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Synthesis of Substituted Azafluorenones from Dihalogeno Diaryl Ketones by Palladium-Catalyzed Auto-Tandem Processes

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1. General Procedures

The reactions were performed in Schlenk tubes under argon atmosphere. THF was freshly distilled over sodium/benzophenone. DMF was dried over CaH_2 and distilled before use. Liquid chromatography separations were achieved on silica gel Merck Geduran Si 60 (63-200 μm). ^1H and ^{13}C Nuclear Magnetic Resonance (NMR) spectra were recorded at 300 and 75 MHz, respectively. ^1H chemical shifts (δ) are given in ppm relative to the residual solvent peak, and ^{13}C chemical shifts relative to the central peak of the solvent signal.[1] High resolution mass spectrometry measurements were performed at the Centre Régional de Mesures Physiques de l'Ouest (CRMPO) in Rennes.

2. Experimental Procedures and Compound Characterizations

General procedure 1: Deprotonation using the lithium-copper base prepared from CuCl (1 equiv) and LiTMP (2 equiv) before trapping with an aroyl chloride. A stirred cooled (0 °C) solution of LiTMP prepared at 0 °C in THF (6 mL) from 2,2,6,6-tetramethylpiperidine (1.7 mL, 10 mmol) and BuLi (1.6 M hexanes solution, 10 mmol) was treated with TMEDA (0.77 mL, 5.0 mmol) and CuCl (495 mg, 5.0 mmol). The mixture was stirred for 15 min at 0 °C before introduction of the required substrate (5 mmol). After 2 h at rt, a solution of the required aroyl chloride (10 mmol) in THF (3 mL) was added. The mixture was stirred at rt or 60 °C overnight before addition of a 1M aqueous solution of NaOH (20 mL) and extraction with Et_2O (2 x 20 mL). After washing the organic phase with an aqueous saturated solution of NH_4Cl (10 mL) and drying over anhydrous Na_2SO_4, the solvent was evaporated under reduced pressure, and the product was isolated after purification by flash chromatography on silica gel (the eluent is given in the product description).

3-(4-Bromobenzoyl)-2-chloropyridine (1-Br) was prepared from 2-chloropyridine (0.47 mL) and 4-bromobenzoyl chloride (2.2 g) according to the general procedure 1 (trapping step at 60 °C) and isolated (eluent: heptane/AcOEt 8/2) as a pale orange powder (yield: 77%, 1.1 g): mp 84 °C; ^1H NMR (300 MHz, $CDCl_3$) 7.40 (dd, 1H, J = 4.6 and 7.4 Hz), 7.65 (m, 4H), 7.75 (dd, 1H, J = 1.4 and 7.4 Hz) 8.57 (br dd, 1H, J = 1.4 and 4.6 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) 122.5 (CH), 129.8 (C), 131.4 (2 CH), 132.3 (2 CH), 134.4 (C), 134.6 (C), 138.1 (CH), 147.7 (C), 151.2 (CH), 192.4 (C); HRMS (ESI): calcd for $C_{12}H_7{}^{79}Br^{35}ClNNaO$ ($[M+Na]^+$) 317.9297, found: 317.9298.

3-(4-Bromobenzoyl)-2-chloro-6-(trifluoromethyl)pyridine (3) was prepared from

2-chloro-6-(trifluoromethyl)pyridine (0.91 g) and 4-bromobenzoyl chloride (2.2 g) according to the general procedure 1 (trapping step at rt) and isolated (eluent: heptane/AcOEt 95/5) as a pale yellow powder (yield: 60%, 1.1 g): mp 61 °C; ^{1}H NMR (300 MHz, $CDCl_3$) 7.66 (s, 4H), 7.78 (d, 1H, *J* = 7.7 Hz), 7.92, (d, 1H, *J* = 7.7 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) 119.4 (q, CH, *J* = 2.8 Hz), 120.4 (q, C, *J* = 275 Hz), 130.4 (C), 131.4 (2 CH), 132.5 (2 CH), 134.0 (C), 137.5 (C), 139.5 (CH), 148.3 (C), 149.3 (q, C, *J* = 36 Hz), 191.2 (C); HRMS (ASAP): calcd for $C_{13}H_7NOF_3{}^{35}Cl^{79}Br$ ($[M+H]^+$) 363.93516, found 363.9352.

2-Chloro-3-(3-bromobenzoyl)pyridine (5) was prepared from 2-chloropyridine (0.47 mL) and 3-bromobenzoyl chloride (1.3 mL) according to the general procedure 1 (trapping step at 60 °C) and isolated (eluent: heptane/AcOEt 9/1) as a yellow oil (yield: 78%, 1.2 g): ^{1}H NMR (300 MHz, $CDCl_3$) 7.36 (dd, 1H, *J* = 7.8 and 7.8 Hz), 7.40 (dd, 1H, *J* = 4.8 and 7.5 Hz), 7.67 (ddd, 1H, *J* = 1.3, 1.7 and 7.8 Hz), 7.74 (dd, 1H, *J* = 1.9 and 7.5 Hz), 7.74 (ddd, 1H, *J* = 1.3, 1.8 and 7.8 Hz), 7.94 (dd, 1H, *J* = 1.7 and 1.8 Hz), 8.56 (dd, 1H, *J* = 4.8 and 1.9 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) 122.4 (CH), 123.0 (C), 128.5 (CH), 130.3 (CH), 132.3 (CH), 134.0 (C), 136.8 (CH), 137.4 (C), 138.0 (CH), 147.4 (C), 151.1 (CH), 191.8 (C); HRMS (ASAP): calcd for $C_{12}H_8NO^{35}Cl^{79}Br$ ($[M+H]^+$) 295.94778, found 295.9481.

2-Chloro-3-benzoyl-4-bromopyridine (10-Br) was prepared from 4-bromo-2-chloropyridine (0.55 mL) and benzoyl chloride (1.2 mL) according to the general procedure 1 (trapping step at 60 °C) and isolated (eluent: heptane/AcOEt 9/1) as a pale yellow powder (yield: 48%, 0.71 g): mp 104 °C; ^{1}H NMR (300 MHz, $CDCl_3$) 7.49-7.54 (m, 2H), 7.67 (m, 2H), 7.82-7.85 (m, 2H), 8.39 (br, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) 127.0 (CH), 129.2 (2 CH), 129.7 (2 CH), 131.8 (C), 134.5 (C), 134.8 (CH), 136.1 (C), 148.1 (C), 150.1 (CH), 191.3 (C); HRMS (ASAP): calcd for $C_{12}H_8NO^{35}Cl^{79}Br$ ($[M+H]^+$) 295.94778, found 295.9475.

2-Chloro-3-(4-iodobenzoyl)pyridine (1-I) was prepared from 2-chloropyridine (0.47 mL) and 4-iodobenzoyl chloride (2.7 g) according to the general procedure 1 (trapping step at 60 °C) and isolated (eluent: heptane/AcOEt 8/2) as a beige powder (yield: 45%, 0.77 g): mp 148 °C; ^{1}H NMR (300 MHz, $CDCl_3$) 7.40 (dd, 1H, *J* = 4.9 and 7.5 Hz), 7.50 (d, 2H, *J* = 8.6 Hz), 7.74 (d, 1H, *J* = 2.0 and 7.5 Hz), 7.87 (d, 2H, *J* = 8.6 Hz), 8.57 (dd, 1H, *J* = 2.0 and 4.9 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) 102.8 (C), 122.4 (CH), 131.2 (2 CH),

134.4 (C), 135.1 (C), 138.1 (CH), 138.3 (2 CH), 147.4 (C), 151.2 (CH), 192.7 (C); HRMS (ESI): calcd for $C_{12}H_7{}^{35}ClINNaO$ ($[M+Na]^+$) 365.9159, found: 365.9158.

General procedure 2: tandem reaction including Suzuki coupling. A degassed mixture containing K_2CO_3 (0.28 g, 2.0 mmol), $Pd(OAc)_2$ (11 mg, 50 µmol, 5 mol%), $Cy_3P{\cdot}HBF_4$ (37 mg, 0.10 mmol, 10 mol%), the required ketone (1.0 mmol) and the required boronic acid (1.0 mmol) in DMF (4 mL) was heated at 130 °C for 24 h. After filtration over a celite pad, washing using CH_2Cl_2 (3 x 10 mL), and removal of the solvent under reduced pressure, the product was isolated after purification by flash chromatography on silica gel (the eluent is given in the product description).

8-Phenyl-5*H*-indeno[1,2-*b*]pyridin-5-one or 6-phenyl-4-azafluorenone (2a) was prepared from **1-Br** (0.30 g) and phenylboronic acid (0.12 g) according to the general procedure 2 and isolated (eluent: heptane/AcOEt 9/1) as a pale yellow powder (yield: 91%, 0.23 g): mp 142 °C; ^{1}H NMR (300 MHz, $CDCl_3$) 7.19 (dd, 1H, *J* = 5.1 and 7.4 Hz), 7.38-7.49 (m, 3H), 7.61-7.68 (m, 3H), 7.74 (d, 1H, *J* = 7.7 Hz), 7.87 (dd, 1H, *J* = 1.4 and 7.4 Hz), 8.07 (d, 1H, *J* = 1.1 Hz), 8.60 (dd, 1H, *J* = 1.4 and 5.1 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) 119.8 (CH), 123.5 (CH), 124.8 (CH), 127.4 (2 CH), 128.8 (CH), 129.1 (C), 129.1 (2 CH), 129.7 (CH), 131.5 (CH), 133.6 (C), 139.7 (C), 144.4 (C), 148.6 (C), 154.1 (CH), 164.9 (C), 191.4 (C). HRMS (ESI): calcd for $C_{18}H_{11}NNaO$ ($[M+Na]^+$) : 258.09189, found : 258.0921.

8-(4-Hydroxyphenyl)-5*H*-indeno[1,2-*b*]pyridin-5-one or 6-(4-hydroxyphenyl-4-azafluorenone (2b) was prepared from **1-Br** (0.30 g) and 4-hydroxyphenylboronic acid (0.14 g) according to the general procedure 2 and isolated (eluent: heptane/AcOEt 7/3) as a pale yellow powder (yield: 41%, 0.11 g): mp > 260 °C; ^{1}H NMR (300 MHz, CD_3COCD_3) 7.01 (d, 2H, *J* = 8.8 Hz), 7.40 (dd, 1H, *J* = 5.1 and 7.5 Hz), 7.72 (d, 2H, *J* = 8.8 Hz), 7.76-7.77 (m, 2H), 7.96 (dd, 1H, *J* = 1.6 and 7.5 Hz), 8.07 (dd, 1H, *J* = 0.9 and 1.4 Hz), 8.69 (dd, 1H, *J* = 1.6 and 5.1 Hz), 8.83 (br s, 1H); ^{13}C NMR (75 MHz, CD_3COCD_3) 117.9 (2 CH), 120.1 (CH), 125.6 (CH), 126.2 (CH), 130.4 (2 CH), 130.5 (CH), 130.6 (C), 132.5 (CH), 132.8 (C), 134.5 (C), 146.4 (C), 150.0 (C), 156.0 (CH), 160.4 (C), 166.3 (C), 192.4 (C); HRMS (ESI): calcd for $C_{18}H_{11}NNaO_2$ ($[M+Na]^+$) 296.0687, found: 296.0685.

8-(3-Thienyl)-5*H*-indeno[1,2-*b*]pyridin-5-one or 6-(3-thienyl)-4-azafluorenone (2c) was prepared from **1-Br** (0.30 g) and 3-thienylboronic acid (0.13 g) according to the

general procedure 2 and isolated (eluent: heptane/AcOEt 9/1) as a pale yellow powder (yield: 80%, 0.21 g): mp 156 °C; ^{1}H NMR (300 MHz, $CDCl_3$) 7.22 (dd, 1H, *J* = 5.1 and 7.5 Hz), 7.42 (dd, 1H, *J* = 2.9 and 5.1 Hz), 7.47 (dd, 1H, *J* = 1.4 and 5.1 Hz), 7.72 (dd, 1H, *J* = 0.5 and 1.5 Hz), 7.66 (dd, 1H, *J* = 1.4 and 2.9 Hz), 7.72 (dd, 1H, *J* = 0.5 and 7.8 Hz), 7.88 (dd, 1H, *J* = 1.6 and 7.5 Hz), 8.07 (dd, 1H, *J* = 0.5 and 1.5 Hz), 8.61 (dd, 1H, *J* = 1.6 and 5.1 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) 118.7 (CH), 122.9 (CH), 123.5 (CH), 124.9 (CH), 126.1 (CH), 127.0 (CH), 128.6 (CH), 129.0 (C), 131.3 (CH), 133.2 (C), 140.9 (C), 142.5 (C), 144.3 (C), 153.8 (CH), 164.5 (C), 191.0 (C); HRMS (ASAP): calcd for $C_{16}H_{10}NOS$ ($[M+H]^+$) 264.0483, found: 264.0484.

8-(2-Benzo[*b*]thienyl)-5*H*-indeno[1,2-*b*]pyridin-5-one or 6-(2-benzo[*b*]thienyl)-4-azafluorenone (2d) was prepared from **1-Br** (0.30 g) and (2-benzo[*b*]thienyl)boronic acid (0.18 g) according to the general procedure 2 and isolated (eluent: heptane/AcOEt 9/1) as a pale yellow powder (yield: 60%, 0.19 g): mp 206 °C; ^{1}H NMR (300 MHz, $CDCl_3$) 7.22 (dd, 1H, *J* = 5.1 and 7.5 Hz), 7.34-7.37 (m, 2H), 7.72 (br s, 3H), 7.77-7.84 (m, 2H), 7.88 (dd, 1H, *J* = 1.6 and 7.5 Hz), 8.17 (dd, 1H, *J* = 1.0 and 1.0 Hz), 8.62 (dd, 1H, *J* = 1.6 and 5.1 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) 118.7 (CH), 122.2 (CH), 122.4 (CH), 123.8 (CH), 124.3 (CH), 125.0 (2 CH), 125.4 (CH), 128.8 (CH), 129.2 (C), 131.8 (CH), 133.9 (C), 140.0 (C), 140.4 (C), 141.2 (C), 142.4 (C), 143.9 (C), 153.4 (CH), 164.0 (C), 190.5 (C); HRMS (ASAP): calcd for $C_{20}H_{12}NOS$ ($[M+H]^+$) 314.0640, found: 314.0637.

8-Phenyl-2-(trifluoromethyl)-5*H*-indeno[1,2-*b*]pyridin-5-one or 6-phenyl-3-(trifluoromethyl)-4-azafluorenone (4a) was prepared from **3** (0.36 g) and phenylboronic acid (0.12 g) according to the general procedure 2 and isolated (eluent: heptane/AcOEt 98/2) as a pale yellow powder (yield: 51%, 0.17 g): mp 204 °C; ^{1}H NMR (300 MHz, $CDCl_3$) 7.45-7.54 (m, 3H), 7.63 (d, 1H, *J* = 7.6 Hz), 7.70-7.75 (m, 3H), 7.85 (dd, 1H, *J* = 0.6 and 7.8 Hz), 8.13 (dd, 1H, *J* = 0.5 and 7.6 Hz), 8.22 (dd, 1H, *J* = 0.6 and 1.6 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) 120.3 (q, CH, *J* = 3.1 Hz), 120.7 (CH), 121.4 (q, C, *J* = 274 Hz), 125.2 (CH), 127.5 (2CH), 129.1 (CH), 129.2 (2CH), 130.6 (CH), 131.3 (C), 132.4 (CH), 133.9 (C), 139.4 (C), 143.5 (C), 149.2 (C), 151.9 (q, C, *J* = 35 Hz), 165.3 (C), 189.9 (C).

7-Phenyl-5*H*-indeno[1,2-*b*]pyridin-5-one or 7-phenyl-4-azafluorenone (6a) was prepared from **5** (0.30 g) and phenylboronic acid (0.12 g) according to the general procedure 2 and isolated (eluent: heptane/AcOEt 9/1) as a pale yellow powder (yield:

30%, 77 mg): mp 172 °C; ^{1}H NMR (300 MHz, $CDCl_3$) 7.25 (dd, 1H, J = 5.2 and 7.5 Hz), 7.37-7.51 (m, 3H), 7.61-7.65 (m, 2H), 7.84 (dd, 1H, J = 1.8 and 7.7 Hz), 7.94 (dd, 1H, J = 1.6 and 7.5 Hz), 7.96-8.00 (m, 2H), 8.62 (dd, 1H, J = 1.6 and 5.2 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) 121.9 (CH), 123.0 (CH), 123.4 (CH), 127.1 (2 CH), 128.5 (CH), 129.0 (C), 129.2 (2 CH), 132.0 (CH), 134.1 (CH), 135.6 (C), 139.6 (C), 141.8 (C), 144.6 (C), 153.5 (CH), 164.7 (C), 191.5 (C).

2-Chloro-3-(3-phenylbenzoyl)pyridine (7a) was also isolated (eluent: heptane/AcOEt 9/1) as a pale yellow powder (yield: 41%, 0.12 g): mp 130 °C; ^{1}H NMR (300 MHz, $CDCl_3$) 7.36-7.49 (m, 4H), 7.34-7.60 (m, 3H), 7.73-7.80 (m, 2H), 7.86 (ddd, 1H, J = 1.2, 1.8 and 7.7 Hz), 8.05 (dd, 1H, J = 1.6 and 1.6 Hz), 8.57 (dd, 1H, J = 1.8 and 4.8 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) 122.5 (CH), 127.3 (2 CH), 128.1 (CH), 128.6 (CH), 129.0 (CH), 129.1 (2 CH), 129.4 (CH), 133.0 (CH), 135.0 (C), 136.4 (C), 138.2 (CH), 139.8 (C), 142.2 (C), 147.9 (C), 151.1 (CH), 193.4 (C); HRMS (ASAP): calcd for $C_{18}H_{13}{}^{35}ClNO$ ($[M+H]^+$) 294.06857, found: 294.0682.

7-(4-Hydroxyphenyl)-5*H*-indeno[1,2-*b*]pyridin-5-one or 7-(4-hydroxyphenyl-4-azafluorenone (6b) was prepared from **5** (0.30 g) and 4-hydroxyphenylboronic acid (0.14 g) according to the general procedure 2 and isolated (eluent: heptane/AcOEt 7/3) as a pale yellow powder (yield: 41%, 0.11 g): mp 268 °C; ^{1}H NMR (300 MHz, CD_3COCD_3) 6.99 (d, 2H, J = 8.8 Hz), 7.36 (dd, 1H, J = 5.1 and 7.5 Hz), 7.65 (d, 2H, J = 8.8 Hz), 7.87-7.90 (m, 2H), 7.92-7.96 (m, 2H), 8.67 (dd, 1H, J = 1.6 and 5.1 Hz), 8.71 (br s, 1H); ^{13}C NMR (75 MHz, CD_3COCD_3) 117.8 (2 CH), 123.1 (CH), 123.2 (CH), 125.3 (CH), 130.0 (2 CH), 130.2 (C), 132.5 (C), 132.9 (CH), 134.8 (CH), 137.4 (C), 143.4 (C), 145.9 (C), 156.2 (CH), 159.9 (C), 166.7 (C), 193.0 (C); HRMS (ASAP): calcd for $C_{18}H_{12}NO_2$ ($[M+H]^+$) 274.0868, found: 274.0869.

