Supplementary Material (ESI) for Chemical Communications

Gold-catalyzed efficient tandem assembly of terminal alkynes and arynes

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Supporting Information

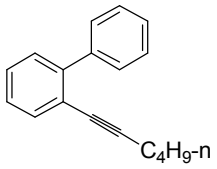
Content

General All reactions were carried out under the nitrogen atmosphere in oven-dried flask. CH_3CN and toluene were distilled from Na using benzophenone as the indicator. Benzyne precursors were prepared according to the method of reference 1. Other materials were purchased from common commercial sources and used without additional purification. ^1H NMR spectra were recorded at 400 MHz or 500 MHz using TMS as internal standard. ^{13}C NMR spectra were recorded at 100 MHz using TMS as internal standard. Mass spectroscopy data of the reaction product were collected on an HRMS-EI instrument.

Representative procedure of the gold-catalyzed coupling reaction of terminal alkynes and arynes : 1-ethynyl-benzene (31 mg, 0.3 mmol), CuI (6 mg, 0.03 mmol), $AuClPPh_3$ (15 mg, 0.03 mmol) and CsF (276 mg, 1.8 mmol) were charged into an oven-dried flask, followed by the addition of MeCN (2 mL) under the protection of nitrogen atmosphere to form a suspension. The solution of 2-(trimethylsilyl)phenyl triflate (180 mg, 0.6 mmol) in MeCN (3 mL) was added into the above suspension by syringe under N_2, and the reaction mixture was then put into a 40 ^oC oil bath to reaction for an hour. After the completion of reaction, the reaction mixture was filtered through a pad of cellite, and the solvent was then removed under reduced pressure. The residue was then separated on a silica gel column by using petroleum ether as eluent and the final product was obtained as colerless oil.

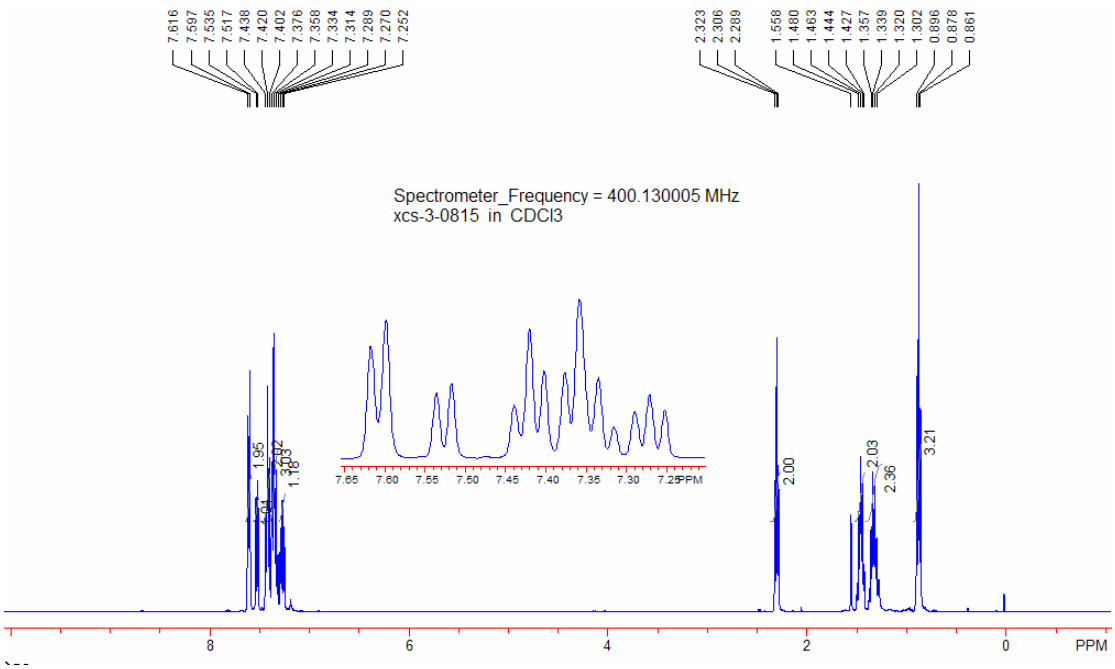
Representative procedure of the intramolecular hydroarylation reaction: Alkynylated biphenyl (127 mg, 0.5 mmol), $AuClPPh_3$ (25 mg, 0.05 mmol) and $AgSbF_6$ (15 mg, 0.05 mmol) were placed into an oven-dried flask, and then distilled toluene (5 mL) was charged into the flask under N_2. The mixture was allowed to react at 110 ^oC for 12 h to finish the reaction. After the completion of the reaction, the mixture was filtered to remove the insoluted powder, and the resulting filtrate was condensed under vacuum. The final product was obtained by flash chromatograph on a silical gel column as a white powder.

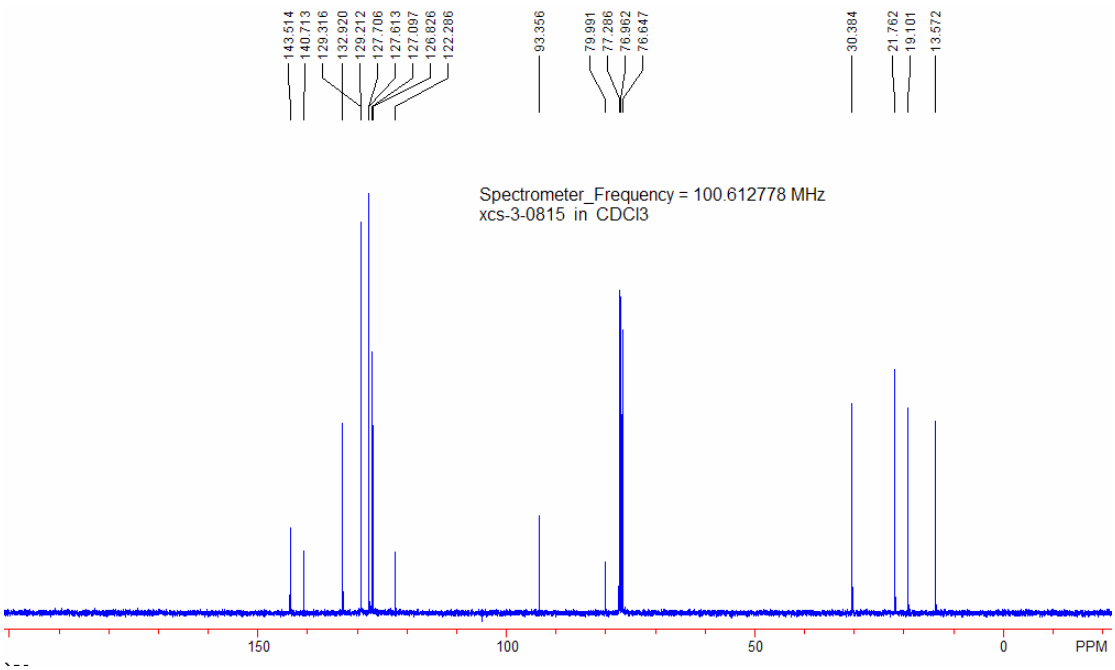
Characterization data of the product

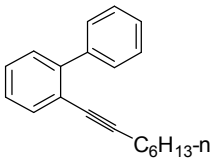


T2-1, 851901-90-1, Ref. 2

^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.61 (d, J = 7.6 Hz, 2 H), 7.53 (d, J = 7.2 Hz, 1 H), 7.42 (t, J = 7.6 Hz, 2 H), 7.31-7.38 (m, 3 H), 7.27 (t, J = 7.4 Hz, 1 H), 2.31 (t, J = 6.8 Hz, 2 H), 1.43-1.50 (m, 2 H), 1.28-1.38 (m, 2 H), 0.88 (t, J = 7.0 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.5, 140.7, 132.9, 129.3, 129.2, 127.7, 127.6, 127.1, 126.8, 122.3, 93.4, 80.0, 30.4, 21.8, 19.1, 12.6. HRMS (EI) Calcd for $C_{18}H_{18}$: $[M]^+$ 234.1409; Found, 234.1413.

