Supplementary Material

Synthesis and characterisation of novel fluorescent imides by a rhodium(III)-catalysed C-H activation/annulation cascade

Nicola J. Webb,[a] Brittany Fisher,[a] Christopher M. Pask,[a] Michael S. Watt,[a] Steven A. Raw,[b] and Stephen P. Marsden*,[a]

[a] School of Chemistry, University of Leeds, Leeds LS2 9JT, U.K.
[b] Chemical Development, Pharmaceutical Technology & Development, Operations, AstraZeneca, Macclesfield, UK (current address: Asymchem Limited, Suite 1, 3rd Floor, 11-12 St James' Square, London, SW1Y 4LB, UK)
Email: s.p.marsden@leeds.ac.uk

Table of Contents

General experimental

All experiments were conducted in oven-dried glassware, under a dry nitrogen atmosphere with anhydrous solvents, unless otherwise stated. Hygroscopic caesium acetate (CsOAc) was stored in a desiccator. Anhydrous solvents were obtained from a solvent purification system. Anhydrous methanol was stored on 3Å molecular sieves. All other solvents and reagents were obtained from commercial sources and used without further purification.

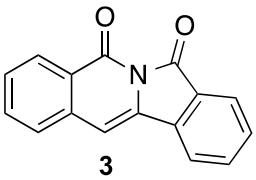
Flash silica chromatography was performed using Fischer Matrix silica gel (35-70 µm particles) and thin layer chromatography was carried out using pre-coated silica plates (Merck Kieselgel 60F254). Spots were visualised using UV fluorescence (λ_{max} = 254 nm) or chemical staining with potassium permanganate. All chromatography eluents were HPLC grade and used without purification. Petrol refers to petroleum ether (b.p. 40-60°C).

N-(Pivaloyloxy)benzamide **1a** and *N*-(pivaloyloxy)2-naphthamide **1c** were prepared according to the procedures of Liebeskind[1] and Glorius[2] respectively.

Proton (^{1}H) and carbon (^{13}C{^{1}H}) nuclear magnetic resonance spectra were recorded using a Bruker DPX 300, a Bruker DRX 500 or a Bruker Avance 500 spectrometer using an internal deuterium lock. ^{1}H NMR chemical shifts (δ) are quoted in ppm downfield of tetramethylsilane or residual solvent peaks and coupling constants (*J*) are quoted in Hz. ^{13}C{^{1}H} NMR spectra were recorded with broadband proton decoupling at 75 MHz and 125 MHz. Assignments were made on the basis of chemical shift and coupling data, using COSY and DEPT where necessary. Infra-red spectra were recorded on a Perkin Elmer Spectrum One FT-IR spectrometer, with absorption reported in wavenumbers (cm^{-1}). High-resolution electrospray mass spectra (ESI-MS) were measured on a Bruker MicroTOF-Q or Bruker MaXis Impact spectrometer in positive mode. Melting points were determined using a Griffin D5 variable temperature apparatus and are uncorrected.

[1] Z. Zhang, Y. Yu and L. S. Liebeskind, *Org. Lett*., **2008**, *10*, 3005–3008
[2] C. Grohmann, H. Wang and F. Glorius, *Org. Lett*., **2012**, *14*, 656–659

Formation of isoindolo[2,1-b]isoquinoline-5,7-dione 3



3

A solution of *N*-methoxybenzamide **1b** (302 mg, 2.00 mmol), CsOAc (115 mg, 0.600 mmol), $[Cp^*RhCl_2]_2$ (12 mg, 2.0 mol%) and vinyl acetate (277 µL, 3.00 mmol) in MeOH (5 mL, 0.4 M) was heated for 48 hours at 60 °C. The reaction mixture was concentrated *in vacuo* and subsequently purified by flash silica chromatography using 50% EtOAc in hexane to afford isoindolo[2,1-b]isoquinoline-5,7-dione **3** as a bright yellow amorphous solid (28 mg, 6%). R_f 0.33 (1:1 petrol–EtOAc) strong blue fluorescent trace; δ_H (500 MHz, $CDCl_3$) 8.51 (1H, d, *J* 7.9, H4), 8.02 (1H, d, *J* 7.6, H8), 7.81 (1H, d, *J* 7.6 H11), 7.74 (1H, t, *J* 7.6, H10), 7.69 (1H, t, *J* 7.9, H2), 7.58 (1H, t, *J* 7.9, H9), 7.57 (1H, d, *J* 7.9, H1), 7.53 (1H, t, *J* 7.6, H3), 6.98 (1H, s, H12); δ_H (500 MHz, DMF-d^7) 8.36 (1H, d, *J* 6.8, ArH), 8.19 (1H, d, *J* 7.1, ArH), 7.98 (1H, d, *J* 7.5, ArH), 7.91 (1H, t, *J* 7.5, ArH), 7.85-7.77 (2H, m, ArH), 7.71 (1H, t, *J* 7.0, ArH), 7.63 (1H, t, *J* 7.5, ArH), 7.55 (1H, s); δ_C (75 MHz, $CDCl_3$) 165.1 (C7O), 159.8 (C5O), 135.6 (Cq), 135.1 (Cq), 134.7 (C10), 134.3 (Cq), 133.9 (C2), 130.6 (C1 or C9), 129.5 (C4), 128.5 (C3), 128.3 (Cq), 127.8 (Cq), 127.4 (C1 or C9), 125.7 (C8), 120.5 (C11), 103.6 (C12); HRMS: m/z calculated for formula $C_{16}H_9NNaO_2$ [MNa^+]: 270.0525; found 270.0528; IR (ν_{max}, solid, cm^{-1}): 2925, 2852, 1838, 1759, 1682, 1639, 1607, 1520, 1473, 1380, 1340, 1289, 1277, 1178, 1089, 1030, 957, 928, 860, 766, 702; spectral data consistent with the literature.[3]

Characterisation data for compound 7:

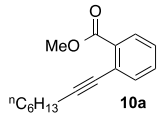
Insoluble material was found to precipitate from the reaction of **1b** and **6** in methanol and was isolated *via* filtration. Characteristic spectral features were identified as follows: δ_H (300 MHz, DMSO-d_6) 7.93 (1H, broad s, NH) 7.67 (2H, m, ArH) 7.29 - 7.56 (9H, m, ArH + alkene H + NH), 3.71 (3H, s, OCH_3), one NH not observed; δ_C (75 MHz, DMSO-d_6) 170.6 (CO), 165.2 ($CONH_2$), 136.5 (C_q), 135.3 (C_q), 134.6 (C_q), 134.0 (C_q), 129.9 (CH), 129.7 (CH), 128.1 (CH), 127.8 (CH), 127.6 (CH), 127.4 (2x CH), 127.0 (CH), 125.3 (2x alkene C), 62.8 (OCH_3); MS: *m/z* calculated for $C_{17}H_{16}N_2O_3Na$, 319.1059 [M+Na]$^+$, found 319.1058. The presence of extra peaks in the ^{1}H NMR (s, 1.60) and ^{13}C NMR (173.1, 24.7) suggest that the presence of acetate in the solid material.

[3] C. J. Saint-Louis, L. L. Magill, J. A. Wilson, A. R. Schroeder, S. E. Harrell, N. S. Jackson, J. A. Trindell, S. Kim, A. R. Fisch, L. Munro, V. J. Catalano, C. E. Webster, P. P. Vaughan, K. S. Molek, A. K. Schrock and M. T. Huggins, *J. Org. Chem.*, **2016**, *81*, 10955-10963

General procedure for the synthesis of methyl-2-alkynyl benzoates by Sonogashira coupling

Following a modification of the procedure by Larock et al.,[4] a nitrogen-degassed solution of the terminal alkyne (1.1 eq.), methyl iodobenzoate (1.0 eq.), CuI (0.05 eq.) and $PdCl_2(PPh_3)_2$ (0.01 eq.) in NEt_3 (0.5 M) was stirred for 16 hours at room temperature. The reaction solution was concentrated in vacuo, rediluted in DCM, washed with saturated sodium thiosulfate, brine, dried ($MgSO_4$) and concentrated *in vacuo*. The crude material was purified by flash silica chromatography to afford the desired product.

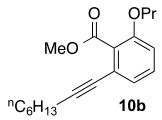
Methyl 2-(oct-1-yn-1-yl)benzoate **10a**



10a

Isolated as a pale yellow oil (3.26 g, 76%) from 1-octyne (3.54 mL, 24.0 mmol) following the general procedure. The product was isolated by flash silica chromatography using 0-5% EtOAc in hexane. R_f 0.4 (10% EtOAc in hexane); δ_H (300 MHz, $CDCl_3$) 7.87 (1H, dd, *J* 7.8, 1.0, H6), 7.51 (1H, dd, *J* 7.7, 1.0, H3), 7.41 (1H, td, *J* 7.6, 1.4, H4), 7.30 (1H, td, *J* 7.7, 1.4, H5), 3.91 (3H, s, OMe), 2.47 (2H, t, *J* 7.0, H3'), 1.68-1.57 (2H, m, H4'), 1.48-1.46 (2H, m, H5'), 1.38-1.28 (4H, m, H6' and H7'), 0.90 (3H, t, *J* 6.8, H8'); δ_C (75 MHz, $CDCl_3$) 167.2 (CO_2Me), 134.4 (C3), 132.1 (Cq), 131.6 (C4), 130.3 (C6), 127.2 (C5), 124.7 (Cq), 96.2 (C2'), 79.3 (C1'), 52.2 (OMe), 31.6 (C3'), 28.8 (C4'), 28.8 (C5'), 22.7 (C6'), 20.0 (C7'), 14.2 (C8'); HRMS (ESI+): m/z calculated for formula: $C_{16}H_{21}O_2$ [MH^+] 245.1536; found 245.1534; IR (ν_{max}, solid, cm^{-1}): 2952, 2857, 2227, 1732, 1484, 1447, 1291, 1247, 1128, 1081. Spectral data consistent with the literature.[4]

Methyl 2-(oct-1-yn-1-yl)-6-propoxybenzoate **10b**



10b

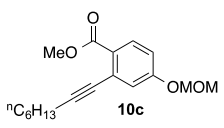
Step 1: Preparation of methyl 2-iodo-6-propoxybenzoate. Following a modification of the procedure by Taylor *et al*.,[5] s-BuLi (7.5 mL, 11 mmol, 1.4 M in cyclohexane) was added to a solution of TMEDA (1.57 mL, 10.5 mmol) in THF (20 mL). The resultant yellow solution was cooled to −100 °C (ethanol–N_2 bath) and a solution of 2-propoxybenzoic acid (800 mg, 4.44 mmol) in THF (9 mL) was added via a syringe pump over 30 minutes. After a further 30 minutes at −100 °C, the orange/brown solution was warmed to −78 °C. Iodine (4.41 g, 17.4 mmol) in THF (5 mL)

[4] T. Yao and R. C. Larock, *J. Org. Chem*., **2003**, *68*, 5936–5942
[5] A. Lewis, I. Stefanuti, S. A. Swain, S. A. Smith and R. J. K. Taylor*, Org. Biomol. Chem*., **2003**, *1*, 104–116

was added dropwise to the stirred solution at −78 °C, and the reaction mixture was subsequently stirred for another hour after the addition was complete. The reaction was quenched with saturated ammonium chloride solution (5 mL) and the solution was warmed to room temperature. The unreacted iodine was quenched with saturated sodium thiosulfate solution (40 mL). The phases were separated and the aqueous phase was extracted with Et_2O (30 mL) and the organic phase was re-extracted with 2N NaOH (10 mL). The aqueous phases were combined and acidified to pH 2 with 4N HCl. The aqueous phase was extracted with DCM (4 × 50 mL) and dried over $MgSO_4$. The reaction was filtered and concentrated *in vacuo* to afford an oily yellow solid. The crude residue was rediluted in DCM (10 mL) with catalytic DMF (10 mL) and oxalyl chloride (300 μL, 3.54 mmol). The reaction mixture was concentrated *in vacuo* and methanol was added to the residue. The solvent was removed *in vacuo* and the crude material was purified by flash silica chromatography, using 10-30% EtOAc in hexane to afford a clear oil (454 mg, 32%). R_f 0.71 (50% EtOAc in hexane); δ_H (300 MHz, $CDCl_3$) 7.37 (1H, d, *J* 7.9, H3), 7.02 (1H, t, *J* 8.1, H4), 6.88 (1H, d, *J* 8.4, H5), 3.98-3.87 (5H, m, OMe and OCH_2), 1.80-1.71 (2H, m, OCH_2CH_2), 0.99 (3H, t, *J* 7.4, $O(CH_2)_2CH_3$); δ_C (75 MHz, $CDCl_3$) 168.1 (CO_2Me), 156.5 (C6), 131.6 (C3), 130.8 (C4), 120.2 (C1), 112.0 (C5), 92.4 (C2), 70.7 (OCH_2), 52.8 (OMe), 22.5 (OCH_2CH_2), 10.5 ($O(CH_2)_2CH_3$); HRMS (ESI+): m/z calculated for formula $C_{11}H_{14}IO_3$ [MH^+]: 320.9982; found 320.9985; IR (ν_{max}, solid, cm^{-1}): 2966, 2877, 1753, 1583, 1567, 1443, 1391, 1265, 1190, 1151, 1106, 1062, 1014.

Step 2: Sonogashira coupling. The desired compound was isolated as a brown oil (382 mg, 90%) from methyl 2-iodo-6-propoxybenzoate (454 mg, 1.41 mmol) and 1-octyne (230 μL, 1.56 mmol) following the general procedure. The product was isolated by flash silica chromatography using 0-10% EtOAc in hexane. R_f 0.49 (10% EtOAc in hexane); δ_H (500 MHz, $CDCl_3$) 7.23 (1H, t, *J* 8.1, H4), 6.99 (1H, d, *J* 7.7, H3), 6.83 (1H, d, *J* 8.4, H5), 3.94 (2H, t, *J* 6.4, OCH_2), 3.90 (3H, s, *J* 3.2, OMe), 2.38 (2H, t, *J* 7.1, H3'), 1.81-1.72 (2H, m, OCH_2CH_2), 1.61-1.53 (2H, m, H4'), 1.43 (2H, q, *J* 7.8, H5'), 1.36-1.26 (4H, m, H6' and H7'), 1.00 (3H, t, *J* 7.4, $O(CH_2)_2CH_3$), 0.90 (3H, t, *J* 7.0, 3H8'); δ_C (125 MHz, $CDCl_3$); 167.9 (CO_2Me), 155.8 (C6), 130.3 (C4), 126.8 (C1), 124.4 (C3), 123.0 (C2), 111.9 (C5), 94.4 (C2'), 77.7 (C1'), 70.5 (OCH_2), 52.4 (OMe), 31.5 (C6'), 28.8 (C5'), 28.7 (C4'), 22.7 (C7'), 22.6 (OCH_2CH_2), 19.6 (C3'), 14.2 ($O(CH_2)_2CH_3$), 10.5 (C8'); HRMS (ESI+): m/z calculated for formula: $C_{19}H_{27}O_3$ [MH^+] 303.1955; found 303.1959; IR (ν_{max}, solid, cm^{-1}): 2933, 2875, 2859, 2246, 1737, 1594, 1574, 1456, 1430, 1390, 1302, 1278, 1261, 1117, 1090, 1067.

Methyl 4-(methoxymethoxy)-2-(oct-1-yn-1-yl)benzoate **10c**



10c

Step 1: Preparation of 2-iodo-4-methoxybenzoic acid[6] A solution of *s*-BuLi (20 mL, 28 mmol, 1.4 M in hexane) was added to a cooled solution (−78 °C) of TMEDA (4.14 mL, 27.7 mmol) in THF (60 mL). The yellow solution was stirred for 30 minutes at −78 °C. *p*-Anisic acid (2.0 g, 13 mmol), dissolved in THF (15 mL) was added dropwise to the s-BuLi/TMEDA solution whilst keeping the temperature of the reaction mixture at −70 °C. The solution was stirred at −78 °C for 2 hours, then the mixture was treated with an excess of iodine (10.0 g, 20.0 mmol) dissolved in THF (10 mL) after which the reaction was stirred for a further 30 minutes. The resulting solution was then allowed to warm to ambient temperature and saturated NH_4Cl (50 mL) was added to the reaction. The aqueous phase was treated with saturated sodium thiosulfate (50 mL) and washed with diethyl ether (2 × 30 mL). The aqueous layer was acidified to pH 1 using 2 M HCl. The aqueous phase was then extracted with diethyl ether (4 × 100 mL) and the organic phases were combined and dried over $MgSO_4$. The solution was concentrated *in vacuo* and the crude product was crystallised from $CHCl_3$–Et_2O to afford a colourless crystalline solid (1.54 g, 78%). δ_H (300 MHz, $CDCl_3$) 8.05 (1H, d, *J* 8.8, H6), 7.58 (1H, d, *J* 2.5, H3), 6.95 (1H, dd, *J* 8.8, 2.5, H5), 3.86 (3H, s, OMe); δ_C (75 MHz, $CDCl_3$) 170.2 (CO_2H), 162.8 (C4), 133.9 (C6), 132.6 (C1), 127.8 (C3), 113.8 (C5), 96.5 (C2), 55.9 (OMe); LRMS (ESI-): m/z 276.9 [M-H^-]; found 276.7. Spectral data consistent with the literature.[11]

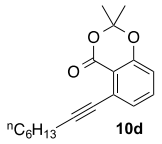
Step 2: Preparation of methyl 2-iodo-4-(methoxymethoxy)benzoate Boron tribromide (1 M solution in DCM, 4.3 mL, 4.3 mmol) was added dropwise to a solution of 2-iodo-4-methoxybenzoic acid (400 mg, 1.44 mmol) in DCM (15 mL, 0.10 M) at 0 °C. After 16 hours, the reaction was cooled to 0 °C and quenched by the dropwise addition of MeOH (20 mL). The solvents were removed *in vacuo*. To achieve full conversion to the methyl ester from the benzoic acid, conc. HCl (5 mL) was added to the crude material in a solution of MeOH (15 mL) and the reaction was heated to reflux for a further 24 hours. The reaction was concentrated *in vacuo* and the reaction was rediluted with DCM (30 mL). The organic layers were combined and washed with water (25 mL) and brine (25 mL), dried with $MgSO_4$ and concentrated *in vacuo*. The solid was washed with cold DCM–pentane (1:4, 30 mL) to give methyl 2-iodo-4-hydroxybenzoate as a colourless amorphous solid (300 mg, 76%). δ_H (500 MHz, $CDCl_3$) 7.84 (1H, d, *J* 8.6, H6), 7.51 (1H, d, *J* 2.6, H3), 6.86 (1H, dd, *J* 8.6, 2.6, H5), 5.35 (1H, s, OH), 3.89 (3H, s, OMe). Methyl 2-iodo-4-hydroxybenzoate (300 mg, 1.08 mmol) was dissolved in THF (10 mL, 0.10 M) with triethylamine (2.8 mL, 20 mmol). The solution was cooled to 0 °C and chloromethyl methyl ether (800 μL, 10.5 mmol) was added dropwise to the solution, which was allowed to stir for one hour. Water (5 mL) was added to quench the reaction and the THF was removed *in vacuo*. The residue was redissolved in EtOAc (30 mL), washed with 1N HCl (20 mL), water (20 mL), brine (20 mL), dried over $MgSO_4$ and concentrated in vacuo to afford a crude oil which was purified by flash silica chromatography using 0-50% EtOAc in hexane to give a colourless oil (273 mg, 79%). δ_H (500 MHz, $CDCl_3$) 7.83 (1H, d, *J* 8.7, H6), 7.68 (1H, d, *J* 2.5, H3), 7.04 (1H, dd, *J* 8.7, 2.5, H5), 5.19 (2H, s, OCH_2O), 3.90 (3H, s, OMe), 3.47 (3H, s, OCH_2OCH_3); δ_C (125 MHz, $CDCl_3$) 166.2 (CO_2Me), 159.8

[6] T.-H. Nguyen, N. T. T. Chau, A.-S. Castanet, K. P. P. Nguyen and J. Mortier, *J. Org. Chem*., **2007**, *72*, 3419–3429

(C4), 132.6 (C6), 131.7 (C1), 129.3 (C3), 115.5 (C5), 95.4 (C2), 94.4 (OCH_2O), 56.5 (OCH_2OCH_3), 52.4 (OMe); HRMS (ESI+): m/z calculated for formula $C_{10}H_{12}IO_4$ [MH^+]: 322.9775; found 322.9775; IR (ν_{max}, film, cm^{-1}): 2951, 2904, 2828, 1725, 1590, 1559, 1486, 1433, 1292, 1258, 1229, 1195, 1152, 1115, 1083.