4-Phenyl-5*H*-indeno[1,2-*b*]pyridin-5-one or 1-phenyl-4-azafluorenone (11a) was prepared from **10-Br** (0.30 g) and phenylboronic acid (0.12 g) according to the general procedure 2 and isolated (eluent: heptane/AcOEt 9/1) as a pale yellow powder (yield: 73%, 0.19 g): mp 178 °C; ^{1}H NMR (300 MHz, $CDCl_3$) 7.17 (d, 1H, J = 5.4 Hz), 7.44 (ddd, 1H, J = 1.0, 7.4 and 7.4 Hz), 7.48-7.52 (m, 3H), 7.59-7.65 (m, 3H), 7.69 (ddd, 1H, J = 1.0, 1.0 and 7.4 Hz), 7.91 (br d, 1H, J = 7.4 Hz), 8.60 (d, 1H, J = 5.4 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) 121.2 (CH), 124.1 (CH), 124.3 (C), 125.0 (CH), 128.4 (2 CH), 129.2 (2 CH), 129.9 (CH), 131.3 (CH), 134.9 (C), 134.9 (C), 135.3 (CH), 142.7 (C), 149.5 (C), 153.0

(CH), 165.9 (C), 191.2 (C); HRMS (ASAP) : calcd for $C_{18}H_{12}NO$ ($[M+H]^+$) 258.09189, found: 258.0919.

4-(4-Methoxyphenyl)-5*H*-indeno[1,2-*b*]pyridin-5-one or 1-(4-methoxyphenyl)-4-azafluorenone (11e) was prepared from **10-Br** (0.30 g) and 4-methoxyphenylboronic acid (0.15 g) according to the general procedure 2 and isolated (eluent: heptane/AcOEt 9/1) as a pale yellow powder (yield: 52%, 0.15 g): mp 168 °C; ^{1}H NMR (300 MHz, $CDCl_3$) 3.88 (s, 3H), 7.00 (d, 2H, J = 8.8 Hz), 7.13 (d, 1H, J = 5.1 Hz), 7.42 (dd, 1H, J = 7.3 and 7.4 Hz), 7.59 (m, 1H), 7.61 (d, 2H, J = 8.8 Hz), 7.67 (d, 1H, J = 7.3 Hz), 7.88 (d, 1H, J = 7.4 Hz), 8.53 (d, 1H, J = 5.1 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) 55.5 (CH_3), 113.8 (2 CH), 120.9 (CH), 123.9 (CH), 124.6 (CH), 127.1 (C), 130.9 (2 CH), 131.1 (CH), 134.9 (C), 135.1 (CH), 142.9 (C), 149.0 (C), 153.0 (CH), 161.1 (C), 166.2 (C), 191.4 (C), 1C not seen.

3-Benzoyl-2-chloro-4-(4-methoxyphenyl)pyridine (12e) was also isolated (eluent: heptane/AcOEt 9/1) as a pale yellow powder (yield: 24%, 78 mg): mp 131 °C; ^{1}H NMR (300 MHz, $CDCl_3$) 3.74 (s, 3H), 6.78 (d, 2H, J = 8.9 Hz), 7.23 (d, 2H, J = 8.9 Hz), 7.33 (d, 1H, J = 5.1 Hz), 7.37 (m, 2H), 7.52 (ddd, 1H, J = 1.3, 1.9 and 7.4 Hz), 7.68-7.71 (m, 2H), 8.51 (d, 1H, J = 5.1 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) 55.4 (CH_3), 114.4 (2 CH), 123.5 (CH), 128.8 (C), 128.9 (2 CH), 129.6 (2 CH), 130.1 (2 CH), 133.5 (C), 134.2 (CH), 136.3 (C), 148.0 (C), 149.8 (CH), 150.8 (C), 160.4 (C), 194.3 (C); HRMS (ASAP): calcd for $C_{19}H_{14}NO_2$ ($[M+H]^+$) 288.10245, found: 288.1022.

4-Methyl-5*H*-indeno[1,2-*b*]pyridin-5-one or 1-methyl-4-azafluorenone or onychine (11f) was prepared from **10-Br** (0.30 g) and methylboronic acid (60 mg) according to the general procedure 2 and isolated (eluent: heptane/AcOEt 9/1) as a pale yellow powder (yield: 52%, 0.10 g): mp 124 °C (lit.[2] mp 128-129 °C); ^{1}H NMR (300 MHz, $CDCl_3$) 2.64 (s, 3H), 6.98 (d, 1H, J = 5.3 Hz), 7.43 (ddd, 1H, J = 1.1, 7.5 and 7.5 Hz), 7.59 (ddd, 1H, J = 1.1, 7.5 and 7.5 Hz), 7.01 (ddd, 1H, J = 1.1, 1.1 and 7.5 Hz), 7.86 (d, 1H, J = 7.5 Hz), 8.42 (d, 1H, J = 5.3 Hz). These data are analogous to those previously described.[3]

1-Phenyl-5*H*-indeno[1,2-*b*]pyridin-5-one or 4-phenyl-3-azafluorenone (15) was prepared from **13** (0.25 g) and phenylboronic acid (0.12 g) according to the general procedure 2 and isolated (eluent: heptane/AcOEt 9/1) as a pale yellow powder (yield: 70%, 0.18 g): mp 164 °C; ^{1}H NMR (300 MHz, $CDCl_3$) 7.09-7.12 (m, 1H), 7.29-7.32 (m, 2H), 7.54-7.57 (m, 4H), 7.66-7.69 (m, 2H), 7.72-7.75 (m, 1H), 8.75 (d, 1H, J = 4.6 Hz);

^{13}C NMR (75 MHz, $CDCl_3$) 116.3 (CH), 123.7 (CH), 125.3 (CH), 128.8 (2 CH), 129.0 (2 CH), 129.7 (CH), 129.8 (CH), 133.6 (C), 135.2 (C), 135.4 (CH), 138.3 (C), 142.1(C), 143.8 (C), 150.6 (CH), 154.5 (C), 192.9 (C); HRMS (ASAP): calcd for $C_{18}H_{12}NO$ ($[M+H]^+$) 258.0919, found: 258.0917.

3-Phenyl-5*H*-indeno[1,2-*c*]pyridin-5-one or 2-phenyl-3-azafluorenone (16) was prepared from **14** (0.25 g) and phenylboronic acid (0.12 g) according to the general procedure 2 and isolated (eluent: heptane/AcOEt 95/5) as a pale yellow powder (yield: 64%, 0.16 g): mp 196 °C; ^{1}H NMR (300 MHz, $CDCl_3$) 7.39 (ddd, 1H, J = 1.1, 7.5 and 7.5 Hz), 7.47-7.60 (m, 3H), 7.60 (ddd, 1H, J = 1.0, 7.5 and 7.5 Hz), 7.69 (ddd, 1H, J = 1.0, 1.0 and 7.5 Hz), 7.77 (ddd, 1H, J = 1.0, 1.0 and 7.5 Hz), 8.00 (d, 1H, J = 1.1 Hz), 8.05-8.09 (m, 2H), 8.95 (d, 1H, J = 1.1 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) 115.5 (CH), 121.9 (CH), 125.8 (CH), 127.4 (2 CH), 129.4 (2 CH), 130.4 (CH), 130.9 (CH), 133.1 (C), 133.8 (C), 136.2 (CH), 136.6 (C), 140.0 (CH), 142.5 (C), 143.1 (C), 158.6 (C), 192.1 (C); HRMS (ASAP): calcd for $C_{18}H_{12}NO$ ($[M+H]^+$) 258.0919, found: 258.0919.

General procedure 3: tandem reaction including Heck coupling. A degassed mixture containing K_2CO_3 (0.28 g, 2.0 mmol), $Pd(OAc)_2$ (11 mg, 50 µmol, 5 mol%), $Cy_3P{\cdot}HBF_4$ (37 mg, 0.10 mmol, 10 mol%), the required ketone (1.0 mmol) and *tert*-butyl acrylate (0.15 mL, 1.0 mmol) in DMF (4 mL) was heated at 130 °C for 24 h. After filtration over a celite pad, washing using CH_2Cl_2 (3 x 10 mL), and removal of the solvent under reduced pressure, the product was isolated after purification by flash chromatography on silica gel (the eluent is given in the product description).

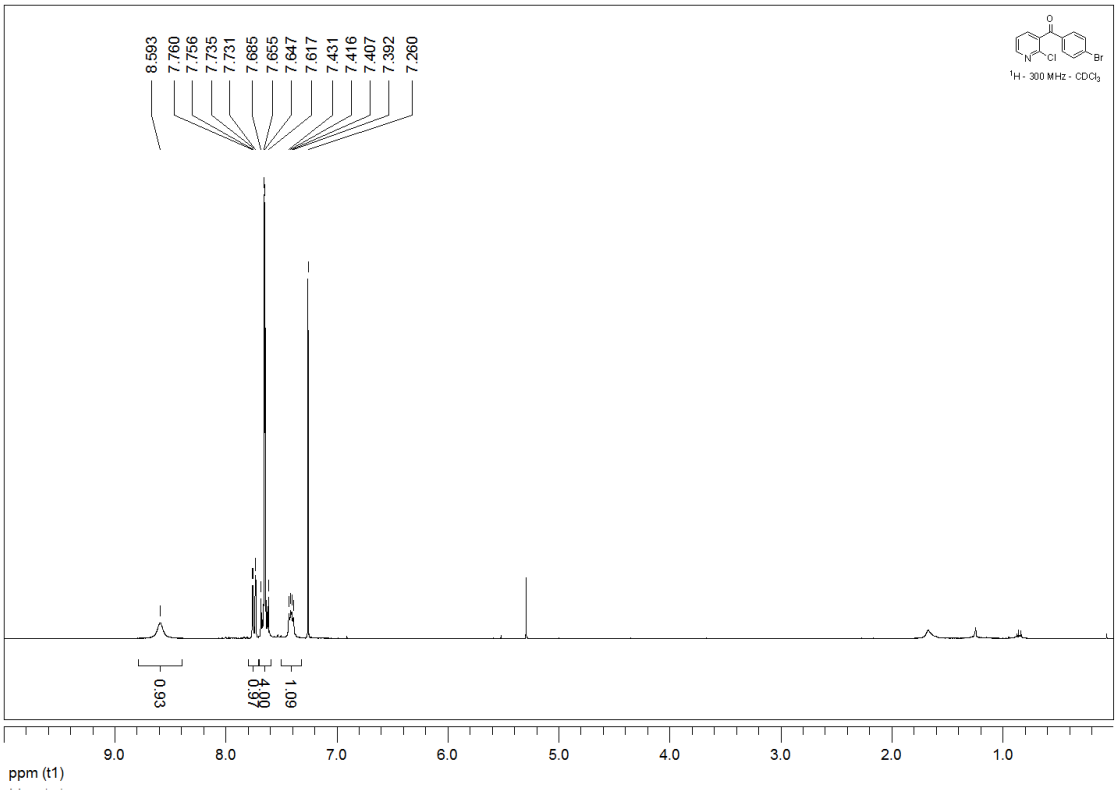
(*E*)-*tert*-Butyl 3-(5-oxo-5*H*-indeno[1,2-*b*]-8-pyridyl)acrylate (17) was prepared from **1-Br** (0.30 g) according to the general procedure 3 and isolated (eluent: heptane/AcOEt 8/2) as a pale yellow powder (yield: 81%, 0.25 g): mp 129 °C; ^{1}H NMR (300 MHz, $CDCl_3$) 1.55 (s, 9H), 6.67 (d, 1H, J = 16.0 Hz), 7.28-7.29 (m, 1H), 7.54 (dd, 1H, J = 0.9 and 7.7 Hz), 7.63 (d, 1H, J = 16.0 Hz), 7.74 (d, 1H, J = 7.7 Hz), 7.94 (dd, 1H, J = 1.5 and 7.5 Hz), 8.07 (br s, 1H), 8.65 (br d, 1H, J = 4.1 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) 28.3 (3 CH_3), 81.2 (C), 119.5 (CH), 123.7 (CH), 123.8 (CH), 124.7 (CH), 128.9 (C), 131.2 (CH), 131.6 (CH), 135.6 (C), 141.7 (C), 141.8 (CH), 144.2 (C), 154.3 (CH), 164.4 (C), 165.7 (C), 190.9 (C); HRMS (ESI): calcd for $C_{19}H_{17}NNaO_3$ ($[M+Na]^+$) 330.1106, found: 330.1104.

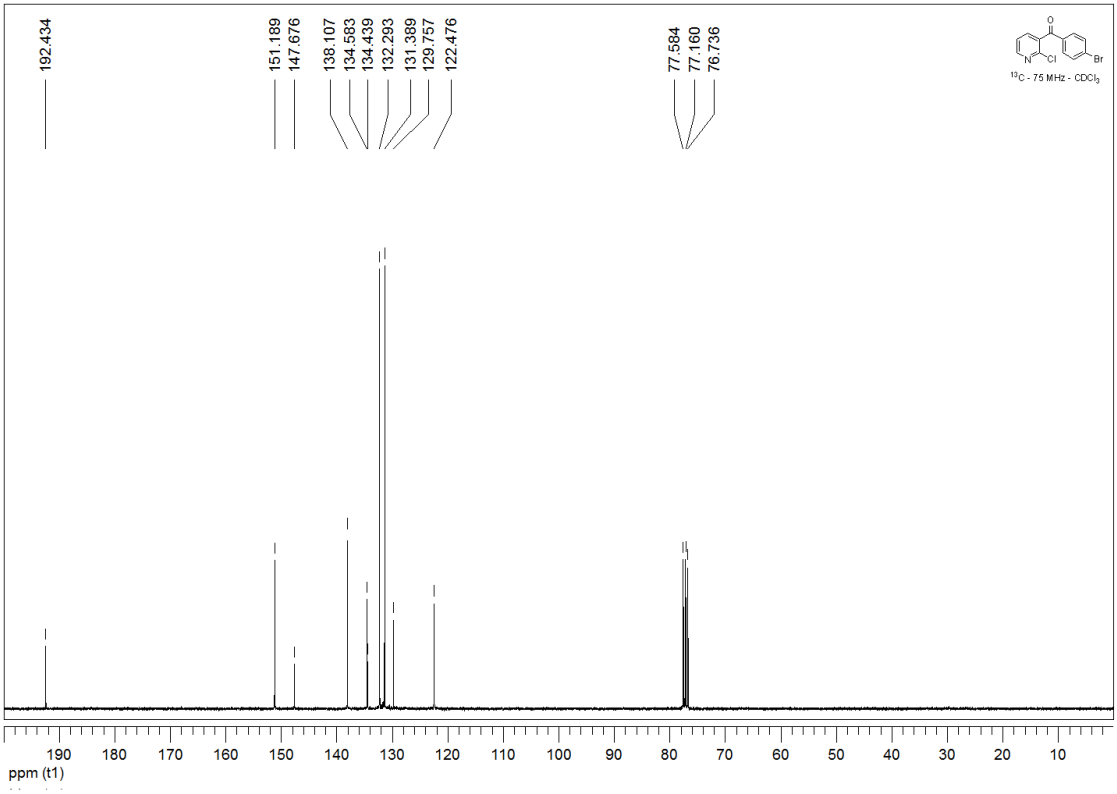
(*E*)-*tert*-Butyl 3-(4-(2-chloronicotinoyl)phenyl)acrylate (18) was prepared from **1-I**

(0.34 g) according to the general procedure 2 and isolated (eluent: heptane/AcOEt 9/1) as a yellow oil (yield: 80%, 0.28 g): ^{1}H NMR (300 MHz, $CDCl_3$) 1.54 (s, 9H), 6.48 (d, 1H, *J* = 16.0 Hz), 7.40 (dd, 1H, *J* = 4.8 and 7.5 Hz), 7.57-7.62 (m, 3H), 7.76 (dd, 1H, *J* = 1.8 and 7.5 Hz), 7.80 (m, 2H), 8.57 (dd, 1H, *J* = 1.8 and 4.8 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) 28.2 (3 CH_3), 81.2 (C), 122.4 (CH), 123.6 (CH), 128.3 (2 CH), 130.5 (2 CH), 134.8 (C), 136.5 (C), 138.1 (CH), 140.2 (C), 141.7 (CH), 147.8 (C), 151.1 (CH), 165.7 (C), 192.7 (C); HRMS (ESI) : calcd for $C_{19}H_{18}NO_3{}^{35}ClNa$ ($[M+Na]^+$) 366.08729, found: 366.0873.