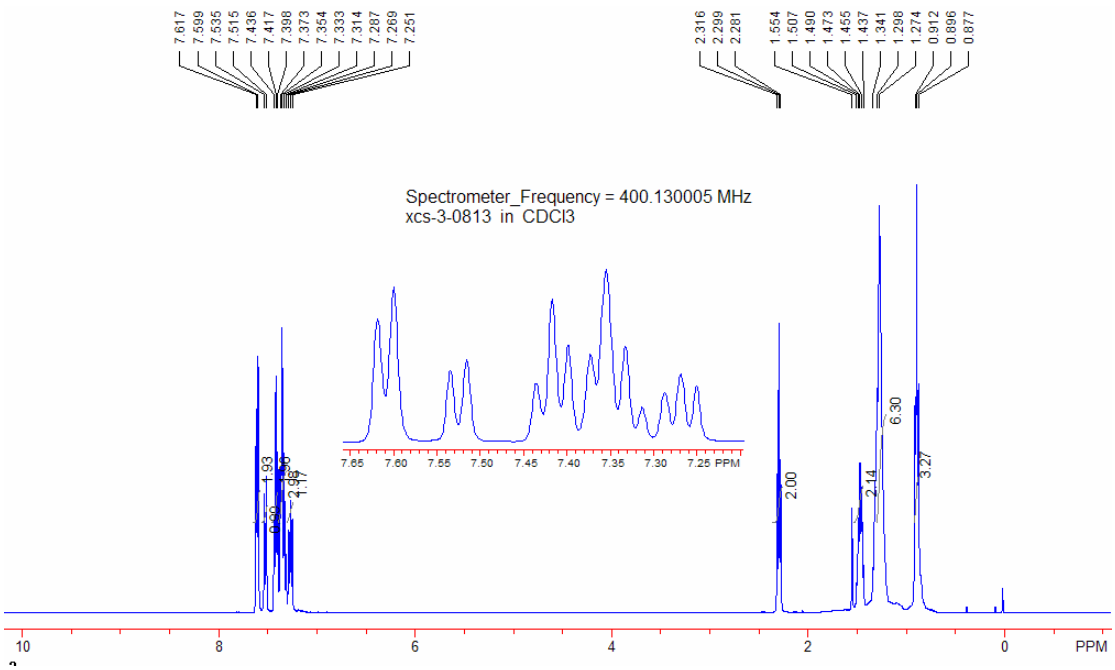


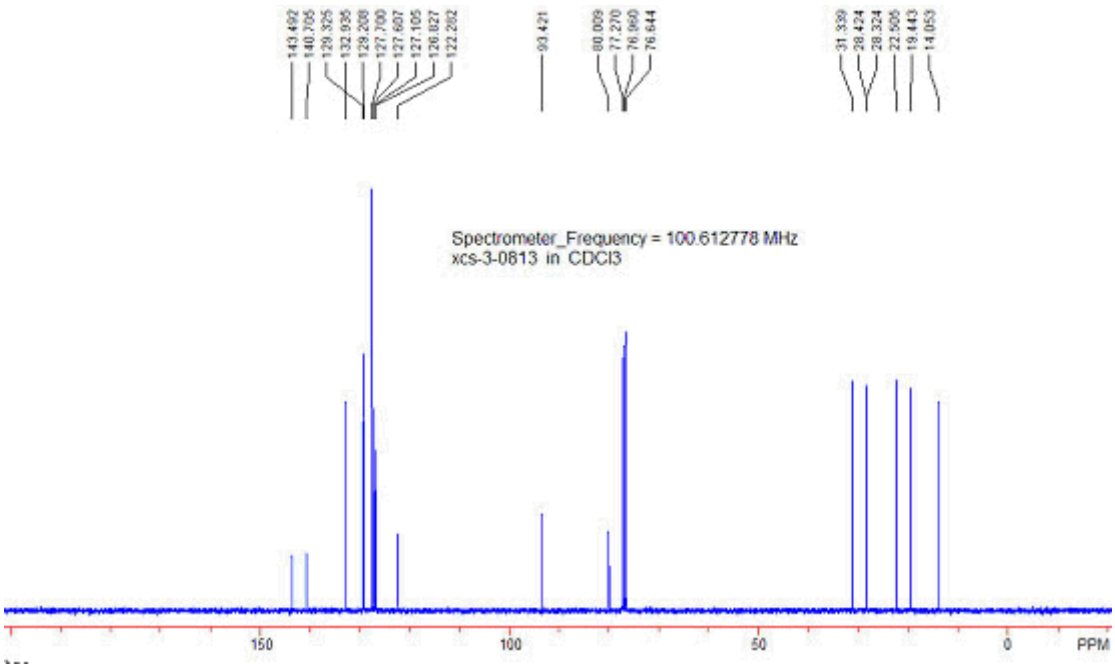


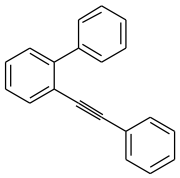


T2-2, 263017-26-1, Ref. 3

^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.61 (d, *J* = 7.2 Hz, 2 H), 7.53 (d, *J* = 8.0 Hz, 1 H), 7.42 (t, *J* = 7.6 Hz, 2 H), 7.31-7.37 (m, 3 H), 7.27 (t, *J* = 7.2 Hz, 1 H), 2.30 (t, *J* = 7.0 Hz, 2 H), 1.44-1.51 (m, 2 H), 1.27-1.34 (m, 6 H), 0.90 (t, *J* = 7.0 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.5, 140.7, 132.9, 129.3, 129.2, 127.7, 127.6, 127.1, 126.8, 122.3, 93.4, 80.0, 31.3, 28.4, 28.3, 22.5, 19.4, 14.0. HRMS (EI) Calcd for $C_{20}H_{22}$: $[M]^+$ 262.1722; Found, 262.1723.

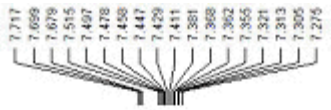


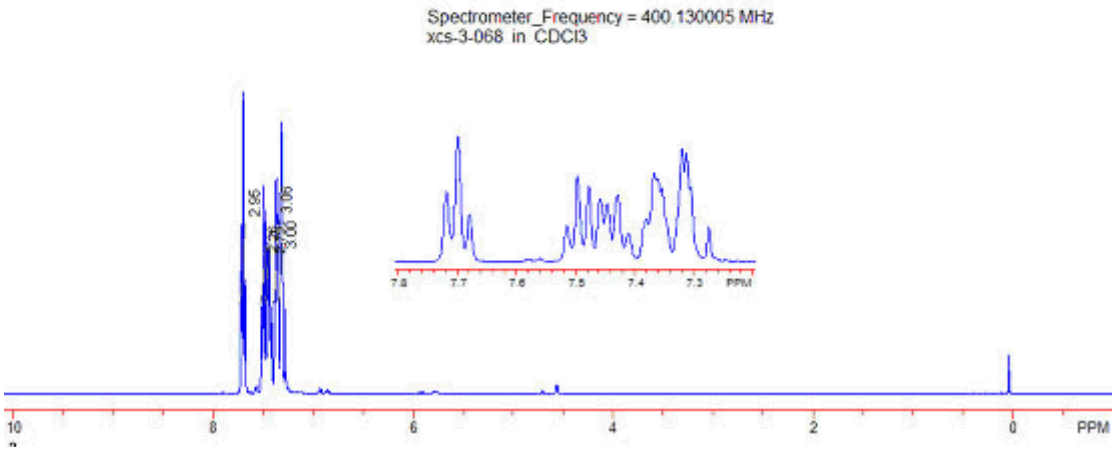


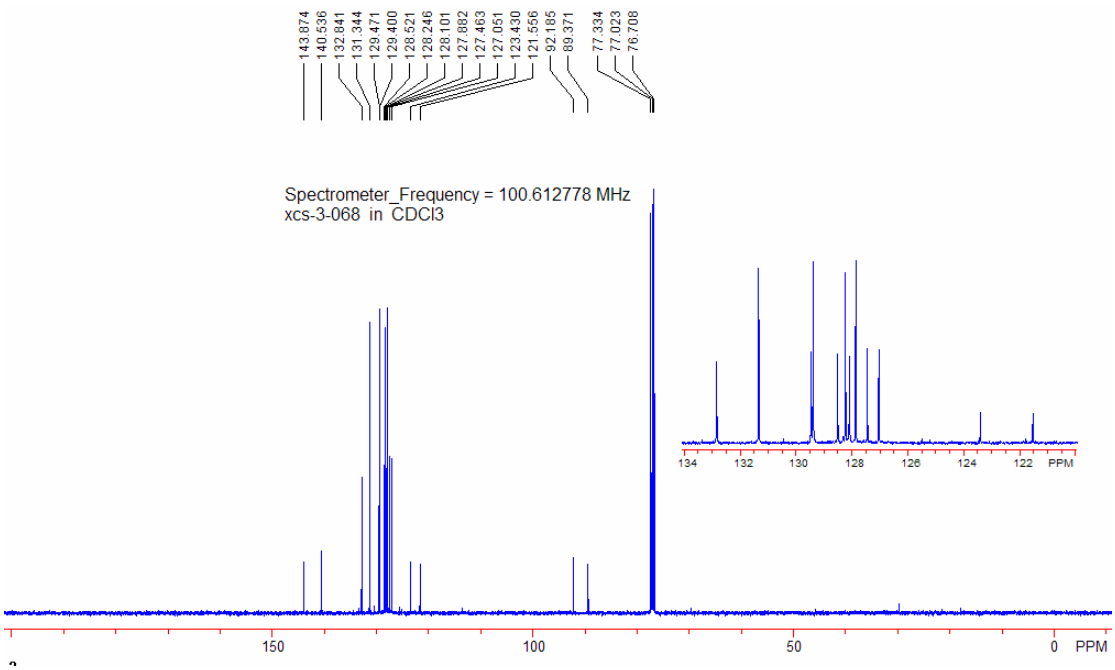


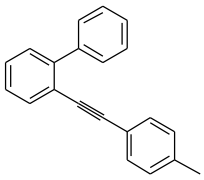
T2-3, 10271-65-5, Ref. 4

^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.68-7.72 (m, 3 H), 7.50 (t, J = 7.4 Hz, 2 H), 7.41-7.46 (m, 3 H), 7.26-7.38 (m, 3 H), 7.30-7.32 (m, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.9, 140.5, 132.8, 131.3, 129.5, 129.4, 128.5, 128.2, 128.1, 127.9, 127.5, 127.0, 123.4, 121.6, 92.2, 89.4. HRMS (EI) Calcd for $C_{20}H_{14}$: $[M]^+$ 254.1096; Found, 254.1090.



