (t, *J* = 7.3, 1H), 7.42-7.44 (m, 4H), 7.32 (t, *J* = 7.5, 2H), 7.24 (s, 1H), 7.02 (d, *J* = 8.7, 2H), 6.47 (d, *J* = 8.7, 2H), 4.93-4.96 (m, 1H), 4.61 (s, 1H), 3.37-3.47 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 198.16, 145.58, 142.51, 136.65, 133.51, 128.92, 128.90, 128.73, 128.19, 127.50, 126.29, 122.48, 114.98, 54.95, 46.20.



4d

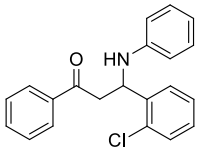
3-(4-Methoxyphenyl)-1-phenyl-3-(*N*-phenylamino)propan-1-one (**4d**): Yield, 96%; white solid; mp 150-151 ℃; *R*f 0.32 (hexane/ethyl acetate = 4:1); IR (KBr): 3374, 1664; HRMS (ESI) *m/z* 332.1647 [$C_{22}H_{21}NO_2$ (M+1) requires 332.1650]; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.88 (d, *J* = 7.3, 2H), 7.53 (t, *J* = 7.4, 1H), 7.41 (t, *J* = 7.7, 2H), 7.35 (d, *J* = 8.6, 2H), 7.09 (t, *J* = 7.9, 2H), 6.83 (d, *J* = 8.7, 2H), 6.71 (t, *J* = 7.3, 1H), 6.63 (d, *J* = 7.8, 2H), 4.97 (t, *J* = 6.4, 1H), 3.74 (s, 3H), 3.49-3.56 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 198.16, 158.98, 145.81, 136.78, 134.04, 133.36, 129.15, 128.67, 128.20, 127.79, 118.87, 114.90, 114.21, 55.28, 55.24, 45.86.



4e

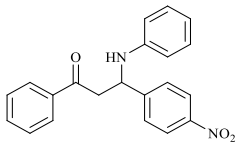
3-(4-Chlorophenyl)-1-phenyl-3-(*N*-phenylamino)propan-1-one(4e): Yield, 88%; white solid; mp 114-115 ℃; Rf 0.39 (hexane/ethyl acetate = 4:1); IR (KBr): 3398, 1676; HRMS (ESI) *m/z* 336.1140

[$C_{21}H_{18}NOCl$ (M+1) requires 336.1155]; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.87 (d, *J* = 8.0, 2H), 7.52-7.54 (m, 1H), 7.41 (t, *J* = 7.6, 2H), 7.35 (d, *J* = 8.2, 2H), 7.22-7.25 (m, 2H), 7.06 (t, *J* = 7.6, 2H), 6.65 (t, *J* = 7.2, 1H), 6.51 (d, *J* = 8.3, 2H), 4.95 (t, *J* = 6.3, 1H), 4.54 (s, 1H), 3.40-3.43 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 197.91, 146.74, 141.56, 136.63, 133.56, 132.99, 129.17, 128.97, 128.77, 128.18, 127.86, 118.09, 113.89, 54.21, 46.11.



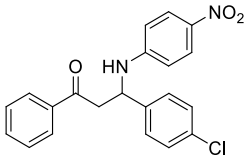
4f

3-(2-Chlorophenyl)-1-phenyl-3-[*N*-(phenylamino]propan-1-one (4f): Yield, 74%; white solid; mp 52-53 ℃; Rf 0.48 (hexane/ethyl acetate = 5:1); IR (KBr): 3402, 1675; HRMS (ESI) *m/z* 336.1156 [$C_{21}H_{18}ClNO$ (M+1) requires 336.1155]; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.97 (d, *J* = 8.0 Hz, 2H), 7.54 (dd, *J* = 10.6, 6.8 Hz, 2H), 7.42-7.44 (m, 3H), 7.15-7.17 (m, 2H), 7.07 (t, *J* = 7.8 Hz, 2H), 6.64 (t, *J* = 7.3 Hz, 1H), 6.47 (d, *J* = 8.5 Hz, 2H), 5.30 (d, *J* = 5.0 Hz, 1H), 4.90 (s, 1H), 3.61 (dd, *J* = 15.5, 3.9 Hz, 1H), 3.29 (dd, *J* = 15.5, 8.7 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 197.49, 145.48, 138.52, 135.50, 132.51, 131.34, 128.80, 128.08, 127.69, 127.51, 127.33, 127.09, 126.41, 116.86, 112.60, 51.01, 42.74.



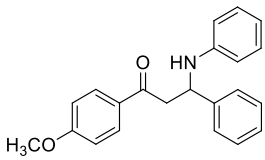
4g

3-(4-nitrophenyl)-1-phenyl-3-(phenylamino)-1-propanone (4g): Yield, 75%; yellow solid; mp 154-156 ℃; Rf 0.32 (hexane/ethyl acetate = 5:1); IR (KBr): 3402, 1675; HRMS (ESI) *m/z* 347.1121[$C_{21}H_{18}N_2O_3$ (M+1) requires 347.1396]; δ_H (400 MHz, $CDCl_3$) 8.08 (d, *J* = 8.7 Hz, 2H), 7.87-7.78 (m, 2H), 7.58-7.47 (m, 3H), 7.37 (t, *J* = 7.7 Hz, 2H), 7.02 (t, *J* = 7.9 Hz, 2H), 6.62 (t, *J* = 7.3 Hz, 1H), 6.44 (d, *J* = 7.8 Hz, 2H), 5.03 (s, 1H), 4.61 (s, 1H), 3.43 (d, *J* = 6.2 Hz, 2H); δ_C (101 MHz, $CDCl_3$) 197.3, 150.8, 147.2, 146.3, 136.4, 133.8, 129.3, 128.9, 128.2, 127.5, 124.1, 118.5, 113.9, 77.4, 77.1, 76.8, 54.2, 45.7.



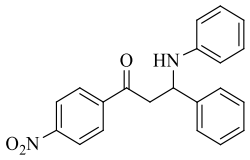
4h

3-[*N*-(4-Nitrophenylamino)]- 3-(4-Chlorophenyl)-1-phenylpropan-1-one (4h): Yield: 81%; yellow solid; mp 137-138 ℃; *R*f 0.25 (hexane/ethyl acetate = 4:1); IR (KBr): 3369, 1687; HRMS (ESI) *m/z* 381.1117 [$C_{21}H_{17}ClN_2O_3$ (M+1) requires 381.1106]; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.00 (d, *J* = 9.1 Hz, 2H), 7.88 (d, *J* = 7.4 Hz, 2H), 7.59 (t, *J* = 7.4 Hz, 1H), 7.45 (d, *J* = 7.6 Hz, 2H), 7.32 (q, *J* = 8.6 Hz, 4H), 6.50 (d, *J* = 9.1 Hz, 2H), 5.08 (t, *J* = 6.0 Hz, 1H), 3.51 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 197.53, 151.91, 139.68, 138.80, 136.32, 133.92, 133.70, 129.29, 128.87, 128.16, 127.62, 126.16, 112.28, 53.80, 45.25.



4i

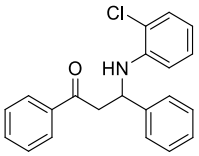
1-(4-Methoxyphenyl)-3-phenyl-3-(*N*-phenylamino)propan-1-one (4i): Yield, 90%; white solid; mp 123-124 ℃; Rf 0.42 (hexane/ethyl acetate = 4:1); IR (KBr): 3383, 1659; HRMS (ESI) *m/z* 332.1650 [$C_{22}H_{21}NO_2$ (M+1) requires 332.1651]; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.81 (d, *J* = 8.9 Hz, 2H), 7.36 (d, *J* = 7.4 Hz, 2H), 7.24 (t, *J* = 7.5 Hz, 2H), 7.16 (dd, *J* = 13.4, 6.1 Hz, 1H), 7.00 (dd, *J* = 8.4, 7.5 Hz, 2H), 6.83 (d, *J* = 8.9 Hz, 2H), 6.57 (t, *J* = 7.3 Hz, 1H), 6.47 (d, *J* = 7.7 Hz, 2H), 4.89 (dd, *J* = 7.6, 5.1 Hz, 1H), 4.53 (s, 1H), 3.78 (s, 3H), 3.24-3.40 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 196.77, 163.77, 147.10, 143.18, 130.56, 129.85, 129.07, 128.80, 127.28, 126.36, 117.69, 113.85, 113.82, 55.50, 55.06, 46.00.



4j

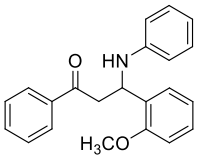
3-(4-Nitrophenyl)-1-phenyl-3-(*N*-phenylamino)propan-1-one (4j): Yield, 81%; yellow solid; mp 121-122 ℃; *R*f 0.21 (hexane/ethyl acetate = 4:1); IR (KBr): 3403, 1674; HRMS (ESI) *m/z* 347.1399

[$C_{21}H_{18}N_2O_3$ (M+1) requires 347.1396]; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.26 (d, *J* = 8.6, 2H), 8.00 (d, *J* = 8.6, 2H), 7.42-7.44 (m, 2H), 7.32 (t, *J* = 7.4, 2H), 7.22-7.25 (m, 1H), 7.11 (t, *J* = 7.7, 2H), 6.71 (t, *J* = 7.3, 1H), 6.60 (d, *J* = 8.0, 2H), 5.04 (t, *J* = 6.3, 1H), 3.55 (d, *J* = 5.7, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 196.83, 150.42, 146.45, 142.03, 141.12, 129.24, 129.16, 128.96, 127.73, 126.41, 123.88, 118.49, 114.13, 54.90, 46.47.



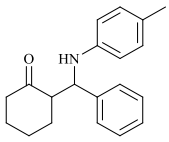
4k

1,3-diphenyl-3-[*N*-(2-Chlorophenylamino)]propan-1-one (4k): Yield, 76%; white solid; mp 77-78 ℃; Rf 0.50 (hexane/ethyl acetate = 4:1); IR (KBr): 3478, 3554, 3413, 1620; HRMS (ESI) *m/z* 336.1150 [$C_{21}H_{18}ClNO$ (M+1) requires 336.1155]; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.90-7.92 (m, 2H), 7.56 (t, *J* = 7.4 Hz, 1H), 7.41-7.44 (m, 4H), 7.32 (t, *J* = 7.5 Hz, 2H), 7.21-7.25 (m, 2H), 6.95-6.99 (m, 1H), 6.58 (td, *J* = 7.7, 1.3 Hz, 1H), 6.51 (dd, *J* = 8.2, 1.2 Hz, 1H), 5.15 (s, 1H), 5.09 (t, *J* = 6.3 Hz, 1H), 3.52 (d, *J* = 6.1 Hz, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 196.72, 141.80, 141.36, 135.78, 132.40, 128.03, 127.86, 127.68, 127.18, 126.60, 126.48, 125.28, 118.59, 116.67, 111.69, 53.48, 45.42.



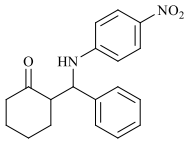
4l

3-(4-Methoxyphenyl)-1-phenyl-3-(*N*-phenylamino)propan-1-one (4l): Yield, 85%; white solid; mp 56-57 ℃; Rf 0.43 (hexane/ethyl acetate = 4:1); IR (KBr): 3403, 1682; HRMS (ESI) *m/z* 332.1643 [$C_{22}H_{21}NO_2$ (M+1) requires 332.1650]; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.88-7.91 (m, 2H), 7.41-7.43 (m, 1H), 7.30-7.34 (m, 3H), 7.12 (dd, *J* = 12.8, 4.7 Hz, 1H), 6.96 (dd, *J* = 8.4, 7.4 Hz, 2H), 6.80 (m, 2H), 6.53 (d, *J* = 7.3 Hz, 1H), 6.43 (d, *J* = 7.7 Hz, 2H), 5.18 (dd, *J* = 8.4, 4.5 Hz, 1H), 3.85 (s, 3H), 3.55 (dd, *J* = 15.1, 4.5 Hz, 1H), 3.13 (dd, *J* = 15.2, 8.4 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 199.08, 156.59, 147.10, 136.77, 133.26, 130.06, 129.06, 128.61, 128.58, 128.42, 128.27, 127.65, 121.01, 117.50, 113.73, 110.55, 55.39, 50.71, 44.53.



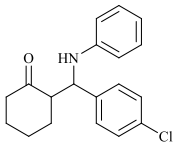
4m

2-[[(4-methylphenyl)amino]phenylmethyl]-cyclohexanone (4m): Yield, 88%; white solid; Rf 0.48 (hexane/ethyl acetate = 4:1); IR (KBr): 3380, 1697; HRMS (ESI) *m/z* 294.1837 [$C_{20}H_{23}NO$ (M+1) requires 294.1859]; Major isomer: ^{1}H NMR (400 MHz, $CDCl_3$) 7.38 (2 H, t, *J* = 7.4, ArH), 7.34-7.28 (2 H, m, ArH), 7.23 (1 H, dd, J_1 = 10.5, J_2 = 3.9, ArH), 6.91 (2 H, dd, J_1 = 7.9, J_2 = 5.8, ArH), 6.50 (2 H, t, *J* = 8.4, ArH), 4.81 (0.38 H, d, *J* = 4.4, syn-CH), 4.63 (0.62 H, d, *J* = 7.2, anti-CH), 4.52 (1 H, br, NH), 2.83-2.72 (1 H, m, CH), 2.47-2.40 (1 H, m, CH_2), 2.35 (1 H, dd, J_1 = 13.1, J_2 = 5.1, CH_2), 2.20 (3 H, d, *J* = 4.9, CH_3), 2.10-2.00 (1 H, m, CH_2), 1.88 (3 H, m, CH_2), 1.76-1.66 (2 H, m, CH_2). ^{13}C NMR (101 MHz, $CDCl_3$) 212.86, 211.39, 145.27, 144.98, 141.92, 141.80, 129.59, 129.55, 128.47, 128.37, 127.55, 127.33, 127.14, 126.96, 126.86, 126.69, 114.31, 113.84, 58.25, 57.61, 57.56, 56.71, 42.43, 41.72, 31.20, 28.69, 27.90, 27.07, 24.88, 23.63, 20.39, 20.36.



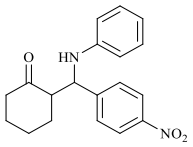
4n

2-[[(4-nitrophenyl)amino]phenylmethyl]-cyclohexanone (4n): Yield, 81%; yellow solid; Rf 0.40 (hexane/ethyl acetate = 4:1); IR (KBr): 3374, 1705; HRMS (ESI) *m/z* 325.1528 [$C_{19}H_{20}N_2O_3$ (M+1) requires 325.1552]; Major isomer: ^{1}H NMR (400 MHz, $CDCl_3$) 7.98 (2 H, d, *J* = 9.2, ArH), 7.32 (4 H, d, *J* = 4.3, ArH), 7.25 (1 H, d, *J* = 5.4, ArH), 6.49 (2 H, d, *J* = 9.2, ArH), 5.75 (0.13 H, d, *J* = 7.6, anti-NH), 5.59 (0.85 H, d, *J* = 7.1, syn-NH), 4.86 (0.87 H, dd, J_1 = 7.2, J_2 = 4.4, syn-CH), 4.65 (0.13 H, m, anti-CH), 2.86 (1 H, dt, J_1 = 9.5, J_2 = 4.6, CH), 2.37 (2 H, m, CH_2), 2.05 (2 H, dd, J_1 = 15.6, J_2 = 9.6, CH_2), 1.90 (1 H, d, *J* = 6.9, CH_2), 1.59 (3 H, m, CH_2). ^{13}C NMR (101 MHz, $CDCl_3$) 212.50, 211.07, 152.77, 152.66, 140.23, 139.72, 138.24, 138.20, 128.76, 128.69, 127.68, 127.65, 127.45, 126.98, 126.20, 126.14, 112.22, 111.98, 58.12, 57.12, 56.90, 55.61, 42.46, 42.28, 32.32, 28.69, 28.09, 26.59, 24.69, 24.34.



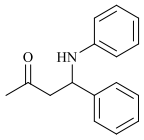
4o

2-[(4-chlorophenyl)(phenylamino)methyl]-cyclohexanone (4o): Yield, 85%; yellow solid; Rf 0.45 (hexane/ethyl acetate = 4:1); IR (KBr): 3386, 1696; HRMS (ESI) *m/z* 314.1330 [$C_{19}H_{20}NOCl$ (M+1) requires 314.1312]; Major isomer: ^{1}H NMR (400 MHz, $CDCl_3$) 7.91 (2 H, d, *J* = 9.1, ArH), 7.21 (5 H, d, *J* = 1.6, ArH), 6.40 (2 H, d, *J* = 9.2, ArH), 5.65 (0.42 H, d, *J* = 7.6, anti-NH), 5.53 (0.58 H, d, *J* = 7.2, syn-NH), 4.71 (0.58 H, dd, J_1 = 7.1, J_2 = 4.6, syn-CH), 4.55 (0.42 H, dd, J_1 = 7.4, J_2 = 5.6, anti-CH), 2.78 (1 H, m, CH), 2.30 (2 H, m, CH_2), 1.90 (4 H, d, *J* = 51.2, CH_2), 1.62 (2 H, dd, J_1 = 20.9, J_2 = 10.2, CH_2). ^{13}C NMR (101 MHz, $CDCl_3$) 211.16, 209.94, 151.49, 151.29, 137.85, 137.55, 137.50, 137.19, 132.48, 132.42, 127.99, 127.92, 127.85, 127.37, 125.20, 125.13, 111.23, 110.99, 56.69, 55.91, 55.79, 54.39, 41.60, 41.30, 31.44, 28.03, 27.01, 25.56, 23.70, 23.53.



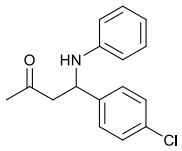
4p

2-[(4-nitrophenyl)(phenylamino)methyl]-cyclohexanone (4p): Yield, 72%; yellow solid; Rf 0.41 (hexane/ethyl acetate = 4:1); IR (KBr): 3374, 1701; HRMS (ESI) *m/z* 325.1520 [$C_{19}H_{20}N_2O_3$ (M+1) requires 325.1552]; Major isomer: ^{1}H NMR (400 MHz, $CDCl_3$) 8.14 (2 H, d, *J* = 8.8, ArH), 7.56 (2 H, m, ArH), 7.07 (2 H, t, *J* = 7.9, ArH), 6.66 (1 H, dd, J_1 = 13.2, J_2 = 6.9, ArH), 6.49 (2 H, d, *J* = 7.7, ArH), 4.86 (0.47 H, d, *J* = 4.5, syn-CH), 4.71 (0.53 H, d, *J* = 5.3, anti-CH), 4.86 (0.47 H, br, syn-NH), 4.60 (0.47 H, br, anti-NH), 2.85 (1 H, dd, J_1 = 11.0, J_2 = 5.0, CH), 2.37 (2 H, dt, J_1 = 26.2, J_2 = 13.9, CH_2), 2.00 (3 H, m, CH_2), 1.70 (3 H, m, CH_2). ^{13}C NMR (101 MHz, $CDCl_3$) 211.74, 210.60, 149.89, 149.61, 147.08, 147.03, 146.71, 146.67, 129.27, 129.17, 128.62, 128.27, 123.66, 123.61, 118.37, 118.10, 114.05, 113.50, 57.77, 57.21, 57.03, 56.21, 42.45, 42.41, 32.01, 29.09, 27.78, 27.05, 24.94, 24.49.



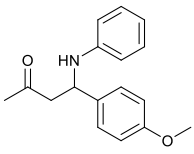
4q

4-phenyl-4-(phenylamino)-2-butanone (4q): Yield, 71%; white solid; mp 90-92 ℃; Rf 0.43 (hexane/ethyl acetate = 4:1); IR (KBr): 3369, 1704; HRMS (ESI) *m/z* 240.1361 [$C_{16}H_{17}NO$ (M+1) requires 240.1388]; ^{1}H NMR (400 MHz, $CDCl_3$) 7.26 (m, 4H), 7.16 (d, *J* = 6.0 Hz, 1H), 7.01 (t, *J* = 7.8 Hz, 2H), 6.59 (t, *J* = 7.3 Hz, 1H), 6.47 (d, *J* = 8.1 Hz, 2H), 4.77 (t, *J* = 6.5 Hz, 1H), 4.36 (s, 1H), 2.84 (d, *J* = 6.5 Hz, 2H), 2.02 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) 206.1, 145.8, 141.5, 128.1, 127.8, 126.3, 125.2, 116.8, 112.7, 53.3, 50.2, 29.7.



4r

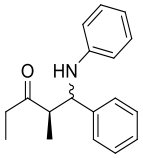
4-(4-chlorophenyl)-4-(phenylamino)-2-butanone(4r). Yield, 68%; yellow solid; mp 122-124 ℃; Rf 0.40 (hexane/ethyl acetate = 4:1); IR (KBr): 3367, 1706; HRMS (ESI) *m/z* 274.0908 [$C_{16}H_{16}NOCl$ (M+1) requires 274.0920]; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.22 (m, 4H), 7.04 (t, *J* = 7.7 Hz, 2H), 6.62 (t, *J* = 7.2 Hz, 1H), 6.45 (d, *J* = 8.0 Hz, 2H), 4.75 (t, *J* = 6.3 Hz, 1H), 4.38 (s, 1H), 2.85 (d, *J* = 6.3 Hz, 2H), 2.05 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 206.7, 146.5, 141.1, 133.0, 129.2, 129.0, 127.7, 118.1, 113.8, 53.8, 51.0, 30.8.



4s

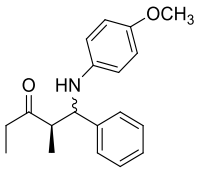
4-(4-methoxyphenyl)-4-(phenylamino)-2-butanone(4s): Yield, 79%; yellow solid; mp 104-105 ℃; Rf 0.44 (hexane/ethyl acetate = 4:1); IR (KBr): 3363, 1707; HRMS (ESI) *m/z* 270.1461 [$C_{17}H_{19}NO_2$ (M+1) requires 269.1416]; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.27 (d, *J* = 7.0 Hz, 2H), 7.09 (t, *J* = 7.0 Hz, 2H), 6.85 (d, *J* = 6.9 Hz, 2H), 6.66 (t, *J* = 7.3 Hz, 1H), 6.54 (d, *J* = 7.7 Hz, 2H), 4.80 (t, *J* = 6.3 Hz, 1H),

4.38 (s, 1H), 3.77 (s, 3H), 2.90 (d, *J* = 6.5 Hz, 2H), 2.08 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 207.3, 158.8, 146.8, 134.4, 129.1, 127.4, 117.8, 114.2, 113.8, 55.2, 53.8, 51.3, 30.8.