Step 3: Sonogashira coupling The desired compound was isolated as a colourless oil (206 mg, 67%) from methyl 2-iodo-4-(methoxymethoxy)benzoate (278 mg, 1.00 mmol) and 1-octyne (221 μL, 1.50 mmol) following the general procedure. The product was isolated by flash silica chromatography using 10-40% EtOAc in hexane. RF 0.68 (50% EtOAc in hexane); δ_H (300 MHz, $CDCl_3$) 7.87 (1H, d, *J* 8.8, H6), 7.14 (1H, d, *J* 2.6, H3), 6.95 (1H, dd, *J* 8.8, 2.6, H5), 5.20 (2H, s, OCH_2O), 3.88 (3H, s, OMe), 3.47 (3H, s, OCH_2OCH_3), 2.47 (2H, t, *J* 7.1, H3'), 1.69-1.57 (2H, m, H4'), 1.52-1.41 (2H, m, H5'), 1.36-1.29 (4H, m, H6' and H7'), 0.90 (3H, t, *J* 6.9, H8'); δ_C (75 MHz, $CDCl_3$) 166.6 (CO_2Me), 159.7 (C4), 132.5 (C6), 126.7 (C2), 125.3 (C1), 121.3 (C3), 115.3 (C5), 96.4 (C2'), 94.3 (OCH_2O), 79.4 (C1'), 56.4 ($OCH_2O\underline{C}H_3$), 52.0 (OMe), 31.6 (C6'), 28.8 (C5' and C4'), 22.7 (C7'), 20.0 (C3'), 14.2 (C8'); HRMS (ESI+): m/z calculated for formula $C_{18}H_{25}O_4$ [MH^+]: 305.1747; found 305.1750; IR (ν_{max}, film, cm^{-1}): 2952, 2930, 2858, 2230, 1730, 1712, 1598, 1563, 1491, 1434, 1318, 1287, 1256, 1217, 1180, 1154, 1140, 1093, 1080, 1016.

2,2-Dimethyl-5-(oct-1-yn-1-yl)-4H-benzo[d][1,3]dioxin-4-one **10d**



10d

Step 1: Preparation of 5-hydroxy-2,2-dimethyl-4H-benzo[d][1,3]dioxin-4-one[7] Thionyl chloride (1.0 mL, 14 mmol) in DME (0.5 mL) was added dropwise to a solution of 2,6-dihydroxybenzoic acid (1.5 g, 10 mmol) in DME (3 mL) with DMAP (61 mg, 0.50 mmol) and acetone (1 mL). After four hours the solvents were removed *in vacuo* and the residue was filtered through a silica plug (1:1 DCM-cyclohexane, 50 mL). The solvent was removed *in vacuo* and the residue was diluted in hexane and cooled to 0 °C. The product began to crystallise out and the resulting solid was collected by vacuum filtration to afford a colourless crystalline solid (1.10 g, 56%). M.p. 65-66 °C ([lit.[7] 59-61 °C] hexane); δ_H (300 MHz, $CDCl_3$) 10.32 (1H, s, OH), 7.40 (1H, t, *J* 8.3, H7), 6.62 (1H, d, *J* 8.4, H8), 6.43 (1H, d, *J* 8.1, H6), 1.74 (6H, s, $(Me)_2$); δ_C (75 MHz, $CDCl_3$) 165.6 (C4O), 161.6 (CqO1), 155.7 (C5), 138.0 (C7), 110.9 (C8), 107.4 (C6), 107.3 (C2), 99.5 (Cq-C4), 25.8 ($(Me)_2$); LRMS (ESI+): m/z 195.0 [MH^+]; IR (ν_{max}, film, cm^{-1}): 3203, 3000, 1687, 1629, 1584, 1486, 1470, 1390, 1379, 1346, 1272, 1199, 1151, 1074, 1054. Spectral data match the literature.[7]

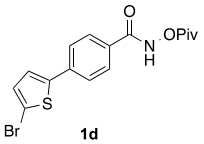
Step 2: Preparation of trifluoromethanesulfonic acid 2,2-dimethyl-4-oxo-4H-1,3-benzodioxin-5-yl ester[7] Triflic anhydride (780 μL, 4.64 mmol) was added dropwise to a cooled solution (0 °C) of 5-hydroxy-2,2-dimethyl-4H-benzo[d][1,3]dioxin-4-one (750 mg, 3.87 mmol) in DCM (0.5 M) with pyridine (1.13 mL, 13.9 mmol). After one hour, the reaction was diluted with 0.1 M HCl (30 mL) and the aqueous phase was extracted three times with diethyl ether (3 × 30 mL). The organic phases were combined and dried over MgSO4. The solvent was removed *in vacuo* and purified by flash silica chromatography using 25% EtOAc in hexane to afford colourless needles (1.01 g, 87%) which were subsequently recrystallised from hexane. M.p. 112-114 °C ([lit.[7] 115-117 °C], hexane); δH (300 MHz, $CDCl_3$) 7.60 (1H, t, *J* 8.4, H7), 7.05 (1H, d, *J* 8.5, H6), 7.00 (1H, d, *J* 8.3, H8), 1.76 (6H, s, $(Me)_2$); δ_C (75 MHz, $CDCl_3$) 157.6 (C4), 157.2 (C5), 148.8 (Cq-O1), 136.4 (C7), 118.9 (q, *J* 320, CF_3), 118.0 (C6), 116.7 (C8), 108.5 (Cq-C4), 107.0 (C2), 25.6 ($(Me)_2$); LRMS (ESI+): m/z 326.9 [MH^+]; IR (ν_{max}, film, cm^{-1}): 1744, 1621, 1474, 1430, 1323, 1293, 1138, 1074. Spectral data match the literature.[7]

Step 3: Sonogashira coupling Following a modification of the procedure by Sakamoto *et al*.,[7] octyne (130 μL, 0.86 mmol) was added to a degassed solution of 2,2-dimethyl-4-oxo-4H-benzo[d][1,3]dioxin-5-yl trifluoromethane sulfonate (254 mg, 0.780 mmol), $PdCl_2(PPh_3)_2$ (30 mg, 0.040 mmol), copper(I) iodide (23 mg, 0.12 mmol) and diethylamine (120 μL, 1.17 mmol) in MeCN (16 mL, 0.05 M). The yellow solution was heated to 70 °C for three hours. The reaction solvent was removed in vacuo and the crude mixture was partitioned between EtOAc (25 mL) and water (25 mL). The two phases were separated, and then the aqueous phase was extracted

[7] M. Uchiyama, H. Ozawa, K. Takuma, Y. Matsumoto, M. Yonehara, K. Hiroya and T. Sakamoto, *Org. Lett*., **2006**, *8*, 5517–5520.

with EtOAc (25 mL). The organic extracts were combined and washed with water (25 mL), brine (25 mL), dried over $MgSO_4$ and concentrated *in vacuo*. The crude oil was purified using flash silica chromatography using 10-30% EtOAc in hexane to afford a brown oil (138 mg, 62%). δ_H (500 MHz, $CDCl_3$) 7.40 (1H, t, *J* 7.9, H7), 7.19 (1H, dd, *J* 7.7, 0.9, H6), 6.86 (1H, dd, *J* 8.2, 0.9, H8), 2.51 (2H, t, *J* 7.2, H3'), 1.71 (6H, s, $(Me)_2$), 1.66 (2H, app q, *J* 7.5, H4'), 1.53-1.45 (2H, m, H5'), 1.37-1.30 (4H, m, H6' and H7'), 0.90 (3H, t, *J* 7.0 Hz, H8'); δ_C (75 MHz, $CDCl_3$); δ 159.1 (C4), 156.7 (Cq-O1), 134.9 (C7), 129.0 (C6), 126.6 (C5), 116.5 (C8), 114.3 (Cq-C4), 105.6 (C2), 98.8 (C2'), 78.8 (C1'), 31.6 (C4'), 28.8 (C5'), 28.6 (C6'), 25.9 ($(Me)_2$), 22.7 (C7'), 20.2 (C3'), 14.2 (C8'); HRMS (ESI+): m/z calculated for formula $C_{18}H_{23}O_3$ $[MH^+]$ 287.1641: found 287.1642; IR (ν_{max}, solid, cm^{-1}): 2998, 2931, 2587, 2228, 1748, 1593, 1578, 1475, 1437, 1389, 1316, 1293, 1271, 1255, 1232, 1205, 1169, 1085, 1039.

4-(5-Bromo-2-thienyl)-*N*-(pivaloyloxy)benzamide 1d



1d

Following a modification of the general procedure of Fagnou *et al*.,[8] pivaloyl hydroxylammonium chloride (1.3 eq.) was added to a cooled solution of EtOAc–H_2O (2:1, 0.2 M) containing K_2CO_3 (1.3 eq.) and 4-(5-bromo-2-thienyl)benzoic acid chloride[9] (299 mg, 1 mmol) in DCM (5 mL) in a RB flask equipped with stirrer bar. The reaction was allowed to stir for half an hour, then was quenched with $NaHCO_3$ and diluted with solvent. The organic layer was washed sequentially with water and brine, dried over $MgSO_4$ and concentrated. The pure product was obtained by crystallisation. The desired compound was isolated as a yellow crystalline solid (187 mg, 0.49 mmol, 66%). The product was purified by crystallisation from DCM-pentane. R_F 0.27 (DCM); M.p. 115.8-116.2 °C (DCM-pentane); δ_H (300 MHz, $CDCl_3$) 9.30 (1H, br s, H_8), 7.82 (2H, d, *J* 8.3, $2H_3$), 7.58 (2H, d, *J* 8.2, $2H_4$), 7.15 (1H, d, *J* 3.9, H_6), 7.07 (1H, d, *J* 3.9, H_7), 1.30 (9H, s, $(CH_3)_3$); δ_C (75 MHz, $CDCl_3$) 177.1 (OC_q=O), 166.2 (HNC_qO), 144.1 (C_q), 137.7 (C_q), 131.2 (C_6), 129.8 (C_q), 128.3 (C_3), 125.6 (C_q), 124.7 (C_5), 113.3 (BrC_q), 38.5 ($(CH_3)_3C_q$), 27.0 ($(CH_3)_3$); HRMS: *m/z* calculated for formula $C_{16}H_{16}{}^{79}BrNO_3S$ $[MH^+]$ 384.0092; found $[MH^+]$ 384.0090; IR (ν_{max}, solid, cm^{-1}): 3190, 2960, 2930, 1777, 1656, 1605, 1479.

[8] N. Guimond, S. Gorelsky and K. Fagnou, *J. Am. Chem. Soc.*, **2011**, *133*, 6449-6457

[9] S. K. Sontag, G. R. Sheppard, N. M. Usselman, N. Marshall, J. Locklin, *Langmuir*, **2011**, *27*, 12033-12041

Absorbance and fluorescence studies

UV-Vis absorbance measurements were recorded on a Perkin-Elmer UV/VIS/NIR Spectrometer Lambda 900. Fluorescence measurements were performed using Jobin Yvon Horiba FluoroMax-3 in a 1 cm-pathlength cell without an incident ray filter and the Xenon lamp calibrated to 467 nm and water peak to 397 nm. The excitation and emission slit widths were set to 1 nm. Spectrophotometric grade solvents were purchased from Sigma-Aldrich. Solvents were undegassed during the measurements. 9,10-Diphenylanthracene (97%) was purchased from Sigma-Aldrich and subsequently recrystallised from toluene to afford yellow needles. Solutions for absorbance and fluorescence studies were prepared prior to the experiment and used within 8 hours. The solutions were stored at 0 °C in the dark to prevent photodegradation.

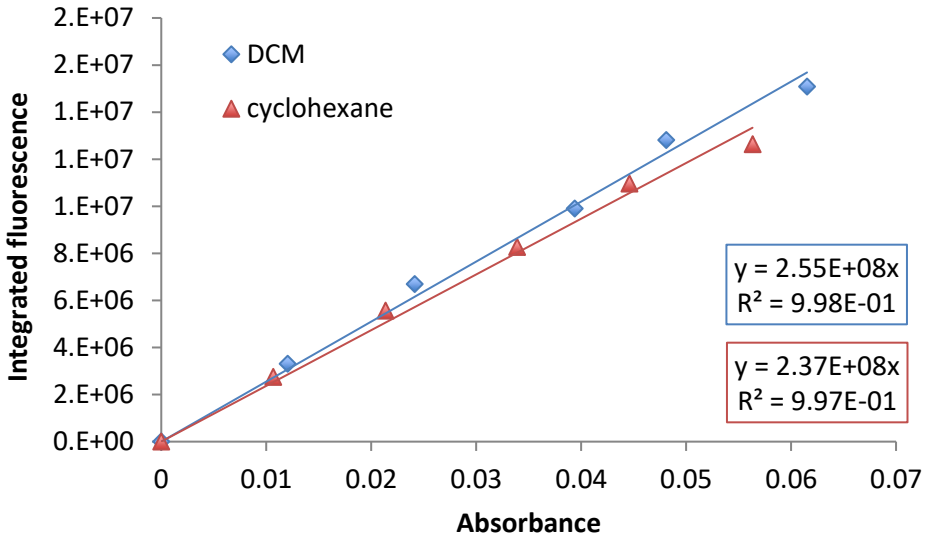
Solvent correction

9,10-Diphenylanthracene was selected as a reference compound, based on the absorbance and fluorescence within the same region as the imide **9a**. The literature value for 9,10-diphenylanthracene is specified in cyclohexane (Φ_F = 0.9231), therefore a correction for measurements performed in DCM was required. Absorbance and fluorescence data for 9,10-diphenylanthracene in DCM and cyclohexane were recorded using solutions prepared from serial dilutions using stock solutions in the corresponding solvent (4.33×10^{-6} M). The emission for 9,10-diphenylanthracene in DCM and cyclohexane (Cy) was integrated from 363-552 nm, with excitation at 375 nm. The relative slope gradients, obtained from a plot of absorbance versus integrated fluorescence, were used to calculated the quantum yield of 9,10-diphenylanthracene in DCM (Φ_F) using the following equation:

$$\phi_{DCM} = \phi_{Cy}\left(\frac{Gradient_{DCM}}{Gradient_{Cy}}\right)\left(\frac{\eta_{DCM}^2}{\eta_{Cy}^2}\right)$$

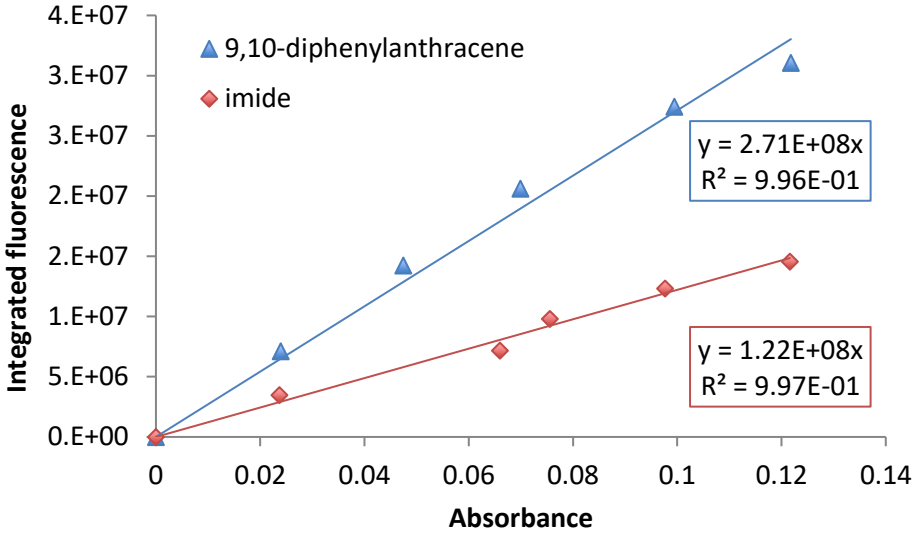
$$\phi_{DCM} = 0.90\left(\frac{2.55 \times 10^8}{2.37 \times 10^8}\right)\left(\frac{1.424^2}{1.426^2}\right)$$

$$\phi_{DCM} = 0.97$$


2.E+07
2.E+07
1.E+07
1.E+07
1.E+07
8.E+06
6.E+06
4.E+06
2.E+06
0.E+00
Integrated fluorescence
DCM
cyclohexane
y = 2.55E+08x
R² = 9.98E-01
y = 2.37E+08x
R² = 9.97E-01
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
Absorbance

Example of quantum yield determination: 12-hexylisoindolo[2,1-b]isoquinoline-5,7-dione 9a

The quantum yield of fluorescence was determined by comparison of the integrated area of the corrected emission spectrum of the imide **5a** to that of 9,10-diphenylanthracene as a standard fluorescence reference. Absorbance and fluorescence data for 9,10-diphenylanthracene and the imide **9a** were recorded using solutions in DCM prepared from serial dilutions from stock solutions (Standard: 5.19 × 10-6 M; imide: 4.33 × 10-6 M). The emission for 9,10-diphenylanthracene and 12-hexylisoindolo-[2,1-b]isoquinoline-5,7-dione **9a** was integrated from 380-545 nm with excitation at 383 nm and 375 nm, respectively.