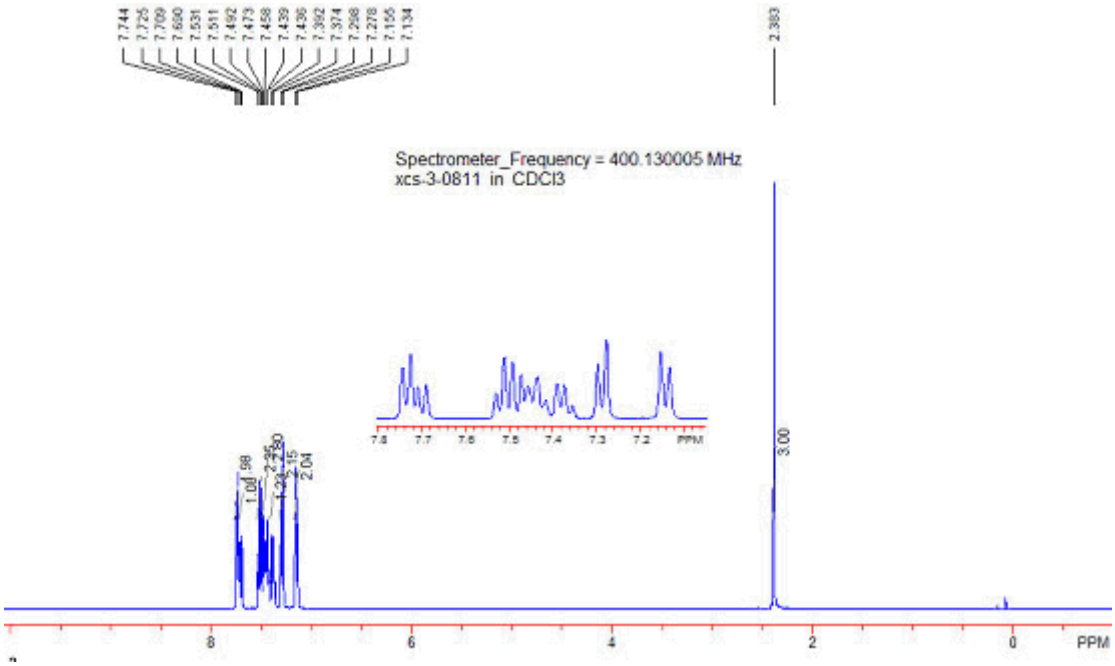


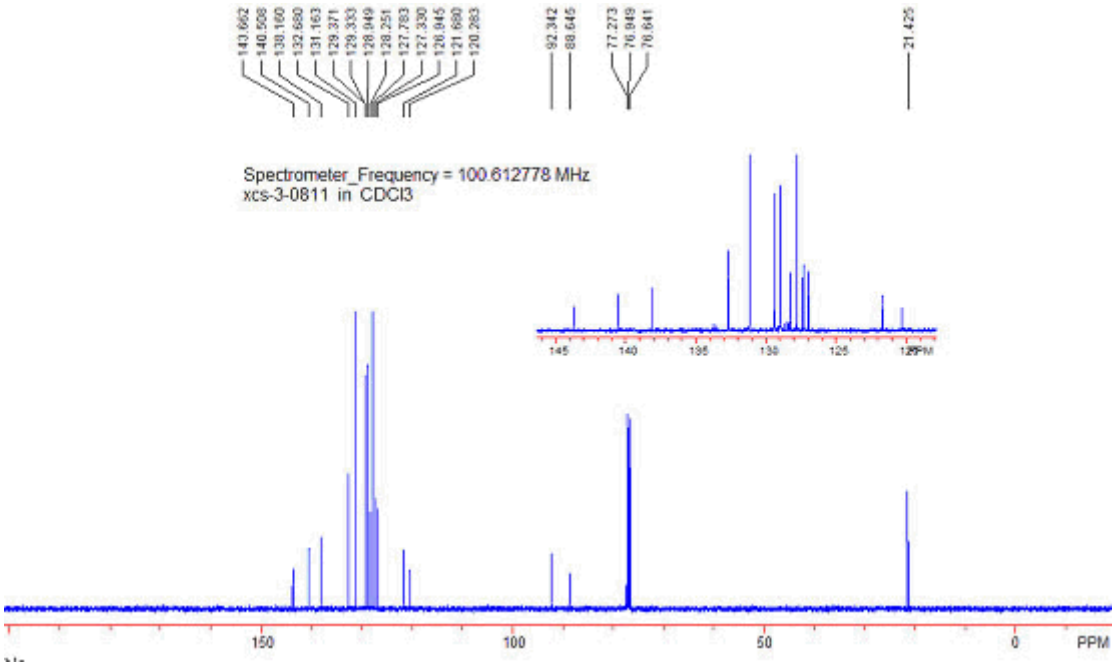


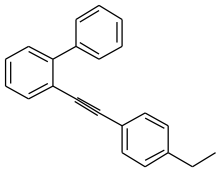


T2-4, 725213-46-7, Ref. 5

^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.73 (d, J = 7.6 Hz, 2 H), 7.70 (d, J = 7.6 Hz, 1 H), 7.51 (t, J = 7.8 Hz, 2 H), 7.42-7.47 (m, 3 H), 7.37 (t, J = 7.2 Hz, 1 H), 7.29 (d, J = 8.0 Hz, 2 H), 7.14 (d, J = 8.4 Hz, 2 H), 2.38 (s, 3 H) ; ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.7, 140.5, 138.2, 132.7, 131.2, 129.4, 129.3, 128.9, 128.3, 127.8, 127.3, 126.9, 121.7, 120.3, 92.3, 88.6, 21.4. HRMS (EI) Calcd for $C_{21}H_{16}$: $[M]^+$ 268.1252; Found, 268.1251.