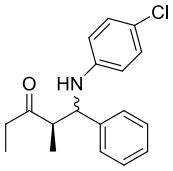
4t

2-Methyl-1-Phenyl-1-(*N*-phenylamino)pentan-3-one (4t): Yield, 85%; white solid; mp 105-106 ℃; Rf 0.40 (hexane/ethyl acetate = 4:1); IR (KBr): 3407, 3370, 1708; HRMS (ESI) *m/z* 268.1699 [$C_{18}H_{21}NO$ (M+1) requires 268.1701]; Major isomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.20-7.26 (m, 5H), 7.02 (t, *J* = 5.9 Hz, 2H), 6.59 (s, 1H), 6.45 (d, *J* = 5.6 Hz, 2H), 4.62 (s, 1H), 4.29 (s, 1H, NH), 2.96 (s, 1H), 2.27-2.30 (m, 2H), 1.05-1.07 (m, 3H), 0.89 (td, *J* = 7.2, 4.0 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 213.30, 147.03, 141.22, 129.06, 128.59, 127.27, 126.85, 117.66, 113.65, 59.24, 52.25, 35.52, 11.57, 7.50.



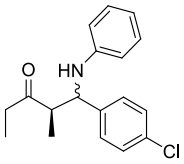
4u

2-Methyl-1-Phenyl-1-[*N*-(4-Methoxyphenylamino] pentan-3-one (4u): Yield, 91%; white solid; Rf 0.53 (hexane/ethyl acetate = 4:1); IR (KBr): 3365, 1703; HRMS (ESI) *m/z* 298.1802 [$C_{19}H_{23}NO_2$ (M+1) requires 298.1807]; Major isomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.30 (d, *J* = 4.4 Hz, 4H), 7.22 (dt, *J* = 8.6, 4.2 Hz, 1H), 6.66 (d, *J* = 8.9 Hz, 2H), 6.45 (d, *J* = 8.9 Hz, 2H), 4.59 (d, *J* = 5.7 Hz, 1H), 3.68 (s, 3H), 2.98 (dd, *J* = 6.8, 6.0 Hz, 1H), 2.35 (dd, *J* = 12.6, 7.2 Hz, 2H), 1.10 (d, *J* = 7.0 Hz, 3H), 0.93 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 212.45, 151.15, 140.48, 140.24, 127.54, 126.19, 125.89, 113.87, 113.70, 59.03, 54.67, 51.30, 34.49, 10.49, 6.50.



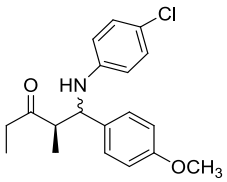
4v

2-Methyl -1-Phenyl-1-[*N*-(4-Chlorophenylamino)]pentan-3-one (4v): Yield, 82%; yellowish solid; mp 112-114 ℃; Rf 0.32 (hexane/ethyl acetate = 4:1); IR (KBr): 3376, 1715; HRMS (ESI) *m/z* 306.1309 [$C_{18}H_{20}ClNO$ (M+1) requires 306.1312]; Major isomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.37 – 7.17 (m, 5H), 7.06 – 6.92 (m, 2H), 6.47 – 6.30 (m, 2H), 4.59 (d, *J* = 5.0 Hz, 1H), 4.41 (s, 1H), 2.99 (dd, *J* = 6.9, 5.8 Hz, 1H), 2.32 (ddd, *J* = 14.3, 8.9, 5.3 Hz, 2H), 1.10 (d, *J* = 7.0 Hz, 3H), 0.93 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 213.31, 145.59, 140.66, 128.89, 128.68, 127.46, 126.81, 122.34, 114.78, 59.38, 52.04, 35.55, 11.58, 7.48.



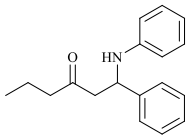
4w

2-Methyl-1-(4-Chlorophenyl)-1-(*N*-phenylamino) pentan-3-one (4w): Yield, 81%; yellowish solid; Rf 0.39 (hexane/ethyl acetate = 4:1); IR (KBr): 3376, 1692; HRMS (ESI) *m/z* 306.1307 [$C_{18}H_{20}ClNO$ (M+1) requires 306.1312]; Major isomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.17 (t, *J* = 8.2 Hz, 4H), 6.99 (t, *J* = 7.5 Hz, 2H), 6.57 (d, *J* = 7.1 Hz, 1H), 6.38 (d, *J* = 7.5 Hz, 2H), 4.56 (d, *J* = 5.3 Hz, 1H), 2.87-2.90 (m, 1H), 2.24-2.31 (m, 2H), 1.02 (d, *J* = 6.9 Hz, 3H), 0.87 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 211.97, 145.69, 138.85, 131.93, 128.09, 127.76, 127.27, 116.92, 112.66, 57.63, 50.98, 34.55, 10.56, 6.48.



4x

2-Methyl-1-(4-methoxyphenyl)-1-[*N*-(4-Chlorophenylamino)] pentan-3-one (4x): Yield, 83%; yellowish solid; Rf 0.48 (hexane/ethyl acetate = 4:1); IR (KBr): 3365, 1720; HRMS (ESI) *m/z* 332.1415 [$C_{19}H_{22}ClNO_2$ (M+1) requires 332.1417]; Major isomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.09 (t, *J* = 10.7 Hz, 2H), 6.93 (d, *J* = 8.9 Hz, 2H), 6.76 (dd, *J* = 8.5, 4.9 Hz, 2H), 6.34 (t, *J* = 6.0 Hz, 2H), 4.47 (s, 1H), 4.31 (s, 1H), 3.70 (d, *J* = 3.5 Hz, 3H), 2.98 – 2.82 (m, 1H), 2.36 – 2.12 (m, 2H), 1.03 (d, *J* = 7.0 Hz, 3H), 0.86 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 212.46, 157.71, 146.08, 132.13, 128.01, 126.87, 116.54, 112.95, 112.63, 57.73, 54.18, 51.38, 34.58, 10.79, 6.48



4y

1-phenyl-1-(phenylamino)-3-hexanone (4y): Yield, 77%; white solid; mp 87-88 ℃; Rf 0.51 (hexane/ethyl acetate = 4:1); IR (KBr): 3376, 1703; HRMS (ESI) *m/z* 268.1689 [$C_{18}H_{21}NO$ (M+1) requires 268.1701]; δ_H (400 MHz, $CDCl_3$) 7.29 (d, *J* = 7.9 Hz, 2H), 7.23 (d, *J* = 7.5 Hz, 2H), 7.17 (d, *J* = 5.8 Hz, 1H), 7.02 (t, *J* = 7.6 Hz, 2H), 6.59 (t, *J* = 7.3 Hz, 1H), 6.48 (d, *J* = 7.8 Hz, 2H), 4.78 (t, *J* = 6.4 Hz, 1H), 4.48 (s, 1H), 2.82 (d, *J* = 6.4 Hz, 2H), 2.28-2.17 (m, 2H), 1.51-1.41 (m, 2H), 0.76 (t, *J* = 7.4 Hz, 3H); δ_C (101 MHz, $CDCl_3$) 208.4, 145.8, 141.6, 128.1, 127.7, 126.3, 125.3, 116.7, 112.7, 53.4, 49.2, 44.6, 15.8, 12.5.

6. ESI mass spectra

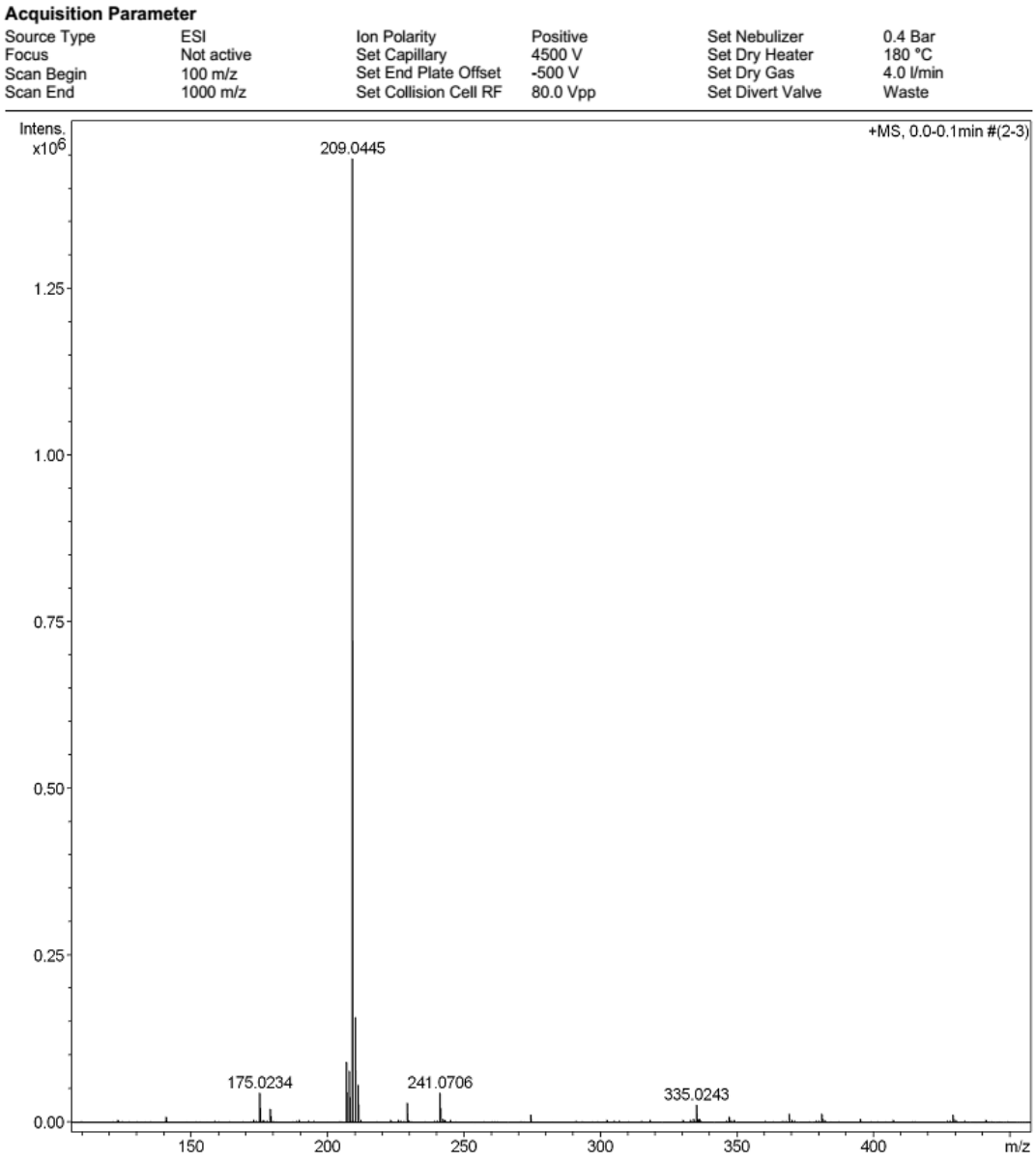


Figure S2: ESI(+)-MS for CID of Cp_2TiCl_2 in CH_3OH solution (m/z 100-450).

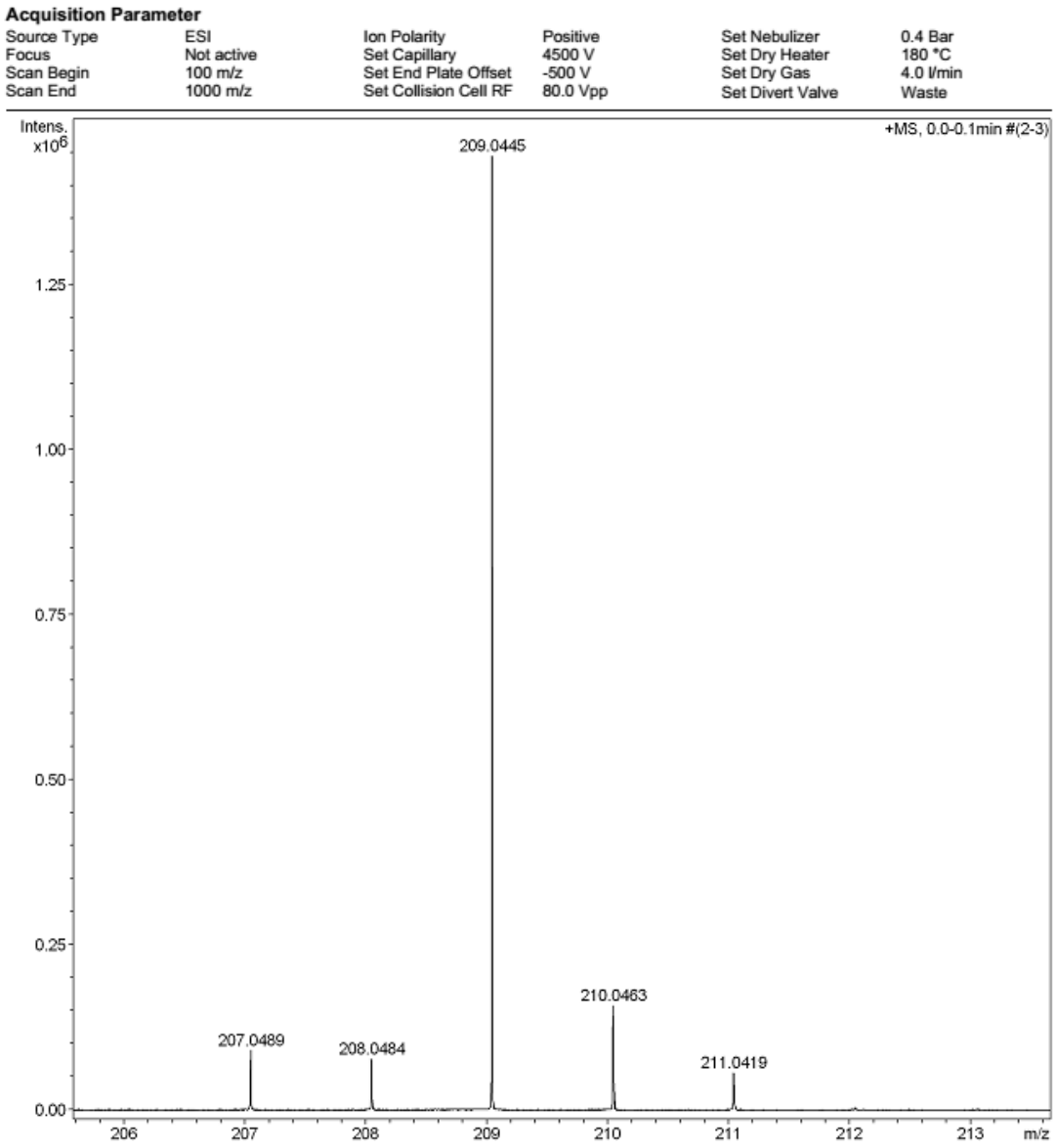


Figure S3: ESI(+)-MS for CID of Cp_2TiCl_2 in CH_3OH (m/z 206-213).

Acquisition Parameter

Source Type	ESI	Ion Polarity	Positive	Set Nebulizer	0.4 Bar
Focus	Not active	Set Capillary	4500 V	Set Dry Heater	180 °C
Scan Begin	100 m/z	Set End Plate Offset	-500 V	Set Dry Gas	4.0 l/min
Scan End	1000 m/z	Set Collision Cell RF	80.0 Vpp	Set Divert Valve	Waste

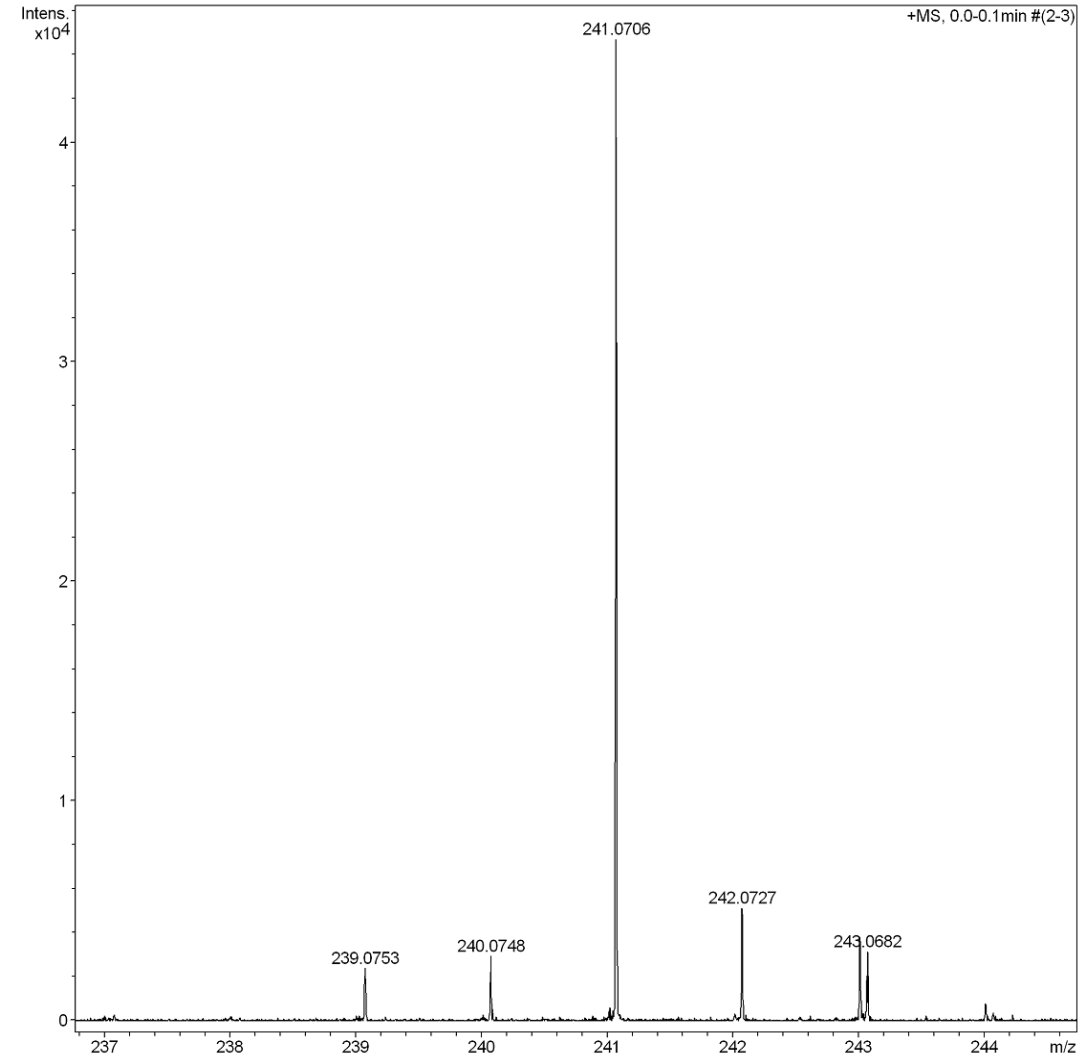
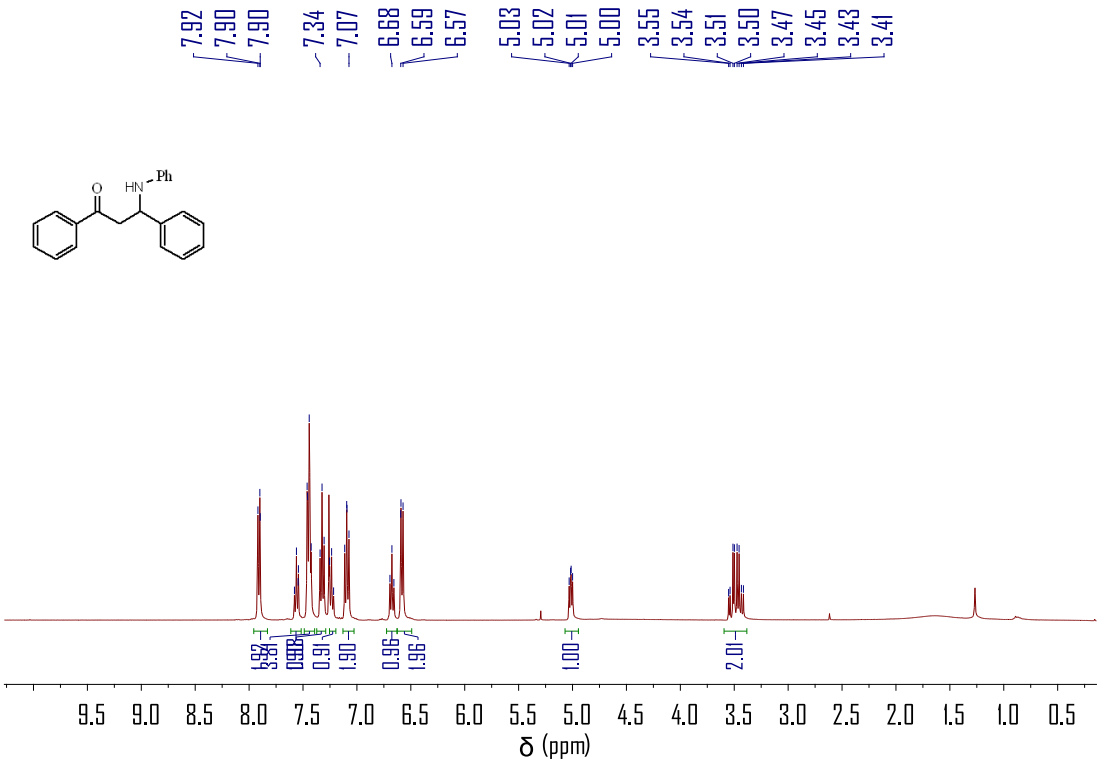
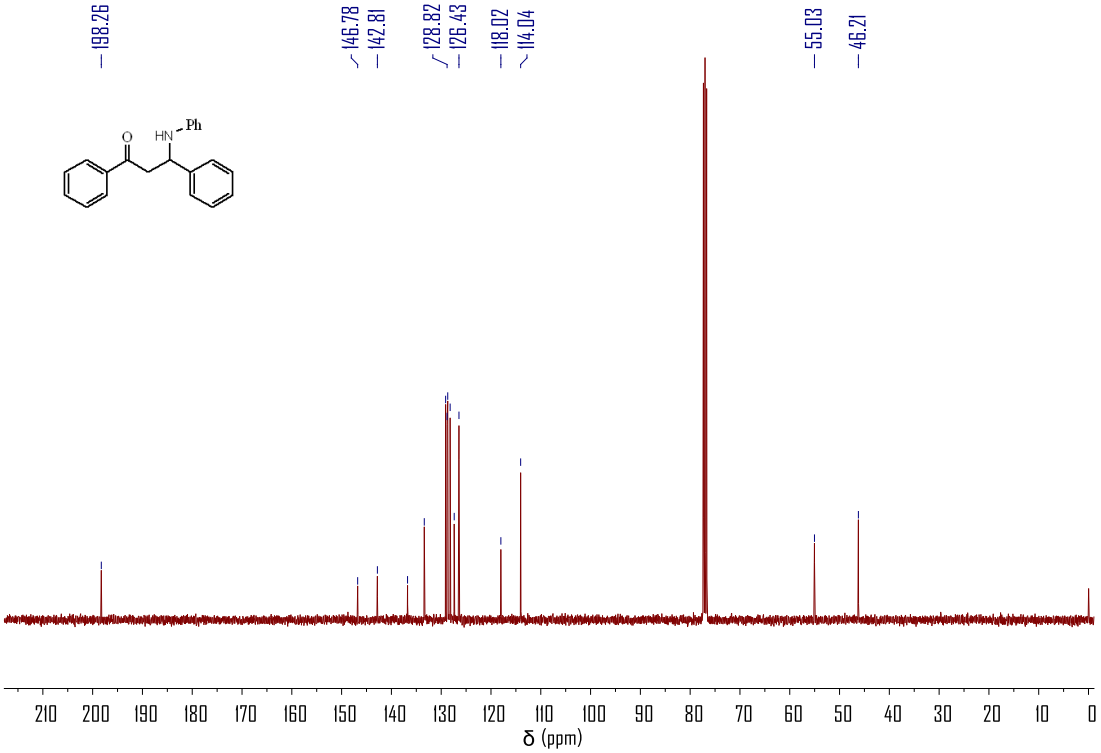
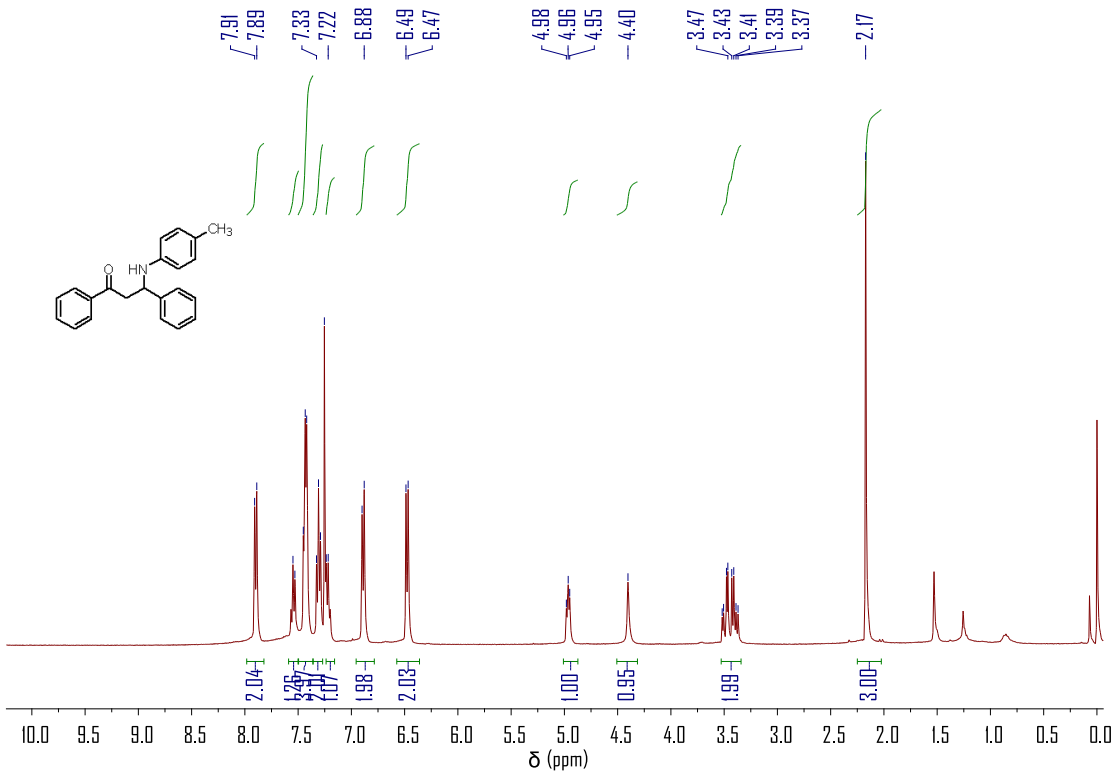


