Electronic Supplementary Material (ESI) for RSC Advances

Polysubstituted Pyrrole Derivatives *via* 1,2-alkenyl migration of novel γ-Amino-α,β-Unsaturated Aldehydes and α-Diazocarbonyls

ShutingCai, Jing Zeng, Yongxin Li and Xue-Wei Liu*

Division of Chemistry and Biological Chemistry, School of Physical and Mathematical Sciences,
Nanyang Technological University, Singapore 637371
E-mail: xuewei@ntu.edu.sg

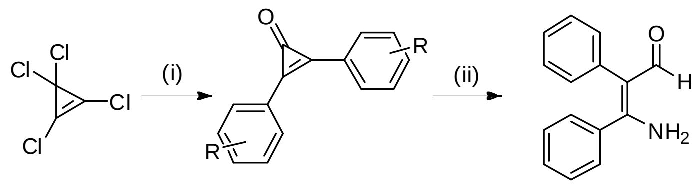
Supporting Information

Table of Contents

General experimental details

All reactions were conducted under an atmosphere of nitrogen, unless otherwise indicated. Anhydrous solvents were transferred *via*oven-dried syringe. Flasks were flame-dried and cooled under a stream of nitrogen. All reagents and solventswere obtained from commercial suppliers (Sigma-Aldrich, Fluka and Alfa Aesar) and used without further purification unless otherwise stated.Evaporation of organic solutions was achieved by rotary evaporation with a water bath temperature below 40 °C. Product purification by flash column chromatography was accomplished using silica gel 60 (0.010- 0.063 mm). Technical grade solvents were used for chromatography and distilled prior to use. Chromatograms were visualized by fluorescence quenchingwith UV light at 254 nm or by staining using a basic solution of potassium permanganate. IR spectra were recorded using FTIR Restige-21 (Shimadzu) and reported in cm^{-1}. High-resolution mass spectra (HRMS) were obtained on a Finnigan/MAT LCQ quadrupole ion trap mass spectrometer, coupled with theTSP4000 HPLC system and the Crystal 310 CE system. Accurate masses are reported for the molecular ion $[M+H]^+$or a suitable fragment ion. NMR spectra were recorded at room temperature on a 400 MHz Bruker ACF 400 NMR spectrometer. The residual solvent signals were taken as the reference (7.26 ppm for ^1H NMR spectroscopy and 77.0 ppm for ^{13}C NMR spectroscopy).Chemical shifts are reported in delta (δ) units, parts per million (ppm) downfield from triethylsilane. Chemical shift (δ) is referred in terms of ppm, coupling constants (J) are given in Hz. Following abbreviations classify the multiplicity: s = singlet, d = doublet, t = triplet, q = quartet, qt = quintent, m = multiplet or unresolved.X-ray crystallographic data was collected by using a Bruker X8Apex diffractometer with Mo K/α radiation (graphite monochromator).Compound numbers used in the experimental section correspond to those employed in the main paper.

General Synthetic procedure for the preparation of starting material, γ-amino-α,β-unsaturated aldehyde(S3)



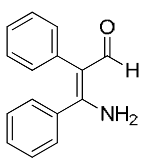
Procedure (i):

To a suspension of tetrachlorocyclopropene (0.07 mL, 0.64 mmol, 1.0 equiv) and anhydrous $AlCl_3$ (180 mg, 1.35 mmol, 1.05 equiv) in CH_2Cl_2 (10 mL) was added dropwise, a solution of benzene (0.11 mL, 1.28 mmol, 2.0 equiv) in CH_2Cl_2 (1 mL) at -78 °C. The mixture was stirred for 2 h then warm up to r.t and stirred for another 2 h (TLC monitored). The resulting mixture was quenched with water, diluted with CH_2Cl_2, washed with water (2 × 50 mL) and brine (2 × 50 mL). The organic layers were dried over Na_2SO_4, filteredand concentrated under reduced pressure to yield the crude residue as a orange oil. The crude residue was then purified by flash column chromatography on silica gel (20% EtOAc in hexanes) to afford diarylcyclopropenone **S2a** (224 mg, 1.09 mmol, 85% yield) as a yellow solid.[1]

Procedure (ii):

To a suspension of diarylcyclopropenone **S2a** (100 mg, 0.49mmol) in Et_2O at -78 °C was added liquid ammonia. The suspension was then allowed to stir for 3 h at -40 °C. After completion of the reaction, the cooling bath was removed and the mixture was concentrated under reduced pressure to yield the crude residue as a brown oil. The crude residue was then purified by flash column chromatography on silica gel (20% EtOAc in hexanes) to afford γ-amino-α,β-unsaturated aldehyde **S3a**(100 mg, 0.45mmol, 92% yield) as a yellow solid.

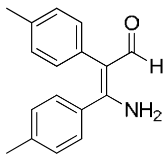
2-Aminobenzaldehyde (**S3a**):



S3a

m.p. 125-127 °C; **^{1}H NMR (400 MHz, $CDCl_3$):** δ 10.71 (s, 1H), 9.46 (s, 1H), 7.35-6.96 (m, 10H), 5.37 (s, 1H); **^{13}C NMR (100 MHz, $CDCl_3$):** δ 191.2, 161.5, 137.9, 137.0, 130.7(2), 129.7, 129.4, 129.1, 128.6, 128.4, 128.0, 127.5, 125.5, 110.7; **FT-IR (neat)** ν_{max} 3439, 3316, 3306, 3080, 3061, 3028, 1600 cm^{-1}; **HRMS (ESI):** *m/z* calcd for $C_{15}H_{13}NO[M+H]^+$, 224.1075, found 224.1071.

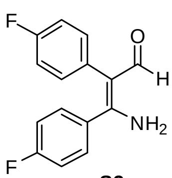
2-Aminobenzaldehyde (**S3b**):



S3b

Orange solid, decomposes upon heating; **^{1}H NMR (400 MHz, $CDCl_3$):** *δ* 10.70 (s, 1H), 9.43 (s, 1H), 7.10 (d, *J* = 8.1 Hz, 2H), 7.04 (d, *J* = 8.1 Hz, 2H), 6.96 (d, *J* = 7.8 Hz, 2H), 6.87 (d, *J* = 8.1 Hz, 2H), 5.30 (s, 1H), 2.31 (s, 3H), 2.27 (s, 3H); **^{13}C NMR (100 MHz, $CDCl_3$):** *δ* 191.3, 161.4, 139.9, 135.0, 130.6, 130.2, 130.0, 129.9, 129.7, 129.3, 129.1, 128.8, 128.4, 128.2, 29.7, 21.3; **FT-IR (neat)** ν_{max} 3445, 3308, 3022, 2920, 2860, 1715, 1626 cm^{-1}; **HRMS (ESI):** *m/z* calcd for $C_{17}H_{18}NO$ $[M+H]^+$, 252.1388, found 252.1388.

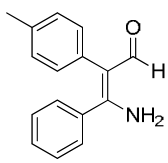
2-Aminobenzaldehyde (**S3c**):



S3c

Yellow solid; **m.p.** 134-136 °C; **^{1}H NMR (400 MHz, $CDCl_3$):** *δ* 10.66 (s, 1H), 9.42 (s, 1H), 7.20-7.17 (m, 2H), 6.97-6.83 (m, 6H), 5.32 (s, 1H); **^{13}C NMR (100 MHz, $CDCl_3$):** *δ* 191.0, 164.5, 162.5, 160.3, 133.7, 130.6, 130.5, 128.6, 128.4, 128.2, 115.9, 115.8, 115.5, 115.2, 109.9; **FT-IR (neat)** ν_{max} 3443, 3383, 1614, 1603, 1217 cm^{-1}; **HRMS (ESI):** *m/z* calcd for $C_{15}H_{11}F_2NO[M+H]^+$, 260.0887, found 260.0885.

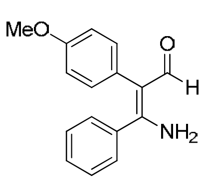
2-Aminobenzaldehyde (**S3d**):



S3d

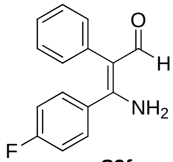
Pale yellow oil; **H NMR (400 MHz, $CDCl_3$):** *δ* 10.73 (s, 1H), 9.45 (s, 1H), 7.33-7.20 (m, 3H), 7.17-7.08 (m, 2H),7.04 (d, *J* = 8.0 Hz, 1H), 6.99-6.94 (m, 2H), 6.85 (d, *J* = 8.0 Hz, 1H), 5.19 (s, 1H), 2.30-2.26 (m, 3H); **^{13}C NMR (100 MHz, $CDCl_3$):** *δ* 191.4, 161.2, 137.2, 134.8, 134.1, 130.7, 129.9, 129.6, 129.3, 129.1, 128.7, 128.4, 128.0, 125.4, 110.6, 21.3; **FT-IR (neat)** ν_{max} 3445, 3329, 3312, 3057, 3030, 1607 cm^{-1}; **HRMS (ESI):** *m/z* calcd for $C_{16}H_{15}NO[M+H]^+$, 238.1232, found 238.1232.

2-Aminobenzaldehyde (**S3e**):



S3e

Orange oil; **^{1}H NMR (400 MHz, $CDCl_3$):** *δ* 10.72 (brs, 1H), 9.41-9.40 (m, 1H), 7.29-7.10 (m, 5H), 7.01-6.97 (m, 1H), 6.87 (d, *J* = 8.8 Hz, 1H), 6.73 (d, *J* = 8.8 Hz, 1H), 6.68 (d, *J* = 8.8 Hz, 1H), 3.76-3.73 (m, 3H); **^{13}C NMR (100 MHz, $CDCl_3$):** δ 191.3, 161.5, 157.6, 138.3, 131.8, 130.7, 130.0, 129.5, 129.1, 128.6, 128.4, 128.0, 125.3, 113.7, 110.1, 55.2; **FT-IR (neat)** ν_{max} 3445, 3312, 3167, 3156, 3078, 3061, 3005, 1749, 1607 cm^{-1}; **HRMS (ESI):** *m/z* calcd for $C_{16}H_{15}NO_2[M+H]^+$, 254.1181, found 254.1179.

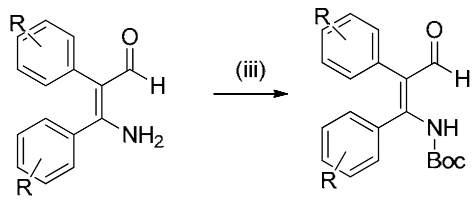


S3f

Yellow oil; **^{1}H NMR (400 MHz, $CDCl_3$):** δ 10.68 (br s, 1H), 9.46 (s, 1H), 7.58-6.83 (m, 9H), 5.37 (br s, 1H); **^{13}C NMR (100 MHz, $CDCl_3$):** δ 191.3, 161.4, 137.9, 137.1, 130.7(2), 130.6, 129.8, 129.7, 129.3, 129.1, 128.6, 128.5, 128.4, 128.1, 128.0(2), 125.5, 114.8; **FT-IR (neat)** ν_{max} 3445, 3389, 3055, 1732, 1661, 1148 cm^{-1}; **HRMS (ESI):** *m/z* calcd for $C_{15}H_{13}FNO$ $[M+H]^+$, 242.0981, found 242.0978.

1. a) G. Kuzmanich, M. N. Gard, M. A. Garcia-Garibay, *J. Am. Chem. Soc.* **2009**, *131*, 11606-11614; b) A. Poloukhtine, V. V. Popik, *J. Org. Chem.* **2003**, *68*, 7833-7840; b) R. West, D. C. Zecher, S. W. Tobey, *J. Am. Chem. Soc.* **1970**, *92*, 168-172.

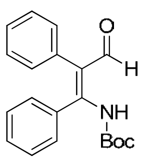
General Synthetic procedure for the preparation of starting material, N-Boc-γ-amino-α,β-unsaturated aldehyde(1)



Procedure (iii):

To a solution of γ-amino-α,β-unsaturated aldehyde**S3a**(100 mg, 0.45 mmol, 1.0 equiv) in CH_2Cl_2(10 mL) were added DMAP (11 mg, 0.09 mmol, 0.2 equiv) and triethylamine (0.19 mL, 1.35mmol, 3.0 equiv). The solution was stirred for 15 mins at r.t, Boc_2O (147 mg, 0.67 mmol, 1.5 equiv) was added and then continued to stirred overnight (TLC monitored). The resulting solution was diluted with CH_2Cl_2, washed with water (2 × 50 mL) and brine (2 × 50 mL). The organic layers were dried over Na_2SO_4, filteredand concentrated under reduced pressure to yield the crude residue as a orange oil. The crude residue was then purified by flash column chromatography on silica gel (10% EtOAc in hexanes) to afford N-Boc-γ-amino-α,β-unsaturated aldehyde**1a**(64 mg, 0.20 mmol, 44% yield) as a yellow solid.

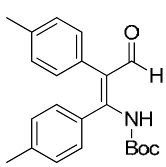
2-Aminobenzaldehyde (**1a**):



1a

m.p. 116-118 °C; **^{1}H NMR (400 MHz, CDCl$_3$):** *δ* 11.58 (s, 1H), 9.60 (s, 1H), 7.49-7.47 (m, 1H), 7.28-7.09 (m, 7H), 6.95-6.93 (m, 2H), 1.36 (s, 9H); **^{13}C NMR (100 MHz, CDCl$_3$):** *δ* 193.8, 153.6, 151.5, 136.2, 134.3, 130.8, 130.4, 130.1, 129.2, 129.0, 128.9, 128.4, 128.2, 128.1, 127.6, 126.5, 118.9, 81.8, 27.9; **FT-IR (neat)** v_{max} 3443, 3404, 2978, 2920, 2851, 1732 cm^{-1}; **HRMS (ESI):** *m/z*calcd for $C_{20}H_{21}NO_3$ $[M+H]^+$, 324.1600, found 324.1602.

2-Aminobenzaldehyde (**1b**):

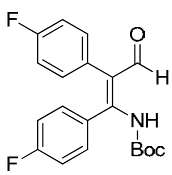


1b

Orange oil; **^{1}H NMR (400 MHz, CDCl$_3$):** *δ* 11.5 (s, 1H), 9.57 (s, 1H), 7.36 (d, *J* = 7.5 Hz, 1H), 7.21-7.14 (m, 1H), 6.98 (s, 3H), 6.96 (d, *J* = 7.8 Hz, 2H), 6.82 (d, *J* = 7.8 Hz, 2H), 2.27 (d, *J* = 8.4 Hz, 6H), 1.37 (s, 9H); **^{13}C NMR**

(100 MHz, $CDCl_3$): δ 194.0, 155.1, 151.6, 140.4, 138.8, 138.2, 136.0, 133.3, 130.6, 130.2, 130.0, 129.9, 128.9, 128.4, 125.6, 118.8, 82.1, 27.9, 27.8, 21.5, 21.1; **FT-IR (neat)** ν_{max} 3443, 3387, 3021, 2982, 2851, 1732, 1584 cm^{-1}; **HRMS (ESI):** *m/z* calcd for $C_{22}H_{26}NO_3[M+H]^+$, 352.1913, found 352.1913.

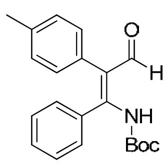
2-Aminobenzaldehyde (**1c**):



1c

Pale yellow soild; **m.p.** 120-122 °C; **^{1}H NMR (400 MHz, $CDCl_3$):** δ 9.34 (s, 1H), 7.49-7.46 (m, 2H), 7.26-7.16 (m, 6H), 6.56 (s, 1H), 1.28 (s, 6H), 1.24 (s, 3H); **^{13}C NMR (100 MHz, $CDCl_3$):** δ 191.0, 154.1, 150.8, 132.3, 132.0, 131.9, 130.0, 128.2, 125.0, 116.5, 116.3, 115.7, 115.5 82.6, 27.9, 27.8, 27.7; **FT-IR (neat)** ν_{max} 3393, 3331, 3171, 3017, 2978, 1730, 1634, 1601, 1215, 1148 cm^{-1}; **HRMS (ESI):** *m/z* calcd for $C_{25}H_{25F2}NO_3[M+H]^+$, 360.1411, found 360.1411.

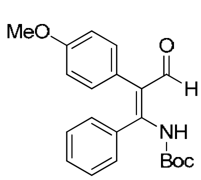
2-Aminobenzaldehyde (**1d**):



1d

Pale yellow oil; **^{1}H NMR (400 MHz, $CDCl_3$):** δ11.54 (s, 1H), 9.59 (s, 1H), 7.50-7.35 (m, 2H), 7.20-7.09 (m, 4H), 6.98 (s, 1H), 6.95 (d, *J* = 8.0 Hz, 2H), 6.82 (d, *J* = 8.0 Hz, 1H), 2.27-2.24 (m, 3H), 1.40-1.36 (m, 9H); **^{13}C NMR (100 MHz, $CDCl_3$):** δ 194.0, 153.2, 138.9, 134.4, 130.8, 130.6, 130.2, 129.7, 129.2, 129.0, 128.7, 128.4, 127.6, 127.2, 126.4, 125.8, 118.8, 81.7, 27.9, 21.3; **FT-IR (neat)** ν_{max} 3393, 3017, 2980, 2930, 2855, 1807, 1717, 1653, 1585 cm^{-1}; **HRMS (ESI):** *m/z* calcd for $C_{21}H_{23}NO_3[M+H]^+$, 338.1756, found 338.1756.

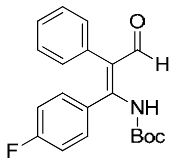
2-Aminobenzaldehyde (**1e**):



1e

Yellow solid; **m.p.** 79-81 °C; **^{1}H NMR (400 MHz, $CDCl_3$):** δ 11.47 (s, 1H), 9.59-9.58 (m, 1H), 7.47 (s, 1H), 7.21-7.09 (m, 3H), 7.03 (d, *J* = 8.5 Hz, 1H), 6.95 (d, *J* = 7.3 Hz, 1H), 6.85 (d, *J* = 8.5 Hz, 1H), 6.70-6.67 (m, 2H),3.73 (d, *J* = 6.2 Hz, 3H), 1.40 (s, 3H), 1.35 (s, 6H); **^{13}C NMR (100 MHz, $CDCl_3$):** δ 194.0, 158.2, 153.1, 151.6, 131.9, 130.8, 130.1, 128.9, 128.7, 128.2, 127.6, 113.6, 113.1, 81.7, 55.1, 27.9; **FT-IR (neat)** ν_{max} 3406, 3389, 3015, 2976, 2959, 2938, 1728, 1634, 1585 cm^{-1}; **HRMS (ESI):** *m/z* calcd for $C_{21}H_{23}NO_4[M+H]^+$, 354.1705, found 354.1705.

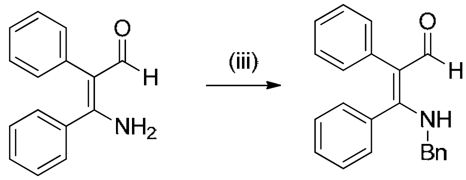
2-Aminobenzaldehyde (**1f**):



1f

Pale yellow oil; **^{1}H NMR (400 MHz, $CDCl_3$):** δ 9.36 (s, 1H), 7.51-7.40 (m, 6H), 7.28-7.18 (m, 3H), 6.63 (s, 1H), 1.27-1.23 (m, 9H); **^{13}C NMR (100 MHz, $CDCl_3$):** δ 191.5, 155.0, 132.0, 131.9, 130.4, 130.3, 130.1, 129.3, 129.2, 129.0, 128.9, 128.5, 128.4, 128.2, 115.6, 82.5, 27.7; **FT-IR (neat)** ν_{max} 3428, 3387, 2976, 2920, 2849, 1749, 1722, 1684 cm^{-1}; **HRMS (ESI):** *m/z* calcd for $C_{20}H_{21}FNO3$ $[M+H]^+$, 342.1505, found 342.1505.

General Synthetic procedure for the preparation of starting material, N-Benzyl-γ-amino-α,β-unsaturated aldehyde(1l)

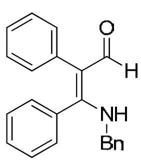


S3a **1l**

Procedure (iii):

To a solution of γ-amino-α,β-unsaturated aldehyde **S3a** (100 mg, 0.45 mmol, 1.0 equiv) in DMF (10 mL) was added NaH (16 mg, 0.67 mmol, 1.5 equiv). The solution was stirred for 15 mins at r.t, benzyl bromide (116 mg, 0.67 mmol, 1.5 equiv) was added and then continued to stirred overnight (TLC monitored). The resulting solution was diluted with ether, washed with water (2 × 50 mL) and brine (2 × 50 mL). The organic layers were dried over Na_2SO_4, filteredand concentrated under reduced pressure to yield the crude residue as aorange oil.The crude residue was then purified by flash column chromatography on silica gel (10% EtOAc in hexanes) to afford N-Benzyl-γ-amino-α,β-unsaturated aldehyde**1n**(47 mg, 0.15mmol, 33% yield) as a yellow oil.

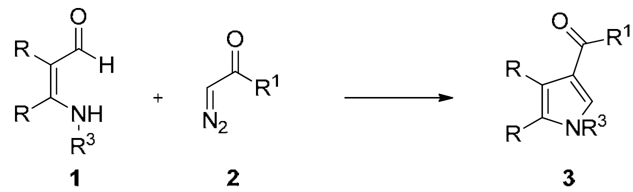
N-Bn2-Aminobenzaldehyde (**1l**):



1l

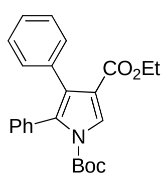
^{1}H NMR (400 MHz, $CDCl_3$): δ 12.13 (s, 1H), 9.37 (s, 1H), 7.37-7.21 (m, 5H), 7.12-7.03 (m, 3H), 6.95-6.93 (m, 2H), 4.36 (d, J = 6.4 Hz, 2H); **^{13}C NMR (100 MHz, $CDCl_3$):** δ 193.8, 153.6, 151.5, 136.2, 134.3, 130.8, 130.4, 130.1, 129.2, 129.0, 128.9, 128.4, 128.2, 128.1, 127.6, 126.5, 118.9, 81.8, 27.9; **FT-IR (neat)** ν_{max} 3421, 3400, 2975, 2935, 2851, 1732 cm^{-1}; **HRMS (ESI):** m/z calcd for $C_{20}H_{21}NO_3[M+H]^+$, 324.1600, found 324.1602.

General Synthetic procedure for the synthesis of polysubstituted pyrrole derivatives(3)



To a solution of N-Boc-γ-amino-α,β-unsaturated aldehyde **1a** (20 mg, 0.06 mmol, 1.0 equiv) in CH_2Cl_2 (10 mL) were added ethyl diazoacetate **2a** (0.02 mL, 0.19 mmol, 3.0 equiv) and $TiCl_4$ (1 M in CH_2Cl_2, 0.01 mL, 0.01 mmol, 0.2 equiv) at r.t. The suspension was then stirred at reflux for 6 h (TLC monitored). The resulting mixture was diluted with CH_2Cl_2, washed with water (2 × 20 mL) and brine (2 × 20 mL). The organic layers were dried over Na_2SO_4, filtered and concentrated under reduced pressure to yield the crude residue as a brown oil. The crude residue was then purified by flash column chromatography on silica gel (5% EtOAc in hexanes) to afford polysubstituted pyrrole derivative **3a**(18 mg, 0.05 mmol, 78% yield) as a yellow oil.

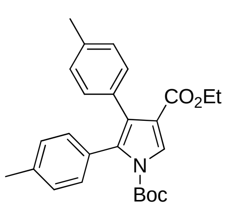
Pyrrole (**3a**):



3a

^{1}H NMR (400 MHz, $CDCl_3$): δ 8.04 (s, 1H), 7.22-7.21 (m, 3H), 7.17-7.09 (m, 7H), 4.16 (q, *J* = 7.1 Hz, 2H), 1.30 (s, 9H), 1.17 (t, *J* = 7.1 Hz, 3H); **^{13}C NMR (100 MHz, $CDCl_3$):** δ 163.9, 148.6, 133.5, 132.5, 132.4, 130.8, 130.7, 127.5, 127.2, 127.0, 126.5, 117.0, 84.8, 59.9, 27.4, 14.1; **FT-IR (neat)** ν_{max} 3055, 1749, 1647, 1558, 1362, 1219 cm^{-1}; **HRMS (ESI):** *m/z* calcd for $C_{24}H_{25}NO_4[M+H]^+$, 392.1862, found 392.1854.