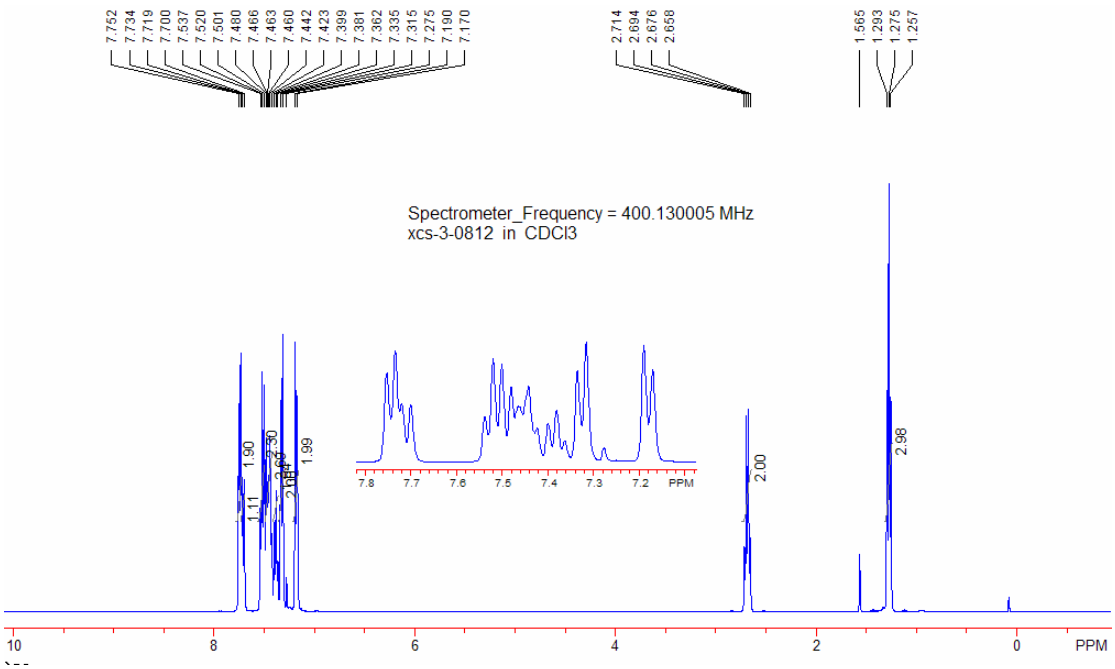


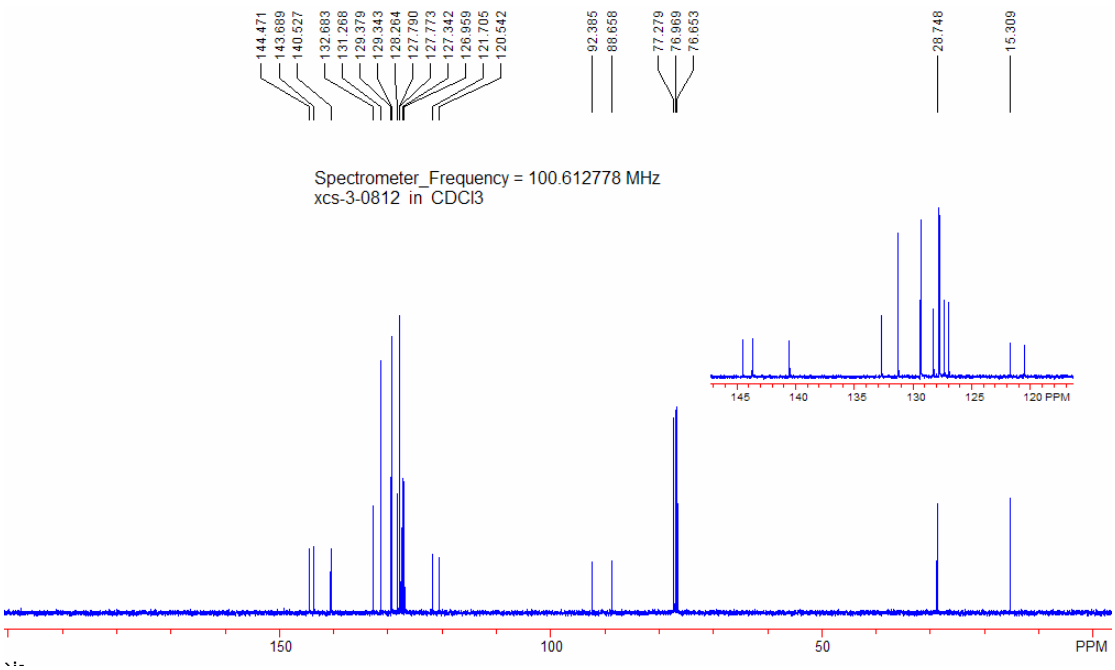


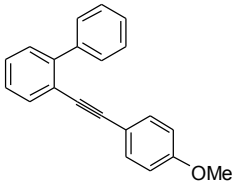


T2-5, new compound

^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.74 (d, J = 7.6 Hz, 2 H), 7.71 (d, J = 7.6 Hz, 1 H), 7.52 (t, J = 7.2 Hz, 2 H), 7.44-7.48 (m, 3 H), 7.38 (t, J = 7.4 Hz, 1 H), 7.33 (d, J = 8.0 Hz, 2 H), 7.18 (d, J = 8.0 Hz, 2 H), 2.68 (q, J = 7.4 Hz, 2 H), 1.28 (t, J = 7.2 Hz, 3 H) ; ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.5, 143.7, 140.5, 132.7, 131.3, 129.4, 129.3, 128.3, 127.8, 127.8, 127.3, 126.9, 121.7, 120.5, 92.4, 88.6, 28.7, 15.3. HRMS (EI) Calcd for $C_{22}H_{18}$: $[M]^+$ 282.1409; Found, 282.1409.

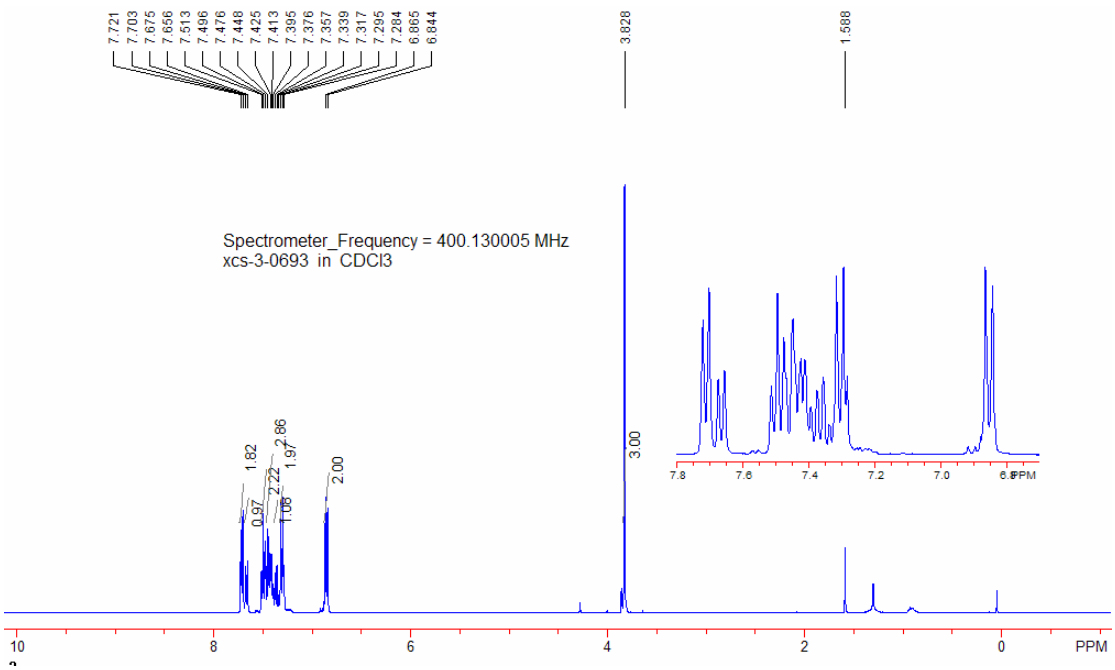


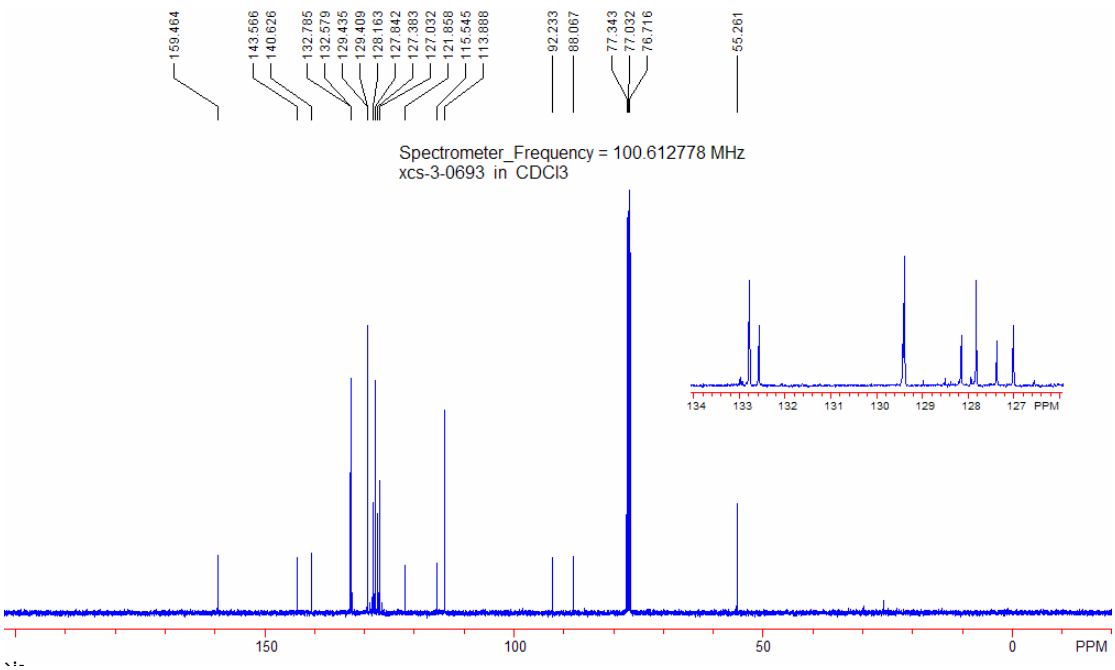


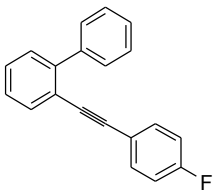


T2-6, 725213-45-6, Ref. 5

^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.71 (d, J = 7.2 Hz, 2 H), 7.67 (d, J = 7.6 Hz, 1 H), 7.50 (t, J = 7.4 Hz, 2 H), 7.40-7.45 (m, 3 H), 7.34 (t, J = 8.0 Hz, 1 H), 7.29 (d, J = 8.4 Hz, 2 H), 6.85 (d, J = 8.4 Hz, 2 H), 3.83 (s, 3 H) ; ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.5, 143.6, 140.6, 132.8, 132.6, 129.44, 129.41, 128.2, 127.8, 127.4, 127.0, 121.8, 115.5, 113.9, 92.2, 88.1, 55.3. HRMS (EI) Calcd for $C_{21}H_{16}O$: $[M]^+$ 284.1201; Found, 284.1203.