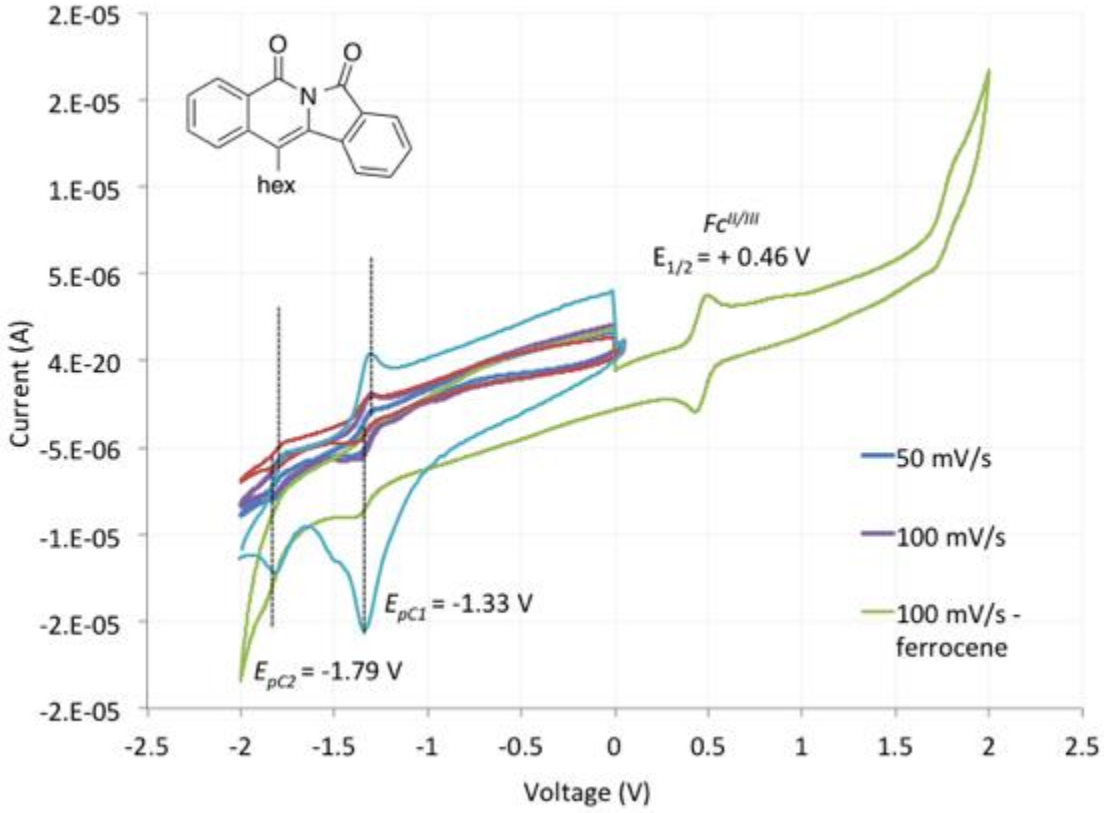
$$\phi_X = 0.97\left(\frac{1.22 \times 10^8}{2.71 \times 10^8}\right)$$

$$\phi_X = 0.44$$

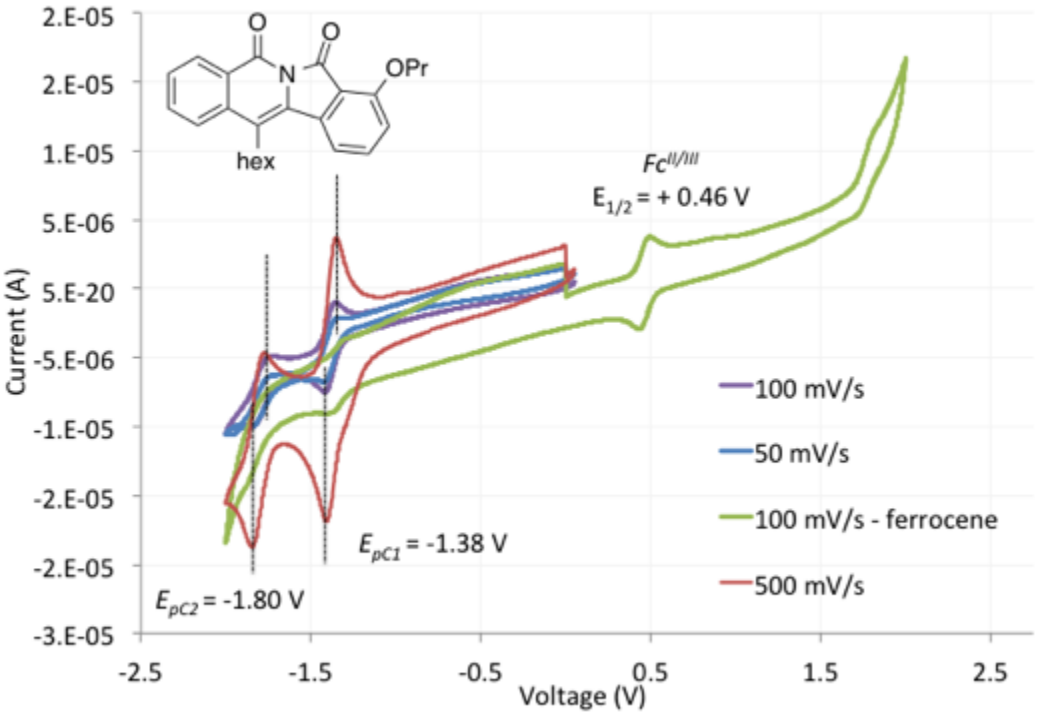
Cyclic voltammetry

Electrochemical measurements were conducted using an Autolab PGSTAT20 voltammetric analyser under an Ar atmosphere, solvated in pre-dried CH_3CN containing 0.10 M $[^nBu_4N]BF_4$ as supporting electrolyte. Voltammetric experiments utilised a Pt disk working electrode, a Pt rod auxiliary electrode and an Ag/AgCl reference electrode. All potentials quoted are referenced to an internal ferrocene/ ferrocenium standard and were obtained at various scan rates (v) of 10-1000 mVs^{-1}. The ferrocene/ ferrocenium couple under these conditions was observed at + 0.45 ≤ E1/2 ≤ 0.47 V vs Ag/AgCl.

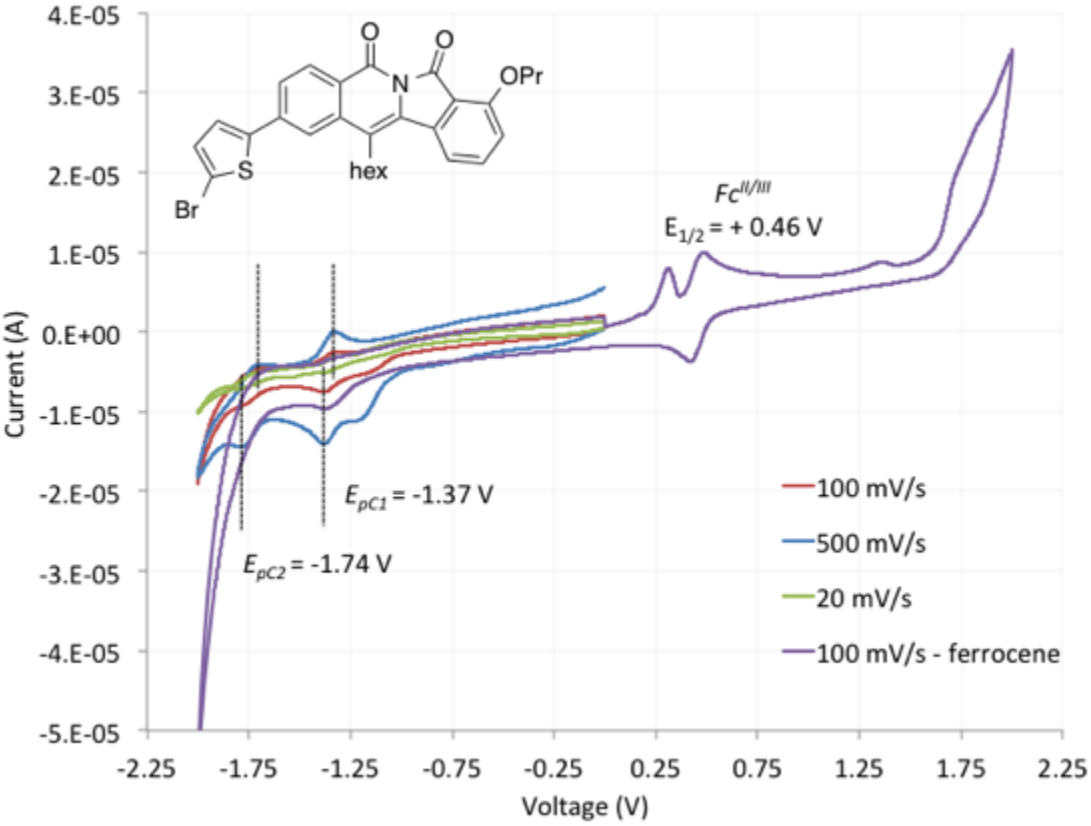
CV of **9a** (1.0 mM) in non-aqueous media (CH_3CN/$[^nBu_4N]BF_4$ 0.10 M), T = 298 K, [Fc] = 1.0 mM.



CV of **9b** (1.0 mM) in non-aqueous media ($CH_3CN/[^nBu_4N]BF_4$ 0.10 M), T = 298 K, [Fc] = 1.0 mM.

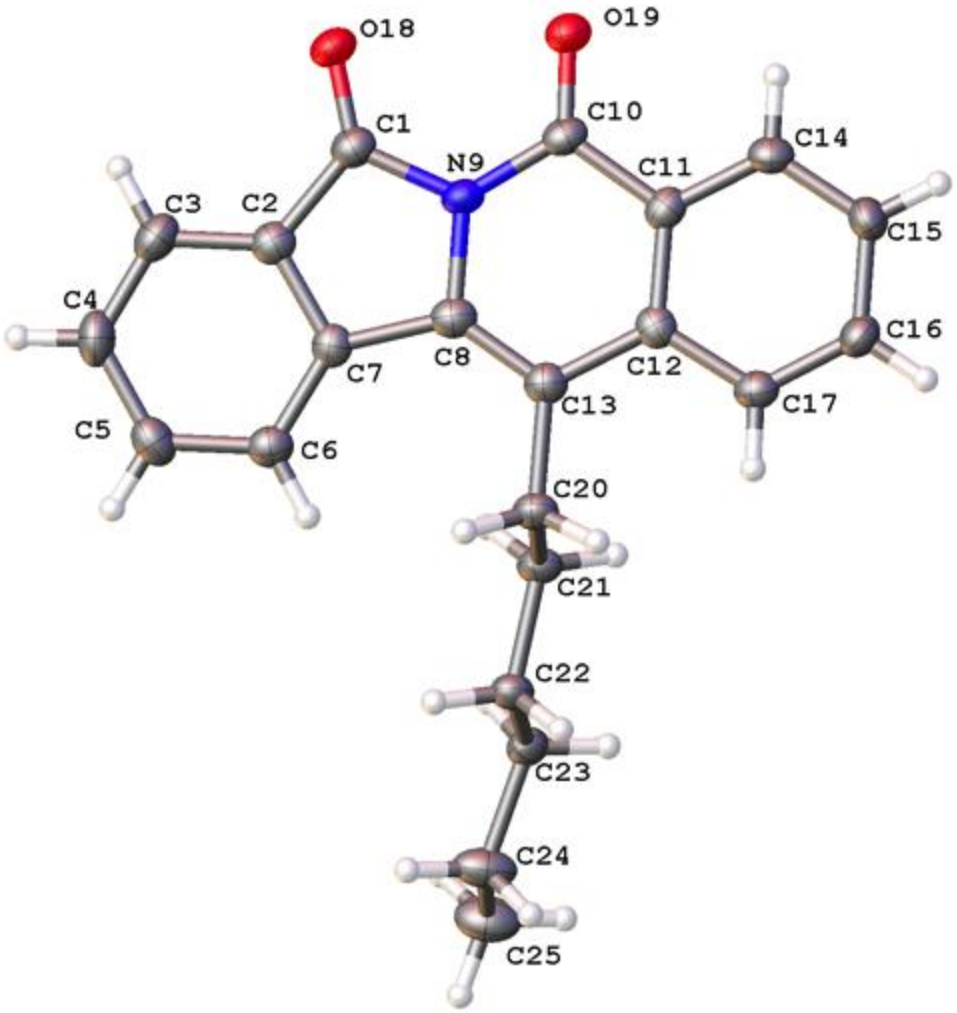


CV of **9g** (1.0 mM) in non-aqueous media ($CH_3CN/[^nBu_4N]BF_4$ 0.10 M), T = 298 K, [Fc] = 1.0 mM.



X-Ray Crystallographic Data

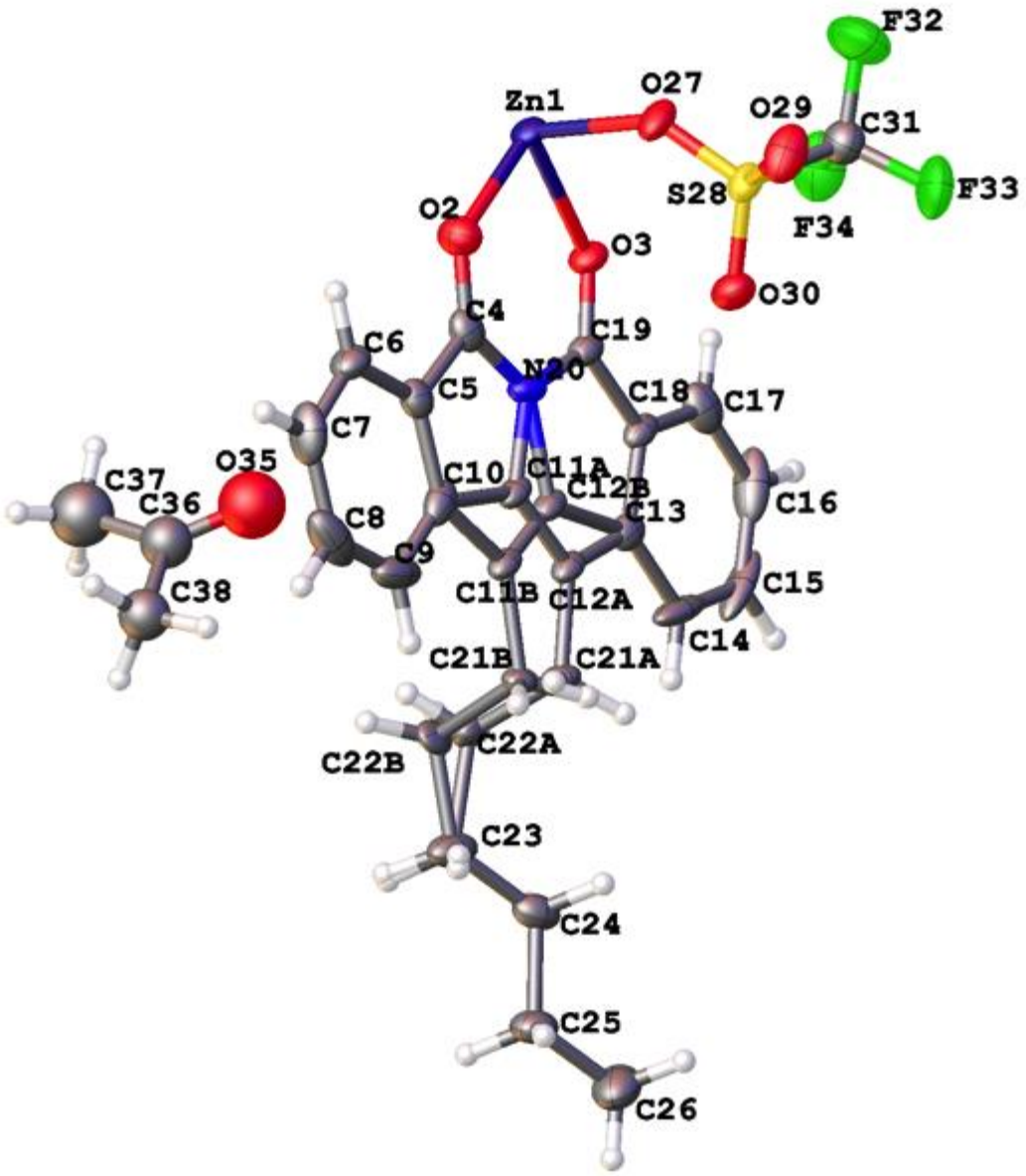
Compound 9a



Identification:	CCDC 2165102	
Formula:	$C_{22}H_{21}NO_2$	
Formula weight:	331.4	
Size:	0.16 x 0.07 x 0.03 mm	
Crystal morphology:	Colourless plate	
Temperature:	99.9(5) K	
Wavelength:	1.54184 Å [Cu-K_α]	
Crystal system:	Monoclinic	
Space group:	*P*2(1)/*c*	
Unit cell dimensions:	*a* = 4.90124(14) Å	α = 90°
	b = 21.2010(5) Å	β = 93.043(2)°
	c = 16.3443(4) Å	γ = 90°
Volume:	1695.96(8) Å^3	
Z:	4	

Density (calculated):	1.298 Mg/m^3
Absorption coefficient:	0.654 mm^{-1}
F(000):	704
Data collection range:	3.42 ≤ θ ≤ 66.6°
Index ranges:	-5 ≤ *h* ≤ 5, -25 ≤ *k* ≤ 25, -19 ≤ *l* ≤ 19
Reflections collected:	11979
Independent reflections:	2989 [*R*(int) = 0.0348]
Observed reflections:	2590 [*I* >2σ(*I*)]
Absorption correction:	analytical
Max. and min. transmission:	0.981 and 0.947
Refinement method:	Full
Data/restraints/parameters:	2989 / 0 / 227
Goodness of fit:	1.045
Final R indices [*I* >2σ(*I*)]:	R_1 = 0.0417, wR_2 = 0.0994
R indices (all data):	R_1 = 0.0497, wR_2 = 0.1044
Largest diff. peak and hole:	0.439 and -0.197e.Å^{-3}

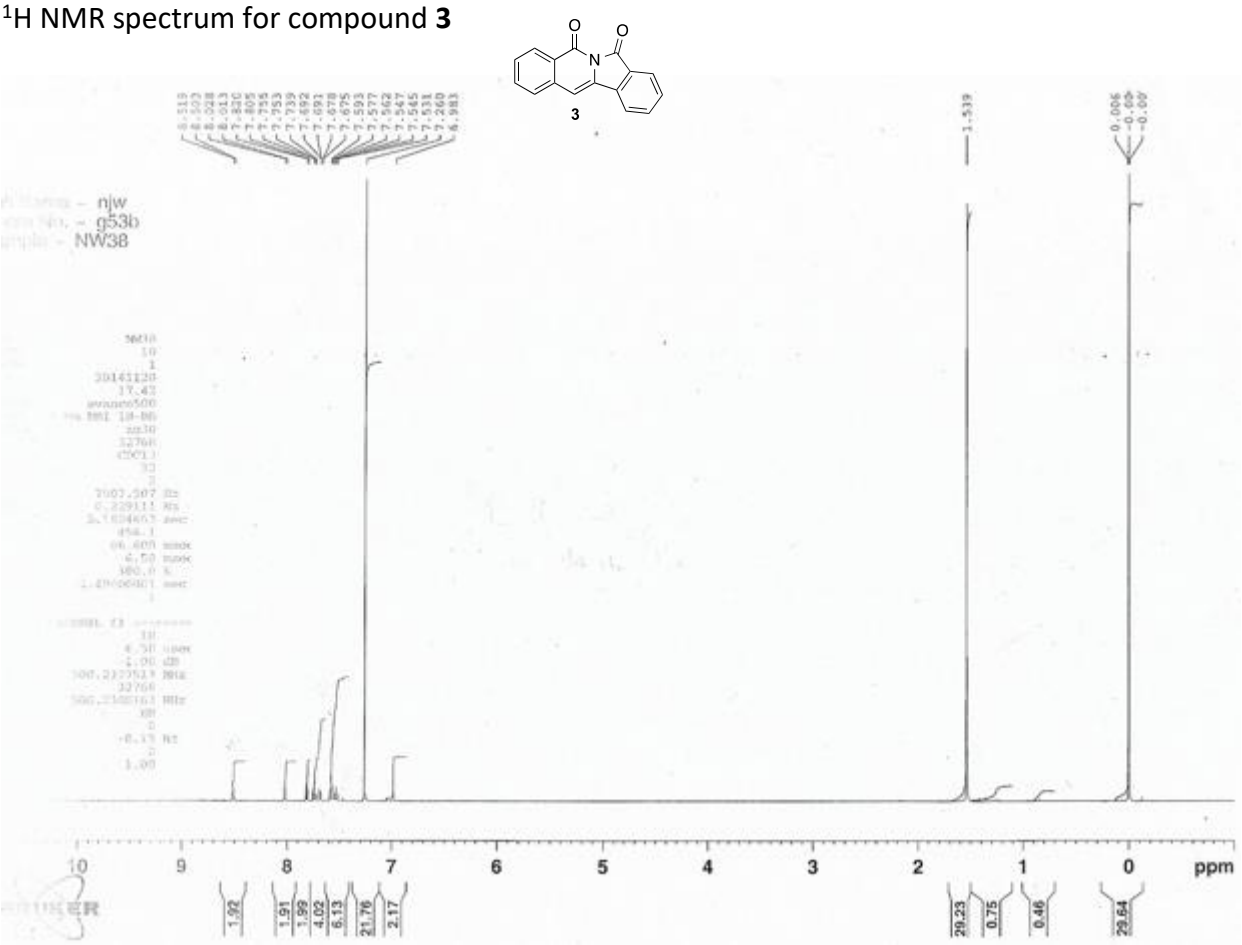
Compound 13



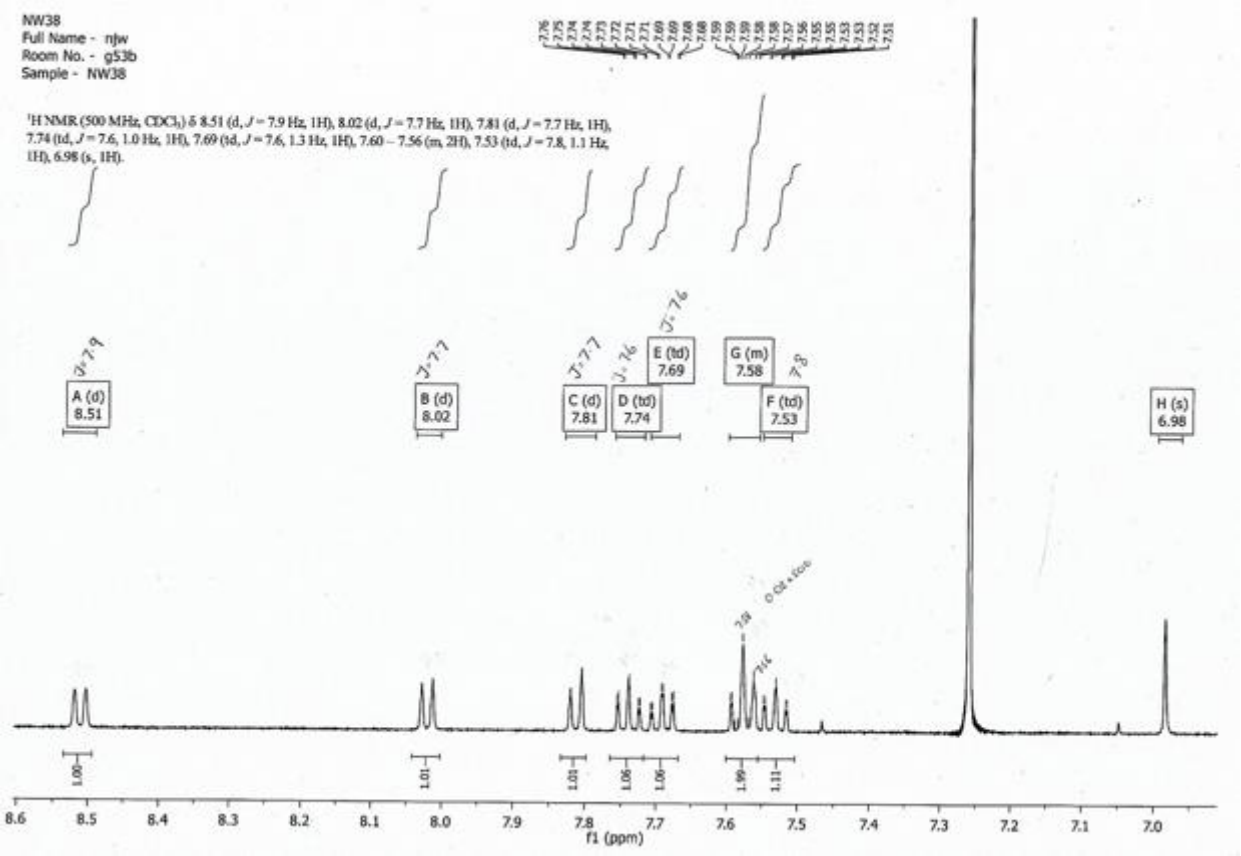
Identification code:	CCDC2165103	
Formula:	$C_{49}H_{48}F_6N_2O_{11}S_2Zn$	
Formula weight:	1084.38	
Size:	0.16 x 0.1 x 0.07 mm	
Crystal morphology:	Yellow Fragments	
Temperature:	120.01(13) K	
Wavelength:	0.71073 Å [Mo-K_α]	
Crystal system:	Triclinic	
Space group:	P_1	
Unit cell dimensions:	a = 6.6901(4) Å	α = 78.707(4)°
	b = 12.7594(7) Å	β= 84.883(4)°
	c = 14.8752(6) Å	γ = 75.297(5)°

