The First Calcium-Catalysed Nazarov Cyclisation

Jacob Davies[a] and Daniele Leonori[a,b]

a. School of Chemistry, University of Bristol, Cantock's Close, Bristol, UK

b. School of Chemistry, University of Manchester, Oxford Road, Manchester, UK

Supporting Information

Contents

1. General Information

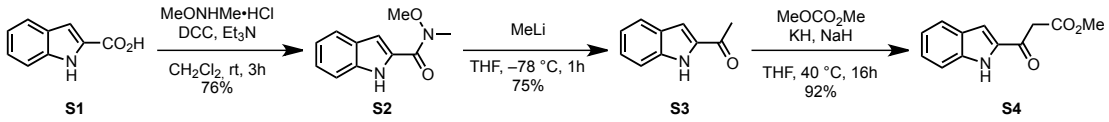
All required fine chemicals were used directly without purification unless mentioned. All air- and water-sensitive reactions were carried out in flame-dried glassware under nitrogen or argon atmosphere using standard Schlenk manifold technique. ^{1}H, ^{13}C and ^{19}F Nuclear Magnetic Resonance (NMR) spectra were acquired at various field strengths as indicated, and were referenced to $CHCl_3$ (7.27 and 77.0 ppm for ^{1}H and ^{13}C respectively). Chemical shifts (δ) are quoted in parts per million (ppm) and coupling constants (*J*) are in Hertz (Hz). High resolution mass spectra were recorded using Electron Spray Ionization (ESI). All IR data was obtained on a Perkin-Elmer Spectrum One FT-IR spectrometer. Analytical TLC: aluminium backed plates pre-coated (0.25 mm) with Merck Silica Gel 60 F254. Compounds were visualized by exposure to UV-light or and/or developed with phosphomolybdic acid or $KMnO_4$ stains. Flash column chromatography was performed using Aldrich Silica Gel 60 (40–63 μm). Solvents were purified by standard methods. Diastereomeric ratios were detrmined by ^{1}H NMR analysis of the crude reaction mixture.

All reaction progressions were recorded using a Mettler Toledo ReactIR 45m FTIR with a fiber optic probe and DiComp ATR window. IR spectra were acquired every 15 s. Product and reagent concentrations were measured as peak heights to the baseline after applying a second-derivative function to all spectra. Absorbance values were converted to molar concentration based on IR calibrations generated from standard samples of known concentrations.

2. Synthesis of Nazarov Precursors

2.1 Synthesis of Substrates 1a–j

2.1.1 Synthesis of the Knoevenagel Precursor S4



***N*-Methoxy-*N*-methyl-1*H*-indole-2-carboxamide (S2)**

A solution of **S1** (3.5 g, 21.80 mmol, 1.0 equiv.) in CH_2Cl_2 (150 mL) was treated with DCC (4.5 g, 21.80 mmol, 1.0 equiv.), *N*,*O*-dimethylhydroxylamine hydrochloride (2.1 g, 21.8 mmol, 1.0 equiv.) and Et_3N (3.1 mL, 21.80 mmol, 1.0 equiv.) and it was stirred for 3 h at room temperature. H_2O (100 mL) was added, the layers were separated and the aqueous layer was extracted with CH_2Cl_2 (3 x 30 mL). The combined organic layers were washed with brine (30 mL), dried ($MgSO_4$), filtered and evaporated. Purification by column chromatography on silica gel, eluting with *n*-hexane:EtOAc (9:1), gave **S2** (3.4 g, 76%) as an amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.33 (1H, s), 7.70 (1H, dd, *J* = 8.1, 0.9 Hz), 7.44 (1H, dd, *J* = 8.4, 0.9 Hz), 7.35-7.26 (1H, m), 7.25-7.23 (1H, m), 7.14 (1H, m), 3.85 (3H, s), 3.44 (3H, s). LRMS *m/z* (ESI): 204 (M+), 144, 116. Data in accordance with the literature.[1]

1-(1*H*-Indol-2-yl)ethan-1-one (S3)

A solution of **S2** (3.4 g, 16.51 mmol, 1.0 equiv.) in THF (165 mL) was cooled to –78 °C and treated with MeLi (26.0 mL, 41.28 mmol, 1.6 M in Et_2O, 2.5 equiv.). The mixture was stirred at –78 °C for 1 h and then H_2O (100 mL) was added. The layers were separated and the aqueous layer was washed with Et_2O (3 x 30 mL). The combined organic layers were washed with brine (30 mL), dried ($MgSO_4$), filtered and evaporated. Purification by column chromatography on silica gel, eluting with *n*-hexane:EtOAc (9:1→8:2), gave **S3** (2.0 g, 75%) as an amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.05 (1H, s), 7.72 (1H, dd, *J* = 8.1, 0.9 Hz), 7.42 (1H, dd, *J* = 8.4, 1.0 Hz), 7.35 (1H, ddd, *J* = 8.3, 6.9, 1.1 Hz), 7.21 (1H, dd, *J* = 2.2, 0.9 Hz), 7.16 (1H, ddd, *J* = 8.0, 6.9, 1.1 Hz), 2.60 (3H, s). Data in accordance with the literature.[2]

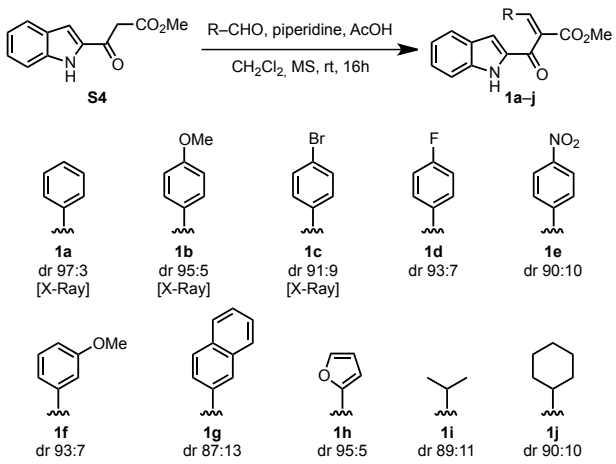
Methyl 3-(1*H*-Indol-2-yl)-3-oxopropanoate (S4)

A solution of **S3** (2.0 g, 12.45 mmol, 1.0 equiv.) in THF (45 mL) was slowly treated with NaH (0.4 g, 16.19 mmol, 60% in mineral oil, 1.3 equiv) and KH (1.9 g, 16.19 mmol, 30% in mineral oil, 1.3 equiv.). The reaction mixture was warmed to 40 °C and stirred overnight. The

[1] M. Rawat, W. D. Wulff *Org. Lett.* **2004**, *6*, 329.
[2] Y. Zhao, D. Li, L. Zhao, J. Zhang *Synthesis* **2011**, 873.

mixture was cooled to 0 °C and 1M HCl (10 mL) was added dropwise. H_2O (50 mL) was added and the layers were separated and the aqueous layer was extracted with Et_2O (3 x 20 mL). The combined organic layers were washed with brine (20 mL), dried ($MgSO_4$), filtered and evaporated. Purification by column chromatography on silica gel, eluting with *n*-hexane:EtOAc (9:1→8:2) gave **S4** (2.5 g, 92%) as an amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.26 (s, 1H), 7.70 (dd, *J* = 8.2, 0.9 Hz, 1H), 7.43 (dd, *J* = 8.4, 0.8 Hz, 1H), 7.39-7.33 (m, 1H), 7.24 (dd, *J* = 2.1, 1.0 Hz, 1H), 7.20-7.12 (m, 1H), 3.98 (s, 2H), 3.75 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 184.4, 167.7, 137.9, 134.4, 127.5, 127.1, 123.4, 121.3, 112.4, 111.1, 52.7, 45.3. Data in accordance with the literature.[3]

2.1.2 General Procedure for the Knoevenagel Condensation of S4 – GP1



A 0.3M solution of **S4** (1.0 equiv.) in CH_2Cl_2 was treated with piperidine (1.2 equiv.), AcOH (1.0 equiv.) and powdered molecular sieves (1 g mol^{-1}). The resultant mixture was stirred for 30 min before the aldehyde (1.2 equiv.) was added dropwise. The mixture was stirred overnight, filtered and adsorbed on silica. Purification by column chromatography on silica gel gave the desired product.

Methyl 2-(1*H*-Indole-2-carbonyl)-3-phenylacrylate (1a)

Following GP-1 (reaction scale: 6.91 mmol) **1a** (1.7 g, 80%) was obtained as an amorphous solid; *E*:*Z* 97:3; R_f 0.54 [*n*-hexane–EtOAc (70:30)]; m.p. 150-155 °C; FT-IR ν_{max} (film)/ cm^{-1} 3301, 2953, 1713, 1634, 1612, 1520, 1480, 1418, 1340, 1239, 1200, 1167, 1141, 1001, 903; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.30 (1H, s, NH), 8.02 (1H, s), 7.59 (1H, dd, *J* = 8.2, 0.9 Hz), 7.45-7.39 (3H, m), 7.34 (1H, ddd, *J* = 8.3, 6.9, 1.1 Hz), 7.26-7.20 (3H, m), 7.10 (1H, ddd, *J* = 8.0, 6.9, 1.0 Hz), 7.02 (1H, dd, *J* = 2.1, 1.0 Hz), 3.77 (3H, s); ^{13}C NMR (100 MHz, $CDCl_3$) δ 186.8 (C=O), 165.6 (C=O), 143.7 (CH), 138.2 (C), 134.9 (C), 132.9 (C), 130.6 (CH), 130.4 (2 x CH), 130.2 (C), 128.9 (2 x CH), 127.6 (C), 127.15 (CH), 123.6 (CH), 121.0 (CH), 112.9

[3] J. A. Malona, J. M. Colbourne, A. J. Frontier *Org. Lett.* **2006**, *8*, 5661.

(CH), 112.4 (CH), 52.8 (CH_3); HRMS m/z (ESI): Found MH^+, 306.1125 $C_{19}H_{16}NO_3$ requires 306.1125.

Crystals suitable for X-ray analysis were obtained by slow evaporation of a Et_2O-pentane solution of **1a**.

Methyl 2-(1*H*-Indole-2-carbonyl)-3-(4-methoxyphenyl)acrylate (1b)

Following GP-1 (reaction scale: 1.38 mmol) **1b** (410 mg, 89%) was obtained as an amorphous solid; *E*:*Z* 95:5; R_f 0.41 [*n*-hexane–EtOAc (70:30)]; m.p. 147-149 °C, FT-IR ν_{max} (film)/cm^{-1} 3324, 1712, 1618, 1600, 1512, 1435, 1342, 1306, 1255, 1204, 1165, 1140, 1018, 905; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.27 (1H, s, NH), 7.95 (1H, s), 7.59 (1H, dd, *J* = 8.2, 0.9 Hz), 7.43 (1H, dd, *J* = 8.3, 0.7 Hz), 7.36 (2H, d, *J* = 8.9 Hz), 7.34 (1H, ddd, *J* = 8.3, 6.9, 1.1 Hz), 7.10 (1H, ddd, *J* = 8.0, 6.9, 1.0 Hz), 7.04 (1H, dd, *J* = 2.2, 1.0 Hz), 6.72 (2H, d, *J* = 8.9 Hz), 3.75 (3H, s), 3.71 (3H, s); ^{13}C NMR (100 MHz, $CDCl_3$) δ 187.4 (C=O), 165.9 (C=O), 161.5 (C), 143.4 (CH), 138.2 (C), 135.1 (C), 132.5 (2 x CH), 127.7 (C), 127.5 (CH), 127.1 (CH), 125.5 (C), 123.1 (C), 121.2 (CH), 114.4 (2 x CH), 112.8 (CH), 112.4 (CH), 55.4 (CH_3), 52.7 (CH_3); HRMS m/z (ESI): Found MH^+, 336.1230 $C_{20}H_{18}NO_4$ requires 336.1230.

Crystals suitable for X-ray analysis were obtained by slow evaporation of a Et_2O-pentane solution of **1b**.

Methyl 2-(1*H*-Indole-2-carbonyl)-3-(4-bromophenyl)acrylate (1c)

Following GP-1 (reaction scale: 2.30 mmol) **1c** (770 mg, 87%) was obtained as an amorphous solid; *E*:*Z* 91:9; R_f 0.55 [*n*-hexane–EtOAc (70:30)]; m.p. 165-169 °C; FT-IR ν_{max} (film)/cm^{-1} 3336, 1707, 1615, 1586, 1517, 1488, 1432, 1341, 1250, 1199, 1165, 1140, 1073, 1010, 904; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.31 (1H, s, NH), 7.94 (1H, s), 7.60 (1H, dd, *J* = 8.1, 0.9 Hz), 7.44 (1H, dd, *J* = 8.4, 1.0 Hz), 7.38-7.33 (1H, m), 7.35 (2H, d, *J* = 8.7 Hz), 7.27 (2H, d, *J* = 8.7 Hz), 7.12 (1H, ddd, *J* = 8.0, 6.9, 1.0 Hz), 7.02 (1H, dd, *J* = 2.2, 1.0 Hz), 3.78 (3H, s); ^{13}C NMR (100 MHz, $CDCl_3$) δ 186.3 (C=O), 165.3 (C=O), 142.1 (CH), 138.2 (C), 134.7 (C), 132.1 (2 x CH), 131.7 (C), 131.5 (2 x CH), 130.8 (C), 127.5 (CH), 127.2 (C), 125.1 (C), 123.5 (CH), 121.3 (CH), 112.9 (CH), 112.4 (CH), 52.8 (CH_3); HRMS m/z (ESI): Found MNa^+, 406.0038 $C_{19}H_{14}BrNNaO_3$ requires 406.0049.

Crystals suitable for X-ray analysis were obtained by slow evaporation of a Et_2O-pentane solution of **1c**.

Methyl 2-(1H-Indole-2-carbonyl)-3-(4-fluorophenyl)acrylate (1d)

Following GP-1 (reaction scale: 2.30 mmol) **1d** (0.60 g, 81%) was obtained as an amorphous solid; *E*:*Z* 93:7; R_f 0.54 [*n*-hexane–EtOAc (70:30)]; m.p 164-170 °C; FT-IR ν_{max} (film)/cm^{-1}

3344, 1712, 1635, 1618, 1596, 1432, 1257, 1228, 1194, 1158, 1020, 905; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.29 (1H, s, NH), 7.96 (1H, s), 7.59 (1H, dd, *J* = 8.2, 0.9 Hz), 7.43 (1H, dd, *J* = 8.4, 1.0 Hz), 7.40 (2H, dd, *J* = 8.9, 5.3 Hz), 7.35 (1H, ddd, *J* = 8.3, 6.9, 1.1 Hz), 7.11 (1H, ddd, *J* = 8.0, 6.9, 1.0 Hz), 7.01 (1H, dd, *J* = 2.2, 1.0 Hz), 6.90 (2H, t, *J* = 8.6 Hz), 3.77 (3H, s); ^{13}C NMR (100 MHz, $CDCl_3$) δ 186.7 (C=O), 165.5 (C=O), 162.3 (C), 142.3 (CH), 138.3 (C), 134.8 (C), 132.4 (J_{CF} = 9.0 Hz, 2 x CH), 129.9 (C), 129.2 (2 x C), 127.3 (CH), 123.6 (CH), 121.4 (CH), 116.2 (J_{CF} = 21.9 Hz, 2 x CH), 113.0 (CH), 112.5 (CH), 52.9 (CH_3); HRMS m/z (ESI): Found MNa^+, 346.0849 $C_{19}H_{14}FNNaO_3$ requires 346.0850.

Methyl 2-(1*H*-Indole-2-carbonyl)-3-(4-nitrophenyl)acrylate (1e)

Following GP-1 (reaction scale: 2.30 mmol) **1e** (490 mg, 57%) was obtained as an amorphous solid; *E*:*Z* 90:10; R_f 0.43 [*n*-hexane–EtOAc (70:30)]; m.p. 77-80 °C; FT-IR ν_{max} (film)/cm^{-1} 3308, 1712, 1617, 1596, 1434, 1342, 1201,1167, 1141, 1015, 904; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.23 (1H, s, NH), 8.05 (2H, d, *J* = 8.9 Hz), 8.03 (1H, s), 7.58 (1H, dd, *J* = 8.2, 1.0 Hz), 7.55 (2H, d, *J* = 8.9 Hz), 7.43 (1H, dd, *J* = 8.4, 1.1 Hz), 7.36 (1H, ddd, *J* = 8.3, 6.9, 1.2 Hz), 7.11 (1H, ddd, *J* = 8.1, 6.9, 1.2 Hz), 6.98 (1H, dd, *J* = 2.1, 1.2 Hz), 3.80 (3H, s); ^{13}C NMR (100 MHz, $CDCl_3$) δ 185.4 (C=O), 164.9 (C=O), 148.3 (C), 140.5 (CH), 139.2 (C), 138.5 (C), 130.7 (2 x CH), 127.7 (C), 127.6 (C), 127.5 (CH), 124.0 (2 x CH), 123.6 (CH), 121.6 (CH), 113.4 (CH), 112.5 (CH), 100.0 (C), 53.2 (CH_3); HRMS m/z (ESI): Found MNa^+, 373.0787 $C_{19}H_{14}N_2NaO_5$ requires 373.0795.

Methyl 2-(1*H*-Indole-2-carbonyl)-3-(3-methoxyphenyl)acrylate (1f)

Following GP-1 (reaction scale: 1.38 mmol) **1f** (440 mg, 96%) was obtained as an amorphous solid; *E*:*Z* 95:5; R_f 0.46 [*n*-hexane–EtOAc (70:30)]; m.p. 136-140 °C; FT-IR ν_{max} (film)/cm^{-1} 3321, 2948, 1706, 1616, 1576, 1520, 1433, 1340, 1226, 1165, 1140, 1020, 901; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.32 (1H, s, NH), 7.98 (1H, s), 7.59 (1H, dd, *J* = 8.2, 0.9 Hz), 7.42 (1H, dd, *J* = 8.4, 0.9 Hz), 7.33 (1H, ddd, *J* = 8.3, 6.9, 1.1 Hz), 7.13 (1H, t, *J* = 8.0 Hz), 7.10 (1H, ddd, *J* = 8.0, 6.9, 1.0 Hz),7.02 (1H, dd, *J* = 2.1, 1.0 Hz), 7.00 (1H, d, *J* = 7.8 Hz), 6.94 (1H, t, *J* = 2.0 Hz), 6.79 (1H, ddd, *J* = 8.0, 2.6, 0.9 Hz), 3.77 (3H, s), 3.62 (3H, s); ^{13}C NMR (100 MHz, $CDCl_3$) δ 186.8 (C=O), 165.6 (C=O), 159.6 (C), 143.6 (CH), 138.3 (C), 135.0 (C), 134.2 (C), 130.4 (C), 129.9 (CH), 127.6 (C), 127.2 (CH), 123.6 (CH), 122.9 (CH), 121.3 (CH), 116.7 (CH), 115.1 (CH), 112.9 (CH), 112.4 (CH), 55.2 (CH_3), 52.8 (CH_3); HRMS m/z (ESI): Found MH^+, 336.1230 $C_{20}H_{18}NO_4$ requires 336.1230.

Methyl 2-(1*H*-Indole-2-carbonyl)-3-(naphthalen-2-yl)acrylate (1g)

Following GP-1 (reaction scale: 1.38 mmol) **1g** (470 mg, 95%) was obtained as an amorphous solid; *E*:*Z* 87:13; R_f 0.51 [*n*-hexane–EtOAc (70:30)]; m.p. 73-77 °C; FT-IR ν_{max} (film)/cm^{-1} 3315, 2948, 1705, 1616, 1520, 1433, 1343, 1237, 1164, 1141, 1126, 1090, 1020; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.35 (1H, s, NH), 8.19 (1H, s), 7.95 (1H, d, *J* = 2.0 Hz), 7.74 (1H, dd, *J* = 6.5, 2.5 Hz), 7.68 (1H, dd, *J* = 6.9, 2.4 Hz), 7.59 (1H, d, *J* = 8.7 Hz), 7.55 (1H, dq, *J* = 8.3, 0.9 Hz), 7.50-7.39 (4H, m), 7.31 (1H, ddd, *J* = 8.3, 6.9, 1.1 Hz), 7.07 (1H, ddd, *J* = 8.1, 6.8, 1.1 Hz), 7.04 (1H, d, *J* = 1.2 Hz), 3.80 (3H, s);^{13}C NMR (100 MHz, $CDCl_3$) δ 186.9 (C=O), 165.7 (C=O), 143.8 (CH), 138.3 (C), 135.1 (C), 134.0 (C), 133.0 (C), 132.2 (CH), 130.5 (C), 130.0 (C), 128.8 (CH), 128.7 (CH), 127.8 (CH), 127.7 (CH), 127.6 (C), 127.2 (CH), 126.8 (CH), 125.9 (CH), 123.6 (CH), 121.3 (CH), 113.1 (CH), 112.4 (CH), 52.9 (CH_3). HRMS m/z (ESI): Found MH^+, 356.1281 $C_{23}H_{18}NO_3$ requires 356.1281.

Methyl 2-(1*H*-Indole-2-carbonyl)-3-(furan-2-yl)acrylate (1h)

Following GP-1 (reaction scale: 1.38 mmol) **1h** (380 mg, 93%) was obtained as an amorphous solid; *E*:*Z* 95:5; R_f 0.44 [*n*-hexane–EtOAc (70:30)]; m.p. 180-184 °C; FT-IR ν_{max} (film)/cm^{-1} 3287, 2953, 1706, 1616, 1521, 1433, 1345, 1241, 1207, 1139, 1094, 1020, 903; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.36 (1H, s, NH), 7.73 (1H, s), 7.62 (1H, dd *J* = 8.1, 0.9 Hz), 7.45 (1H, dd, *J* = 8.5, 1.0 Hz), 7.34 (1H, ddd, *J* = 8.3, 7.0, 1.2 Hz), 7.25 (1H, dd, *J* = 2.4, 0.6 Hz), 7.11 (1H, ddd, *J* = 8.0, 7.0, 1.0 Hz), 7.03 (1H, dd, *J* = 2.1, 1.0 Hz), 6.69 (1H, d, *J* = 3.5 Hz), 6.34 (1H, dd, *J* = 3.5, 1.8 Hz), 3.76 (3H, s); ^{13}C NMR (100 MHz, $CDCl_3$) δ 186.0 (C=O), 165.6 (C=O), 149.2 (C), 146.5 (CH), 138.1 (C), 135.4 (C), 129.1 (CH), 127.6 (C), 126.7 (CH), 125.9 (C), 123.5 (CH), 121.1 (CH), 118.5 (CH), 112.6 (CH), 112.4 (CH), 112.3 (CH), 52.8 (CH_3); HRMS m/z (ESI): Found MH^+, 296.0917 $C_{17}H_{14}NO_4$ requires 296.0917.

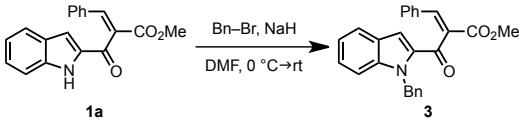
Methyl 2-(1*H*-Indole-2-carbonyl)-4-methylpent-2-enoate (1i)

Following GP-1 (reaction scale: 2.30 mmol) **1i** (580 mg, 93%) was obtained as an amorphous solid; *E*:*Z* 89:11; R_f 0.65 [*n*-hexane–EtOAc (70:30)]; m.p. 139-142 °C; FT-IR ν_{max} (film)/cm^{-1} 3311, 2963, 1723, 1611, 1517, 1434, 1417, 1342, 1231, 1168, 1136, 1022, 934; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.50 (1H, s, NH), 7.68 (1H, dd, *J* = 8.1, 0.9 Hz), 7.46 (1H, dd, *J* = 8.5, 1.0 Hz), 7.36 (1H, ddd, *J* = 8.3, 6.9, 1.1 Hz), 7.15 (1H, ddd, *J* = 8.0, 7.0, 1.0 Hz), 7.06 (1H, dd, *J* = 2.2, 1.0 Hz), 7.01 (1H, d, *J* = 11.0 Hz), 3.72 (3H, s), 2.51 (1H, dp, *J* = 11.0, 6.6 Hz), 1.03 (6H, d, *J* = 6.6 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 185.9 (C=O), 165.3 (C=O), 154.8 (CH), 138.3 (C), 135.6 (C), 130.4 (C), 127.6 (C), 127.1 (CH), 123.5 (CH), 121.3 (CH), 112.7 (CH), 112.7 (CH), 52.5 (CH_3), 29.5 (CH), 22.1 (2 x CH_3); HRMS m/z (ESI): Found MH^+, 272.1279 $C_{16}H_{18}NO_3$ requires 272.1281.