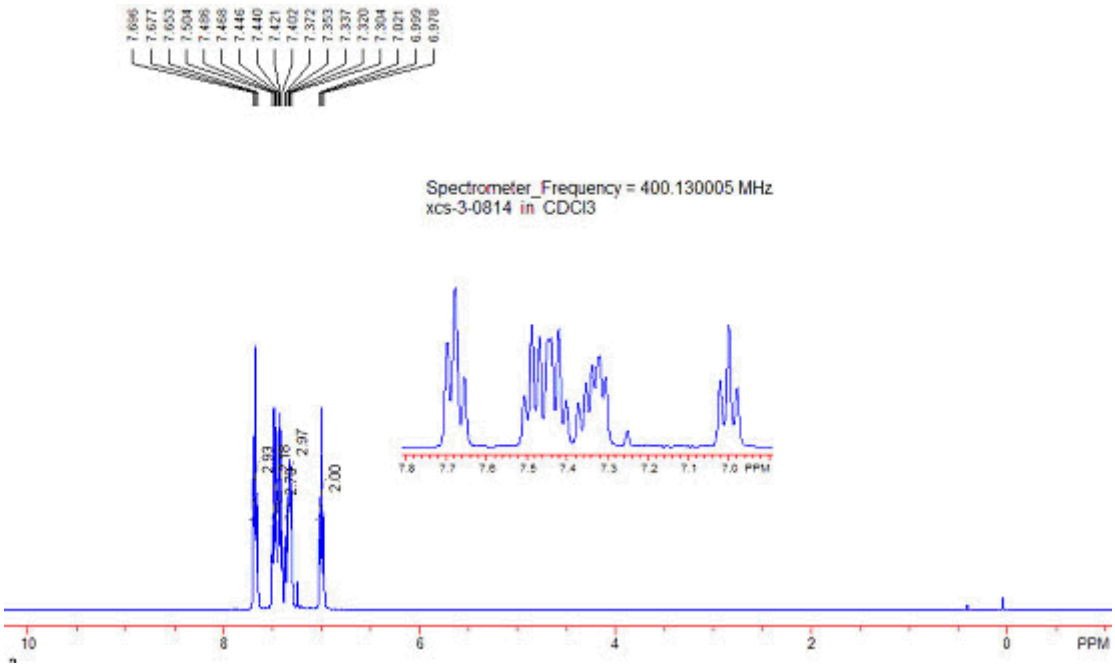


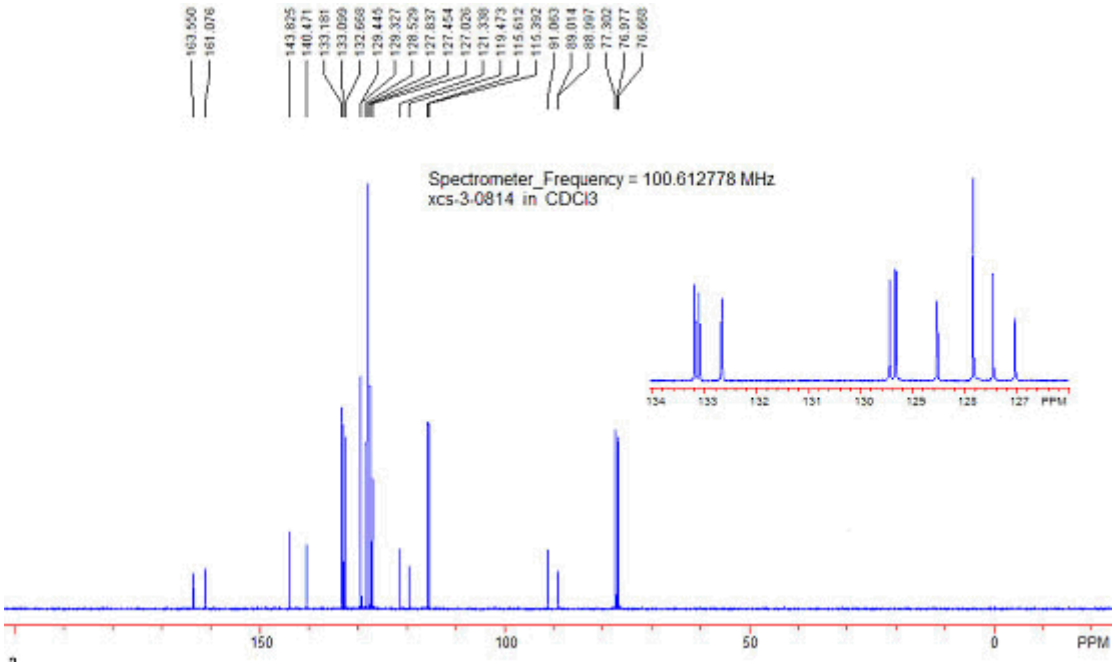


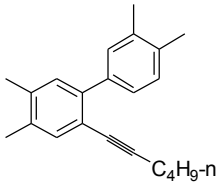


T2-7, new compound

^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.65-7.70 (m, 3 H), 7.49 (t, *J* = 7.2 Hz, 2 H), 7.40-7.45 (m, 3 H), 7.30-7.37 (m, 3 H), 7.00 (t, *J* = 8.6 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.3 (d, *J* = 247.4 Hz), 143.8, 140.5, 133.1 (d, *J* = 8.2 Hz), 132.7, 129.4, 129.3, 128.5, 127.8, 127.4, 127.0, 121.3, 119.4 (d, *J* = 3.9 Hz), 115.5 (d, *J* = 22.0 Hz), 91.1, 89.0 (d, *J* = 1.7 Hz). HRMS (EI) Calcd for $C_{20}H_{13}F$: $[M]^+$ 272.1001; Found, 272.1003.

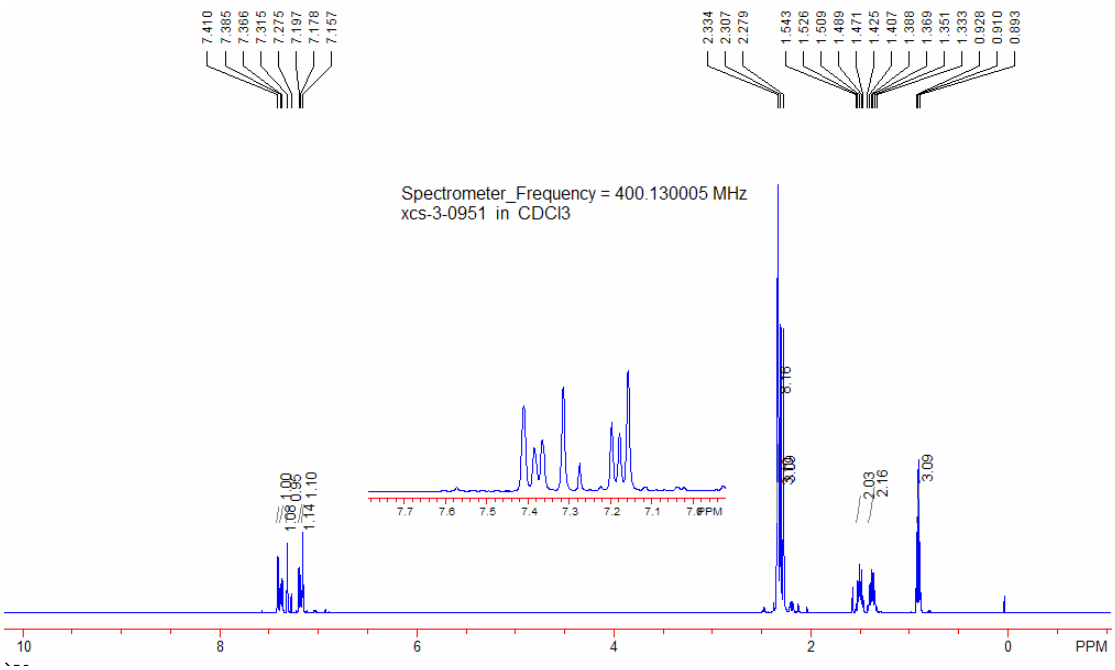


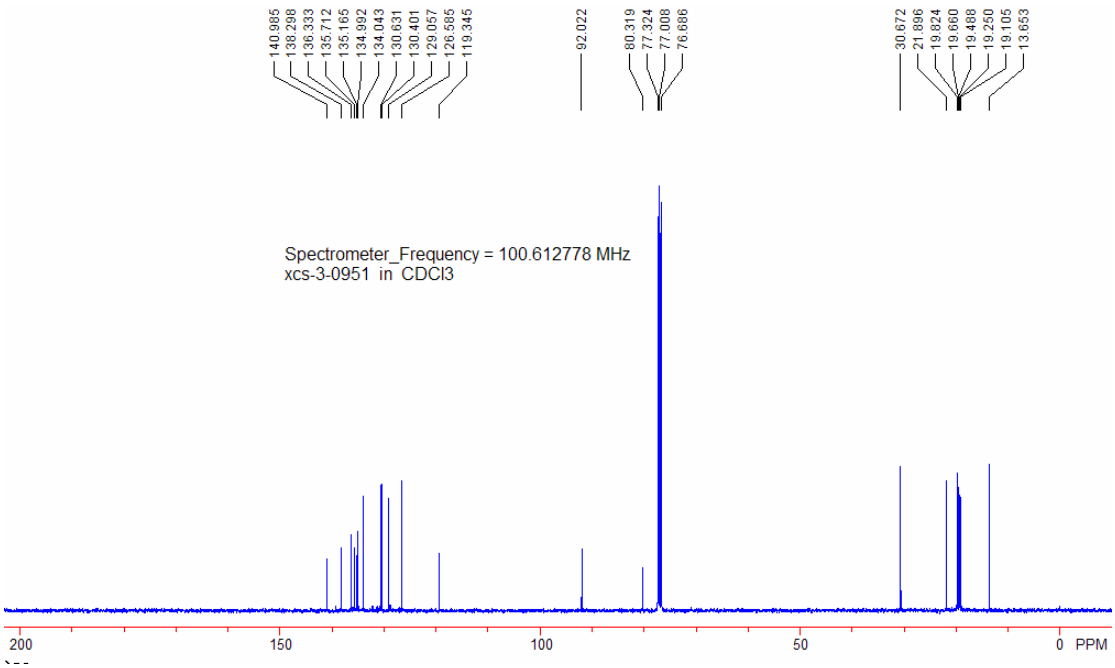


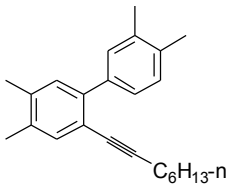


T2-8, new compound

^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.41 (s, 1 H), 7.37 (d, *J* = 7.6 Hz, 1 H), 7.32 (s, 1 H), 7.19 (d, *J* = 7.6 Hz, 1 H), 7.16 (s, 1 H), 2.31-2.35 (m, 8 H), 2.31(s, 3 H), 2.28 (s, 3 H), 1.47-1.54 (m, 2 H), 1.33-1.42 (m, 2 H), 0.91 (t, *J* = 7.0 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.9, 138.3, 136.3, 135.7, 135.2, 135.0, 134.0, 130.6, 130.4, 129.0, 126.6, 119.3, 92.0, 80.3, 30.7, 21.9, 19.8, 19.7, 19.5, 19.2, 19.1, 13.6. HRMS (EI) Calcd for $C_{22}H_{26}$: $[M]^+$ 290.2035; Found, 290.2037.