Pyrrole (**3b**):



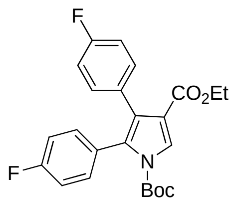
3b

Yellow solid, decomposes upon heating; **^{1}H NMR (400 MHz, $CDCl_3$):** δ 8.00 (s, 1H), 7.00 (d, *J* = 12.5 Hz, 8H), 4.17 (q, *J* = 7.1 Hz, 2H), 2.29 (s, 3H), 2.27 (s, 3H), 1.33 (s, 9H), 1.19 (t, *J* = 7.1 Hz, 3H); **^{13}C NMR (100 MHz, $CDCl_3$):** δ 163.9, 148.7, 137.0, 135.9, 132.4, 130.5(2), 129.5, 128.2, 127.9, 127.2, 126.8, 116.9, 84.6, 59.9, 27.5, 21.3, 21.2,

Electronic Supplementary Material (ESI) for RSC Advances

14.2; **FT-IR (neat)** ν_{max} 3584, 3289, 2957, 2922, 2851, 1609 cm^{-1}; **HRMS (ESI):** *m/z* calcd for $C_{26}H_{29}NO_4[M+H]^+$, 420.2175, found 420.2179.

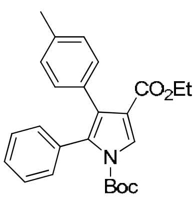
Pyrrole (**3c**):



3c

Yellow oil; **^{1}H NMR (400 MHz, CDCl$_3$):** δ 8.03 (s, 1H), 7.10-7.03 (m, 4H), 6.96-6.85 (m, 4H), 4.17 (q, *J* = 7.1 Hz, 2H), 1.35 (s, 9H), 1.19 (t, *J* = 7.1 Hz, 1H);**^{13}C NMR (100 MHz, CDCl$_3$):** δ 163.8, 148.4, 133.3, 132.4, 132.2, 131.4, 130.7, 130.6, 129.2, 128.3, 127.6, 127.1, 126.8, 126.7, 116.9, 114.7, 114.6, 114.4, 114.3, 114.2, 85.1, 60.0, 27.4, 14.1; **FT-IR (neat)** ν_{max} 3584, 3406, 3387, 2957, 2934, 2918, 2851, 2806, 1749, 1607, 1595, 1153 cm^{-1}; **HRMS (ESI):***m/z*calcd for $C_{24}H_{23}F_2NO_4[M+H]^+$, 428.1673, found 428.1673.

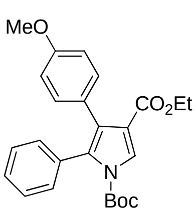
Pyrrole (**3d**):



3d

Yellow solid; **m.p.** 96-98 °C; **^{1}H NMR (400 MHz, CDCl$_3$):** δ 8.03-8.02 (m, 1H), 7.23-7.21 (m, 2H), 7.18-7.09 (m, 3H), 7.01-6.98 (m, 4H), 4.17 (d, *J* = 7.2 Hz, 2H), 2.29-2.26 (m, 3H), 1.34 (s, 3H), 1.29 (s, 6H), 1.22-1.14 (m, 3H); **^{13}C NMR (100 MHz, CDCl$_3$):** δ 164.0, 148.7, 137.1, 136.0, 132.7, 132.5, 132.2, 130.7, 130.5, 130.4, 129.3, 128.6, 128.2, 127.9, 127.5, 127.1, 126.9, 126.5, 116.9, 84.7, 59.9, 27.4, 21.3, 14.1; **FT-IR (neat)** ν_{max} 3019, 2932, 2870, 1748, 1703, 1371, 1360, 1256, 1215 cm^{-1}; **HRMS (ESI):** *m/z* calcd for $C_{25}H_{27}NO_4[M+H]^+$, 406.2018, found 406.2005.

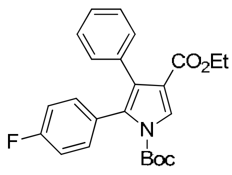
Pyrrole (**3e**):



3e

Yellow oil; **^{1}H NMR (400 MHz, CDCl$_3$):** δ 8.03-8.02 (m, 1H), 7.23-7.21 (m, 2H), 7.18-7.16 (m, 1H), 7.13-7.09 (m, 2H), 7.05-7.00 (m, 2H), 6.76-6.70 (m, 2H), 4.21-4.13 (m, 2H), 3.76-3.74 (m, 3H), 1.36 (s, 3H), 1.30 (s, 6H), 1.22-1.16 (m, 3H); **^{13}C NMR (100 MHz, CDCl$_3$):** δ 164.0, 158.7, 148.5, 131.9, 131.7, 130.8, 130.7, 127.5, 127.4, 127.2, 127.0, 113.0, 112.7, 84.7, 59.9, 55.1, 27.5; **FT-IR (neat)** ν_{max} 3019, 2978, 2959, 2934, 1742, 1719, 1686 cm^{-1}; **HRMS (ESI):** *m/z* calcd for $C_{25}H_{27}NO_5[M+H]^+$, 422.1967, found 422.1964.

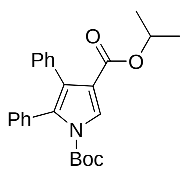
Pyrrole (**3f**):



3f

Yellow oil; **^{1}H NMR (400 MHz, $CDCl_3$):** δ 8.04 (s, 1H), 7.22-7.11 (m, 9H), 4.16 (q, J = 6.8 Hz, 1H), 1.35 (s, 3H), 1.30 (s, 6H), 1.17 (t, J = 6.8 Hz, 3H); **^{13}C NMR (100 MHz, $CDCl_3$):** δ 163.9, 132.5, 132.4, 130.8, 130.7, 130.6, 127.5, 127.3, 127.2, 127.0, 126.5, 114.5, 84.8, 59.9, 27.5, 14.1; **FT-IR (neat)** ν_{max} 3017, 2957, 2918, 2851, 1755, 1722, 1682, 1651, 1213, 1153 cm^{-1}; **HRMS (ESI):** *m/z* calcd for $C_{24}H_{24}FNO_4$ $[M+H]^+$, 409.1595, found 409.1861.

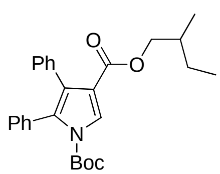
Pyrrole (**3g**):



3g

Yellow oil; **^{1}H NMR (400 MHz, $CDCl_3$):** δ 8.03 (s, 1H), 7.23-7.20 (m, 3H), 7.19-7.08 (m, 7H), 5.05 (qt, J = 6.2 Hz, 1H), 1.30 (s, 9H), 1.14 (d, J = 6.2 Hz, 6H); **^{13}C NMR (100 MHz, $CDCl_3$):** δ 163.5, 148.7, 133.6, 132.6, 132.3, 130.7(2), 127.5, 127.4, 127.1, 126.9, 126.5, 117.5, 84.7, 67.2, 27.4, 21.7;**FT-IR (neat)** ν_{max} 3019, 2976, 2920, 2851, 1749, 1717, 1373, 1215 cm^{-1}; **HRMS (ESI):** *m/z* calcd for $C_{25}H_{27}NO_4[M+H]^+$, 406.2018, found 406.2017.

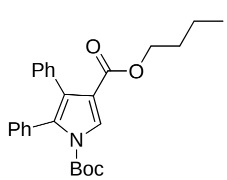
Pyrrole (**3h**):



3h

Yellow oil; **^{1}H NMR (400 MHz, $CDCl_3$):** δ 8.06 (s, 1H), 7.21-7.20 (m, 3H), 7.16-7.08 (s, 7H), 4.01-3.89 (m, 2H), 1.56 (m 1H), 1.29 (s, 9H), 1.27 (s. 2H), 0.82 (t, J = 7.4 Hz, 3H), 0.77 (d, J = 6.8 Hz, 3H); **^{13}C NMR (100 MHz, $CDCl_3$):** δ 164.2, 148.7, 133.6, 132.5, 132.4, 130.7, 130.6, 127.4, 127.3, 127.2, 127.1, 126.5, 117.1, 84.8, 68.8, 34.0, 27.4, 25.9, 16.3, 11.2;**FT-IR (neat)** ν_{max} 3057, 3032, 2963, 2934, 2876, 1748, 1703, 1558, 1522, 1287, 1258, 1213 cm^{-1}; **HRMS (ESI):** *m/z* calcd for $C_{27}H_{31}NO_4[M+H]^+$, 434.2331, found 434.2332.

Pyrrole (**3i**):

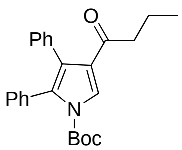


3i

Yellow oil; **^{1}H NMR (400 MHz, $CDCl_3$):** δ 8.05 (s, 1H), 7.22-7.20 (m, 3H), 7.16-7.09 (m, 7H), 4.10 (t, J = 6.5 Hz, 2H), 1.53-1.46 (m, 2H), 1.30 (s, 9H), 1.26-1.19 (m, 2H),0.85 (t, J = 7.4 Hz, 1H); **^{13}C NMR (100

MHz, $CDCl_3$): δ 164.1, 148.6, 133.6, 132.5, 132.4, 130.7, 130.6, 127.5, 127.4, 127.2, 127.0, 126.5, 117.0, 84.8, 63.9, 30.6, 27.4, 23.0, 19.1, 13.7;**FT-IR (neat)** ν_{max} 2959, 2932, 2872, 1748, 1724, 1705, 1362 cm^{-1}; **HRMS (ESI):** *m/z* calcd for $C_{26}H_{29}NO_4[M+H]^+$, 420.2175, found 420.2191.

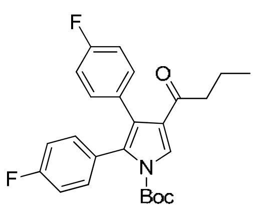
Pyrrole (**3j**):



3j

Yellow oil; **^{1}H NMR (400 MHz, $CDCl_3$):** δ 8.00 (s, 1H), 7.22-7.20 (m, 3H), 7.17-7.16 (m, 3H), 7.12-7.07 (m, 4H), 2.58 (t, *J* = 7.4 Hz, 2H), 1.68-1.60 (m, 2H), 1.28 (s, 9H), 0.88 (t, *J* = 7.4 Hz, 3H); **^{13}C NMR (100 MHz, $CDCl_3$):** δ 196.7, 148.8, 133.8, 132.5, 130.7, 130.58, 127.5(2), 127.4, 126.9, 126.7, 126.2, 125.4, 84.9, 42.6, 35.8, 27.4, 17.8, 13.8; **FT-IR (neat)** ν_{max} 3021, 2970, 2920, 2878, 1755, 1668, 1647, 1215, 1152 cm^{-1}; **HRMS (ESI):** *m/z* calcd for $C_{25}H_{27}NO_3[M+H]^+$, 390.2069, found 390.2069.

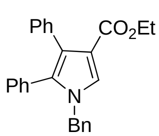
Pyrrole (**3k**):



3k

Yellow oil; **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.38-7.30 (m, 2H), 7.15-7.03 (m, 4H), 6.91 (t, *J* = 8.6 Hz, 2H), 2.80 (t, *J* = 7.4 Hz, 2H), 1.80 (q, *J* = 7.4 Hz, 2H), 1.38 (s, 9H), 1.02 (t, *J* = 7.4 Hz, 3H); **^{13}C NMR (100 MHz, $CDCl_3$):** δ 190.0, 149.7, 134.7, 132.7, 131.8, 130.6, 130.0, 129.6, 128.9, 128.3, 128.0, 126.5, 123.6, 117.1, 115.6, 115.4, 115.3, 115.2, 115.1, 85.5, 40.5, 27.2, 18.6, 14.0; **FT-IR (neat)** ν_{max} 3019, 2968, 2934, 2878, 2857, 1767, 1761, 1732, 1215 cm^{-1}; **HRMS (ESI):** *m/z* calcd for $C_{25}H_{25}F_2NO_3[M+H]^+$, 426.1881, found 426.1881.

Pyrrole (**3l**):

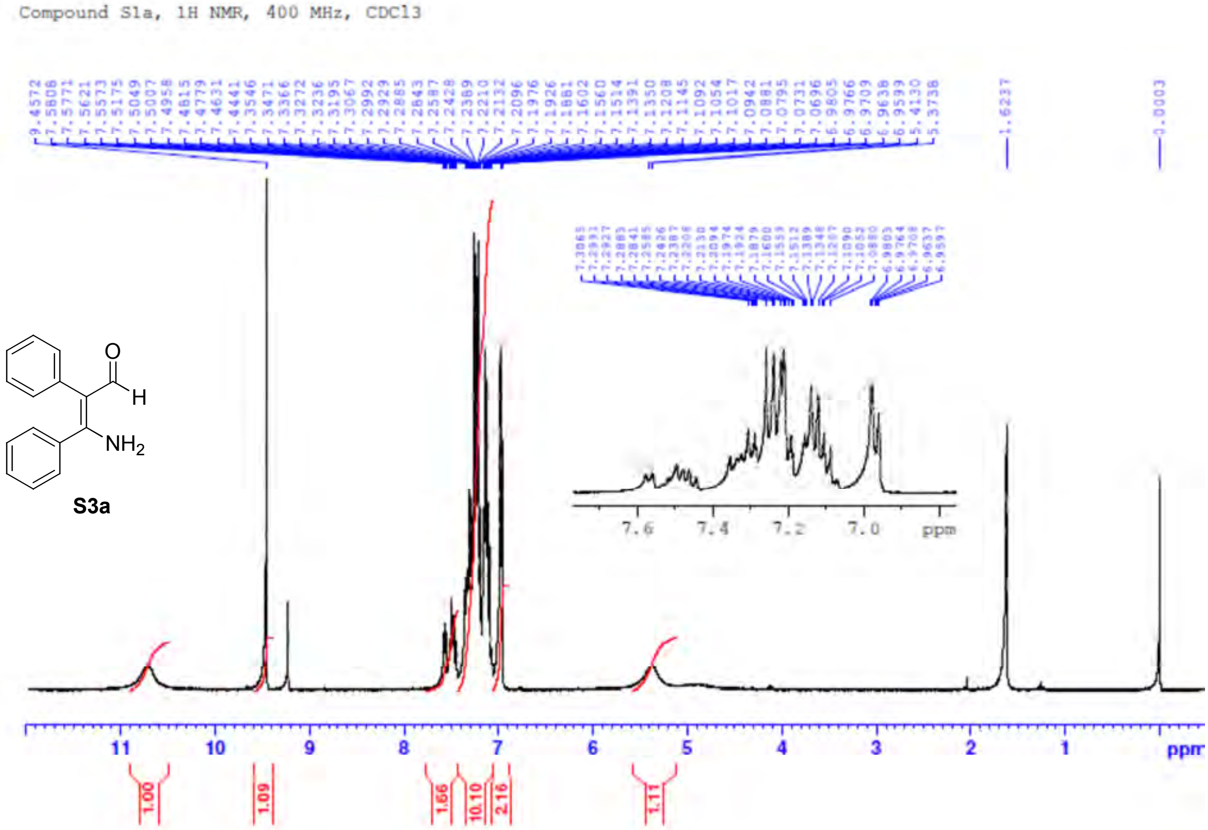


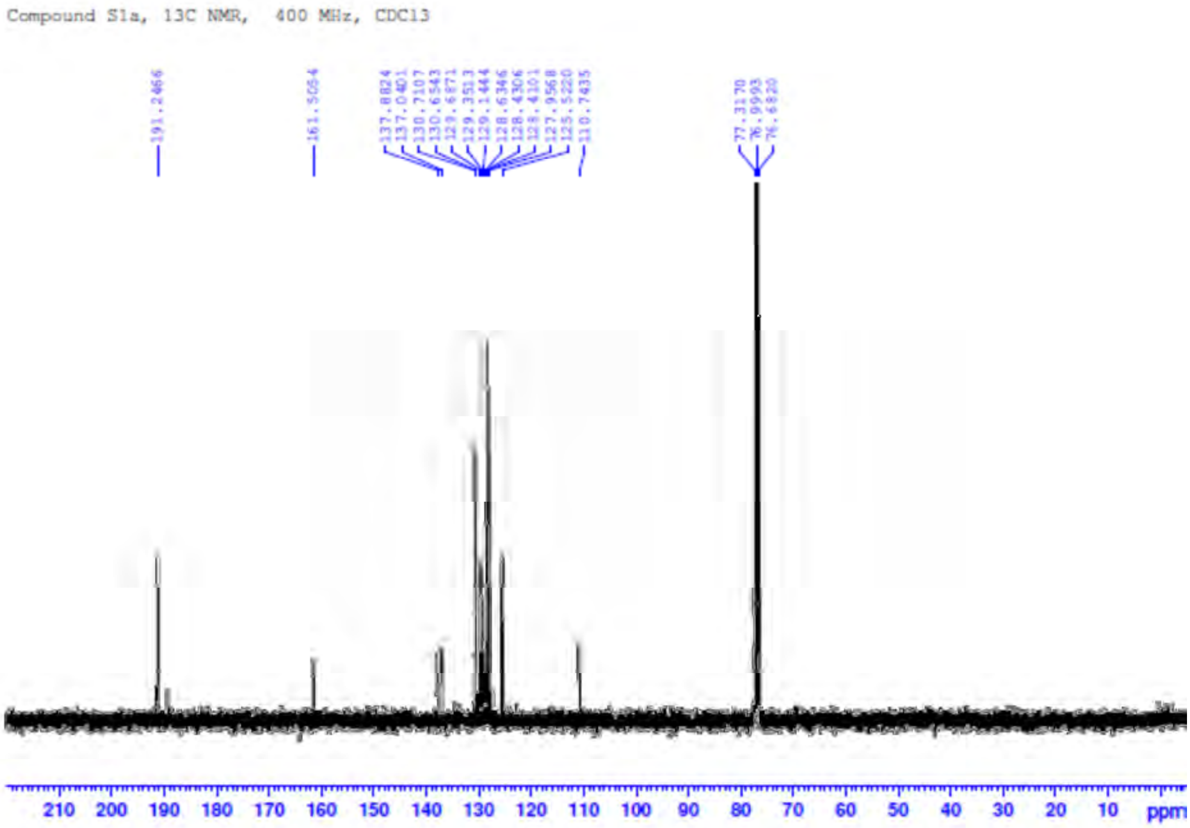
3l

Yellow oil; **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.34 (s, 1H), 7.33-7.13 (m, 13H), 6.84 (d, *J* = 7.0 Hz, 2H), 5.50 (s, 2H), 4.24 (q, *J* = 7.1 Hz, 1H), 1.29 (t, *J* = 7.1 Hz, 3H); **^{13}C NMR (100 MHz, $CDCl_3$):** δ 161.1, 139.1, 138.0, 135.1, 131.6, 131.0, 128.6, 128.3, 128.1, 127.7, 126.8, 125.8, 125.7, 123.5, 122.5, 117.7, 60.0, 49.0, 29.7, 14.4; **FT-IR (neat)** ν_{max} 3019, 2976, 2920, 2899, 1749, 1722, 1215 cm^{-1}; **HRMS (ESI):** *m/z* calcd for $C_{26}H_{23}NO_2[M+H]^+$, 382.1807, found 382.1809.

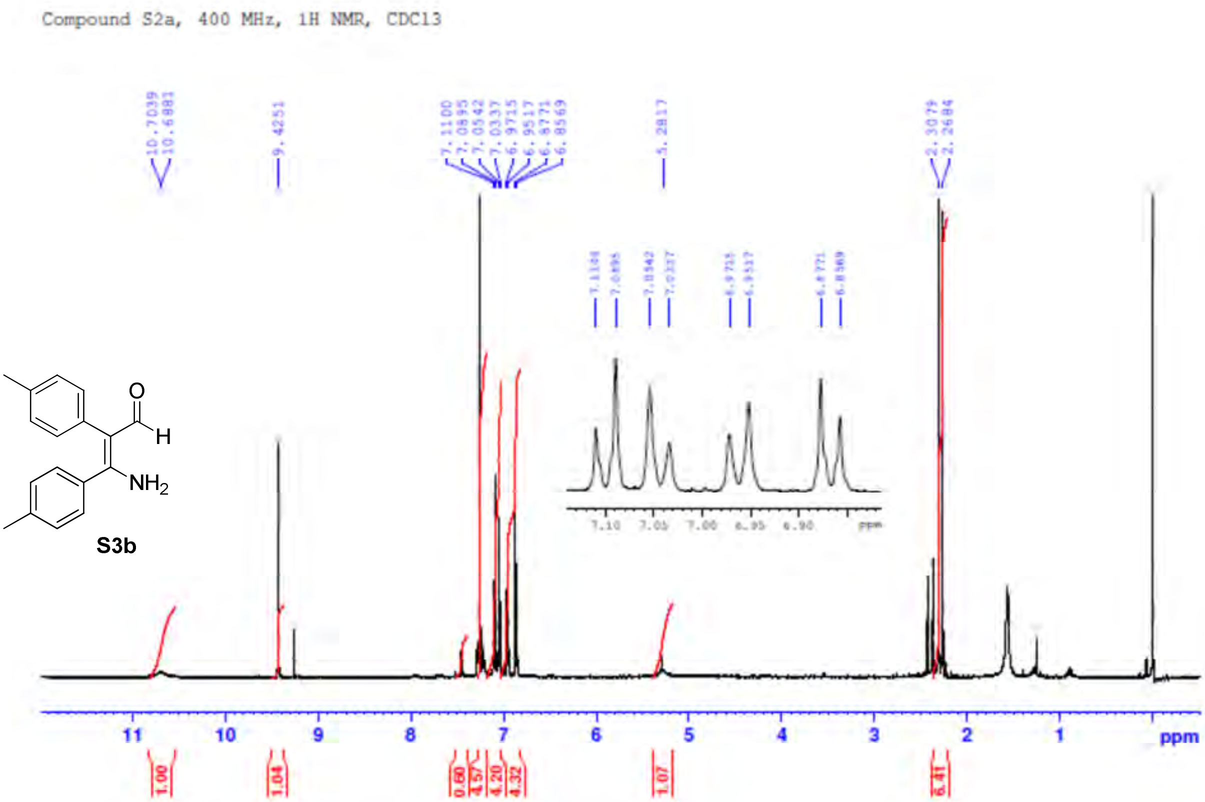
Electronic Supplementary Material (ESI) for RSC Advances

[1]H and [13]C NMR spectra of 2-Aminoaldehyde (S3)

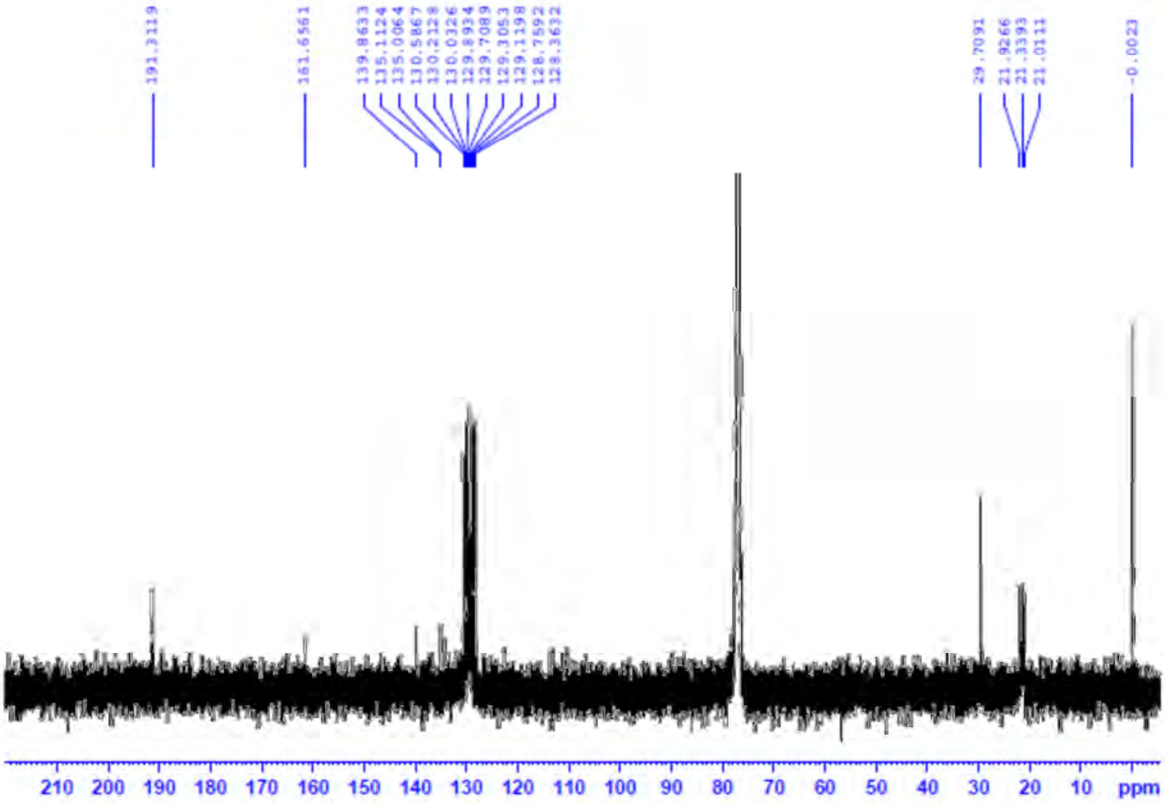




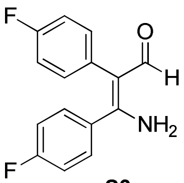
Electronic Supplementary Material (ESI) for RSC Advances