Methyl 2-(1*H*-Indole-2-carbonyl)-3-cyclohexyl-acrylate (1j)

Following GP-1 (reaction scale: 0.921 mmol) **1j** (170 mg, 59%) was obtained as an amorphous solid; *E*:*Z* 90:10; R_f 0.80 [*n*-hexane–EtOAc (70:30)]; m.p: 122-126 °C; FT-IR νmax (film)/cm^{-1} 3304, 2927, 2855, 1723, 1616, 1572, 1519, 1435, 1418, 1342, 1221, 1172, 1139, 1082, 978; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.83 (1H, s, NH), 7.70 (1H, dd, *J* = 8.1, 0.9 Hz), 7.49 (1H, dd, *J* = 8.4, 0.8 Hz), 7.37 (1H, ddd, *J* = 8.2, 7.0, 1.1 Hz), 7.15 (1H, ddd, *J* = 8.1, 7.0, 1.0 Hz), 7.11-7.06 (1H, m), 7.07 (1H, d, *J* = 10.9 Hz), 3.72 (3H, s), 2.25 (1H, qt, *J* = 11.0, 3.6 Hz), 1.75-1.54 (5H, m), 1.31-1.04 (5H, m); ^{13}C NMR (100 MHz, $CDCl_3$) δ 186.0 (C=O), 165.4 (C=O), 153.4 (CH), 138.4 (C), 135.6 (C), 130.7 (C), 127.5 (C), 126.9 (CH), 123.4 (CH), 121.1 (CH), 112.7 (CH), 112.5 (CH), 52.3 (CH_3), 38.8 (CH), 32.1 (CH_2), 25.5 (CH_2), 25.2 (CH_2); HRMS m/z (ESI): Found MH^+ 312.1604 $C_{19}H_{22}NO_3$ requires 312.1594.

2.2 Synthesis of 3

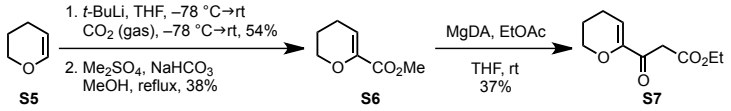


Methyl-2-(1-benzyl-1H-indole-2-carbonyl)-3-phenylacrylate (3)

A solution of **1a** (189 mg, 0.62 mmol, 1.0 equiv) in DMF (3.0 mL) was cooled to 0 °C and NaH (26 mg, 1.23 mmol, 60% dispersion in mineral oil, 2.0 equiv) was added portionwise. After stirring for 10 minutes, Bn–Br (0.15 mL, 1.23 mmol, 2.0 equiv) was added and the mixture was allowed to warm to rt. After 2 h, the reaction was quenched with NH_4Cl (3 mL). The layers were separated and the aqueous layer was extracted with EtOAc (3 x 5 mL). The combined organic layers were washed with brine (5 mL), dried ($MgSO_4$), filtered and evaporated. Purification by column chromatography on silica gel, eluting with *n*-hexane:EtOAc (90:10→80:20), gave **3** (121 mg, 47%) as an amorphous solid; *E*:*Z* 97:3; R_f 0.63 [*n*-hexane–EtOAc (70:30)]; m.p 80–85 °C; FT-IR ν_{max} (film)/cm^{-1} 2922, 1715, 1644, 1512, 1493, 1451, 1407, 1352, 1254, 1199, 1165, 1136, 1024; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.94 (1H, s), 7.62 (1H, dd, *J* = 8.1, 1.0 Hz), 7.41 (1H, dd, *J* = 8.6, 1.0 Hz), 7.36 (1H, ddd, *J* = 8.1, 6.8, 1.1 Hz), 7.35-7.26 (6H, m), 7.27-7.07 (6H, m), 6.02 (2H, s), 3.74 (3H, s); ^{13}C NMR (100 MHz, $CDCl_3$) δ 186.5 (C=O), 169.5 (C=O), 142.3 (CH), 138.1 (C), 132.9 (C), 130.3 (CH), 130.2 (2 x CH), 129.0 (C), 128.8 (C), 128.7 (CH), 128.5 (CH), 127.2 (2 x CH), 127.0 (CH), 126.8 (CH), 126.2 (C), 123.5 (CH), 121.2 (CH), 116.0 (CH), 111.0 (CH), 52.6 (CH_3), 48.1 (CH_2); HRMS m/z (ESI): Found MH^+, 396.1595 $C_{26}H_{22}NO_3$ requires 396.1594.

2.3 Synthesis of Substrates 4a–c

2.3.1 Synthesis of the Knoevenagel Precursor S7



Methyl 3,4-dihydro-2*H*-pyran-6-carboxylate (S6)

A solution of **S5** (2.9 g, 34.50 mmol, 1.0.equiv) in THF (100 mL) was cooled to –78 °C and treated with *t*-BuLi (24.3 mL, 41.40 mmol, 1.7 M in *n*-pentane, 1.2 equiv.) dropwise. The mixture was allowed to warm to rt, stirred for 30 min and cooled to –78 °C. Dry CO_2 was bubbled through the solution while it was warmed to 0 ºC over 30 minutes. The CO_2 supply was then removed and the reaction mixture was diluted with Et_2O (100 mL) and quenched with H_2O (50 mL). The layers were separated and the organic phase was washed with H_2O (3 x 20 mL). The combined aqueous layers were acidified to pH 2 with 2M HCl and extracted with EtOAc (4 x 30 mL). The combined organic layers were dried ($MgSO_4$), filtered and evaporated to give S6 (2.4 g, 54%) that was used directly in the next step.

A solution of the crude acid (2.4 g, 18.75 mmol, 1.0 equiv.) in MeOH (20 mL) was treated with $NaHCO_3$ (2.4 g, 28.25 mmol, 1.5 equiv.) and a stirred at rt for 30 min. Me_2SO_4 (2.8 mL, 30.00 mmol, 1.6 equiv.) was added and the mixture was heated under reflux for 5 h. The mixture was allowed to cool to rt, diluted with EtOAc (75 mL) and H_2O (30 mL). The layers were separated and the aqueous layer was washed with EtOAc (3 x 10 mL). The combined organic layers were washed with brine (10 mL), dried ($MgSO_4$), filtered and evaporated. Purification by column chromatography on silica gel, eluting with *n*-hexane:EtOAc (90:10) gave **S6** (1.0 g, 38%) as a colourless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.07 (1H, t, J = 4.2 Hz), 4.10 (2H, t, J = 5.1 Hz), 3.78 (3H, s), 2.18 (2H, td, J = 6.3, 4.1 Hz,), 1.91-1.79 (2H, m); ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.6, 144.3, 111.5, 66.8, 21.5, 20.7. Data in accordance with the literature.[4]

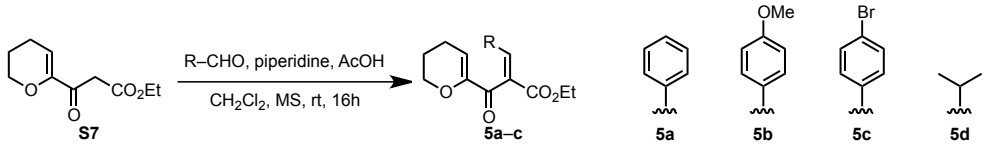
Ethyl 2-(3,4-Dihydro-2H-pyran-6-carbonyl)-3-phenylacrylate (S7)

A solution of EtMgBr (2.4 mL, 7.04 mmol, 3M in Et_2O, 2.0 equiv.) in THF (3.0 mL) was treated with di-*i*-propyl amine (1.0 mL, 7.04 mmol, 2.0 equiv.) and stirred at rt for 5 h. A solution of **S6** (550 mg, 3.52 mmol, 1.0 equiv.) in THF (3.0 mL) was added by dropwise. The mixture was stirred overnight, diluted with EtOAc (10 mL), cooled to 0 °C and quenched with MeOH (5 mL). H_2O was added to dissolve all the magnesium salts (50 mL) and the layers were separated. The aqueous layer was extracted with EtOAc (3 x 20 mL). The combined organic layers were washed with brine, dried ($MgSO_4$), filtered and evaporated. Purification by column chromatography on silica gel, eluting with *n*-hexane:EtOAc (90:10→80:20) gave

[4] D. L. J. Clive, M. Yang, H. Yang *J. Org. Chem.* **2008**, *73*, 6743.

S7 (284 mg, 37%) as an oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.98 (1H, t, *J* = 4.3 Hz), 4.14 (2H, q, *J* = 7.2 Hz), 4.03 (2H, t, *J* = 5.1 Hz), 3.55 (2H, s), 2.17 (2H, td, *J* = 6.5, 4.3 Hz), 1.81 (2H, dt, *J* = 10.4, 6.3 Hz), 1.22 (H, t, *J* = 7.1 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 189.3 (C=O), 167.7 (C=O), 150.5 (C), 110.7 (CH), 66.4 (CH), 61.2 (CH_2), 45.0 (CH_2), 21.5 (CH_2), 20.8 (CH_2), 14.1 (CH_3); LRMS m/z (ESI): 198 (M^+), 152, 110, 83.

2.3.2 Knoevenagel Condensation of S7



Ethyl 2-(3,4-Dihydro-4H-pyran-2-carbonyl)-3-phenylacrylate (5a)

Following GP-1 (reaction scale: 0.66 mmol) **5a** (90 mg, 47%) was obtained as a colourless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.78 (1H, s), 7.39-7.24 (5H, m), 5.96 (1H, t, *J* = 4.3 Hz), 4.24 (2H, q, *J* = 7.1 Hz), 4.03 (2H, t, *J* = 5.1 Hz), 2.10 (2H, td, *J* = 6.3, 4.2 Hz), 1.85-1.70 (2H, m), 1.26 (3H, t, *J* = 7.1 Hz). LRMS m/z (ESI): 286 (M^+), 257, 241, 212, 203. Data in accordance with the literature.[5]

Ethyl 2-(3,4-Dihydro-2*H*-pyran-6-carbonyl)-3-(4-methoxyphenyl)acrylate (5b)

Following GP-1 (reaction scale: 0.66 mmol) **5b** (129 mg, 62%) was obtained as a colourless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.78 (1H, s), 7.34 (2H, d, *J* = 8.7 Hz), 6.85 (2H, d, *J* = 8.7 Hz), 6.05 (1H, t, *J* = 4.0 Hz), 4.23 (2H, q, *J* = 7.2 Hz), 4.14-4.09 (2H, m), 3.83 (3H, s), 2.16 (2H, dd, *J* = 10.5, 6.3 Hz), 1.85-1.80 (2H, m), 1.29 (3H, t, *J* = 7.1 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 191.0, 165.3, 161.5, 151.5, 142.6, 132.4, 127.9, 125.5, 116.1, 114.1, 66.4, 61.3, 55.3, 21.3, 21.0, 14.2. Data in accordance with the literature.[6]

Ethyl 3-(4-Bromophenyl)-2-(3,4-dihydro-2*H*-pyran-6-carbonyl)acrylate (5c)

Following GP-1 (reaction scale: 0.66 mmol) **5c** (117 mg, 49%) was obtained as a colourless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.76 (1H, s), 7.48 (2H, d, *J* = 8.3 Hz), 7.27 (2H, d, *J* = 8.4 Hz), 6.03 (1H, t, *J* = 4.3 Hz), 4.29 (2H, q, *J* = 7.0 Hz), 4.14-4.08 (2H, m), 2.15 (2H, dd, *J* = 10.7, 6.3 Hz), 1.88-1.80 (2H m), 1.33 (3H, t, *J* = 6.9 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 190.2, 164.6, 151.2, 141.4, 132.1, 131.8, 131.6, 131.3, 124.8, 116.5, 66.8, 61.6, 21.3, 21.2, 14.2. Data in accordance with the literature.[6]

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[5] D. P. Canterbury, I. R. Herrick, J. Um, K. N. Houk, A. J. Frontier *Tetrahedron* **2009**, *65*, 3165.

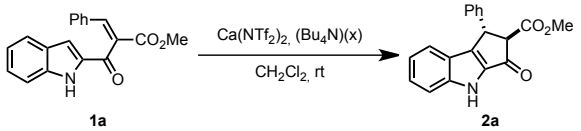
[6] F. Guo, L. Wang, S. Mao, C. Zhang, J. Yu, J. H. *Tetrahedron* **2012**, *68*, 8367.

Ethyl 2-(3,4-Dihydro-2*H*-pyran-6-carbonyl)-4-methylpent-2-enoate (5d)

Following GP-1 (reaction scale: 0.53 mmol) **5d** (68 mg, 51%) was obtained as a colourless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.81 (1H, d, *J* = 10.8 Hz), 5.98 (1H, t, *J* = 4.4 Hz), 4.20 (2H, q, *J* = 7.0 Hz), 4.15-4.10 (2H, m), 2.57-2.47 (1H, m), 2.23 (2H, dd, *J* = 10.5, 6.3 Hz), 1.94-1.85 (2H, m), 1.26 (3H, t, *J* = 7.0 Hz), 1.04 (6H, d, *J* = 6.1 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 189.4, 164.6, 153.8, 151.7, 130.6, 115.1, 66.5, 61.0, 29.1, 21.7, 21.3, 20.9, 14.1. Data in accordance with the literature.[6]

3. Nazarov Cyclisations

3.1 General Procedure for the Screening of the Calcium Catalysts

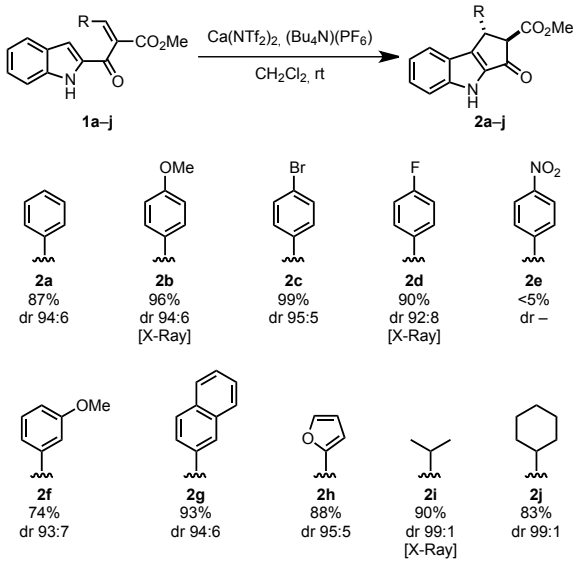


A dry tube was charged with $Ca(NTf_2)_2$ (5.0 mg, 8.2 µmol, 5 mol%) and $(Bu_4N)(X)$ (8.2 µmol, 5 mol%) and CH_2Cl_2 (1.0 mL) was added. The mixture was stirred for 30 min to ensure complete solubilisation of the solids. A solution of **1a** (50 mg, 0.16 mmol, 1.0 equiv.) in CH_2Cl_2 (0.6 mL) was added. The mixture was stirred overnight (16 h) and then H_2O (2.0 mL) was added. The layers were separated and the aqueous layer was extracted with CH_2Cl_2 (2 x 2 mL). The combined organic layers were dried ($MgSO_4$), filtered and evaporated. Purification by column chromatography on silica gel gave **2a**.

Entry	X^-	Yield (%)
1	PF_6	87
2[a]	PF_6	66
3	BF_4	21
4	$SiPh_3F_2$	<5
5	I	9
6	Br	<5
7	Cl	–
8	OTf	–
9	Br_3	–
10	OAc	–
11	HSO_4	–
a) 2,6-di-tert-butyl pyridine (1.0 equiv.) was added		

3.2 Synthesis of Products 2a–j

3.2.1 General Procedure for the Nazarov Cyclisation of Substrates 1a–j and 5a–c – GP2



A dry tube was charged with $Ca(NTf_2)_2$ (5 mol%) and $(Bu_4N)(PF_6)$ (5 mol%) and CH_2Cl_2 was added. The mixture was stirred for 30 min to ensure complete solubilisation of the solids. A solution of substrate **1** (1.0 equiv.) in CH_2Cl_2 was added (the final concentration of the reaction was 0.1M). The mixture was stirred overnight and then H_2O (2.0 mL) was added. The layers were separated and the aqueous layer was extracted with CH_2Cl_2 (2 x 5 mL). The combined organic layers were dried ($MgSO_4$), filtered and evaporated. Purification by column chromatography on silica gel gave **2**.

Methyl-3-oxo-1-phenyl-1,2,3,4-tetrahydrocyclopenta[*b*]indole-2-carboxylate (2a)

Following GP-2 (reaction scale: 0.15 mmol), **2a** (42 mg, 85%) was obtained as an amorphous solid; *anti:syn* 94:6; R_f 0.39 [*n*-hexane–EtOAc (70:30); m.p. 141-144 °C; FT-IR ν_{max} (film)/cm^{-1} 3305, 2952, 1734, 1672, 1620, 1540, 1434, 1321, 1246, 1151, 1009, 988, 745, 698; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.76 (1H, s, NH), 7.54 (1H, dt, *J* = 8.4, 0.9 Hz), 7.39 (1H, ddd, *J* = 8.4, 7.0, 1.2 Hz), 7.38-7.21 (6H, m), 7.07 (1H, ddd, *J* = 8.1, 7.0, 0.9 Hz), 5.07 (1H, d, *J* = 2.8 Hz), 3.94 (1H, d, *J* = 2.9 Hz), 3.85 (3H, s); ^{13}C NMR (100 MHz, $CDCl_3$) δ 187.2 (C=O), 169.6 (C=O), 148.2 (C), 144.7 (C), 140.8 (C), 137.1 (C), 129.0 (2 x CH), 128.1 (CH), 127.4 (2 x CH), 122.9 (C), 122.3 (CH), 121.3 (CH), 114.0 (CH), 67.8 (CH), 53.0 (CH_3), 44.2 (CH); HRMS m/z (ESI): Found MH^+, 306.1127 $C_{19}H_{15}NO_3$ requires 306.1125.

This reaction was also performed using 250 mg of **1a** to give **2a** in 83% yield.

Methyl-1-(4-methoxyphenyl)-3-oxo-1,2,3,4-tetrahydrocyclopenta[*b*]indole-2-carboxylate (2b)

Following GP-2 (reaction scale: 0.15 mmol), **2b** (48 mg, 96%) was obtained as an amorphous solid; *anti:syn* 94:6; R_f 0.29 [*n*-hexane–EtOAc (70:30)]; m.p. 130-133 °C; FT-IR ν_{max} (film)/cm^{-1} 3229, 2924, 1735, 1676, 1614, 1512, 1435, 1321, 1244, 1151, 1026, 988; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.77 (1H, s, NH), 7.52 (1H, dt, *J* = 8.5, 0.8 Hz), 7.38 (1H, ddd, *J* = 8.4, 7.1, 1.0 Hz), 7.33 (1H, dd, *J* = 8.1 Hz), 7.20-7.10 (2H, m), 7.07 (1H, ddt, *J* = 8.0, 7.0, 0.9 Hz), 6.90-6.79 (2H, m), 5.01 (1H, d, *J* = 2.8 Hz), 3.89 (1H, d, *J* = 2.8 Hz), 3.84 (3H, s), 3.78 (3H, s); ^{13}C NMR (100 MHz, $CDCl_3$) δ 187.3 (C=O), 169.7 (C=O), 159.0 (C), 148.4 (C), 144.7 (C), 137.0 (C), 132.8 (C), 128.5 (2 x CH), 128.2 (CH), 122.9 (C), 122.3 (CH), 121.2 (CH), 114.4 (2 x CH) 114.0 (CH), 68.1 (CH), 55.4 (CH_3), 52.9 (CH_3), 43.5 (CH); HRMS m/z (ESI): Found MH^+, 336.1221 $C_{20}H_{18}NO_4$ requires 336.1230.

Crystals suitable for X-ray analysis were obtained by slow evaporation of a Et_2O-pentane solution of **2b**.

Methyl-1-(4-bromophenyl)-3-oxo-1,2,3,4-tetrahydrocyclopenta[*b*]indole-2-carboxylate (2c)

Following GP-2 (reaction scale: 0.15 mmol), **2c** (49 mg, 99%) was obtained as an amorphous solid; *anti:syn* 95:5; R_f 0.40 [*n*-hexane–EtOAc (70:30)] ; m.p. 134-137 °C; FT-IR ν_{max} (film)/cm^{-1} 3312, 2928, 1736, 1677, 1619, 1537, 1487, 1327, 1246, 1225, 1154, 1072, 1010; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.78 (1H, s, NH), 7.53 (1H, dt, *J* = 8.5, 0.9 Hz), 7.44 (2H, d, *J* = 8.4 Hz), 7.40 (1H, ddd, *J* = 8.4, 7.1, 1.3 Hz), 7.31 (1H, dd, *J* = 8.3, 1.0 Hz), 7.12 (2H, d, *J* = 8.4 Hz), 7.11-7.09 (1H, m), 5.03 (1H, d, *J* = 2.9 Hz), 3.86 (1H, d, *J* = 2.9 Hz), 3.85 (3H, s); ^{13}C NMR (100 MHz, $CDCl_3$) δ 186.7 (C=O), 169.4 (C=O), 147.3 (C), 144.7 (C), 139.8 (C), 137.1 (C), 132.2 (2 x CH), 129.2 (2 x CH), 128.4 (CH), 122.7 (CH), 122.1 (C), 121.5 (C), 121.5 (CH), 114.1 (CH), 67.6 (CH), 53.1 (CH_3), 43.5 (CH); HRMS m/z (ESI): Found MH^+, 384.0217 $C_{20}H_{18}NO_4$ requires 384.0230.

Crystals suitable for X-ray analysis were obtained by slow evaporation of a Et_2O-pentane solution of **2c**.

Methyl-1-(4-flurophenyl)-3-oxo-1,2,3,4-tetrahydrocyclopenta[*b*]indole-2-carboxylate (2d)

Following GP-2 (reaction scale: 0.15 mmol), **2d** (45 mg, 90%) was obtained as an amorphous solid; *anti:syn* 92:8; R_f 0.24 [*n*-hexane–EtOAc (70:30)]; m.p. 143-147 °C; FT-IR ν_{max} (film)/cm^{-1} 3212, 2928, 1741, 1679, 1509, 1325, 1225, 1153, 1102, 1026, 985; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.85 (1H, s, NH), 7.53 (1H, dt, *J* = 8.5, 0.9 Hz), 7.39 (1H, ddd, *J* = 8.3, 7.1,

1.2 Hz), 7.31 (1H, ddt, *J* = 8.2, 1.3, 0.8 Hz), 7.25-7.15 (2H, m), 7.08 (1H, ddd, *J* = 8.0, 7.0, 0.9 Hz), 7.05-6.96 (2H, m), 5.05 (1H, d, *J* = 2.9 Hz), 3.87 (1H, d, *J* = 2.9 Hz), 3.85 (3H, s); ^{13}C NMR (100 MHz, $CDCl_3$) δ 186.9 (C=O), 169.5 (C=O), 163.4 (C), 147.7 (C), 144.7 (C), 137.1 (C), 136.5 (C), 129.0 (J_{CF} = 7.8 Hz, 2 x CH), 128.3 (CH), 122.8 (CH), 122.2 (CH), 121.4 (C), 116.0 (J_{CF} = 21.5 Hz, 2 x CH) 114.1 (CH), 67.9 (CH), 53.0 (CH_3), 43.4 (CH); HRMS m/z (ESI): Found MNa^+, 346.0845 $C_{19}H_{14}FNNaO_3$ requires 346.0850.