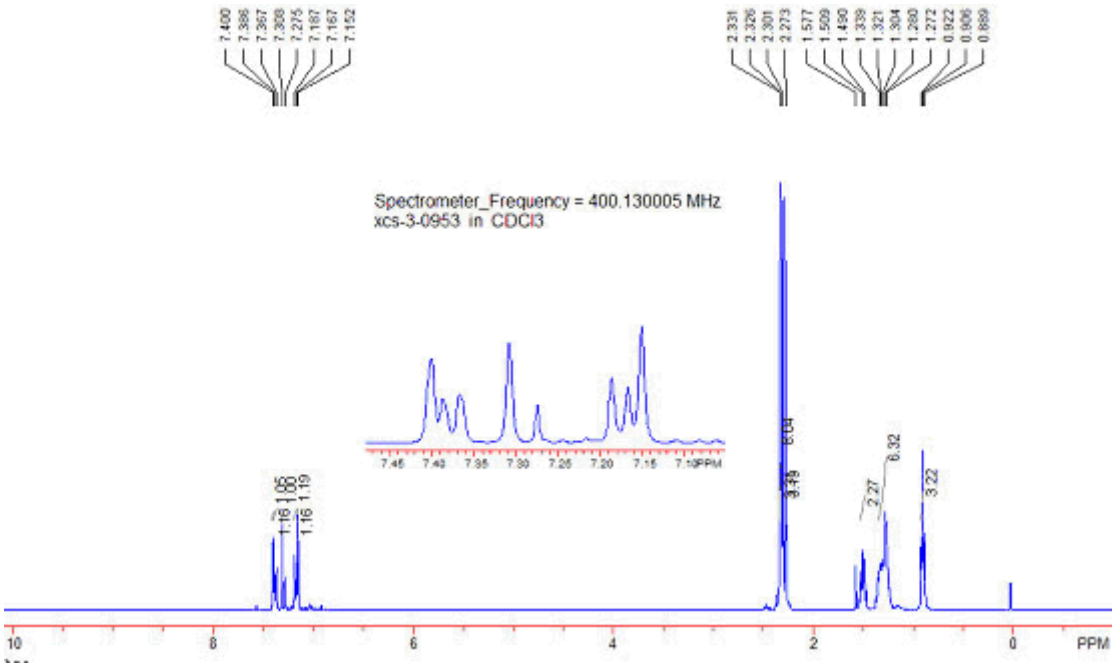


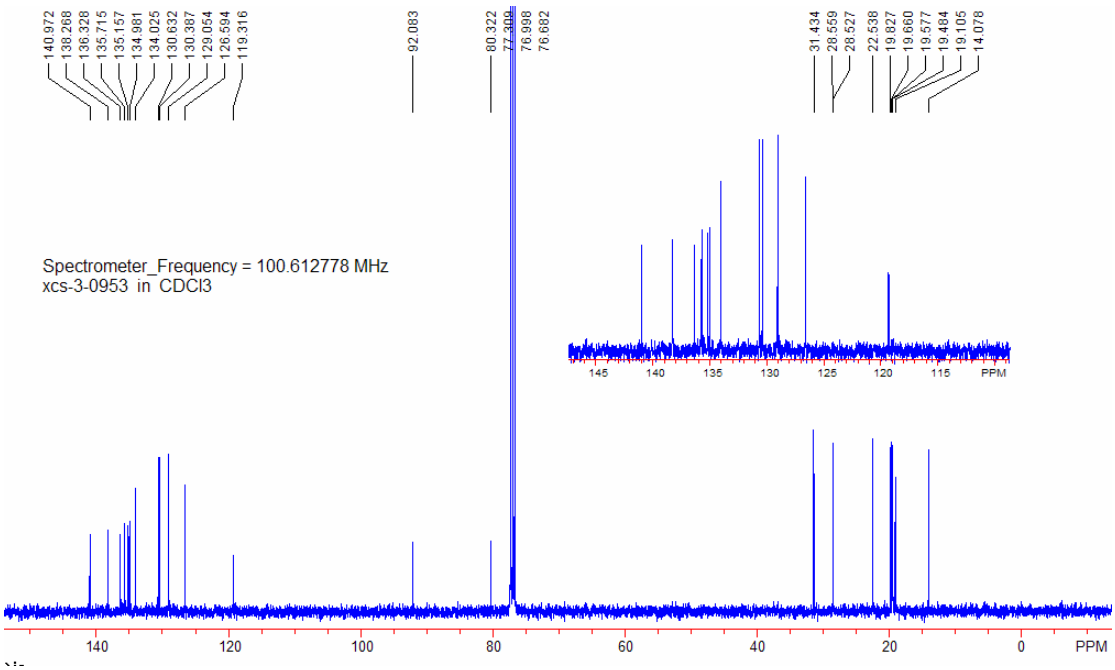


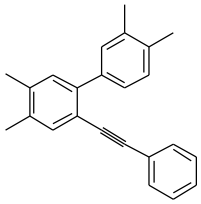


T2-9, new compound

^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.40 (s, 1 H), 7.38 (d, *J* = 7.6 Hz, 1 H), 7.31 (s, 1 H), 7.18 (d, *J* = 8.0 Hz, 1 H), 7.15 (s, 1 H), 2.32-2.33 (m, 8 H), 2.30 (s, 3 H), 2.27 (s, 3 H), 1.47-1.54 (m, 2 H), 1.27-1.38 (m, 6 H), 0.91 (t, *J* = 6.6 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.9, 138.3, 136.3, 135.7, 135.2, 134.9, 134.0, 130.6, 130.4, 129.0, 126.6, 119.3, 92.1, 80.3, 31.4, 28.6, 28.5, 22.5, 19.8, 19.7, 19.6, 19.5, 19.1, 14.1. HRMS (EI) Calcd for $C_{24}H_{30}$: $[M]^+$ 318.2348; Found, 318.2350.