Volume:	1203.36(10) Å^3
Z:	1
Density (calculated):	1.496 Mg/m3
Absorption coefficient:	0.683 mm^{-1}
F(000):	560
Data collection range:	3.15 ≤ θ ≤ 26.37°
Index ranges:	-8 ≤ *h* ≤ 8, -15 ≤ *k* ≤ 15, -18 ≤ *l* ≤ 17
Reflections collected:	13053
Independent reflections:	4910 [*R*(int) = 0.0451]
Observed reflections:	3789 [*I* >2σ(*I*)]
Absorption correction:	analytical
Max. and min. transmission:	0.965 and 0.94
Refinement method:	Full
Data / restraints / parameters:	4910 / 1 / 341
Goodness of fit:	1.052
Final *R* indices [*I* >2σ(*I*)]:	R_1 = 0.0479, wR_2 = 0.0976
R indices (all data):	R_1 = 0.0713, wR_2 = 0.1077
Largest diff. peak and hole:	0.724 and -0.462 e.Å^{-3}

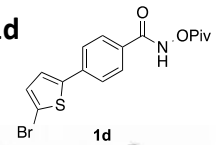
^{1}H NMR spectrum for compound **3**



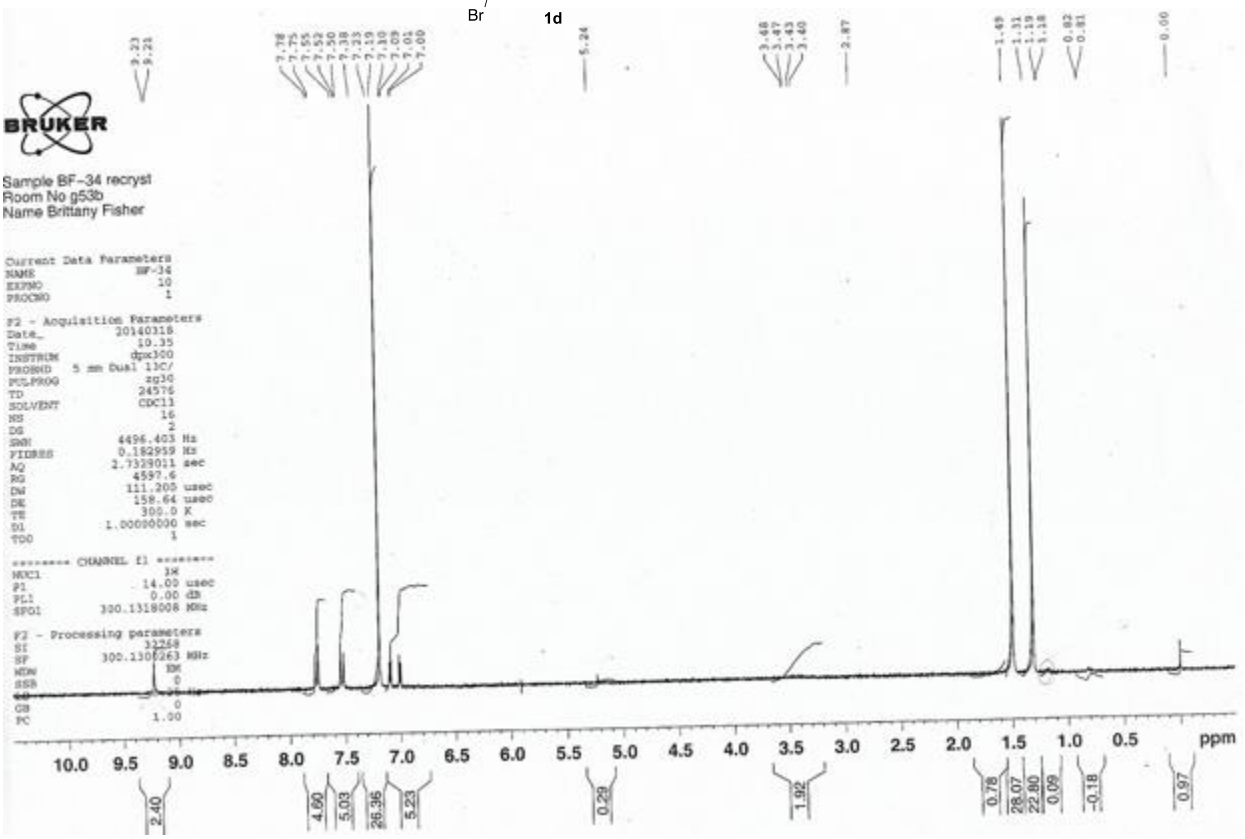
Zoom of aromatic region:



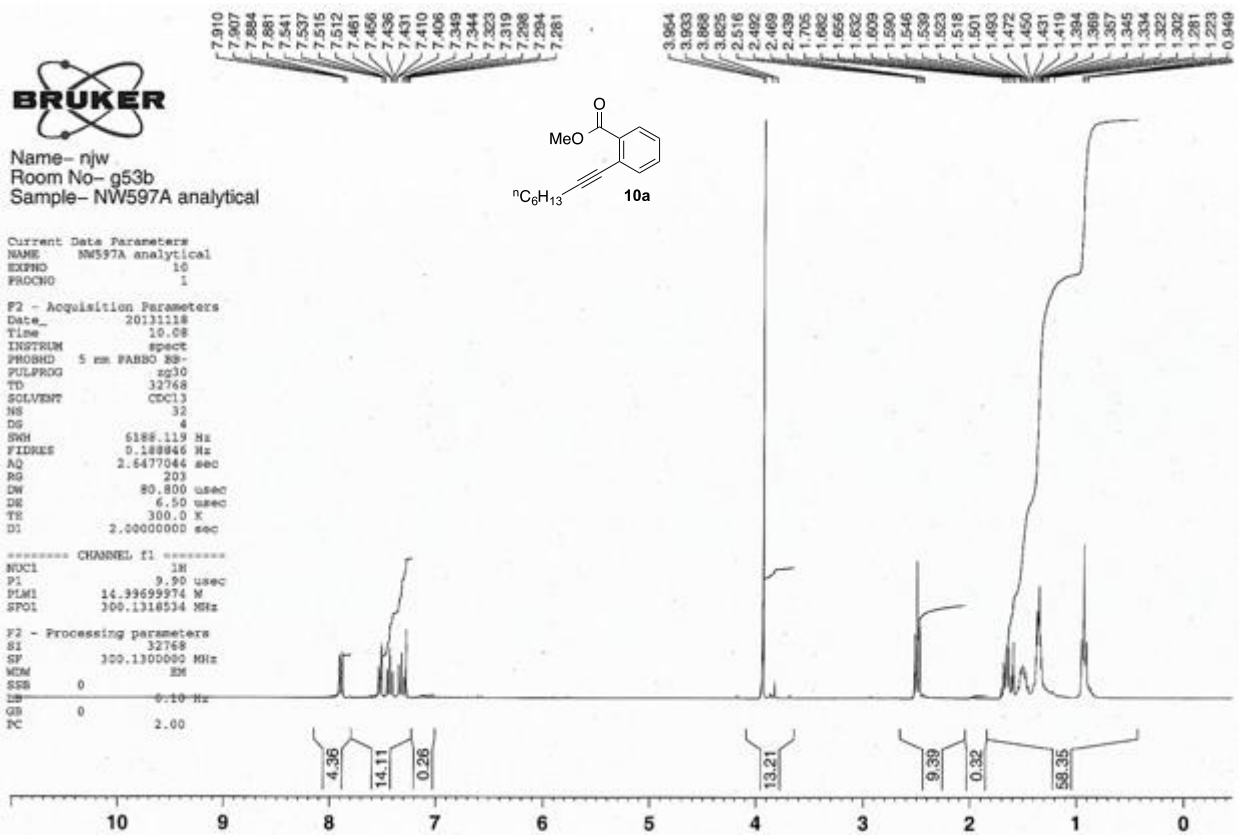
^{1}H NMR spectrum for compound **1d**

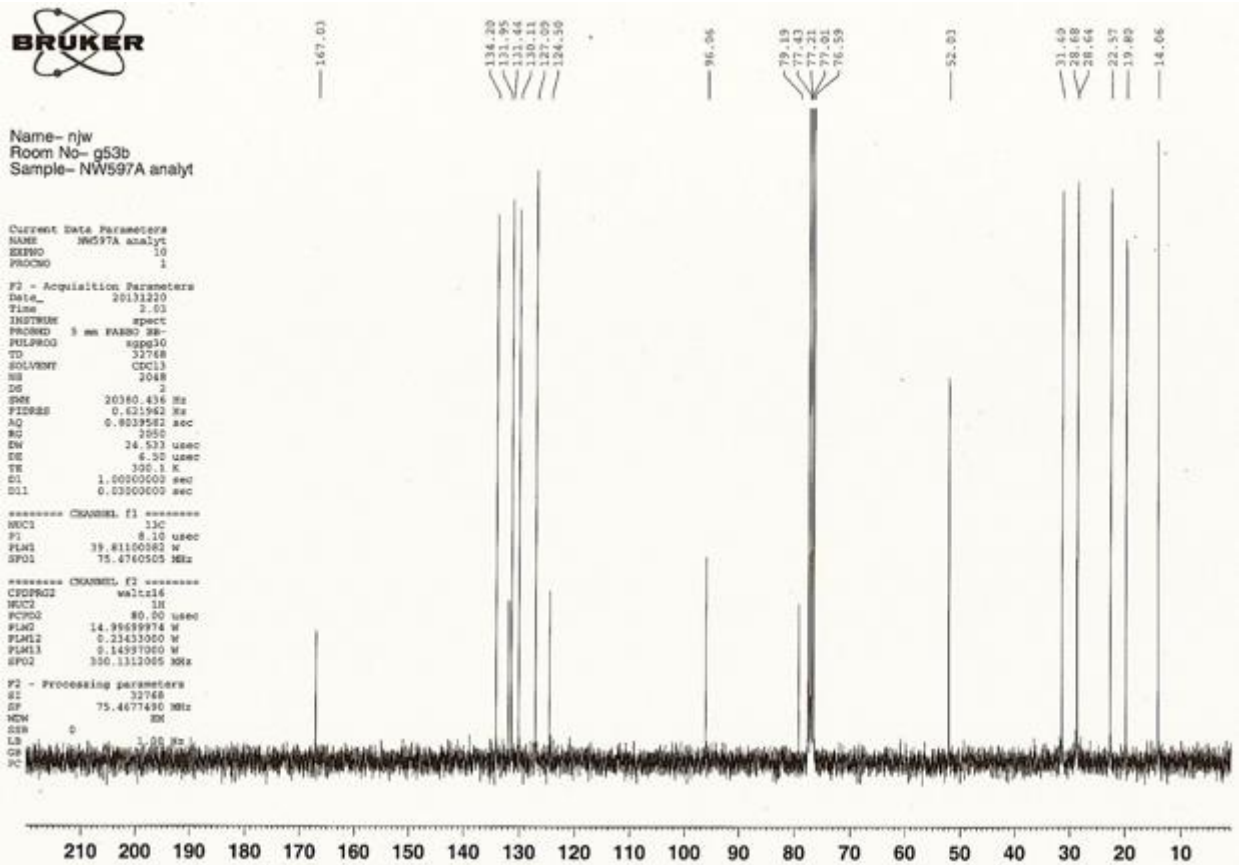


1d

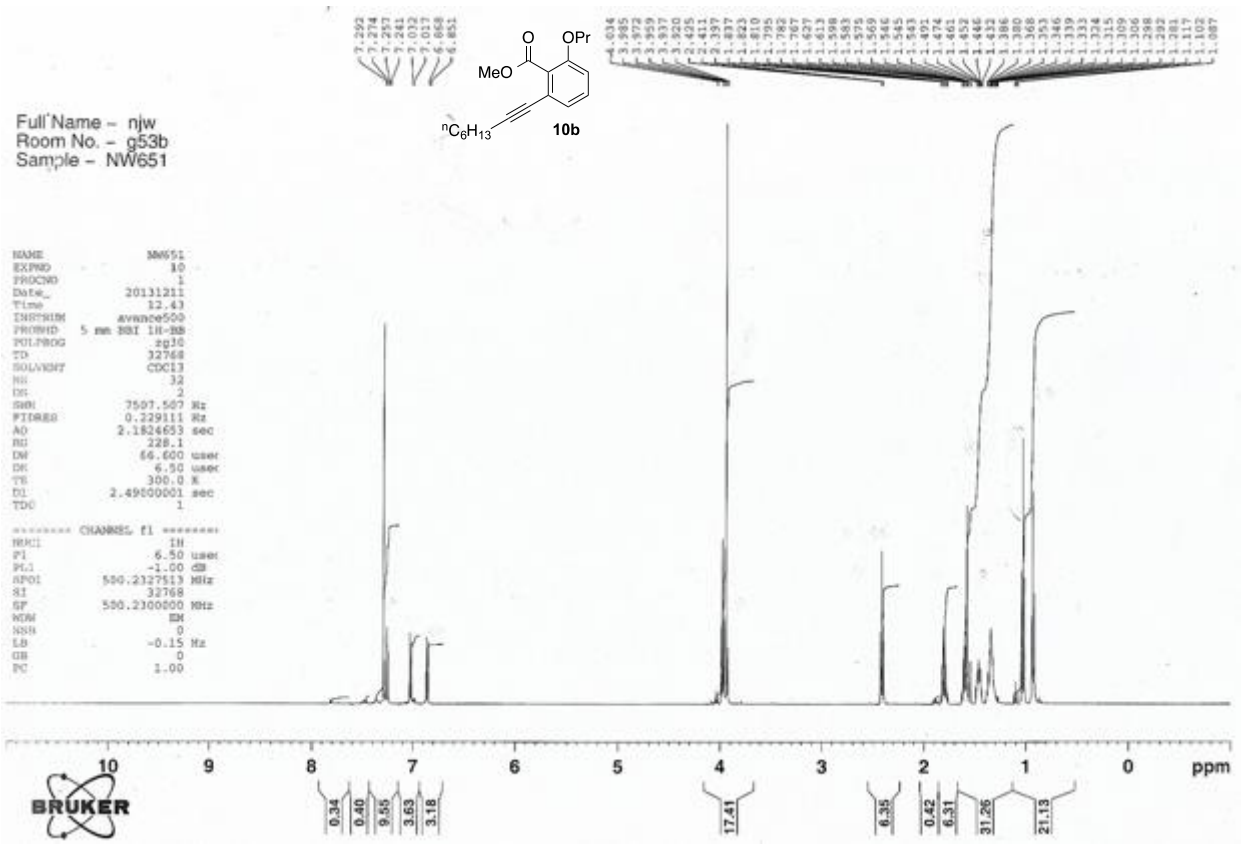


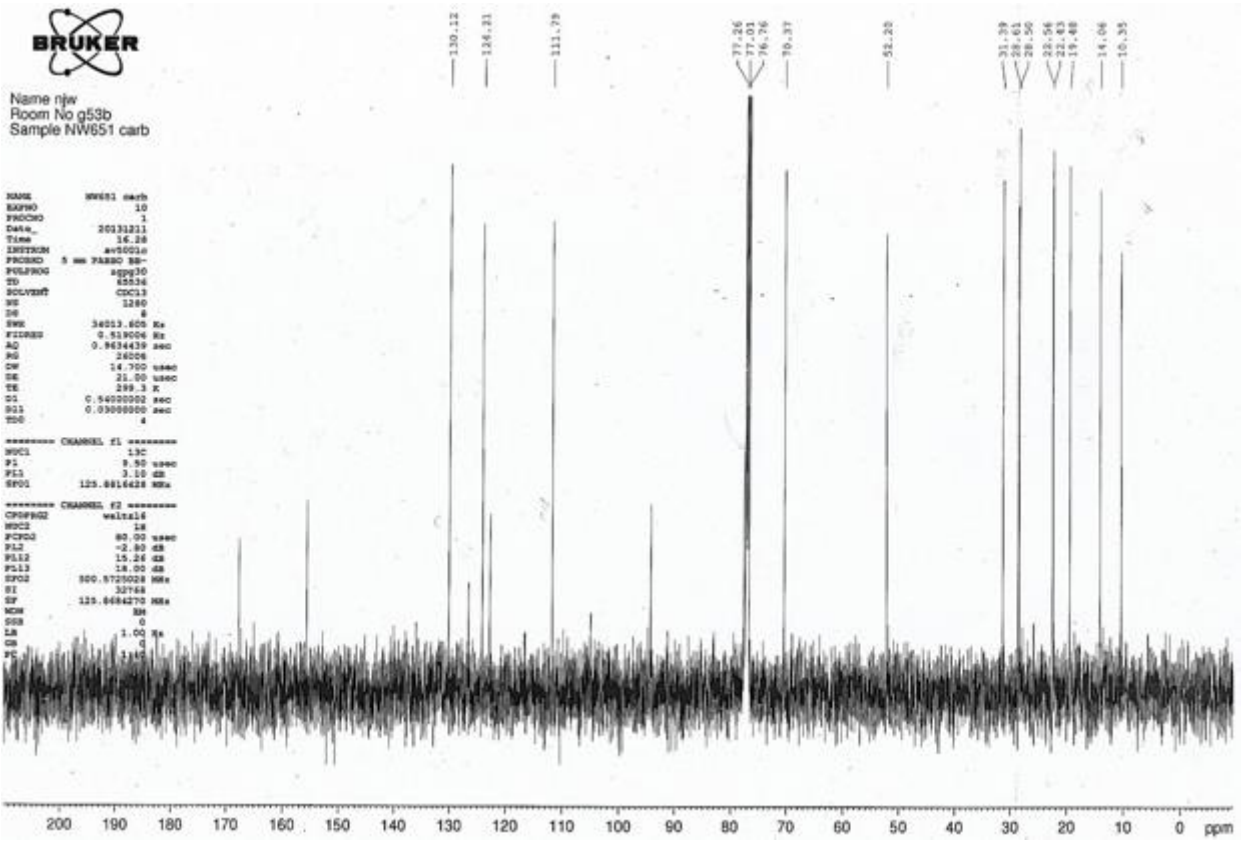
^{1}H and ^{13}C NMR spectra for compound **10a**