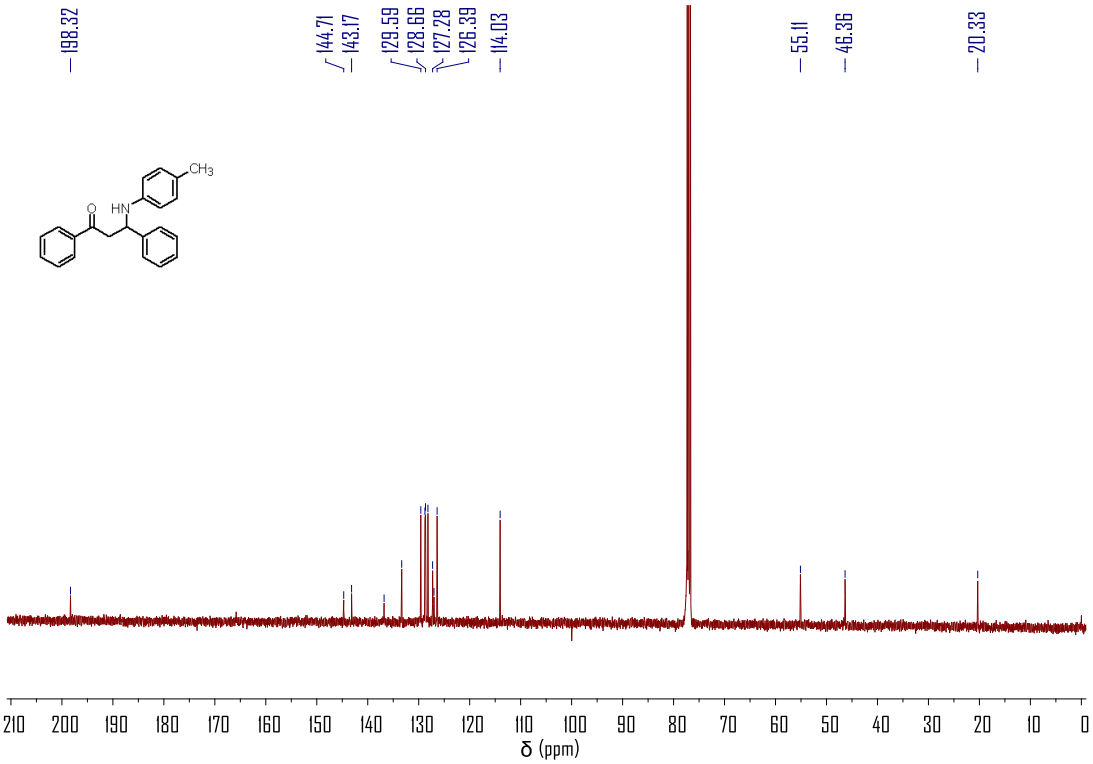
Figure S4: ESI(+)-MS for CID of Cp_2TiCl_2 in CH_3OH(m/z 237-244).

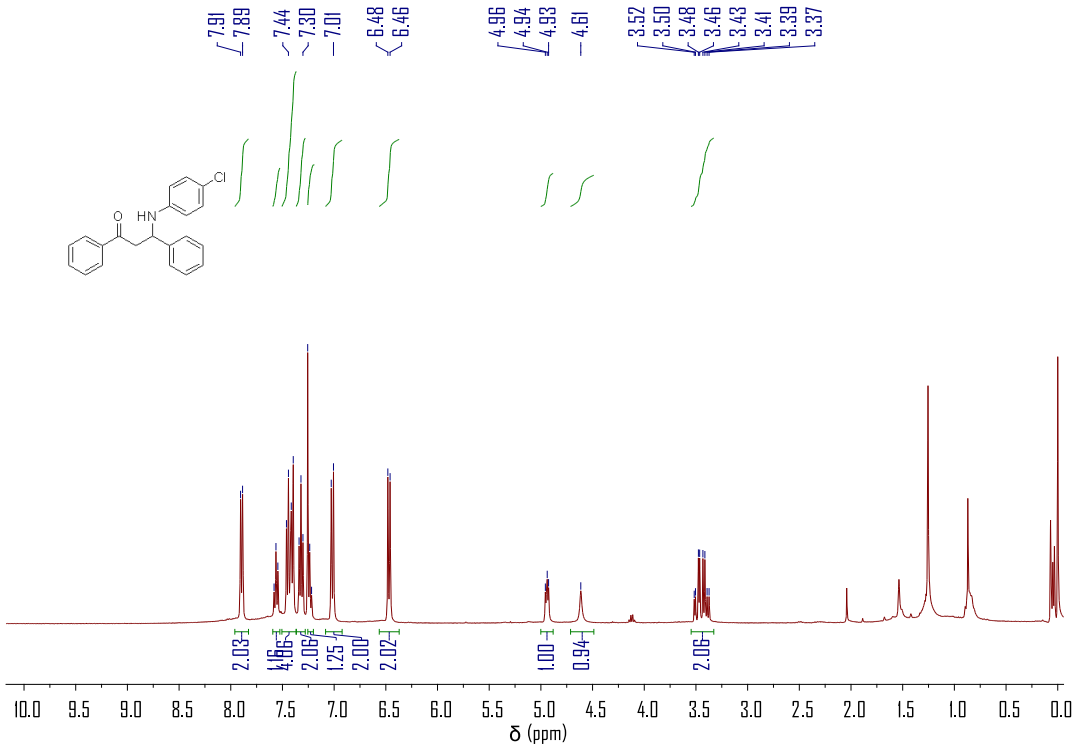
7. Copies of ^{1}H NMR and ^{13}C NMR spectra

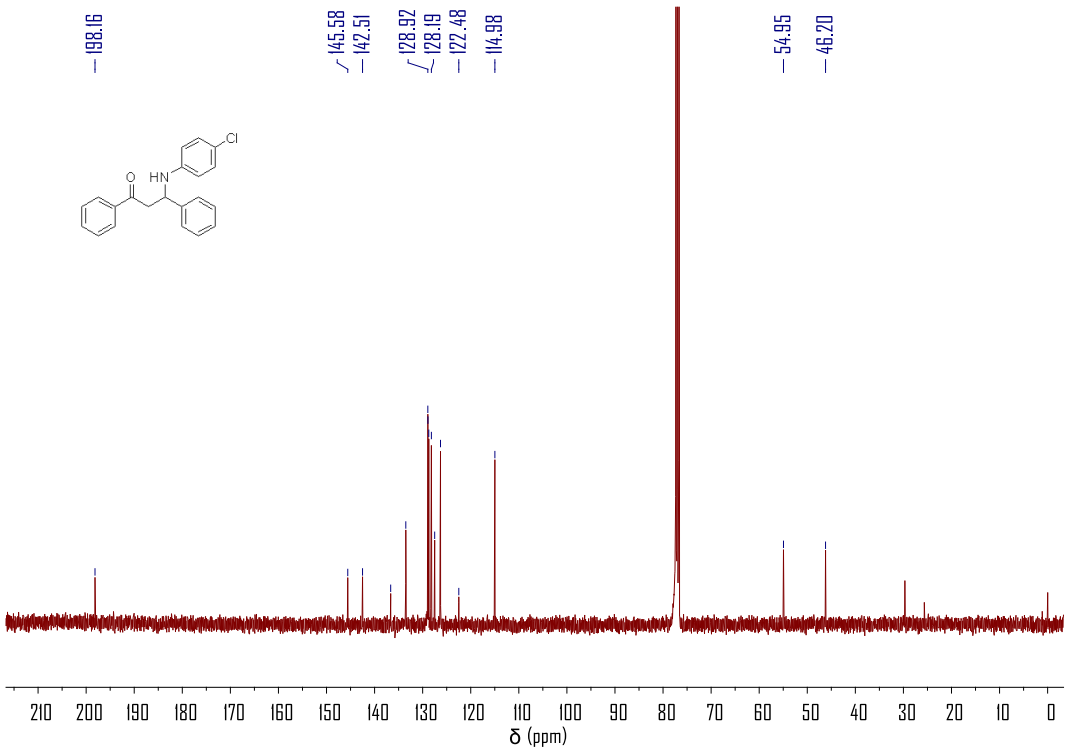


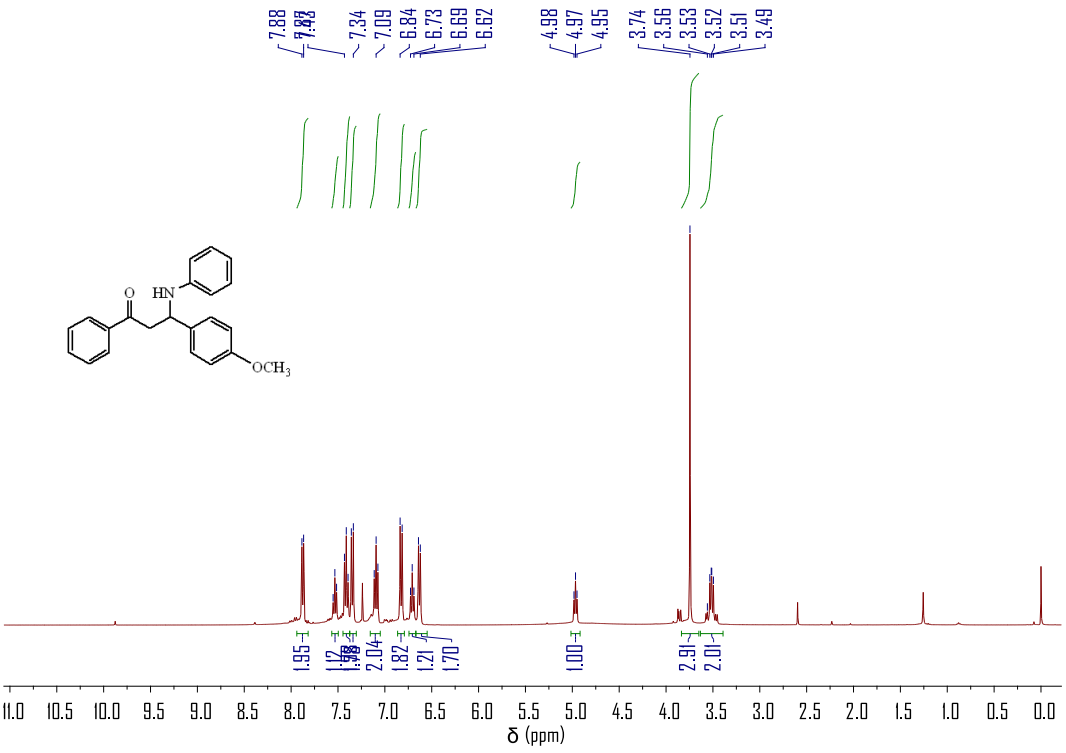


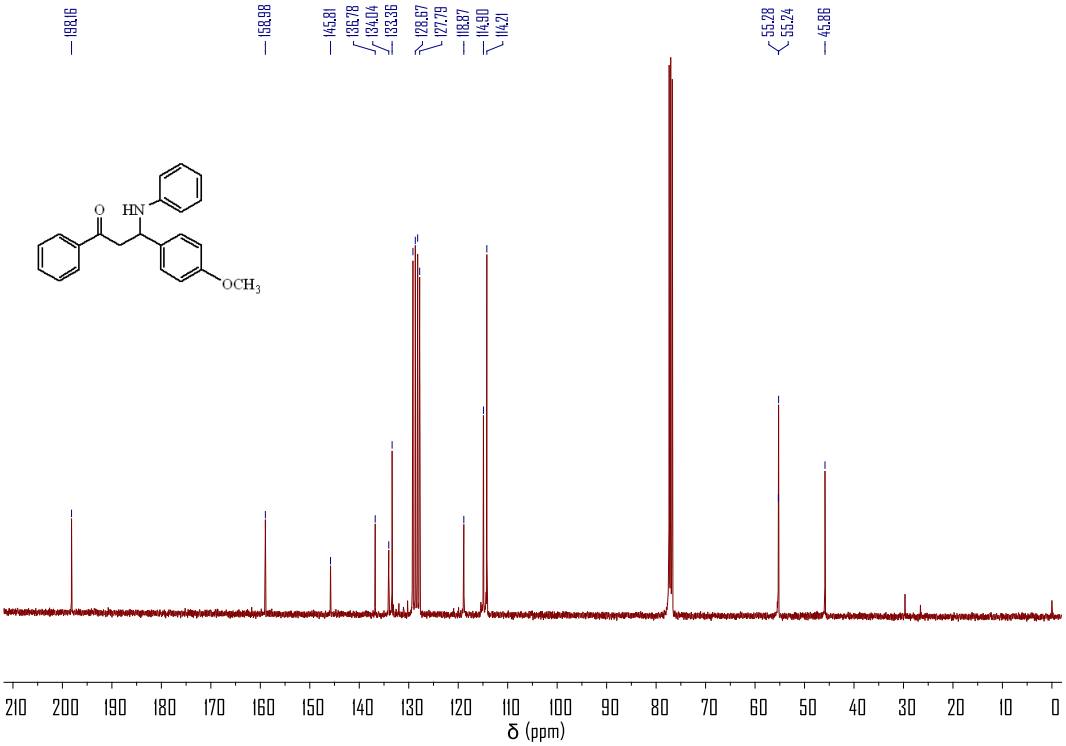

7.91
7.89
7.33
7.22
6.88
6.49
6.47
4.98
4.96
4.95
4.40
3.47
3.43
3.41
3.39
3.37
2.17
CH3
HN
O
2.04
1.98
2.03
1.00
0.95
1.99
3.00
δ (ppm)

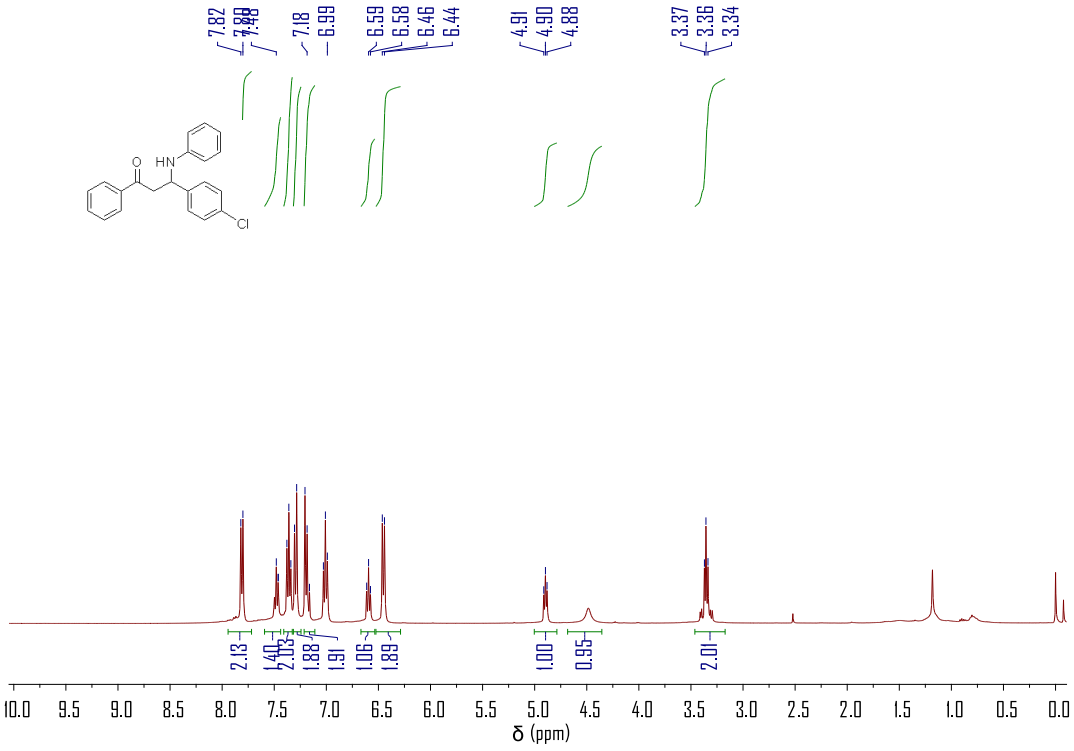

198.32
144.71
143.17
129.59
128.66
127.28
126.39
114.03
55.11
46.36
20.33
CH3
HN
O
δ (ppm)

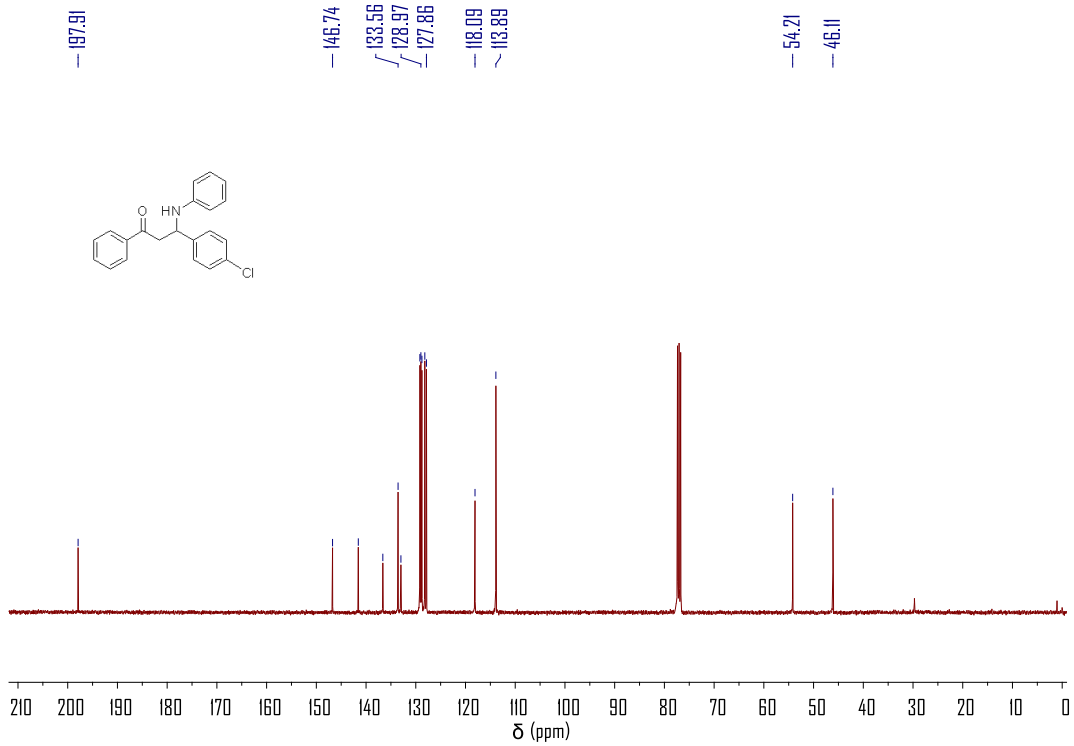

7.91
7.89
7.44
7.30
7.01
6.48
6.46
4.96
4.94
4.93
4.61
3.52
3.50
3.48
3.46
3.43
3.41
3.39
3.37
Cl
HN
O
2.03
4.16
4.06
2.08
1.25
2.00
2.02
1.00
0.94
2.06
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
δ (ppm)


198.16
145.58
142.51
128.92
128.19
122.48
114.98
54.95
46.20
Cl
HN
O
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
δ (ppm)


7.88
7.34
7.09
6.84
6.73
6.69
6.62
4.98
4.97
4.95
3.74
3.56
3.53
3.52
3.51
3.49
O
HN
OCH3
1.95
2.04
1.82
1.21
1.70
1.00
2.91
2.01
δ (ppm)