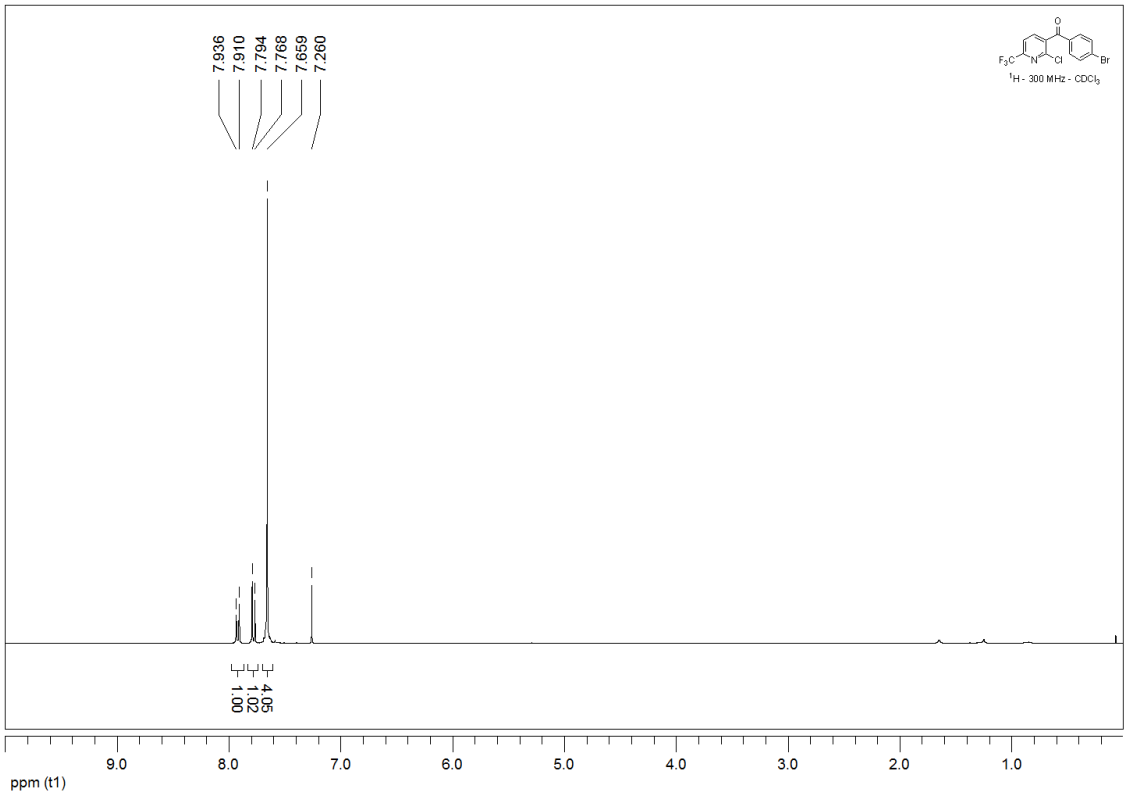
3. ^{1}H- and ^{13}C-NMR Spectra

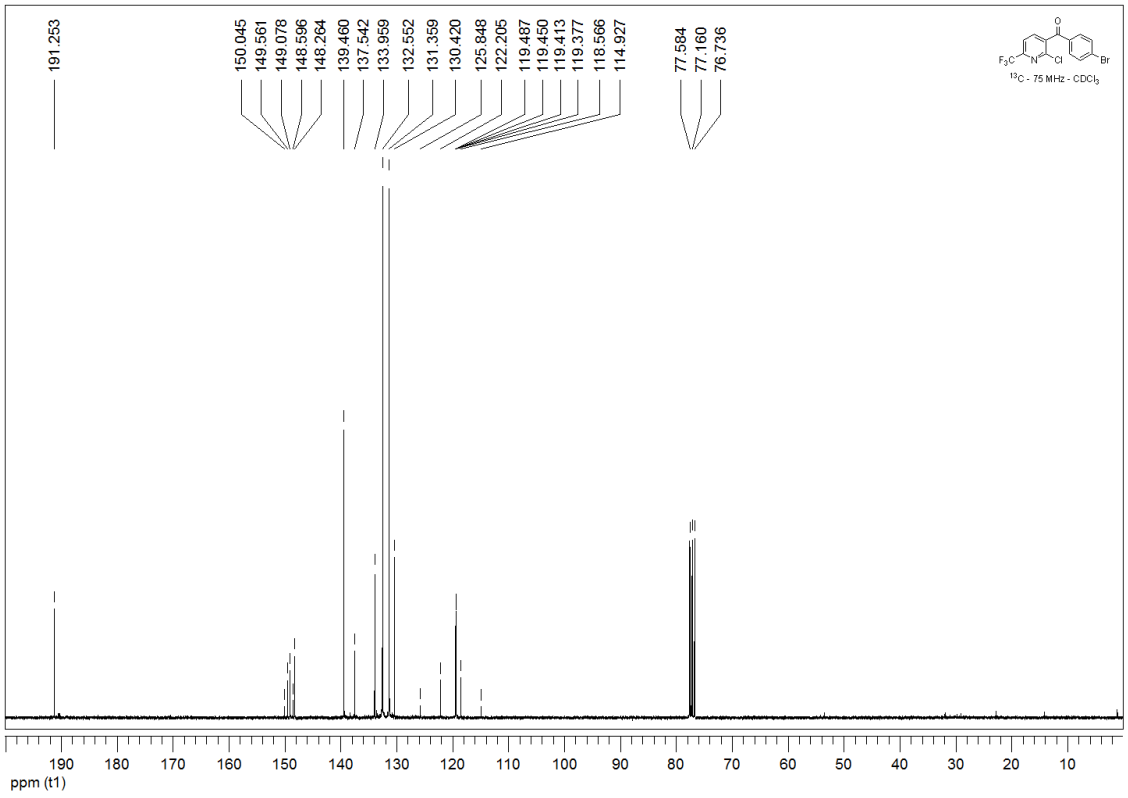
3-(4-Bromobenzoyl)-2-chloropyridine (1-Br)



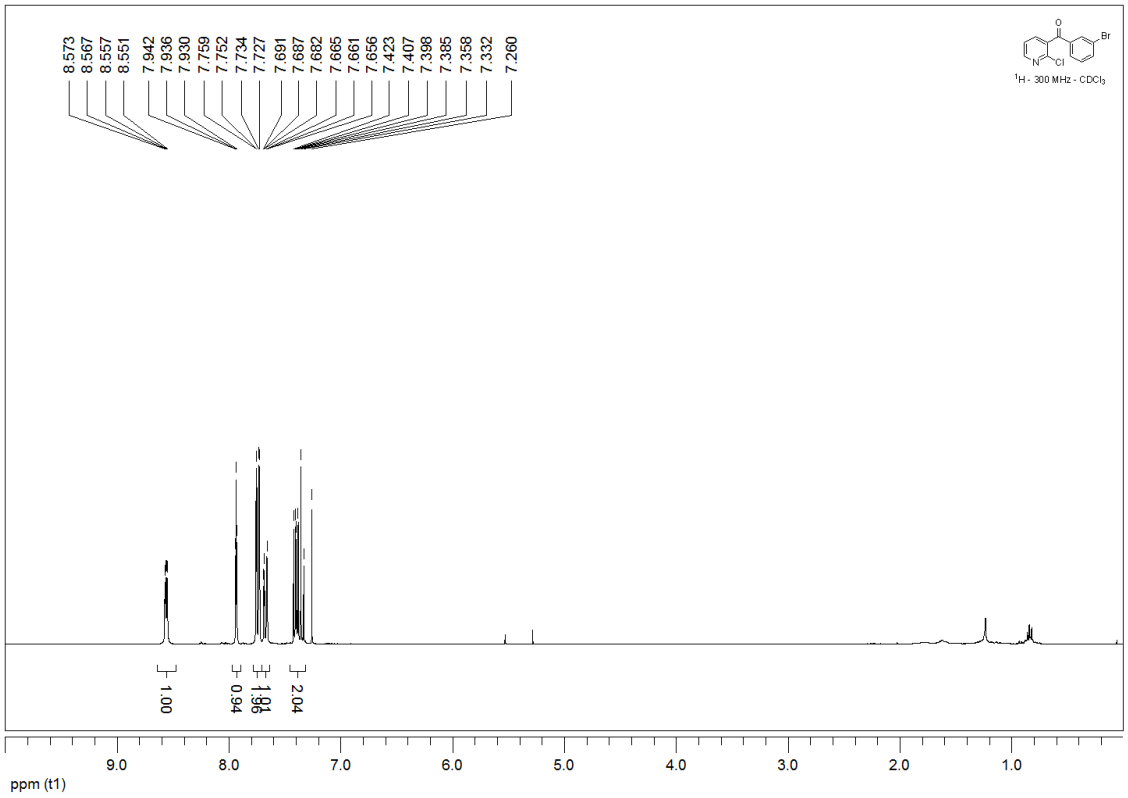


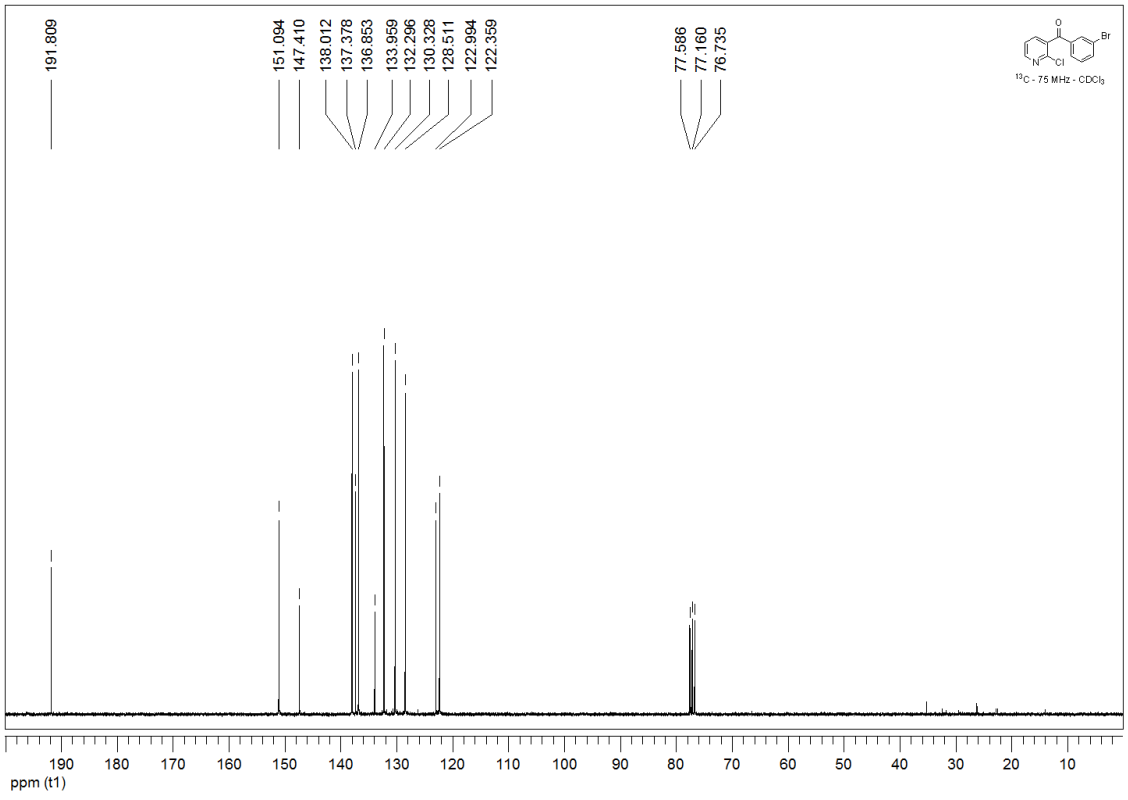
3-(4-Bromobenzoyl)-2-chloro-6-(trifluoromethyl)pyridine (3)



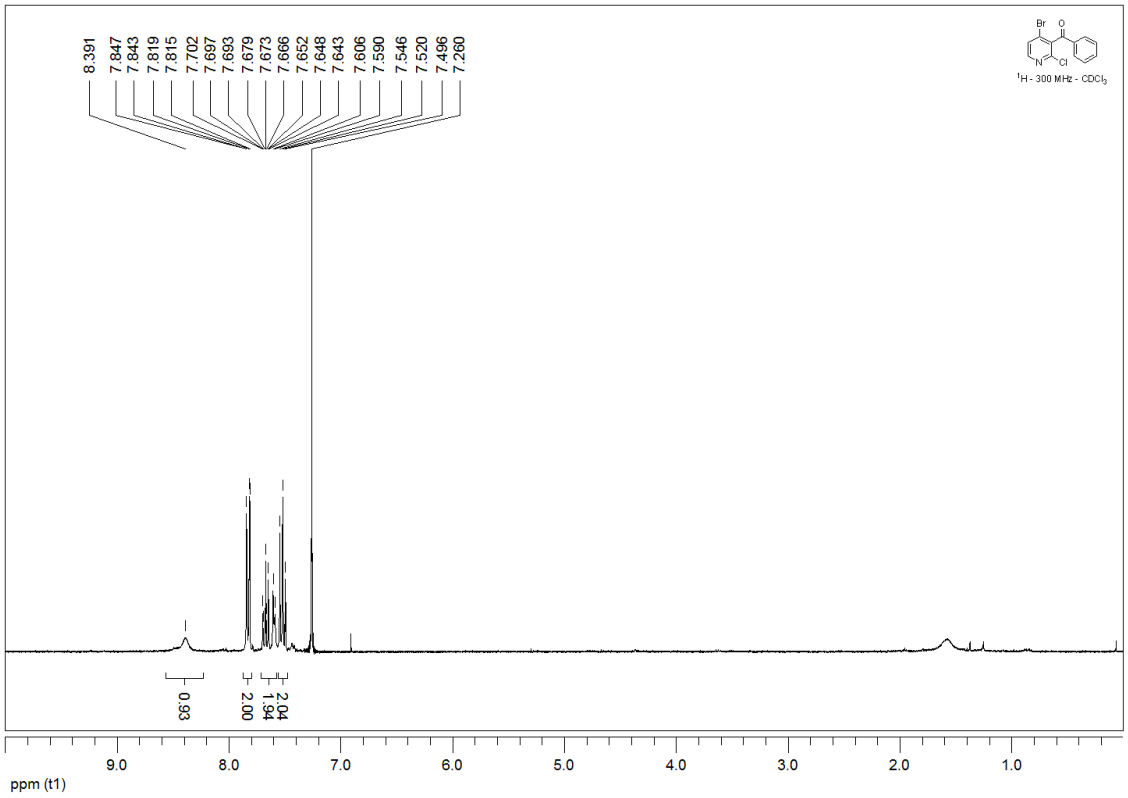


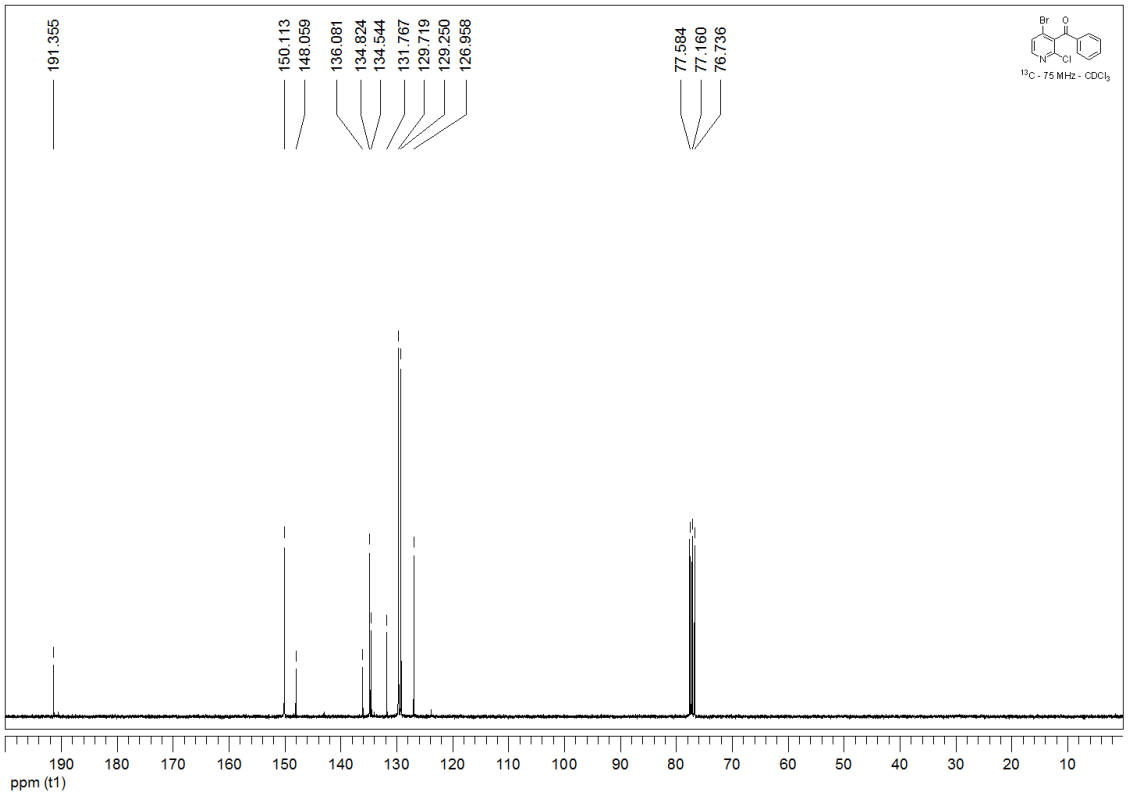
2-Chloro-3-(3-bromobenzoyl)pyridine (5)



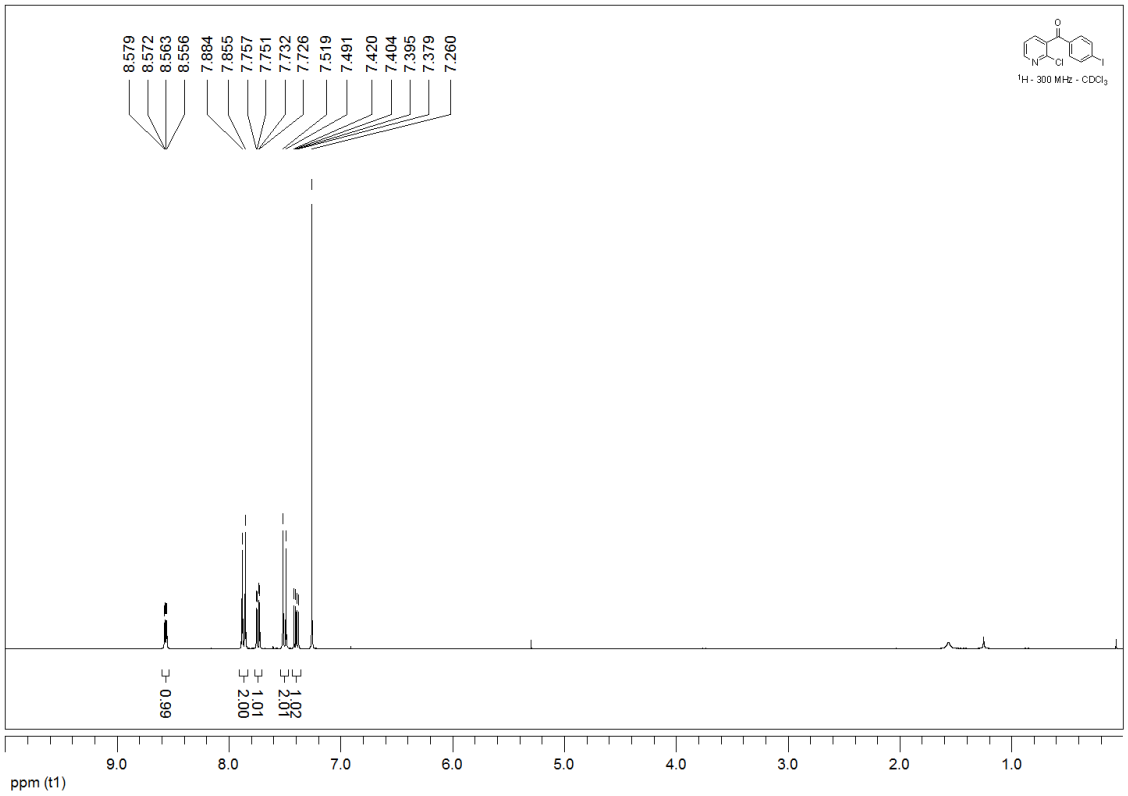


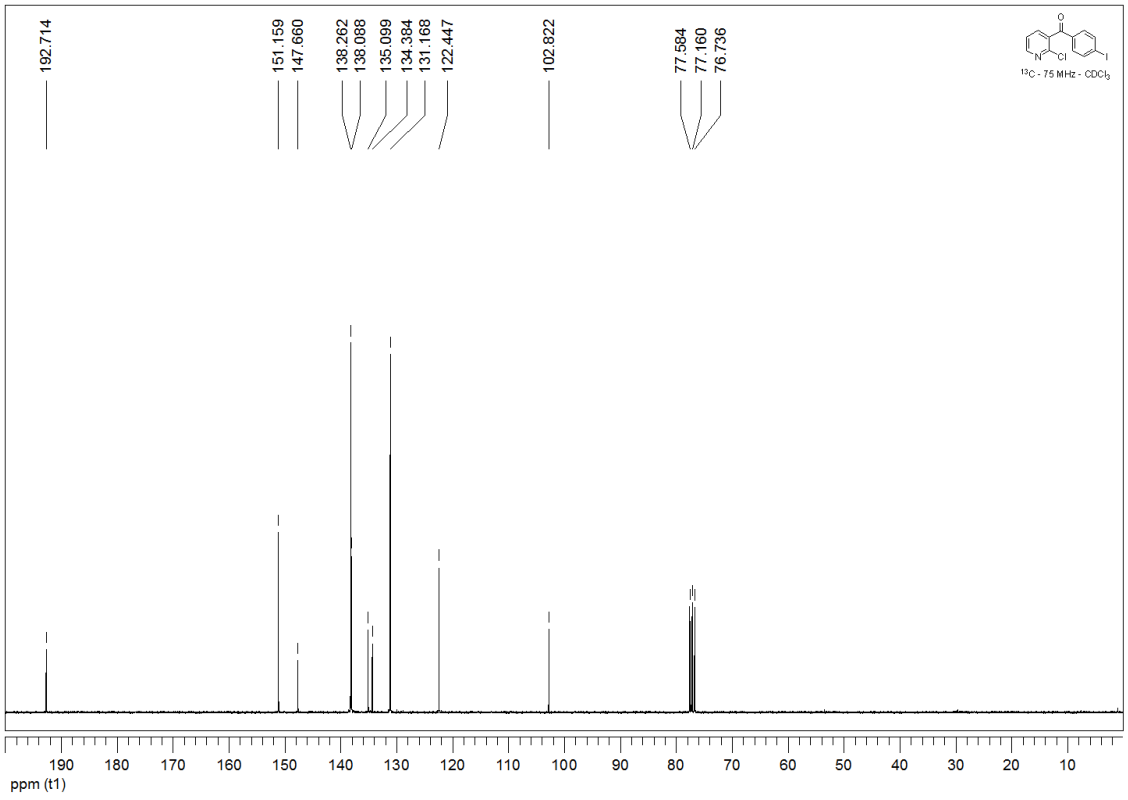
2-Chloro-3-benzoyl-4-bromopyridine (10-Br)