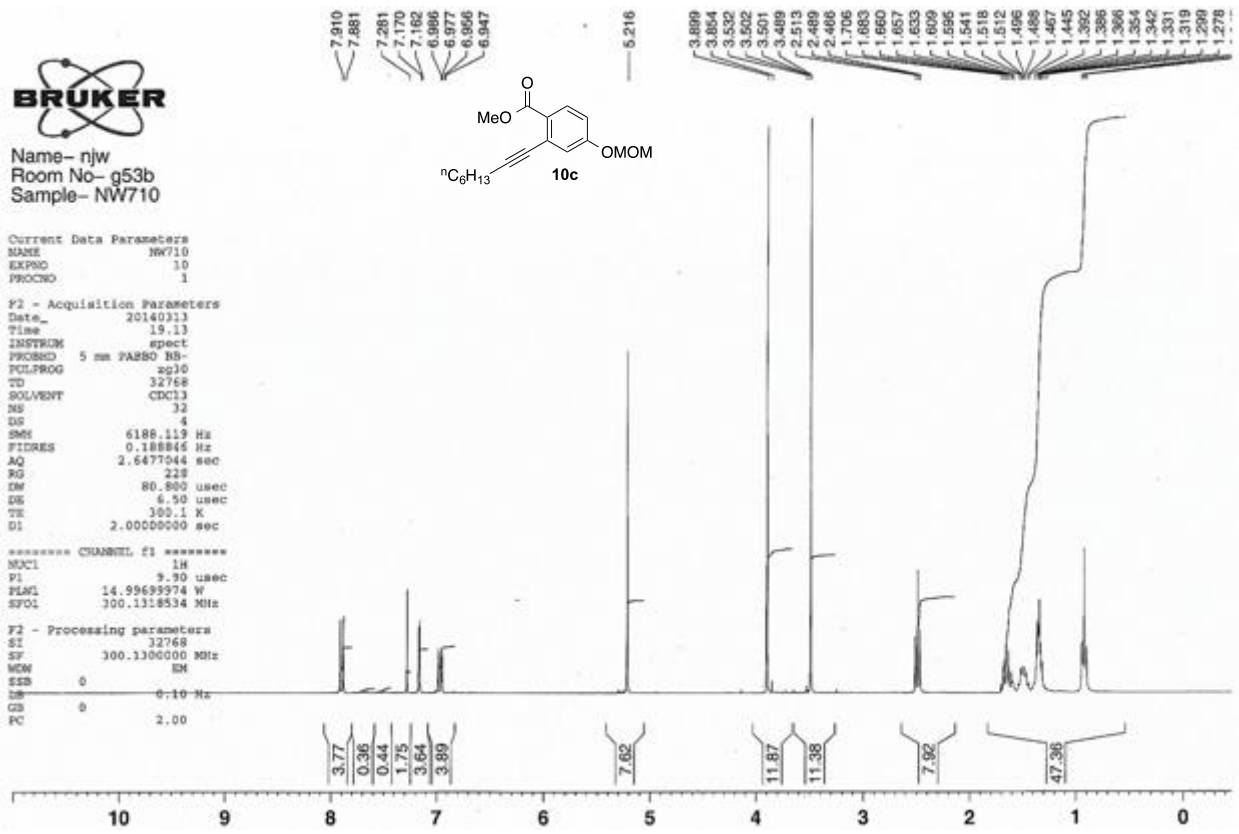


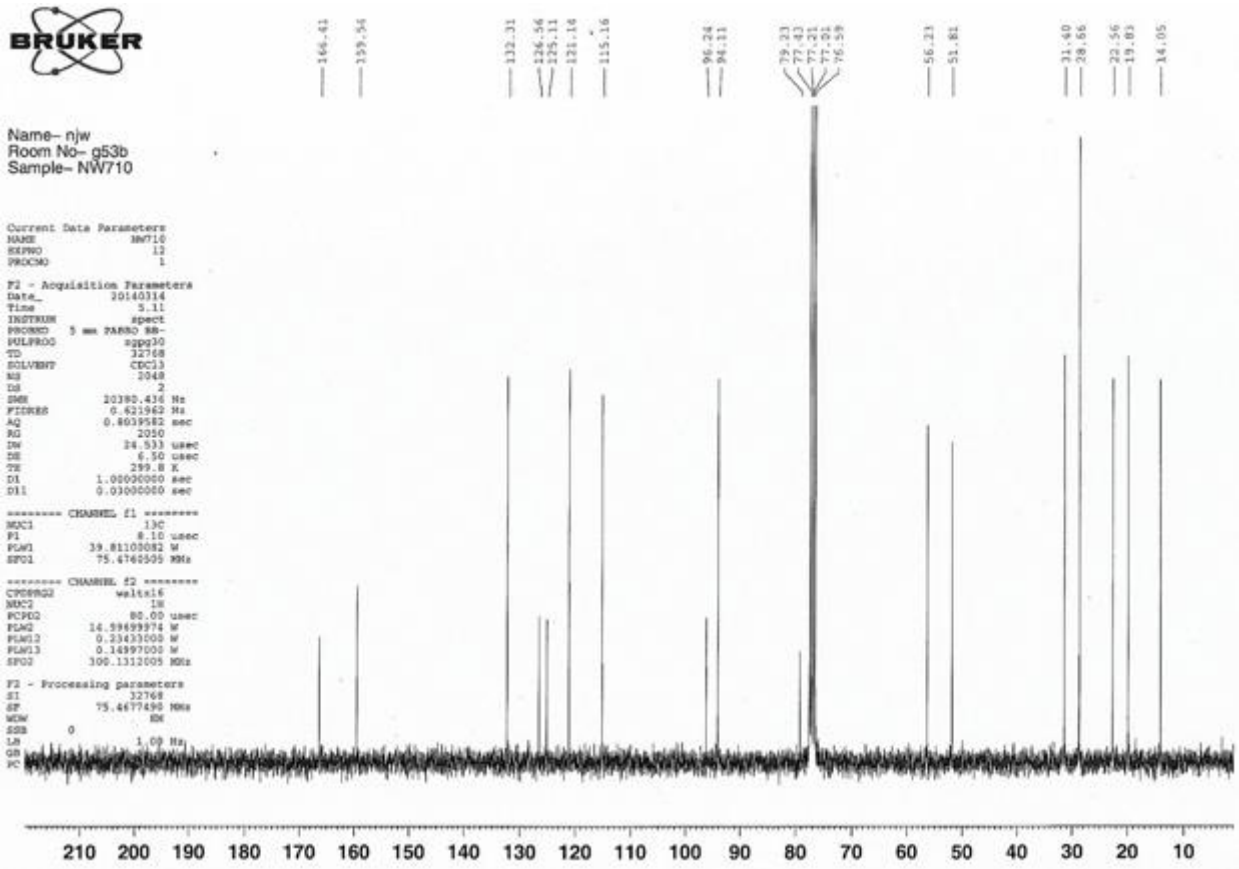
^{1}H and ^{13}C NMR spectra for compound **10b**



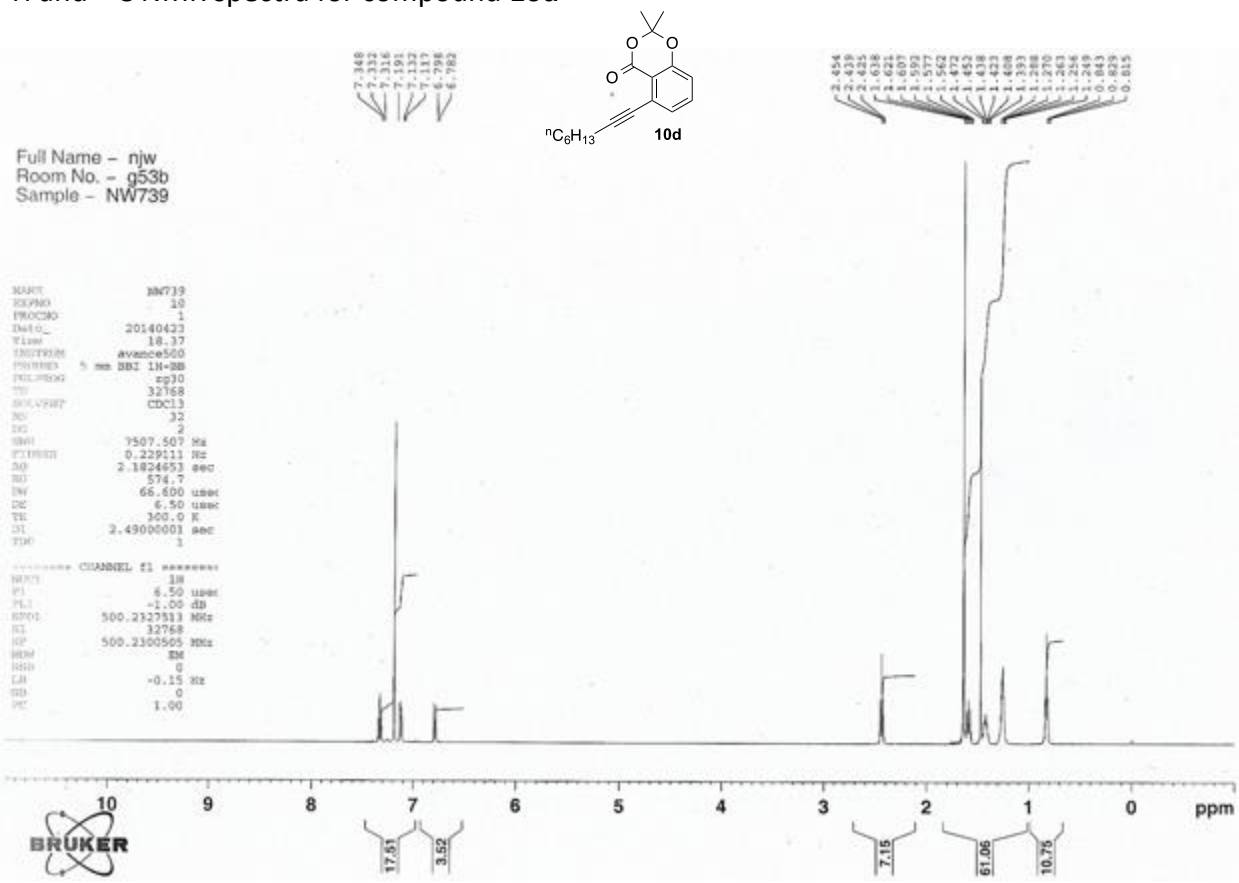


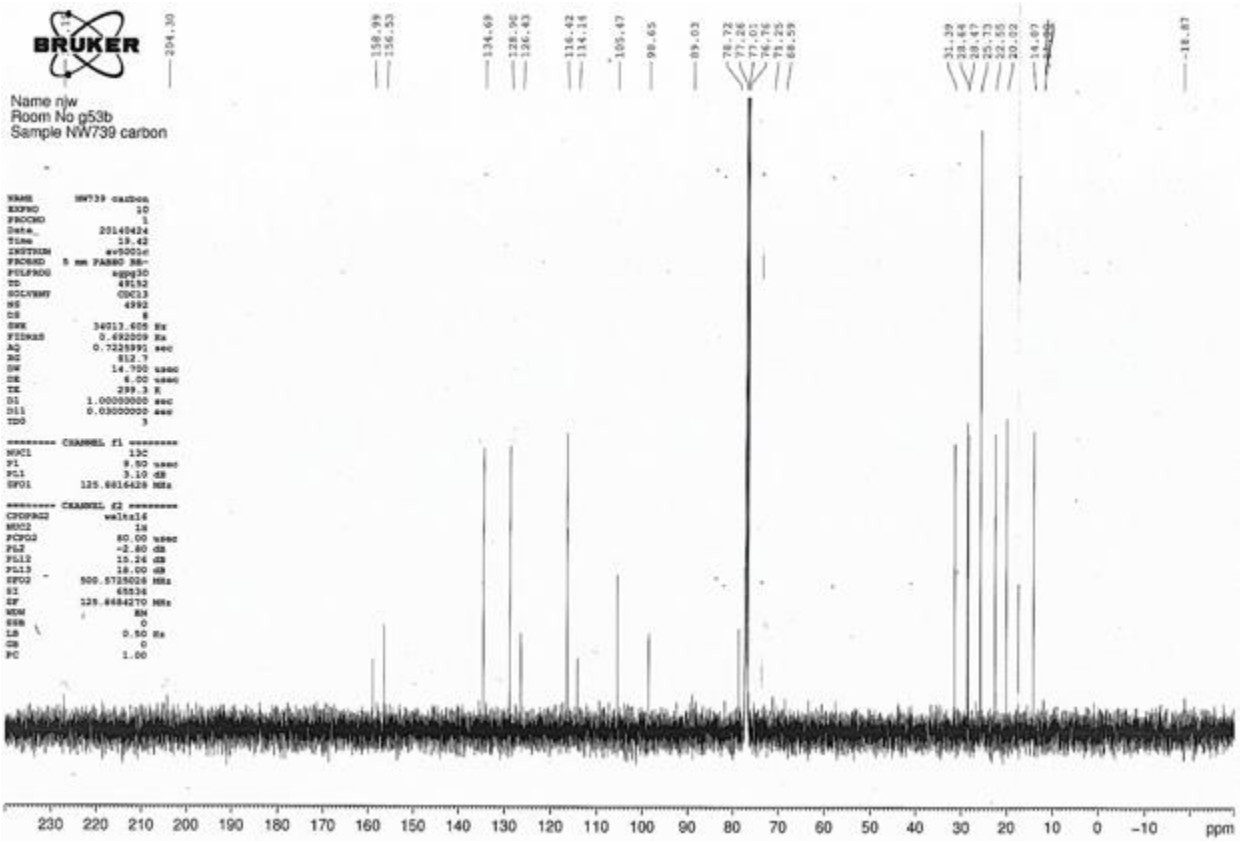
^{1}H and ^{13}C NMR spectra for compound **10c**



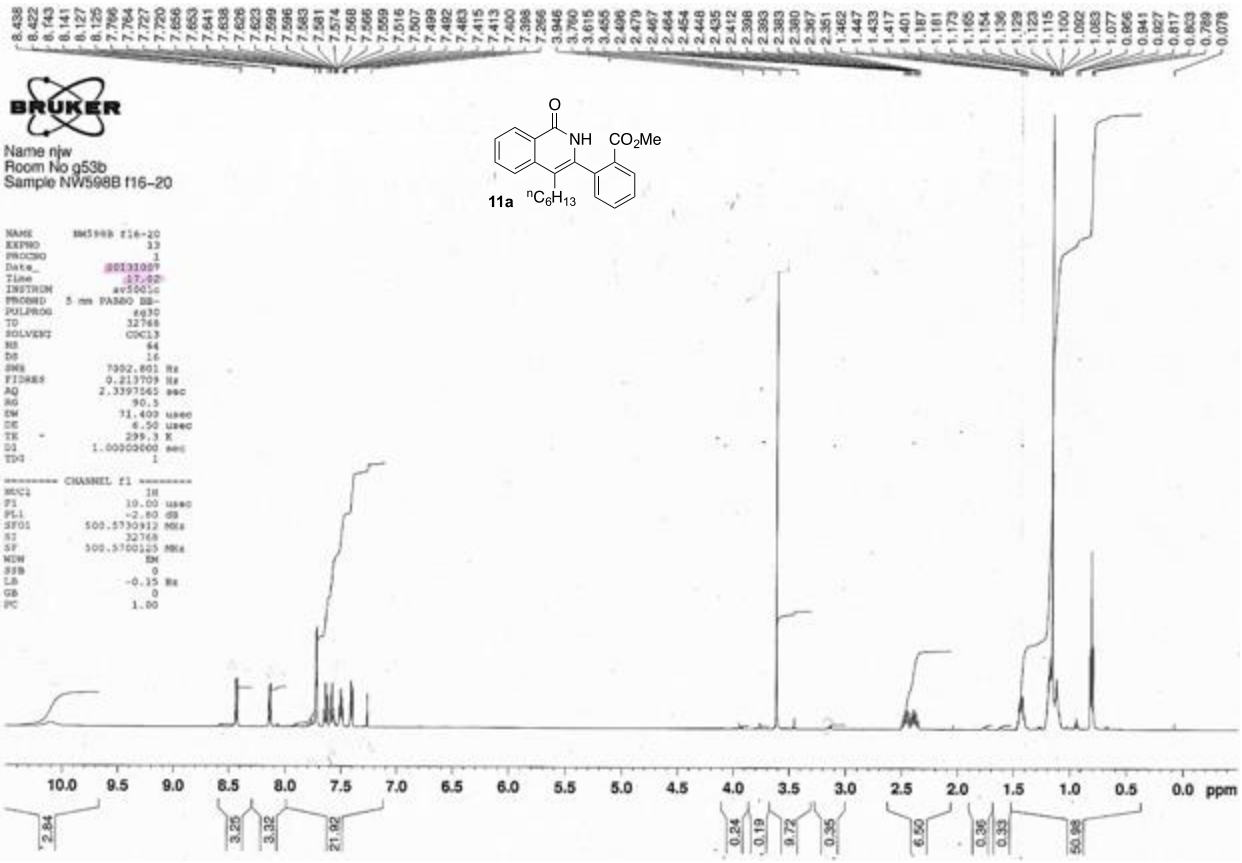


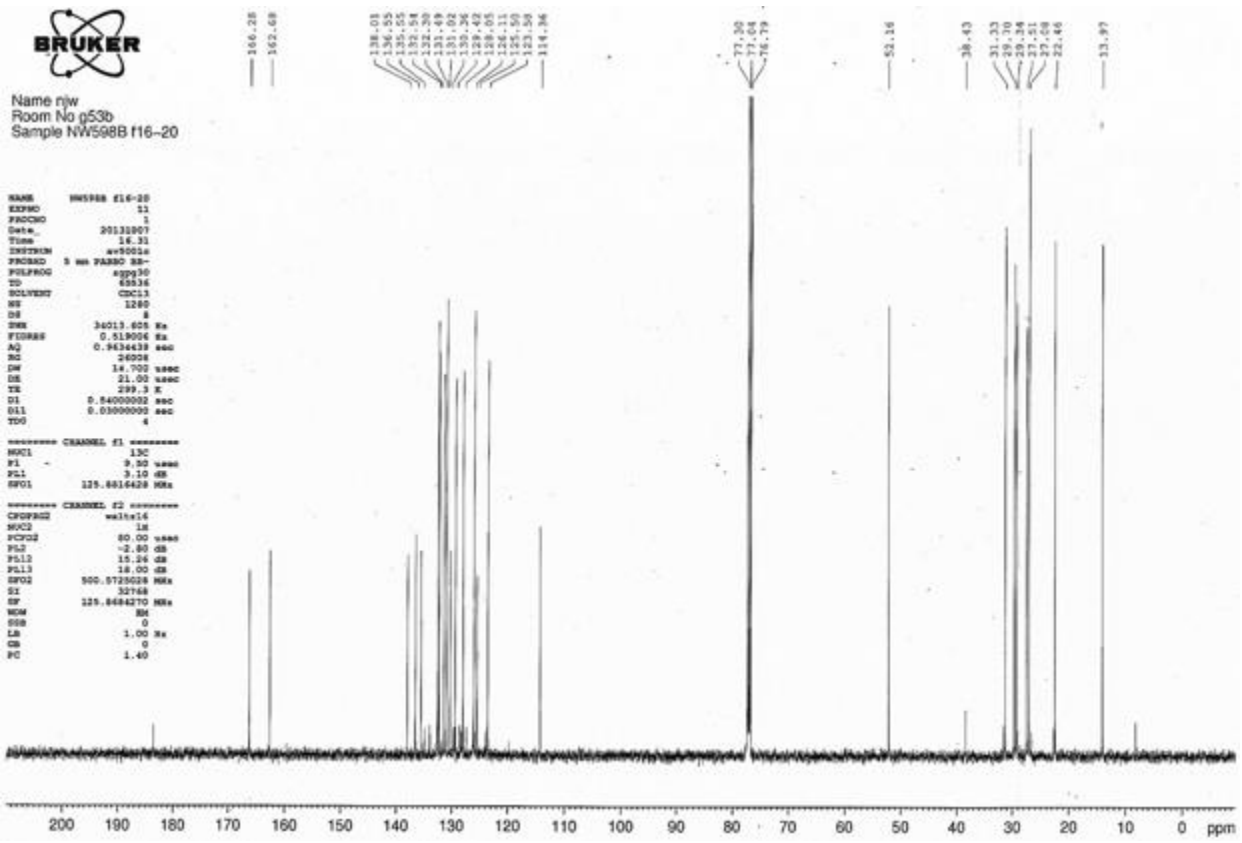
^{1}H and ^{13}C NMR spectra for compound **10d**