198.16
158.98
145.81
136.78
134.04
133.36
128.67
127.79
118.87
114.90
114.21
55.28
55.24
45.86
O
HN
OCH3
δ (ppm)


7.82
7.18
6.99
6.59
6.58
6.46
6.44
4.91
4.90
4.88
3.37
3.36
3.34
O
HN
Cl
2.13
1.40
2.03
1.88
1.91
1.06
1.89
1.00
0.95
2.01
δ (ppm)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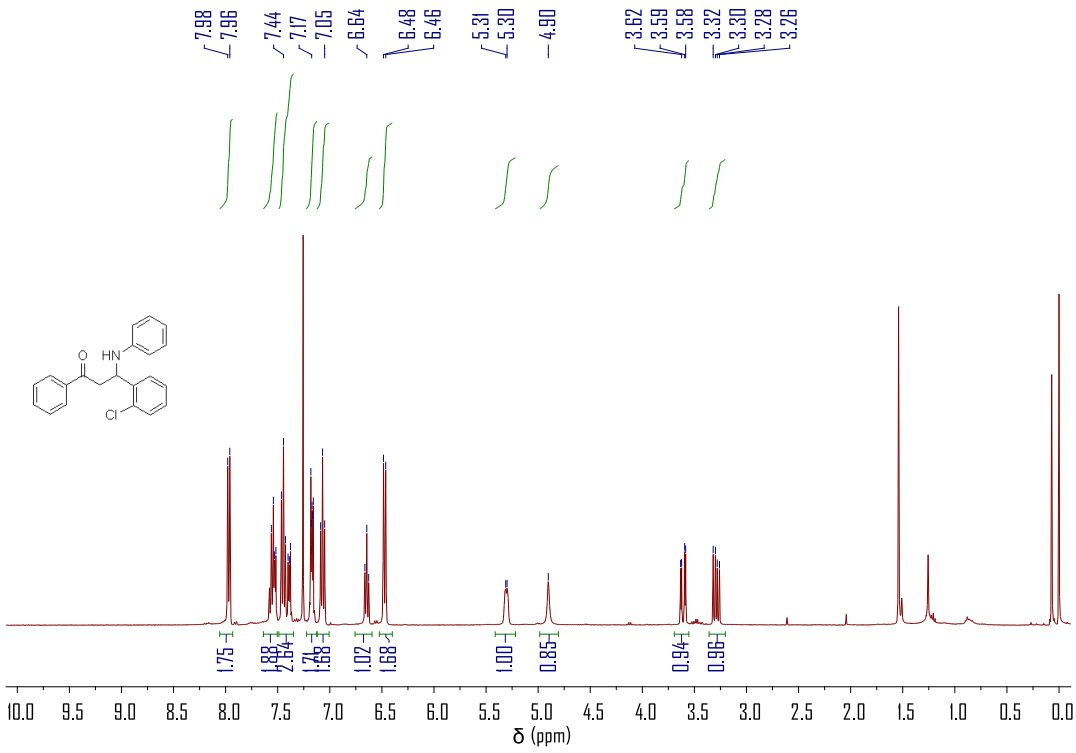
146.74
133.56
128.97
127.86
118.09
113.89
54.21
46.11
O
HN
Cl
δ (ppm)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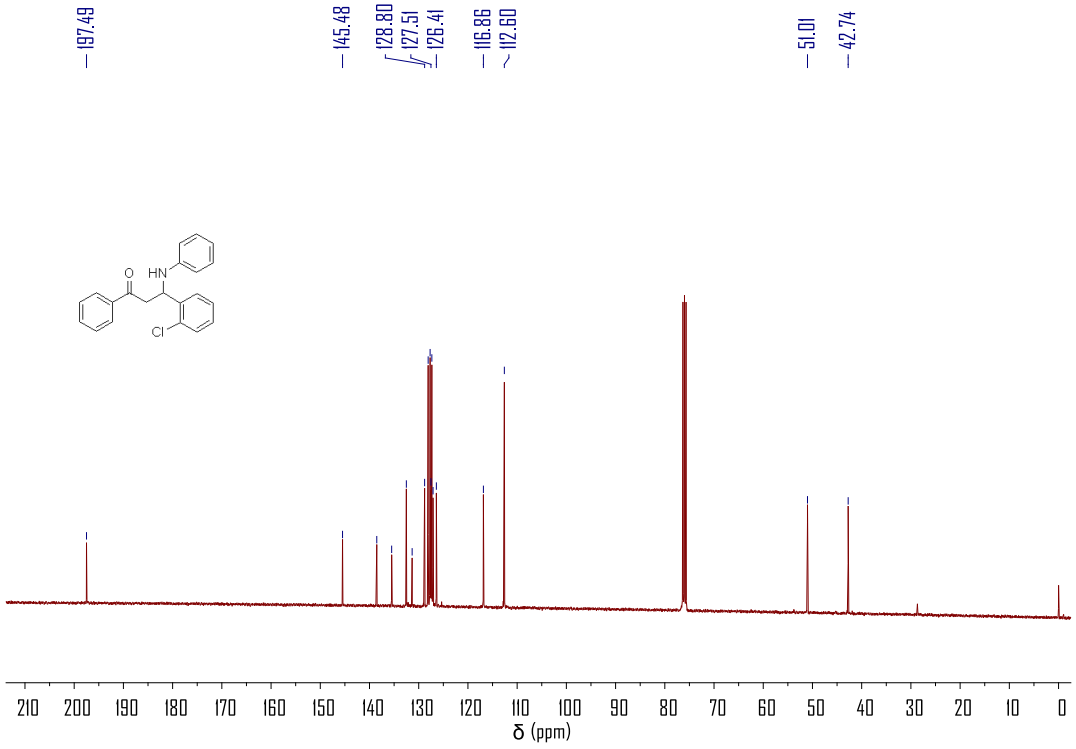
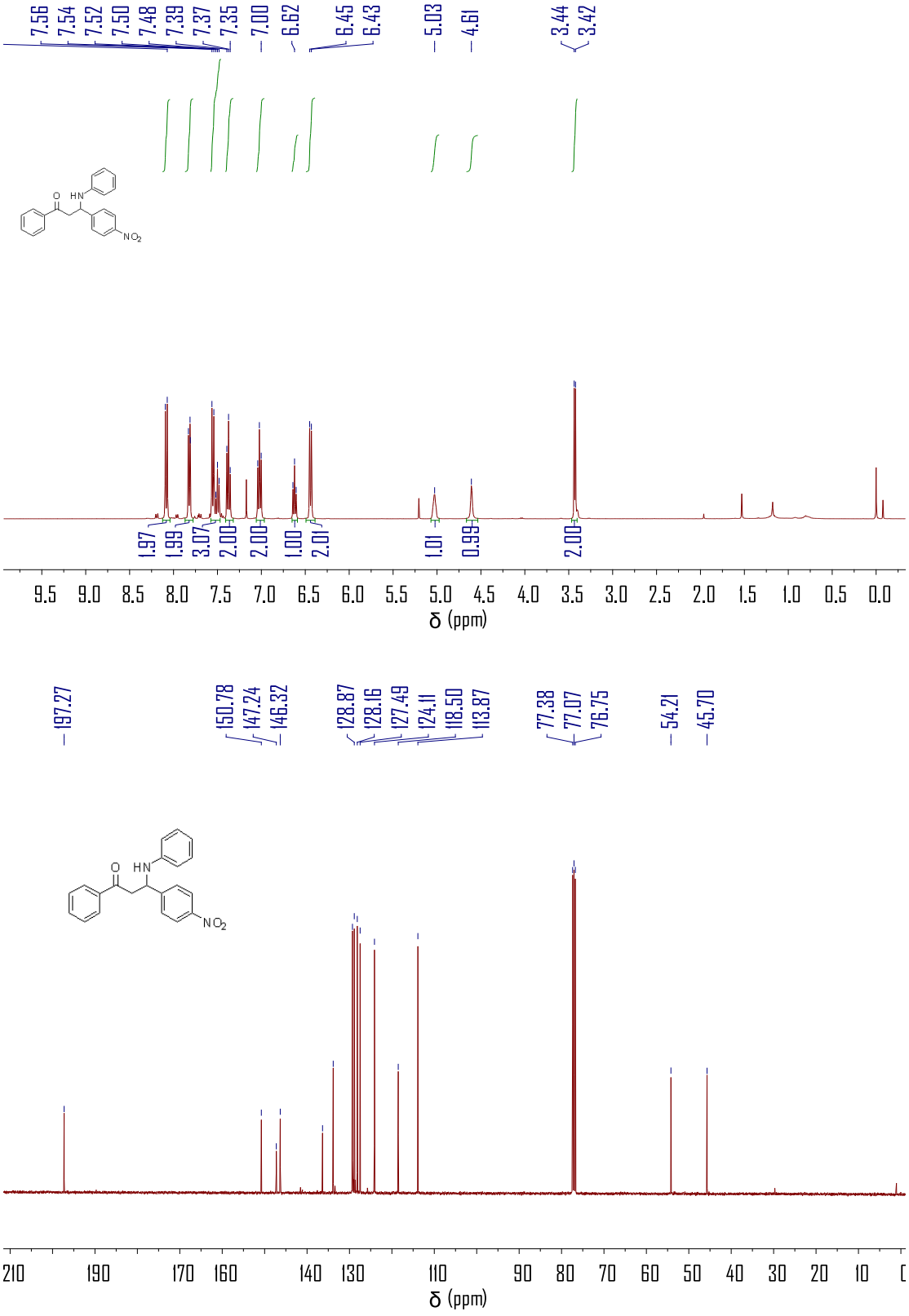
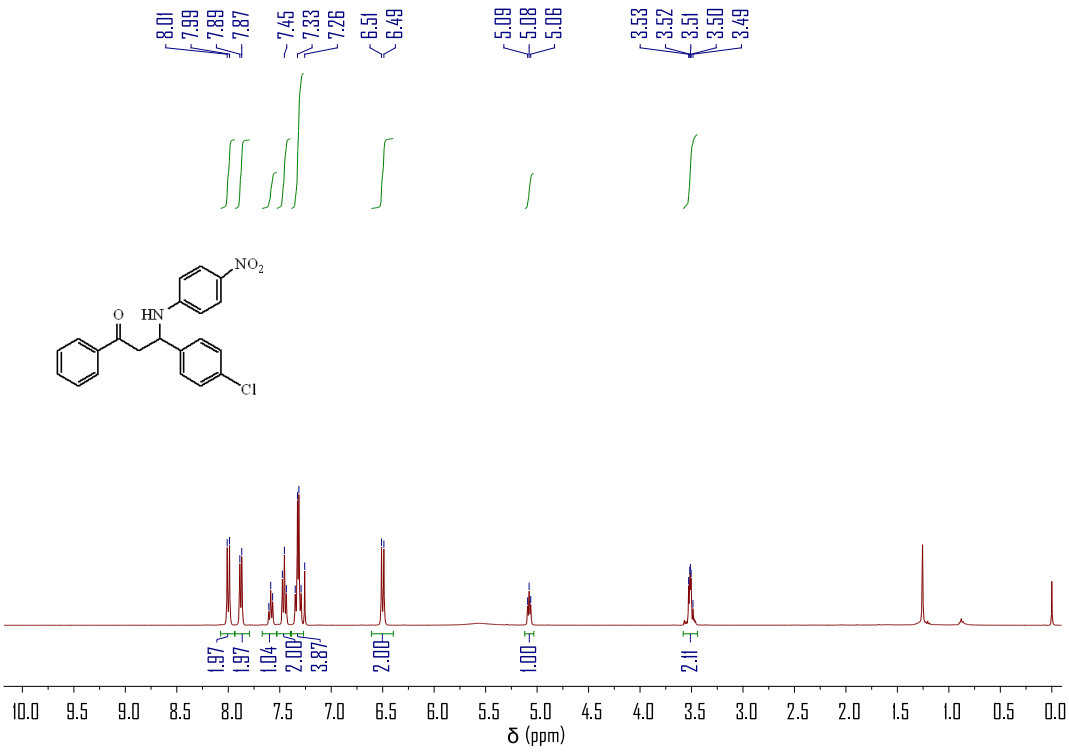
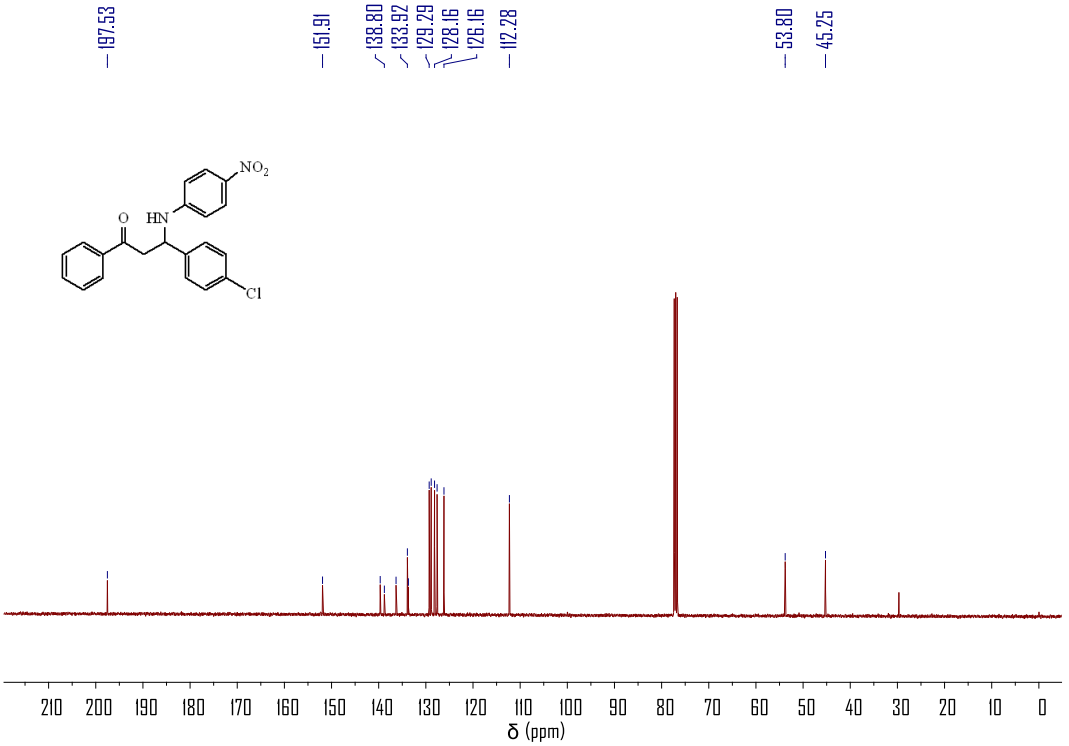
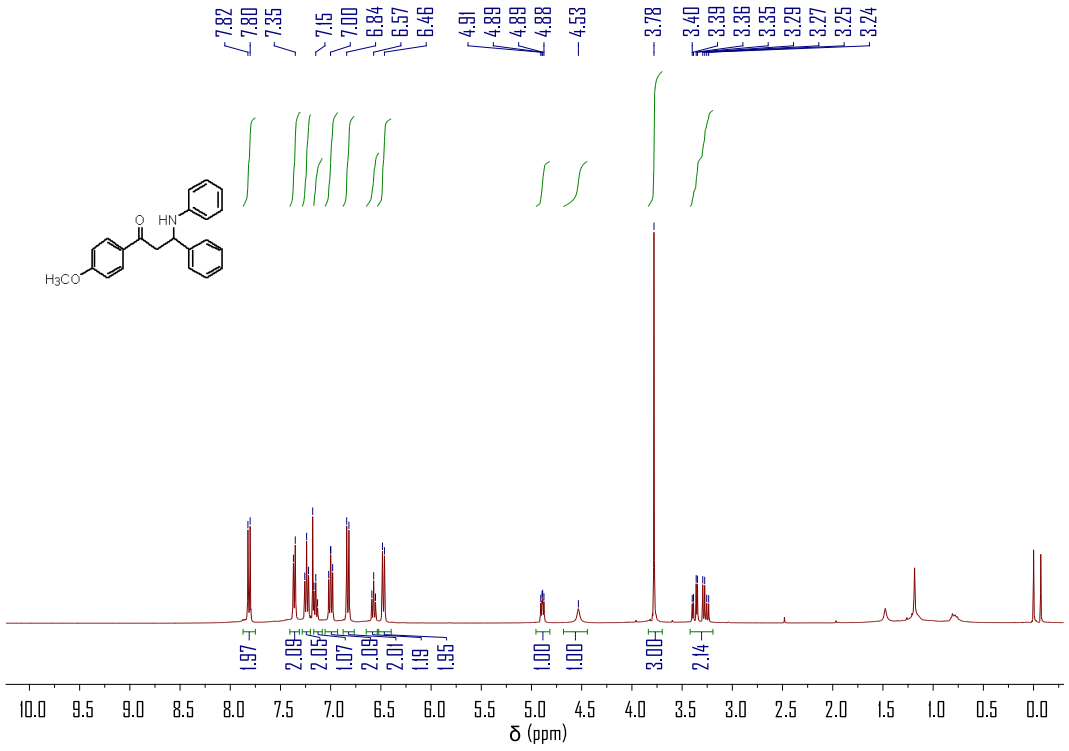
7.96
7.44
7.17
7.05
6.64
6.48
6.46
5.31
5.30
4.90
3.62
3.59
3.58
3.32
3.30
3.28
3.26
O
HN
Cl
1.75
1.88
2.84
1.71
1.68
1.02
1.68
1.00
0.85
0.94
0.96
δ (ppm)

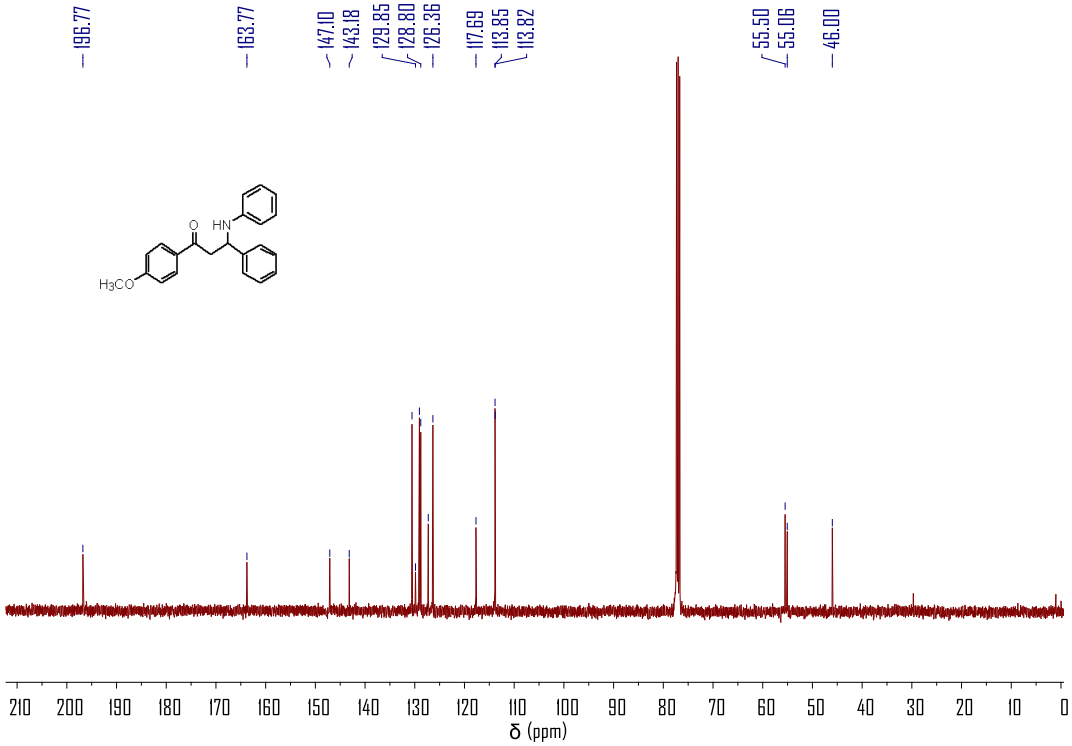

197.49
145.48
128.80
127.51
126.41
116.86
112.60
51.01
42.74
O
HN
Cl
δ (ppm)

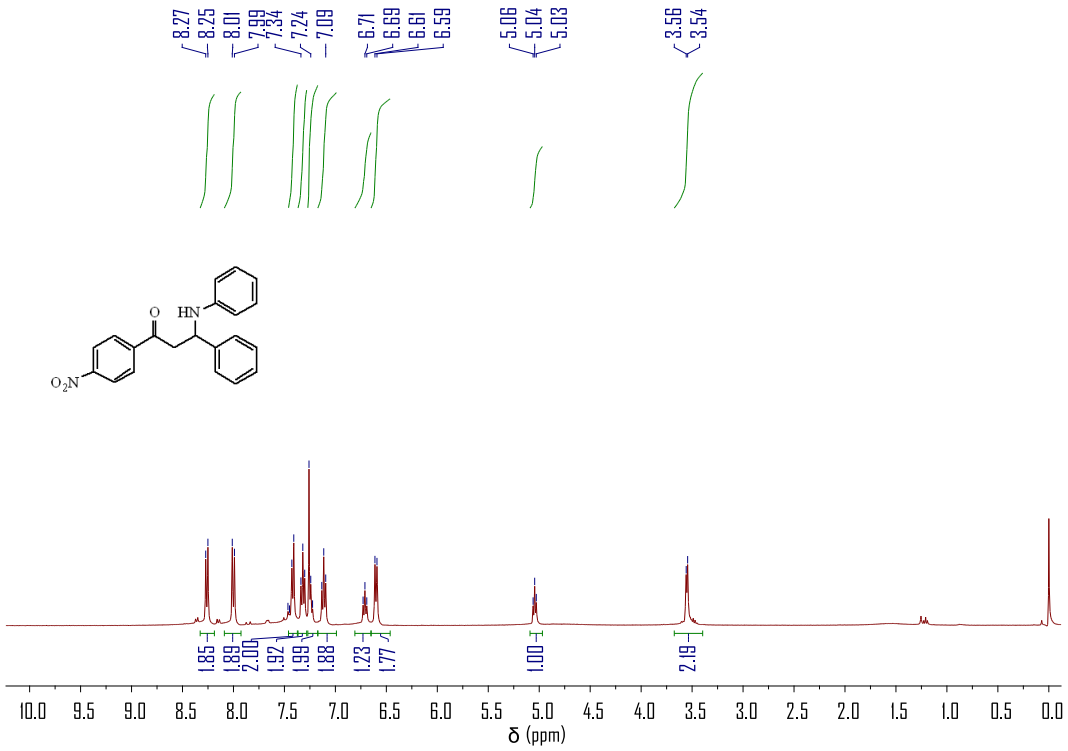

7.56
7.54
7.52
7.50
7.48
7.39
7.37
7.35
7.00
6.62
6.45
6.43
5.03
4.61
3.44
3.42
O
HN
NO2
1.97
1.99
3.07
2.00
2.00
1.00
2.01
1.01
0.99
2.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
δ (ppm)
197.27
150.78
147.24
146.32
128.87
128.16
127.49
124.11
118.50
113.87
77.38
77.07
76.75
54.21
45.70
O
HN
NO2
210 190 170 160 140 130 110 90 80 70 60 50 40 30 20 10
δ (ppm)