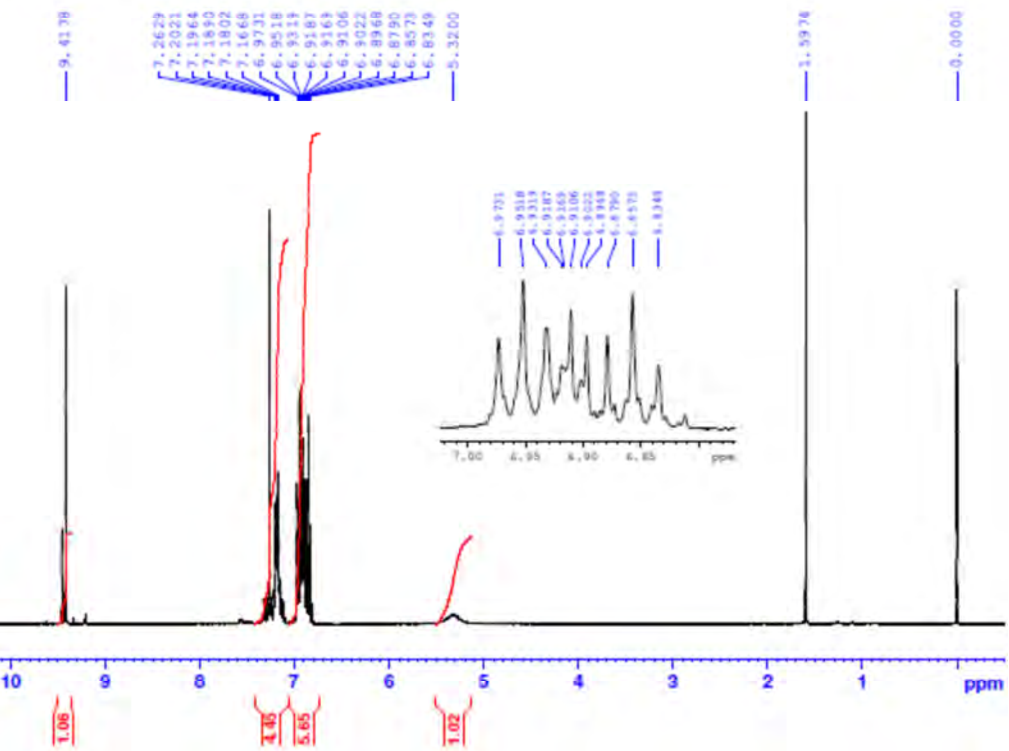
S3b



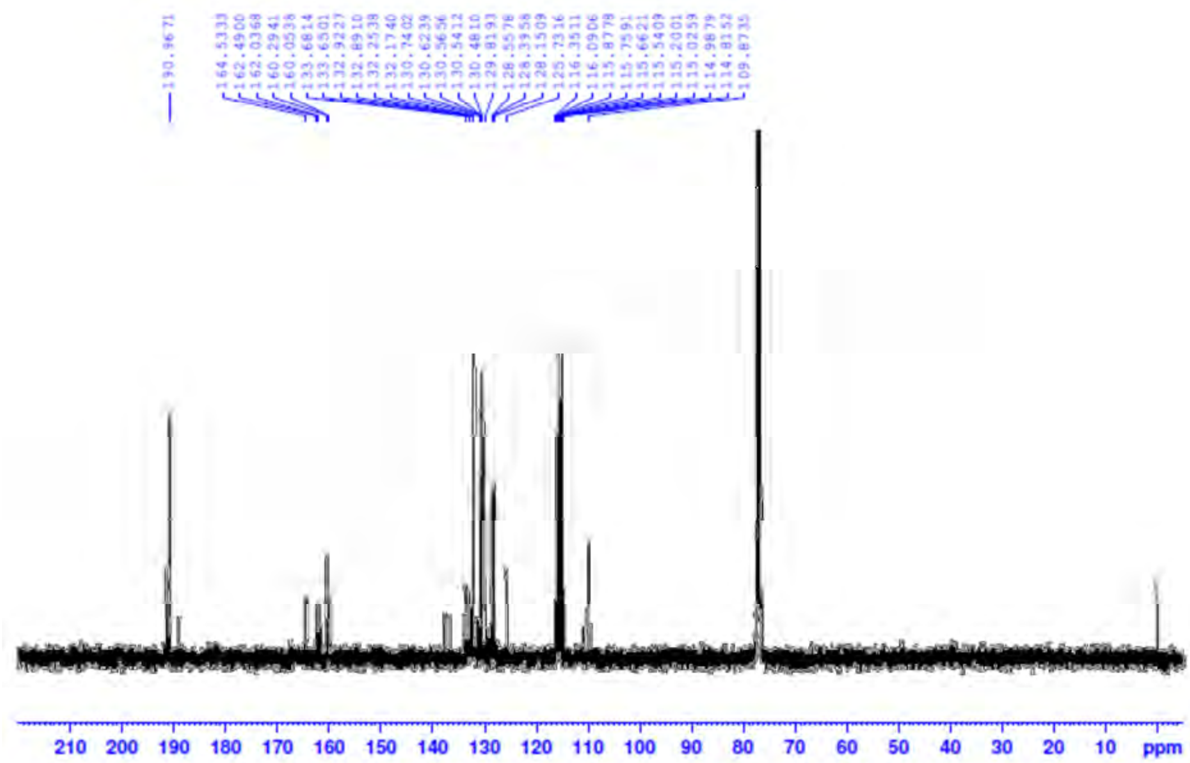
Compound S1c, 400 MHz, 1H NMR, CDCl3



S3c

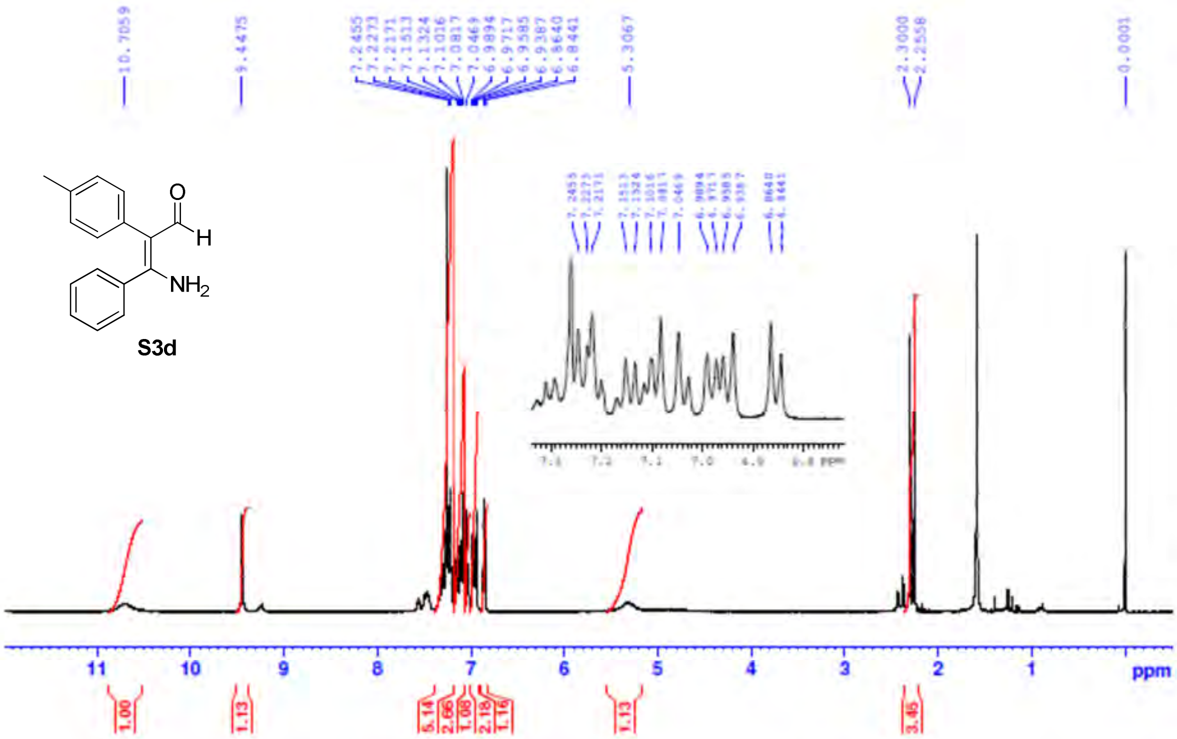


Compound S1c, 400 MHz, 13C NMR, CDCl3

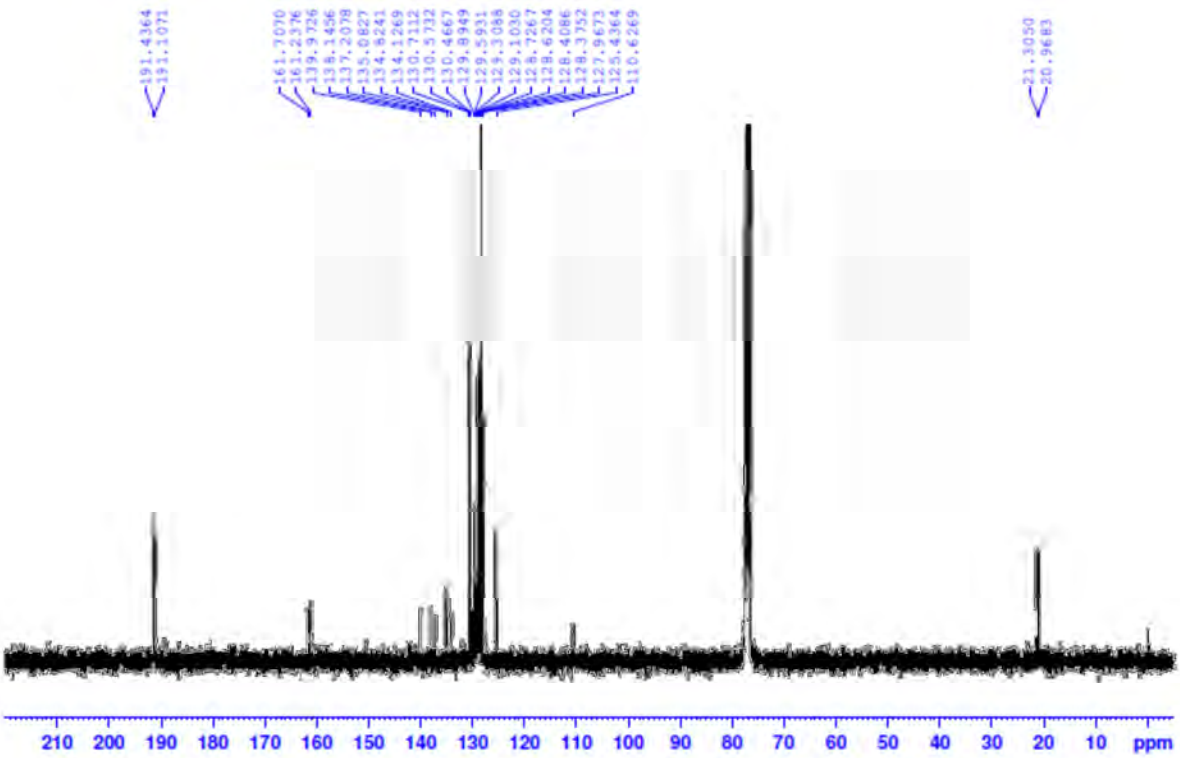


Electronic Supplementary Material (ESI) for RSC Advances

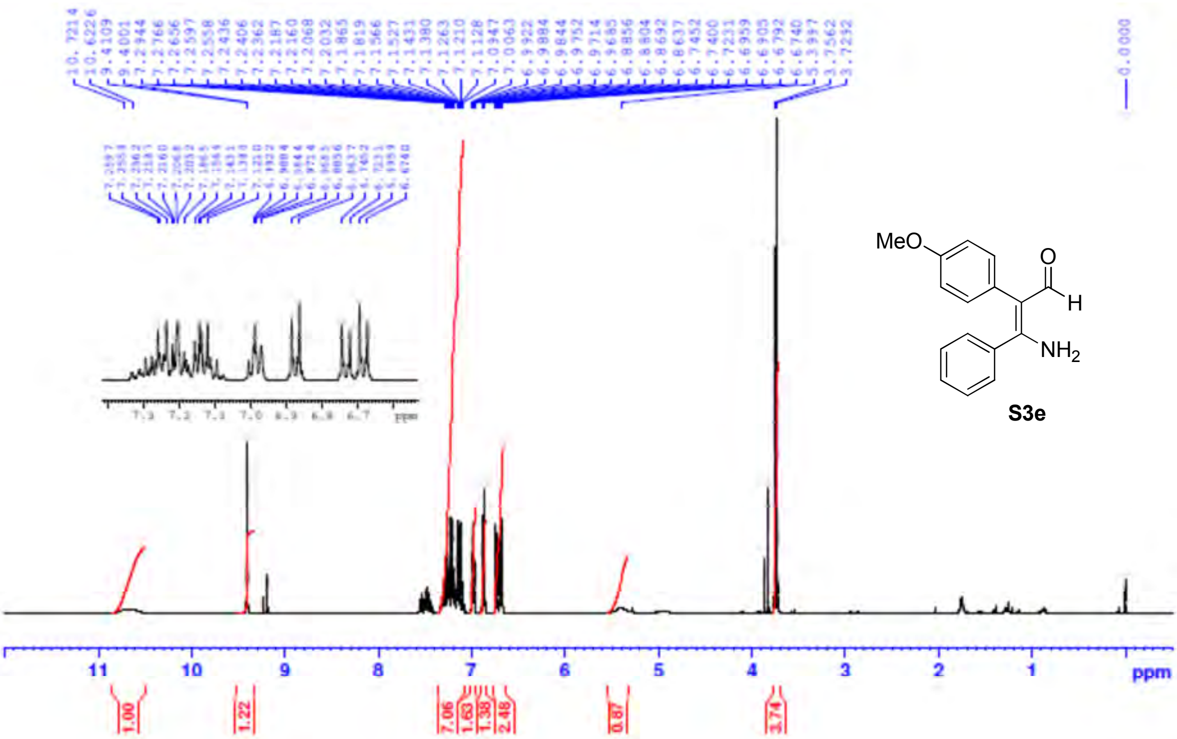
Compound S1d, 1H NMR, 400 MHz, CDCl3



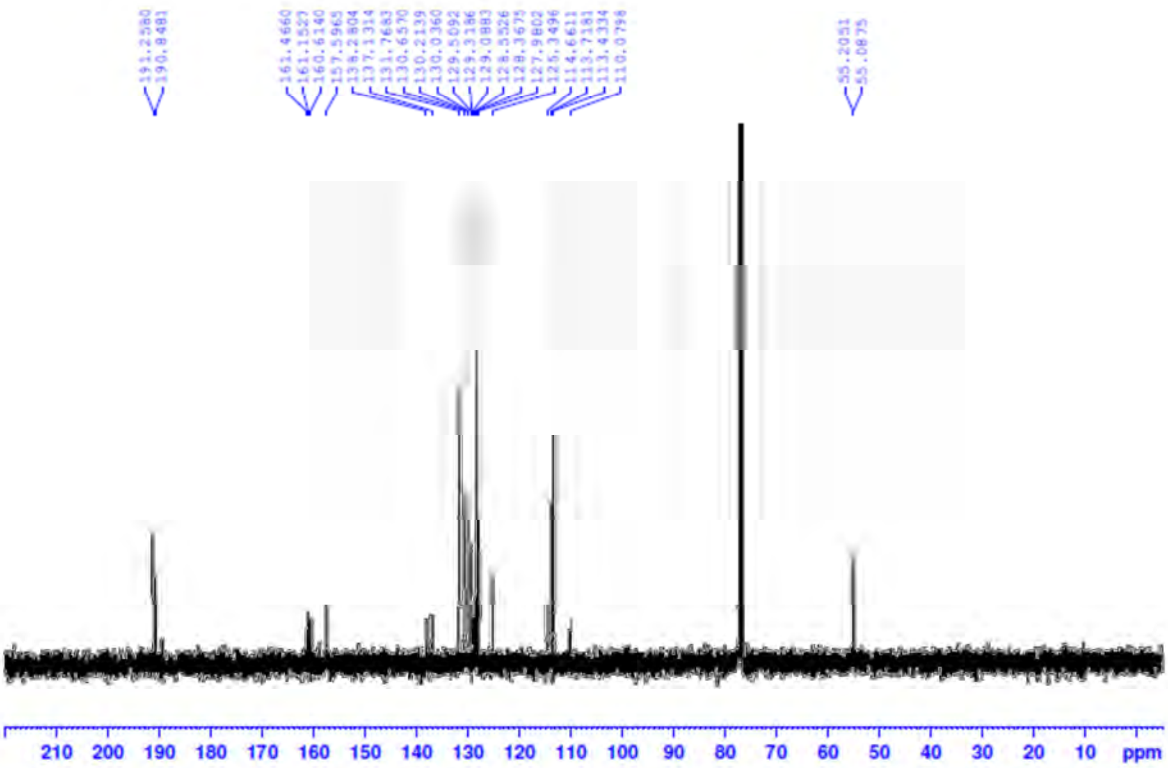
Compound S1d, 13C NMR, 400 MHz, CDCl3



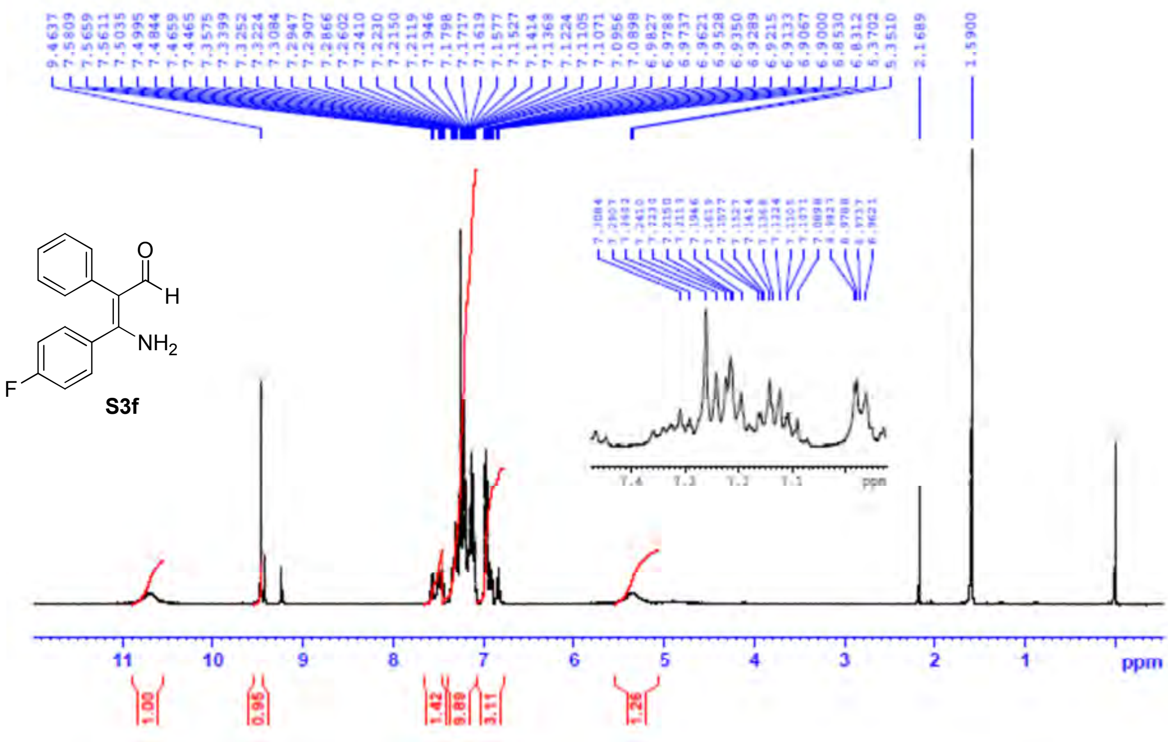
Compound S1e, 400MHz, 1H NMR, CDCl3



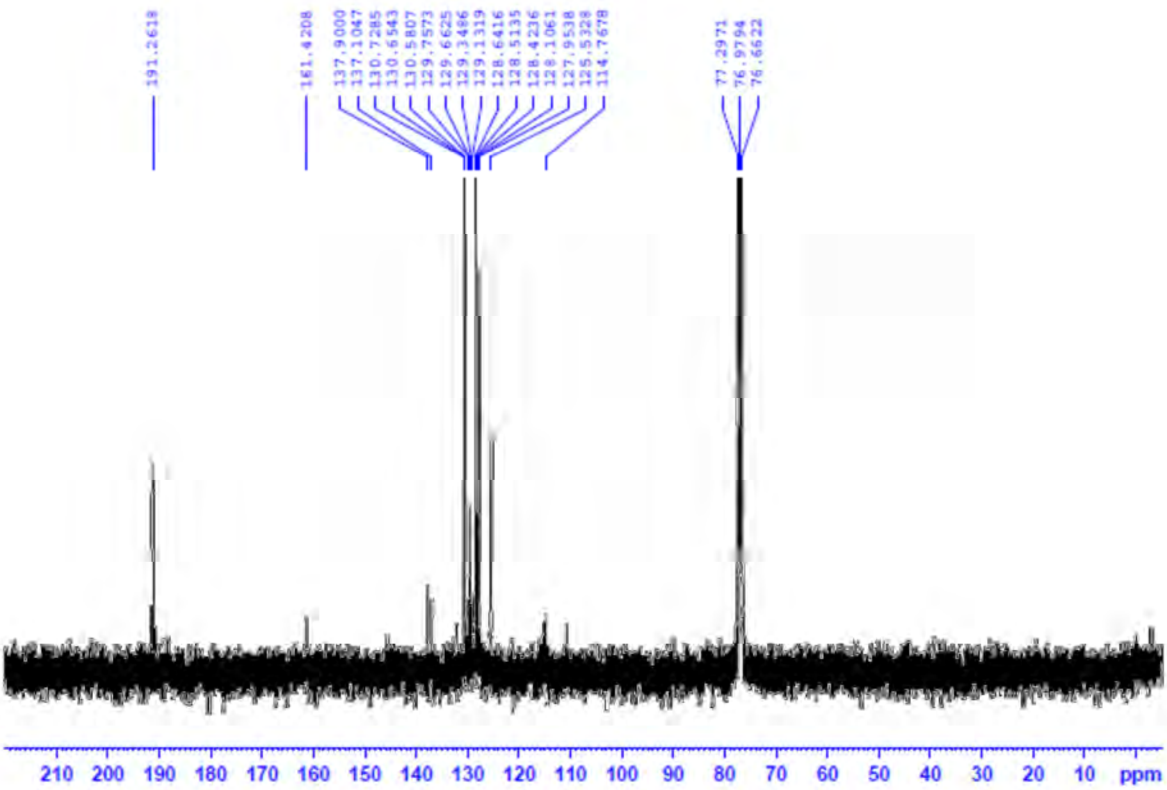
Compound S1e, 400MHz, 13C NMR, CDCl3