Methyl-1-(3-methoxyphenyl)-3-oxo-1,2,3,4-tetrahydrocyclopenta[*b*]indole-2-carboxylate (2f)

Following GP-2 (reaction scale: 0.15 mmol), **2f** (37 mg, 74%) was obtained as an amorphous solid; *anti:syn* 93:7; R_f 0.32 [*n*-hexane–EtOAc (70:30)]; m.p. 146-148 °C; FT-IR ν_{max} (film)/cm^{-1} 3207, 2952, 1734, 1676, 1598, 1487, 1436, 1322, 1241, 1151, 1026; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.67 (1H, s, NH), 7.52 (1H, dt, *J* = 8.4, 0.9 Hz), 7.39 (1H, ddd, *J* = 8.3, 6.9, 1.1 Hz), 7.36 (1H, d, *J* = 8.1 Hz) 7.23 (1H, t, *J* = 8.4 Hz), 7.08 (1H, ddd, *J* = 8.0, 7.0, 1.0 Hz), 6.85-6.80 (2H, m), 6.80-6.76 (1H, m), 5.04 (1H, d, *J* = 2.8 Hz), 3.94 (1H, d, *J* = 2.8 Hz), 3.85 (3H, s), 3.74 (3H, s); ^{13}C NMR (100 MHz, $CDCl_3$) δ 187.0 (C=O), 169.6 (C=O), 160.1 (C), 148.0 (C), 144.7 (C), 142.4 (CH), 137.0 (C), 130.2 (CH), 128.3 (C), 122.9 (C), 122.4 (CH), 121.3 (CH), 119.8 (CH), 113.9 (CH), 113.3 (CH), 112.7 (CH), 67.7 (CH), 55.3 (CH_3), 53.0 (CH_3), 44.1 (CH); HRMS m/z (ESI): Found MH^+, 336.1233 $C_{20}H_{18}NO_4$ requires 336.1230.

Methyl-1-(naphthalen-2-yl)-3-oxo-1,2,3,4-tetrahydrocyclopenta[*b*]indole-2-carboxylate (2g)

Following GP-2 (reaction scale: 0.15 mmol), **2g** (43 mg, 93%) was obtained as an amorphous solid; *anti:syn* 94:6; R_f 0.35 [*n*-hexane–EtOAc (70:30)]; m.p. 84-88 °C; FT-IR ν_{max} (film)/cm^{-1} 3211, 2948, 1734, 1674, 1619, 1540, 1434, 1321, 1246, 1152, 1008; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.17 (1H, s, NH), 7.86-7.70 (4H, m), 7.52 (1H, dt, *J* = 8.4, 0.9 Hz), 7.47 (1H, d, *J* = 9.5 Hz), 7.47 (1H, dd, *J* = 3.0, 1.2 Hz), 7.40 (1H, ddd, *J* = 8.4, 7.0, 1.2 Hz), 7.32 (1H, dd, *J* = 8.1, 1.0 Hz), 7.32 (1H, dd, *J* = 8.1, 1.0 Hz), 7.05 (1H, ddd, *J* = 8.0, 7.0, 1.0 Hz), 5.24 (1H, d, *J* = 2.9 Hz), 3.99 (1H, d, *J* = 2.9 Hz), 3.86 (3H, s); ^{13}C NMR (100 MHz, $CDCl_3$) δ 187.0 (C=O), 169.6 (C=O), 148.0 (C), 144.7 (C), 138.2 (C), 137.2 (C), 133.6 (C), 132.9 (C), 129.1 (CH), 128.3 (CH), 127.9 (CH), 127.8 (C), 126.3 (CH), 126.2 (CH), 126.1 (CH), 125.3 (CH), 123.0 (CH), 122.3 (CH), 121.4 (CH), 113.9 (CH), 67.7 (CH), 53.0 (CH_3), 44.4 (CH); HRMS m/z (ESI): Found MH^+, 356.1273 $C_{23}H_{18}NO_3$ requires 356.1281.

Methyl-1-(furan-2-yl)-3-oxo-1,2,3,4-tetrahydrocyclopenta[*b*]indole-2-carboxylate (2h)

Following GP-2 (reaction scale: 0.15 mmol), **2h** (42 mg, 88%) was obtained as an amorphous solid; *anti:syn* 95:5; R_f 0.39 [*n*-hexane–EtOAc (70:30)]; m.p. 125-127 °C; FT-IR ν_{max} (film)/cm^{-1} 3255, 2953, 1734, 1673, 1619, 1540, 1434, 1320, 1221, 1151, 1007, 929; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.42 (1H, s, NH), 7.63 (1H, dd, *J* = 8.1, 1.2 Hz), 7.50 (1H, dd, *J* = 8.5, 1.0 Hz), 7.41 (1H, ddd, *J* = 8.4, 7.0, 1.2 Hz), 7.37 (1H, dd, *J* = 1.9, 0.8 Hz), 7.16 (1H, ddd, *J* = 8.1, 7.0, 0.9 Hz), 6.31 (1H, dd, *J* = 3.2, 1.9 Hz), 6.17 (1H, dd, *J* = 3.3, 0.8 Hz), 5.15 (1H, d, *J* = 2.7 Hz), 4.13 (1H, d, *J* = 2.7 Hz), 3.85 (3H, s); ^{13}C NMR (100 MHz, $CDCl_3$) δ 186.1 (C=O), 169.2 (C=O), 153.1 (C), 145.5 (C), 144.6 (CH), 142.5 (C), 136.6 (C), 128.3 (CH), 122.9 (C), 122.3 (CH), 121.5 (CH), 113.9 (CH), 110.5 (CH), 106.6 (CH), 64.2 (CH), 53.0 (CH_3), 37.6 (CH); HRMS m/z (ESI): Found MH^+, 296.0909 $C_{17}H_{14}NO_4$ requires 296.0917.

Methyl-1-isopropyl-3-oxo-1,2,3,4-tetrahydrocyclopenta[*b*]indole-2-carboxylate (2i)

Following GP-2 (reaction scale: 0.15 mmol), **2i** (45 mg, 90%) was obtained as an amorphous solid; *anti:syn* 99:1; R_f 0.44 [*n*-hexane–EtOAc (70:30)]; m.p. 128-131 °C; FT-IR ν_{max} (film)/cm^{-1} 3217, 2958, 1737, 1665, 1620, 1536, 1466, 1436, 1324, 1248, 1159, 1025, 983; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.96 (1H, s, NH), 7.71 (1H, dd, *J* = 8.2, 0.8 Hz), 7.52 (1H, dt, *J* = 8.5, 0.9 Hz), 7.39 (1H, ddd, *J* = 8.3, 7.0, 1.1 Hz), 7.16 (1H, ddd, *J* = 8.1, 7.0, 1.0 Hz), 3.83 (1H, dd, *J* = 4.7, 2.3 Hz), 3.79 (1H, d, *J* = 2.3 Hz), 3.78 (3H, s), 2.40 (1H, pd, *J* = 6.8, 4.6 Hz), 1.08 (3H, d, *J* = 6.8 Hz), 0.88 (3H, d, *J* = 6.9 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 188.2 (C=O), 170.7 (C=O), 149.5 (C), 144.8 (C), 137.3 (C), 128.0 (CH), 123.3 (C), 122.6 (CH), 121.0 (CH), 114.1 (CH), 60.6 (CH), 52.8 (CH_3), 46.1 (CH), 31.4 (CH), 20.9 (CH_3), 18.5 (CH_3); HRMS m/z (ESI): Found MH^+, 272.1272 $C_{16}H_{18}NO_3$ requires 272.1281.

Crystals suitable for X-ray analysis were obtained by slow evaporation of a Et_2O-pentane solution of **2i**.

Methyl-1-cyclohexyl-3-oxo-1,2,3,4-tetrahydrocyclopenta[*b*]indole-2-carboxylate (2j)

Following GP-2 (reaction scale: 0.19 mmol), **2j** (46 mg, 83%) was obtained as an amorphous solid; *anti:syn* >99:1; R_f 0.56 [*n*-hexane–EtOAc (70:30)]; m.p. 65-67 °C; FT-IR ν_{max} (film)/cm^{-1} 3238, 2923, 2851, 1736, 1670, 1619, 1536, 1482, 1434, 1323, 1224, 1152, 1010; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.77 (1H s, NH), 7.73 (1H d, *J* = 7.9 Hz), 7.51 (1H, d, *J* = 8.9 Hz), 7.39 (1H, ddd, *J* = 8.3, 7.0, 1.1 Hz), 7.22-7.11 (1H, m), 3.84 (1H, d, *J* = 2.2 Hz), 3.79 (1H, m), 3.77 (3H, s), 1.96 (1H, tdd, *J* = 11.8, 6.5, 3.8 Hz), 1.85 (1H, d, *J* = 12.5 Hz), 1.77 (1H, d, *J* = 12.9 Hz), 1.68 (2H, t, *J* = 13.6 Hz), 1.52 (1H, d, *J* = 12.3 Hz), 1.28 (1H, dt, *J* = 13.0, 3.2 Hz), 1.21 (1H, dt, *J* = 12.9, 3.6 Hz), 1.18-1.02 (3H, m); ^{13}C NMR (100 MHz,

$CDCl_3$) δ 188.0 (C=O), 170.6 (C=O), 149.2 (C), 144.7 (C), 137.3 (C), 128.0 (CH), 123.5 (C), 122.7 (CH), 121.0 (CH), 114.1 (CH), 61.5 (CH), 52.8 (CH_3), 45.7 (CH), 41.8 (CH), 31.5 (CH_2), 29.4 (CH_2), 26.5 (CH_2), 26.4 (CH_2), 26.3 (CH_2); HRMS m/z (ESI): Found MNa^+, 334.1409 $C_{19}H_{21}NNaO_3$ requires 334.1414.

Methyl-4-benzyl-3-oxo-1-phenyl-1,2,3,4-tetrahydrocyclopenta[*b*]indole-2-carboxylatemethyl (4)

Following GP-2 (reaction scale: 0.13 mmol), **4** (39 mg, 77%) was obtained as an amorphous solid; *anti:syn* 88:12; R_f 0.52 [*n*-hexane–EtOAc (80:20)]; m.p. 122-124 °C; FT-IR ν_{max} (film)/cm^{-1} 2921, 1730, 1698, 1483, 1456, 1435, 1345, 1320, 1221, 1156, 1016, 954; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.45-7.20 (13H, m), 7.06 (1H, ddd, *J* = 7.6, 6.4, 1.3 Hz), 5.57 (2H, s), 5.06 (1H, d, *J* = 3.1 Hz), 3.91 (1H, dd, *J* = 3.1, 0.9 Hz), 3.84 (3H, s); ^{13}C NMR (100 MHz, $CDCl_3$) δ 186.6 (C=O), 169.5 (C=O), 146.2 (C), 145.0 (C), 141.0 (C), 137.1 (C), 137.0 (C), 129.1 (2 x CH), 128.9 (2 x CH), 127.9 (C), 127.7 (CH), 127.5 (CH), 127.3 (4 x CH), 123.0 (CH), 122.7 (C), 121.1 (CH), 112.1 (CH), 68.2 (CH), 52.9 (CH_3), 47.8 (CH_2), 43.6 (CH); HRMS m/z (ESI): Found MH^+, 396.1585 $C_{26}H_{22}NO_3$ requires 396.1594.

Ethyl-7-oxo-5-phenyl-2,3,4,5,6,7-hexahydrocyclopenta[*b*]pyran-6-carboxylate (6a)

Following GP-2 (reaction scale: 0.31 mmol), **5a** (76 mg, 85%) was obtained as an amorphous solid; *anti:syn* 97:3; m.p. 122-124 C; FT-IR ν_{max} (film)/cm^{-1} 2980, 1733, 1710, 1648, 1486, 1459, 1392, 1371, 1326, 1295, 1265, 1246, 1161, 1127, 1050; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.35-7.22 (3H, m), 7.11 (2H, dd, *J* = 6.7, 1.7 Hz), 4.20 (2H, qd, *J* = 7.0, 1.0 Hz), 4.14 (2H, td, *J* = 6.4, 3.9 Hz), 3.27 (1H, d, *J* = 2.1 Hz), 2.20 (1H, td, *J* = 12.6, 6.2 Hz), 2.07 (1H, dt, *J* = 19.7, 6.6 Hz), 2.01 – 1.81 (2H, m), 1.25 (3H, t, *J* = 7.1 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.2, 168.4, 149.9, 147.5, 140.0, 129.3, 127.7, 127.5, 67.2, 61.9, 59.4, 47.8, 22.3, 21.4, 14.2; HRMS m/z (ESI): Found MH^+, 287.12780 $C_{26}H_{22}NO_3$ requires 287.1278. Data in accordance with the literature.[5]

Ethyl 5-(4-Methoxyphenyl)-7-oxo-2,3,4,5,6,7-hexahydrocyclopenta[*b*]pyran-6-carboxylate (6b)

Following GP-2 (reaction scale: 0.24 mmol), **6b** (72 mg, 90%) was obtained as an amorphous solid; *anti:syn* 94:6; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.06 (d, *J* = 8.5 Hz, 2H), 6.88 (d, *J* = 8.5 Hz, 2H), 4.23 (q, *J* = 7.1 Hz, 2H), 4.19-4.11 (m, 3H), 3.81 (s, 3H), 3.27 (d, *J* = 1.6 Hz, 1H), 2.22 (dt, *J* = 18.8, 6.0 Hz, 1H), 2.11 (dt, *J* = 19.1, 6.1 Hz, 1H), 2.03-1.85 (m, 2H), 1.29 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.23, 168.47, 159.07, 149.70, 147.65, 131.79,

128.39, 114.53, 67.06, 61.78, 59.59, 55.31, 47.03, 22.20, 21.31, 14.17. Data in accordance with the literature.[6]

Ethyl 5-(4-Bromophenyl)-7-oxo-2,3,4,5,6,7-hexahydrocyclopenta[*b*]pyran-6-carboxylate (6c)

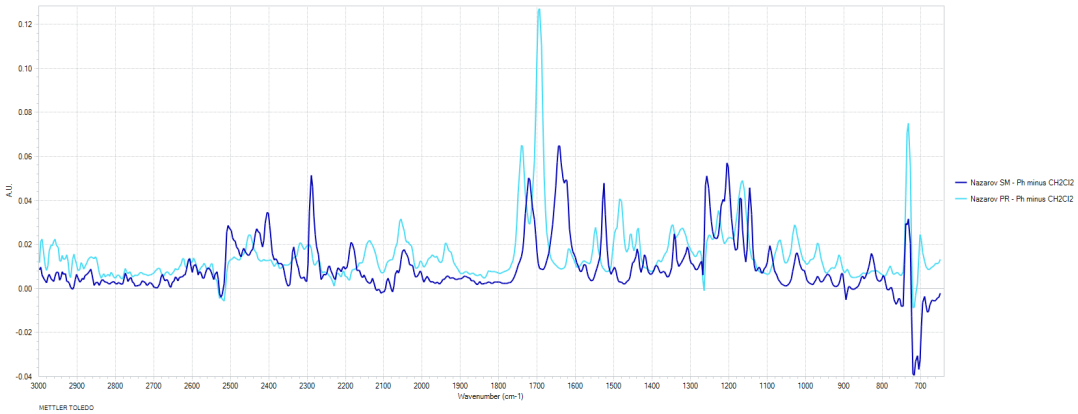
Following GP-2 (reaction scale: 0.24 mmol), **6c** (72 mg, 90%) was obtained as an amorphous solid; *anti:syn* 95:5; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.48 (2H, d, *J* = 8.2 Hz), 7.03 (2H, d, *J* = 8.3 Hz), 4.26-4.15 (5H, m), 3.24 (1H, d, *J* = 1.9 Hz), 2.22 (1H, dt, *J* = 19.0, 6.0 Hz), 2.13-2.06 (1H, m), 2.02-1.89 (2H, m), 1.29 (3H, t, *J* = 7.1 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 191.9, 167.8, 150.2, 146.6, 139.2, 132.3, 129.1, 121.6, 67.2, 62.0, 59.0, 47.1, 22.4, 21.3, 14.1. Data in accordance with the literature.[6]

Ethyl 5-isopropyl-7-oxo-2,3,4,5,6,7-hexahydrocyclopenta[*b*]pyran-6-carboxylate (6d)

Following GP-2 (reaction scale: 0.27 mmol), **6d** (61 mg, 90%) was obtained as an amorphous solid; *anti:syn* 98:2; ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.31-4.18 (3H, m), 4.10-4.03 (1H, m), 3.13 (1H, d, *J* = 2.5 Hz), 3.11-3.08 (1H, m), 2.39-2.32 (2H, m), 2.17-2.12 (1H, m), 2.01-1.94 (2H, m), 1.32 (3H, t, *J* = 7.0 Hz), 1.01 (3H, d, *J* = 7.0 Hz), 0.76 (3H, d, *J* = 7.0 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.8, 169.7, 149.8, 148.2, 66.9, 61.6, 50.9, 47.8, 27.9, 22.7, 21.4, 20.6, 16.1, 14.2. Data in accordance with the literature.[6]

4. Kinetic Studies by React-IR

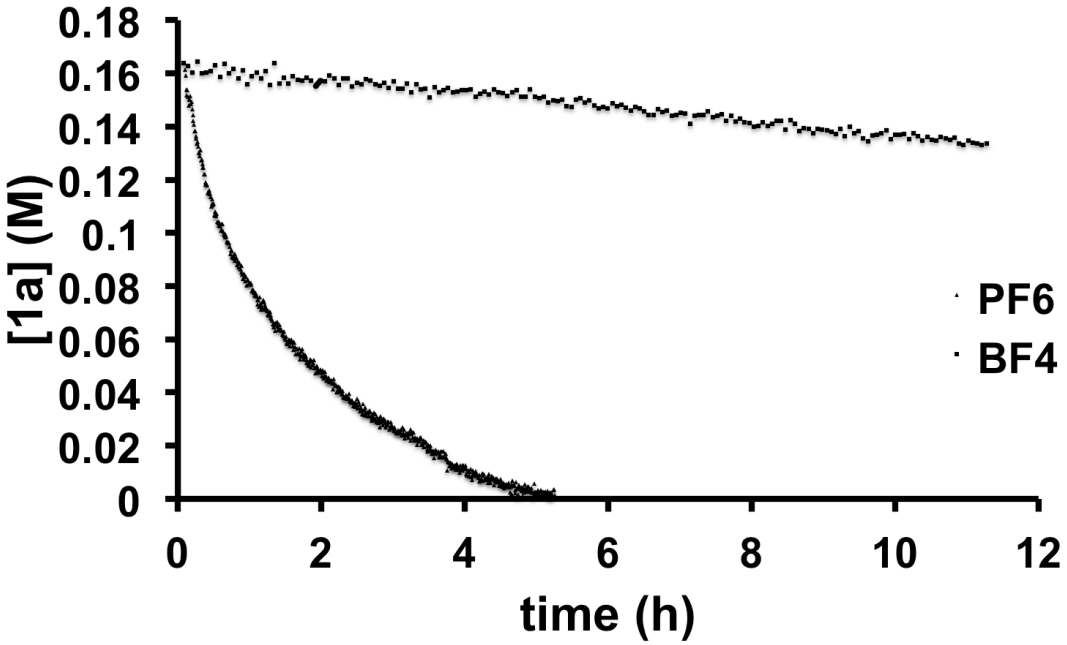
4.1 Overlaid IR Spectra of 1a (dark blue) and 2a (light blue)

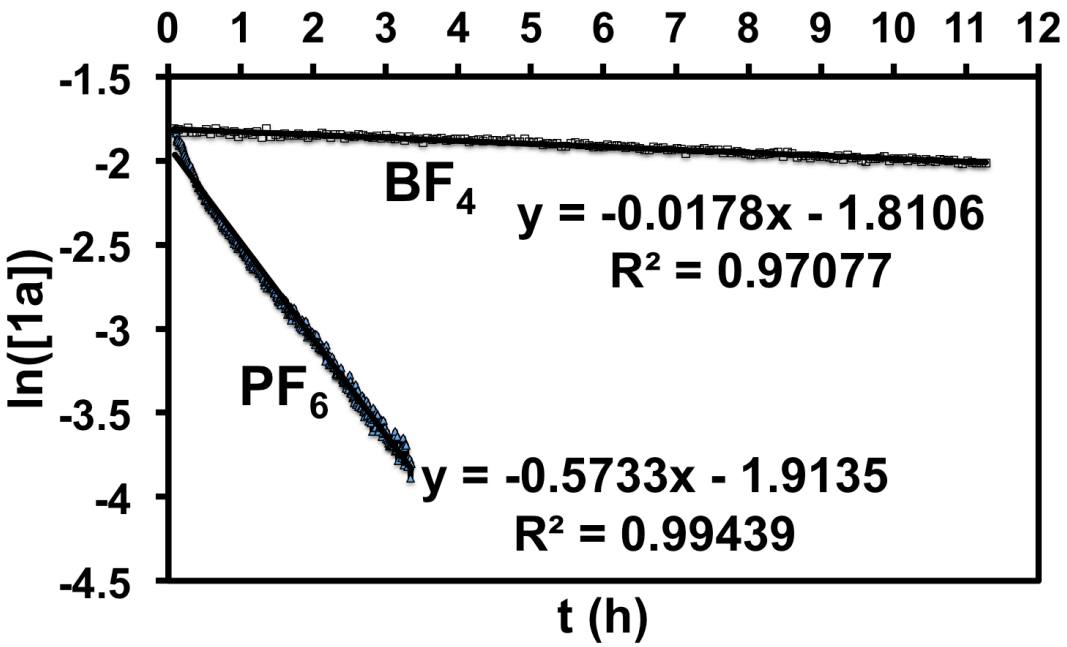


4.2 General Procedure for Kinetic Experiments

$Ca(NTf_2)_2$ (10.0 mg, 16 µmol, 5 mol%) and $(Bu_4N)(X)$ (16 µmol, 5 mol%) were combined in a dry tube equipped with a stirring bar. CH_2Cl_2 (3.3 mL) was added and the mixture was stirred for 30 min to ensure complete solubilisation. The vial was then equipped with a screw-top cap containing a septum through which the IR probe was inserted and submerged directly into the reaction medium. Spectra were acquired as the solution was stirred before adding **1a** (100 mg, 0.33 mmol, 1.0 equiv.). Reaction progress was monitored in real time looking at the change in the carbonyl stretch part of the IR spectrum.

The concentrations detected by React-IR in the reaction with $Ca(NTf_2)(PF_6)$ have been validated by taking samples from the reaction mixture and analysing them by ^1H NMR spectroscopy.