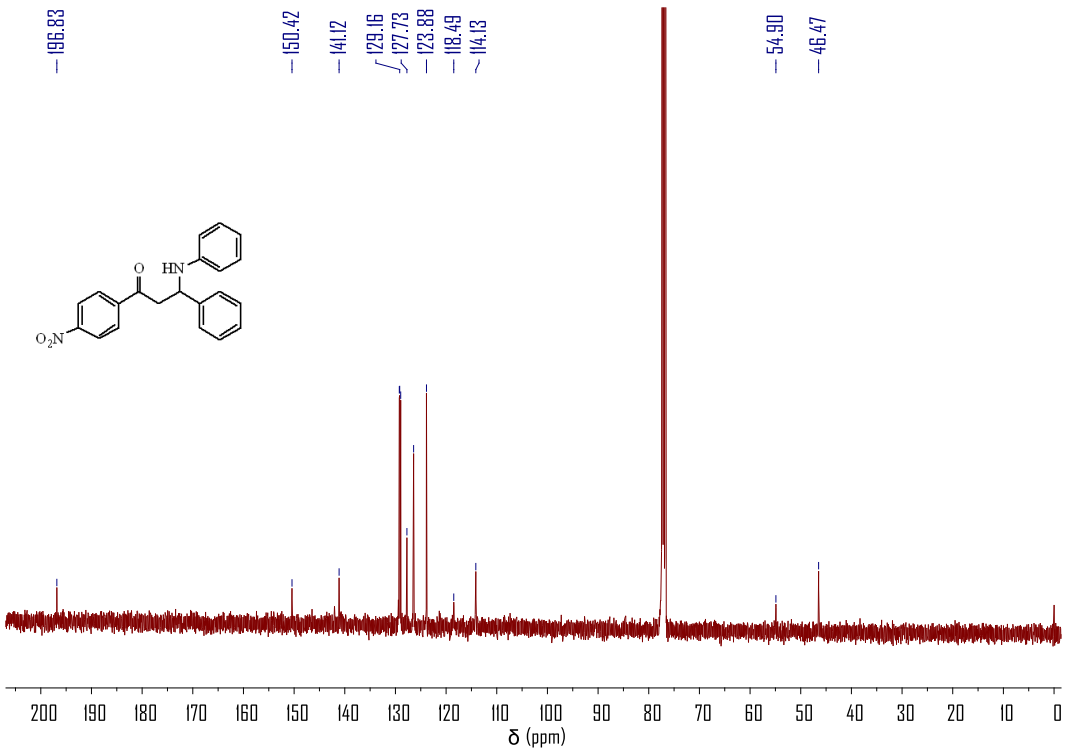

8.01
7.99
7.89
7.87
7.45
7.33
7.26
6.51
6.49
5.09
5.08
5.06
3.53
3.52
3.51
3.50
3.49
NO2
O
HN
Cl
1.97
1.97
1.04
2.00
3.87
2.00
1.00
2.11
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
δ (ppm)

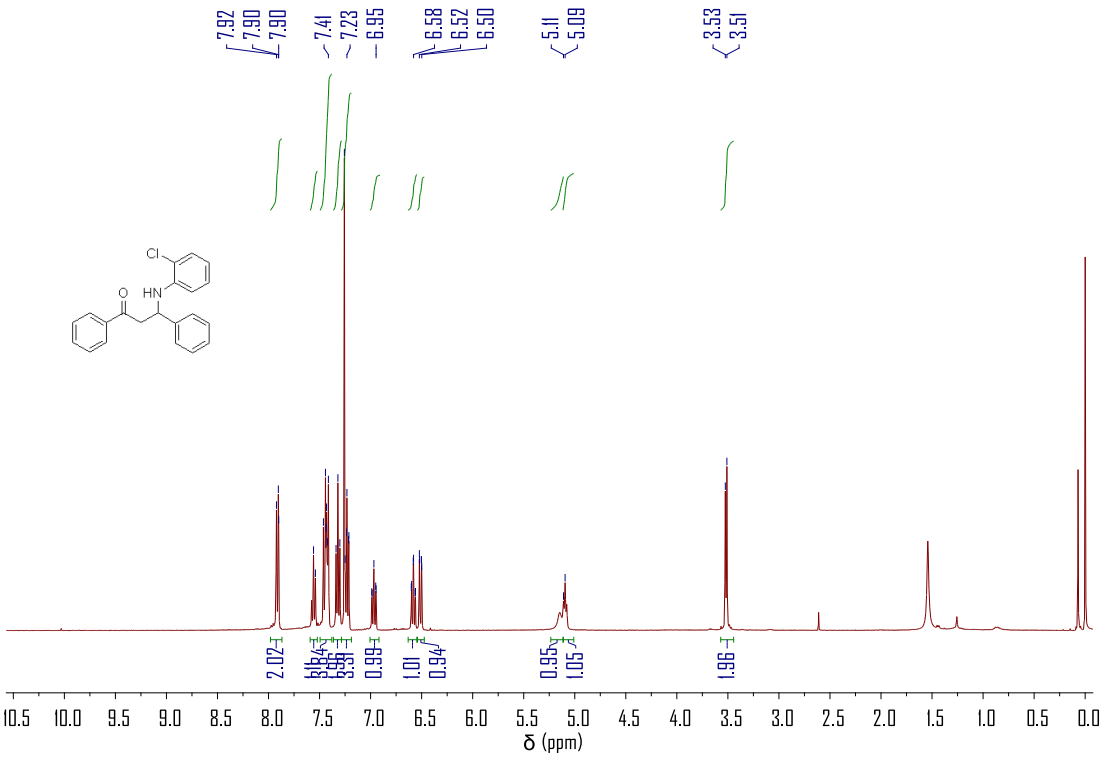

197.53
151.91
138.80
133.92
129.29
128.16
126.16
112.28
53.80
45.25
NO2
O
HN
Cl
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
δ (ppm)

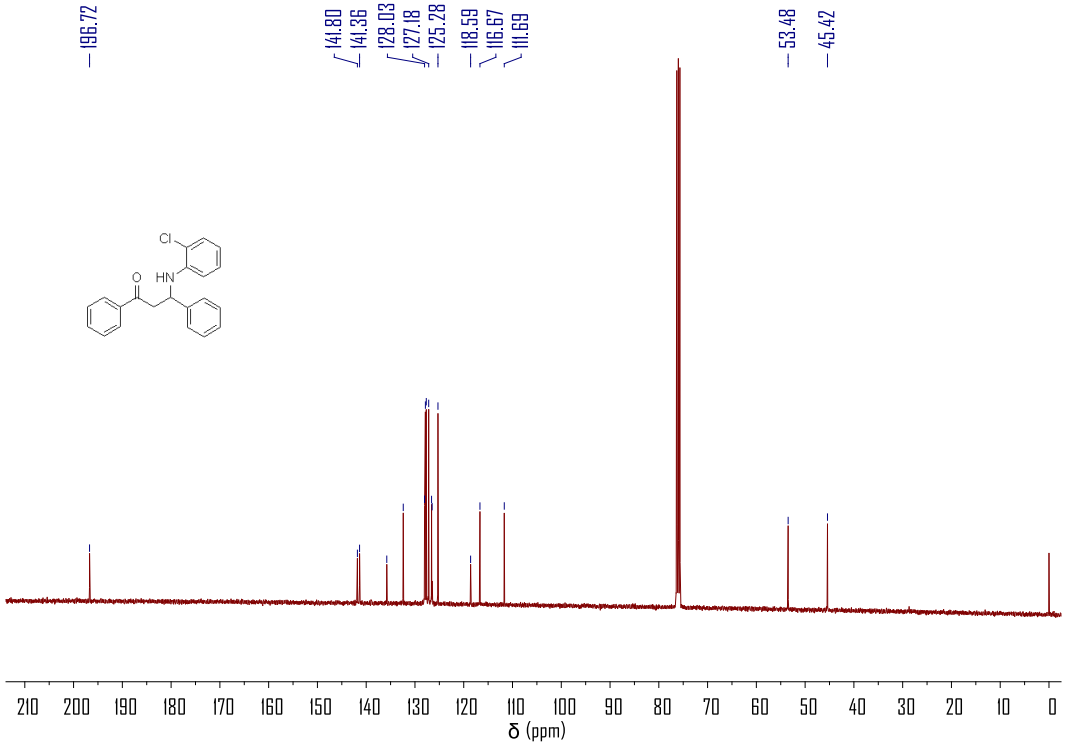

7.82
7.80
7.35
7.15
7.00
6.84
6.57
6.46
4.91
4.89
4.89
4.88
4.53
3.78
3.40
3.39
3.36
3.35
3.29
3.27
3.25
3.24
O
HN
H3CO
1.97
2.09
2.05
1.07
2.09
2.01
1.19
1.95
1.00
1.00
3.00
2.14
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
δ (ppm)


196.77
163.77
147.10
143.18
129.85
128.80
126.36
117.69
113.85
113.82
55.50
55.06
46.00
O
HN
H3CO
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
δ (ppm)


8.27
8.25
8.01
7.99
7.34
7.24
7.09
6.71
6.69
6.61
6.59
5.06
5.04
5.03
3.56
3.54
O
HN
O2N
1.85
1.89
2.00
1.92
1.99
1.88
1.23
1.77
1.00
2.19
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
δ (ppm)


196.83
150.42
141.12
129.16
127.73
123.88
118.49
114.13
54.90
46.47
O
HN
O2N
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
δ (ppm)


7.92
7.90
7.90
7.41
7.23
6.95
6.58
6.52
6.50
5.11
5.09
3.53
3.51
Cl
HN
O
2.02
0.99
1.01
0.94
0.95
1.05
1.96
δ (ppm)


196.72
141.80
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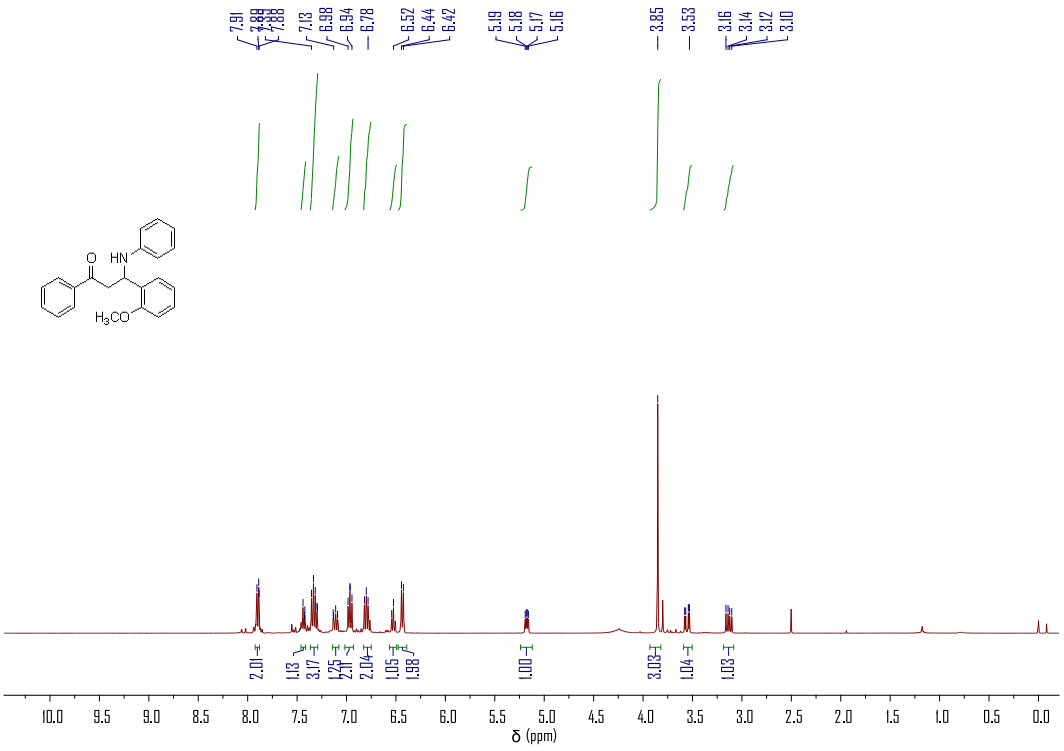
128.03
127.18
125.28
118.59
116.67
111.69
53.48
45.42
Cl
HN
O
δ (ppm)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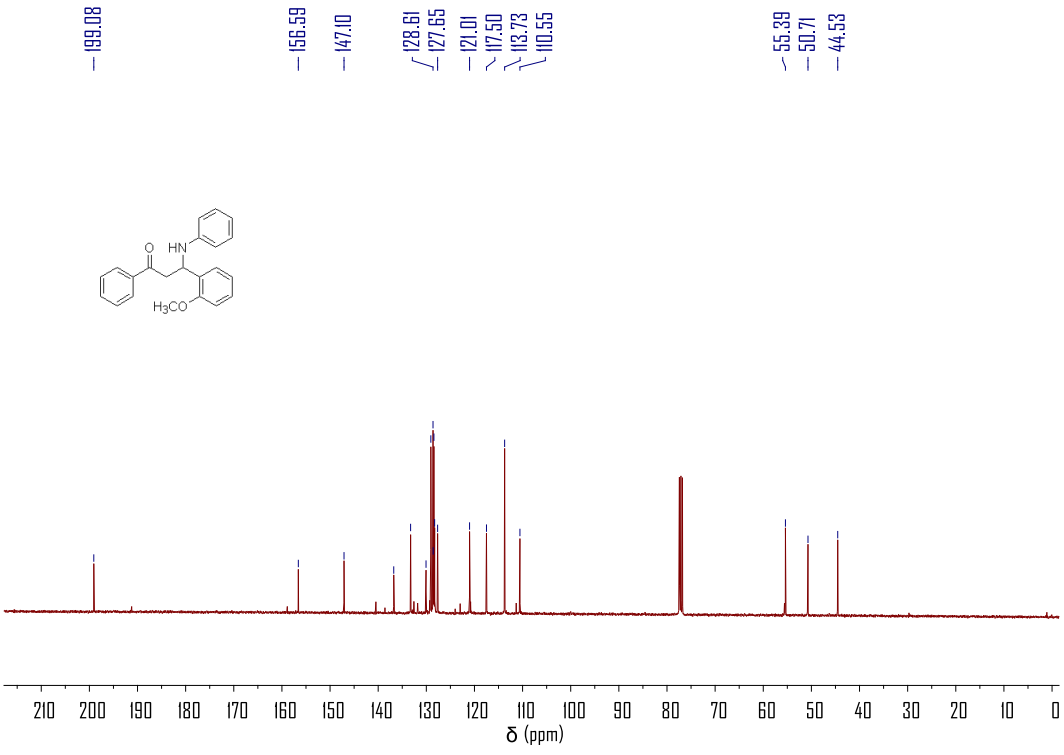
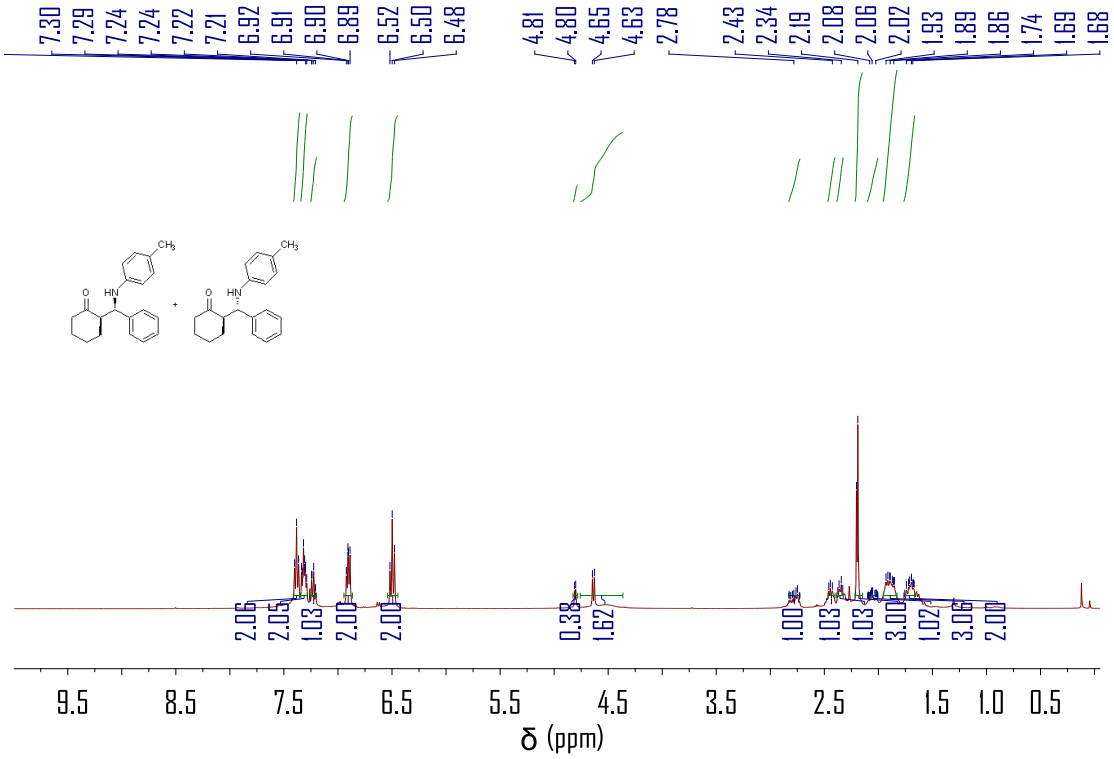
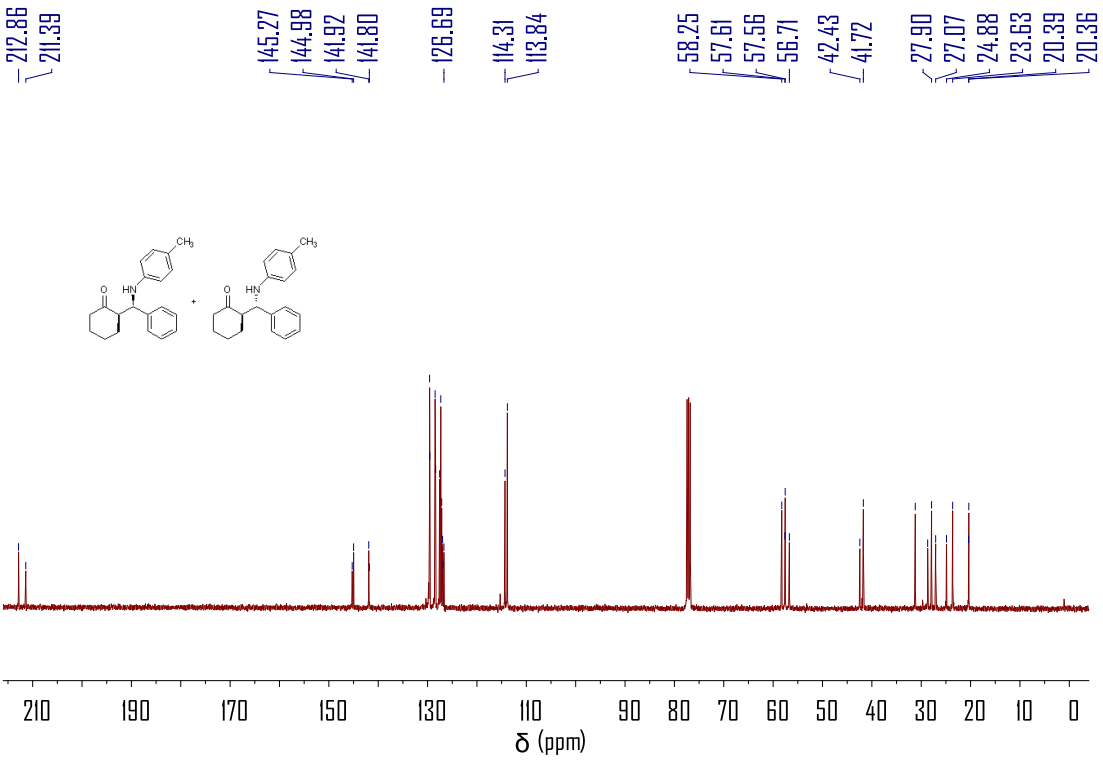
7.89
7.88
7.13
6.98
6.94
6.78
6.52
6.44
6.42
5.19
5.18
5.17
5.16
3.85
3.53
3.16
3.14
3.12
3.10
O
HN
H3CO
2.01
1.13
3.17
1.25
2.11
2.04
1.05
1.98
1.00
3.03
1.04
1.03
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
δ (ppm)


199.08
156.59
147.10
128.61
127.65
121.01
117.50
113.73
110.55
55.39
50.71
44.53
O
HN
H3CO
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
δ (ppm)