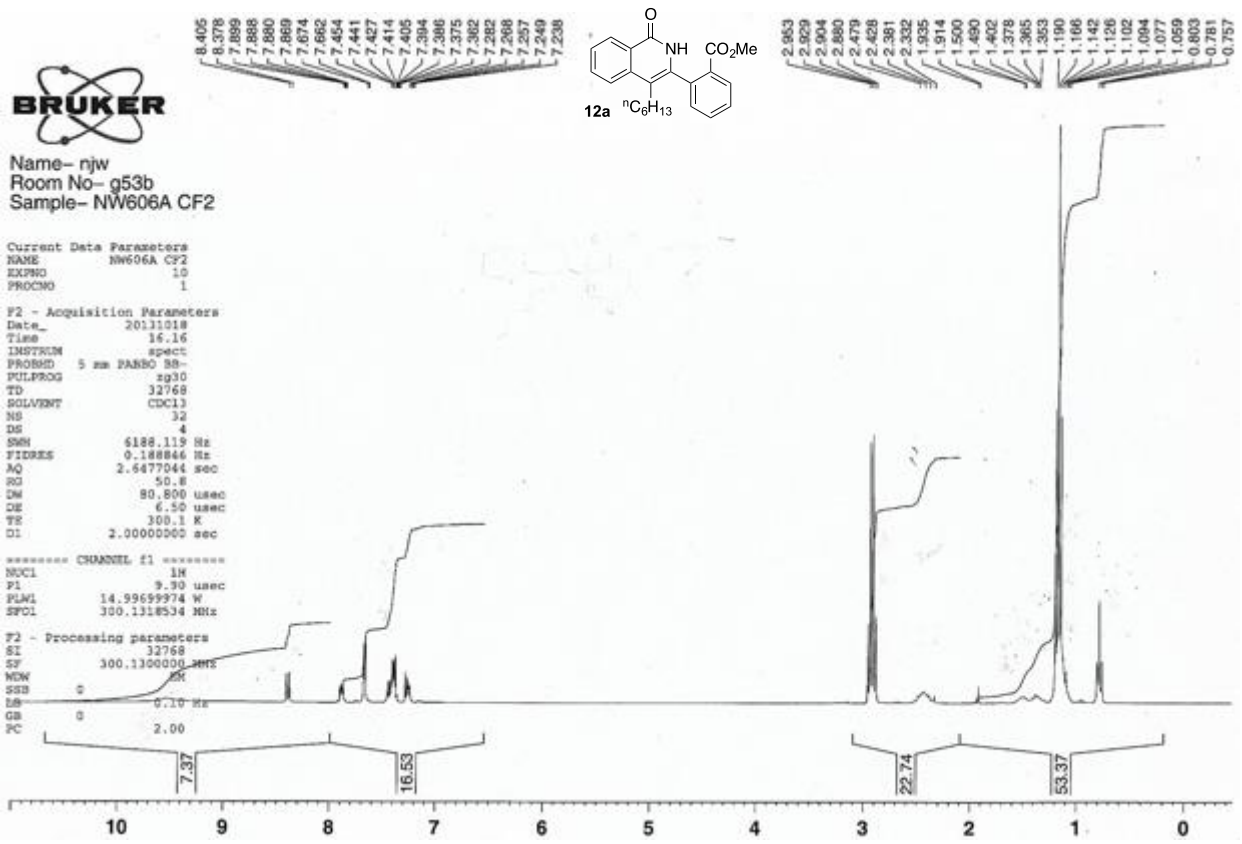


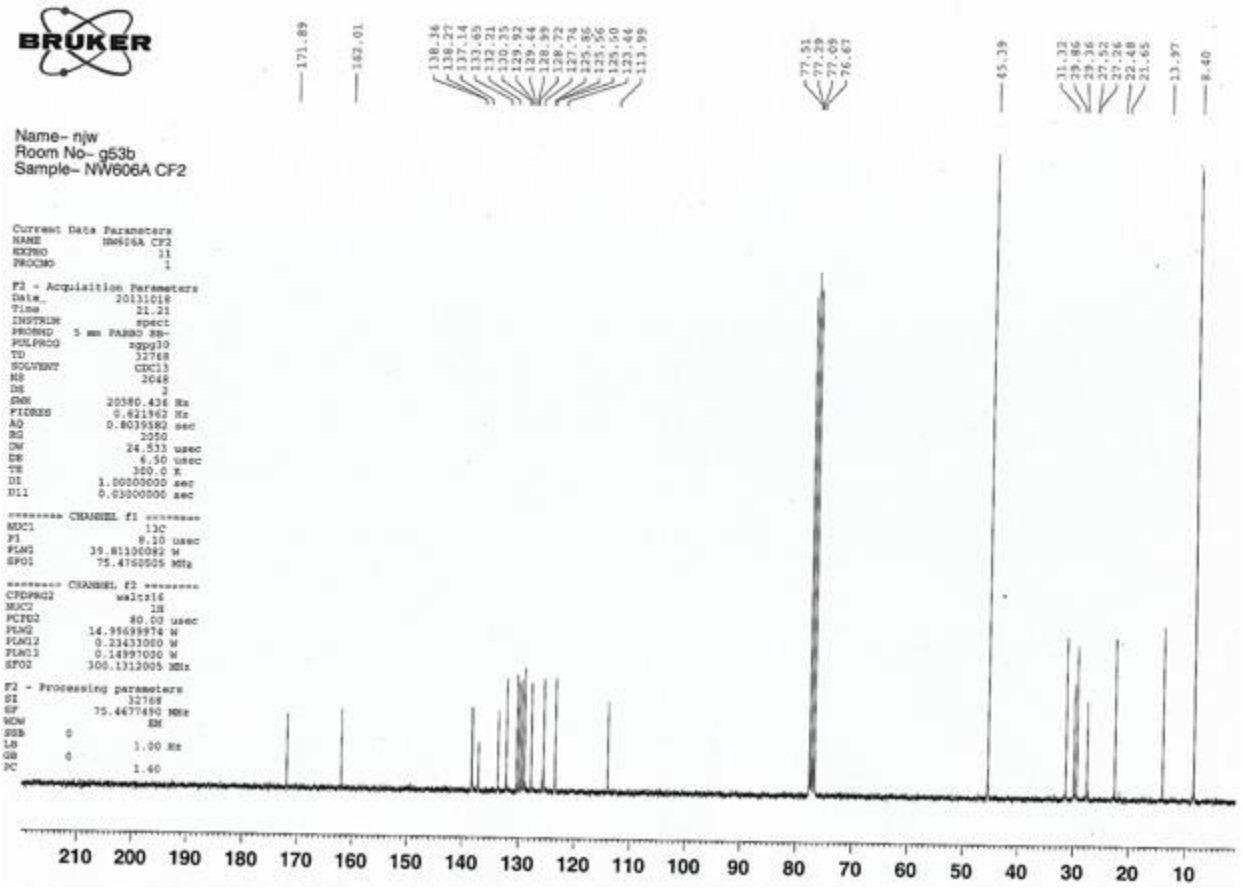
^{1}H and ^{13}C NMR spectra for compound **11a**



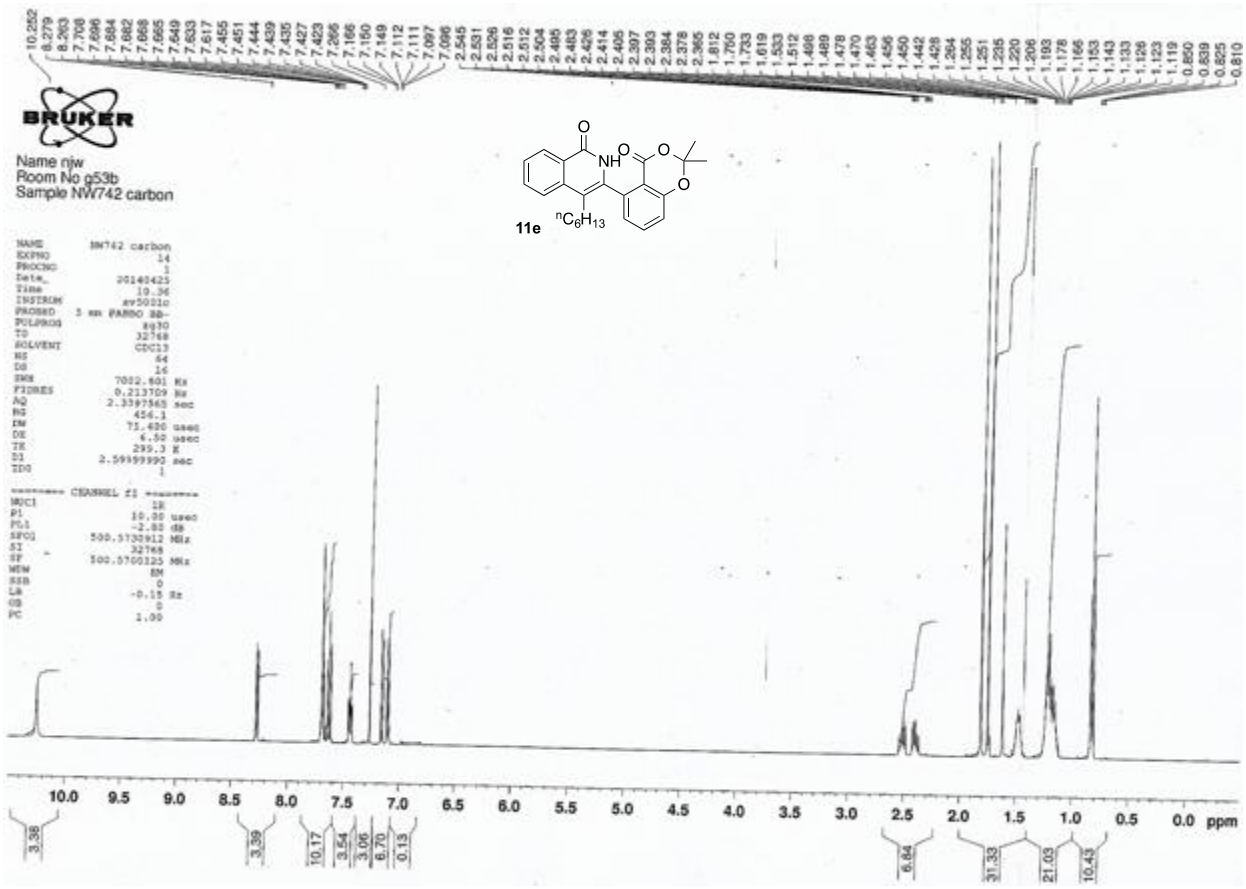


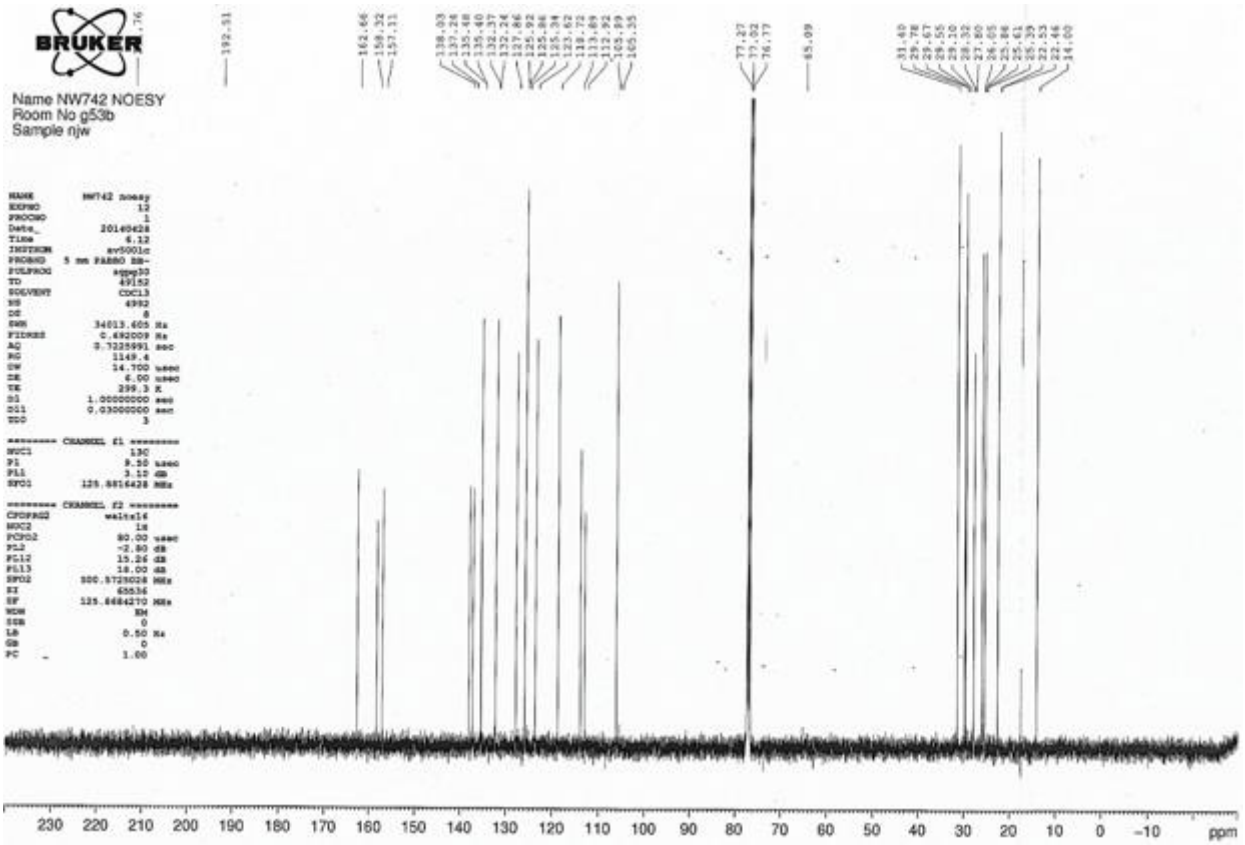
^{1}H and ^{13}C NMR spectra for compound **12a**



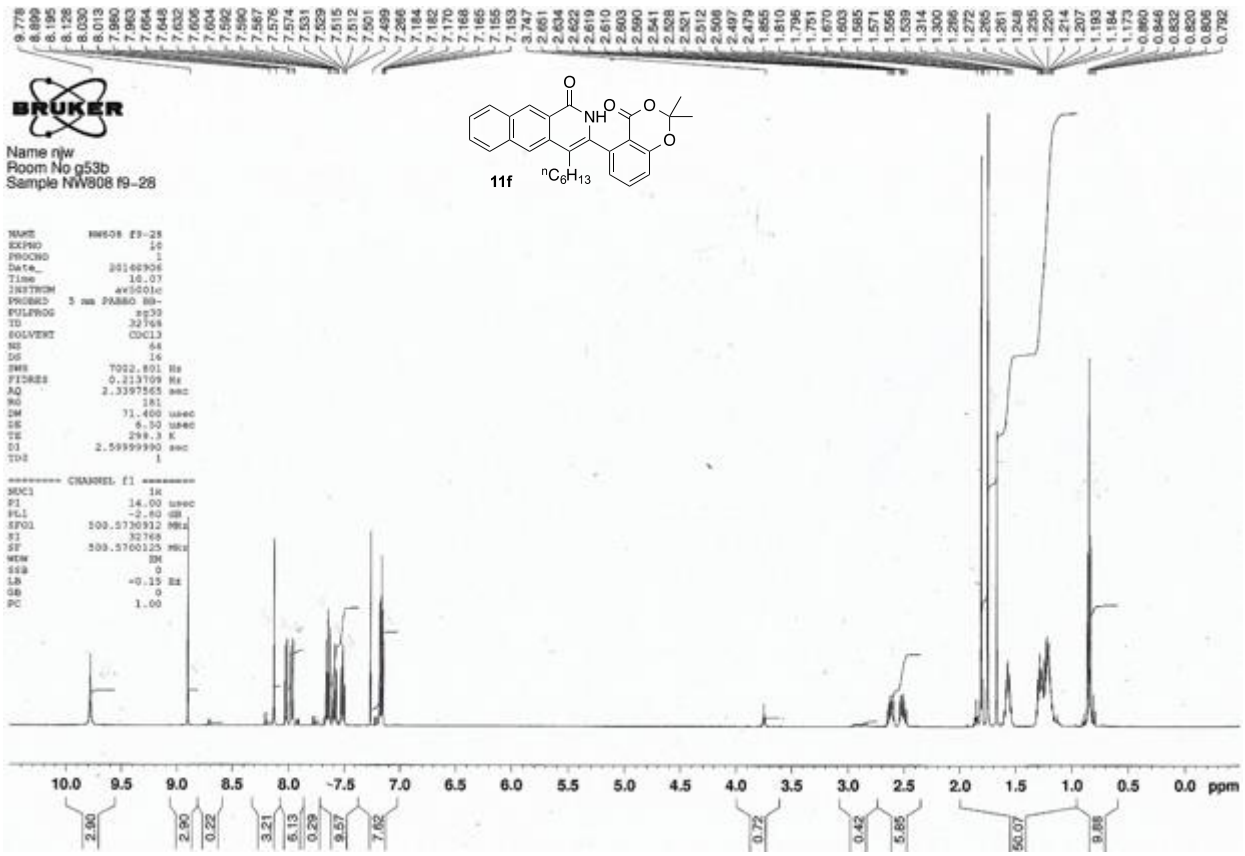


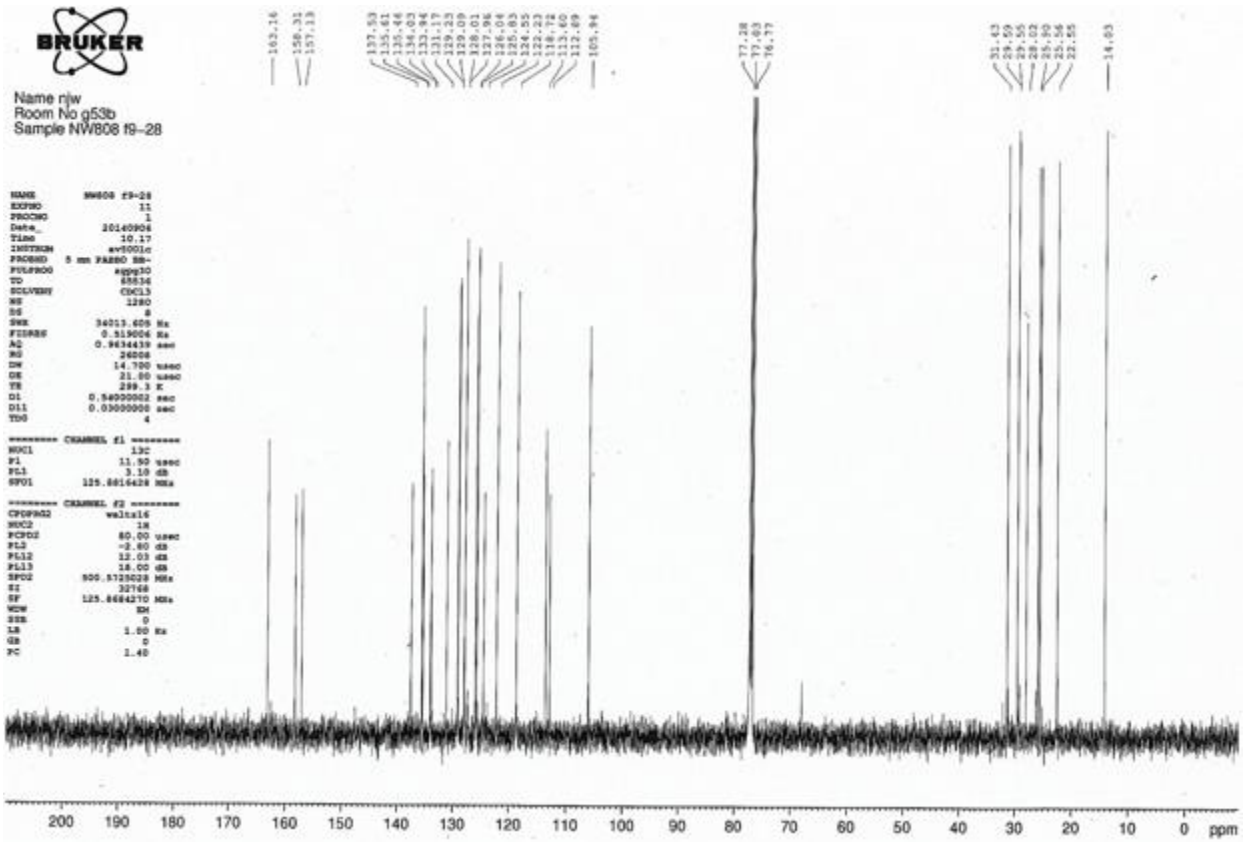
^{1}H and ^{13}C NMR spectra for compound **11e**