0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
[1a] (M)
0
2
4
6
8
10
12
time (h)
PF6
BF4

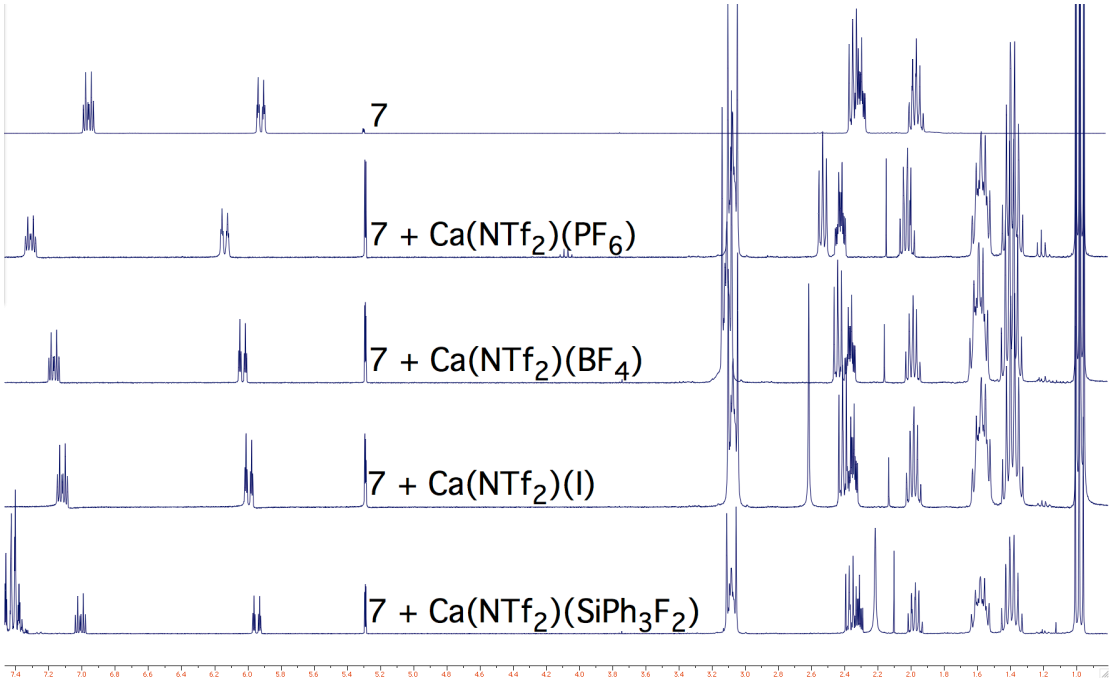

0
1
2
3
4
5
6
7
8
9
10
11
12
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
ln([1a])
t (h)
BF4
y = -0.0178x - 1.8106
R² = 0.97077
PF6
y = -0.5733x - 1.9135
R² = 0.99439

5. Lewis Acidity Studies

Sample preparation:

A dry tube equipped with a stirring bar was charged with $Ca(NTf_2)_2$ (30 mg, 0.05 mmol, 1.0 equiv.), the appropriate $(Bu_4N)(X)$ (0.05 mmol, 1.0 equiv.) and CD_2Cl_2 (2.0 mL) under nitrogen. The heterogeneous mixture was stirred at room temperature for 1h. **7** (4.8 µL, 0.05 mmol, 1.0 equiv.) was added and the mixture was stirred for 1h. The solution (0.5 mL) was transferred into a dry NMR tube and the ^1H NMR spectrum recorded.

Each experiment has been repeated twice.



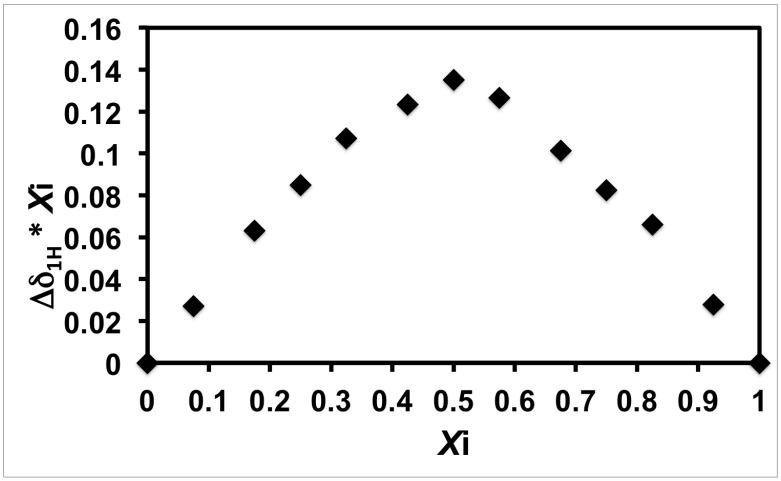
6. Binding Studies

Determination of complexes stoichiometry using the Method of Continuous Variations – Job Plots

Binding of 7 with $Ca(NTf_2)(PF_6)$

Two equimolar (0.015 M) solution of **7** and $Ca(NTf_2)(PF_6)$ in CD_2Cl_2 were prepared. Then 12 samples were prepared with defined volumes of the two stock solutions to give a total volume of 400 µL and were analysed by ^1H NMR spectroscopy. The study has been repeated twice.

V_7 (µL)	$V_{Ca(NTf2)(PF6)}$ (µL)	Xi_7	$X_{Ca(NTf2)(PF6)}$	d_7 (ppm)	$\Delta d_7 * Xi_7$
400	0	1	0	6.96	0
370	30	0.925	0.075	6.99	0.02775
330	70	0.825	0.175	7.04	0.066
300	100	0.75	0.25	7.07	0.0825
270	130	0.675	0.325	7.11	0.10125
230	170	0.575	0.425	7.18	0.1265
200	200	0.5	0.5	7.23	0.135
170	230	0.425	0.575	7.25	0.12325
130	270	0.325	0.675	7.29	0.10725
100	300	0.25	0.75	7.3	0.085
70	330	0.175	0.825	7.32	0.063
30	370	0.075	0.925	7.32	0.027
0	400	0	1	0	0

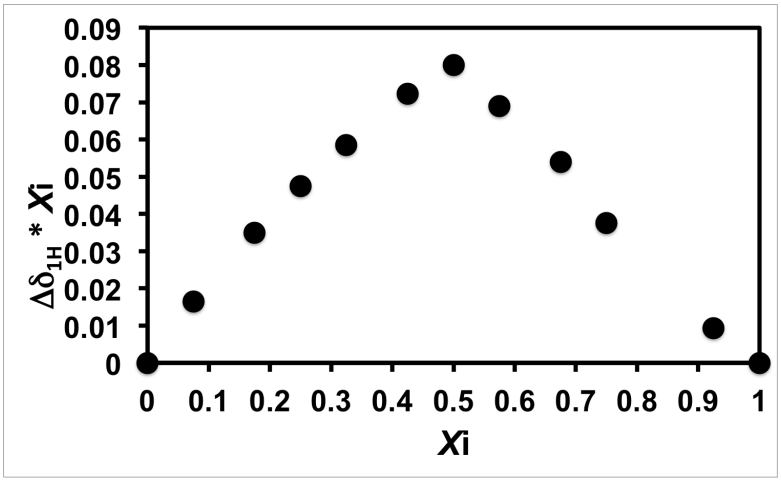


The maximum of the plot is at $Xi_7 = 0.5$ thus indicating a 1:1 stoichiometry.

Binging of 7 with $Ca(NTf_2)(BF_4)$

Two equimolar (0.015 M) solution of **7** and $Ca(NTf_2)(BF_4)$ in CD_2Cl_2 were prepared. Then 11 samples were prepared with defined volumes of the two stock solutions to give a total volume of 400 µL and were analysed by ^1H NMR spectroscopy. The study has been repeated twice.

V_7 (µL)	$V_{Ca(NTf2)(PF6)}$ (µL)	X_7	$X_{Ca(NTf2)(PF6)}$	d_7 (ppm)	$\Delta d_7 * X_7$
400	0	1	0	0	0
370	30	0.925	0.075	0.01	0.00925
300	100	0.75	0.25	0.05	0.0375
270	130	0.675	0.325	0.08	0.054
230	170	0.575	0.425	0.12	0.069
200	200	0.5	0.5	0.16	0.08
170	230	0.425	0.575	0.17	0.07225
130	270	0.325	0.675	0.18	0.0585
100	300	0.25	0.75	0.19	0.0475
70	330	0.175	0.825	0.2	0.035
30	370	0.075	0.925	0.22	0.0165
0	400	0	1	0	0

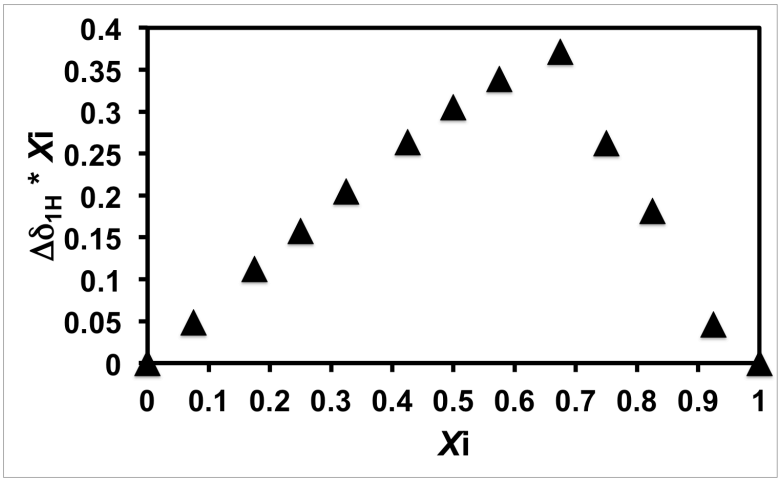


The maximum of the plot is at $Xi_7 = 0.5$ thus indicating a 1:1 stoichiometry.

Binging of 8 with $Ca(NTf_2)(PF_6)$

Two equimolar (0.015 M) solution of **8**[7] and $Ca(NTf_2)(PF_6)$ in CD_2Cl_2 were prepared. Then 12 samples were prepared with defined volumes of the two stock solutions to give a total volume of 400 µL and were analysed by ^1H NMR spectroscopy. The study has been repeated three times.

V_7 (µL)	$V_{Ca(NTf2)(PF6)}$ (µL)	X_7	$X_{Ca(NTf2)(PF6)}$	d_7 (ppm)	$\Delta d_7 * X_7$
400	0	1	0	7.73	0
370	30	0.925	0.075	7.81	0.04625
330	70	0.825	0.175	7.95	0.1815
300	100	0.75	0.25	8.08	0.2625
270	130	0.675	0.325	8.28	0.37125
230	170	0.575	0.425	8.32	0.33925
200	200	0.5	0.5	8.34	0.305
170	230	0.425	0.575	8.35	0.2635
130	270	0.325	0.675	8.36	0.20475
100	300	0.25	0.75	8.36	0.1575
70	330	0.175	0.825	8.37	0.112
30	370	0.075	0.925	8.38	0.04875
0	400	0	1	0	0



The maximum of the plot is at $Xi_{\mathbf{8}} = 0.66$ thus indicating a 1:2 stoichiometry.

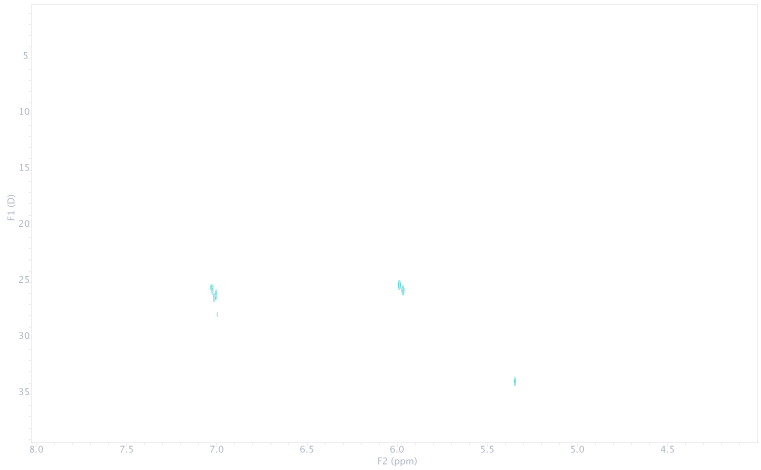
[7] **8** was prepared according to D. Liotta, C. Barnum, R. Puleo, G. Zima, C. Bayer, H. S. Kezar III *J. Org. Chem.* **1981**, *46*, 2920.

7. DOSY Studies

Four samples were prepared and analysed by DOSY: a solution of **7**, a 1:1 solution of **7** and $Ca(NTf_2)(PF_6)$, a solution of **8** and a 1:1 solution of **8** and $Ca(NTf_2)(PF_6)$.

Sample A – 7

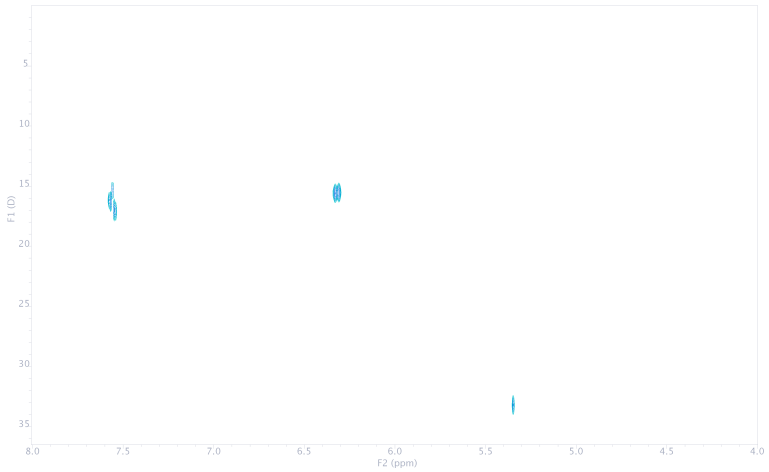
A dry tube was charged with **7** (3.0 µL, 0.03 mmol) and CD_2Cl_2 (0.3 mL). The mixture was stirred for 30 min, transferred into a dry NMR tube and the DOSY experiment was started.



$D_a = (26.7 \pm 1.0)\ 10^{-10}\ m^2\ s^{-1}$

Sample B – 7 + $Ca(NTf_2)(PF_6)$

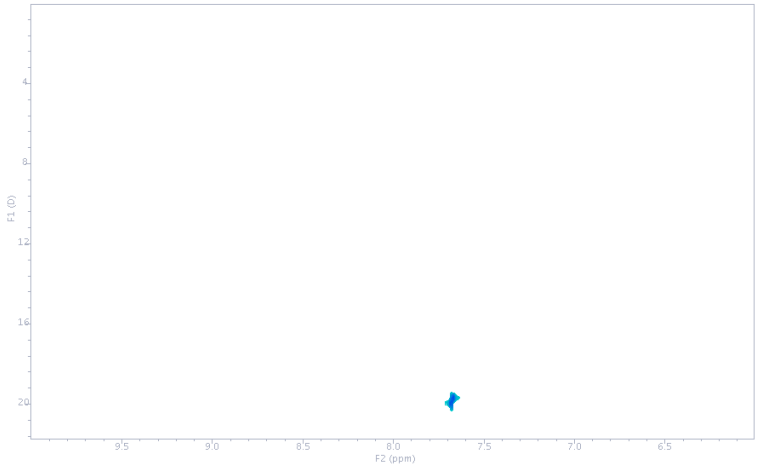
A dry tube was charged with $Ca(NTf_2)_2$ (24 mg, 0.04 mmol, 1.0 equiv.), $(Bu_4N)(PF_6)$ (15 mg, 0.04 mmol, 1.0 equiv.) and CD_2Cl_2 (0.4 mL). The mixture was stirred for 30 min and **7** (4.0 µL, 0.04 mmol, 1.0 equiv.) was added. The mixture was stirred for 30 min, transferred into a dry NMR tube and the DOSY experiment was started.



$D_a = (15.7 \pm 0.5)\ 10^{-10}\ m^2\ s^{-1}$

Sample C – 8

A dry tube was charged with **8** (4.6 mg, 0.04 mmol) and CD_2Cl_2 (0.4 mL). The mixture was stirred for 30 min, transferred into a dry NMR tube and the DOSY experiment was started.



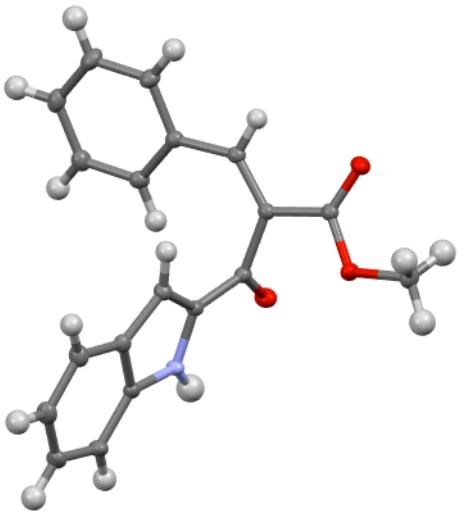
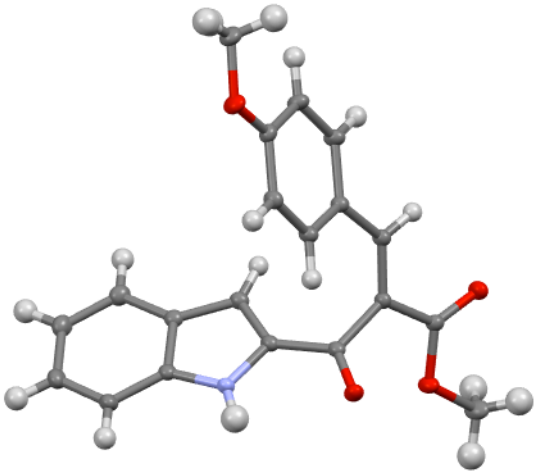
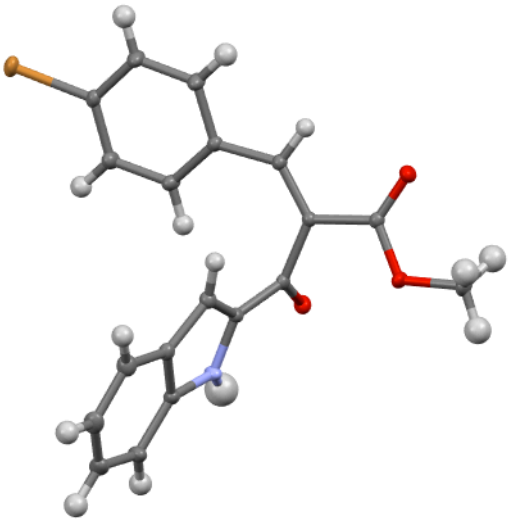
$D_a = (19.7 \pm 0.3)\ 10^{-10}\ m^2\ s^{-1}$

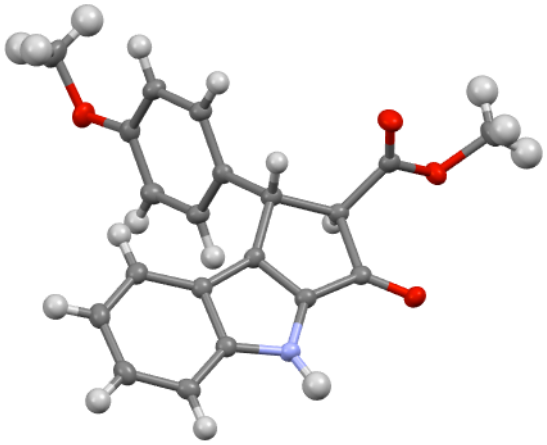
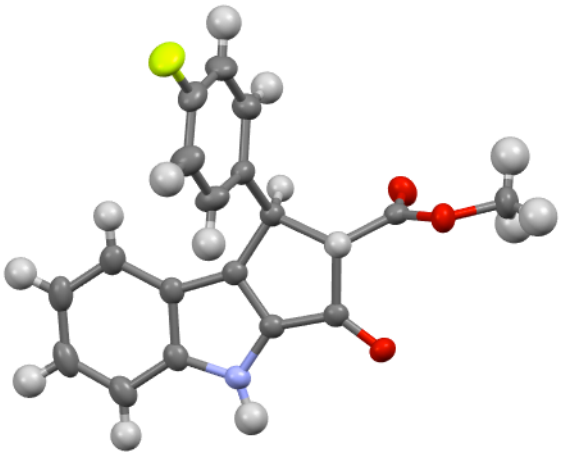
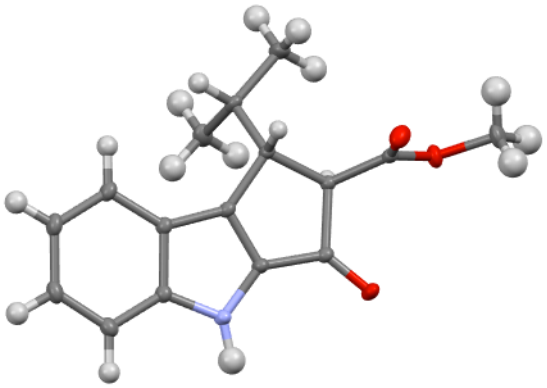
Sample D – 8 + Ca(NTf$_2$)(PF$_6$) (1:1)

A dry tube was charged with $Ca(NTf_2)_2$ (24 mg, 0.04 mmol, 1.0 equiv.), $(Bu_4N)(PF_6)$ (15 mg, 0.04 mmol, 1.0 equiv.) and CD_2Cl_2 (0.3 mL). The mixture was stirred for 30 min and a solution of **8** (4.6 mg, 0.04 mmol, 1.0 equiv.) in CD_2Cl_2 (0.1 mL) was added. The mixture was stirred for 30 min, transferred into a dry NMR tube and the DOSY experiment was started.

$D_a = (9.4 \pm 0.2)\ 10^{-10}\ m^2\ s^{-1}$

8. X-Ray Structures

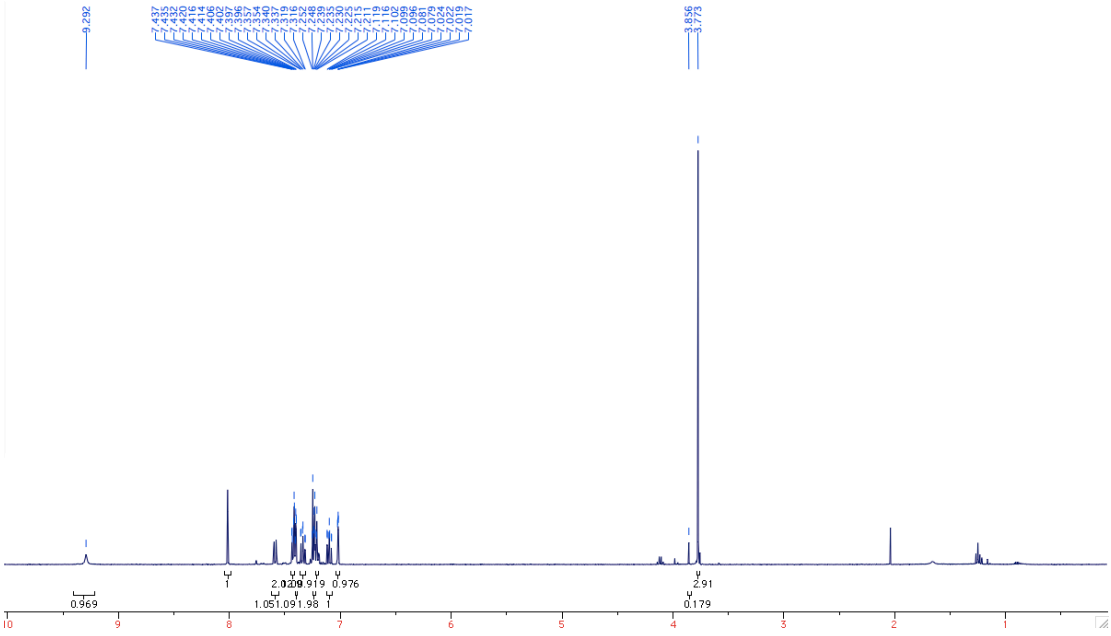
Compound	X-Ray
1a	
1b	
1c	

Structure	X-Ray
2b	
2c	
2i	

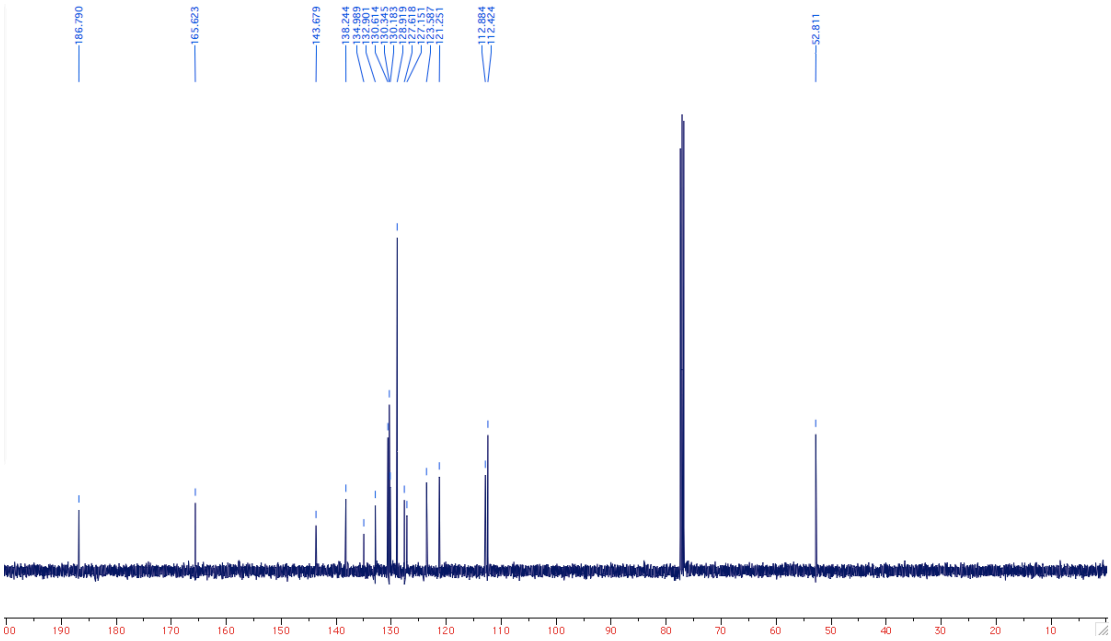
9. ^{1}H and ^{13}C NMR Spectra

1a

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

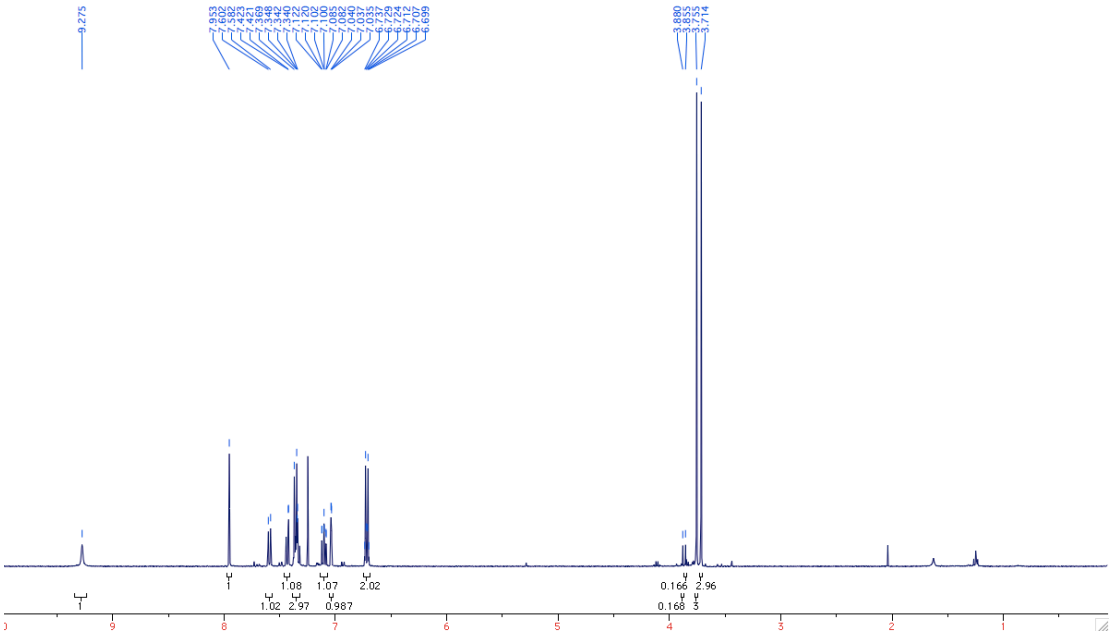


^{13}C NMR (100 MHz, $CDCl_3$)