7.30
7.29
7.24
7.24
7.22
7.21
6.92
6.91
6.90
6.89
6.52
6.50
6.48
4.81
4.80
4.65
4.63
2.78
2.43
2.34
2.19
2.08
2.06
2.02
1.93
1.89
1.86
1.74
1.69
1.68
2.06
2.05
1.03
2.00
2.00
0.38
1.62
1.00
1.03
1.03
3.00
1.02
3.06
2.00
9.5
8.5
7.5
6.5
5.5
4.5
3.5
2.5
1.5
1.0
0.5
δ (ppm)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144.98
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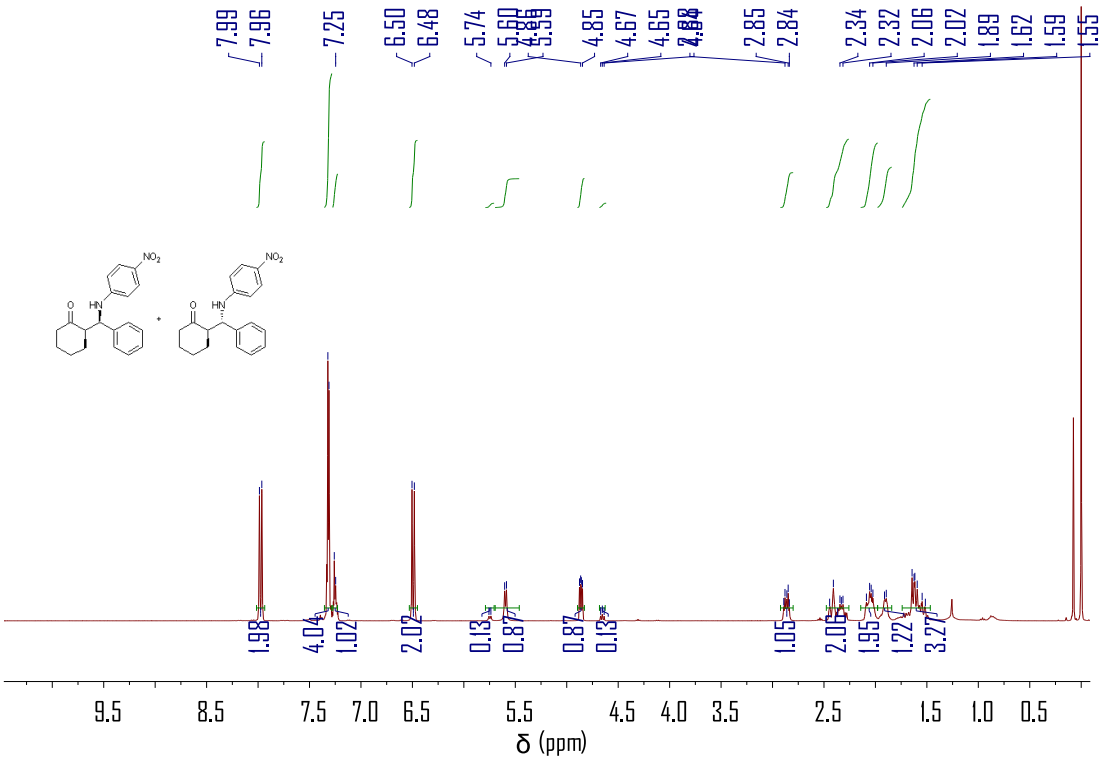
141.80
126.69
114.31
113.84
58.25
57.61
57.56
56.71
42.43
41.72
27.90
27.07
24.88
23.63
20.39
20.36
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
δ (ppm)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6.50
6.48
5.74
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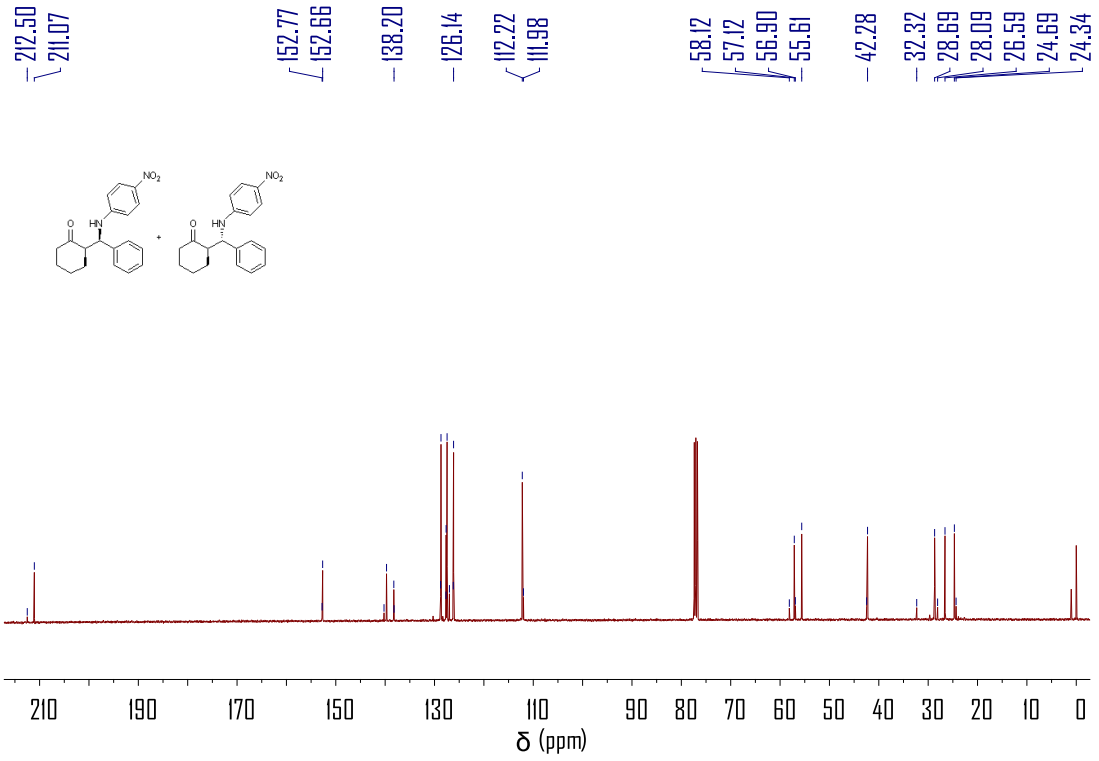
4.67
4.65
2.85
2.84
2.34
2.32
2.06
2.02
1.89
1.62
1.59
1.55
1.98
4.04
1.02
2.02
0.13
0.87
0.87
0.13
1.05
2.06
1.95
1.22
3.27
9.5
8.5
7.5
7.0
6.5
5.5
4.5
4.0
3.5
2.5
1.5
1.0
0.5
δ (ppm)


212.50
211.07
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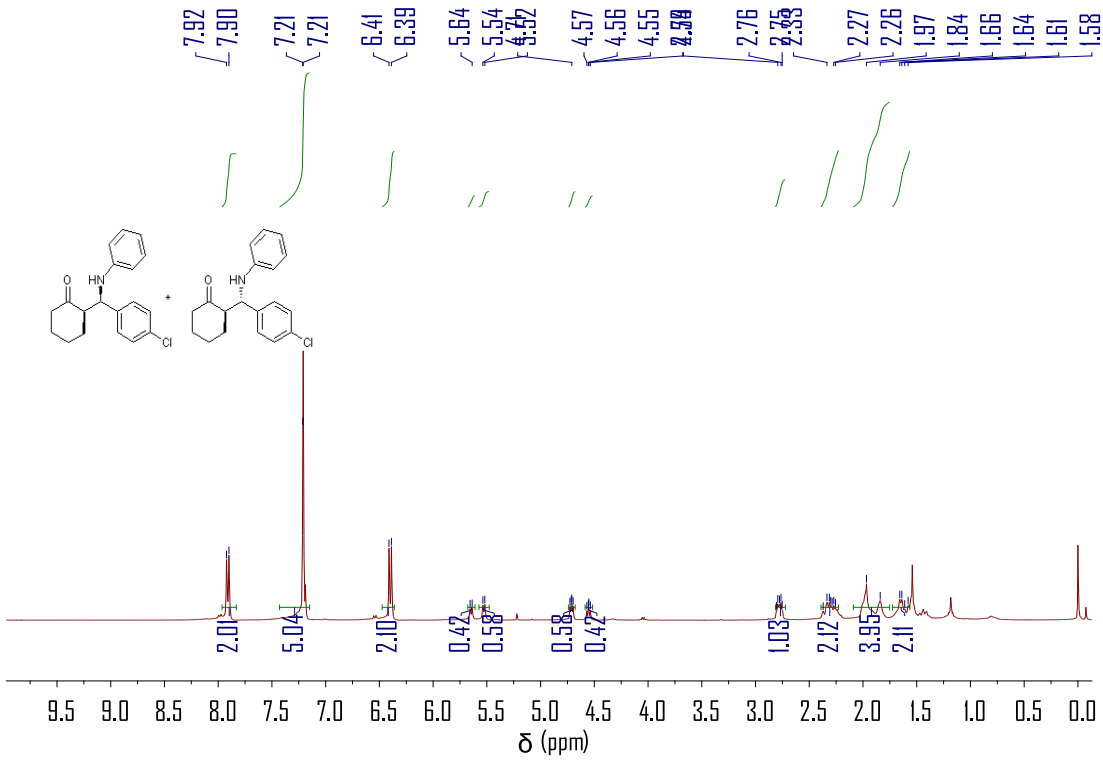
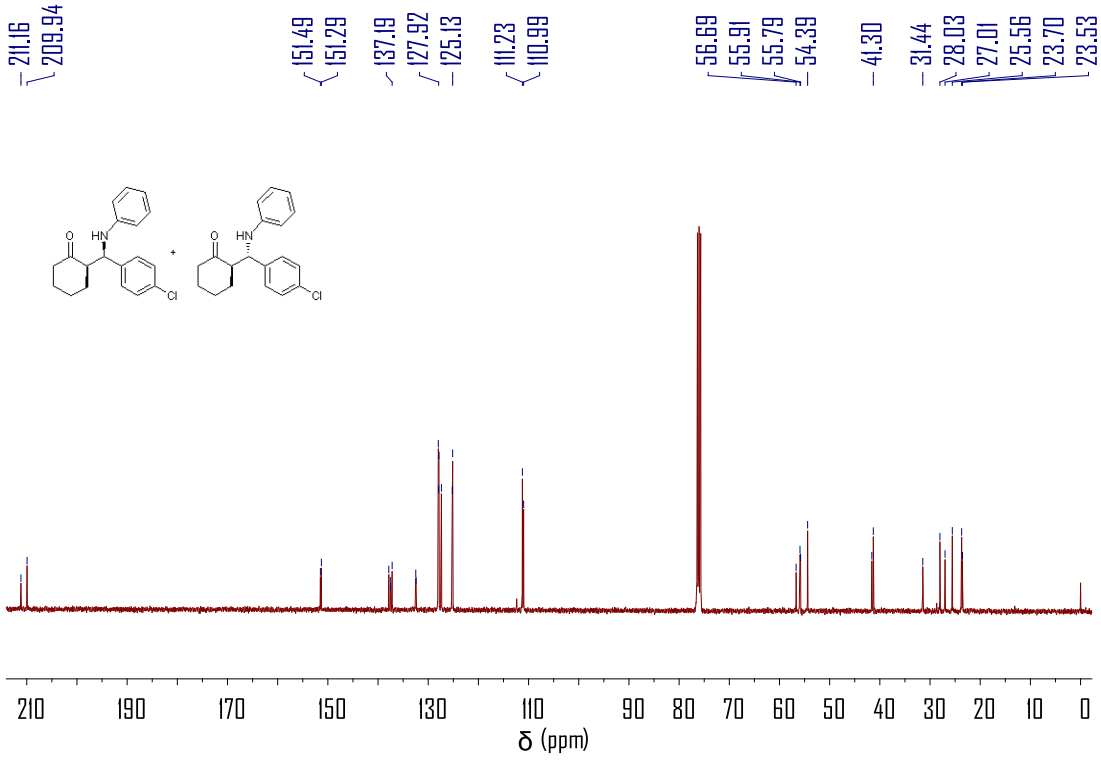
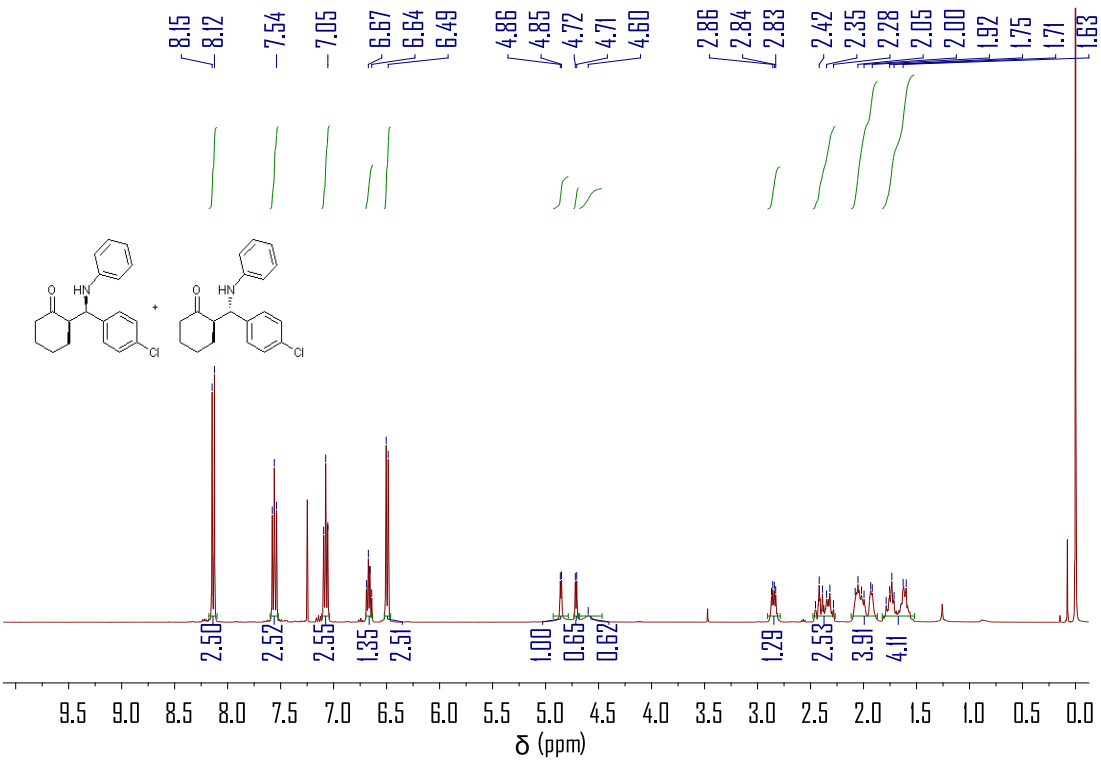
152.66
138.20
126.14
112.22
111.98
58.12
57.12
56.90
55.61
42.28
32.32
28.69
28.09
26.59
24.69
24.34
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
δ (ppm)


7.92
7.90
7.21
7.21
6.41
6.39
5.64
5.54
4.57
4.56
4.55
2.76
2.27
2.26
1.97
1.84
1.66
1.64
1.61
1.58
2.01
5.04
2.10
0.42
0.58
0.58
0.42
1.03
2.12
3.95
2.11
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
δ (ppm)


211.16
209.94
151.49
151.29
137.19
127.92
125.13
111.23
110.99
56.69
55.91
55.79
54.39
41.30
31.44
28.03
27.01
25.56
23.70
23.53
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10 0
δ (ppm)


8.15
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7.54
7.05
6.67
6.64
6.49
4.86
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4.72
4.71
4.60
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2.84
2.83
2.42
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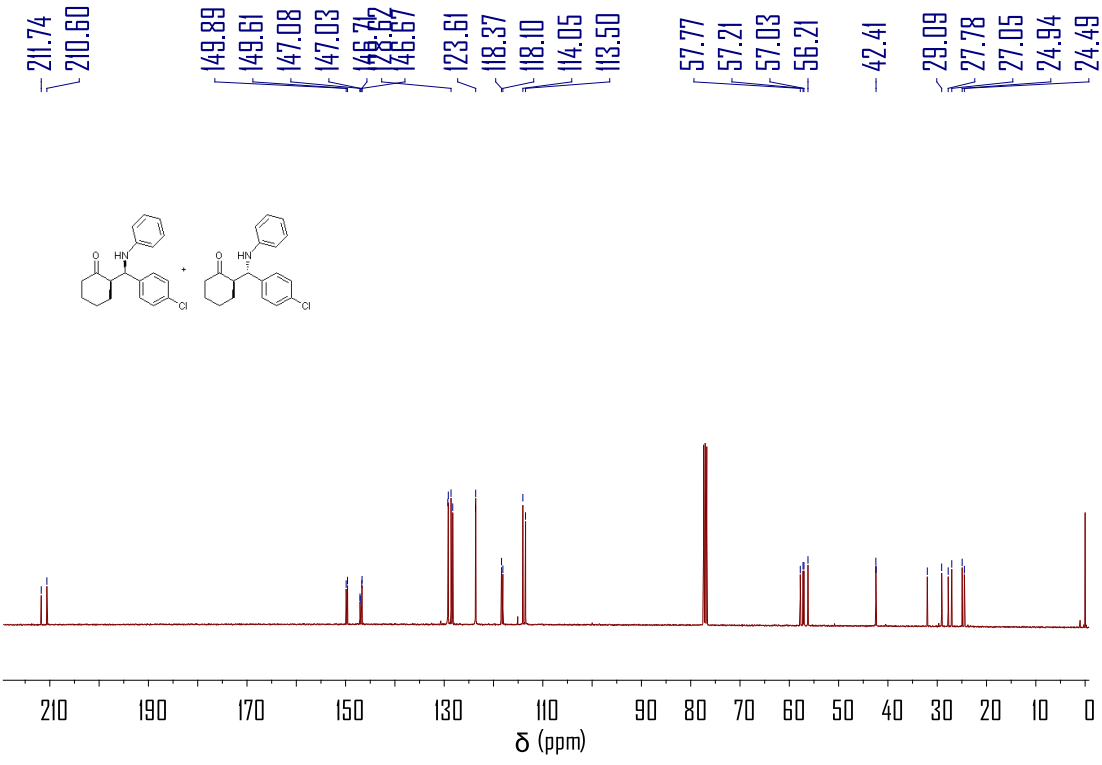
2.28
2.05
2.00
1.92
1.75
1.71
1.63
2.50
2.52
2.55
1.35
2.51
1.00
0.65
0.62
1.29
2.53
3.91
4.11
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
δ (ppm)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147.03
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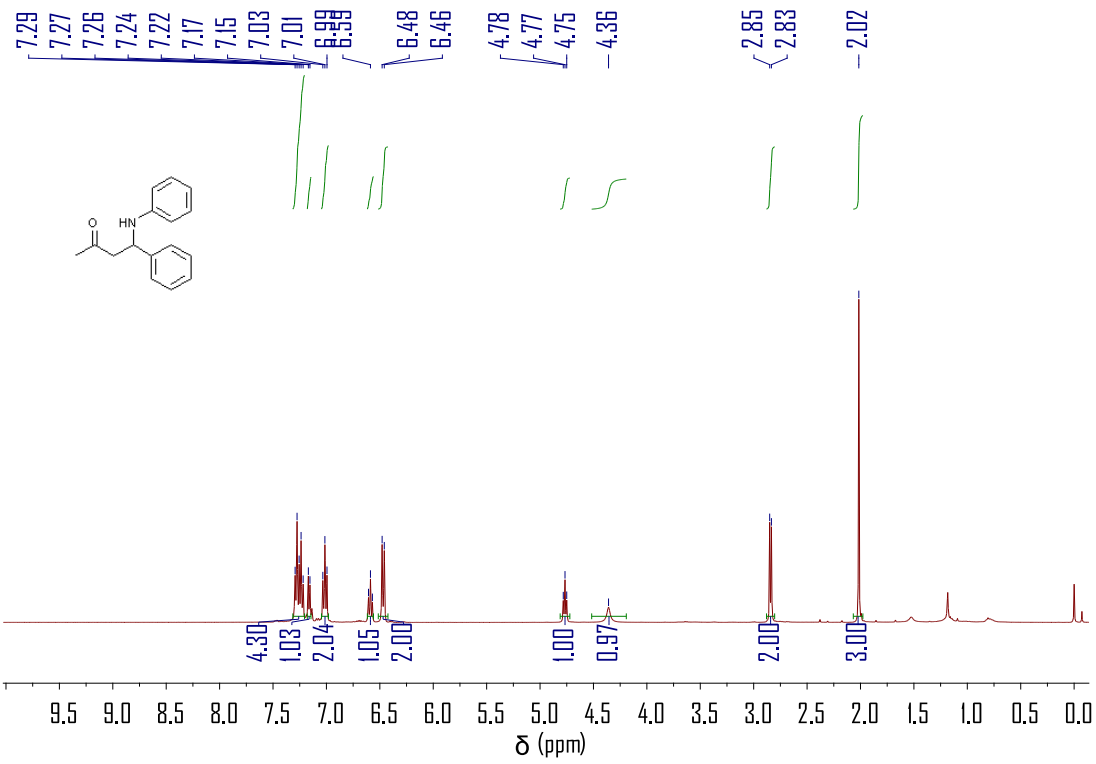
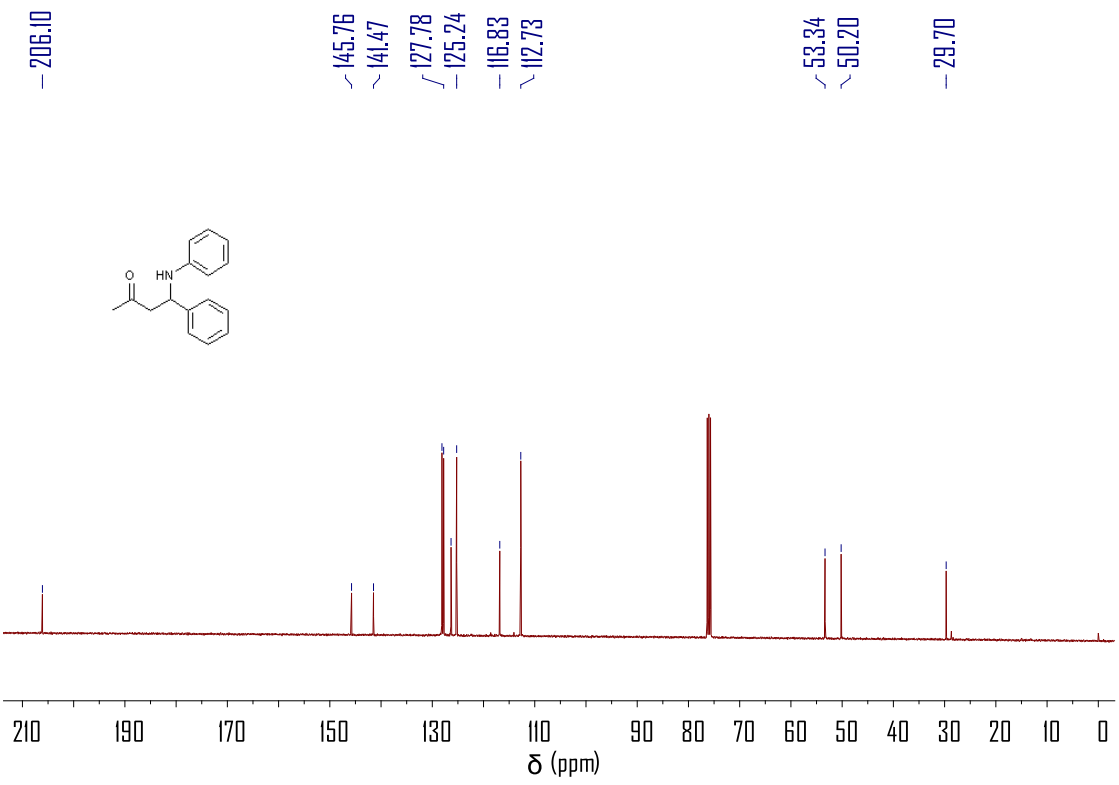
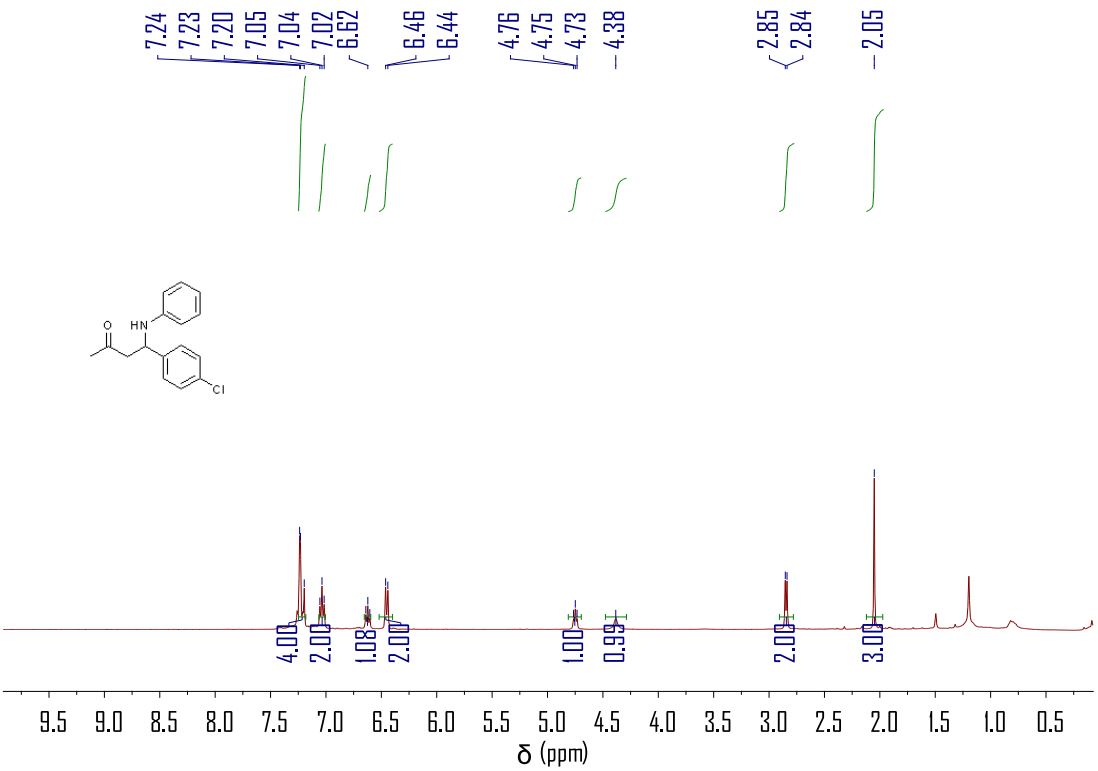
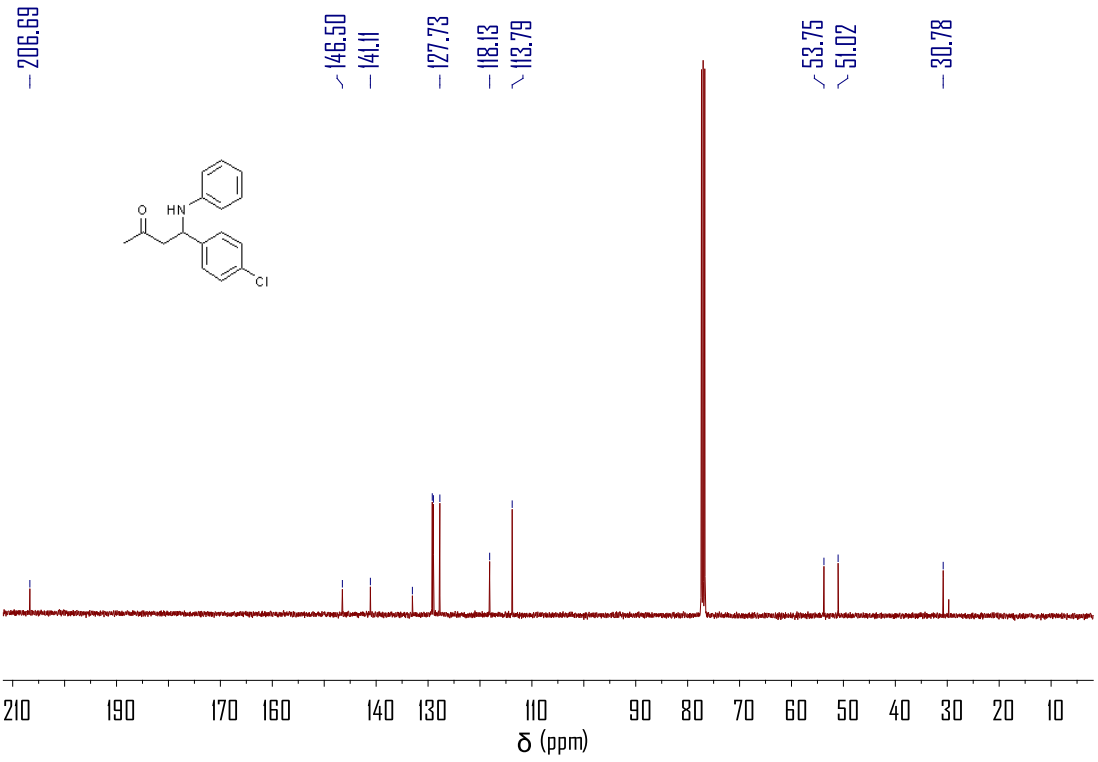
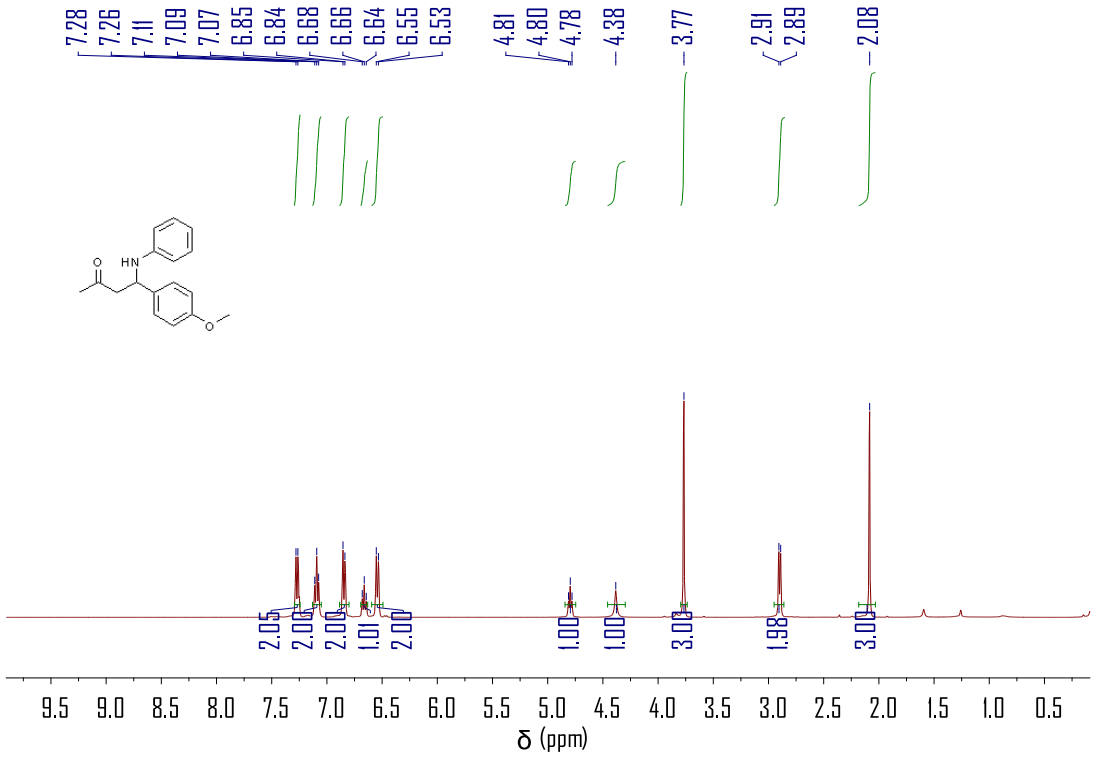
118.37
118.10
114.05
113.50
57.77
57.21
57.03
56.21
42.41
29.09
27.78
27.05
24.94
24.49
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10 0
δ (ppm)