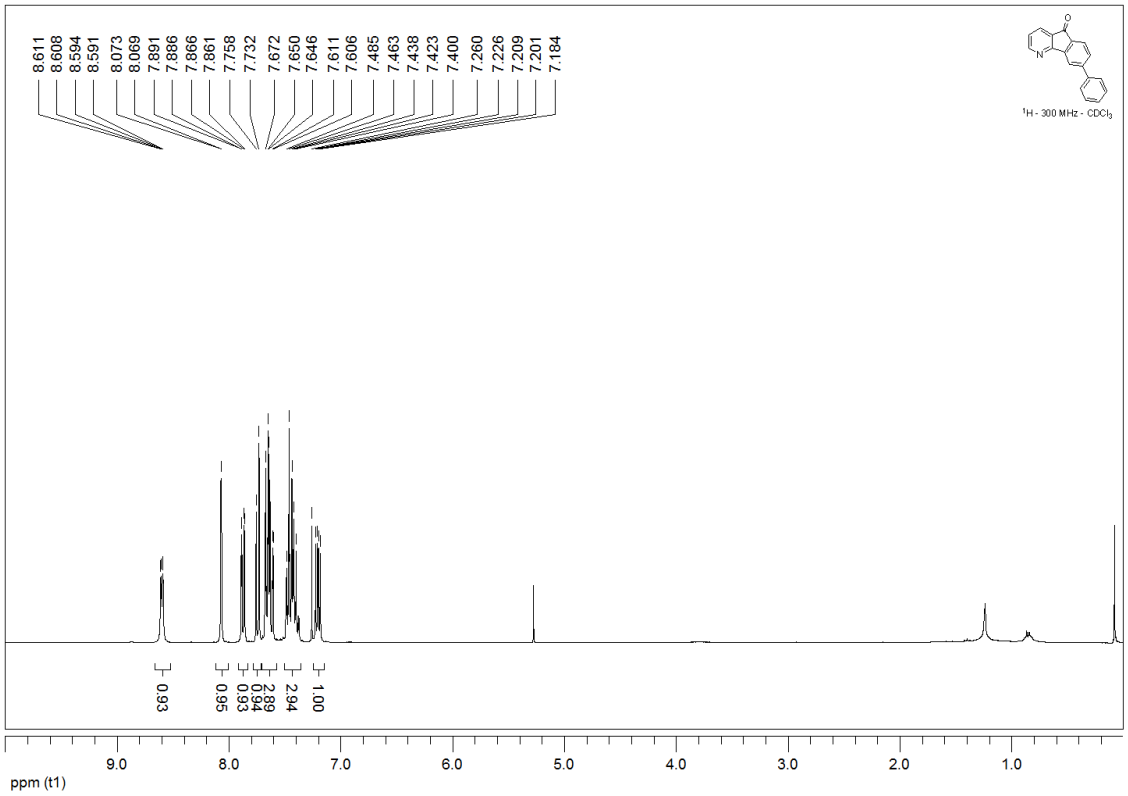


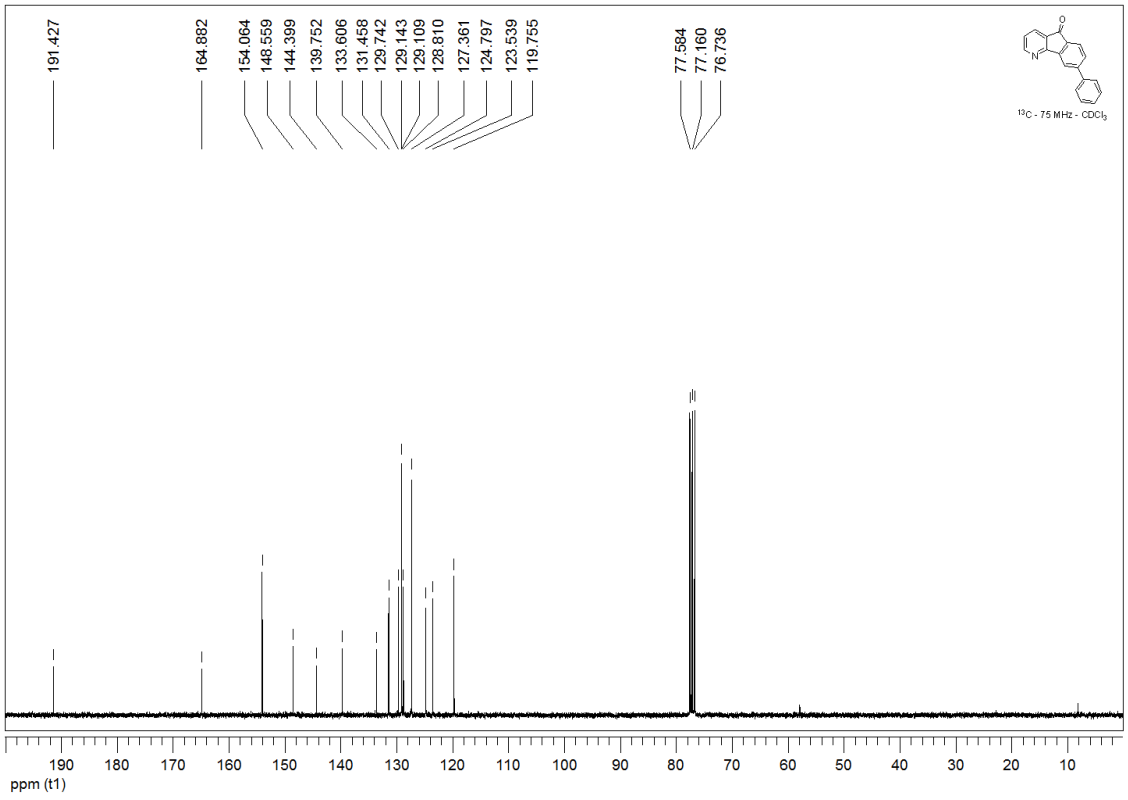
2-Chloro-3-(4-iodobenzoyl)pyridine (1-I)



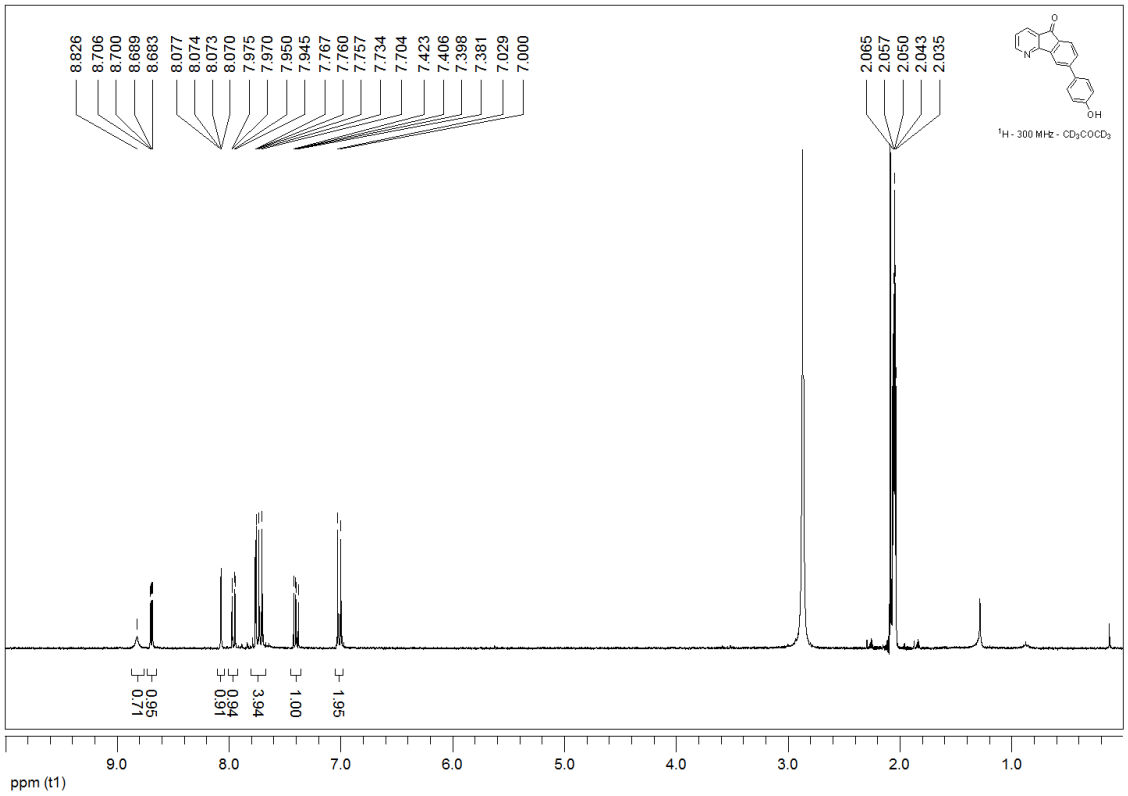


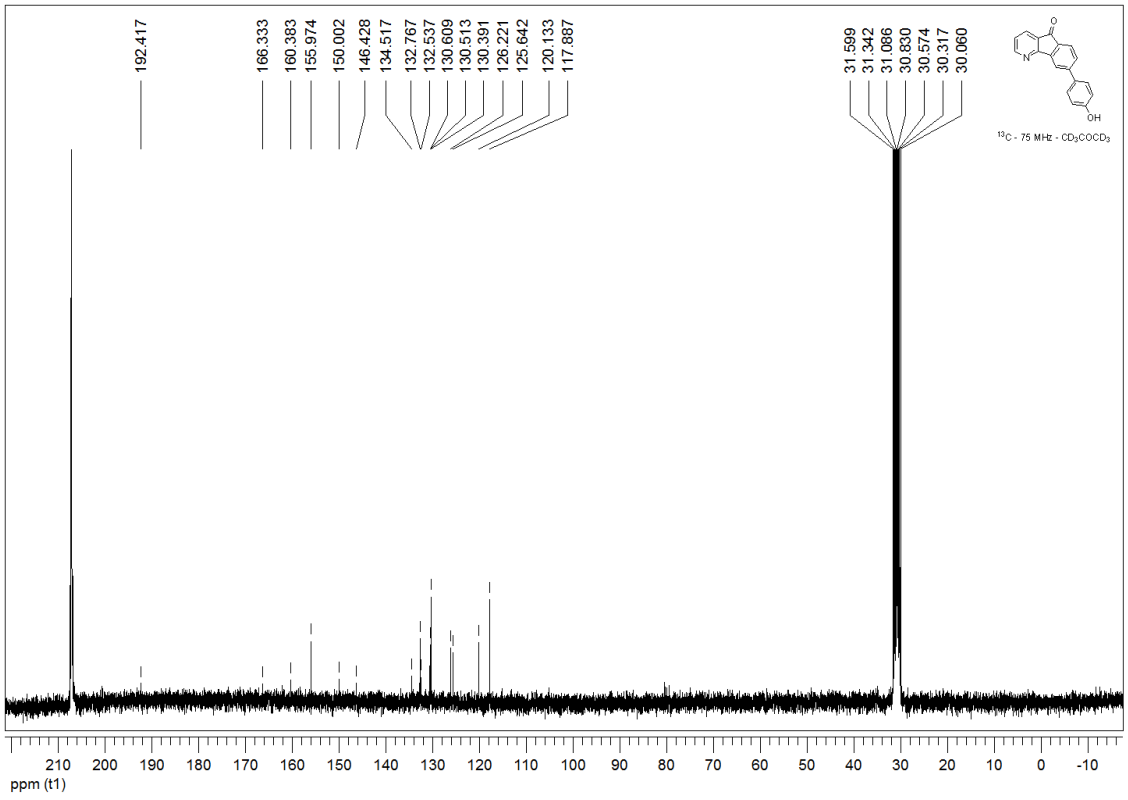
6-Phenyl-4-azafluorenone (2a)



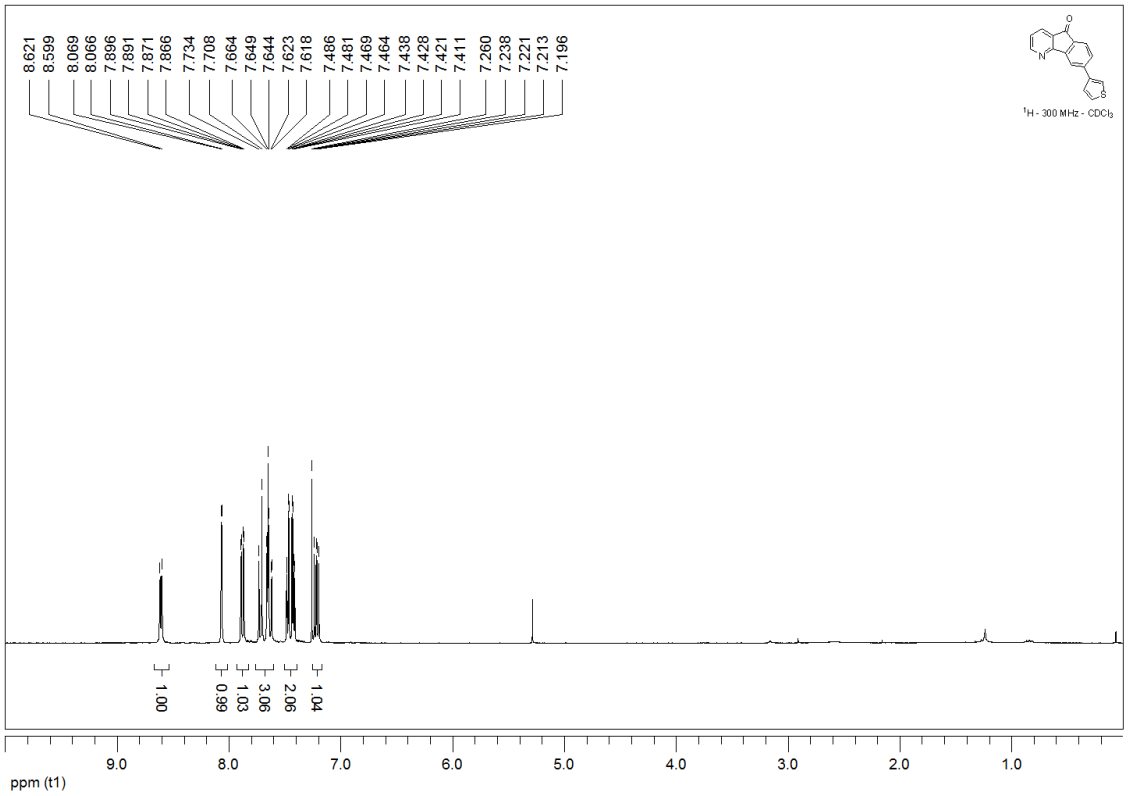


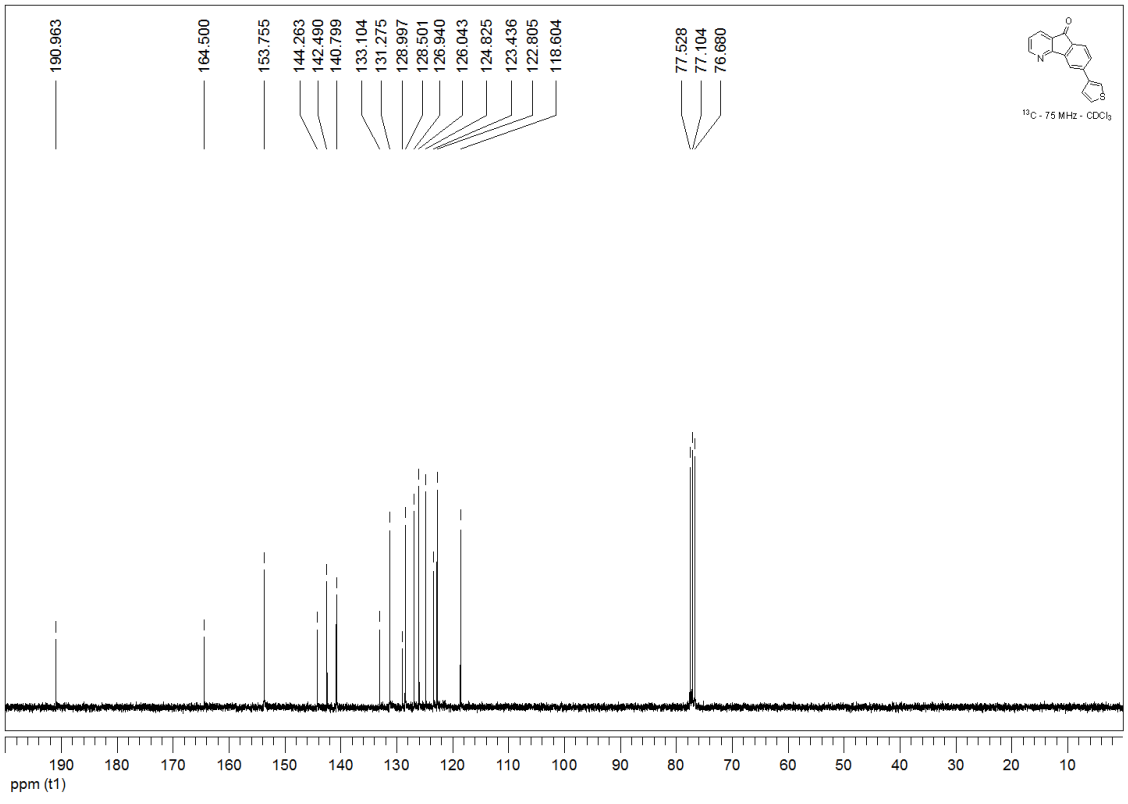
6-(4-Hydroxyphenyl-4-azafluorenone (2b)