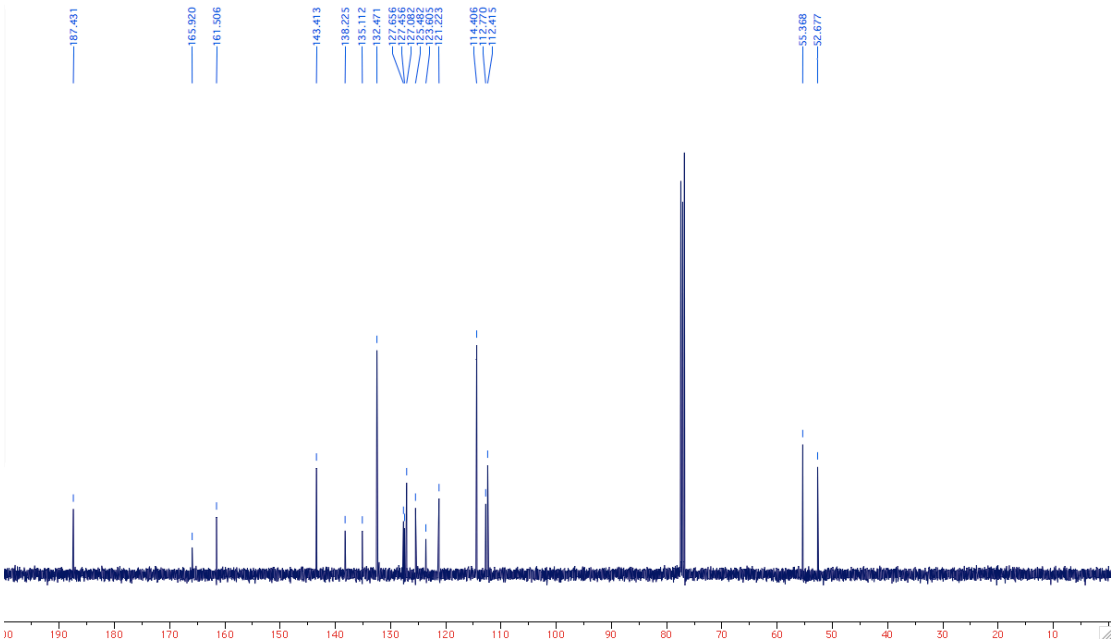


1b

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

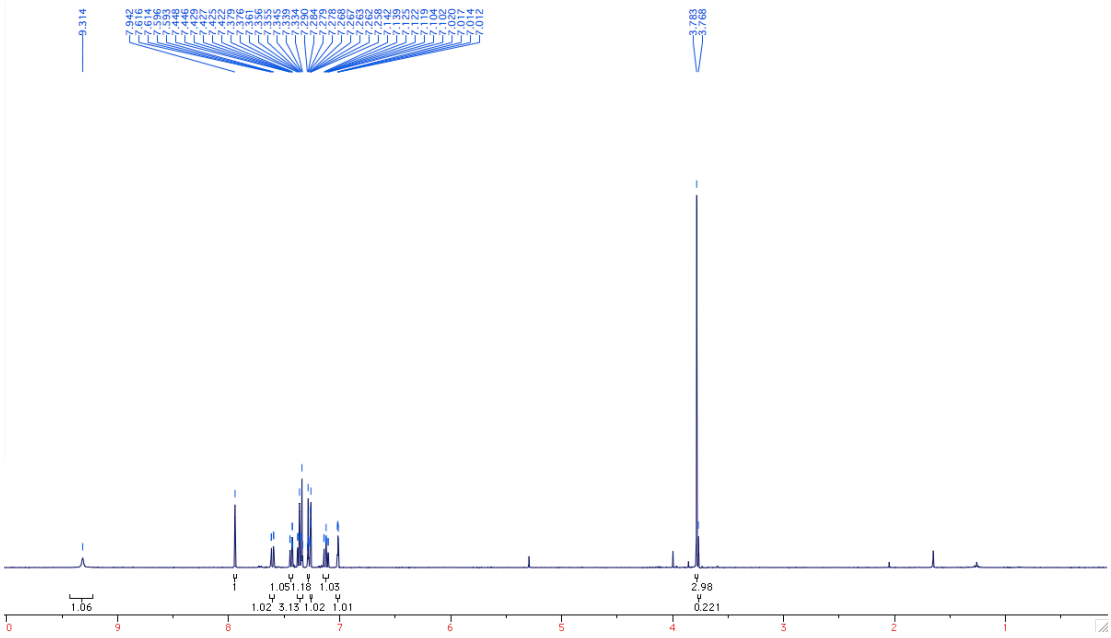


^{13}C NMR (100 MHz, $CDCl_3$)

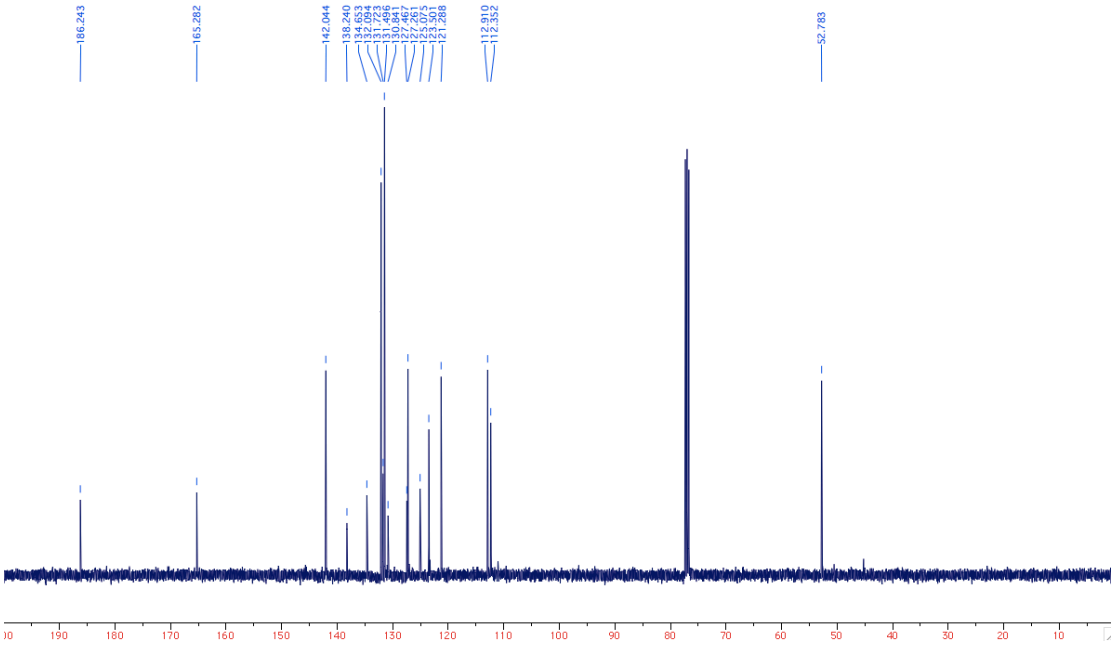


1c

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

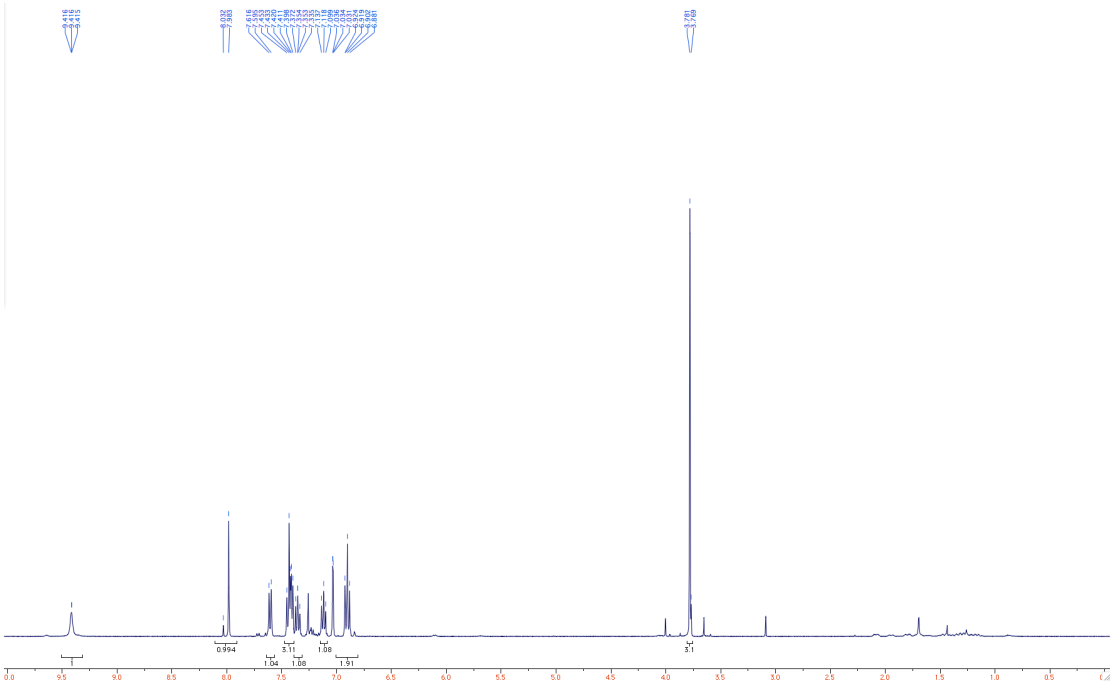


^{13}C NMR (100 MHz, $CDCl_3$)

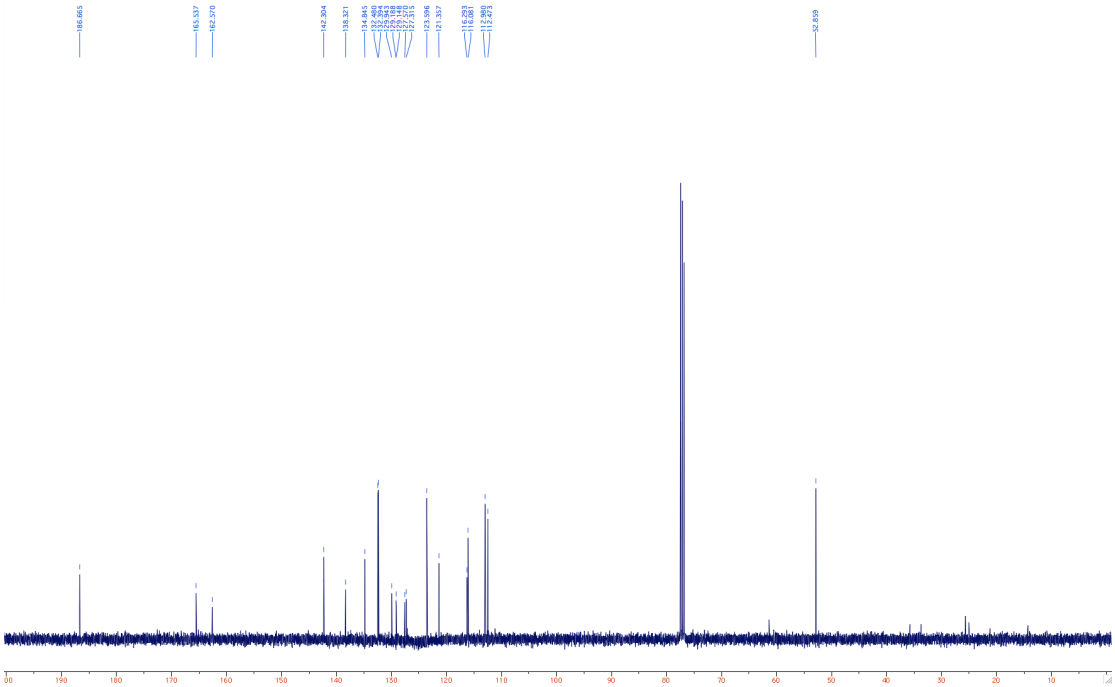


1d

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

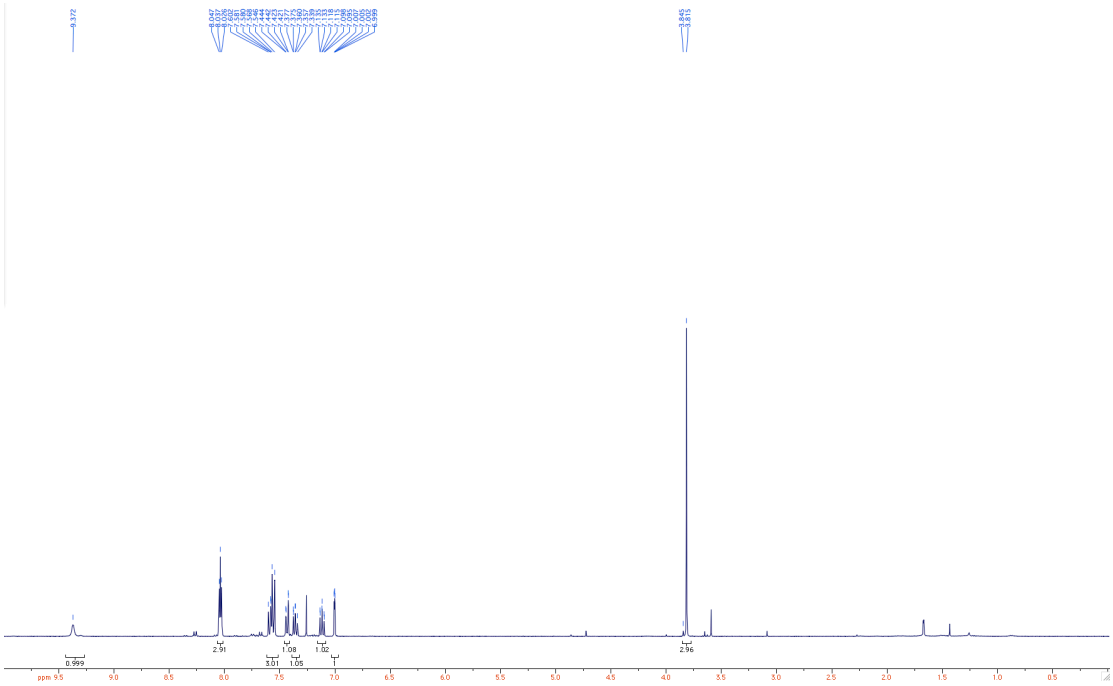


^{13}C NMR (100 MHz, $CDCl_3$)

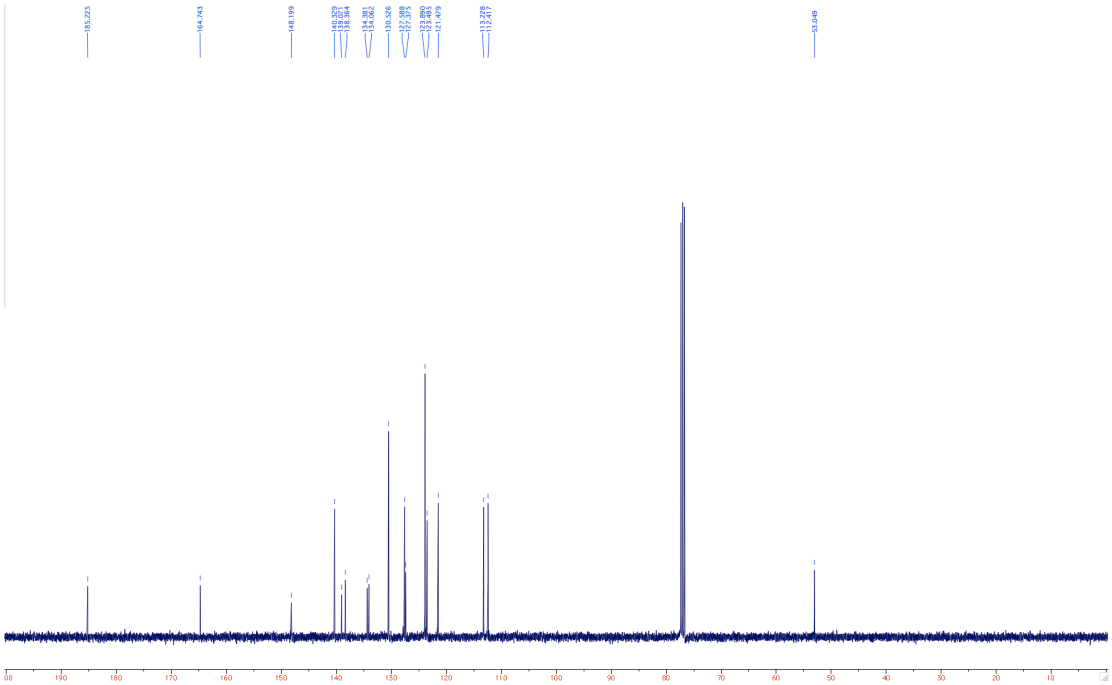


1e

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

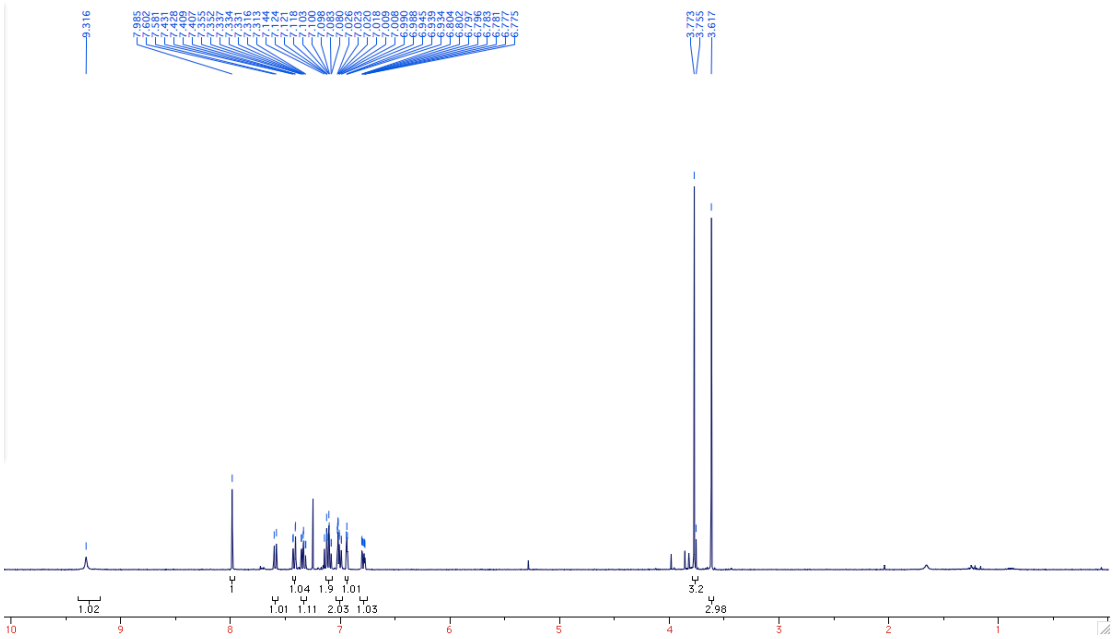


^{13}C NMR (100 MHz, $CDCl_3$)