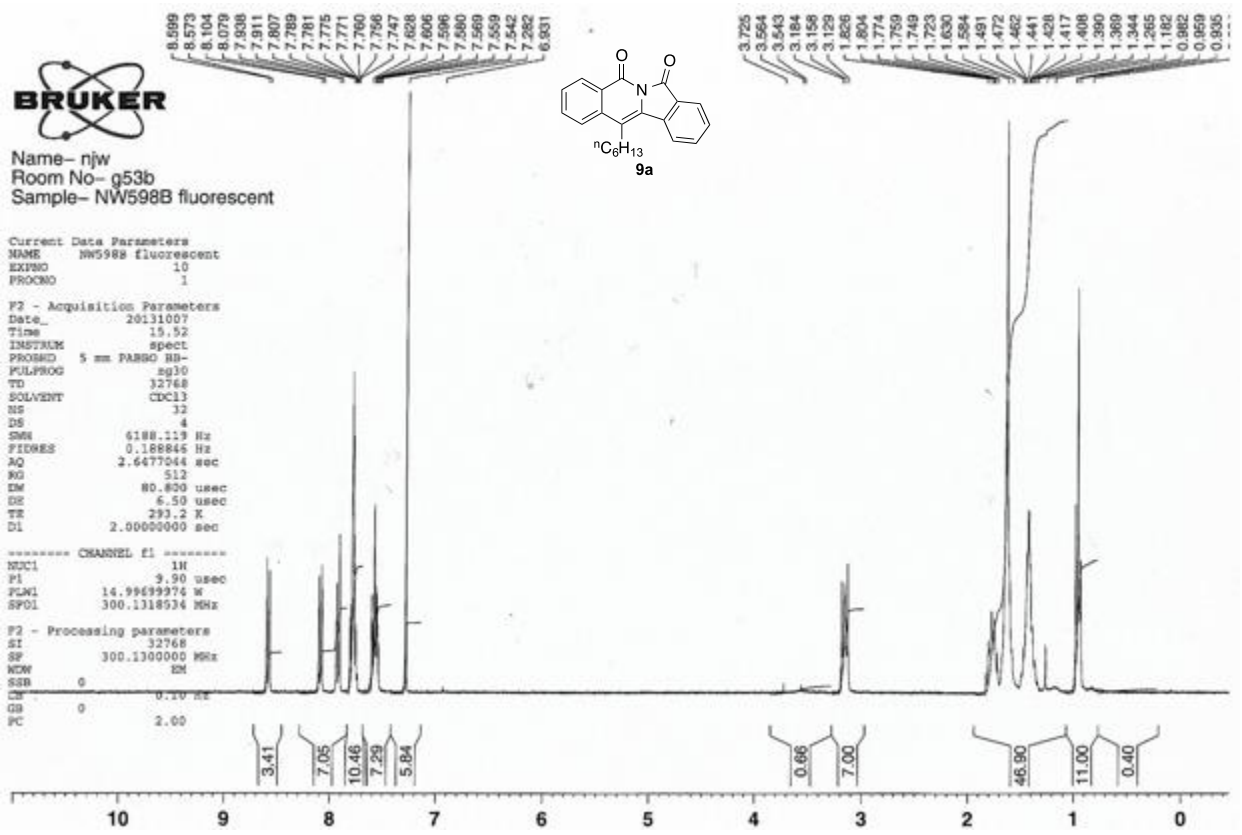


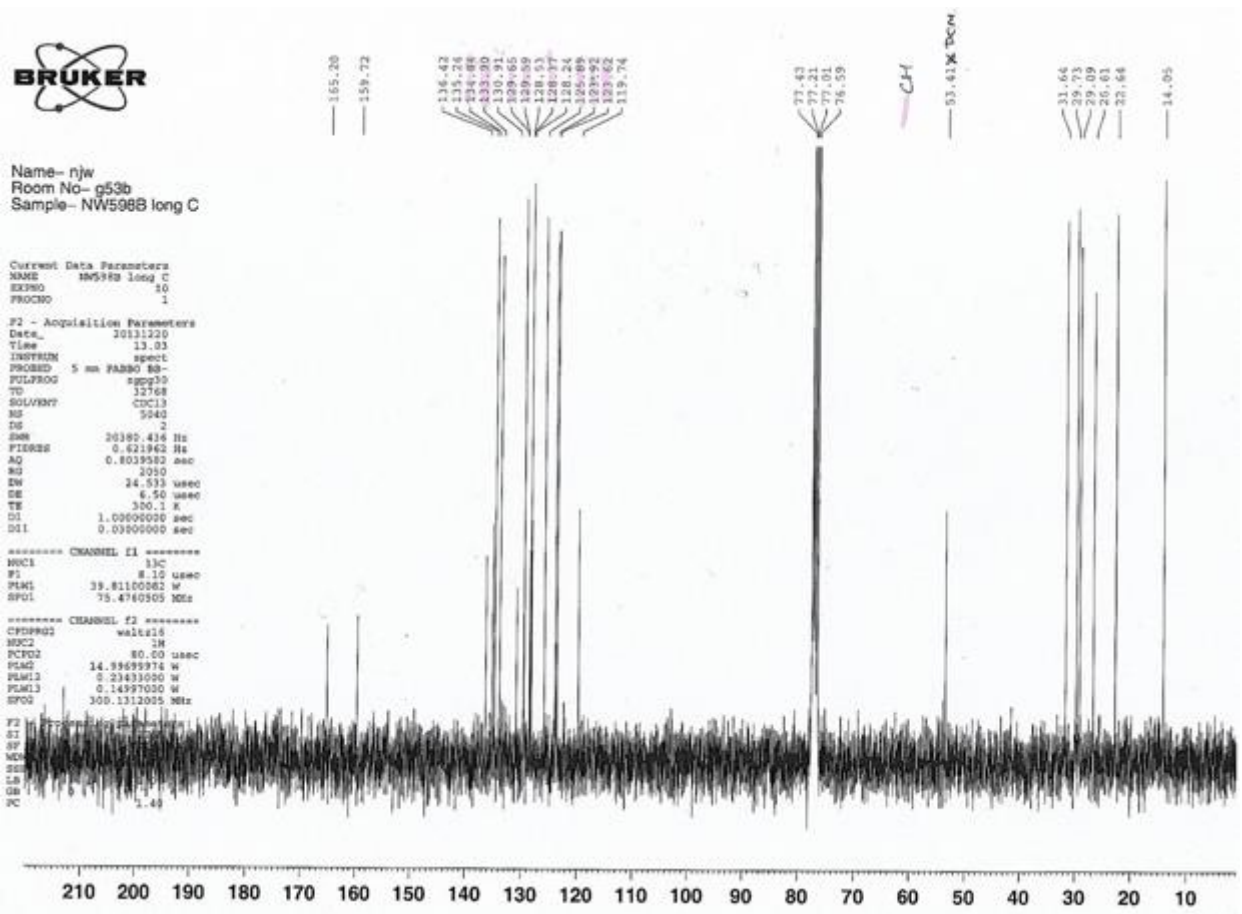
^{1}H and ^{13}C NMR spectra for compound **11f**