Compound 3,1H NMR,CDCl3, AV400

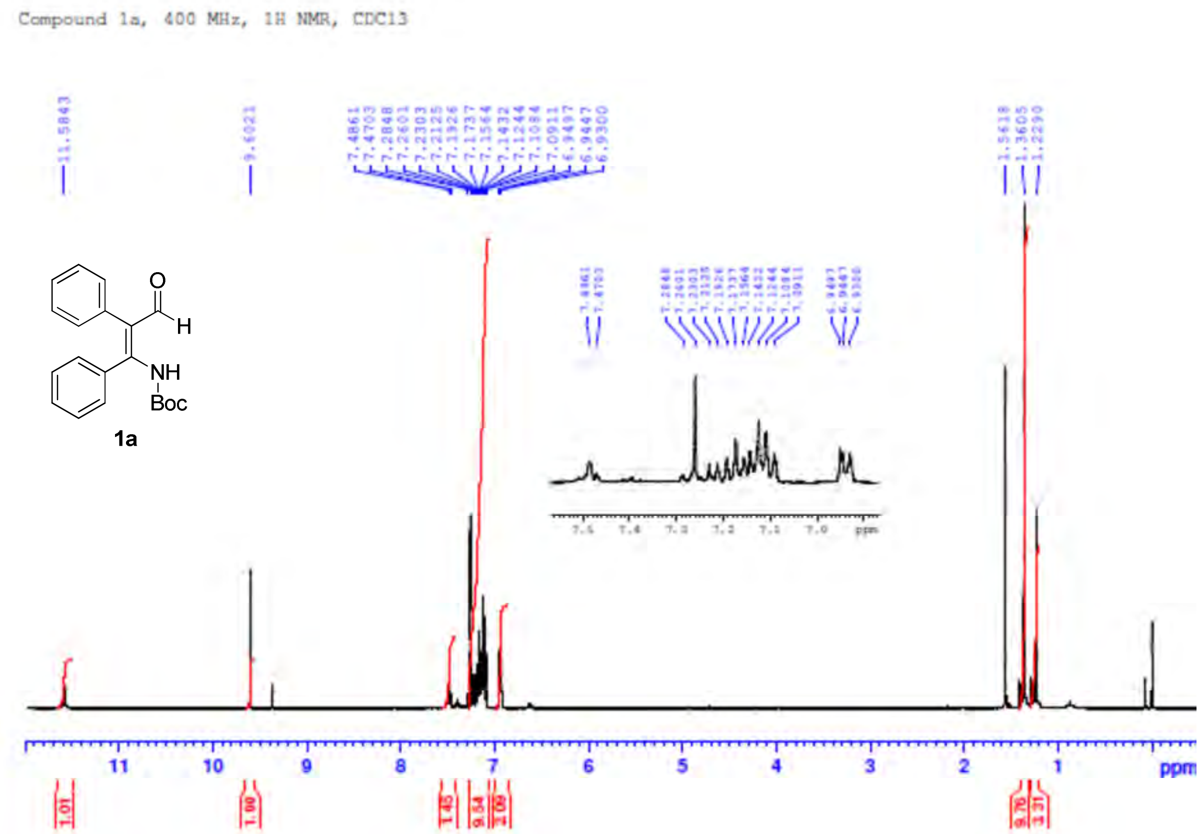


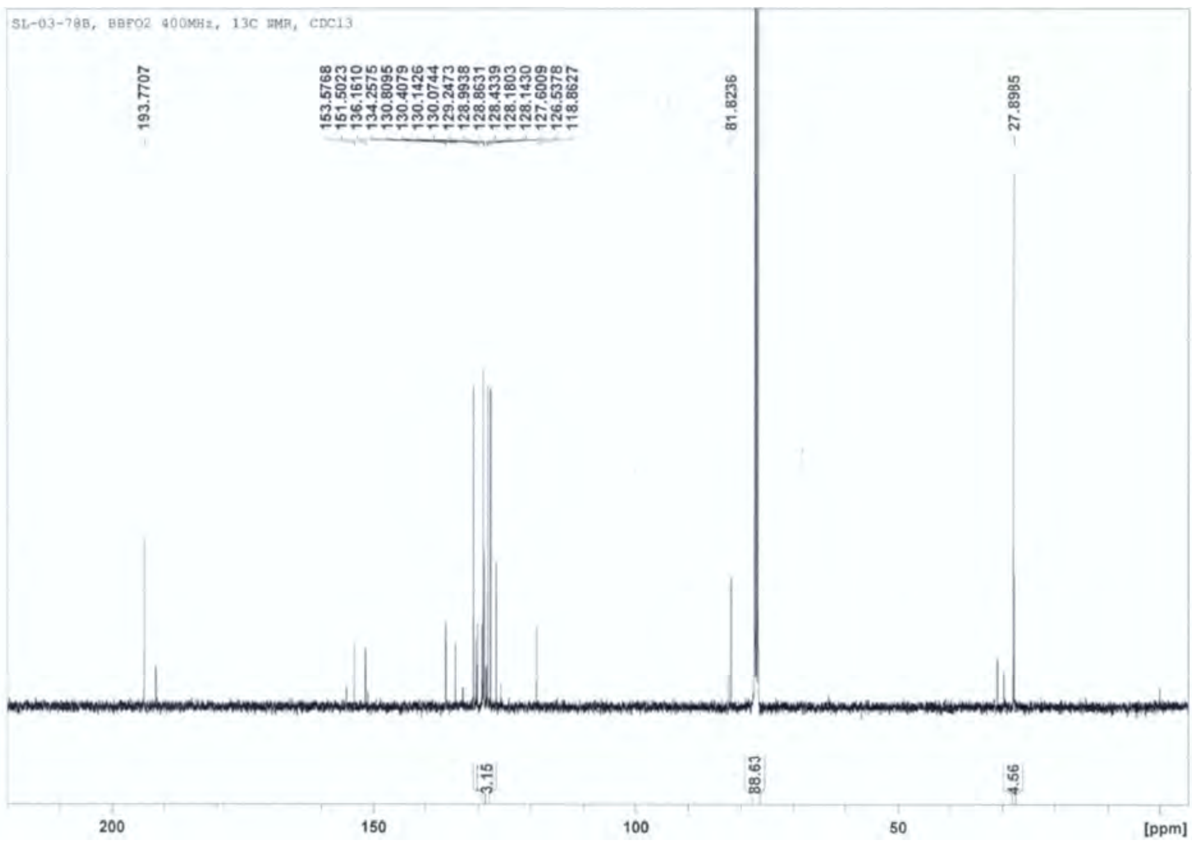
Compound 3, 13C NMR, 400 MHz, CDCl3



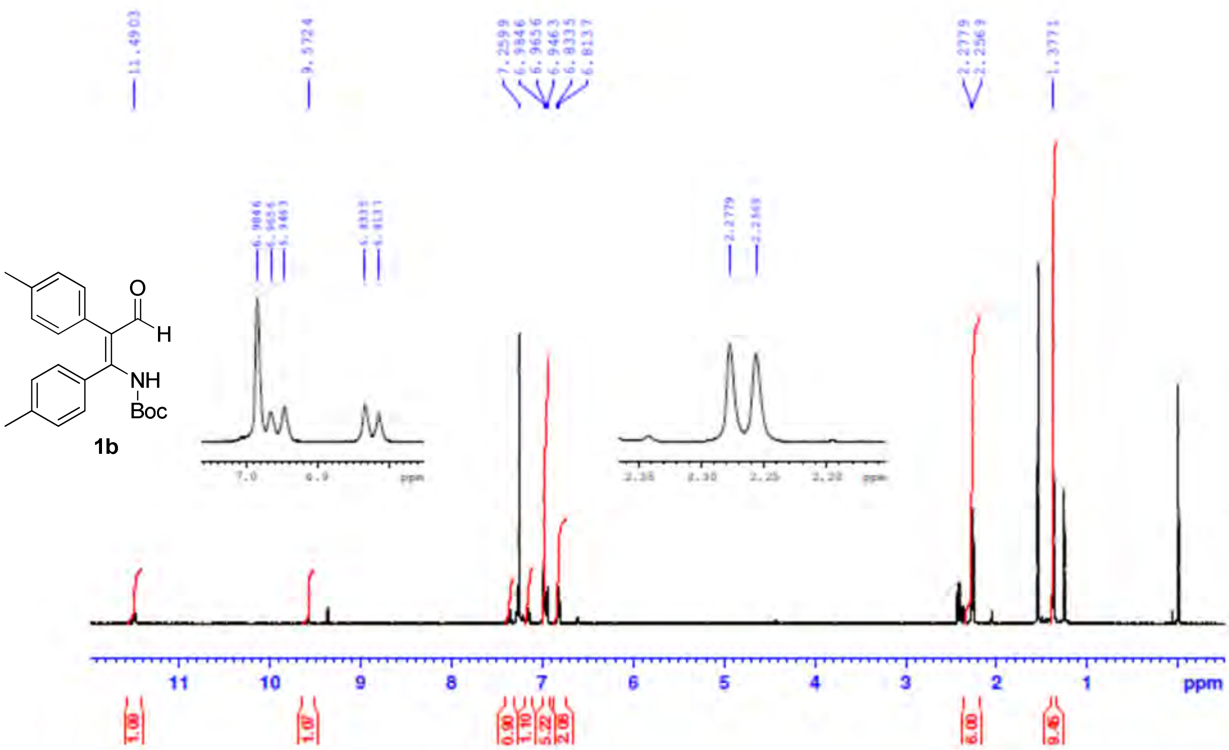
Electronic Supplementary Material (ESI) for RSC Advances

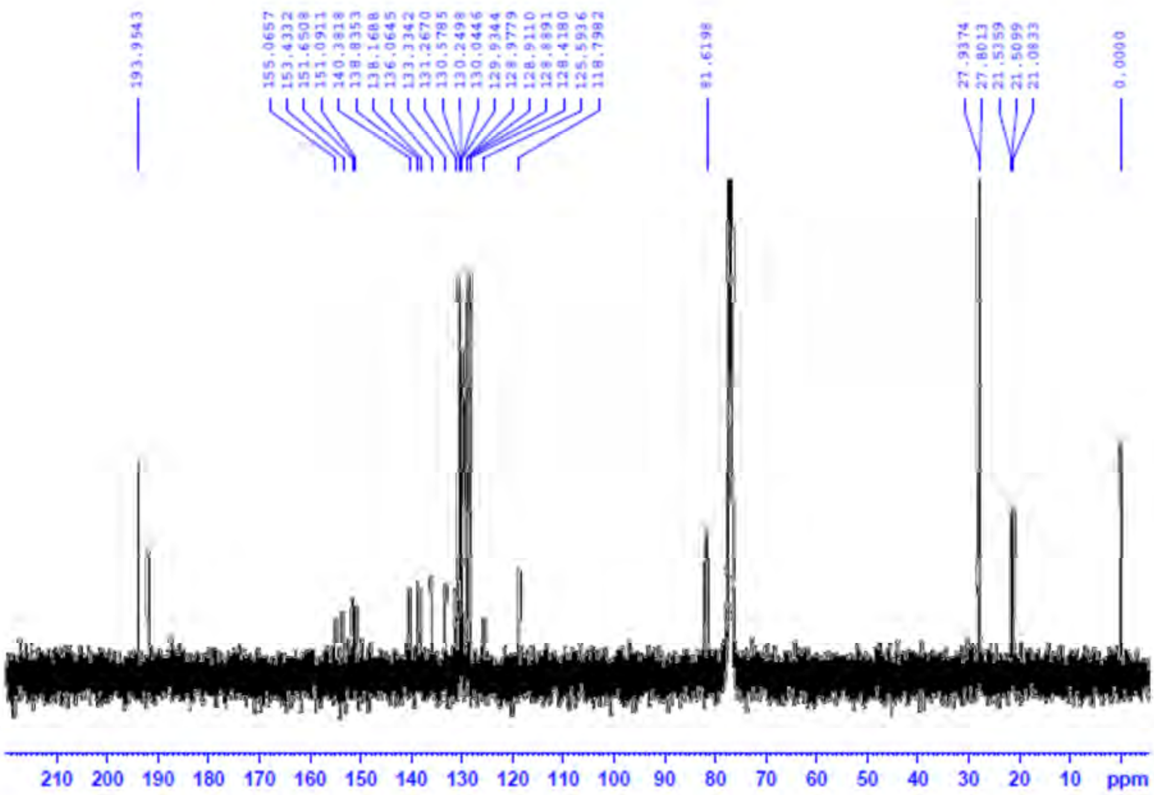
^{1}H and ^{13}C NMR spectra of N-Boc-γ-amino-α,β-unsaturated aldehyde (1)





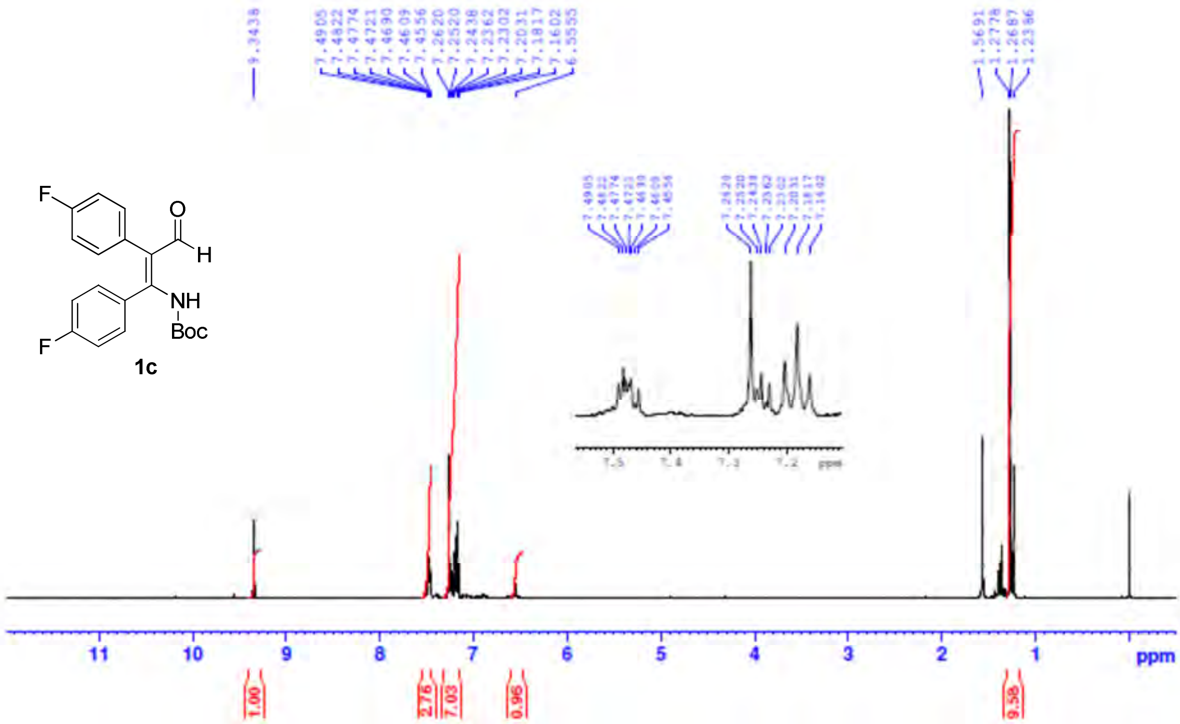
Compound 2a, 400 MHz, CDCl3,1H NMR



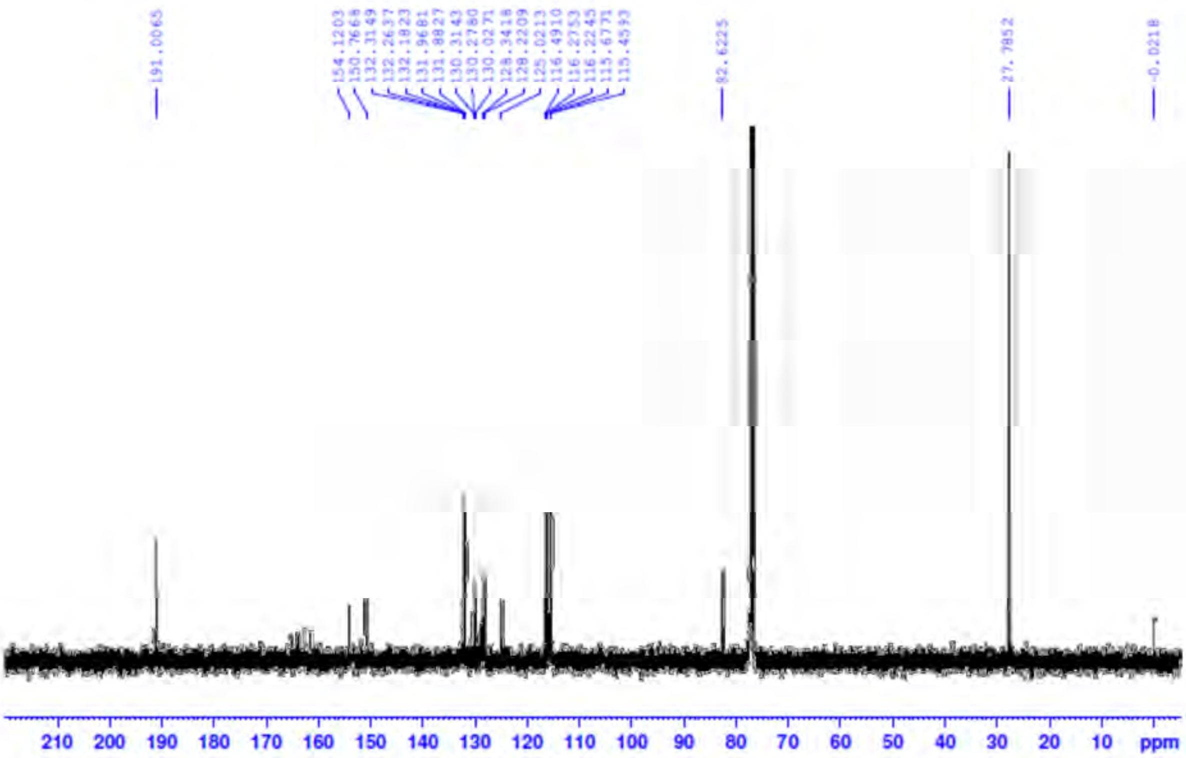


Electronic Supplementary Material (ESI) for RSC Advances
This journal is © The Royal Society of Chemistry 2014