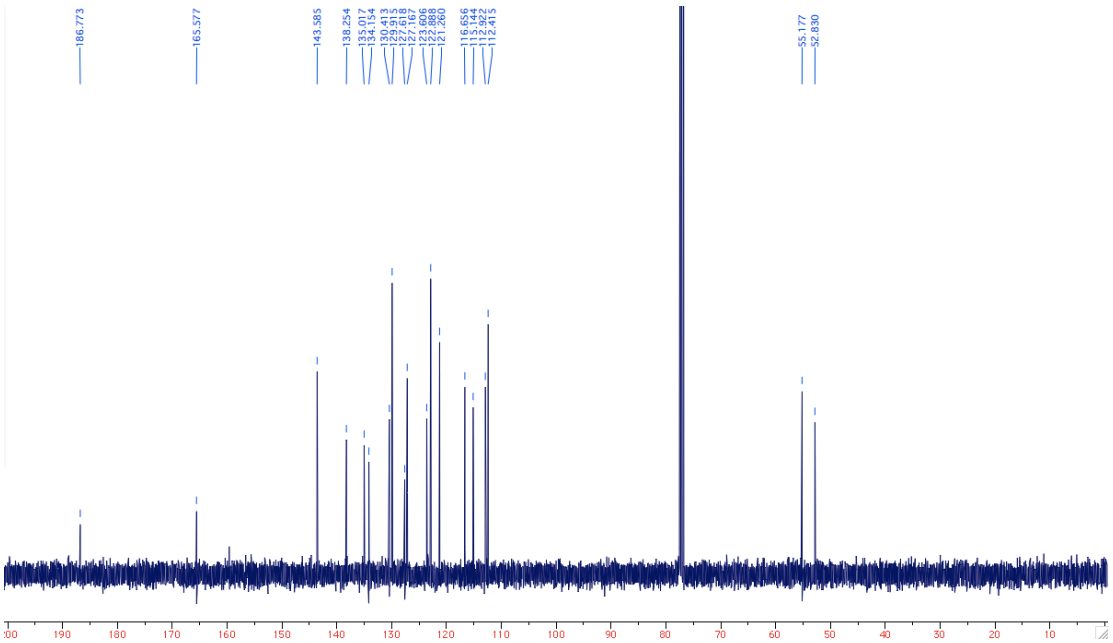


1f

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

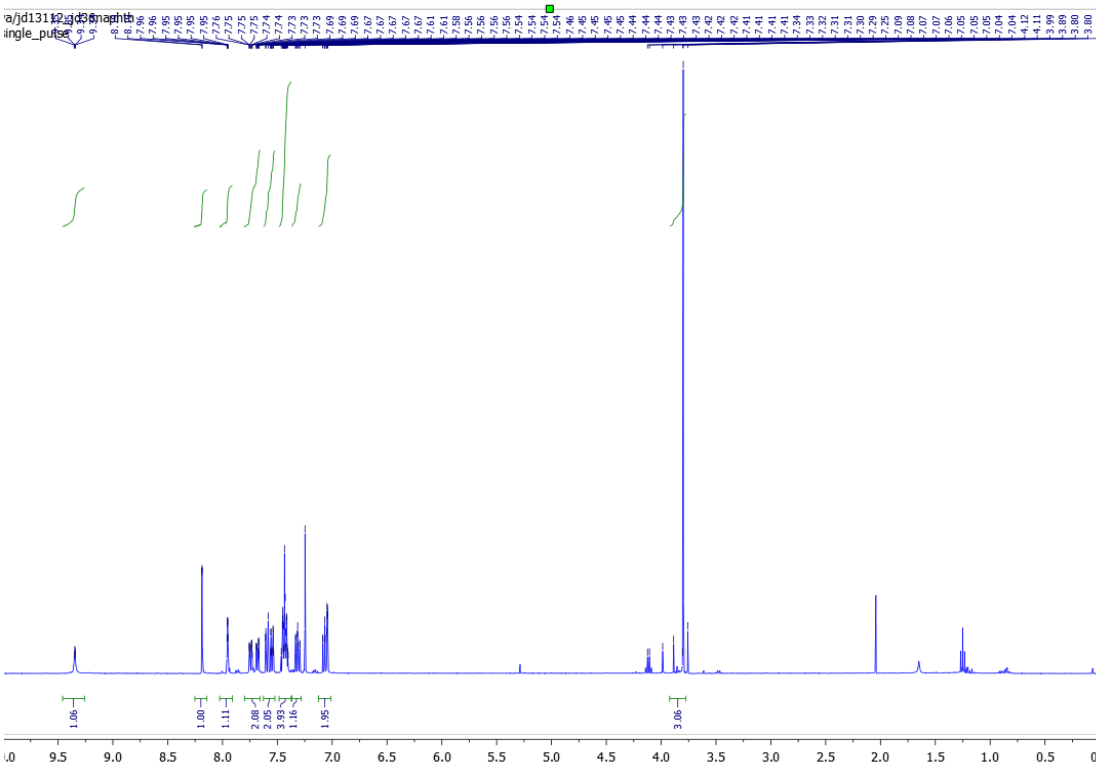


^{13}C NMR (100 MHz, $CDCl_3$)

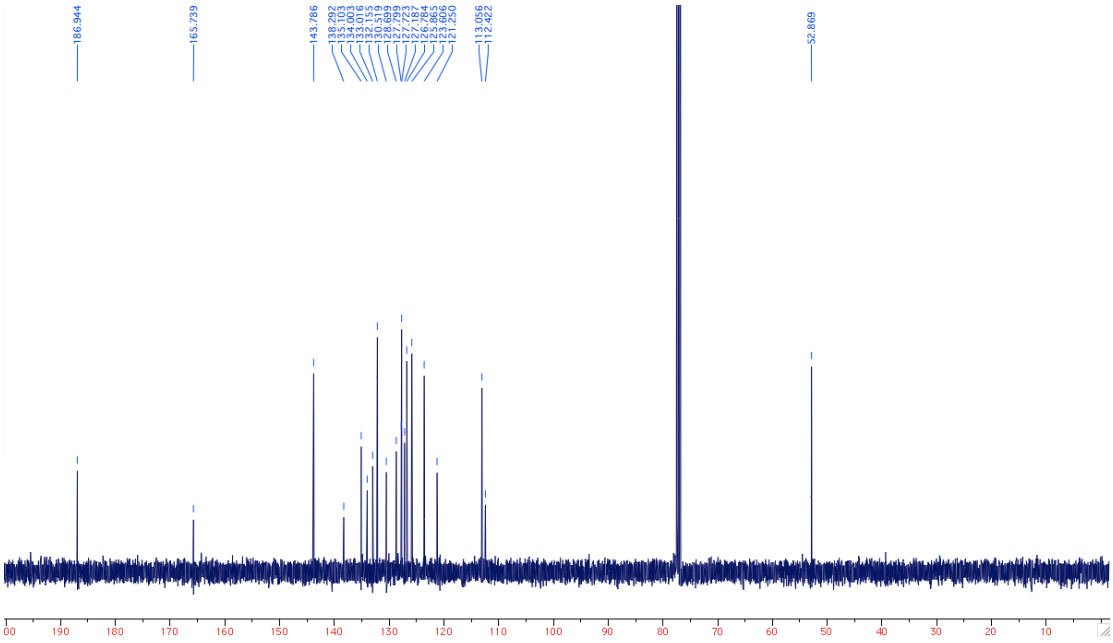


1g

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

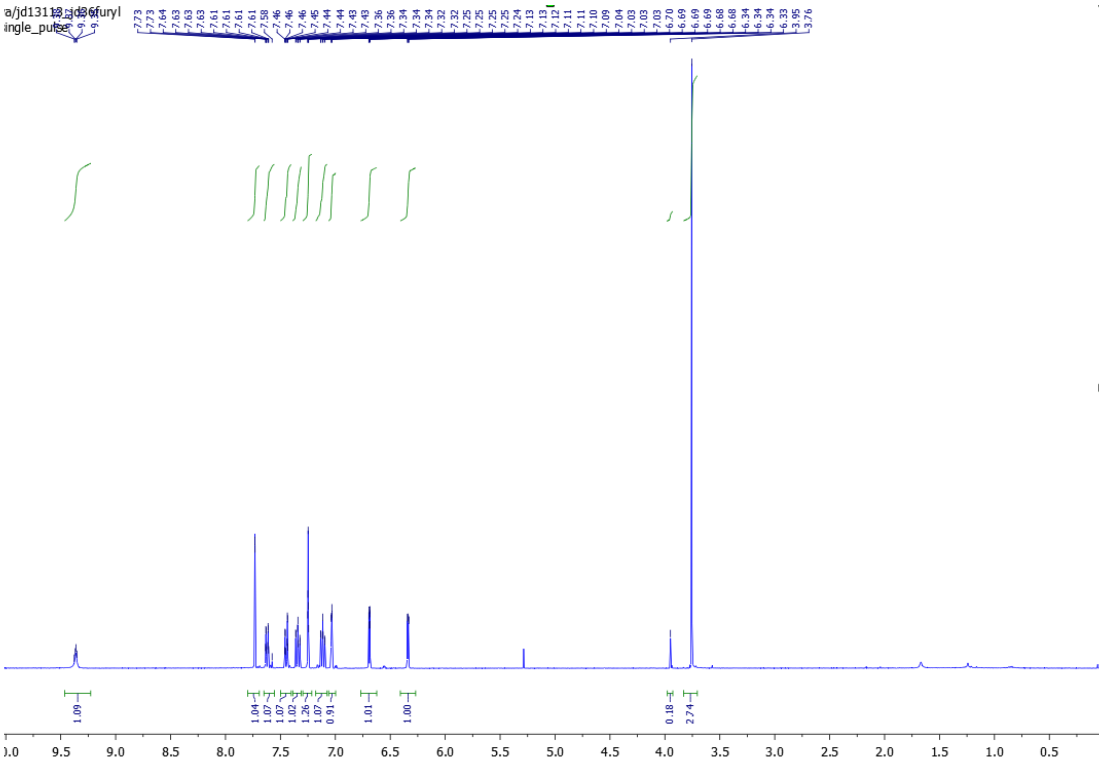


^{13}C NMR (100 MHz, $CDCl_3$)

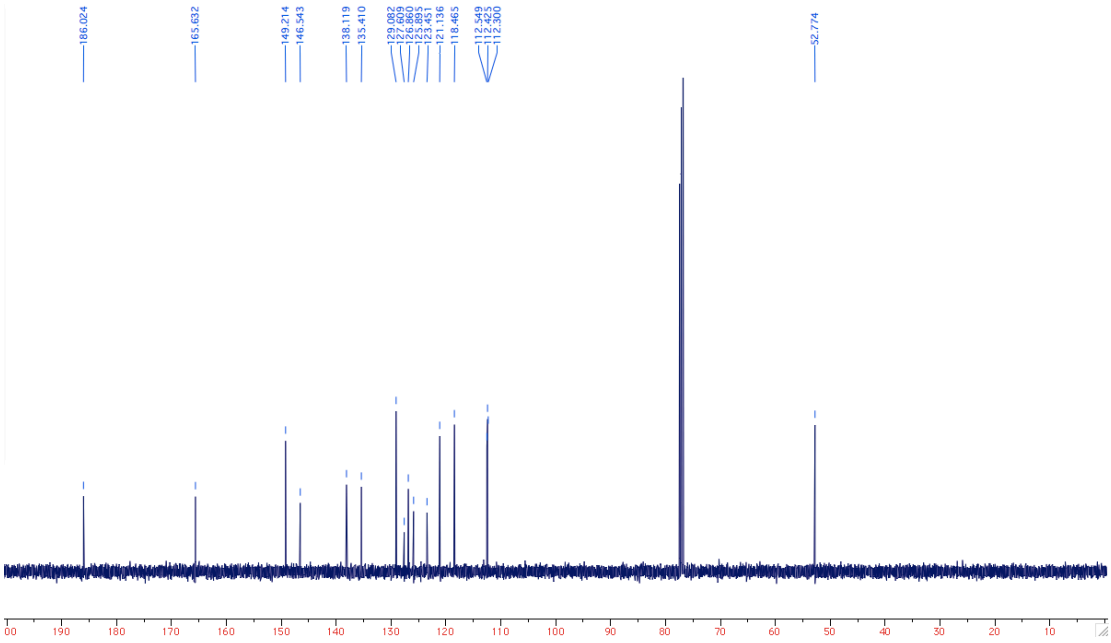


1h

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

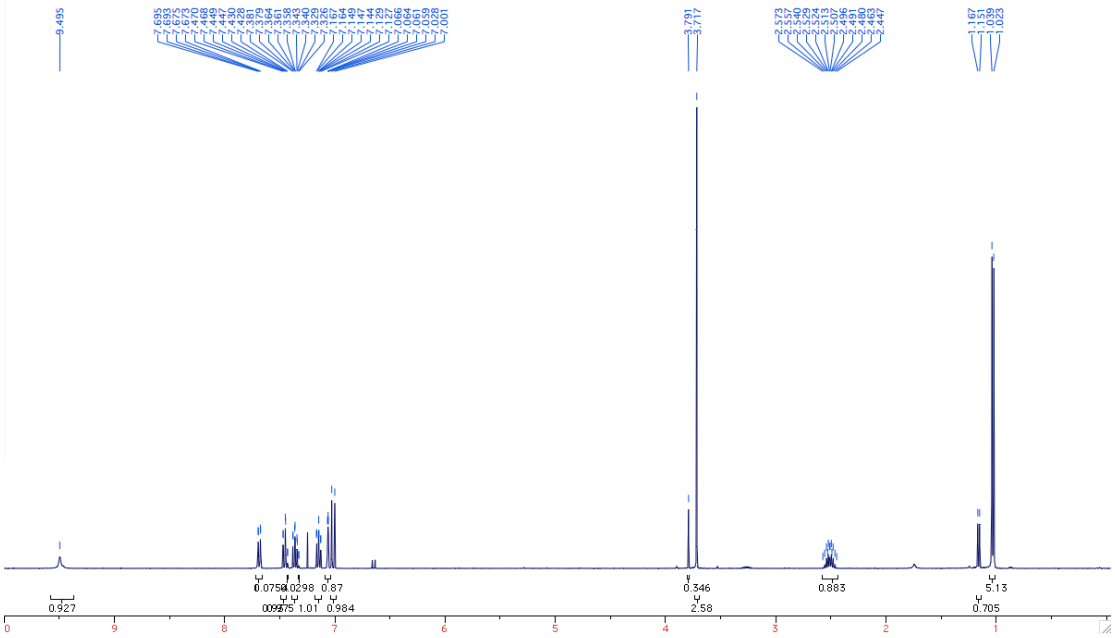


^{13}C NMR (100 MHz, $CDCl_3$)

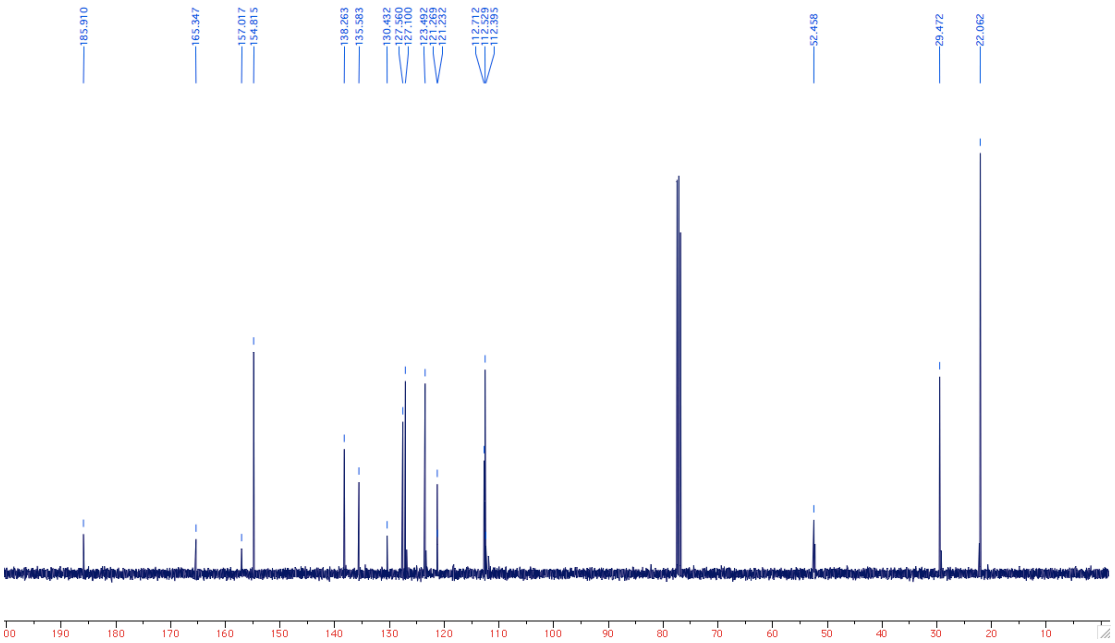


1i

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

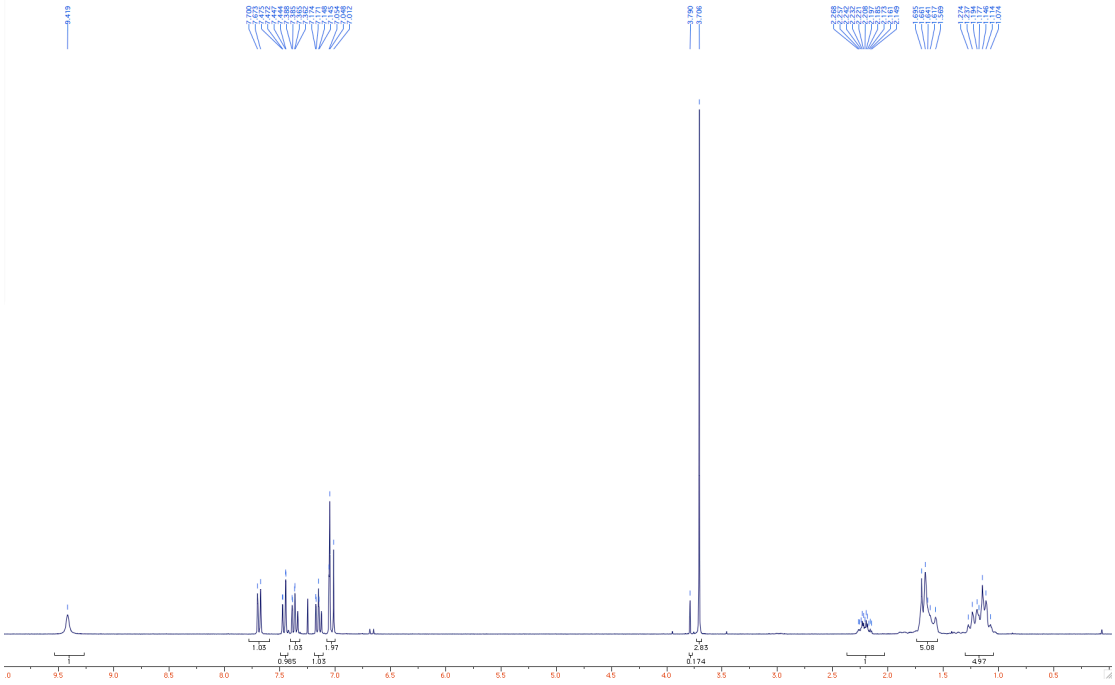


^{13}C NMR (100 MHz, $CDCl_3$)

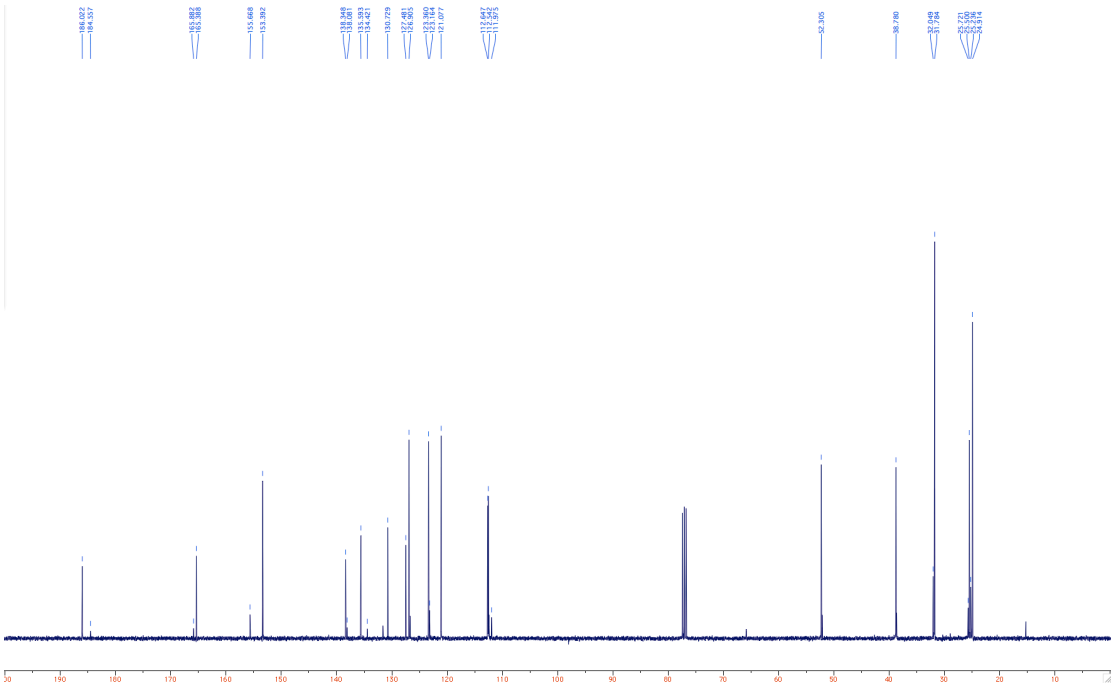


1j

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

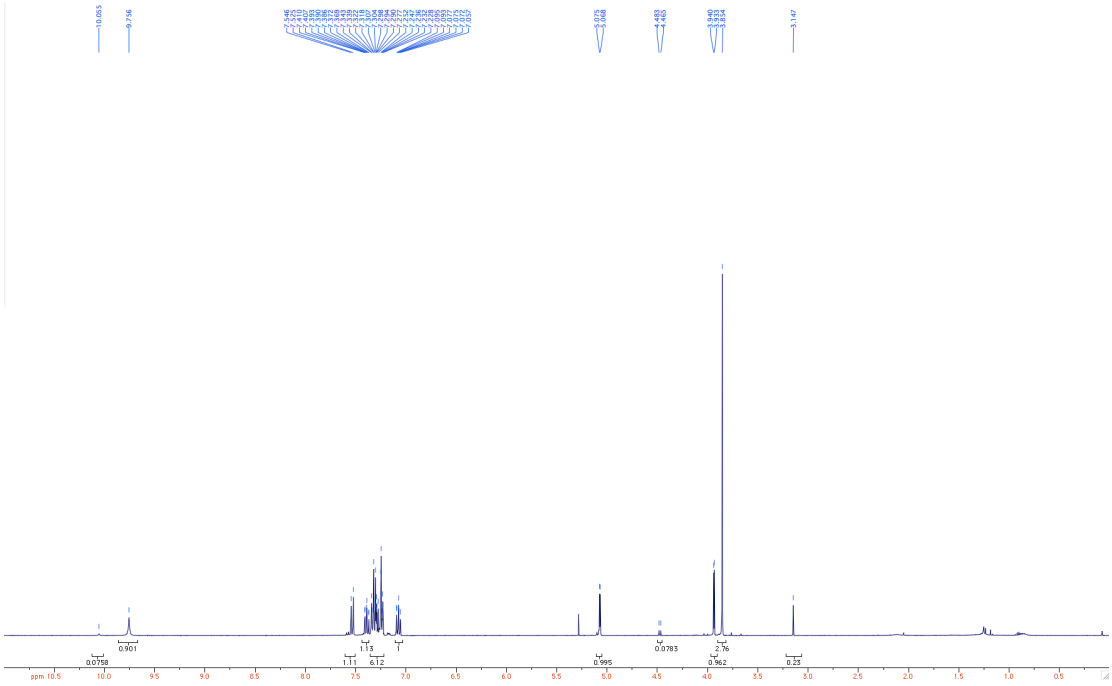


^{13}C NMR (100 MHz, $CDCl_3$)