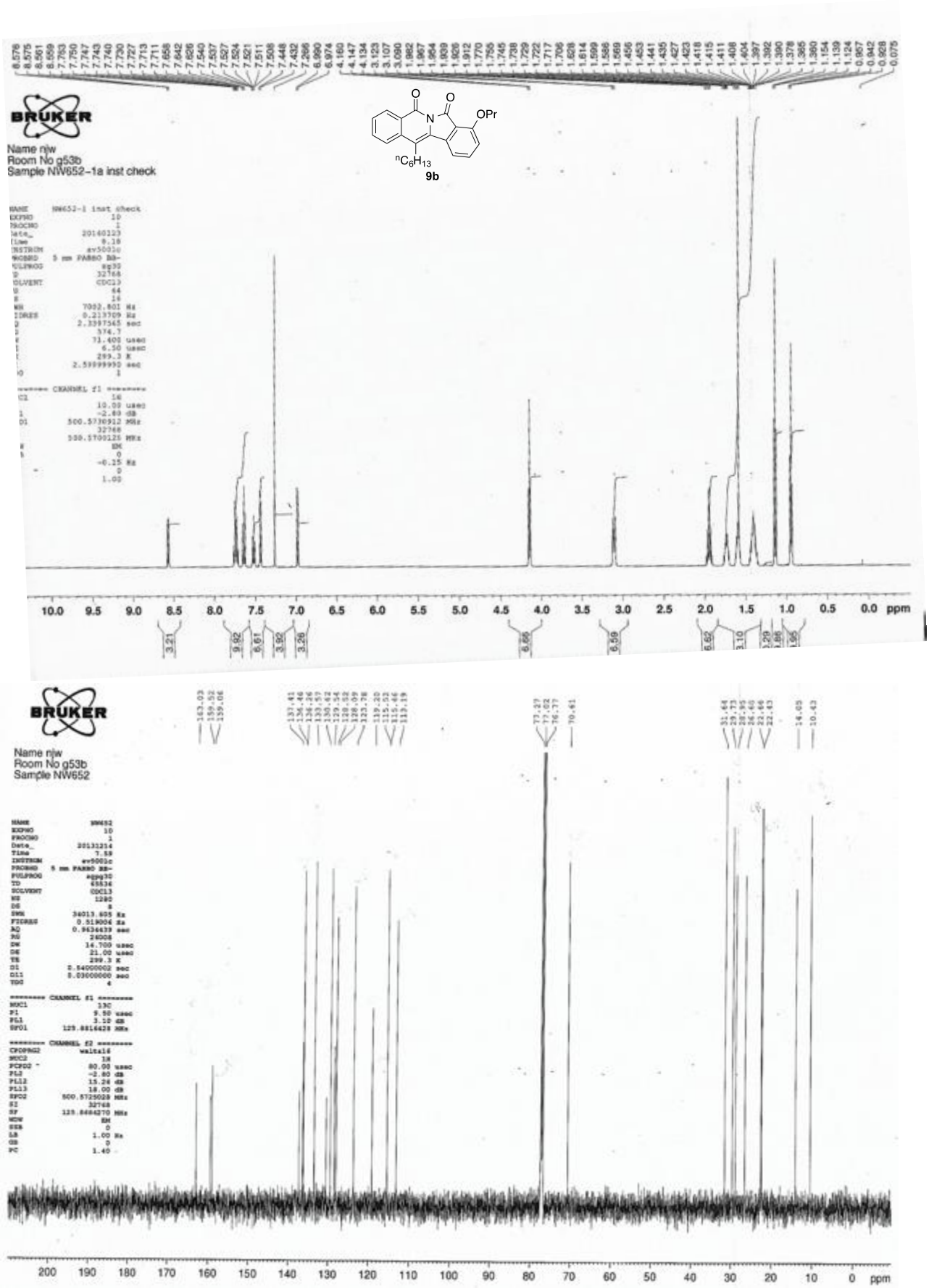


^{1}H and ^{13}C NMR spectra for compound **9a**

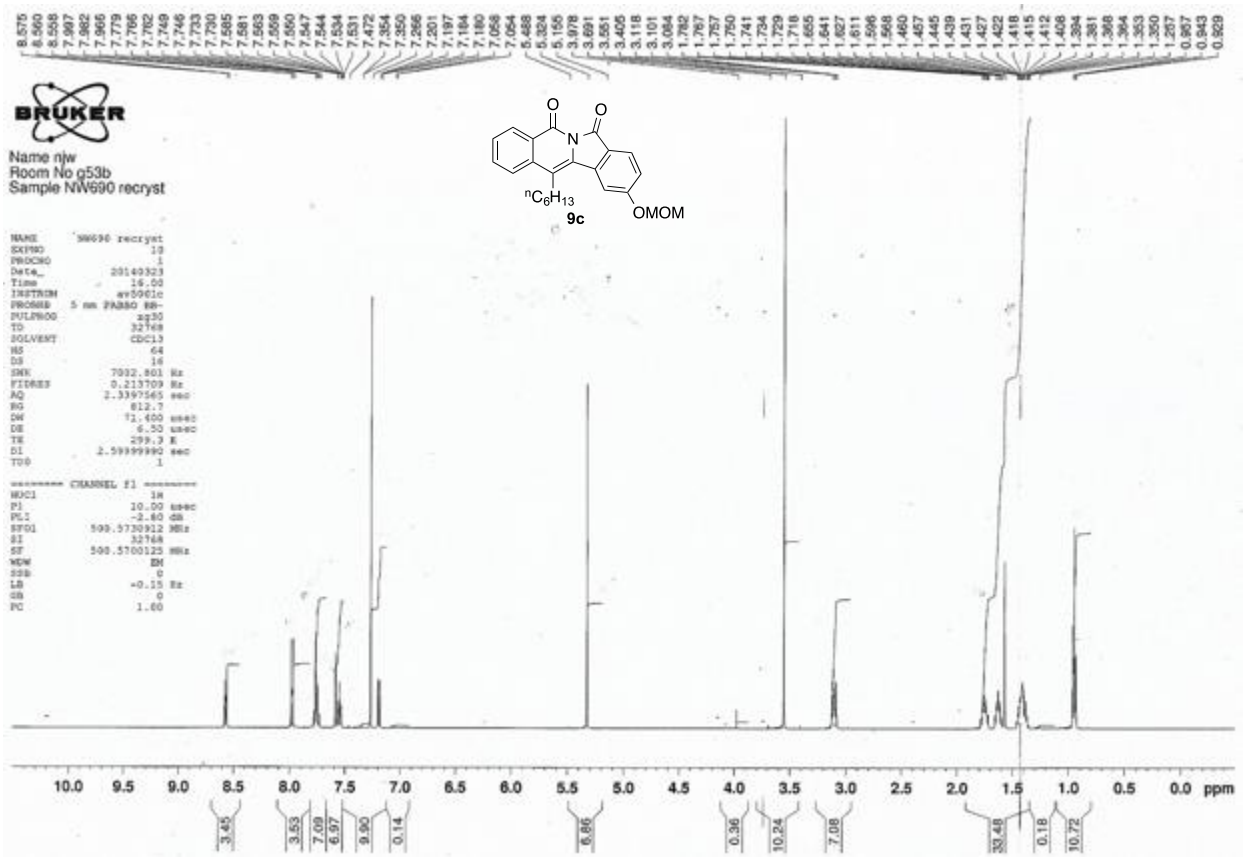


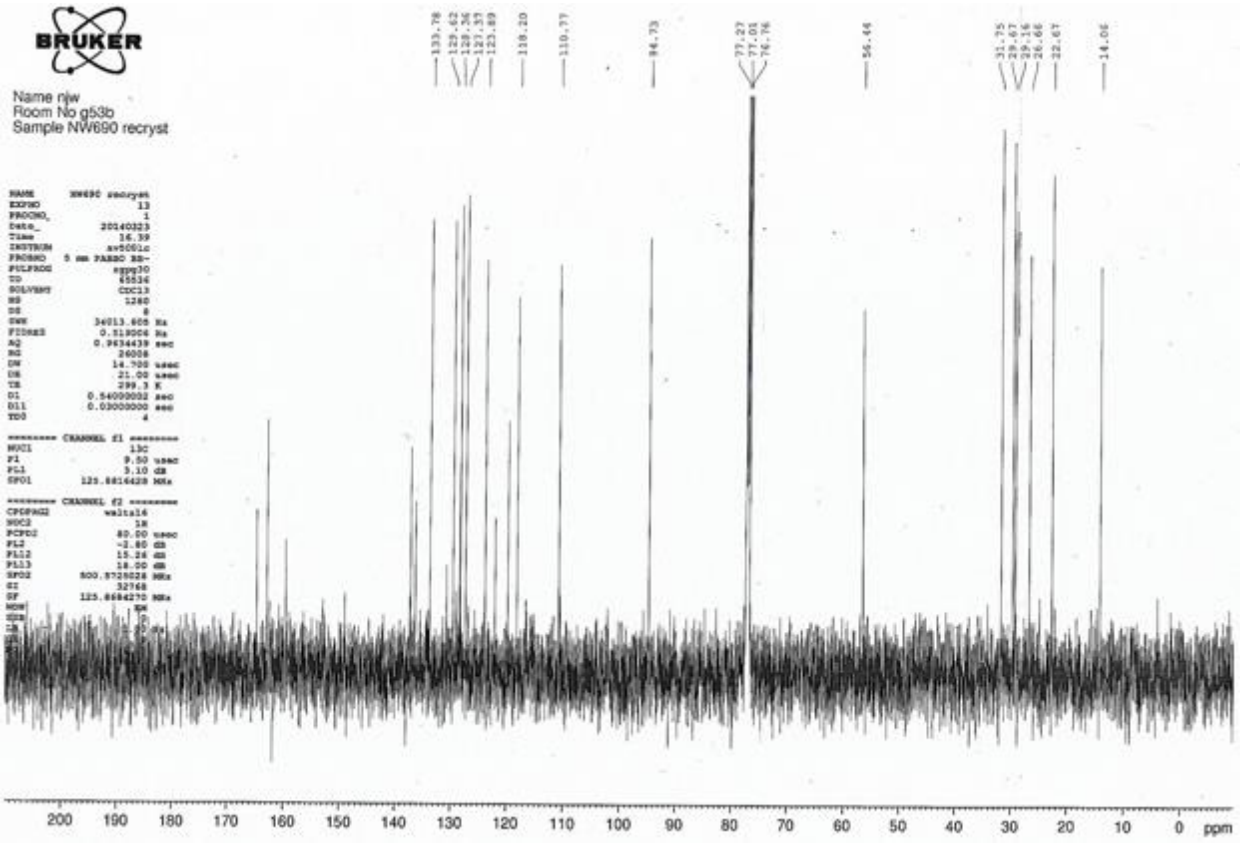


^{1}H and ^{13}C NMR spectra for compound **9b**

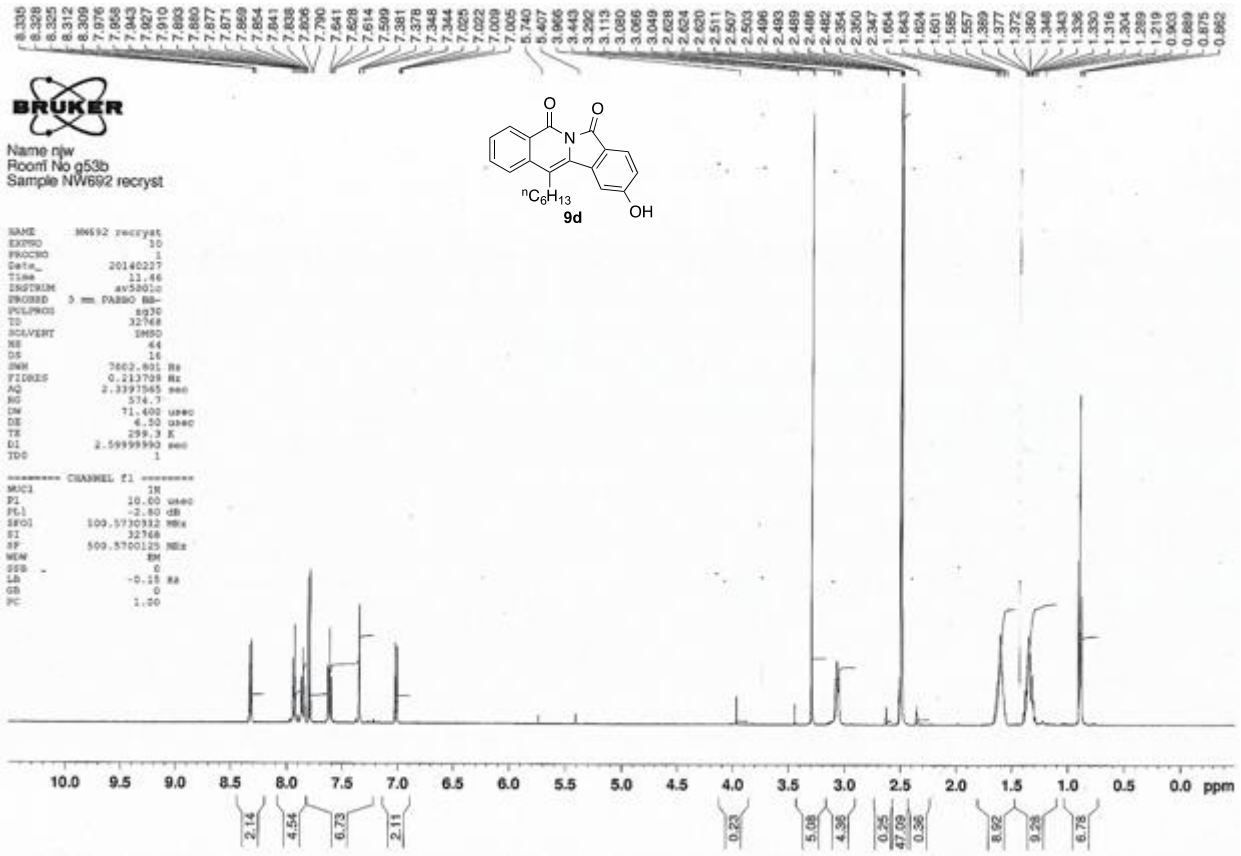


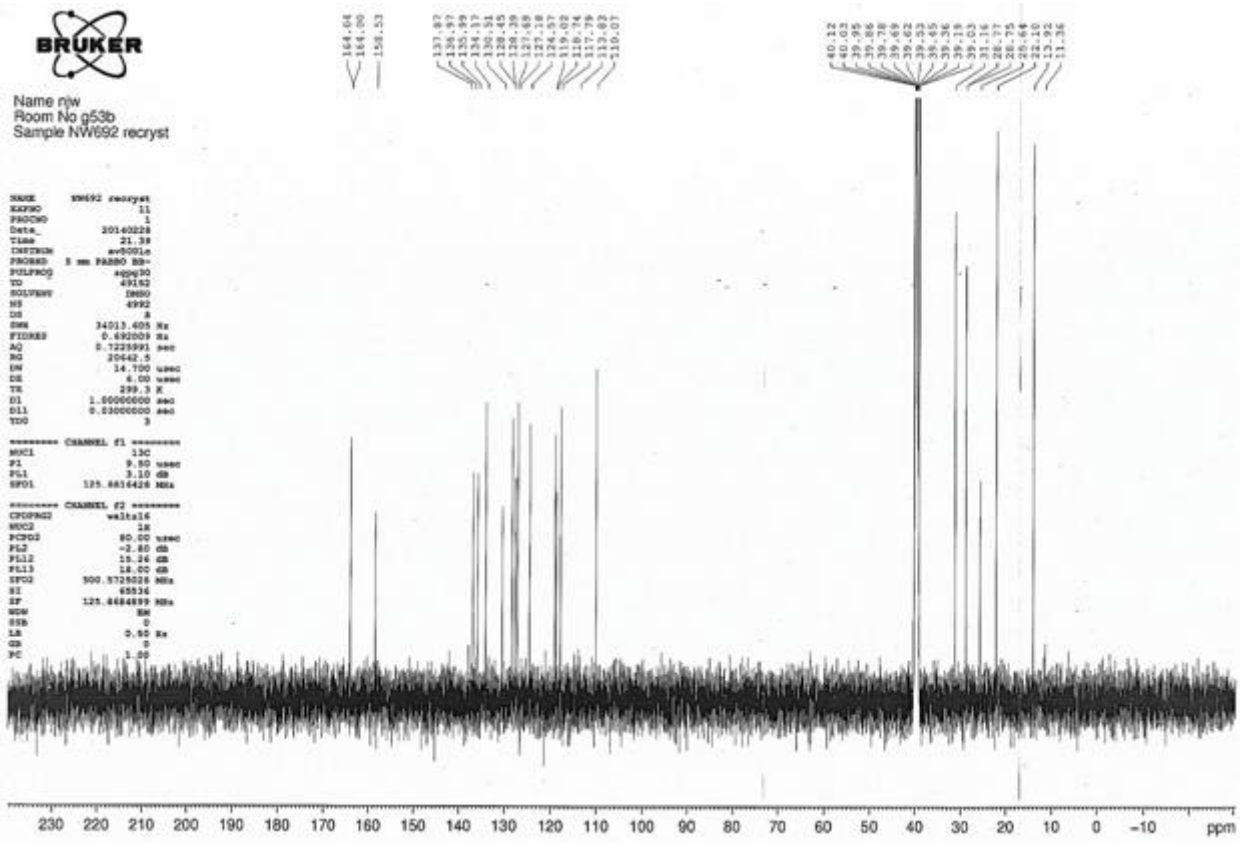
^{1}H and ^{13}C NMR spectra for compound **9c**



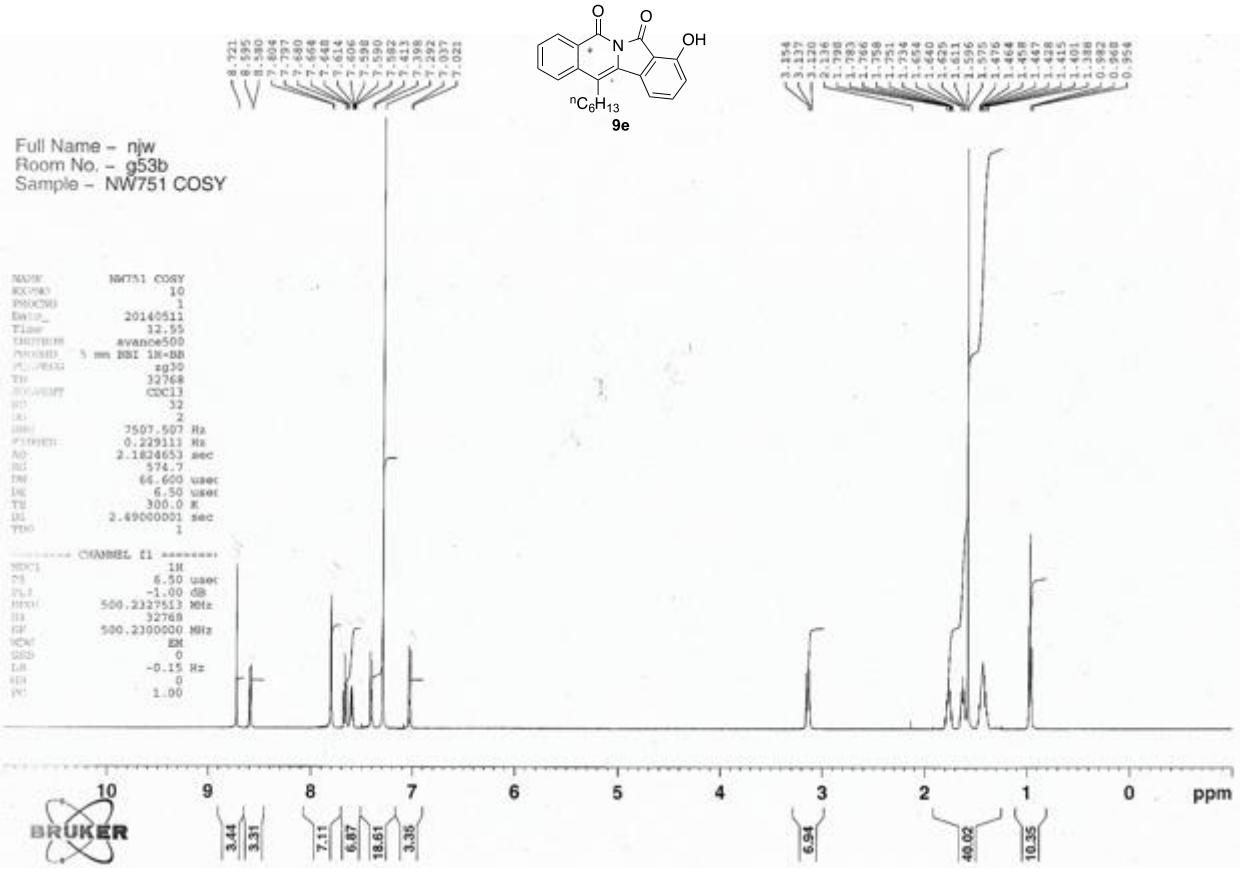


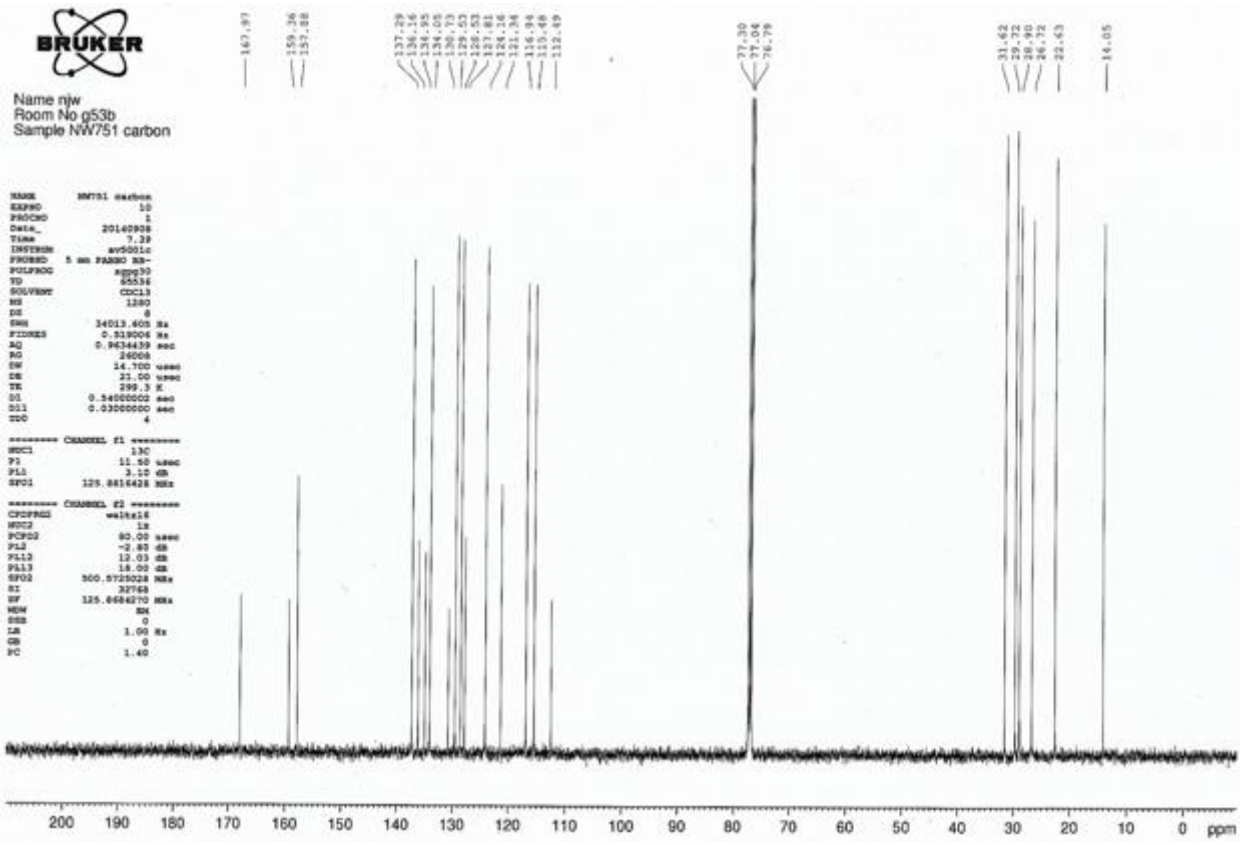
^{1}H and ^{13}C NMR spectra for compound **9d**



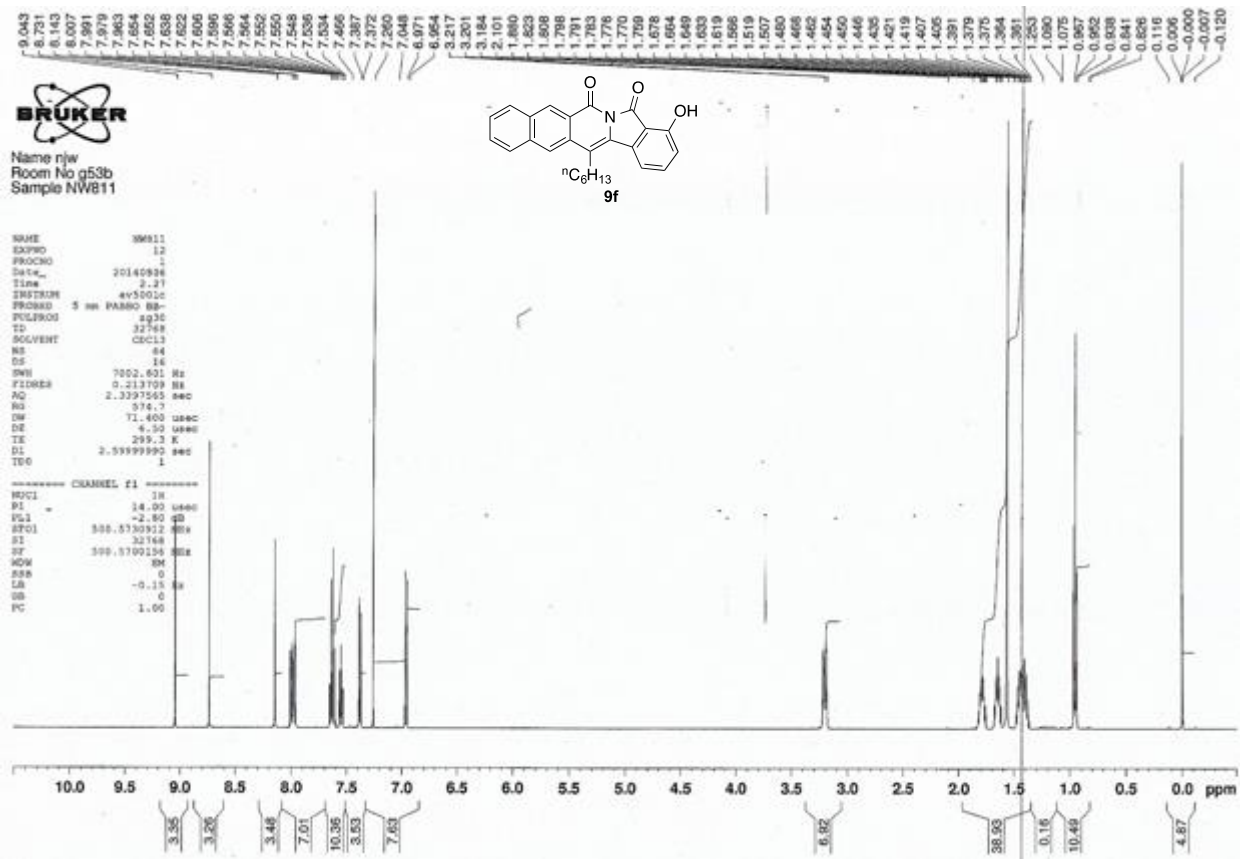


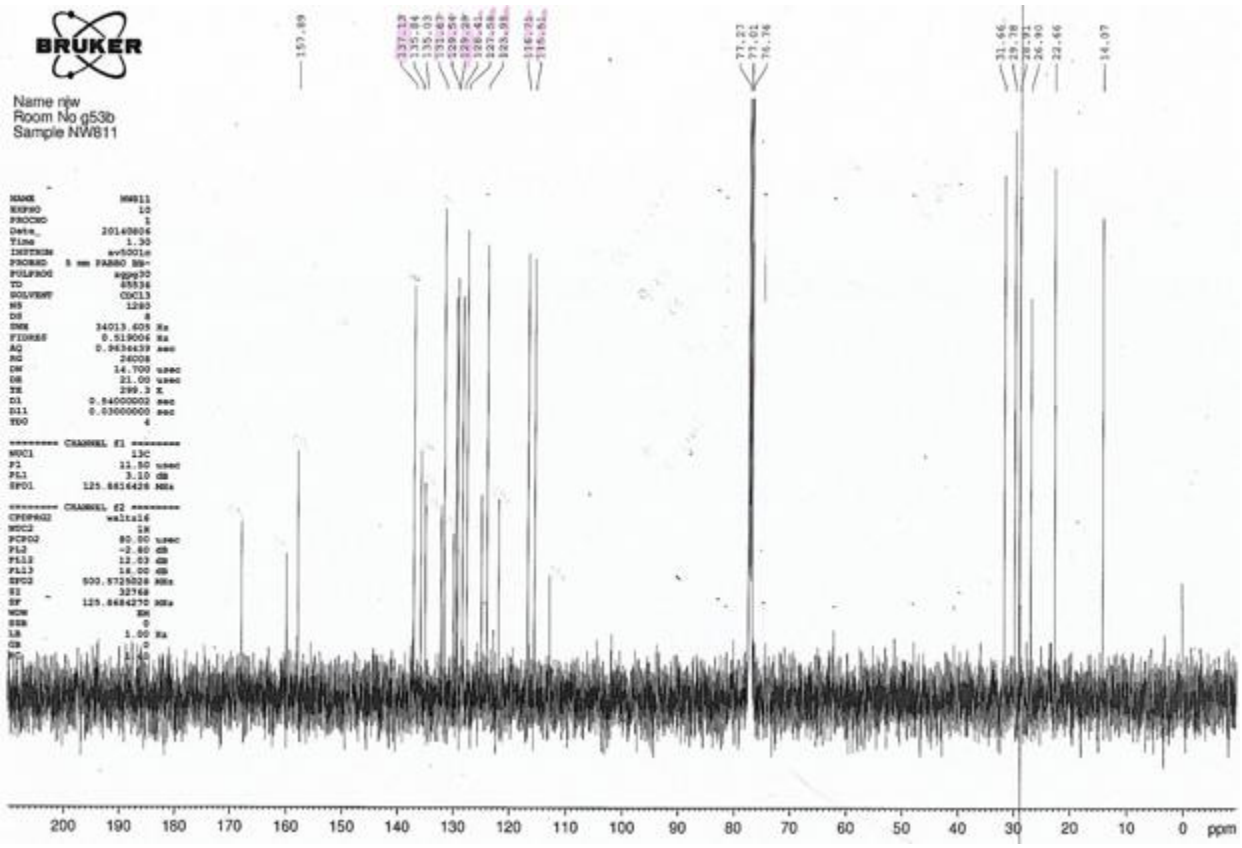
^{1}H and ^{13}C NMR spectra for compound **9e**





^{1}H and ^{13}C NMR spectra for compound **9f**





^{1}H and ^{13}C NMR spectra for compound **9g**