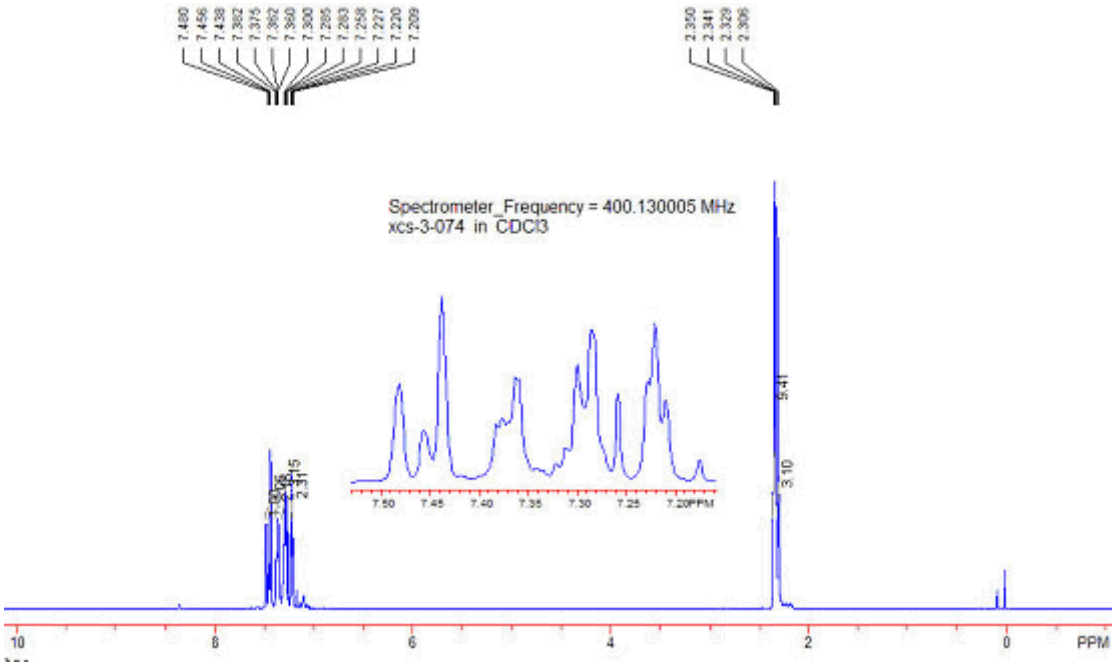


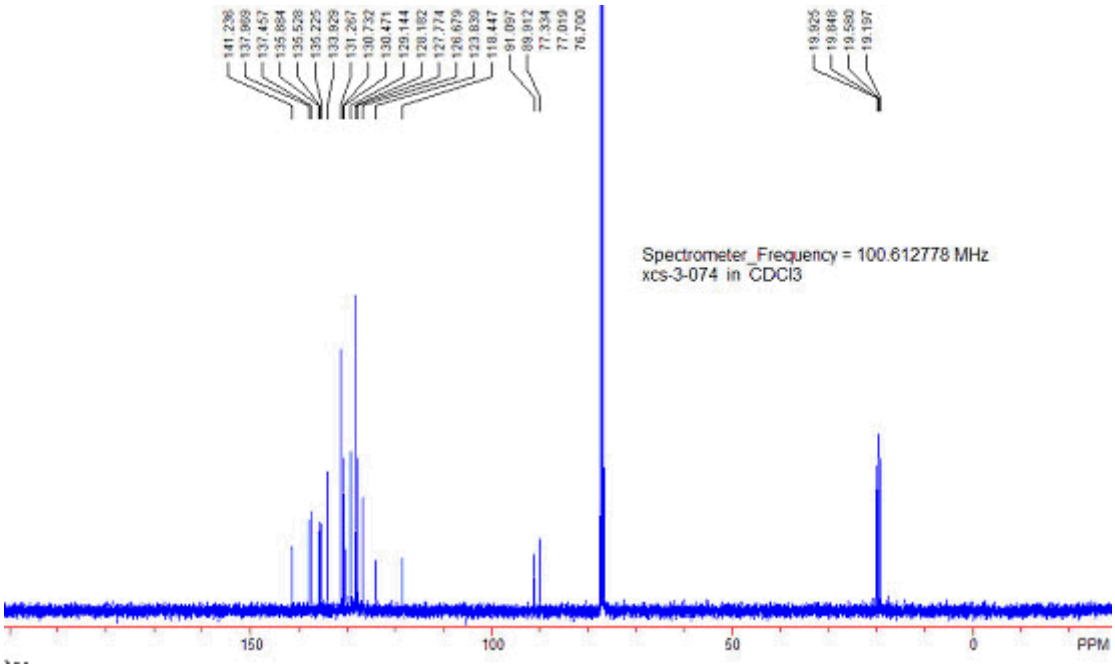


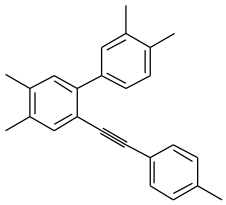


T2-10, new compound

^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.48 (s, 1 H), 7.45 (d, J = 7.2 Hz, 1 H), 7.44 (s, 1 H), 7.36-7.38 (m, 2 H), 7.28-7.30 (m, 3 H), 7.21-7.23 (m, 2 H), 2.35 (s, 3 H), 2.34 (s, 3 H), 2.33 (s, 3 H), 2.31 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 141.2, 138.0, 137.4, 135.9, 135.5, 135.2, 133.9, 131.3, 130.7, 130.5, 129.1, 128.2, 127.8, 126.7, 123.8, 118.4, 91.1, 89.9, 19.9, 19.8, 19.6, 19.2. HRMS (EI) Calcd for $C_{24}H_{22}$: $[M]^+$ 310.1722; Found, 310.1724.

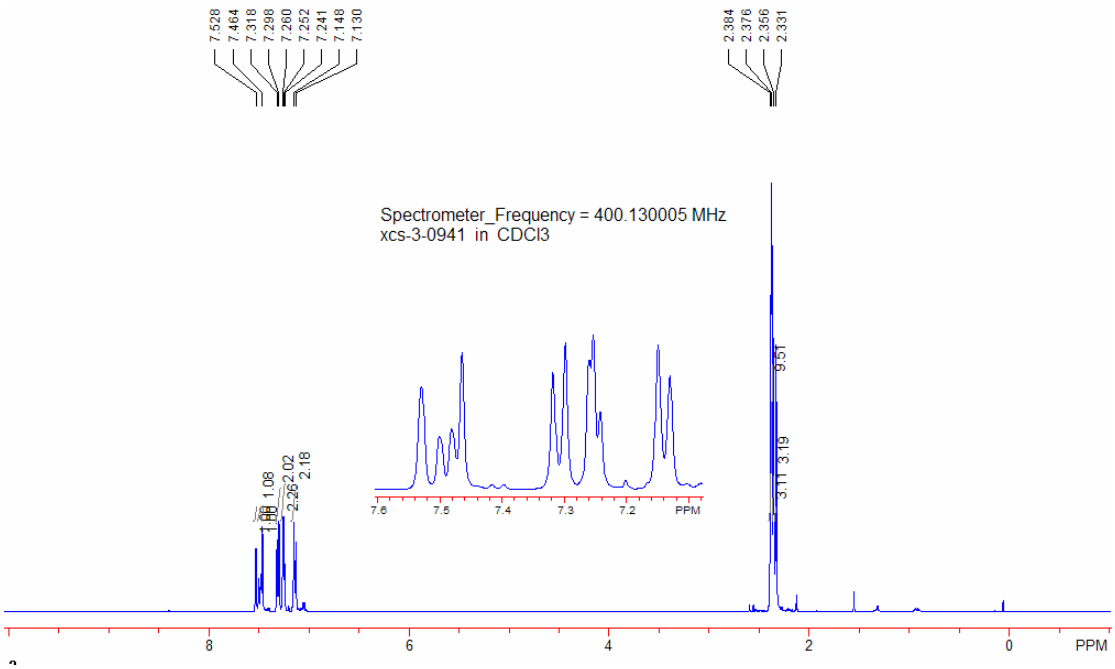


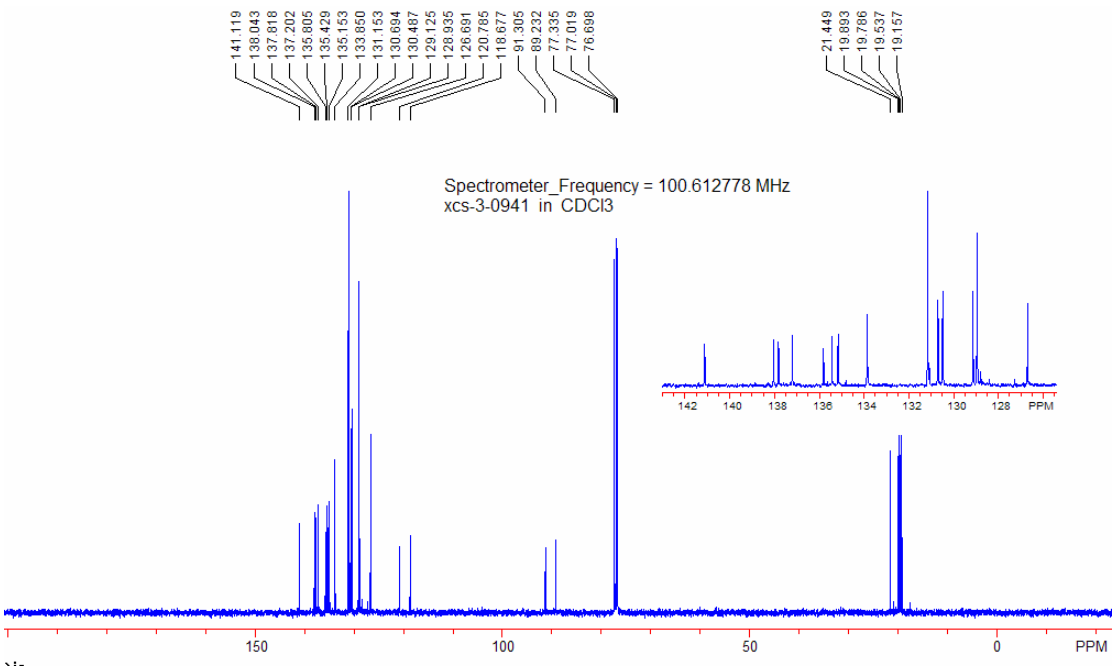


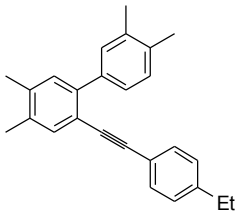


T2-11, new compound

^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.53 (s, 1 H), 7.49 (d, J = 7.6 Hz, 1 H), 7.46 (s, 1 H), 7.31 (d, J = 8.0 Hz, 2 H), 7.24-7.26 (m, 2 H), 7.14 (d, J = 7.2 Hz, 2 H), 2.38-2.37 (m, 9 H), 2.36 (s, 3 H), 2.33 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 141.1, 138.0, 137.8, 137.2, 135.8, 135.4, 135.2, 133.8, 131.2, 130.7, 130.5, 129.1, 128.9, 126.7, 120.8, 118.7, 91.3, 89.2, 21.4, 19.9, 19.8, 19.5, 19.2. HRMS (EI) Calcd for $C_{25}H_{24}$: $[M]^+$ 324.1878; Found, 324.1876.