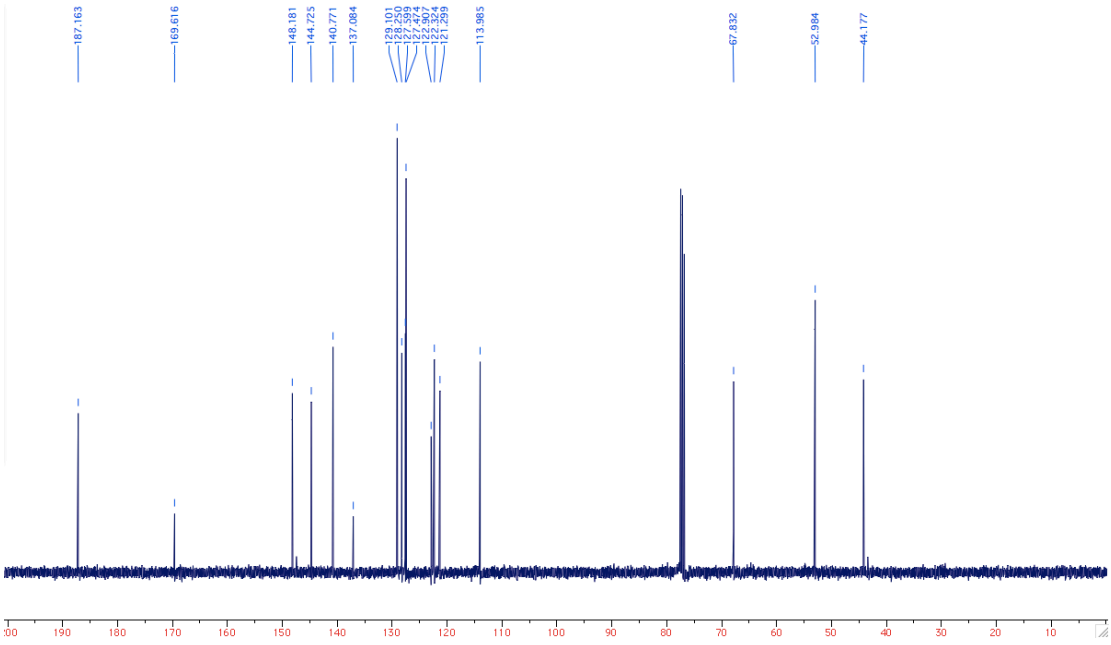


2a

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

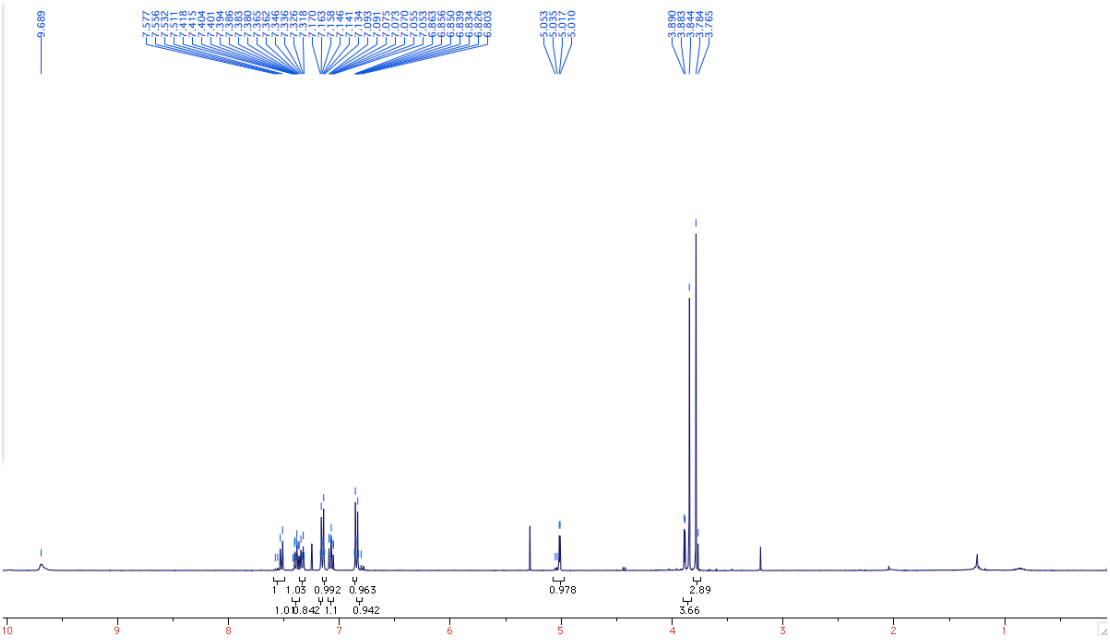


^{13}C NMR (100 MHz, $CDCl_3$)

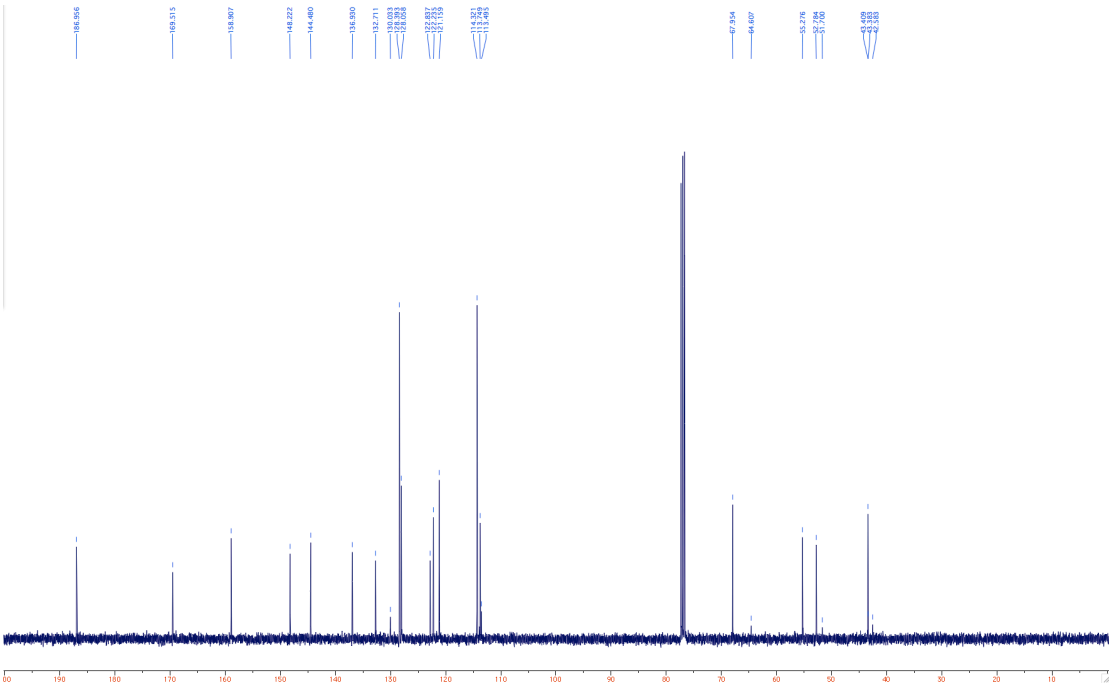


2b

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

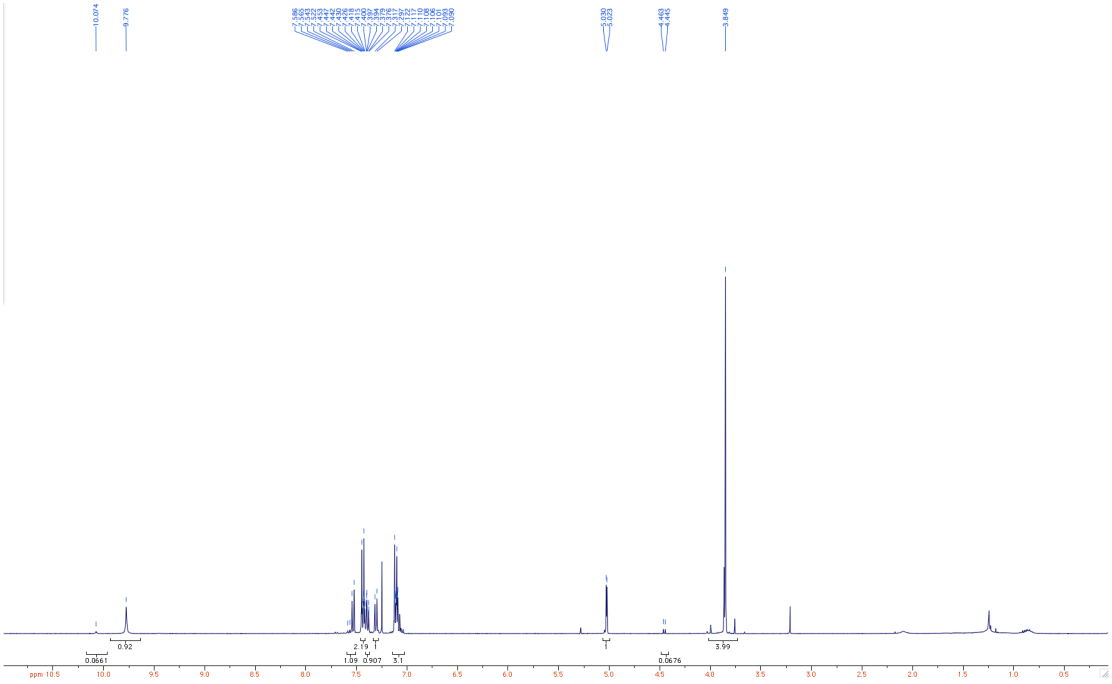


^{13}C NMR (100 MHz, $CDCl_3$)

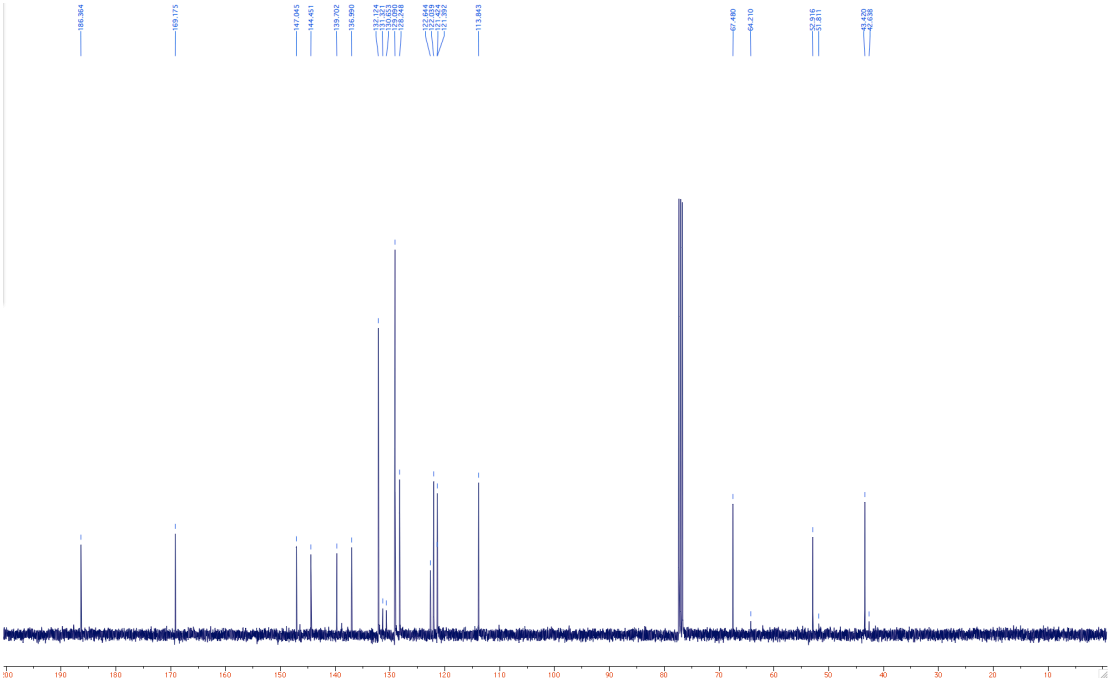


2c

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

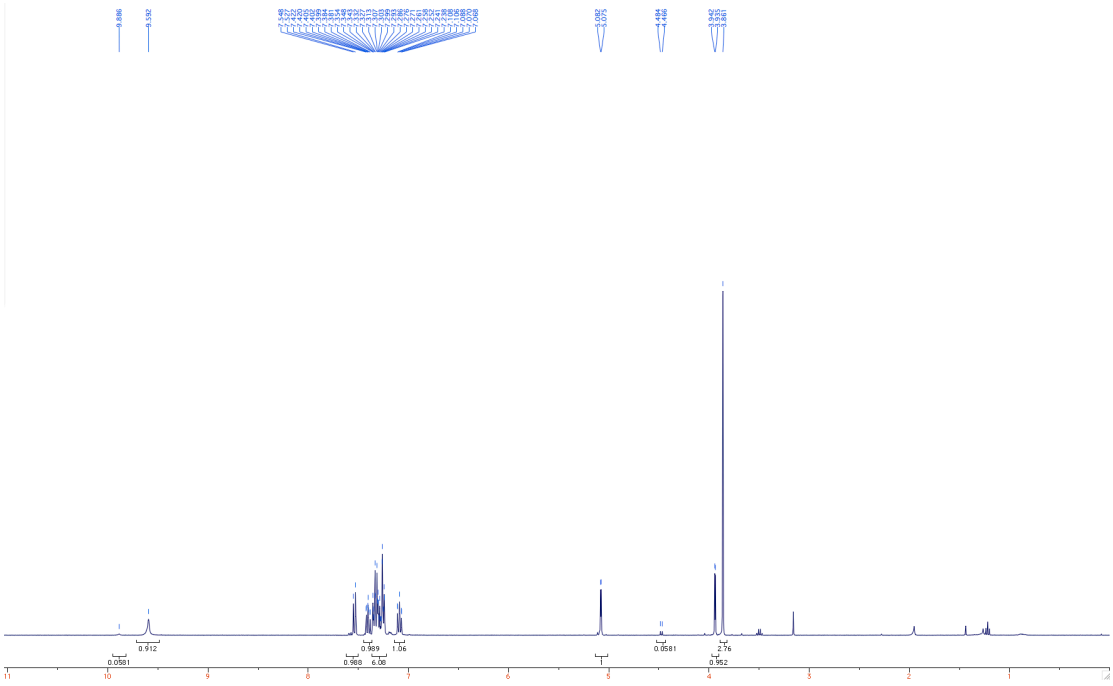


^{13}C NMR (100 MHz, $CDCl_3$)

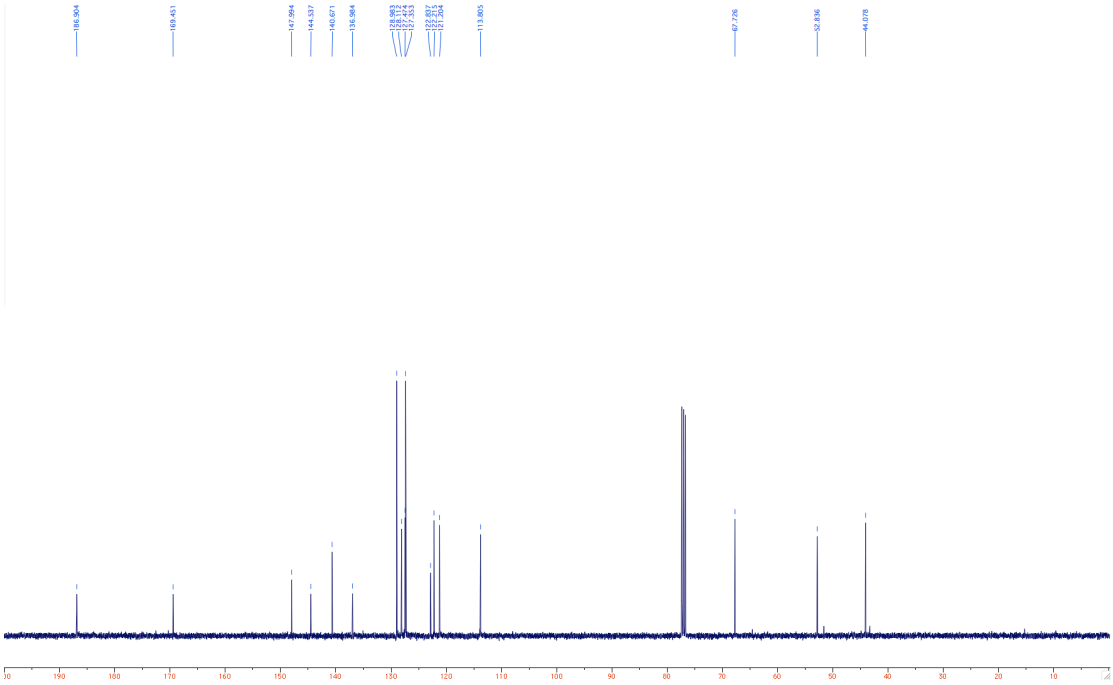


2d

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

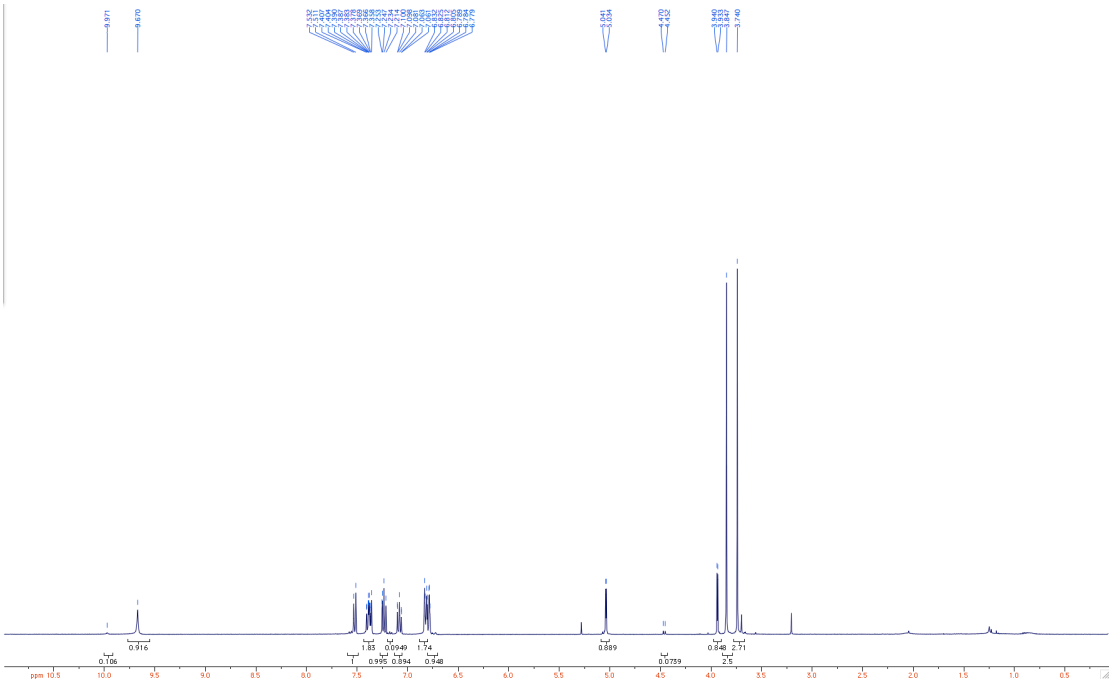


^{13}C NMR (100 MHz, $CDCl_3$)

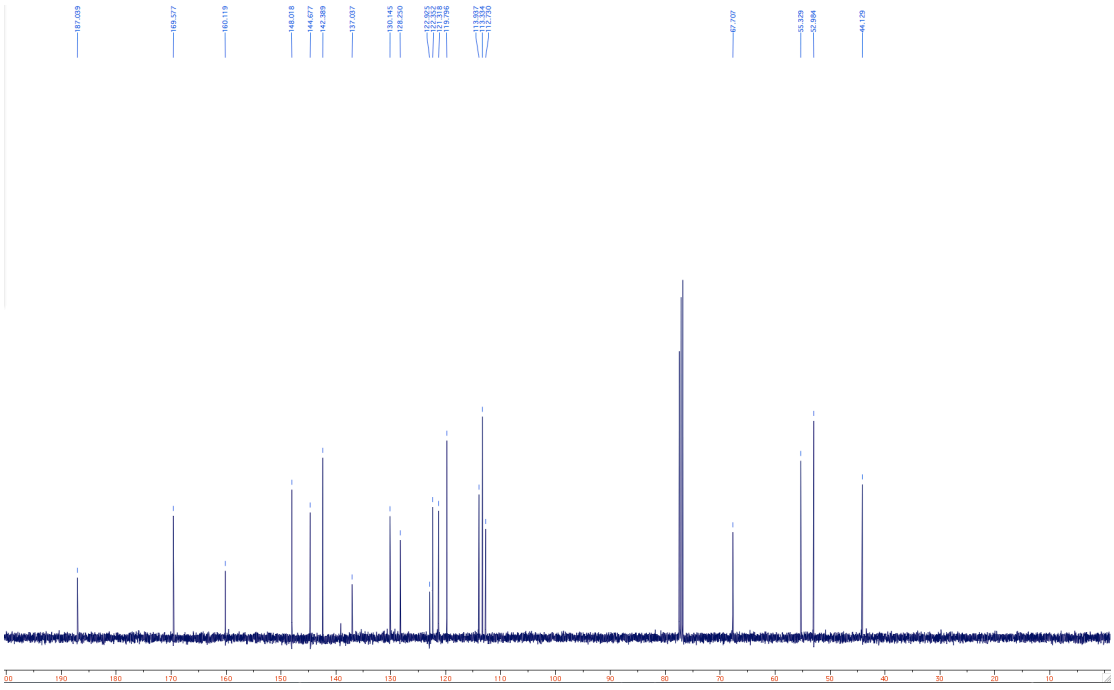


2f

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

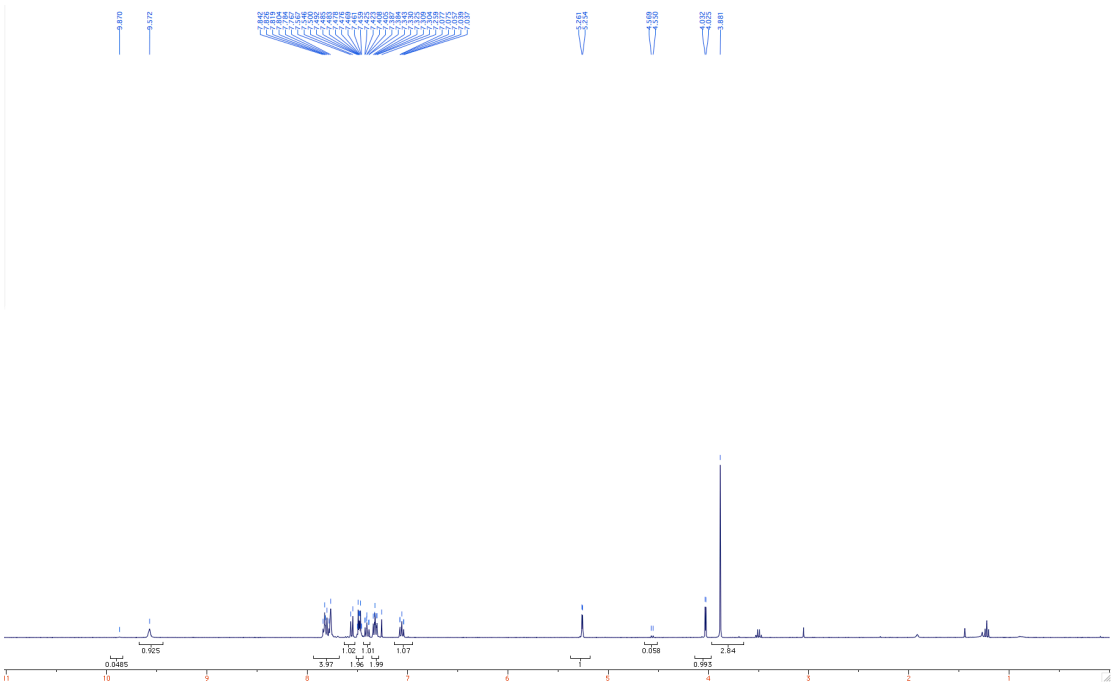


^{13}C NMR (100 MHz, $CDCl_3$)