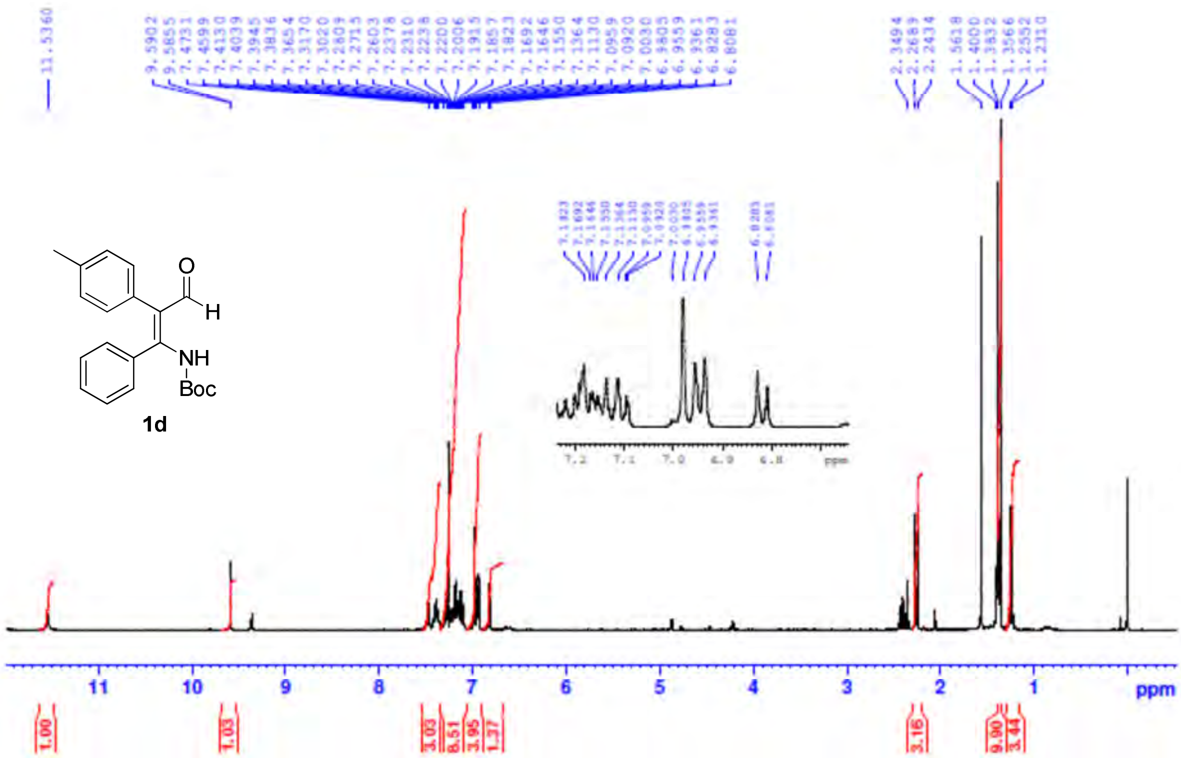
Compound 1c, CDCl3, 1H NMR, 400 MHz



Compound 1c, CDCl3, 13C NMR, 400 MHz

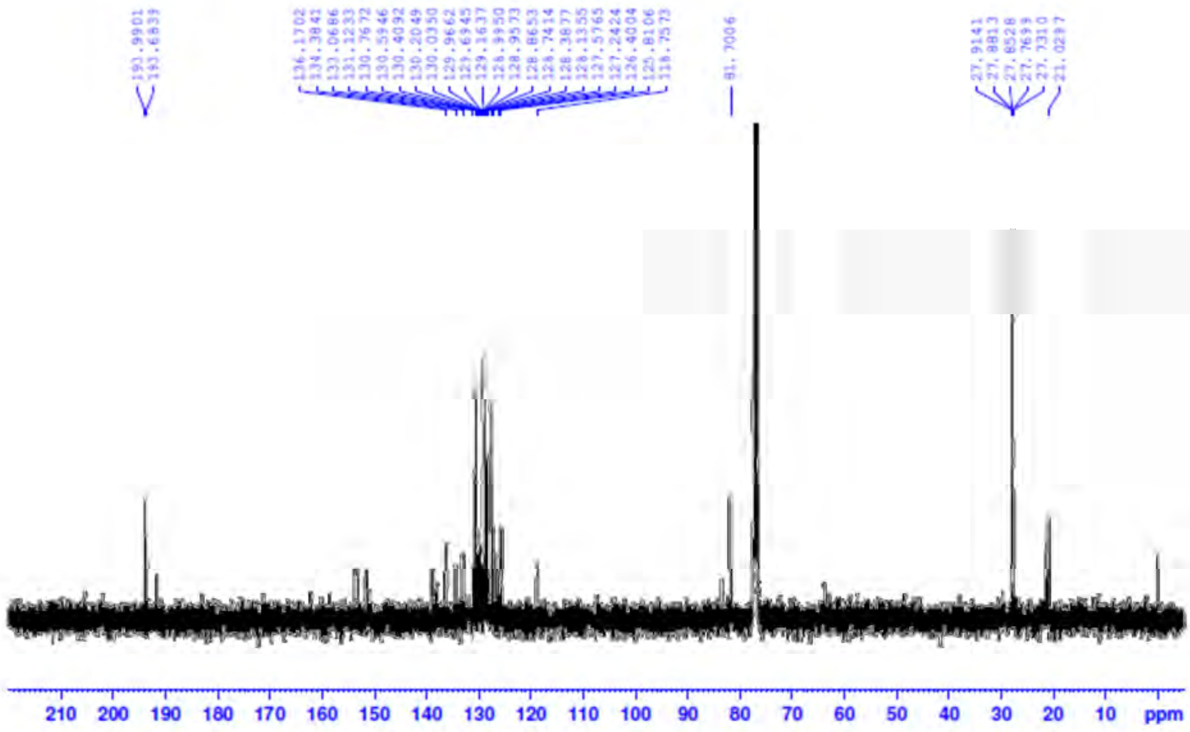


Compound 1d, 1H NMR, 400 MHz, CDCl3

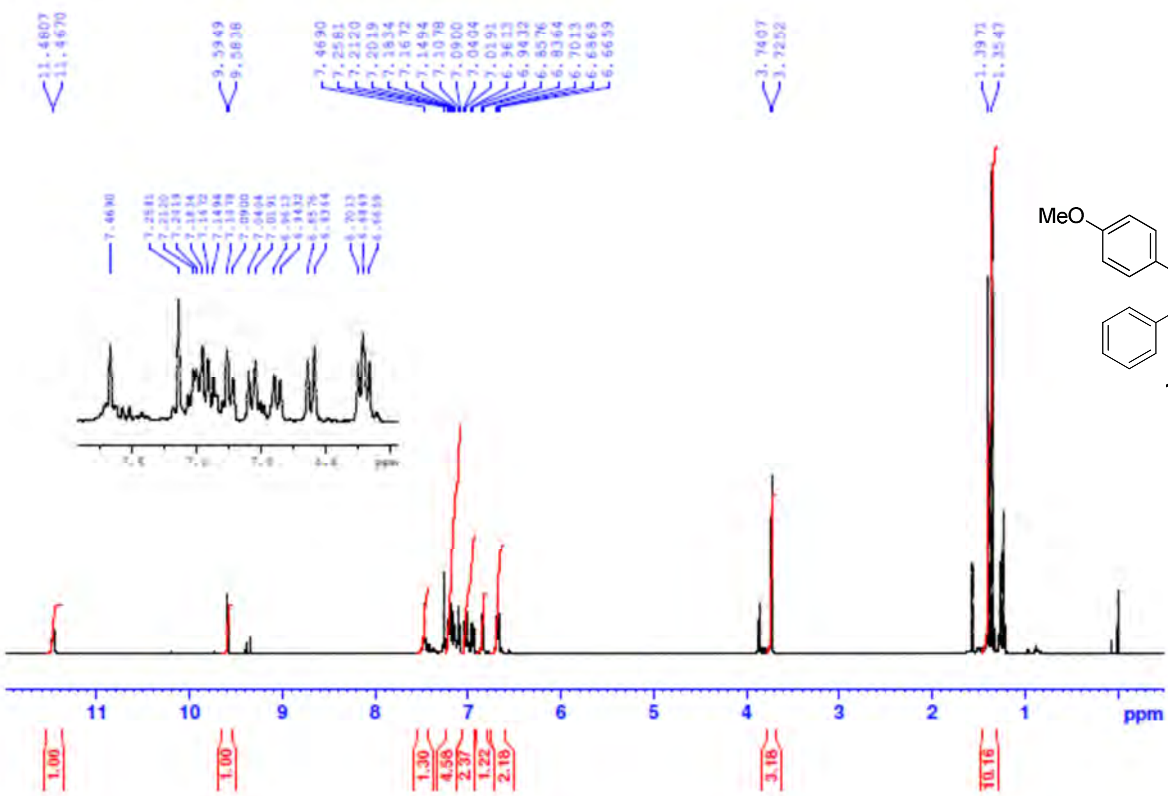


1d

Compound 1d,13C NMR, 400 MHz, CDCl3

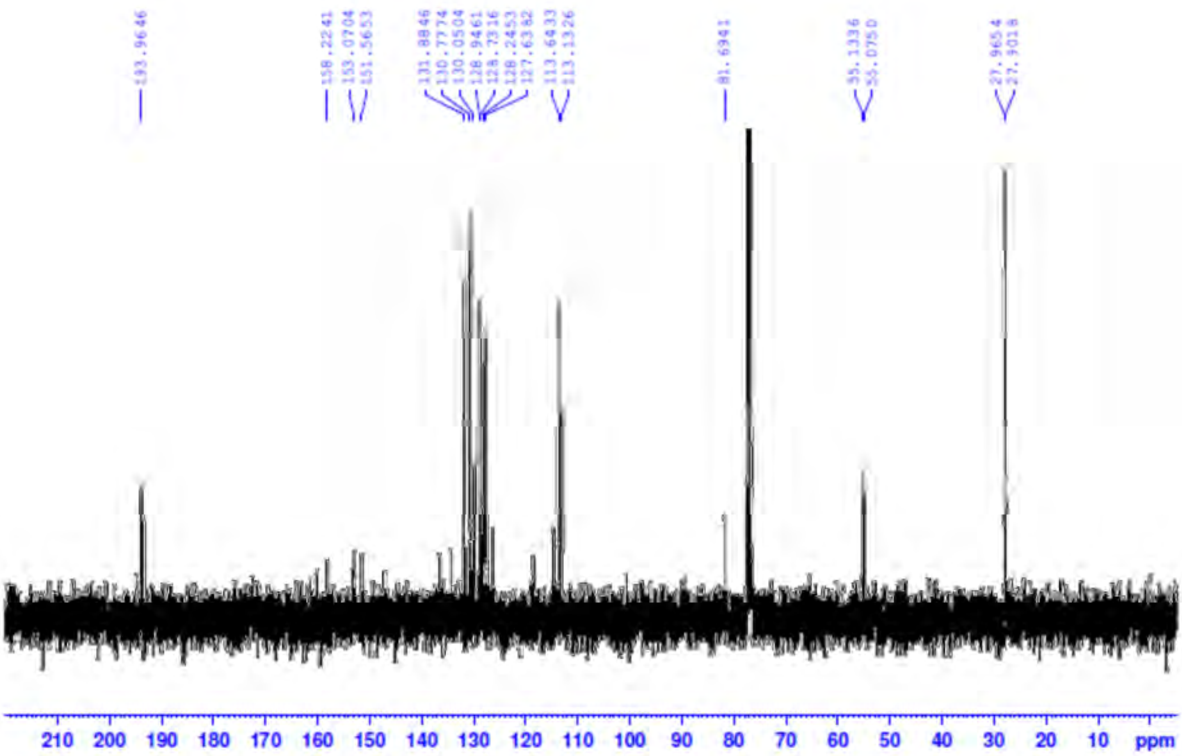


Compound 1e, 400 MHz, CDCl3,1H NMR

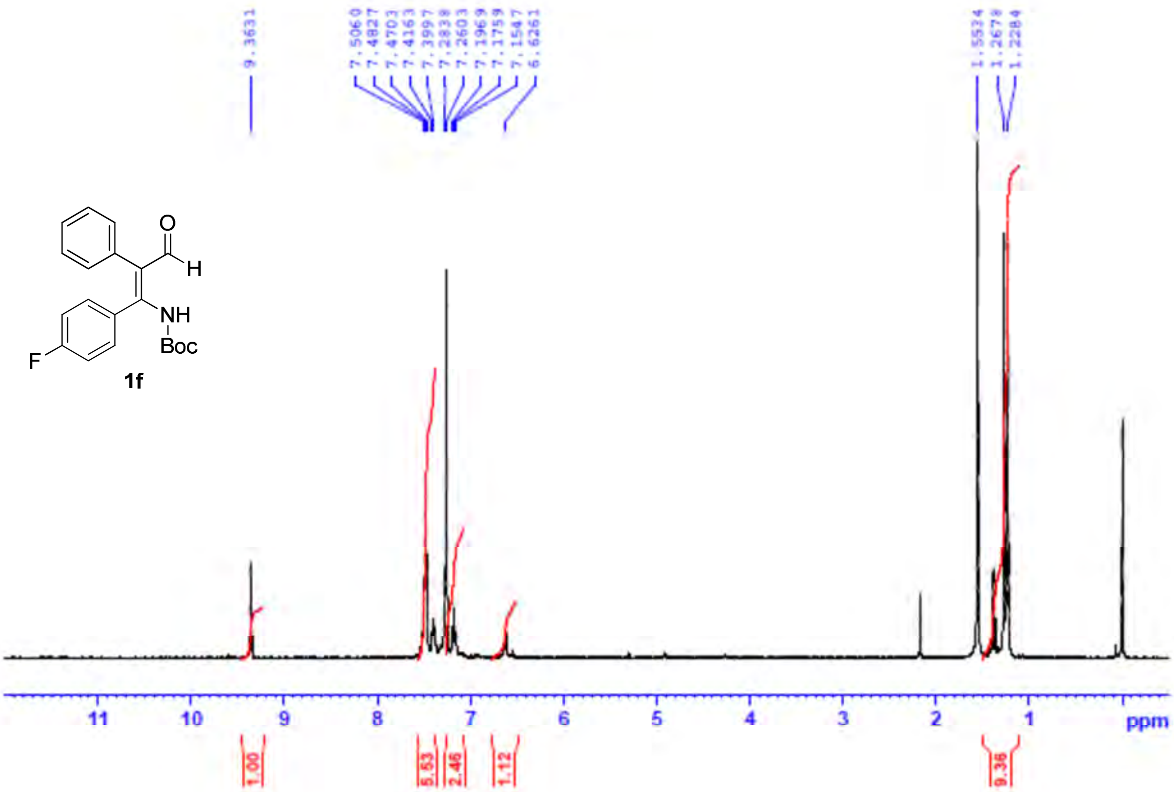


1e

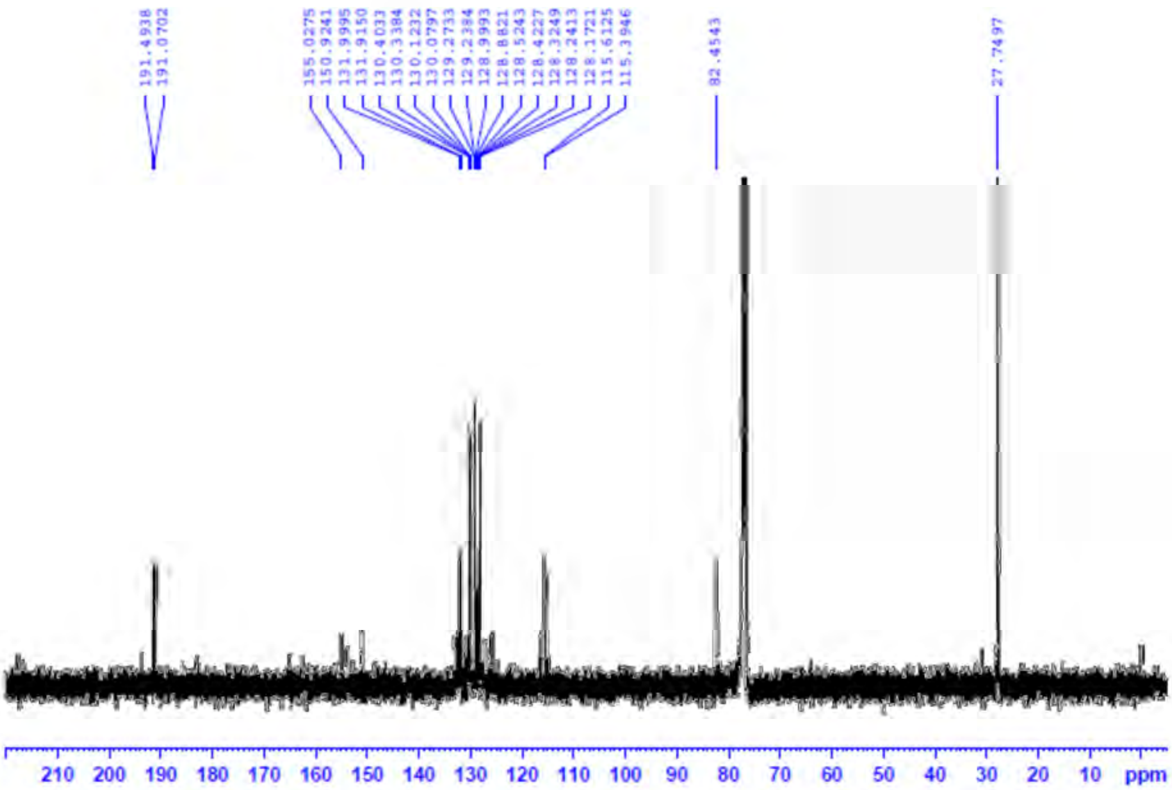
Compound 1e, 400 MHz, CDCl3,13C NMR



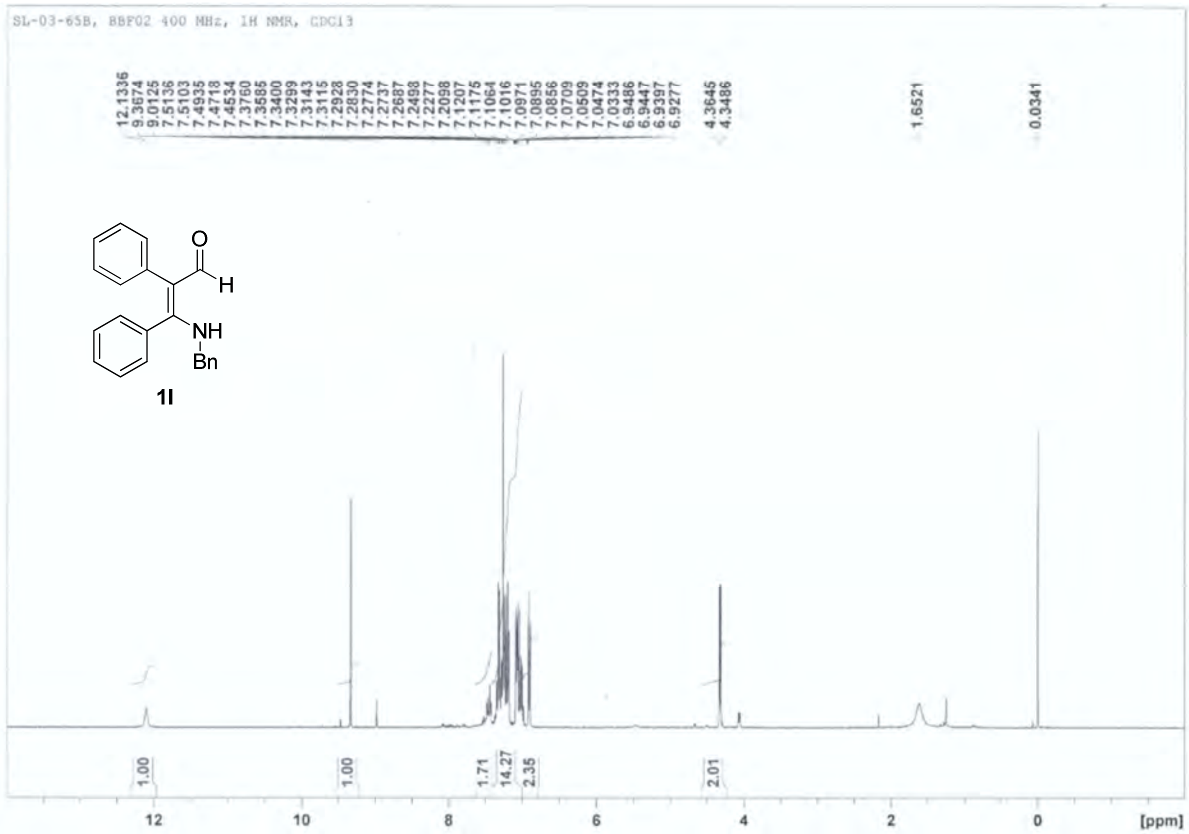
Compound 1f,CDCl3, 1H NMR, 400 MHz,BBFO2

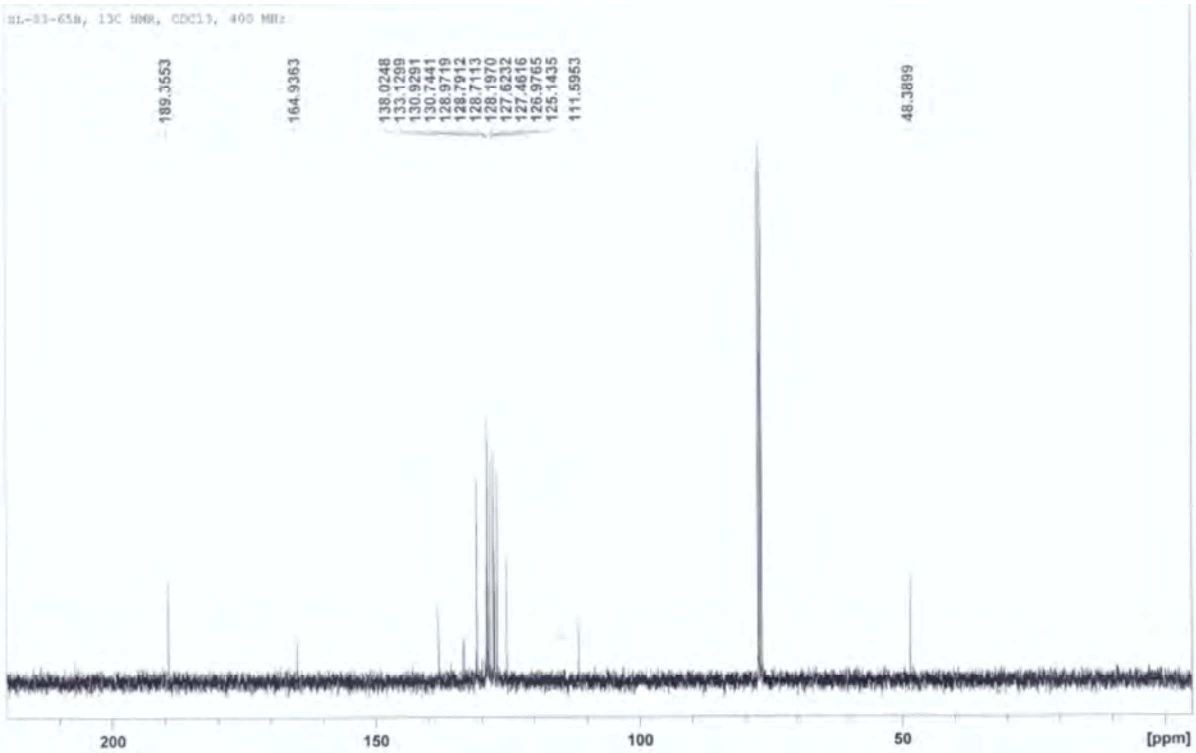


Compound 1f, 13C NMR, 400 MHz, CDCl3



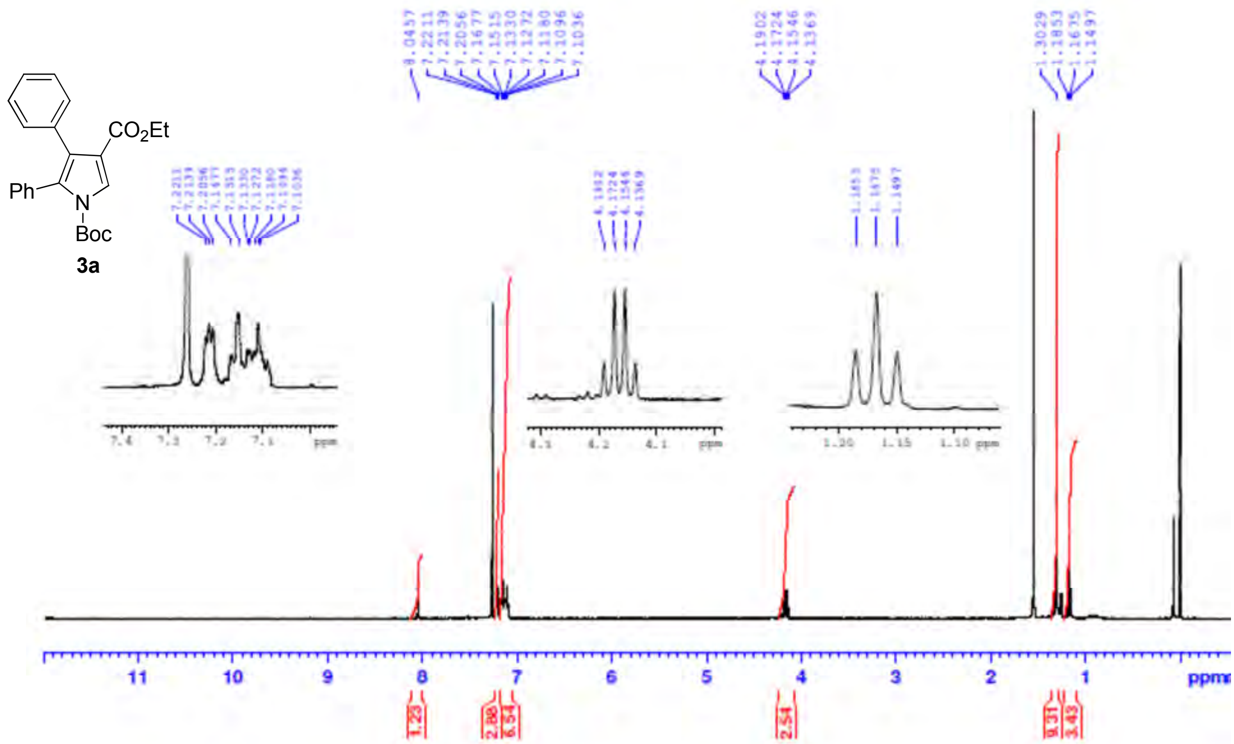
^{1}H and ^{13}C NMR spectra of N-Benzyl-γ-amino-α,β-unsaturated aldehyde (1l)



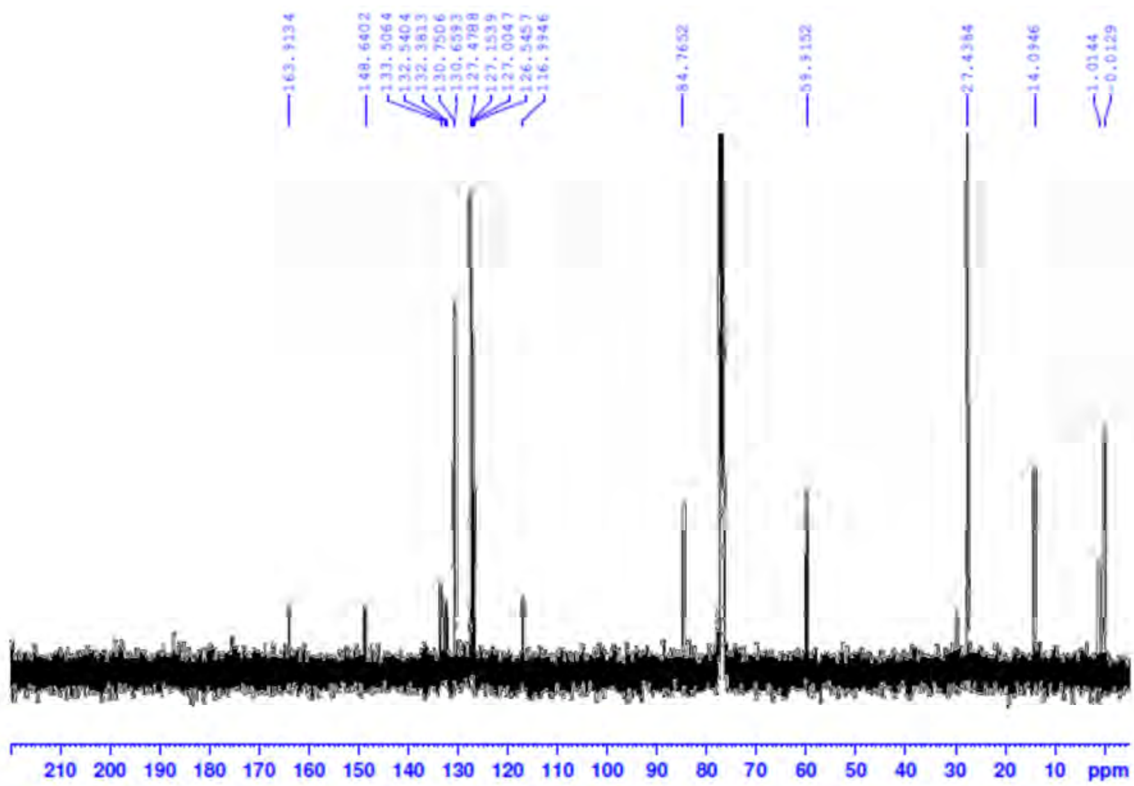


^{1}H and ^{13}C NMR spectra of polysubstituted pyrrole derivatives (3)