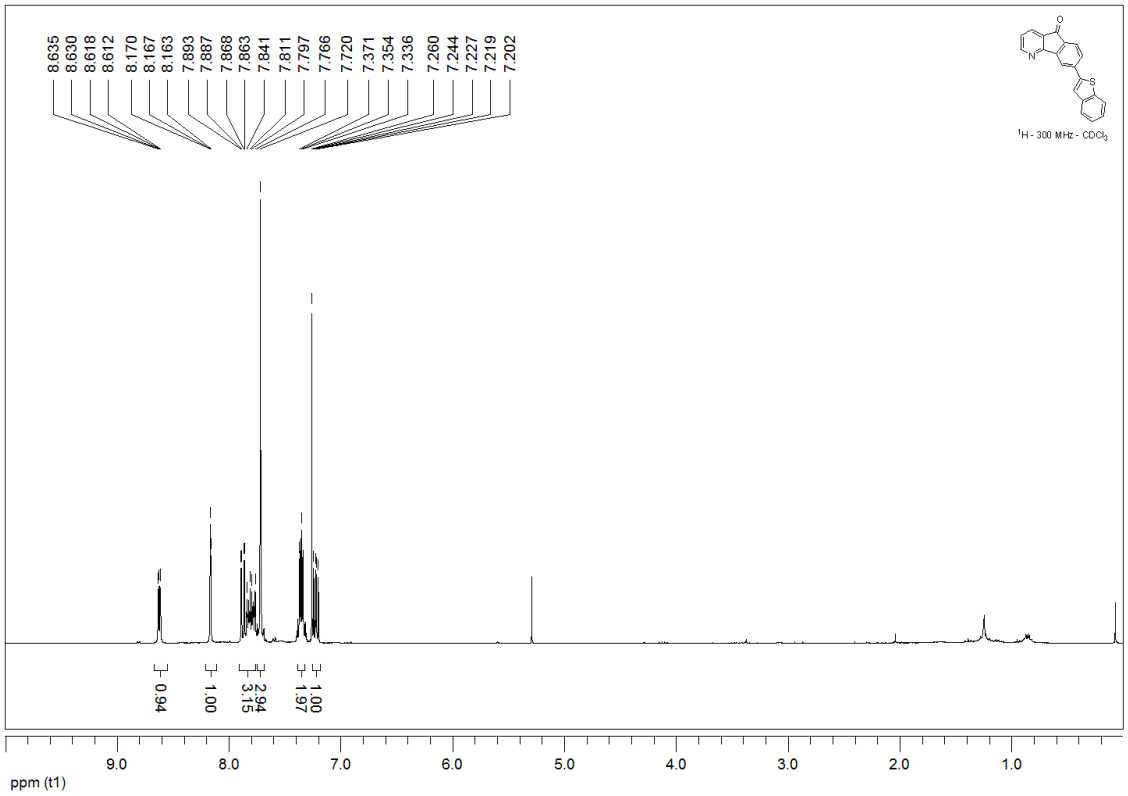


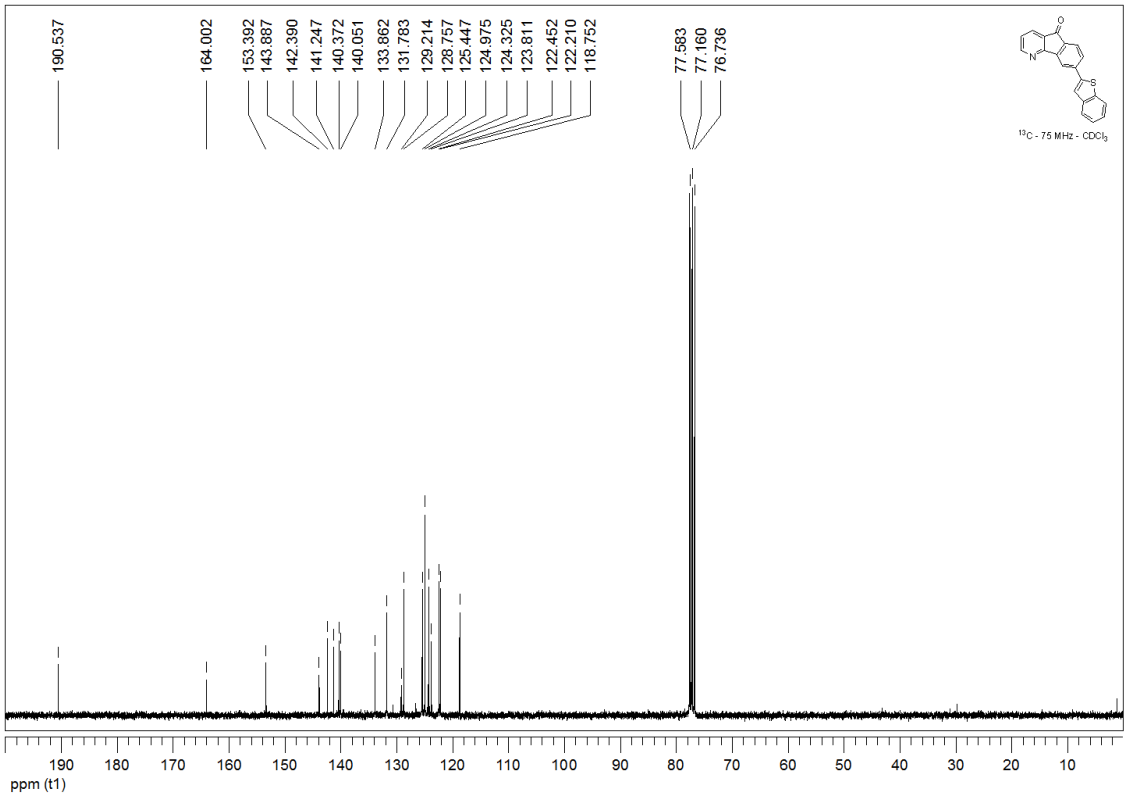
6-(3-Thienyl)-4-azafluorenone (2c)



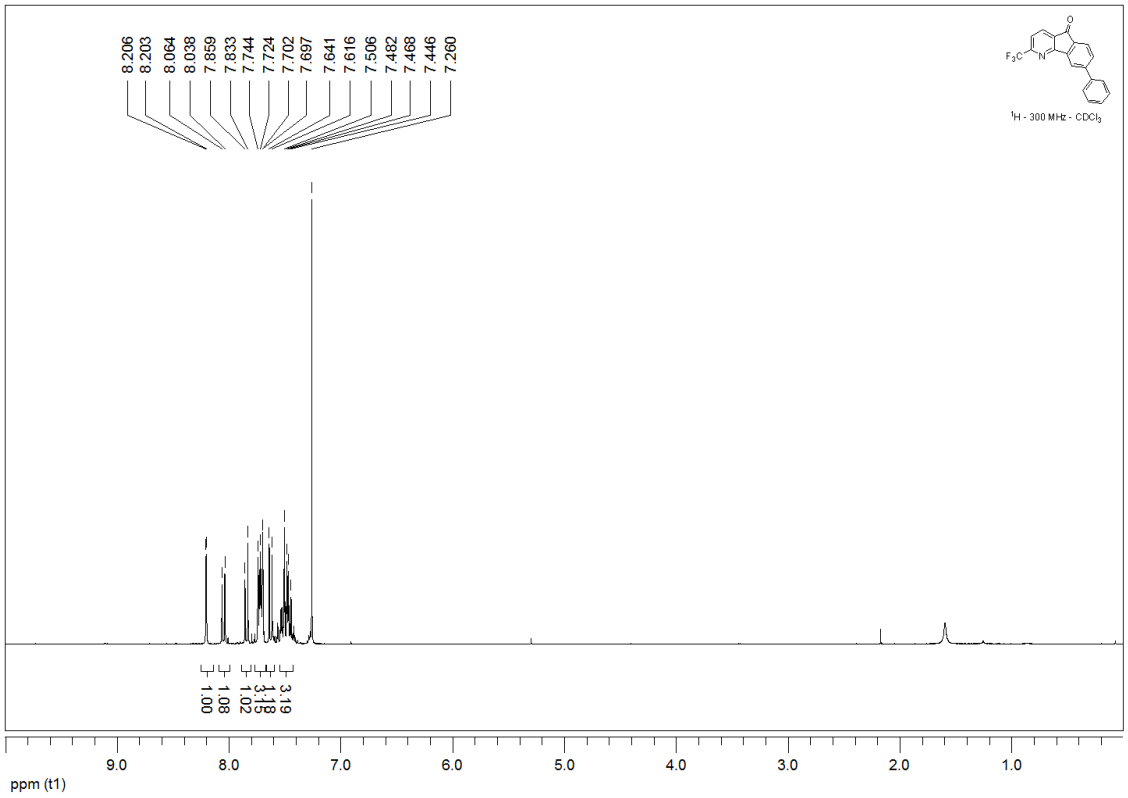


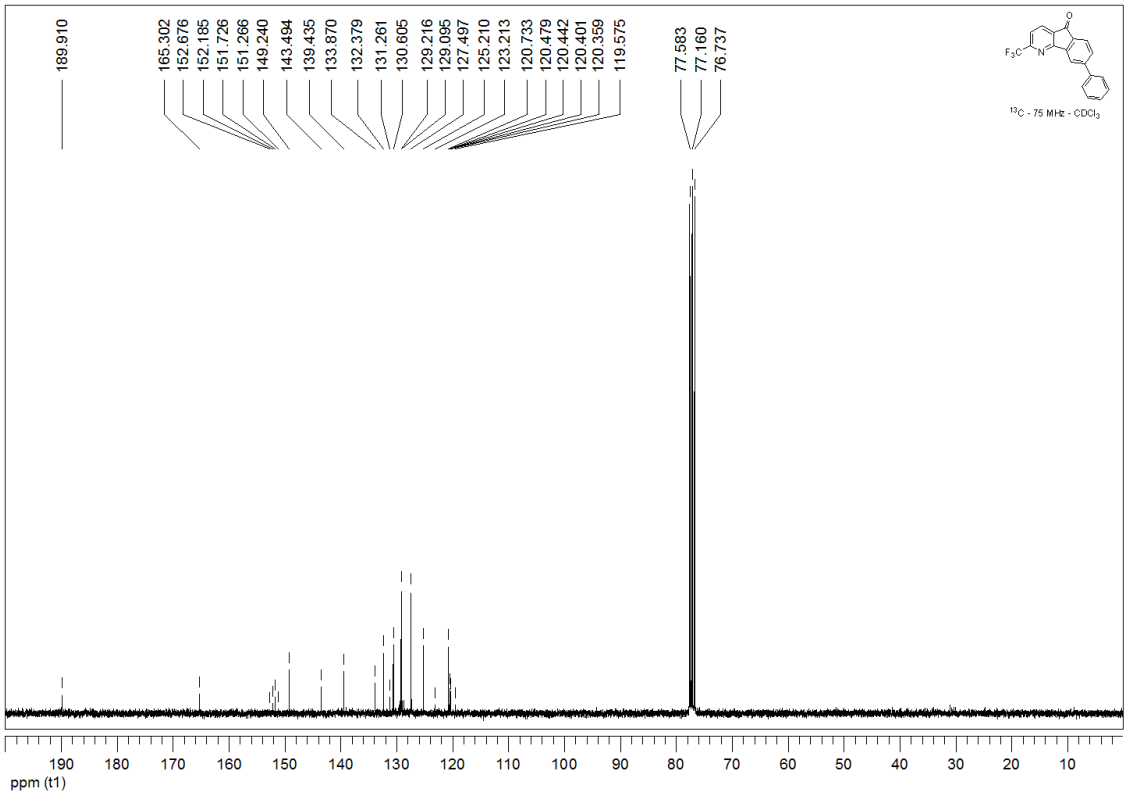
6-(2-Benzo[*b*]thienyl)-4-azafluorenone (2d)



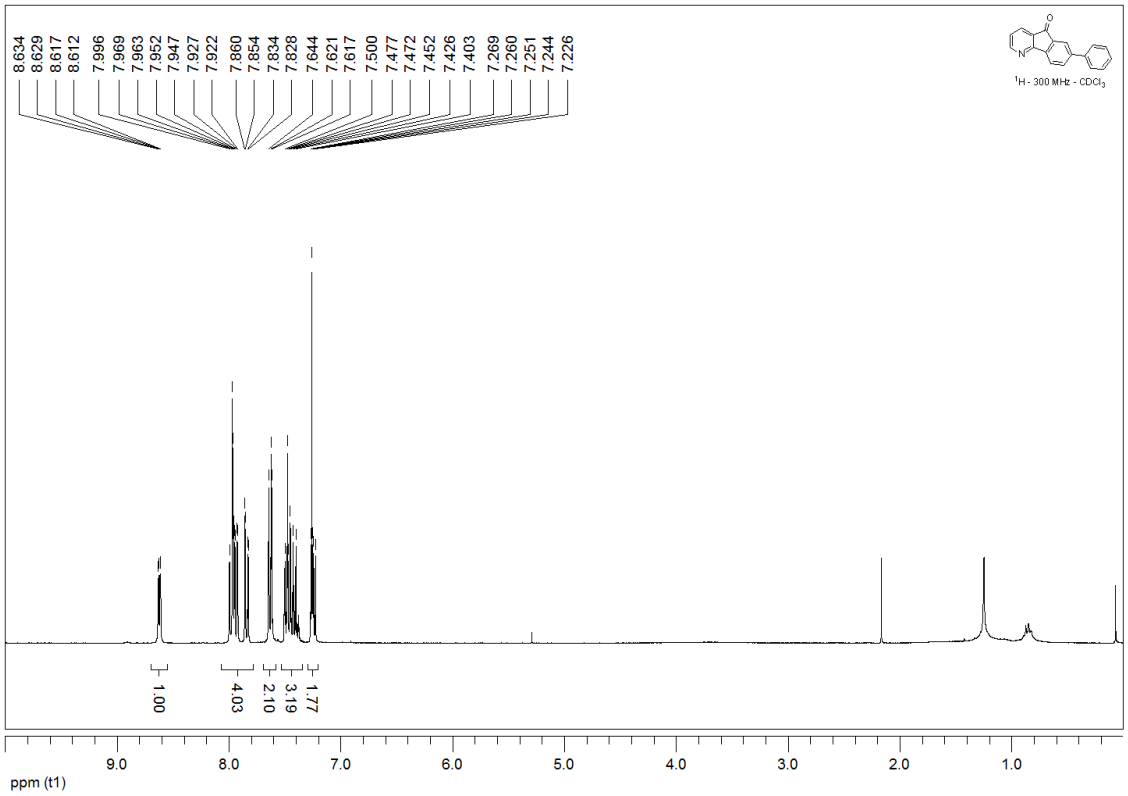


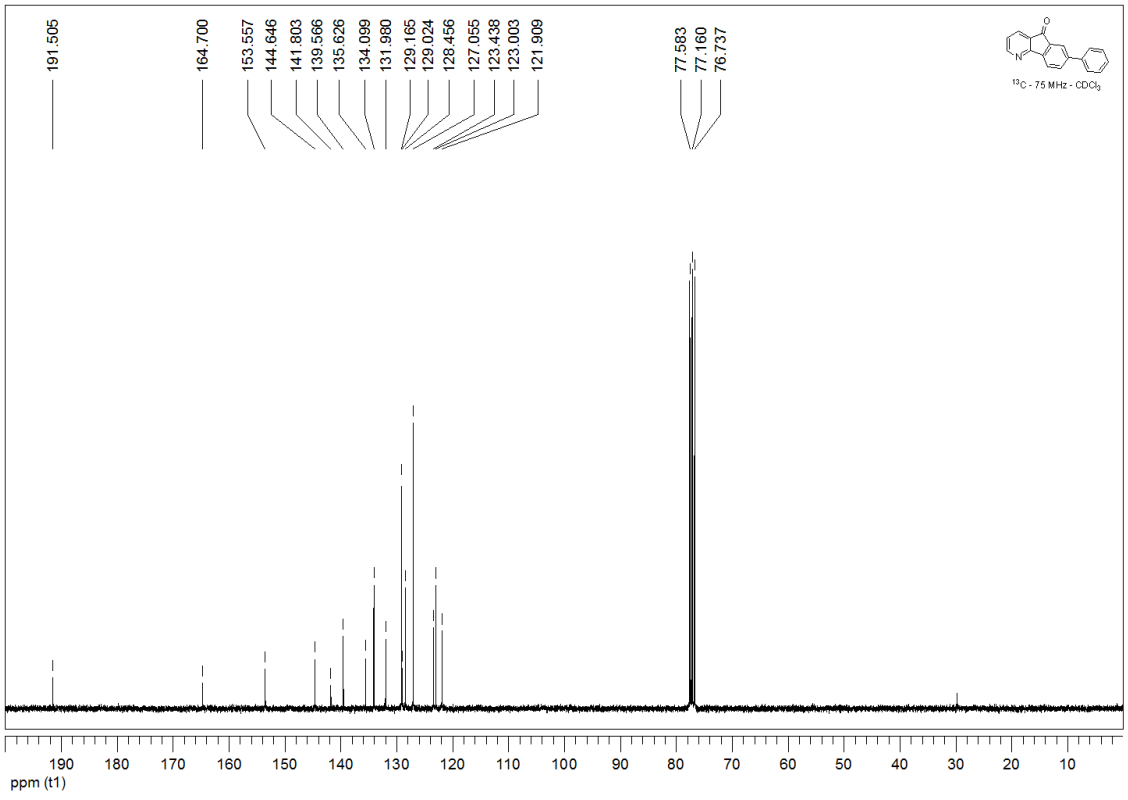
6-Phenyl-3-(trifluoromethyl)-4-azafluorenone (4a)