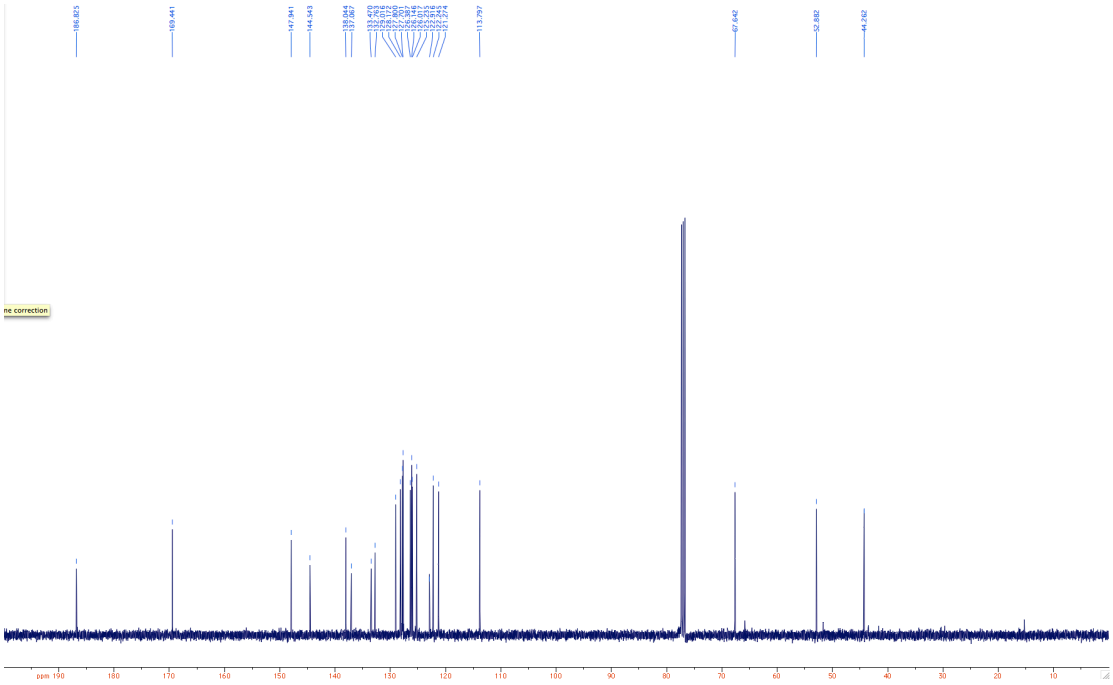


2g

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

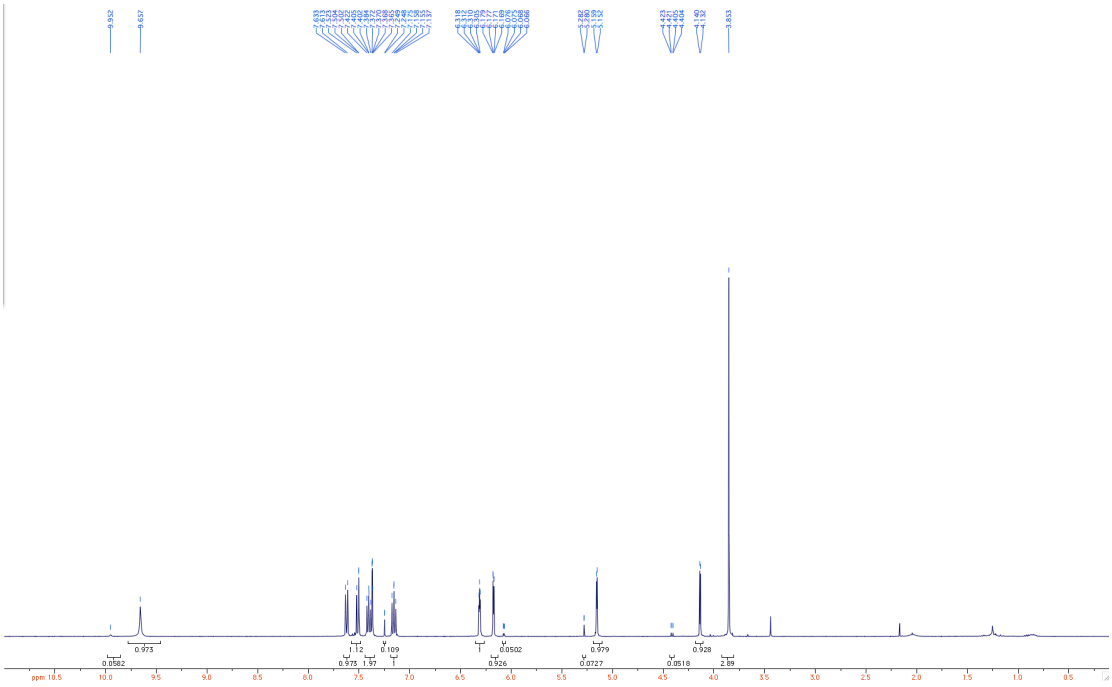


^{13}C NMR (100 MHz, $CDCl_3$)

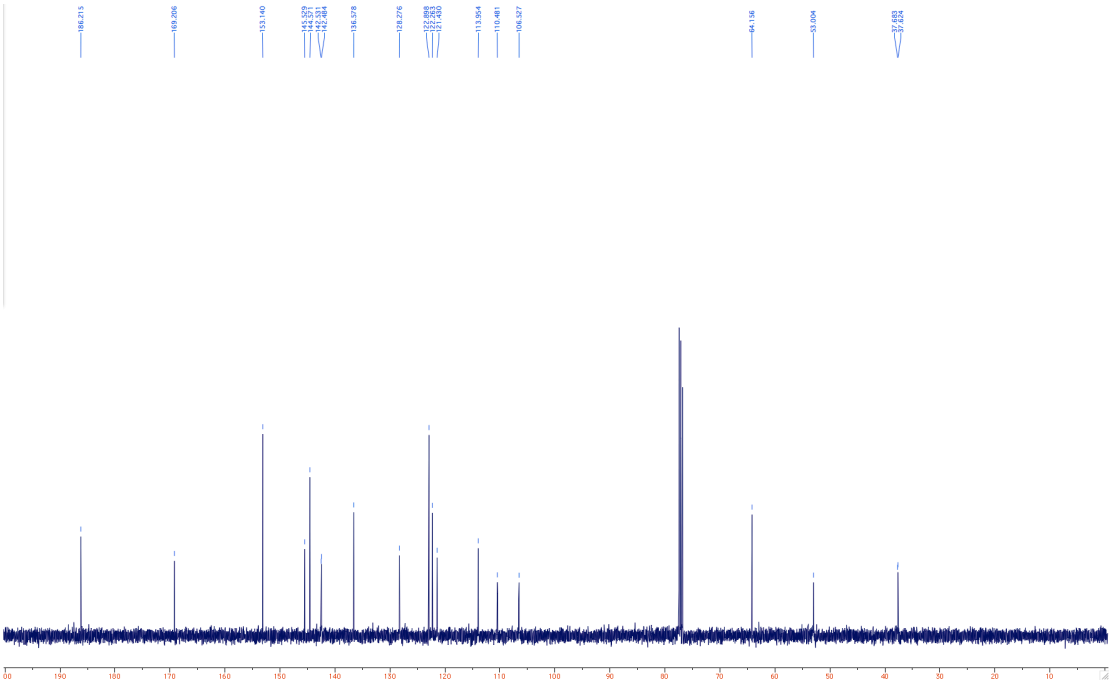


2h

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

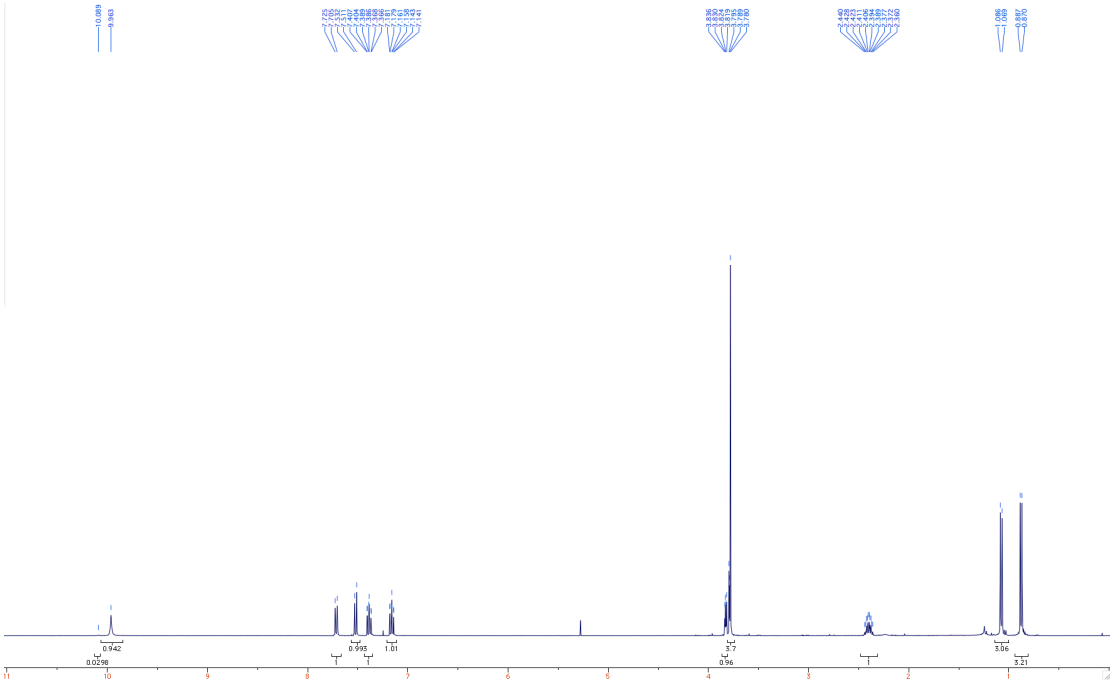


^{13}C NMR (100 MHz, $CDCl_3$)

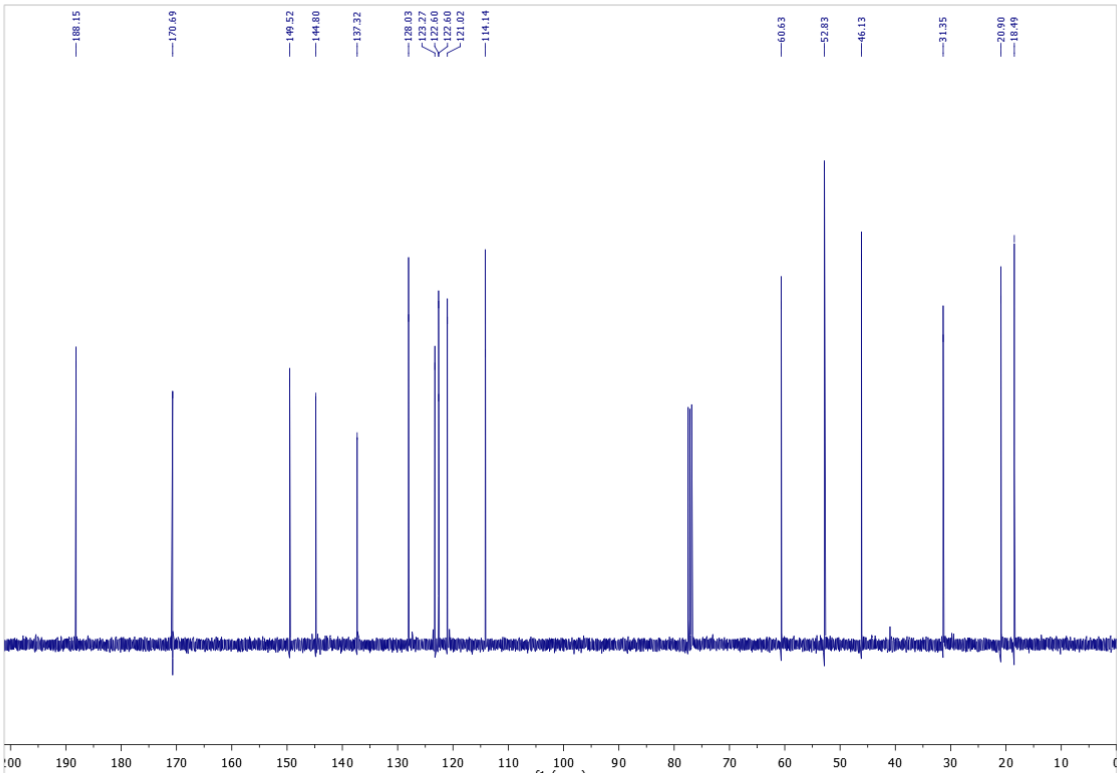


2i

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

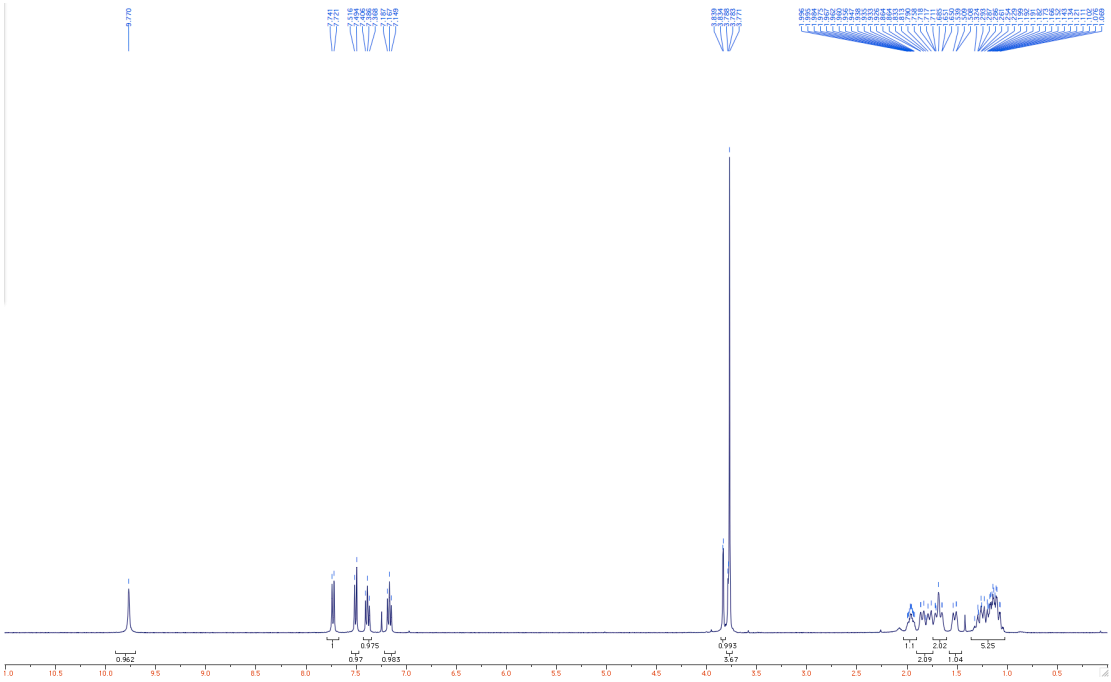


^{13}C NMR (100 MHz, $CDCl_3$)

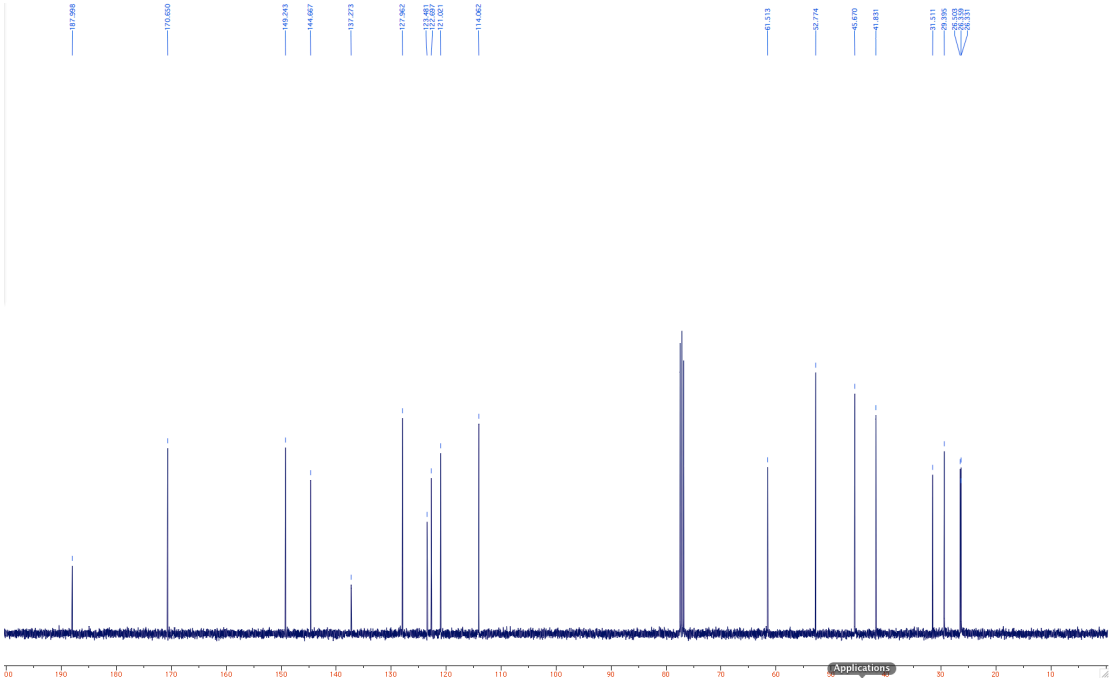


2j

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

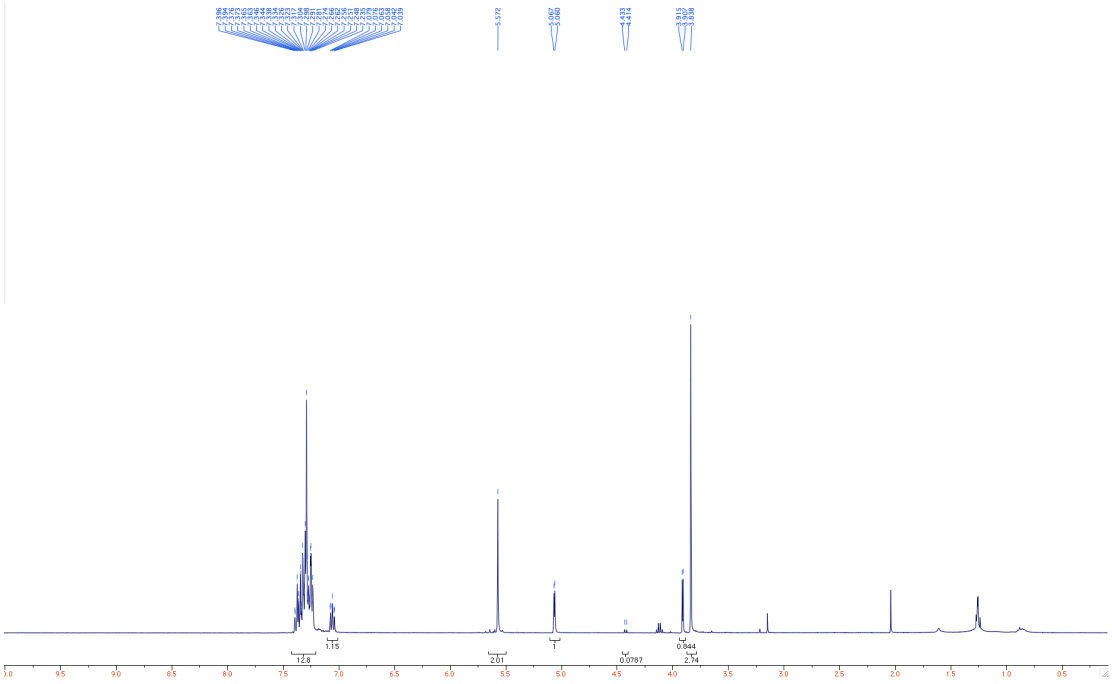


^{13}C NMR (100 MHz, $CDCl_3$)

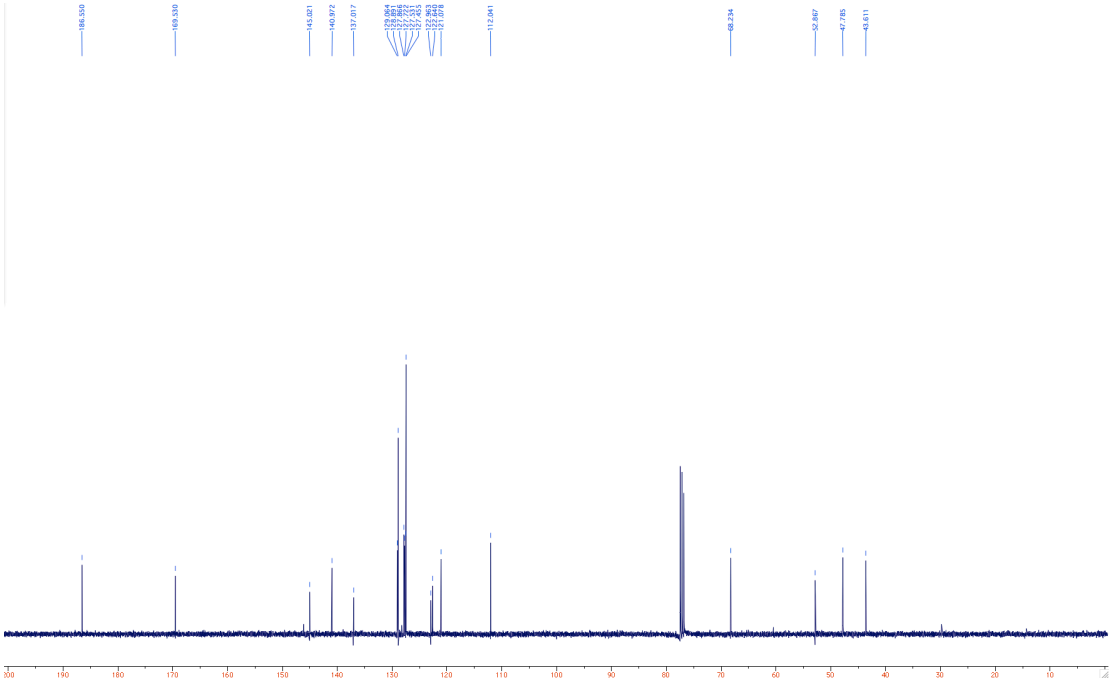


3

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

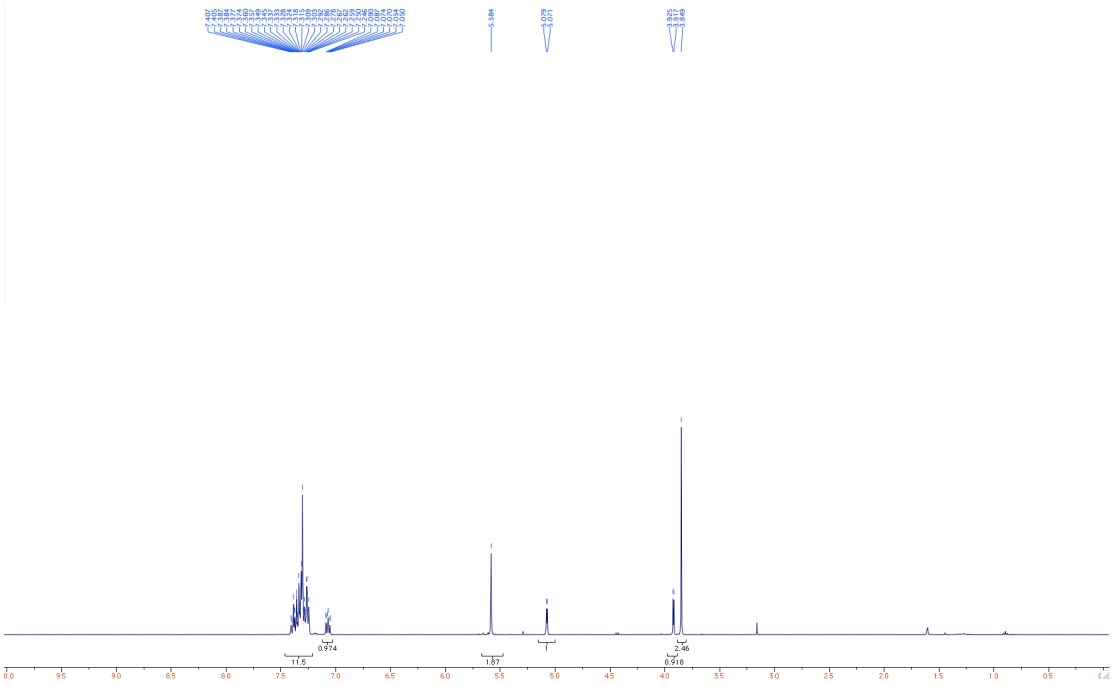


^{13}C NMR (100 MHz, $CDCl_3$)



4

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



^{13}C NMR (100 MHz, $CDCl_3$)