Compound 3a, 1H NMR, 400 MHz, CDCl3

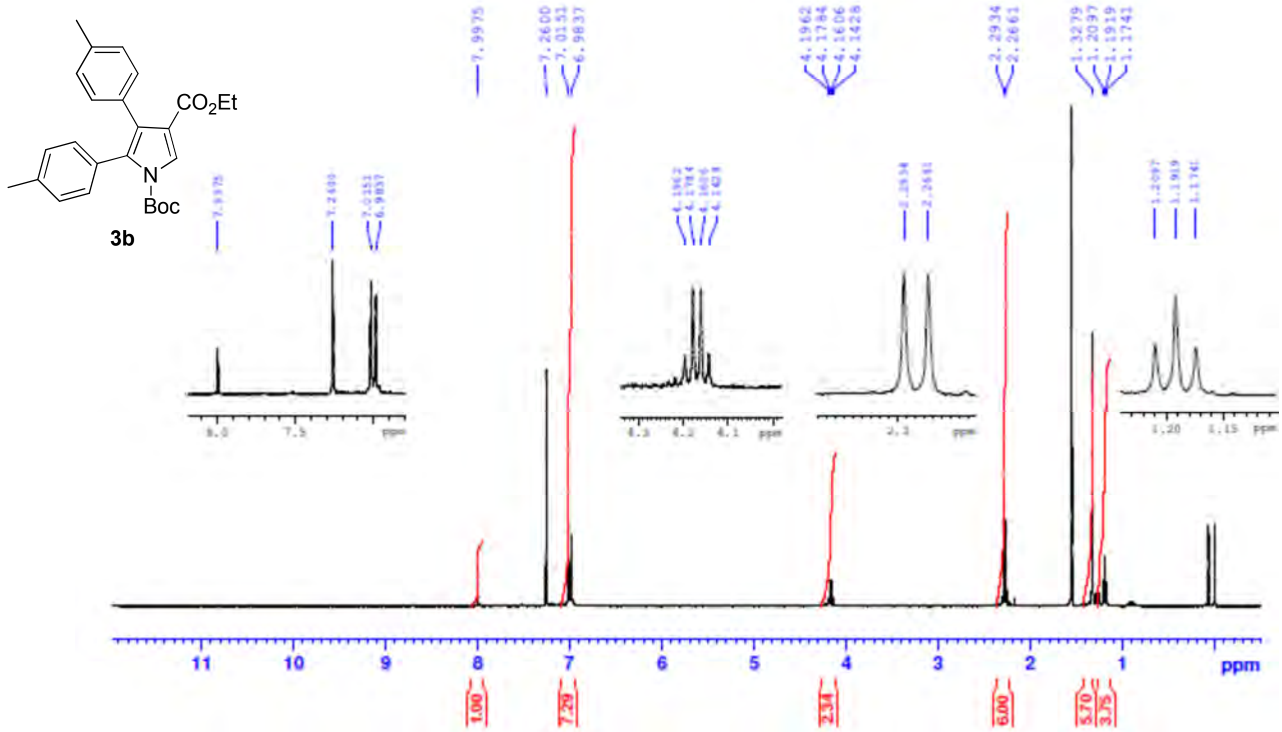


Compound 3a, 400 MHz, 13C NMR, CDCl3

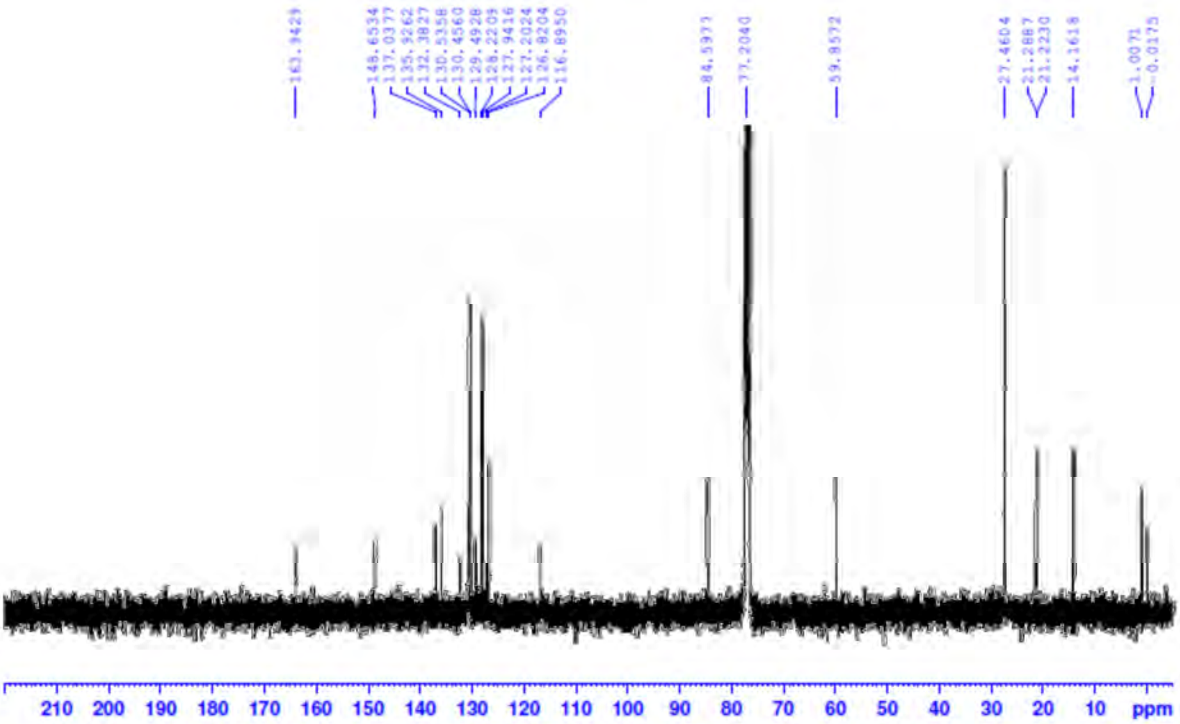


Electronic Supplementary Material (ESI) for RSC Advances

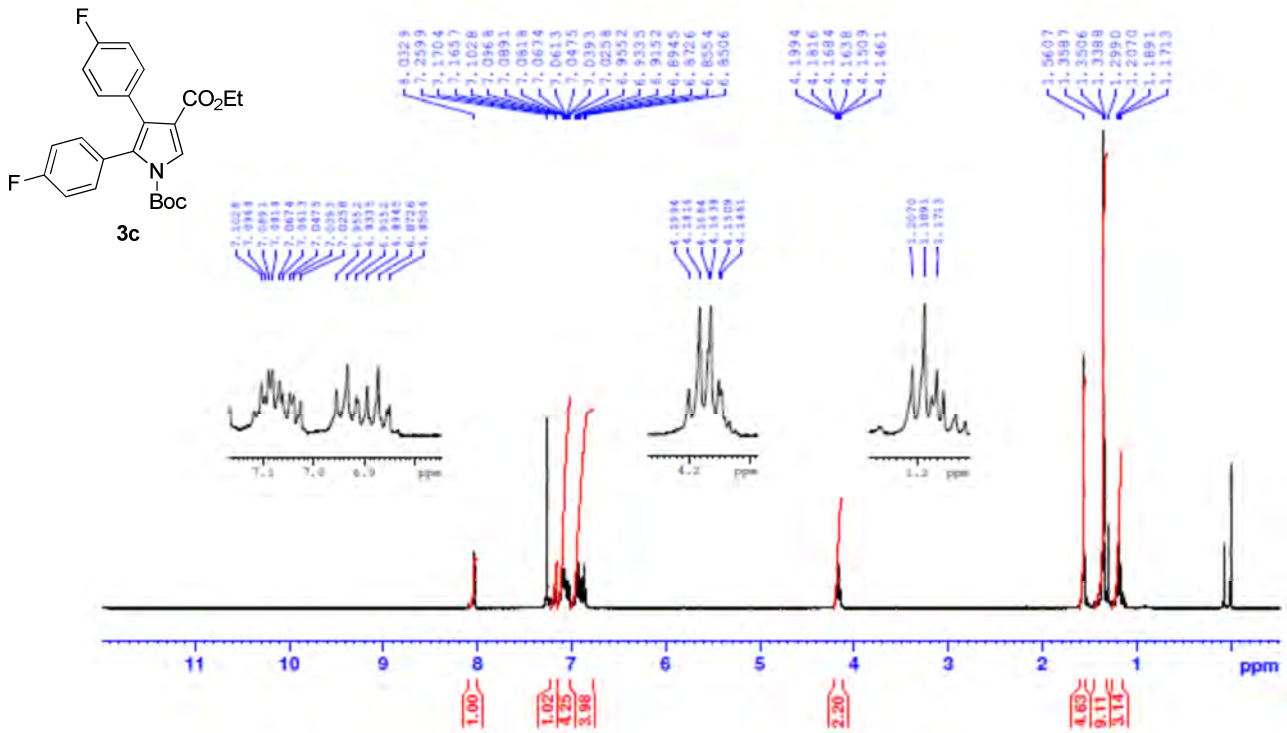
Compound 3b, AV 400 MHz, 1H NMR, CDC13

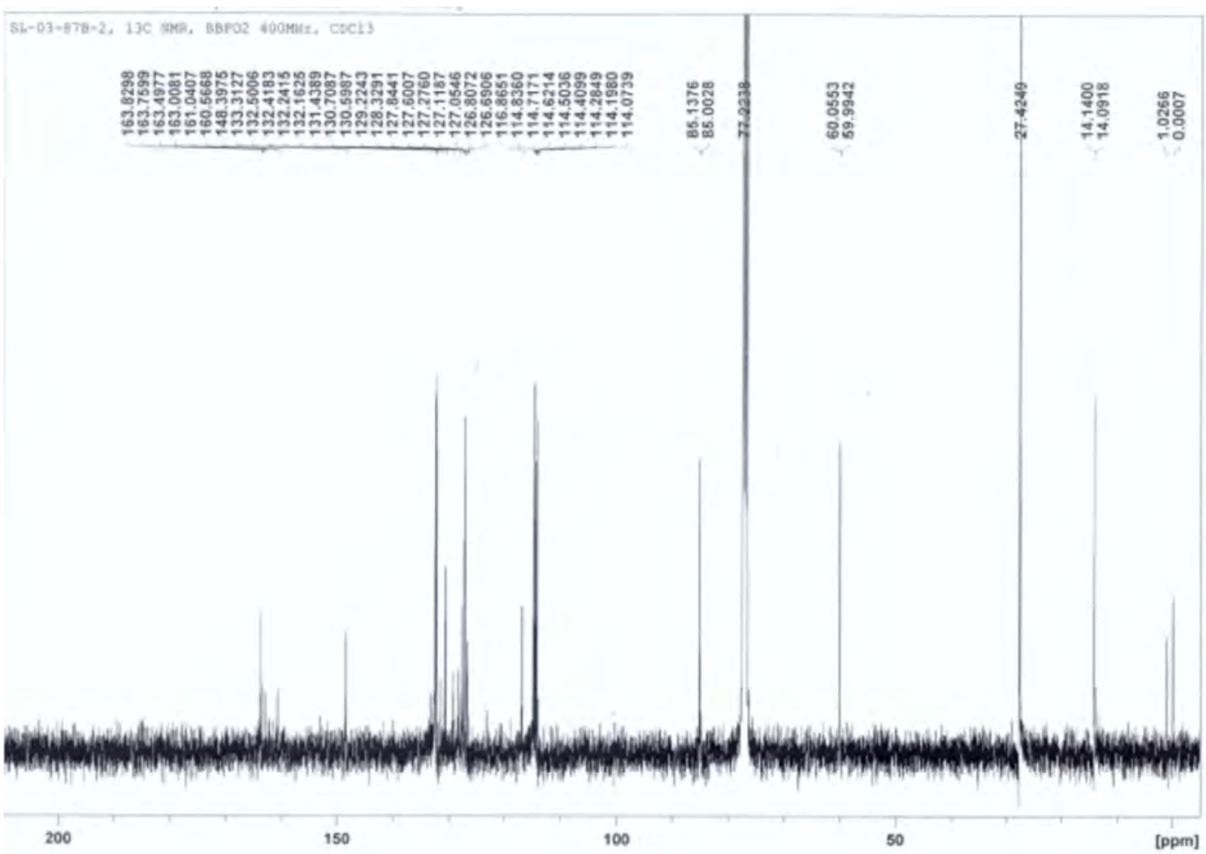


Compound 3b, 400MHz, 13C NMR, CDC13

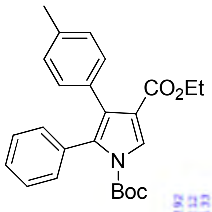


Compound 3c, CDCl3, 1H NMR, 400 MHz

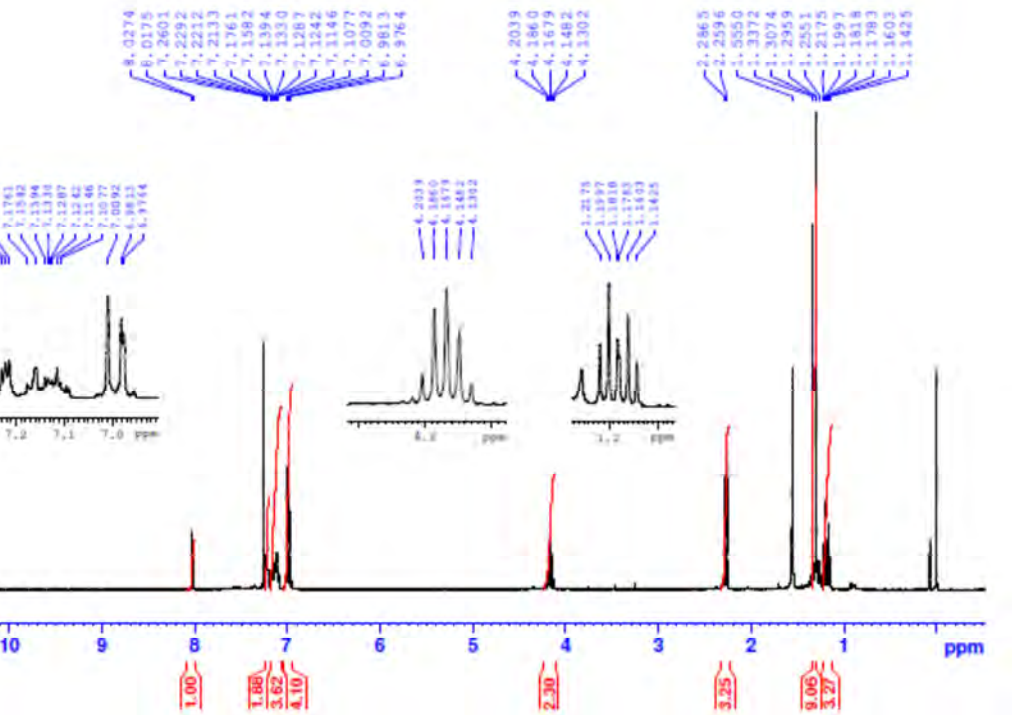




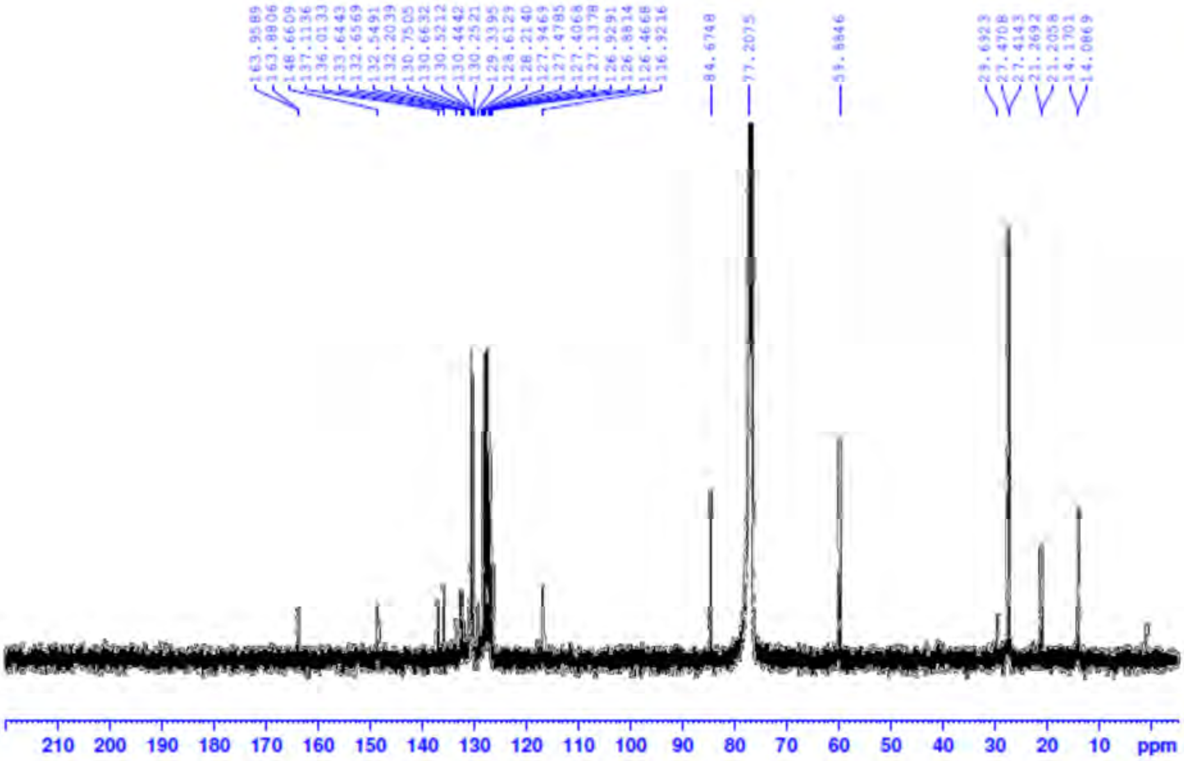
Compound 3d, 1H NMR, 400 MHz, CDCl3

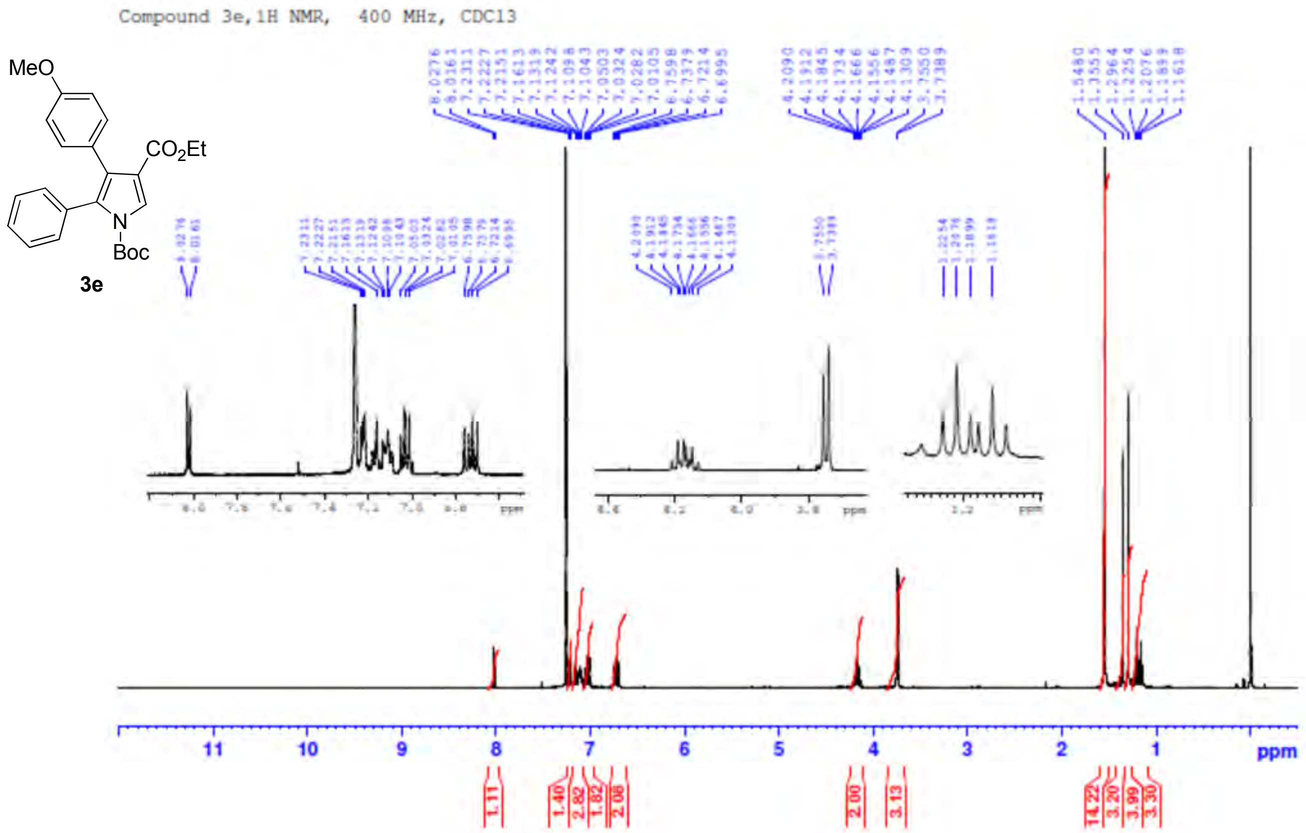


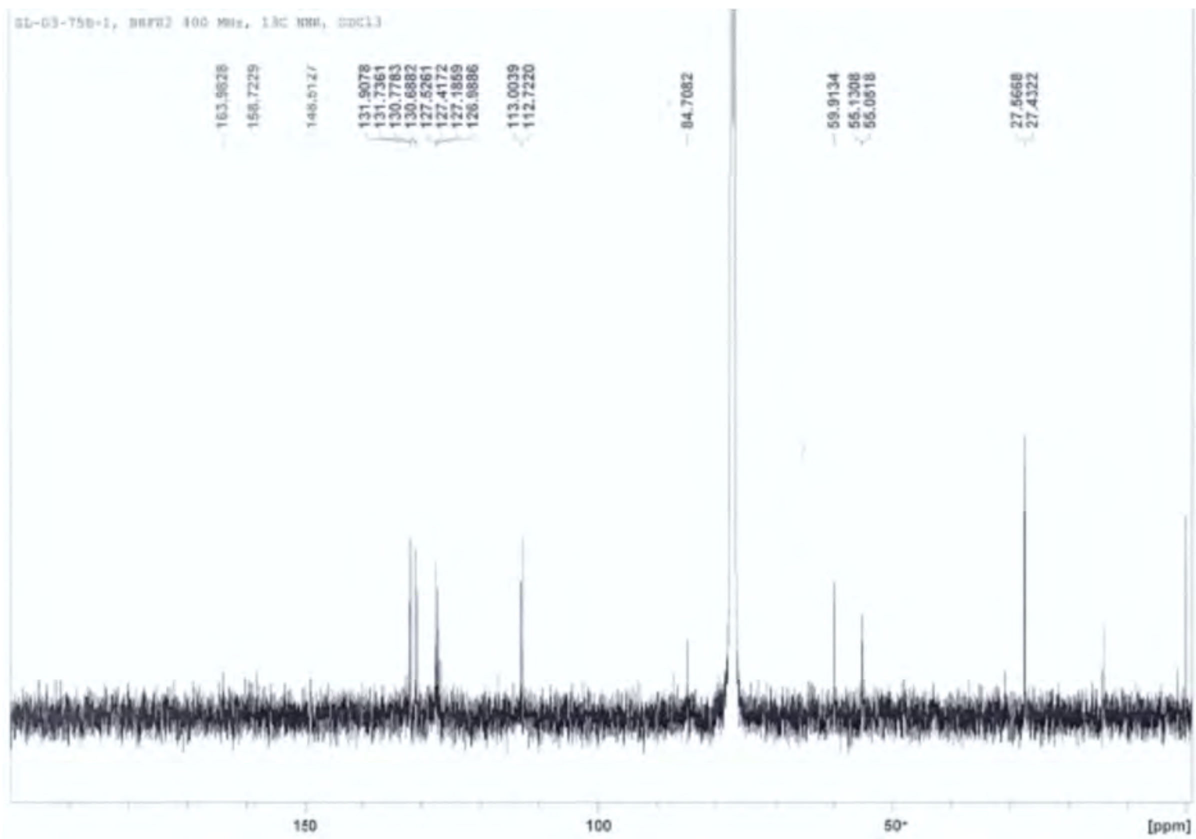
3d



Compound 3d,13C NMR, 400 MHz, CDCl3

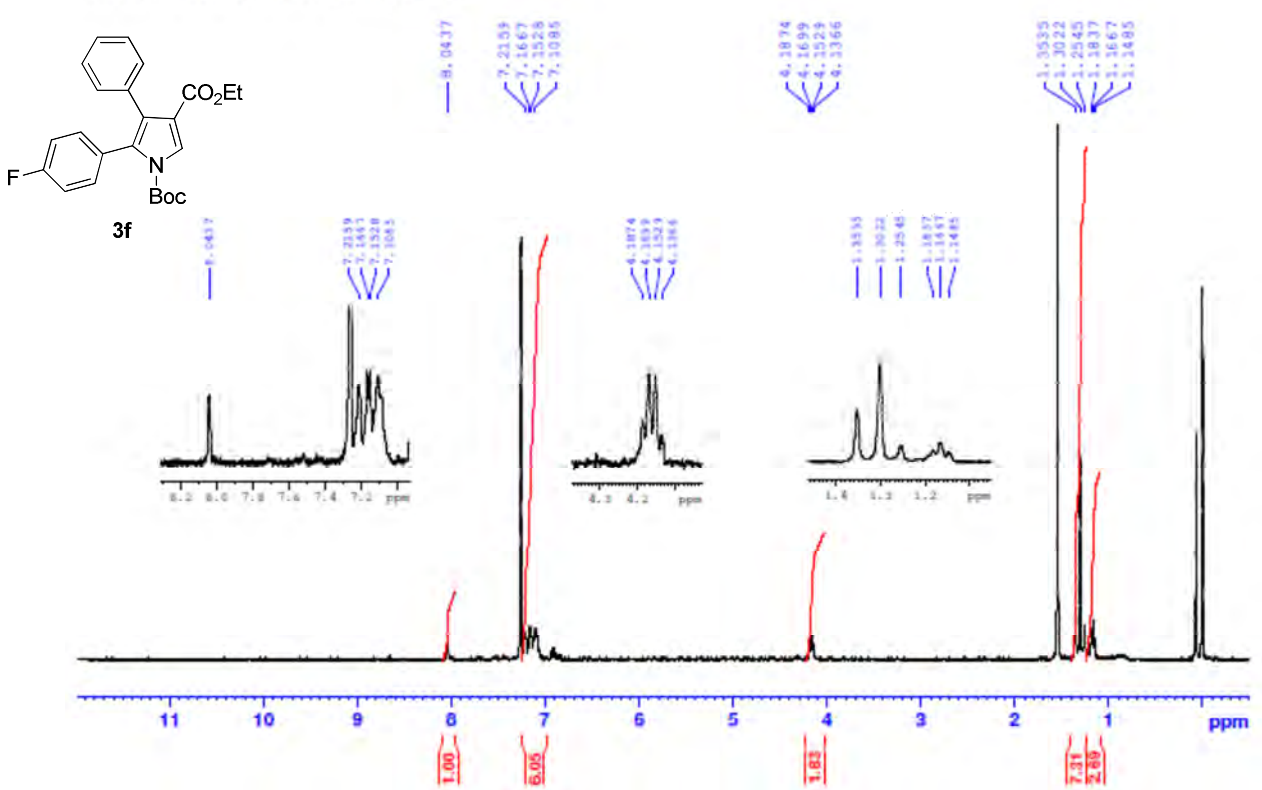



Compound 3e, 1H NMR, 400 MHz, CDCl3