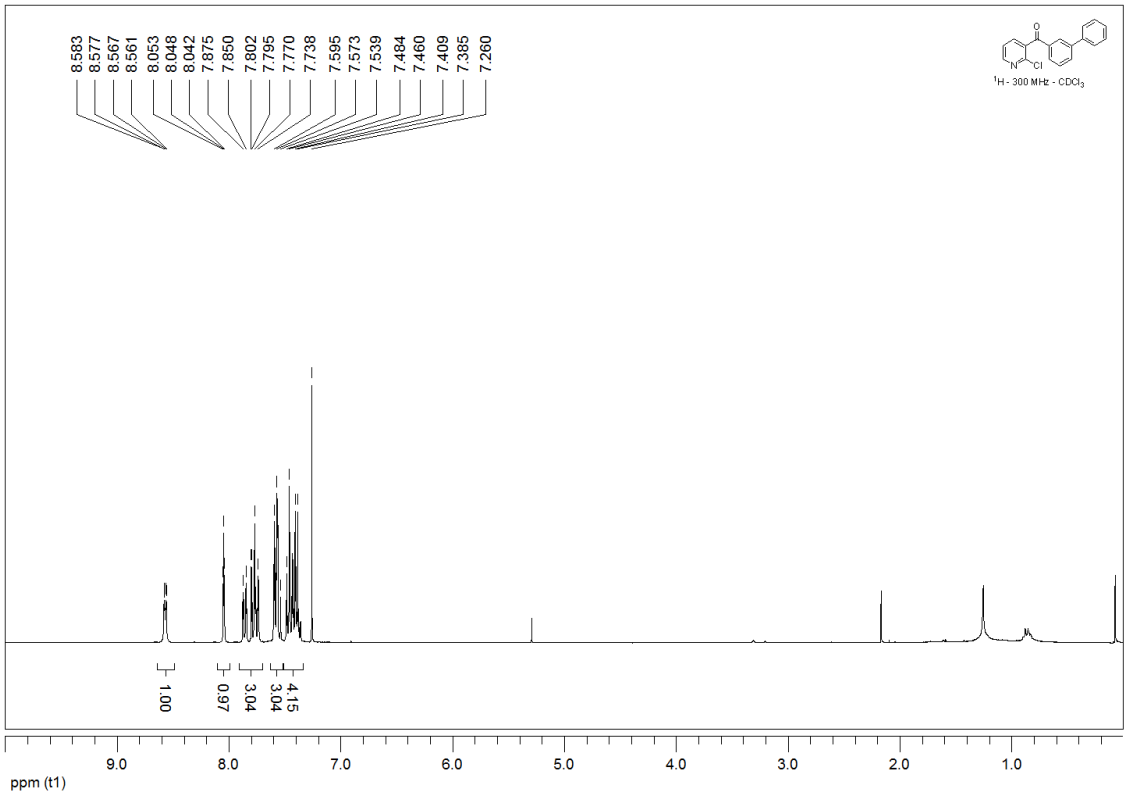


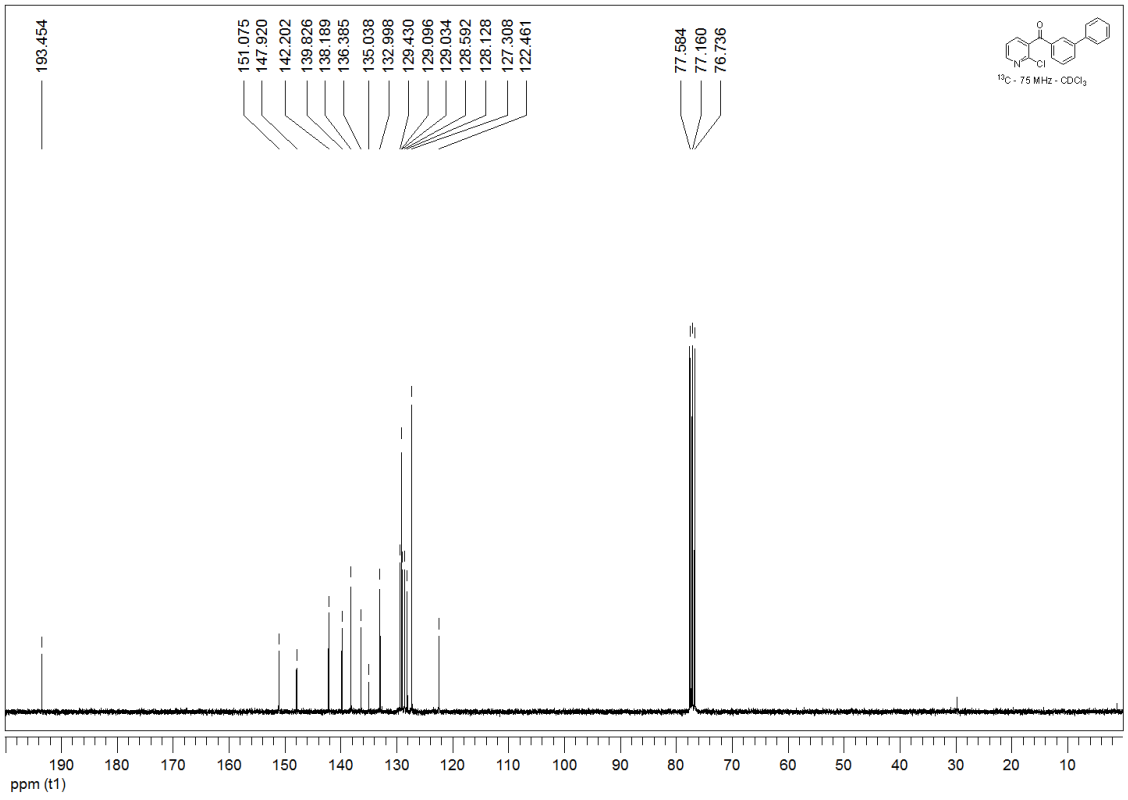
7-Phenyl-4-azafluorenone (6a)



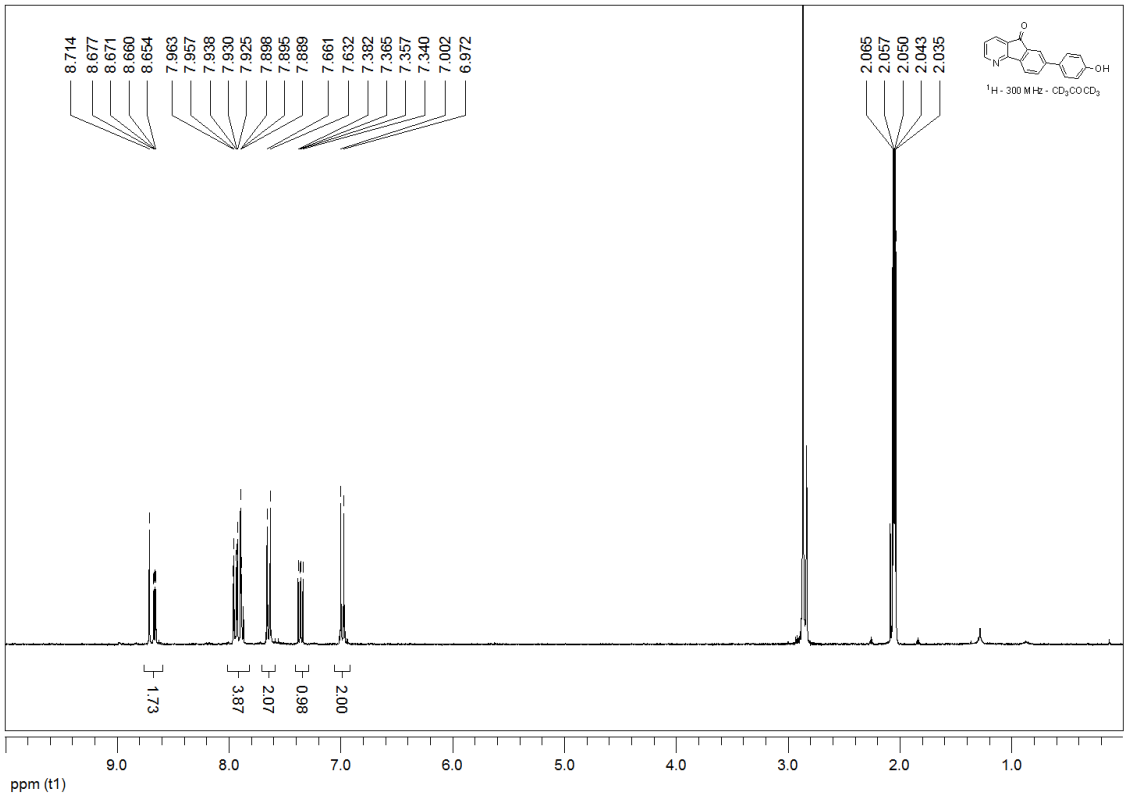


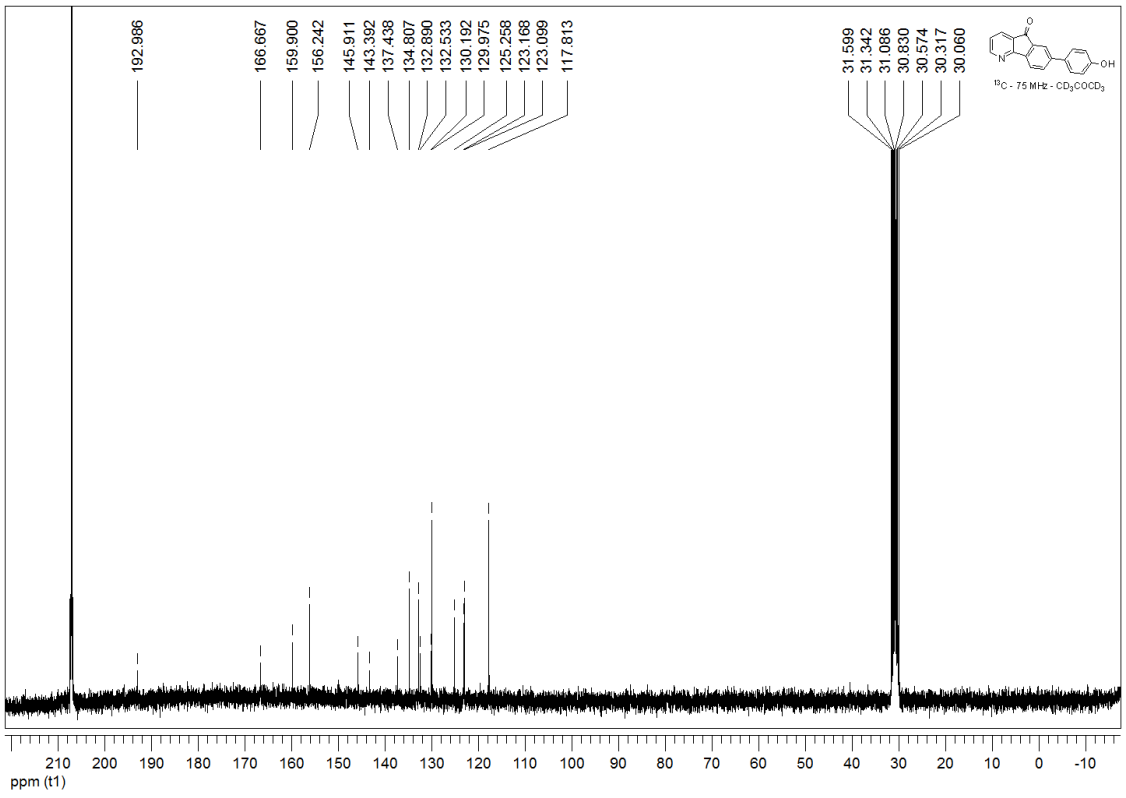
2-Chloro-3-(3-phenylbenzoyl)pyridine (7a)



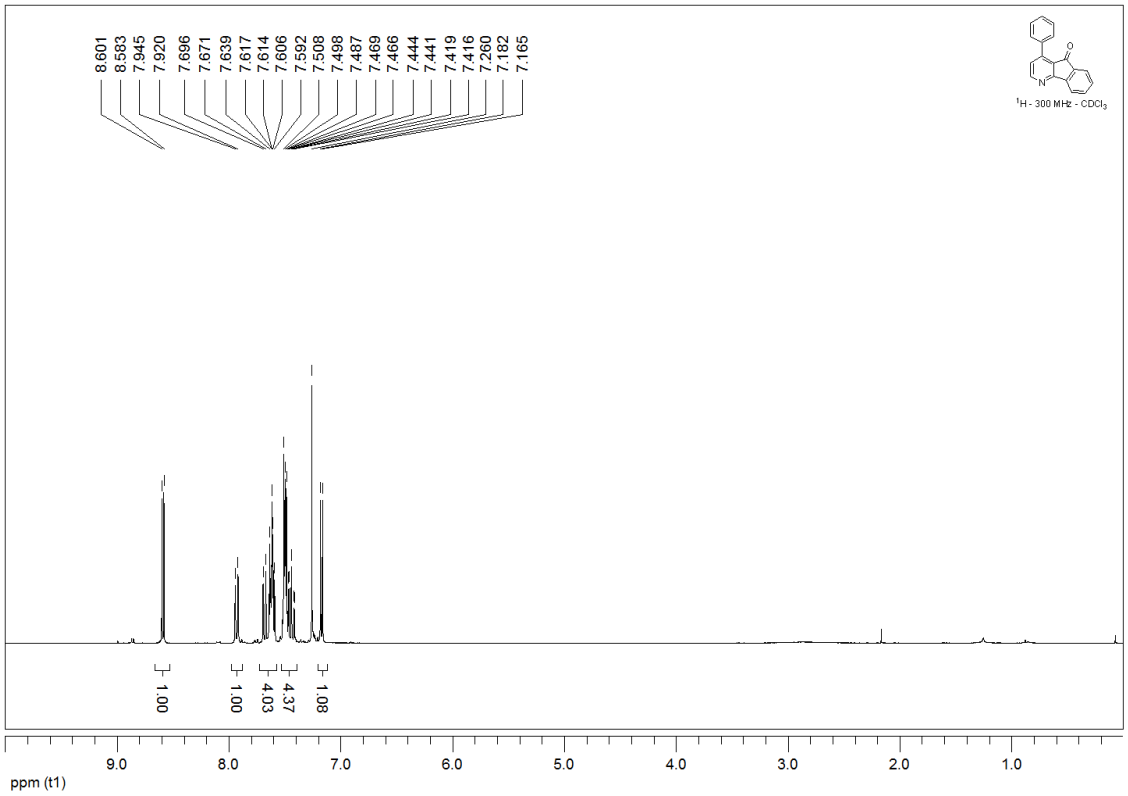


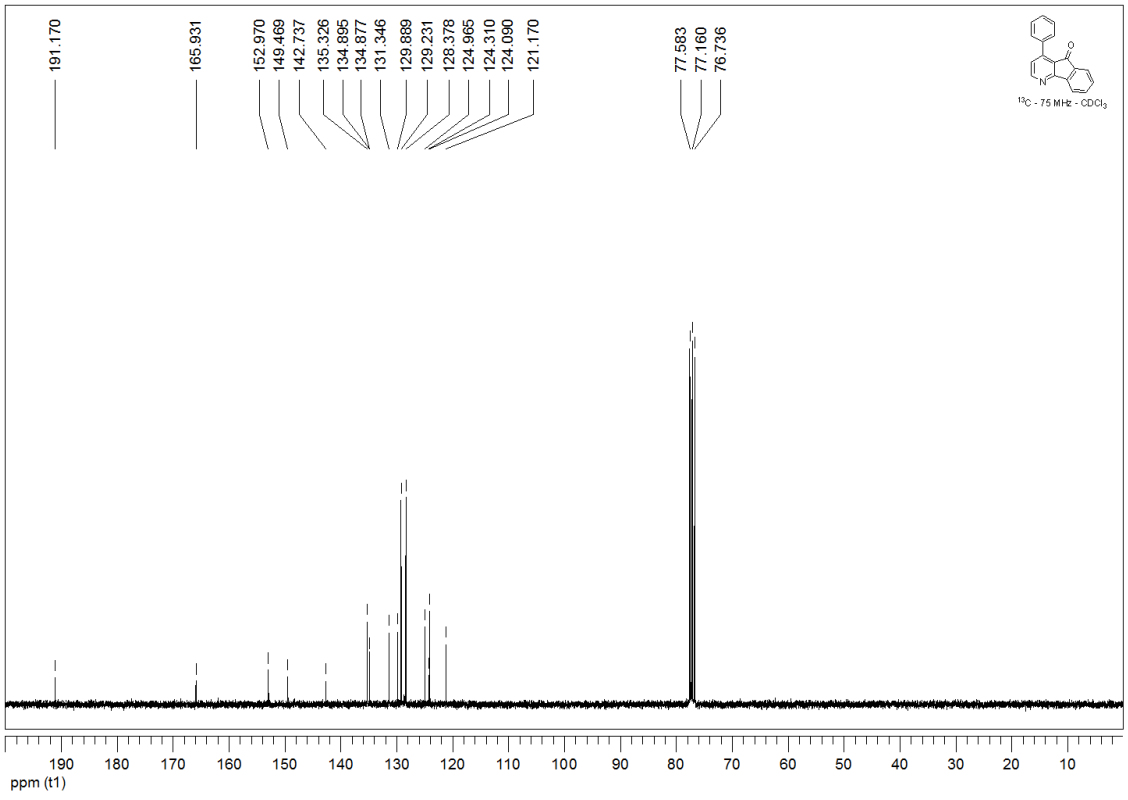
7-(4-Hydroxyphenyl-4-azafluorenone (6b)