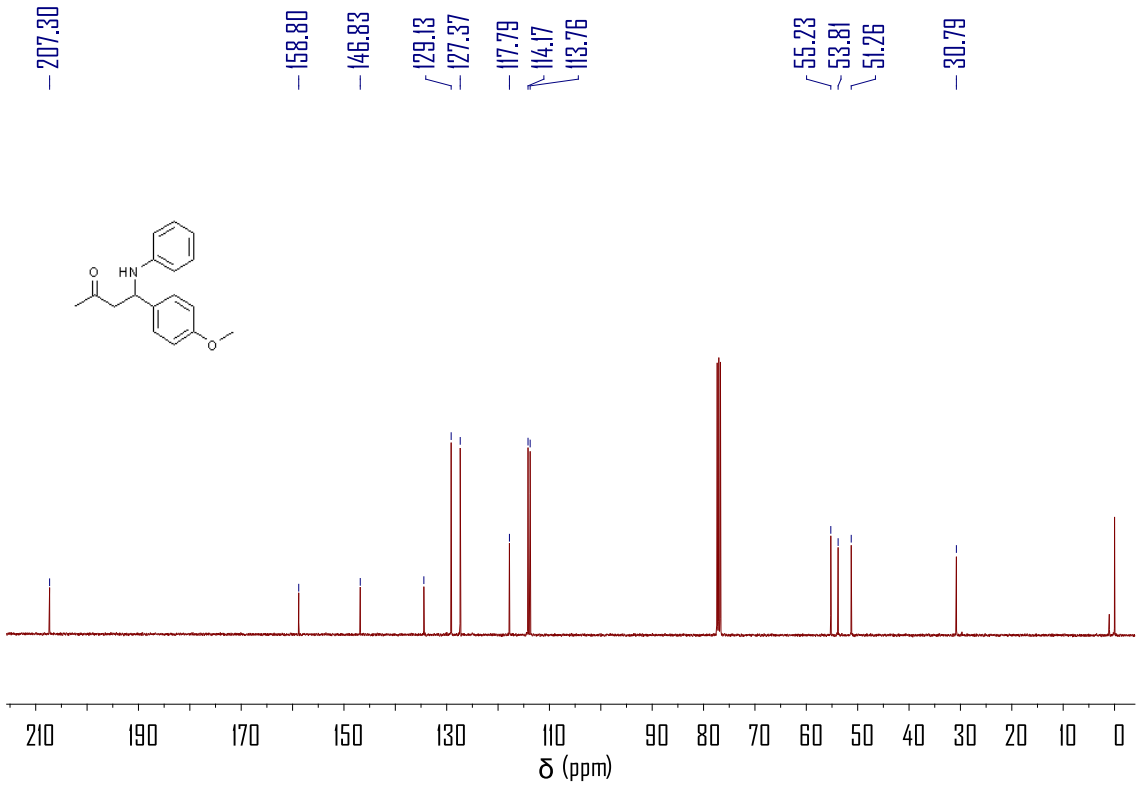

7.29
7.27
7.26
7.24
7.22
7.17
7.15
7.03
7.01
6.48
6.46
4.78
4.77
4.75
4.36
2.85
2.83
2.02
O
HN
4.30
1.03
2.04
1.05
2.00
1.00
0.97
2.00
3.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
δ (ppm)

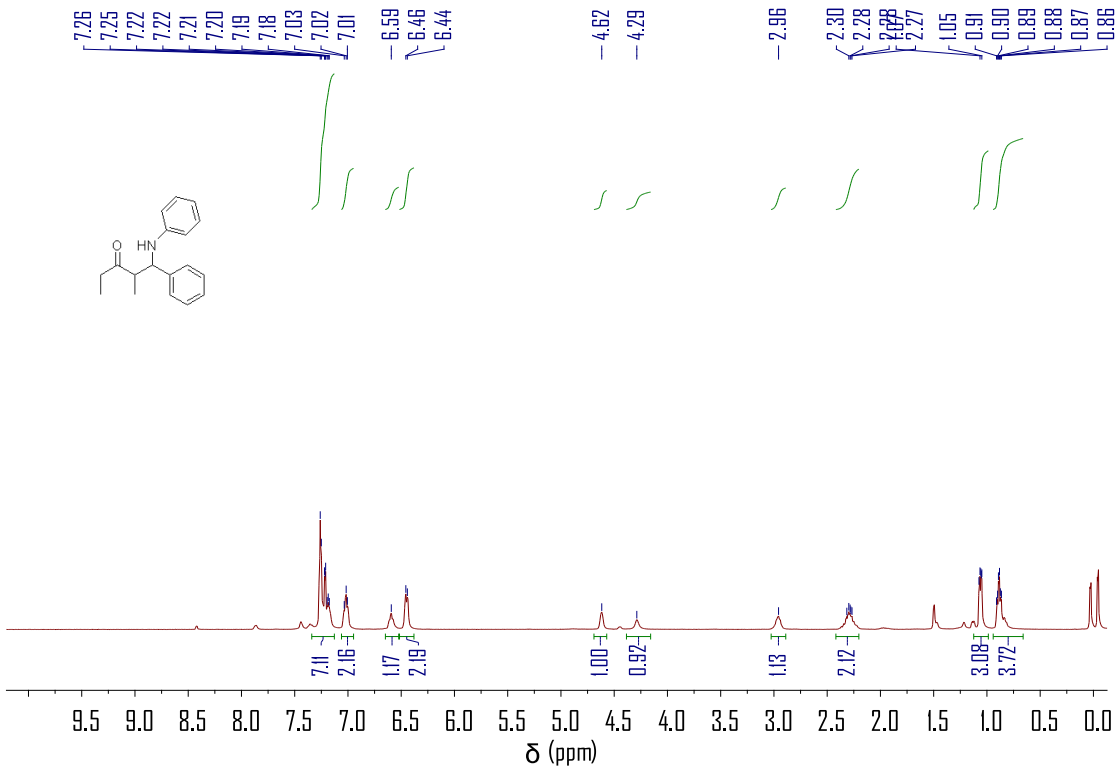

206.10
145.76
141.47
127.78
125.24
116.83
112.73
53.34
50.20
29.70
O
HN
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10 0
δ (ppm)


7.24
7.23
7.20
7.05
7.04
7.02
6.62
6.46
6.44
4.76
4.75
4.73
4.38
2.85
2.84
2.05
O
HN
Cl
4.00
2.00
1.08
2.00
1.00
0.99
2.00
3.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
δ (ppm)


206.69
146.50
141.11
127.73
118.13
113.79
53.75
51.02
30.78
O
HN
Cl
210 190 170 160 140 130 110 90 80 70 60 50 40 30 20 10
δ (ppm)


7.28
7.26
7.11
7.09
7.07
6.85
6.84
6.68
6.66
6.64
6.55
6.53
4.81
4.80
4.78
4.38
3.77
2.91
2.89
2.08
HN
O
O
2.05
2.00
2.00
1.01
2.00
1.00
1.00
3.00
1.98
3.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
δ (ppm)


207.30
158.80
146.83
129.13
127.37
117.79
114.17
113.76
55.23
53.81
51.26
30.79
HN
O
O
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10 0
δ (ppm)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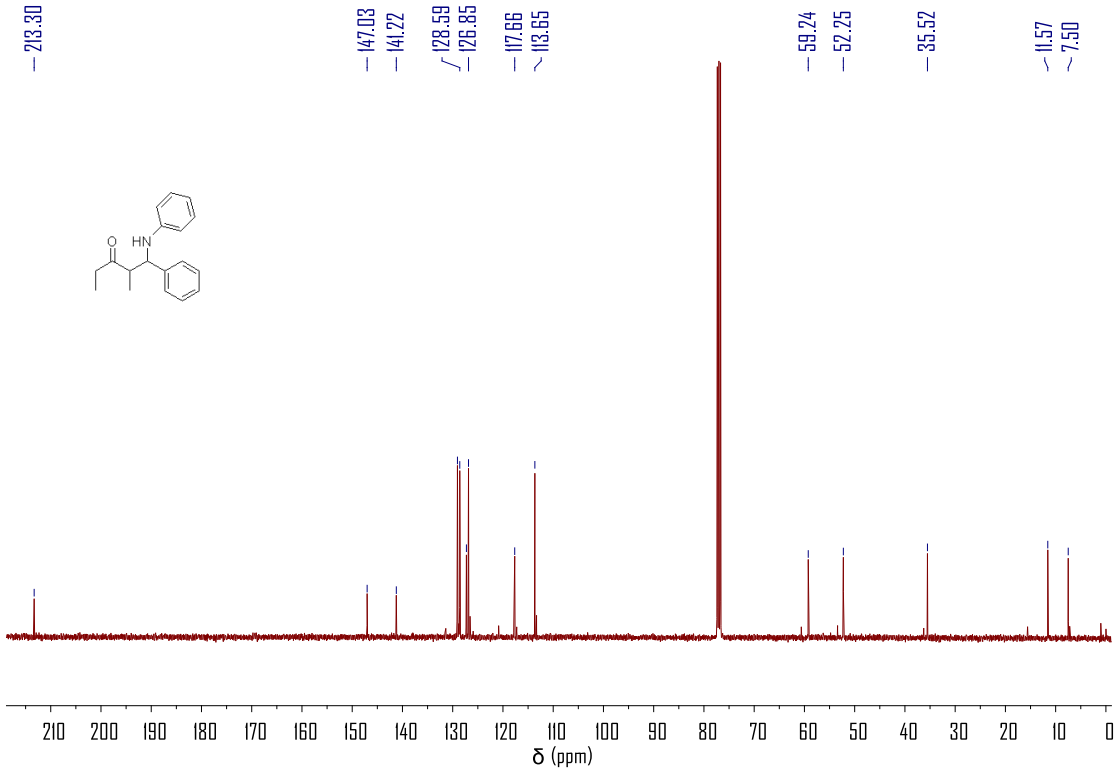
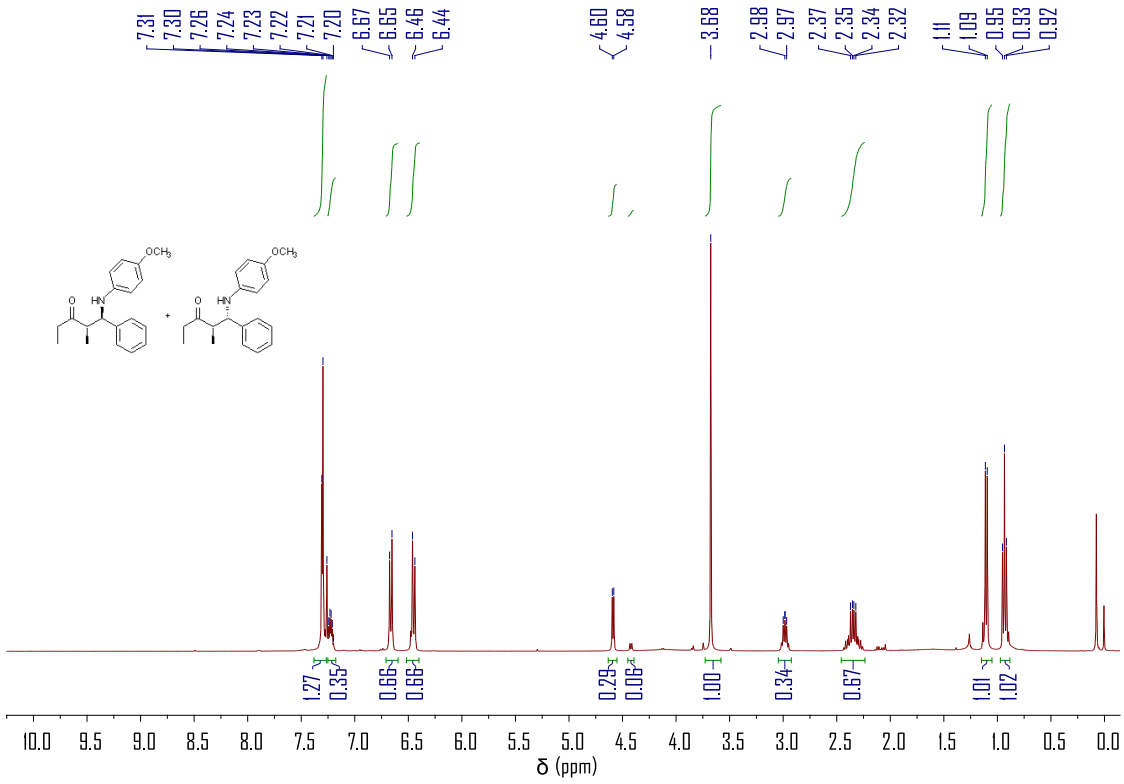
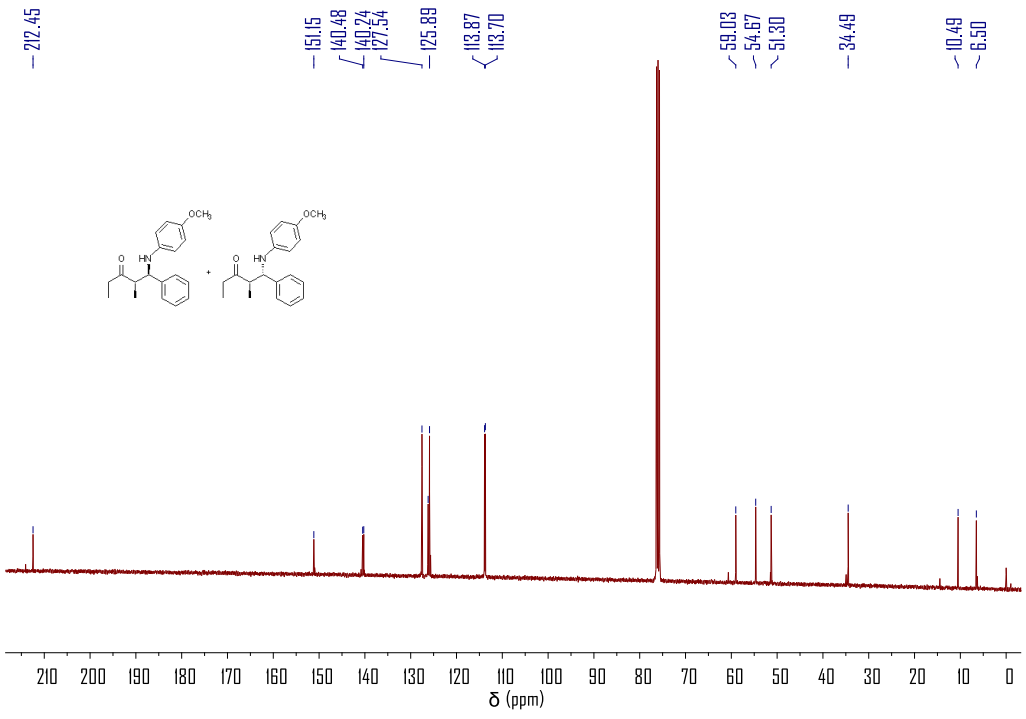
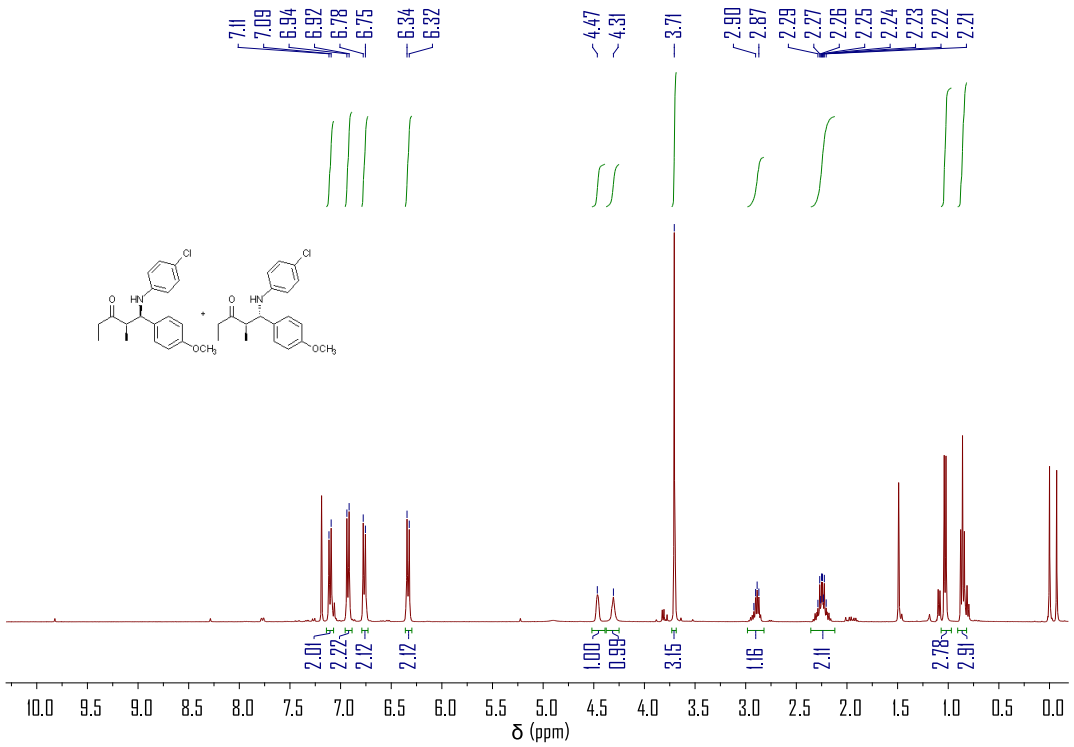
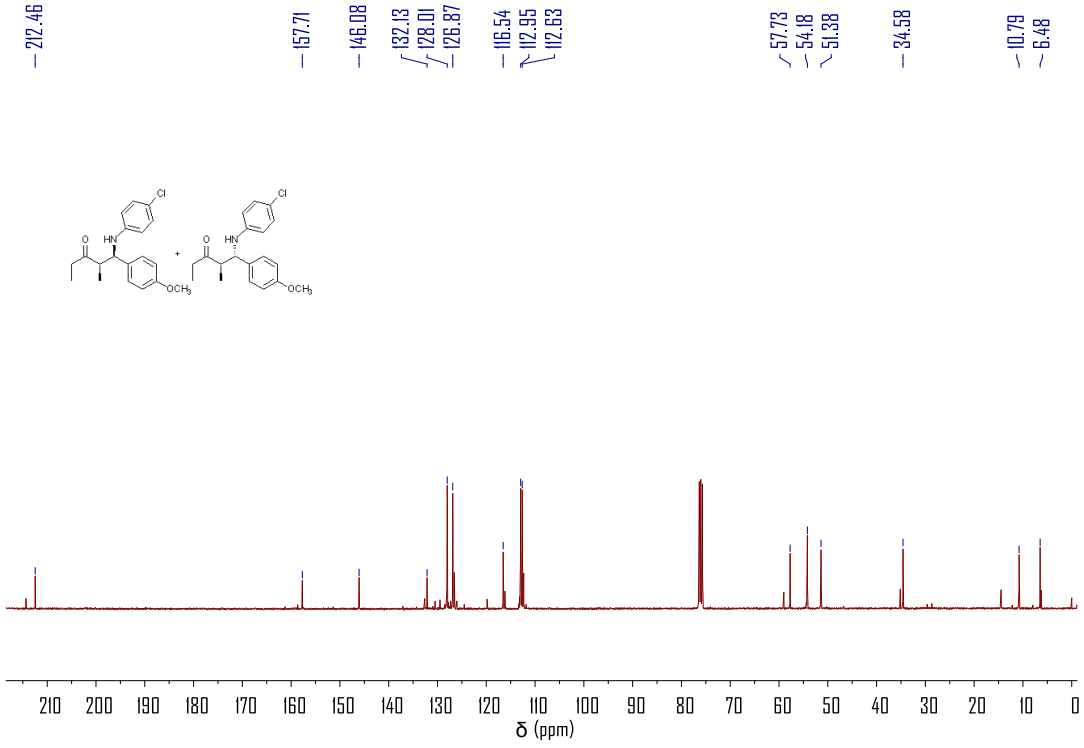
7.25
7.22
7.22
7.21
7.20
7.19
7.18
7.03
7.02
7.01
6.59
6.46
6.44
4.62
4.29
2.96
2.30
2.28
2.27
1.05
0.91
0.90
0.89
0.88
0.87
0.86
O
HN
7.11
2.16
1.17
2.19
1.00
0.92
1.13
2.12
3.08
3.72
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
δ (ppm)