MeO
CO2Et
N
Boc
3e
ppm

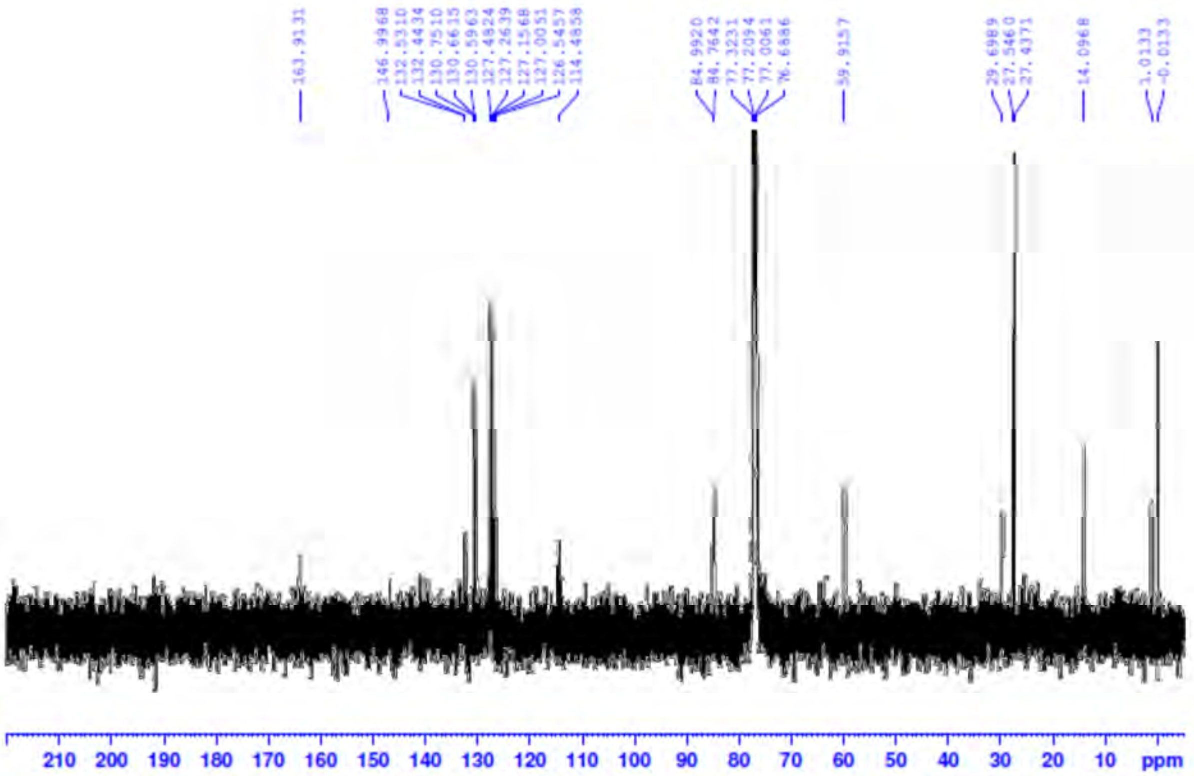

[ppm]

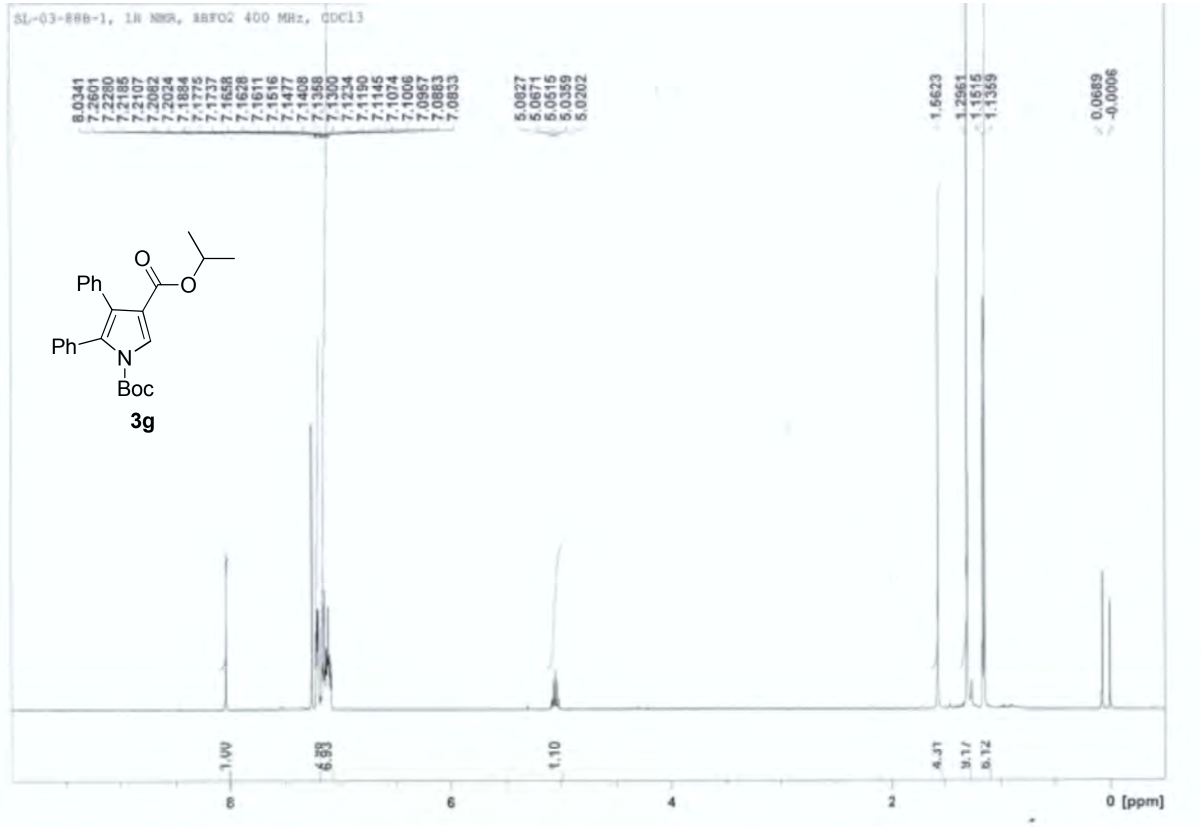
Electronic Supplementary Material (ESI) for RSC Advances

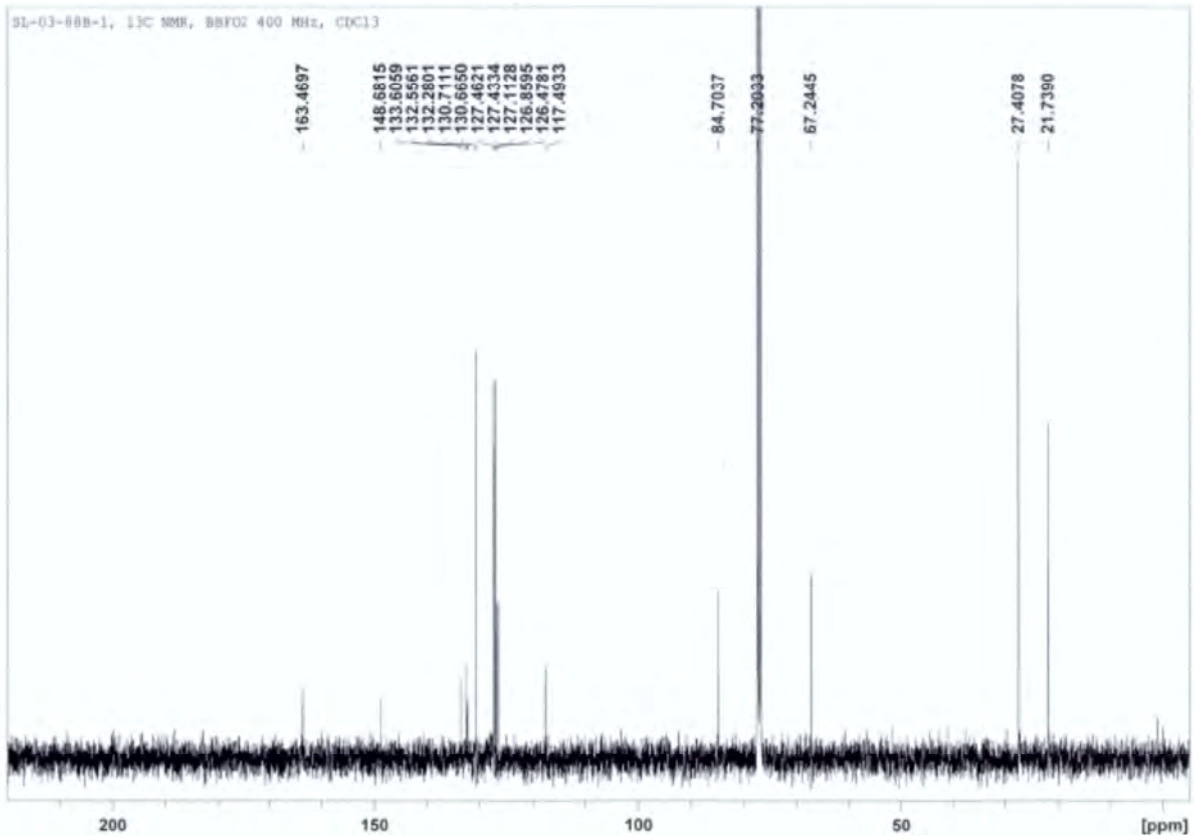
Compound 3f, 400 MHz, CDCl3,1H NMR



Compound 3f, 13C NMR, 400 MHz, CDCl3

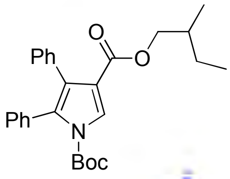



SL-03-088-1, 1H NMR, BBFO2 400 MHz, CDCl3
Ph
Ph
N
Boc
O
O
3g
[ppm]

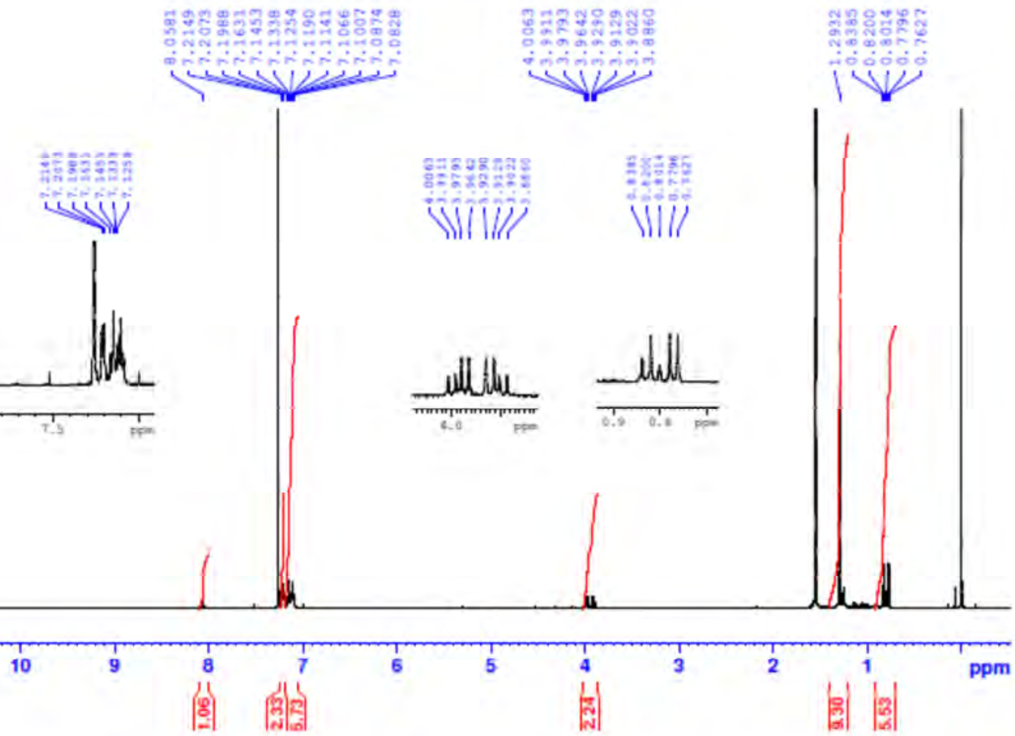

SL-03-088-1, 13C NMR, BBFO2 400 MHz, CDCl3
163.4697
148.6815
133.6059
132.5561
132.2801
130.7111
130.6650
127.4621
127.4334
127.1128
126.8595
126.4781
117.4933
84.7037
77.2033
67.2445
27.4078
21.7390
200
150
100
50
[ppm]

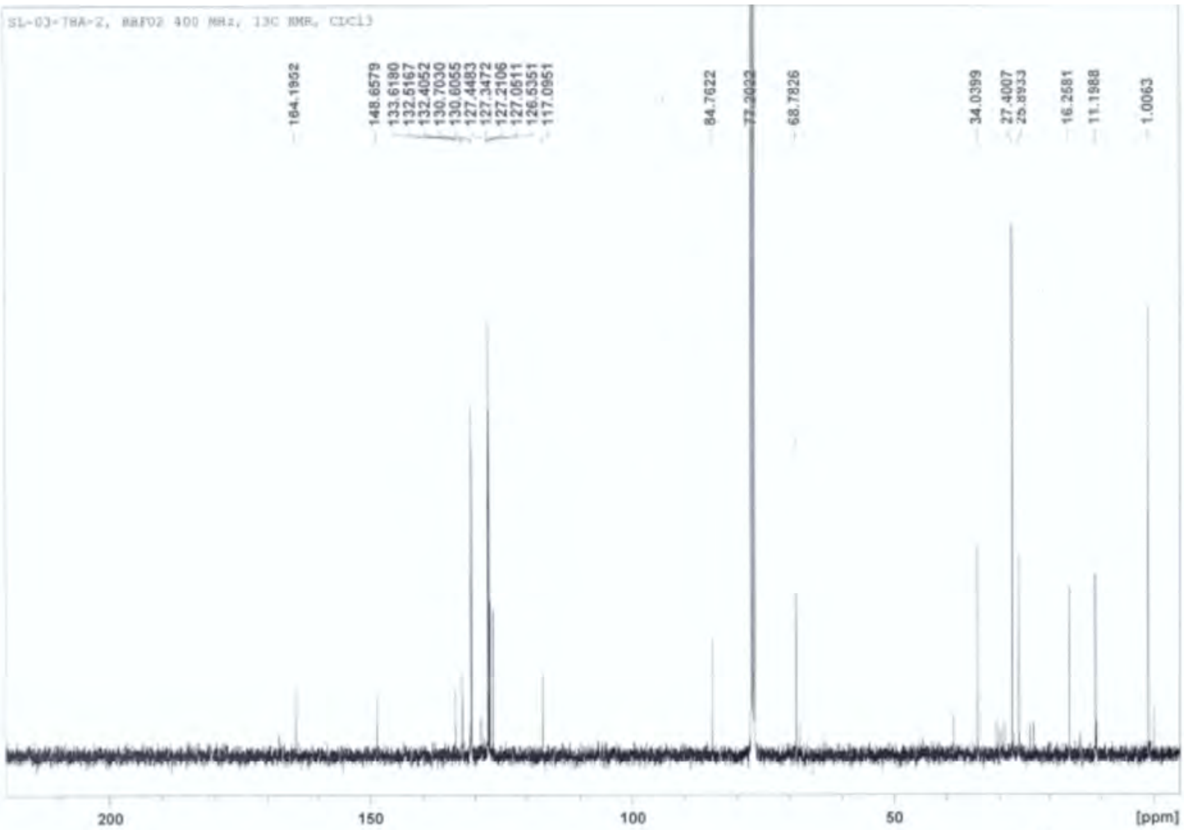
Electronic Supplementary Material (ESI) for RSC Advances