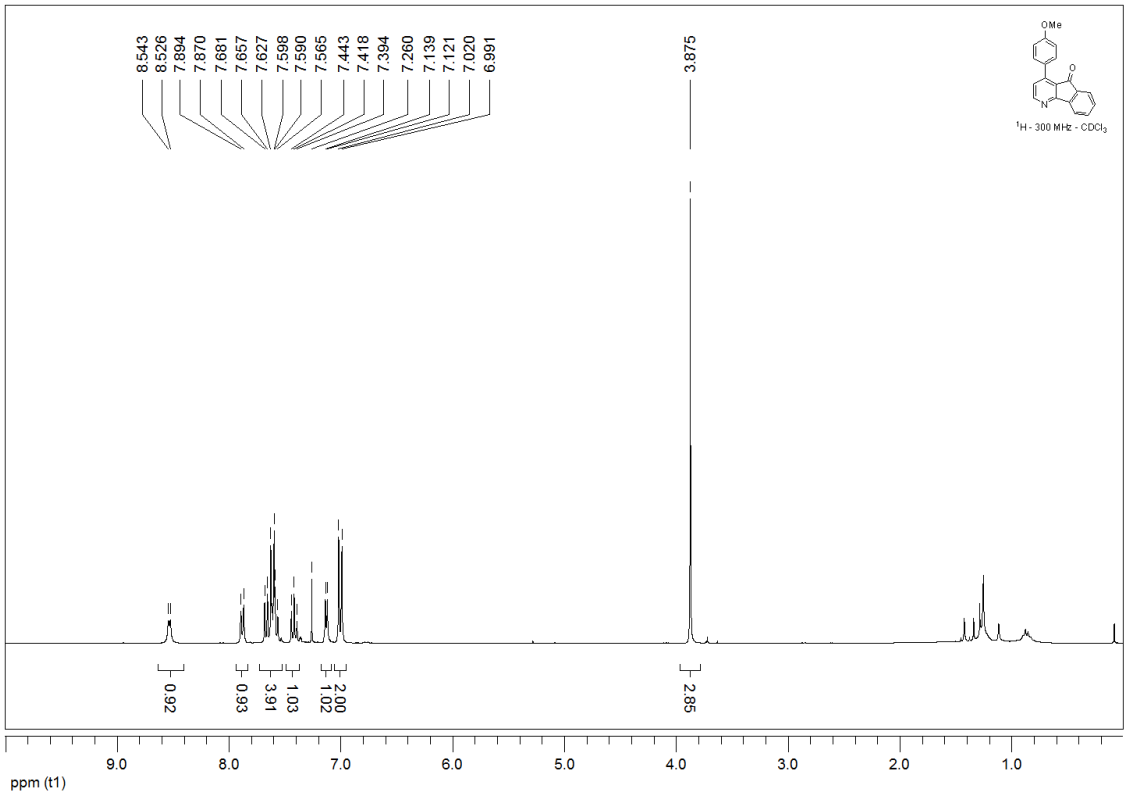


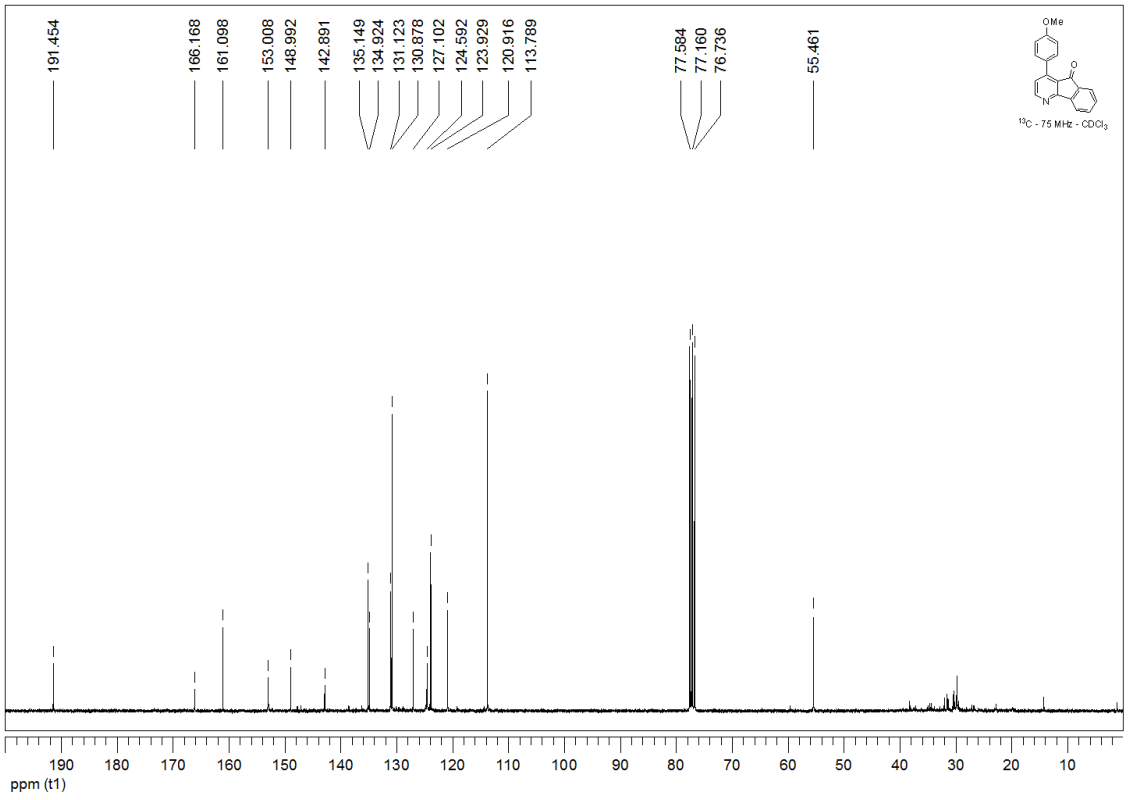
1-Phenyl-4-azafluorenone (11a)



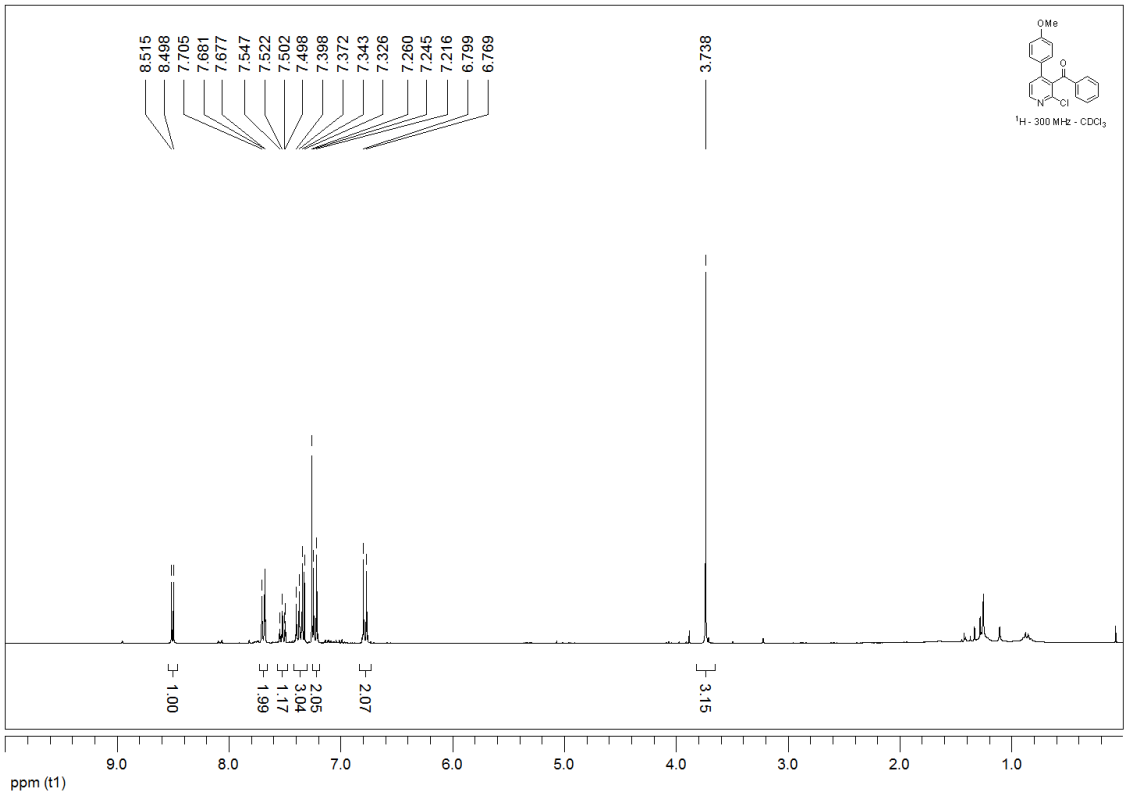


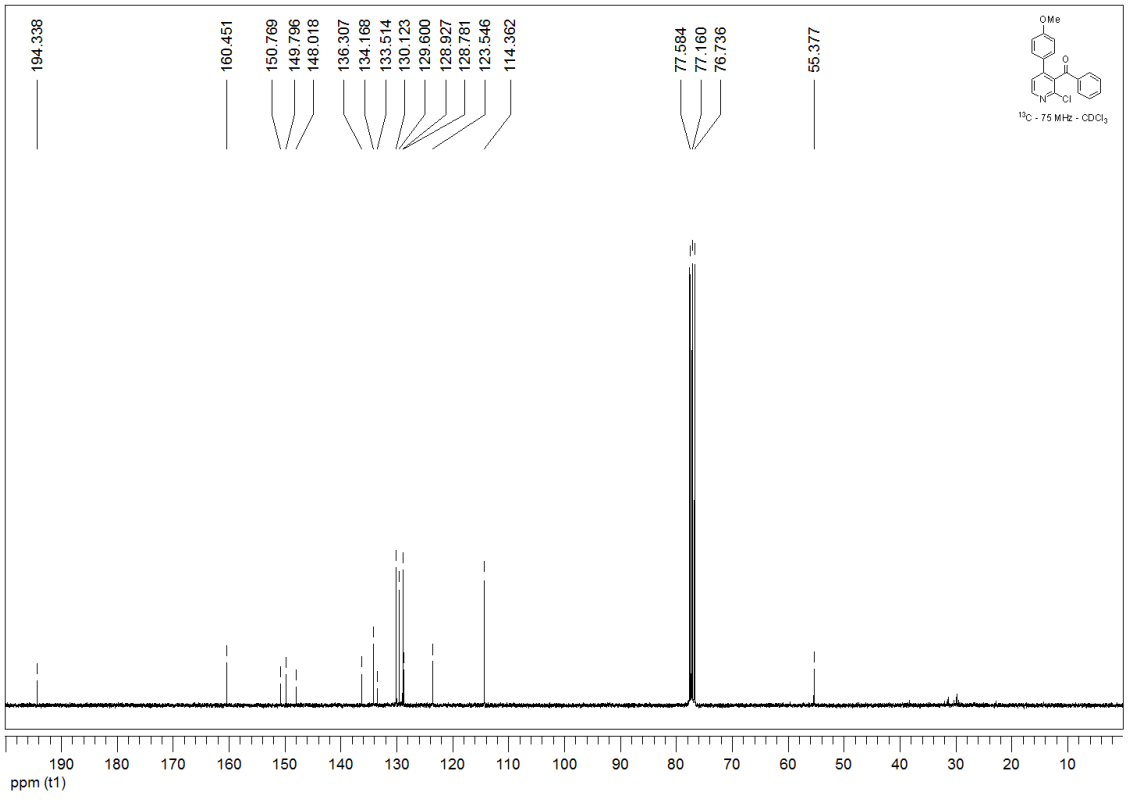
1-(4-Methoxyphenyl)-4-azafluorenone (11e)



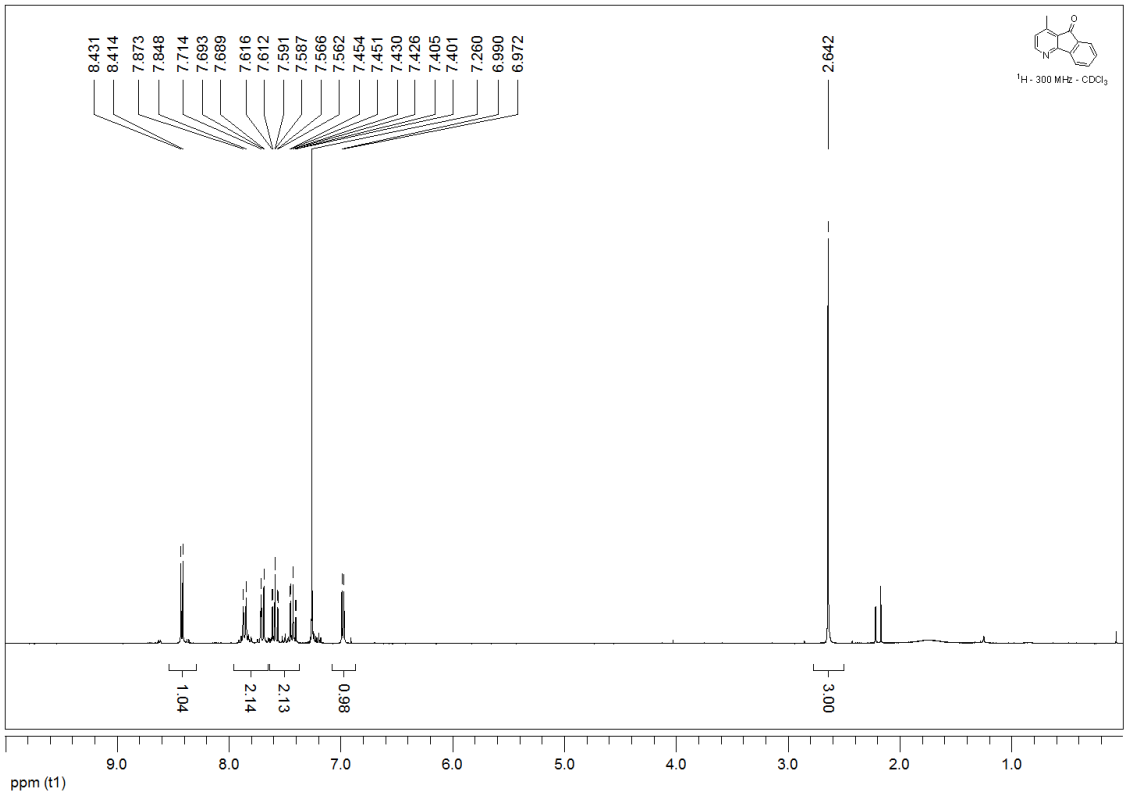


3-Benzoyl-2-chloro-4-(4-methoxyphenyl)pyridine (12e)

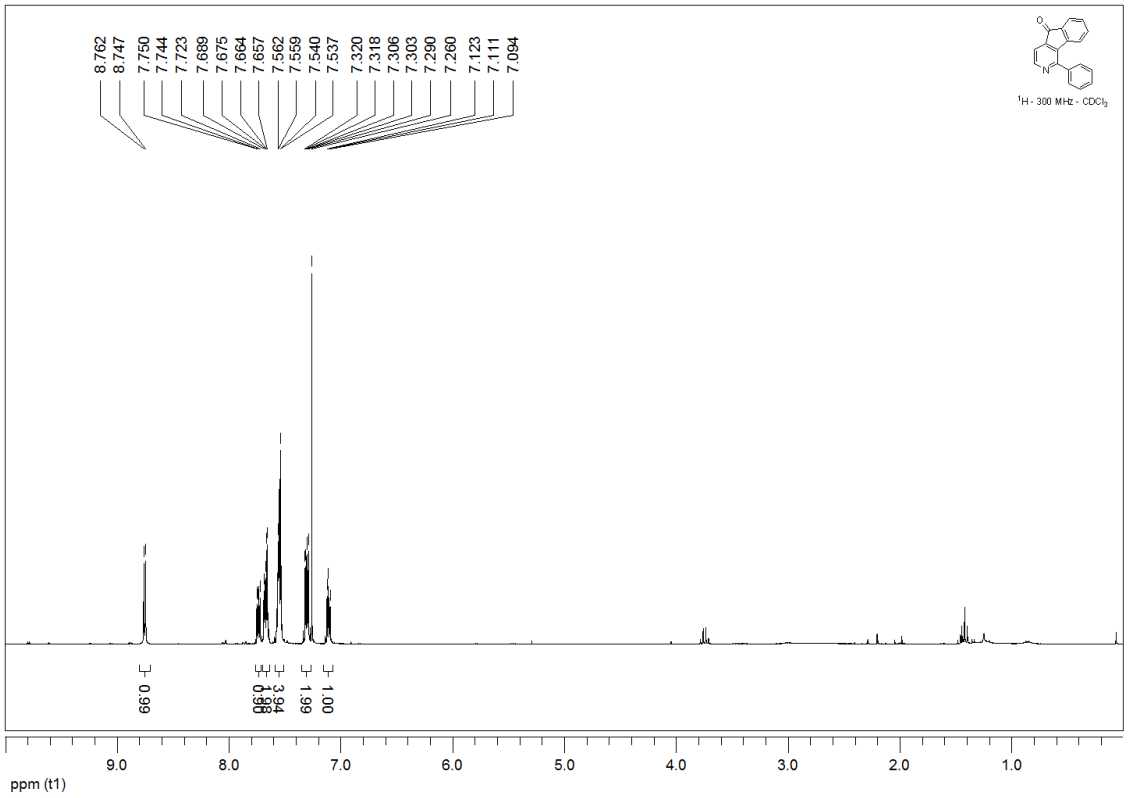


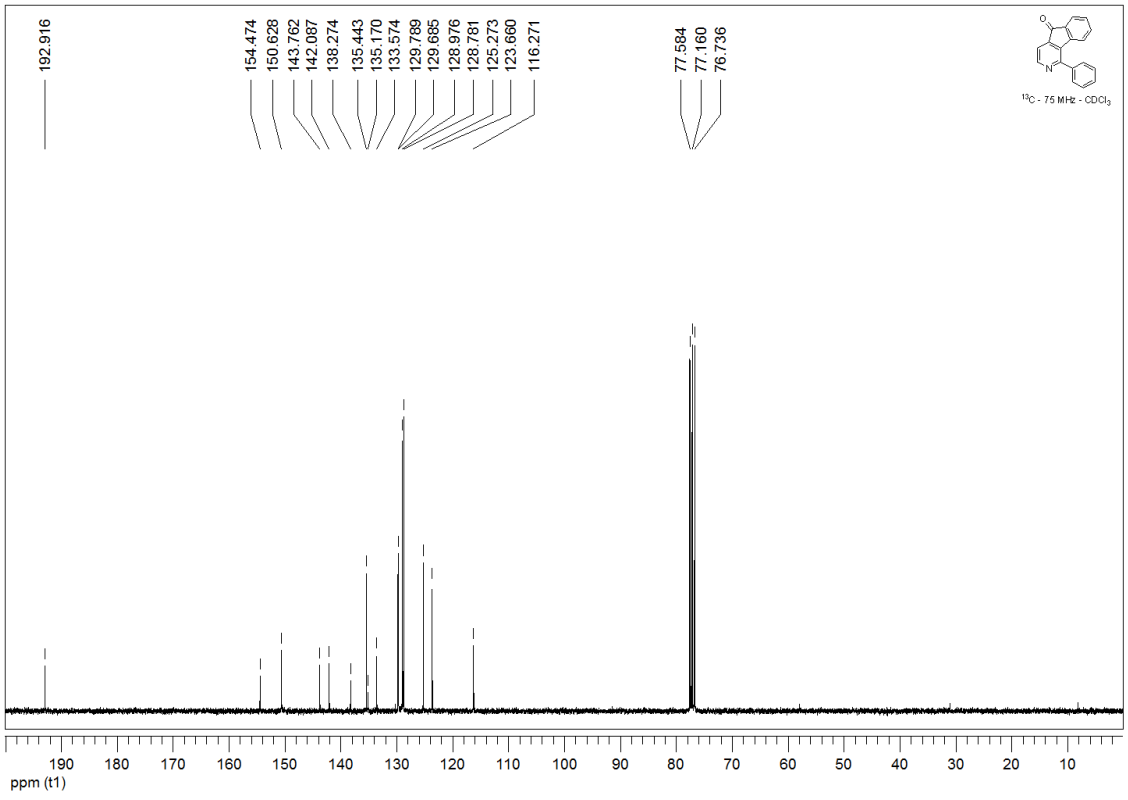


Onychine (11f)