213.30
147.03
141.22
128.59
126.85
117.66
113.65
59.24
52.25
35.52
11.57
7.50
O
HN
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
δ (ppm)


7.31
7.30
7.26
7.24
7.23
7.22
7.21
7.20
6.67
6.65
6.46
6.44
4.60
4.58
3.68
2.98
2.97
2.37
2.35
2.34
2.32
1.11
1.09
0.95
0.93
0.92
1.27
0.35
0.66
0.66
0.29
0.06
1.00
0.34
0.67
1.01
1.02
δ (ppm)


212.45
151.15
140.48
140.24
127.54
125.89
113.87
113.70
59.03
54.67
51.30
34.49
10.49
6.50
δ (ppm)


7.11
7.09
6.94
6.92
6.78
6.75
6.34
6.32
4.47
4.31
3.71
2.90
2.87
2.29
2.27
2.26
2.25
2.24
2.23
2.22
2.21
2.01
2.22
2.12
2.12
1.00
0.99
3.15
1.16
2.11
2.78
2.91
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
δ (ppm)


212.46
157.71
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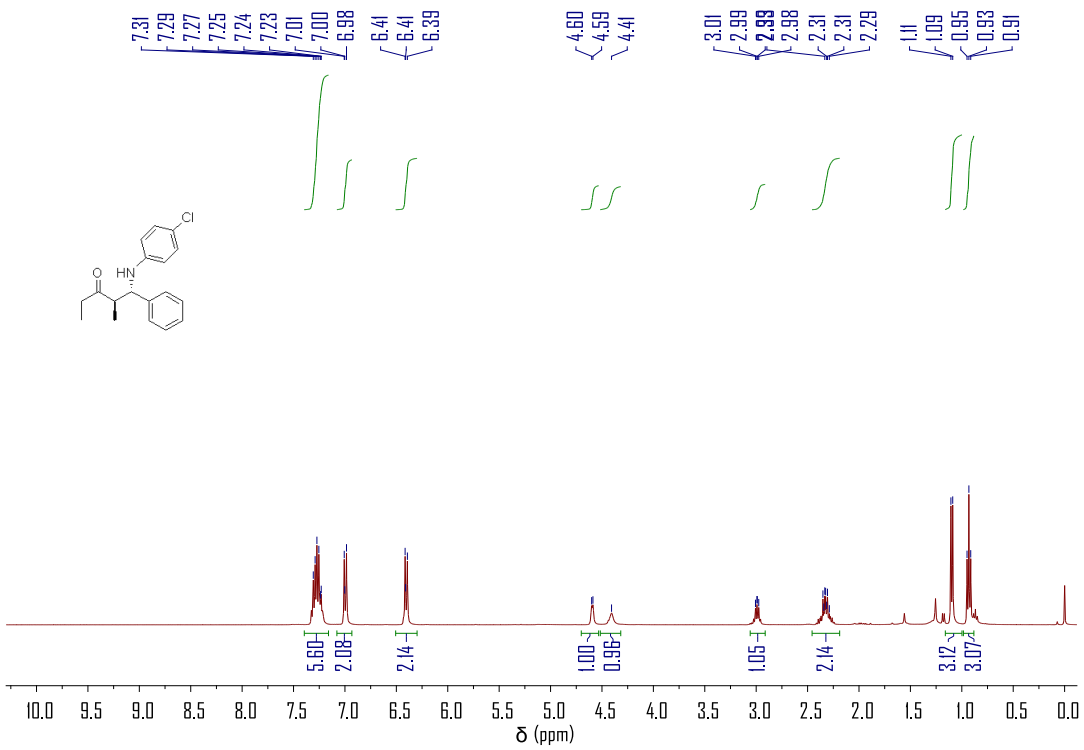
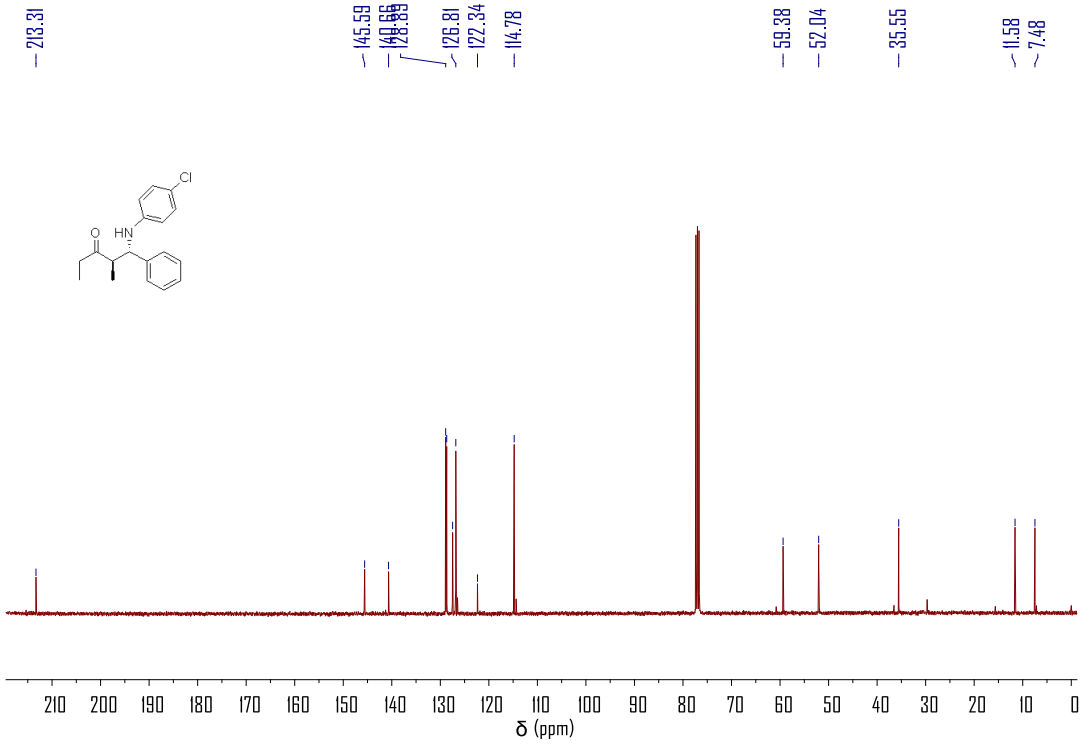
132.13
128.01
126.87
116.54
112.95
112.63
57.73
54.18
51.38
34.58
10.79
6.48
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
δ (ppm)


7.31
7.29
7.27
7.25
7.24
7.23
7.01
7.00
6.98
6.41
6.41
6.39
4.60
4.59
4.41
3.01
2.99
2.98
2.31
2.31
2.29
1.11
1.09
0.95
0.93
0.91
Cl
HN
O
5.60
2.08
2.14
1.00
0.96
1.05
2.14
3.12
3.07
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
δ (ppm)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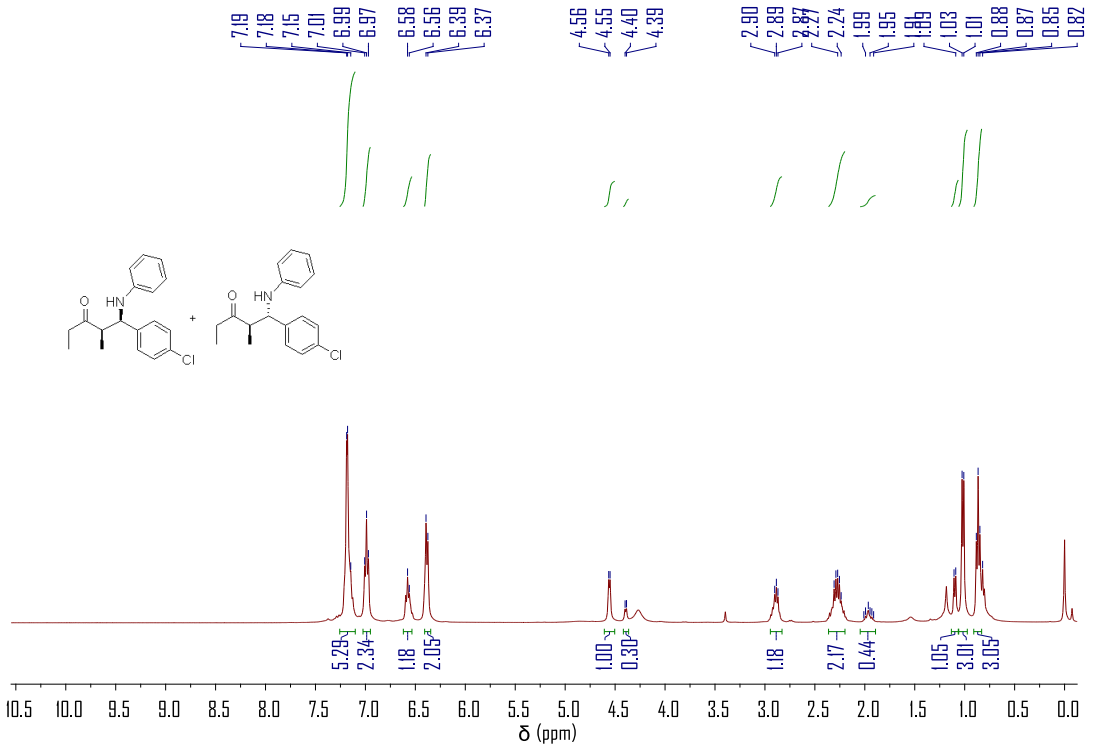
145.59
140.66
128.85
126.81
122.34
114.78
59.38
52.04
35.55
11.58
7.48
Cl
HN
O
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
δ (ppm)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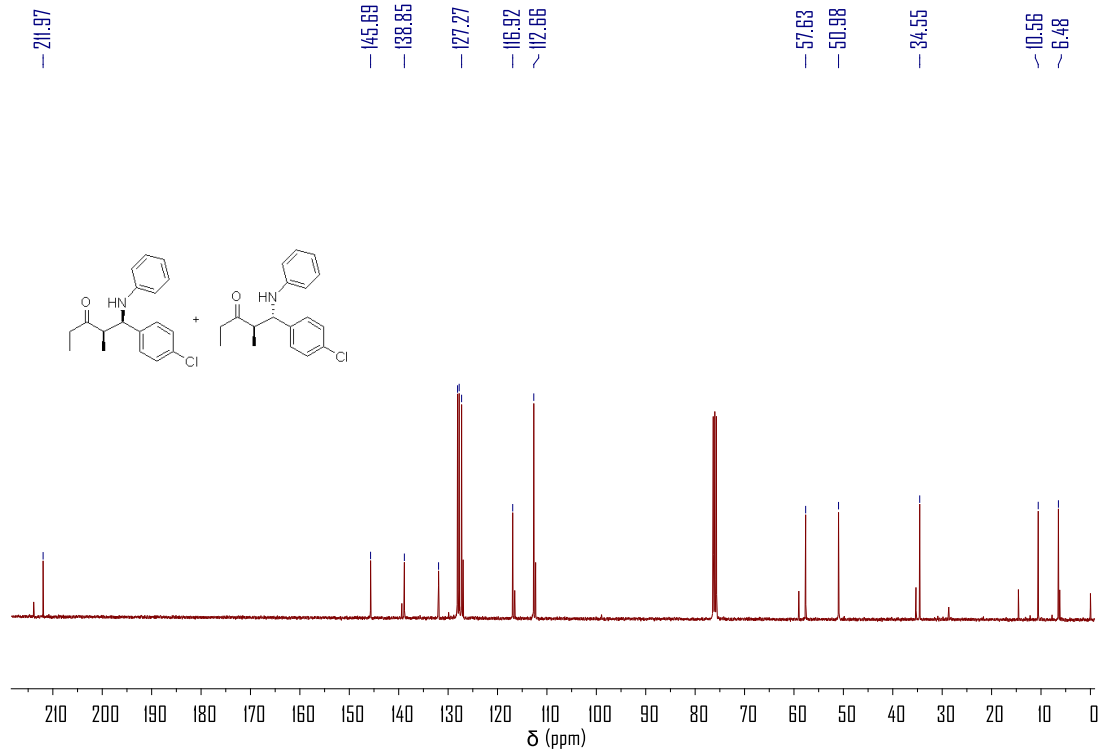
7.18
7.15
7.01
6.99
6.97
6.58
6.56
6.39
6.37
4.56
4.55
4.40
4.39
2.90
2.89
2.87
2.27
2.24
1.99
1.95
1.03
1.01
0.88
0.87
0.85
0.82
5.29
2.34
1.18
2.05
1.00
0.30
1.18
2.17
0.44
1.05
3.01
3.05
δ (ppm)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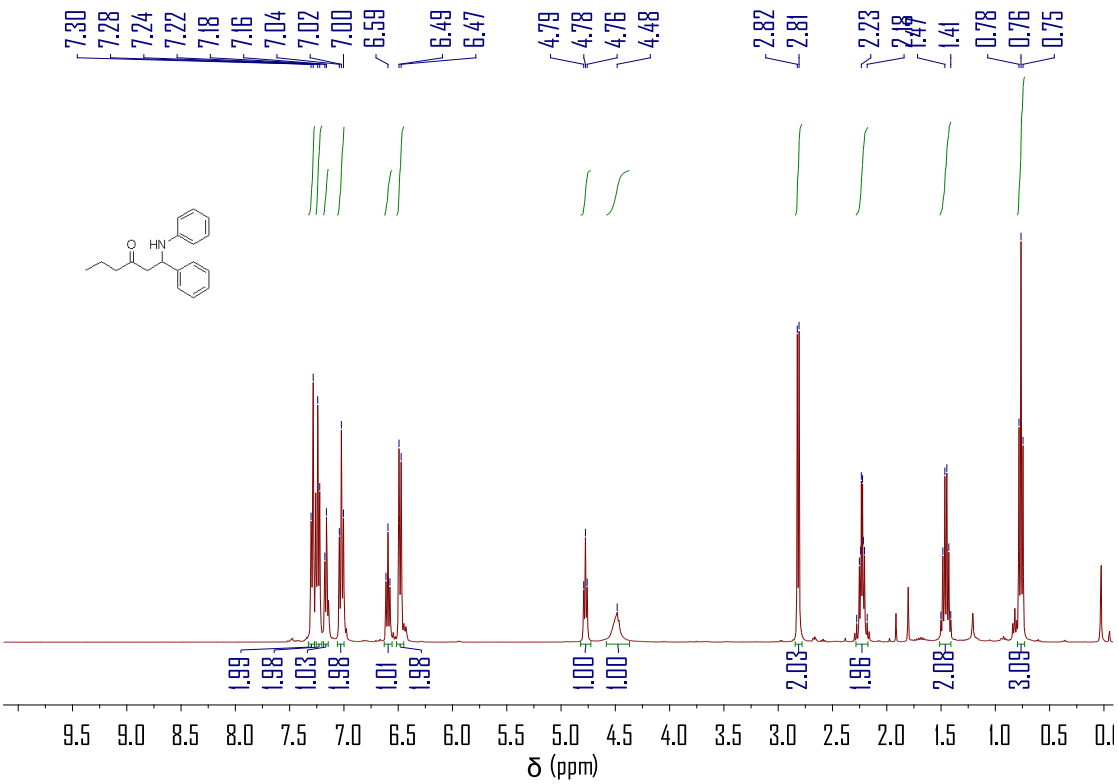
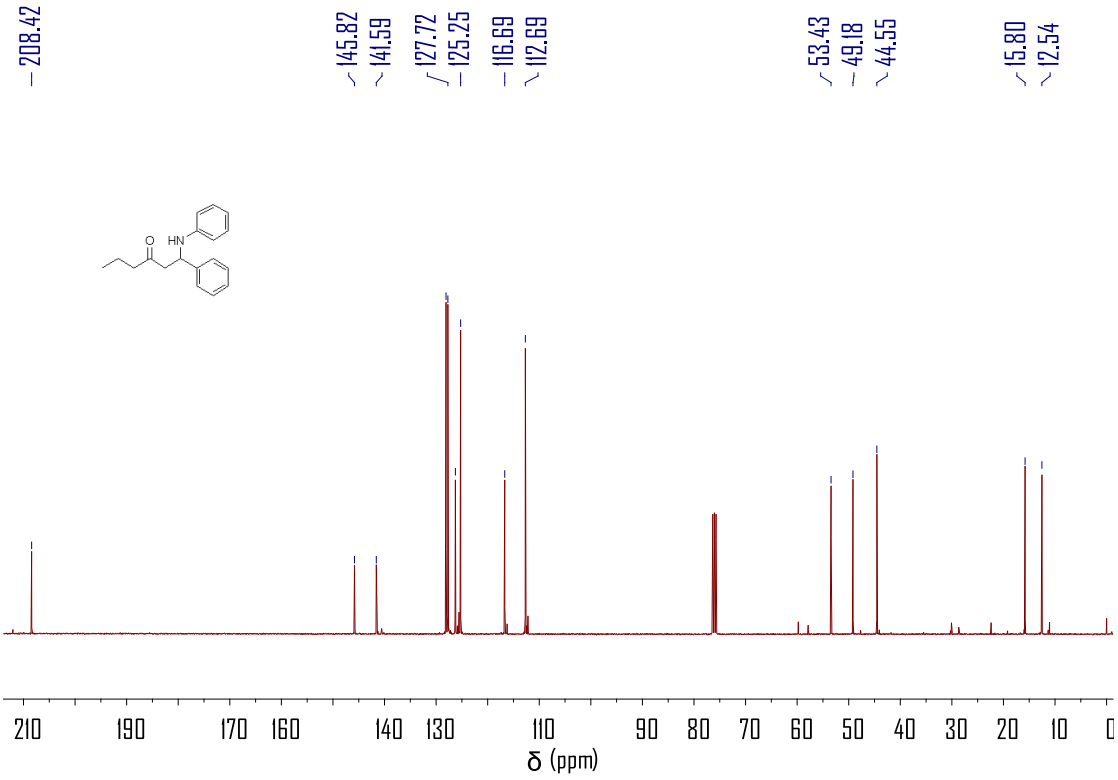
127.27
116.92
112.66
57.63
50.98
34.55
10.56
6.48
δ (ppm)


7.30
7.28
7.24
7.22
7.18
7.16
7.04
7.02
7.00
6.59
6.49
6.47
4.79
4.78
4.76
4.48
2.82
2.81
2.23
1.41
0.78
0.76
0.75
O
HN
1.99
1.98
1.03
1.98
1.01
1.98
1.00
1.00
2.03
1.96
2.08
3.09
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
δ (ppm)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125.25
116.69
112.69
53.43
49.18
44.55
15.80
12.54
O
HN
210 190 170 160 140 130 110 90 80 70 60 50 40 30 20 10
δ (ppm)