Compound 3h, 400 MHz, 1H NMR, CDCl3

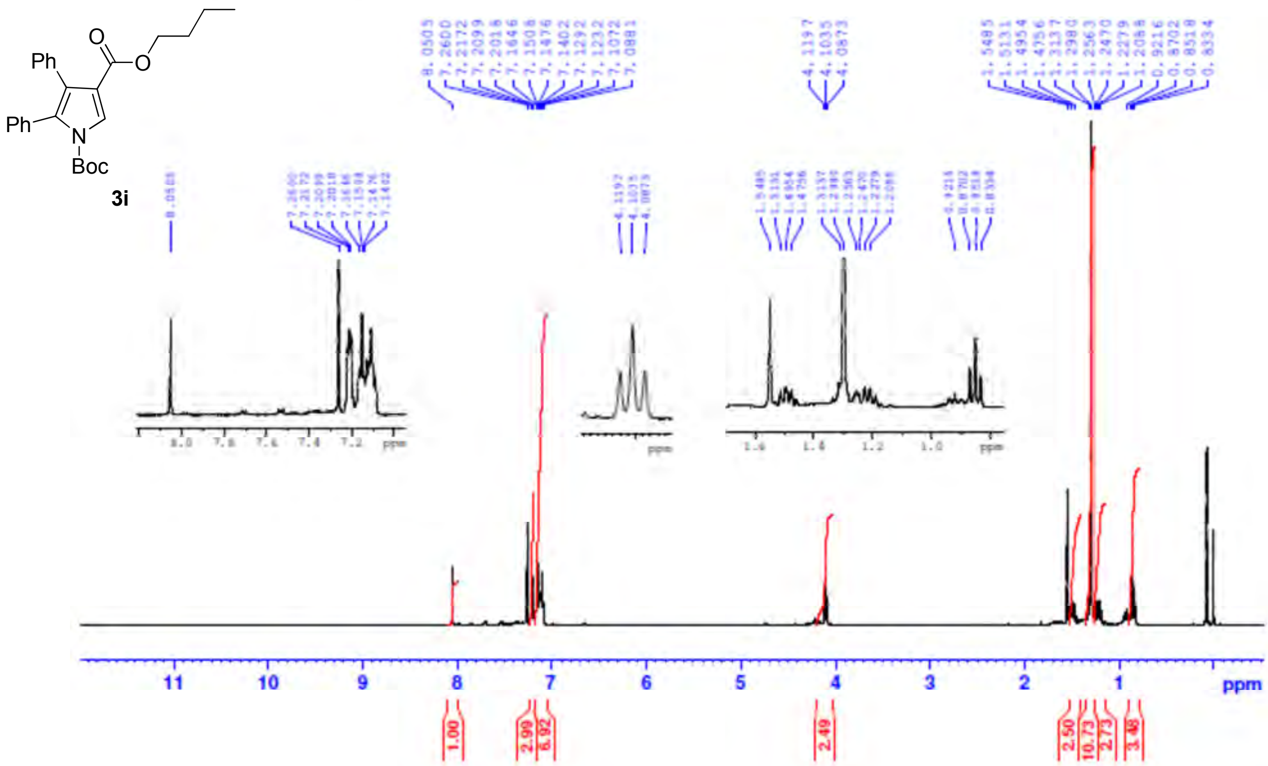


3h

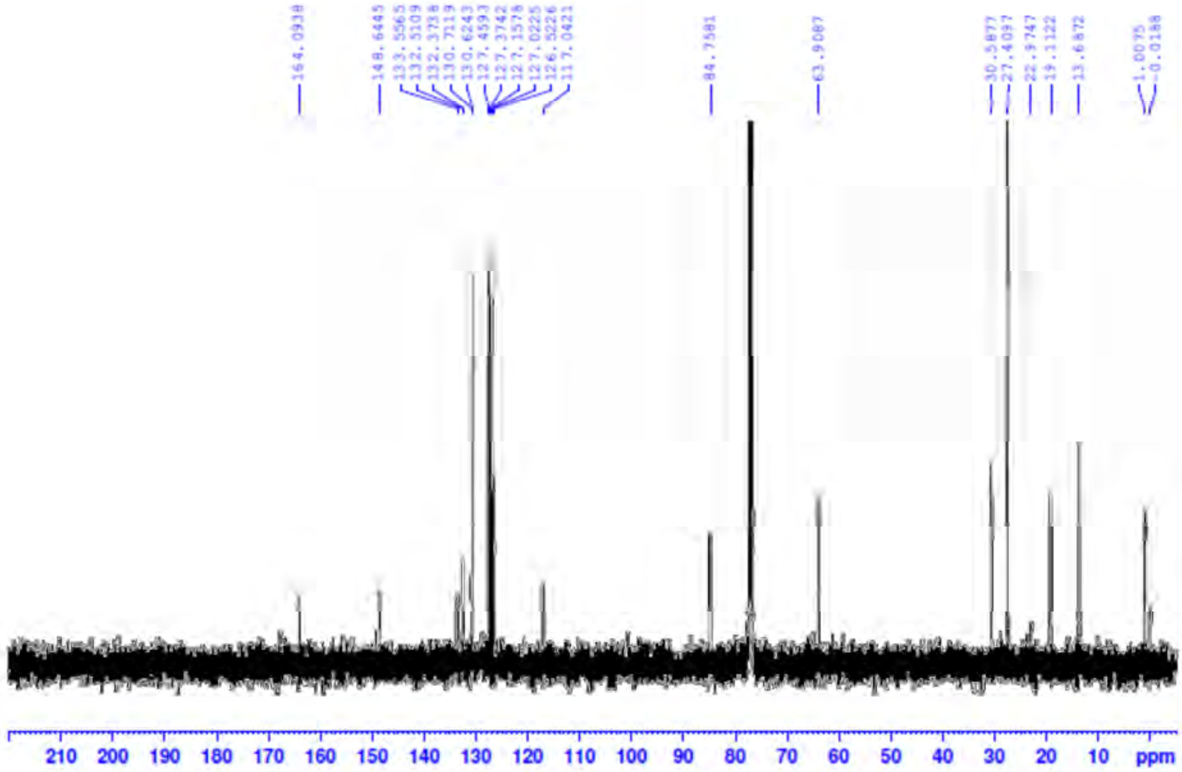




Compound 3i, 1H NMR, 400 MHz, CDCl3

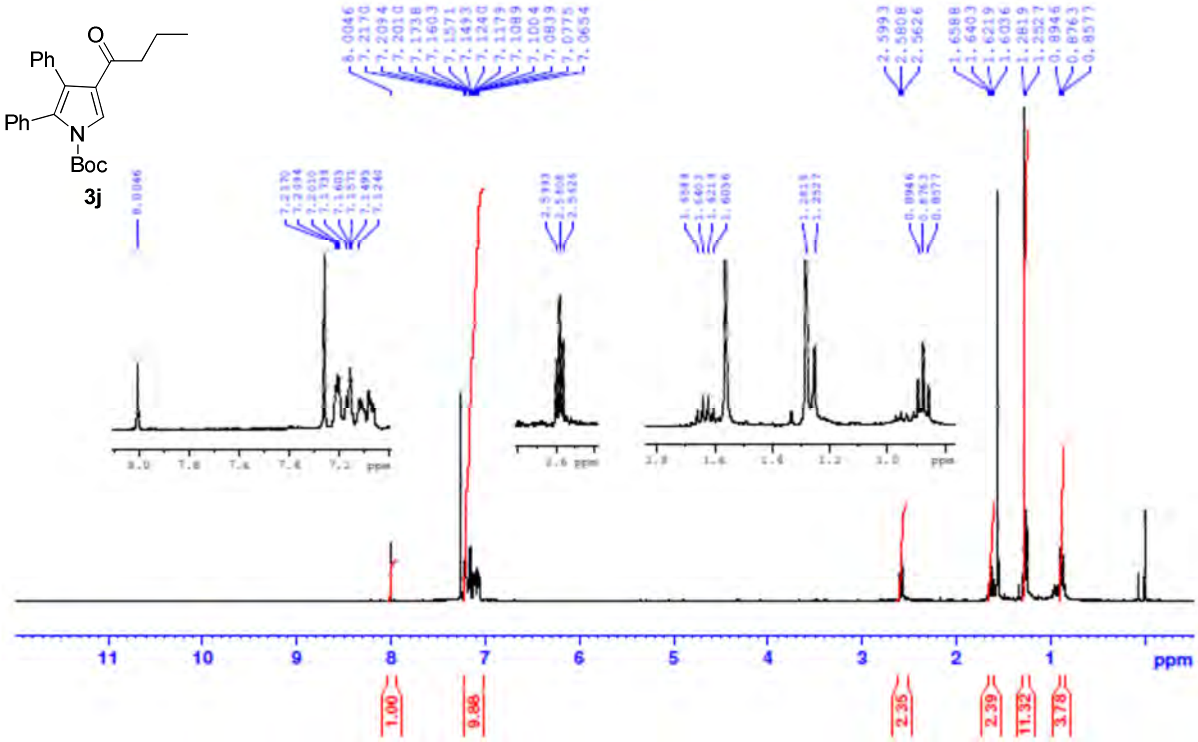


Compound 3i,13C NMR, 400 MHz, CDCl3

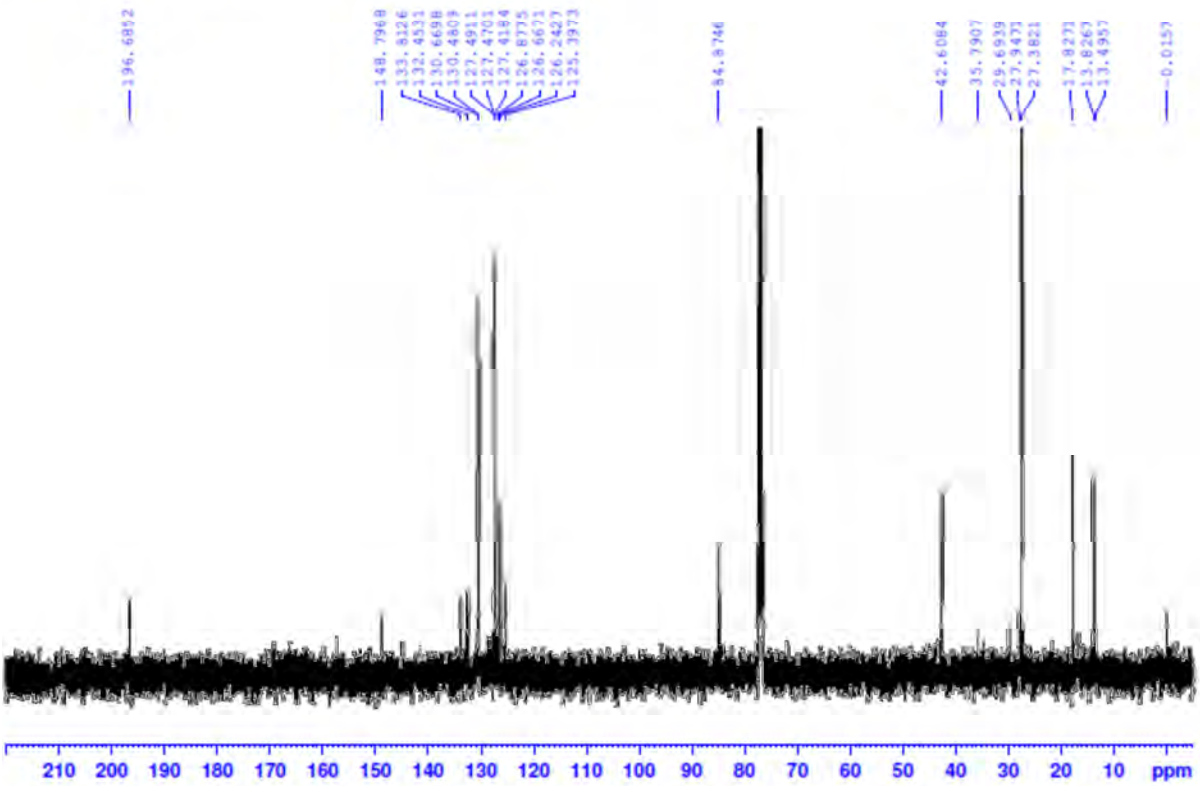


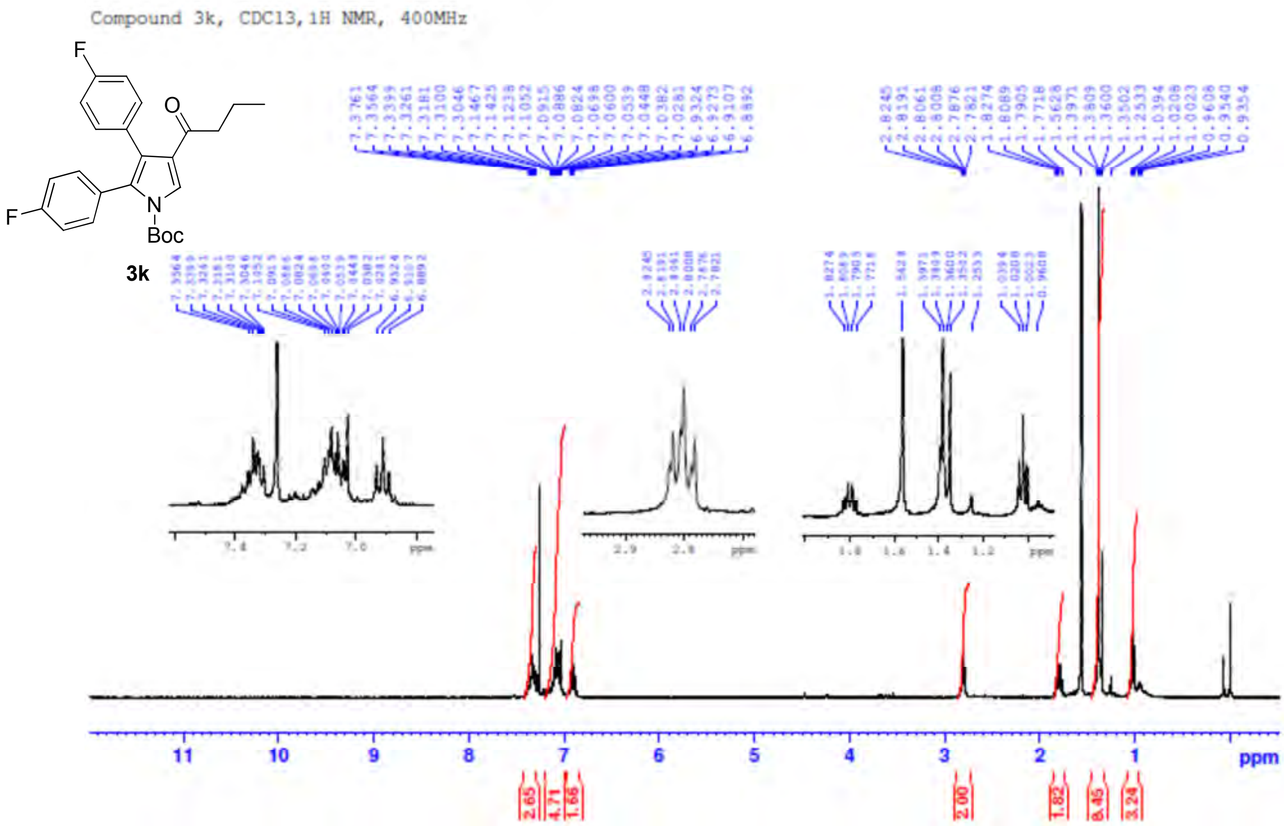
Electronic Supplementary Material (ESI) for RSC Advances

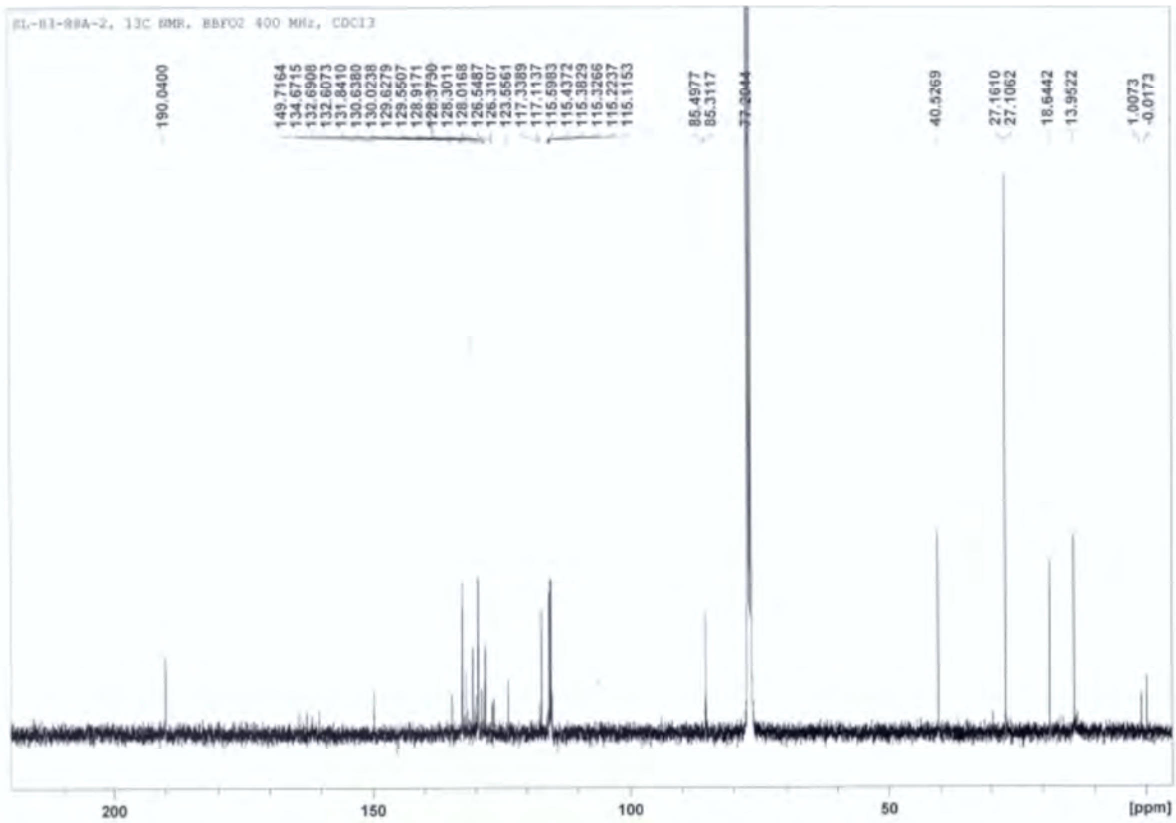
Compound 3j, CDCl3,1H NMR, 400MHz

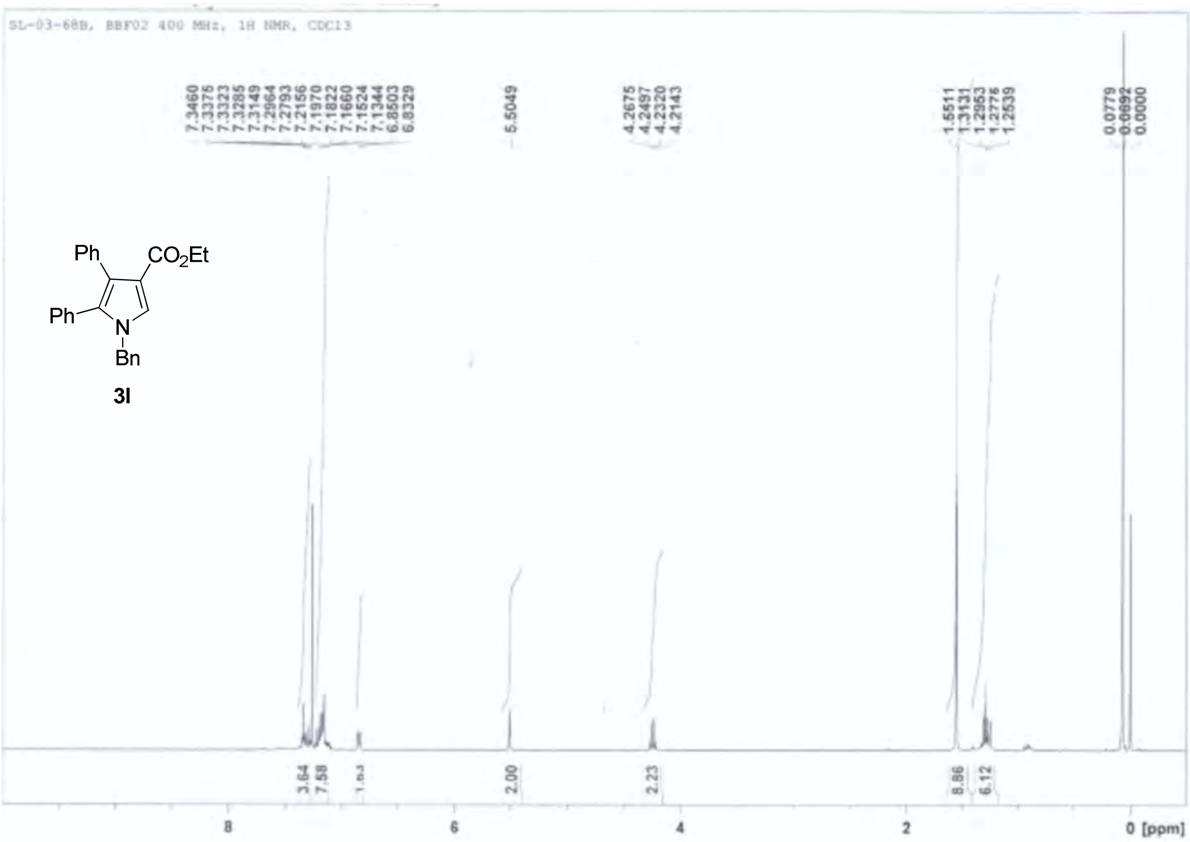


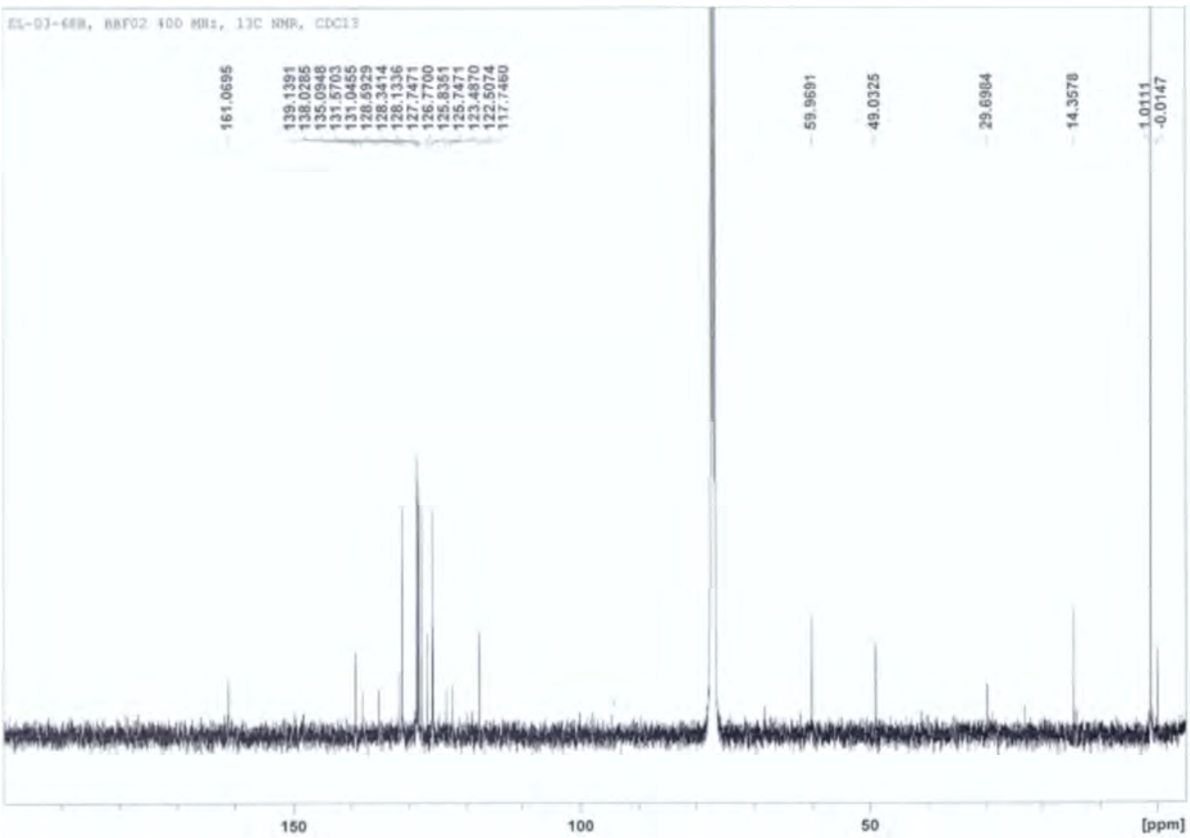
Compound 3j, CDCl3, 13C NMR, 400MHz




Compound 3k, CDCl3, 1H NMR, 400MHz
3k
ppm


190.0400
85.4977
85.3117
77.2044
40.5269
27.1610
27.1062
18.6442
13.9522
1.0073
-0.0172
[ppm]


SL-03-68B, BBF02 400 MHz, 1H NMR, CDCl3
7.3460
7.3376
7.3323
7.3285
7.3149
7.2964
7.2793
7.2156
7.1970
7.1822
7.1660
7.1524
7.1344
6.8503
6.8329
5.5049
4.2675
4.2497
4.2320
4.2143
1.5511
1.3131
1.2953
1.2776
1.2539
0.0779
0.0692
0.0000
Ph
CO2Et
Ph
N
Bn
3l
3.64
7.58
2.00
2.23
8.86
6.12
8
6
4
2
0 [ppm]


SL-03-68B, BBF02 400 MHz, 13C NMR, CDCl3
161.0695
139.1391
138.0285
135.0948
131.5703
131.0455
128.6929
128.3414
128.1336
127.7471
126.7700
125.8351
125.7471
123.4870
122.5074
117.7460
59.9691
49.0325
29.6984
14.3578
1.0111
-0.0147
150
100
50
[ppm]

Electronic Supplementary Material (ESI) for RSC Advances

Table 1.Crystal data and structure refinement for Compound S1f.

Identification code	Compound S1f	
Empirical formula	C24 H23 F2 N O4	
Formula weight	427.43	
Temperature	103(2) K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group	P2/c	
Unit cell dimensions	a = 14.9219(4) Å	α= 90°.
	b = 6.4133(2) Å	β= 98.979(2)°.
	c = 22.9718(7) Å	γ = 90°.
Volume	2171.43(11) $Å^3$	
Z	4	
Density (calculated)	1.307 Mg/m^3	
Absorption coefficient	0.100 mm^{-1}	
F(000)	896	
Crystal size	0.40 x 0.38 x 0.38 mm^3	
Theta range for data collection	2.09 to 26.37°.	
Index ranges	-18<=h<=18, -8<=k<=8, -28<=l<=28	
Reflections collected	15786	
Independent reflections	4423 [R(int) = 0.0310]	
Completeness to theta = 26.37°	99.8 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	0.9630 and 0.9611	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	4423 / 13 / 284	
Goodness-of-fit on F^2	1.052	
Final R indices [I>2sigma(I)]	R1 = 0.0526, wR2 = 0.1553	
R indices (all data)	R1 = 0.0642, wR2 = 0.1675	
Largest diff. peak and hole	0.430 and -0.704 e.$Å^{-3}$	

Table 1.Crystal data and structure refinement for Compound 3c.

Identification code	Compound 3c	
Empirical formula	C15 H12.66 F0.34 N O	
Formula weight	229.34	
Temperature	103(2) K	
Wavelength	0.71073 Å	
Crystal system	Orthorhombic	
Space group	Pbcn	
Unit cell dimensions	a = 21.3178(15) Å	α= 90°.
	b = 7.5336(6) Å	β= 90°.
	c = 7.2988(4) Å	γ = 90°.
Volume	1172.19(14) $Å^3$	
Z	4	
Density (calculated)	1.300 Mg/m^3	
Absorption coefficient	0.085 mm^{-1}	
F(000)	483	
Crystal size	0.40 x 0.40 x 0.36 mm^3	
Theta range for data collection	1.91 to 31.03°.	
Index ranges	-30<=h<=30, -10<=k<=10, -10<=l<=10	
Reflections collected	21637	
Independent reflections	1876 [R(int) = 0.0451]	
Completeness to theta = 31.03°	99.5 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	0.9700 and 0.9667	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	1876 / 267 / 140	
Goodness-of-fit on F^2	1.212	
Final R indices [I>2sigma(I)]	R1 = 0.0459, wR2 = 0.1425	
R indices (all data)	R1 = 0.0695, wR2 = 0.1672	
Largest diff. peak and hole	0.269 and -0.261 e.$Å^{-3}$	