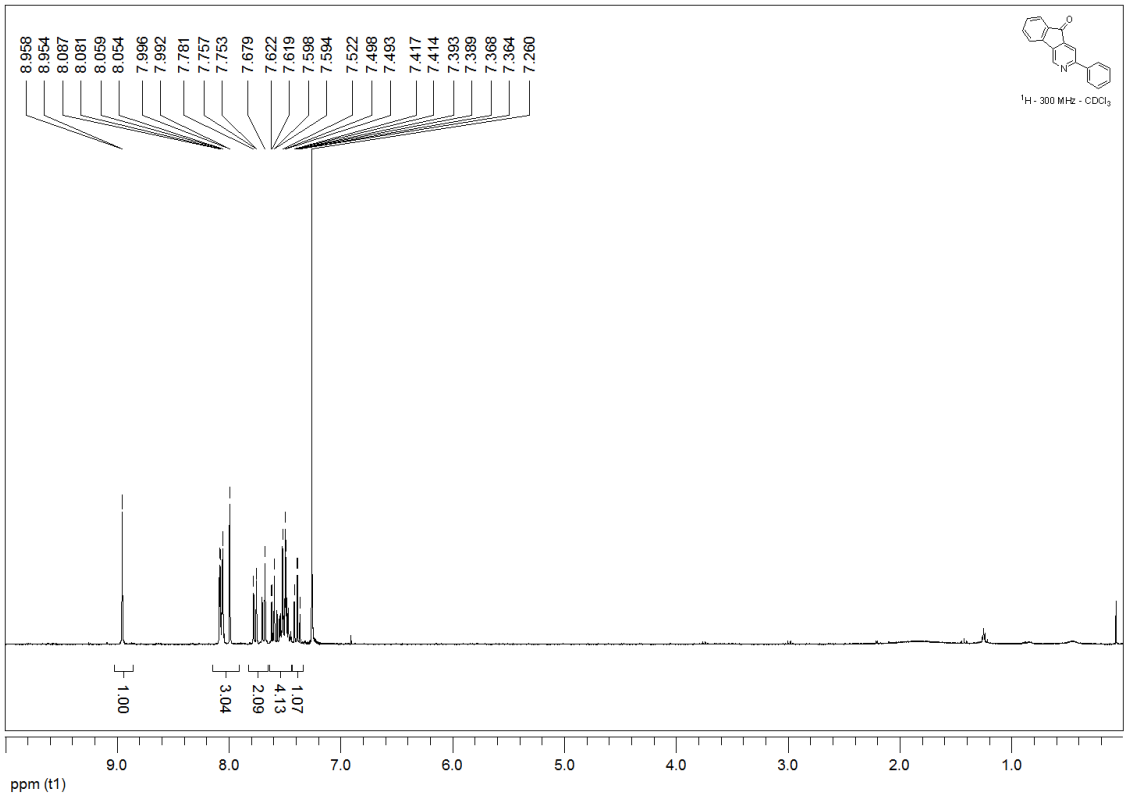


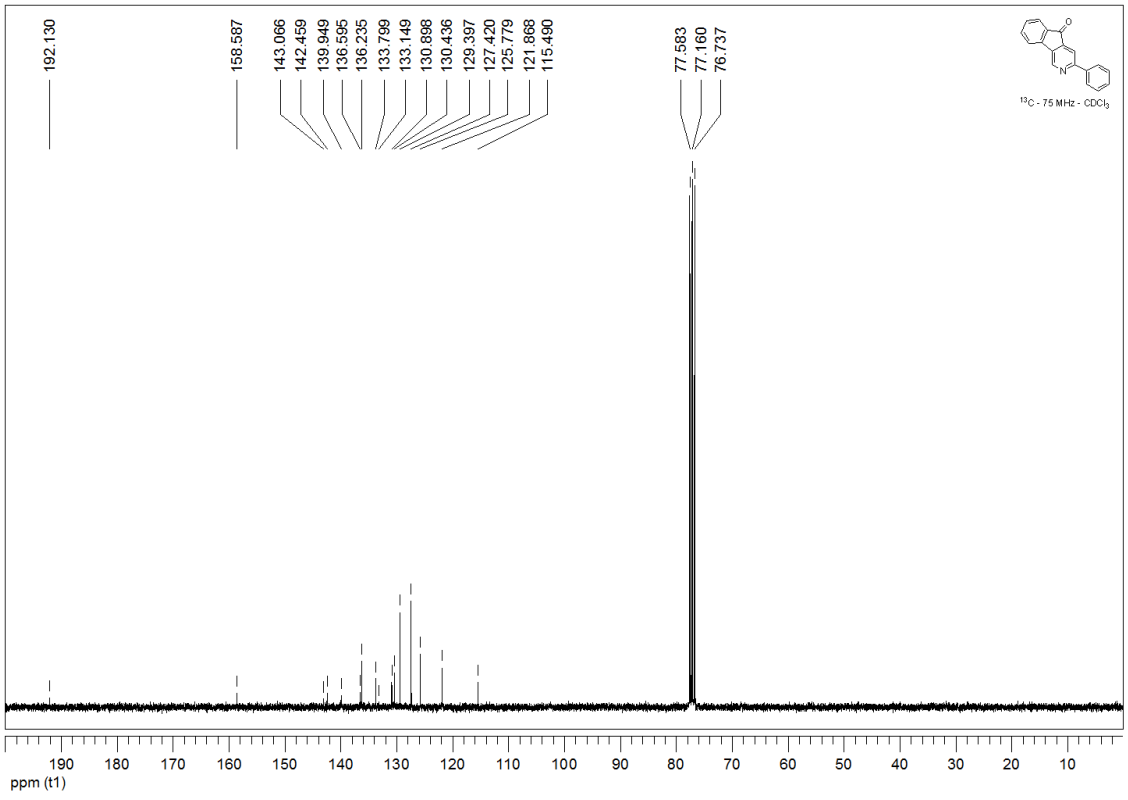
4-Phenyl-3-azafluorenone (15)



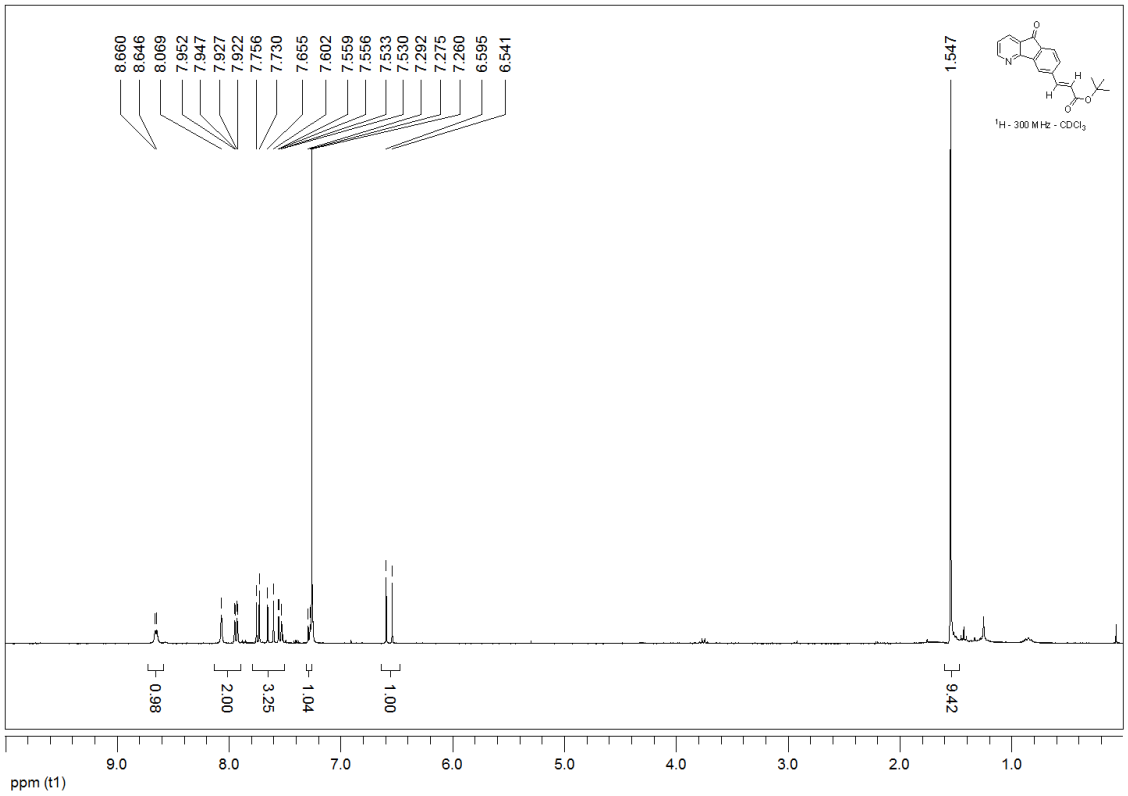


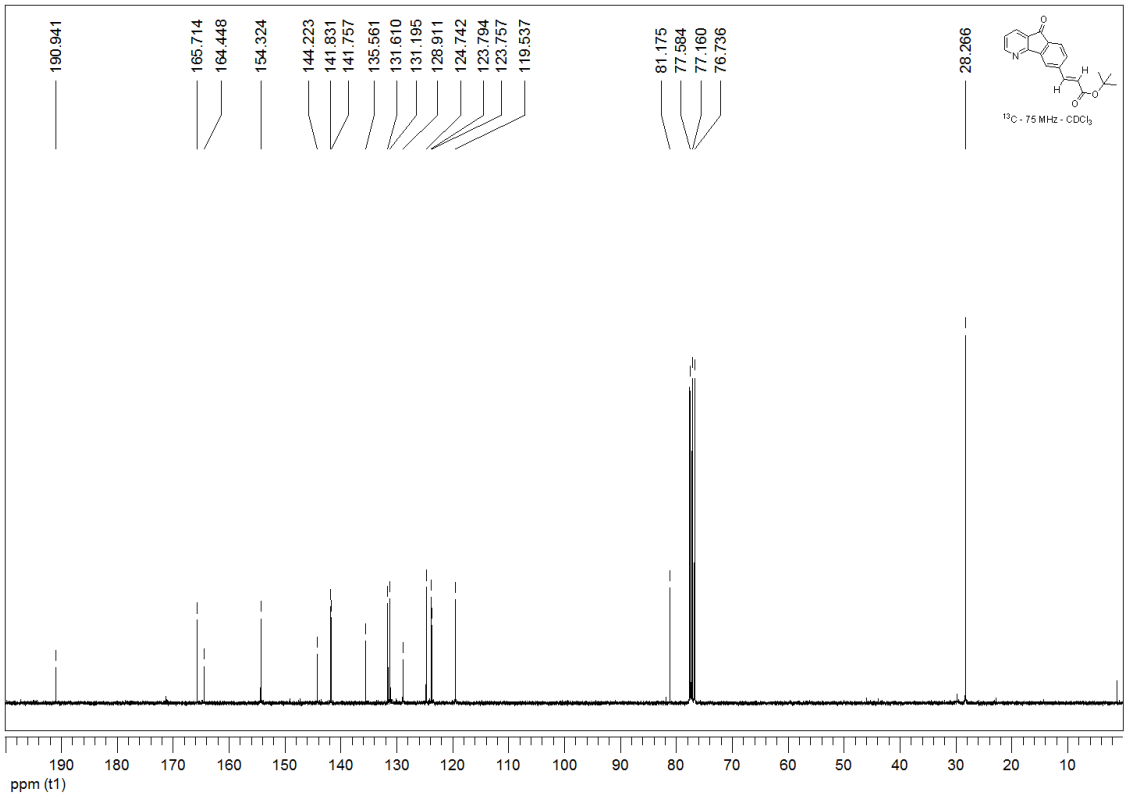
2-Phenyl-3-azafluorenone (16)



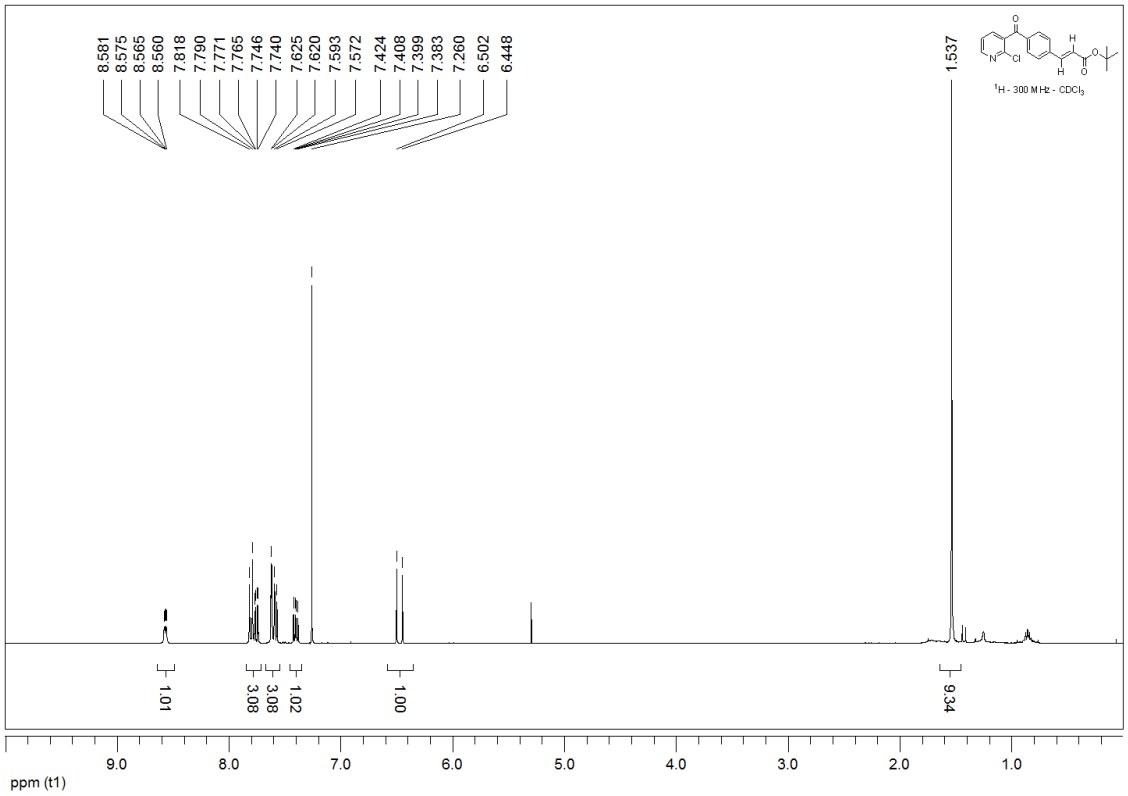


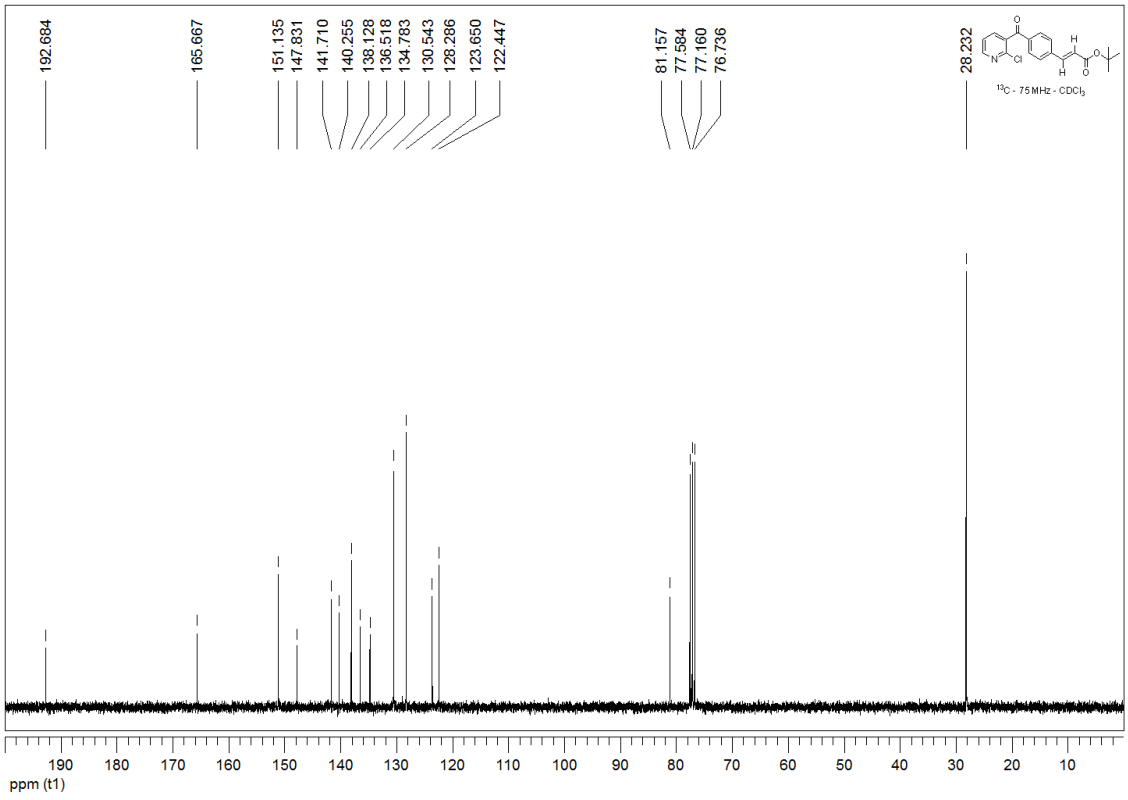
(*E*)-*tert*-Butyl 3-(5-oxo-5*H*-indeno[1,2-*b*]-8-pyridyl)acrylate (17)





(*E*)-*tert*-Butyl 3-(4-(2-chloronicotinoyl)phenyl)acrylate (18)





4. Crystal Data

The samples were studied with graphite monochromatized Mo-Kα radiation (λ = 0.71073 Å). The X-ray diffraction data were collected at T = 150(2) K. The structure was solved by direct methods using the *SIR97* program,[4] and then refined with full-matrix least-square methods based on F^2 (*SHELXL-97*)[5] with the aid of the *WINGX*[6] program. All non-hydrogen atoms were refined with anisotropic atomic displacement parameters. H atoms were finally included in their calculated positions.

Compound **2a** (CCDC-1015380):

$C_{18}H_{11}NO$; M = 257.28, triclinic; space group *P -1* (I.T.#2), a = 9.6136(9), b = 15.2925(12), c = 17.8493(15) Å, α = 94.364(4), β = 105.608(4), γ = 90.128(4) °, V = 2519.3(4) Å^3, Z = 8, d = 1.357 g.cm^{-3}, μ = 0.084 mm^{-1}. A final refinement on F^2 with 11317 unique intensities and 722 parameters converged at ωR(F^2) = 0.271 (R(F) = 0.1065) for 6270 observed reflections with I > 2σ(I).

Compound **4a** (CCDC-1015381):

$C_{19}H_{10}F_3NO$; M = 325.28, orthorhombic; space group *P b c a* (I.T.#61), a = 11.6541(10), b = 7.3177(6), c = 33.887(3) Å, V = 2889.9(4) Å^3, Z = 8, d = 1.495 g.cm^{-3}, μ = 0.119 mm^{-1}. A final refinement on F^2 with 3311 unique intensities and 218 parameters converged at ωR(F^2) = 0.123 (R(F) = 0.0618) for 1483 observed reflections with I > 2σ(I).

Compound **6a** (CCDC-1015382):

2($C_{18}H_{11}NO$); M = 514.56, monoclinic; space group *P* $2_1/a$ (I.T.#14), a = 7.4383(10), b = 12.2361(17), c = 27.524(3) Å, β = 96.983(5) °, V = 2486.5(6) Å^3, Z = 4, d = 1.375 g.cm^{-3}, μ = 0.086 mm^{-1}. A final refinement on F^2 with 5694 unique intensities and 361 parameters converged at ωR(F^2) = 0.1292 (R(F) = 0.0587) for 3045 observed reflections with I > 2σ(I).

Compound **9a** (CCDC-1015383):

$C_{18}H_{11}NO$; M = 257.28, monoclinic; space group *P* $2_1/c$ (I.T.#14), a = 15.9675(6), b = 4.9591(2), c = 16.0534(9) Å, β = 95.093(2) °, V = 1266.16(10) Å^3, Z = 4, d = 1.35 g.cm^{-3}, μ = 0.084 mm^{-1}. A final refinement on F^2 with 2911 unique intensities and 194 parameters converged at ωR(F^2) = 0.1091 (R(F) = 0.0527) for 2072 observed reflections with I > 2σ(I).

5. Literature

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