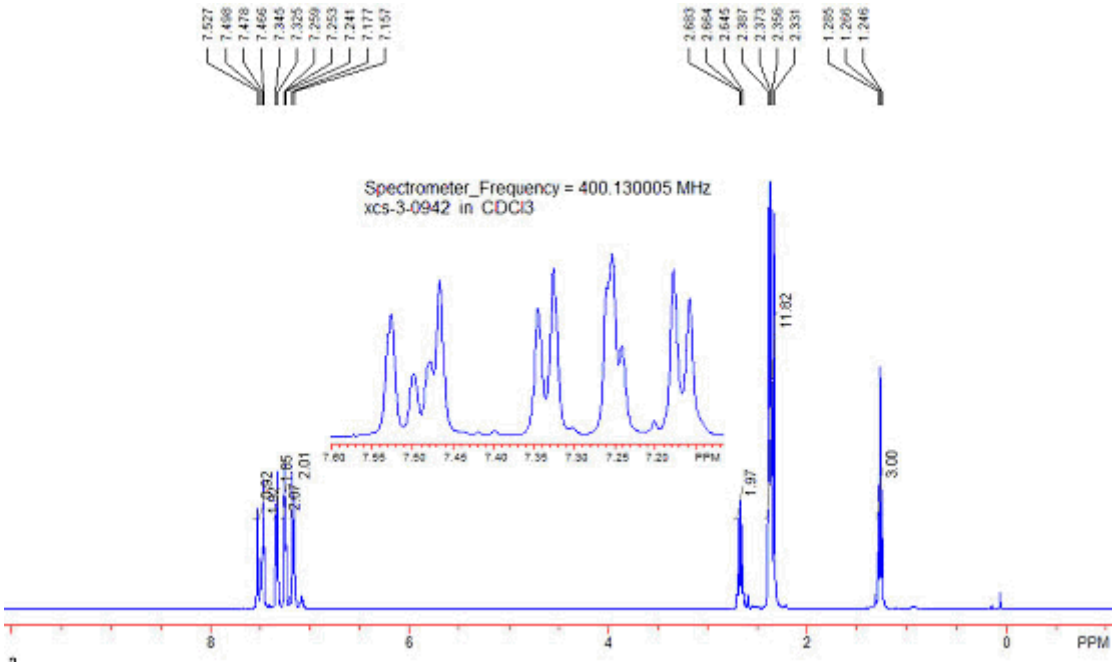


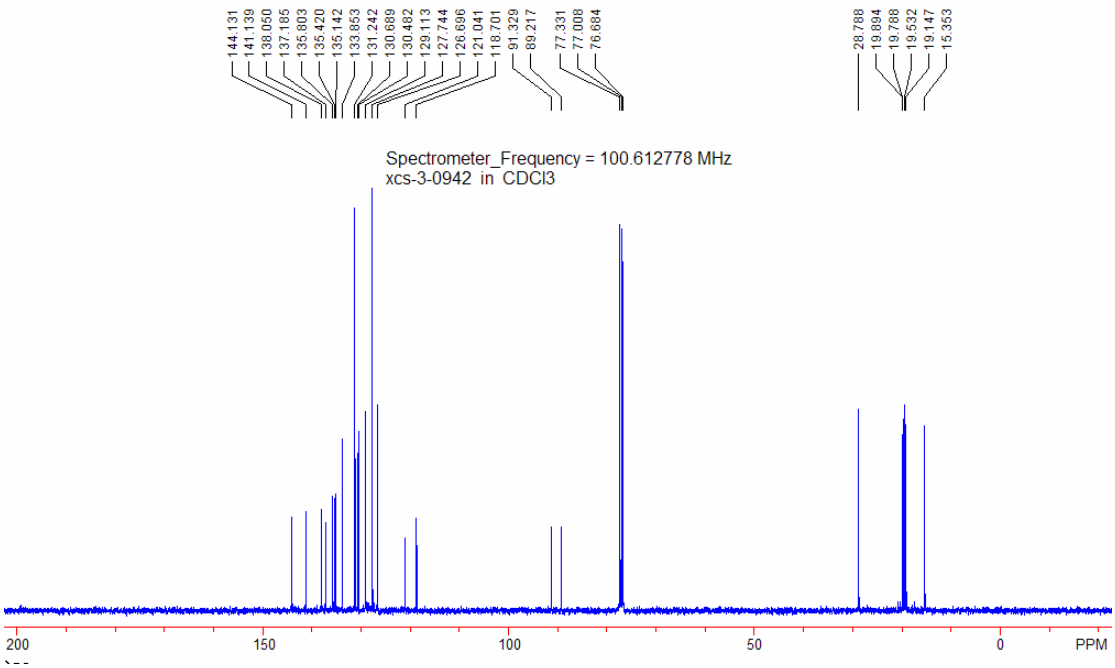


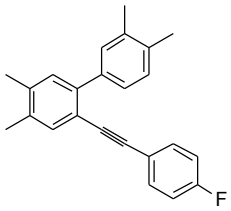


T2-12, new compound

^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.53 (s, 1 H), 7.49 (d, *J* = 8.0 Hz, 1 H), 7.47 (s, 1 H), 7.34 (d, *J* = 8.0 Hz, 2 H), 7.24-7.26 (m, 2 H), 7.17 (d, *J* = 8.0 Hz, 2 H), 2.67 (q, *J* = 7.6 Hz, 2 H), 2.39 (s, 3 H), 2.37 (s, 3 H), 2.36 (s, 3 H), 2.33 (s, 3 H), 1.27 (t, *J* = 7.8 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.1, 141.1, 138.0, 137.2, 135.8, 135.4, 135.1, 133.8, 131.2, 130.7, 130.5, 129.1, 127.7, 126.7, 121.0, 118.7, 91.3, 89.2, 28.8, 19.9, 19.8, 19.5, 19.1, 15.3. HRMS (EI) Calcd for $C_{26}H_{26}$: $[M]^+$ 338.2035; Found, 338.2030.

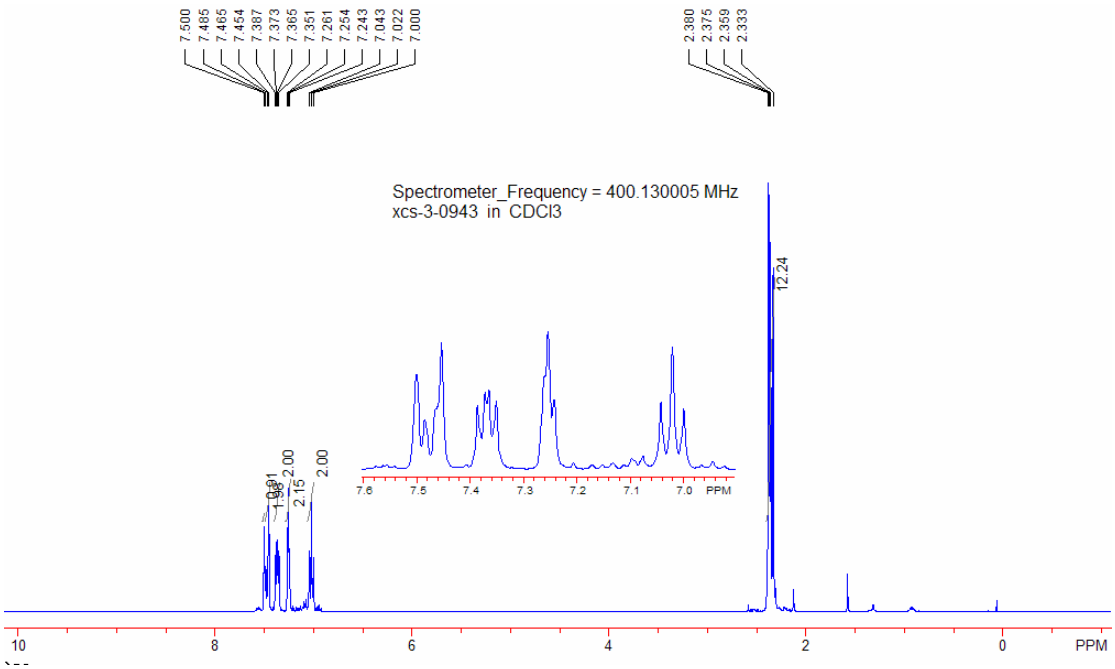


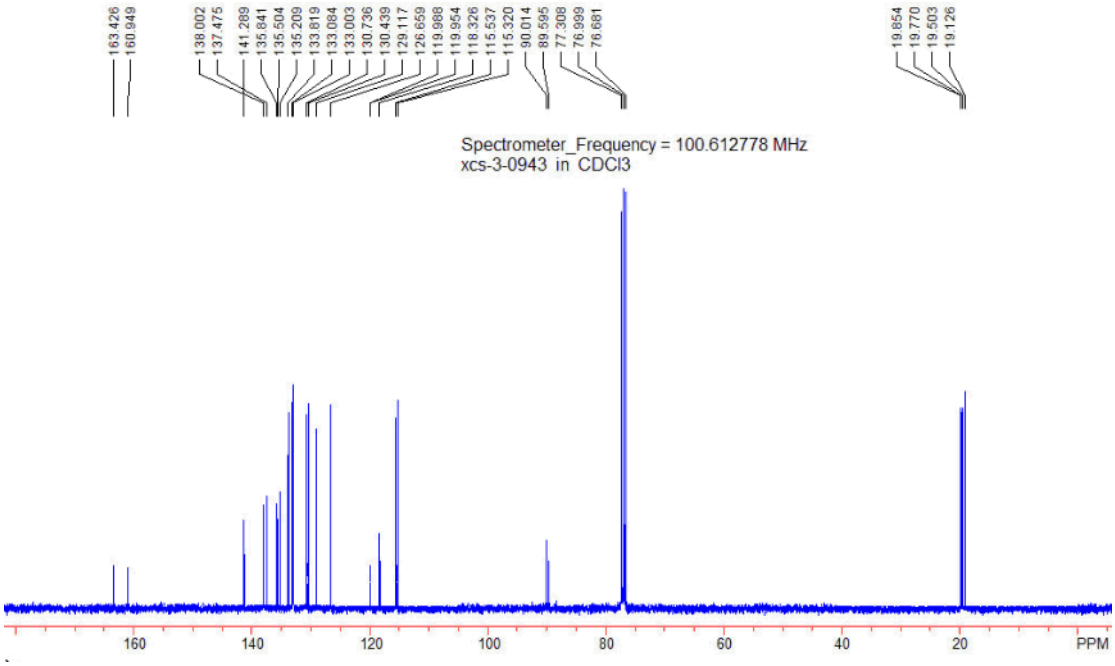


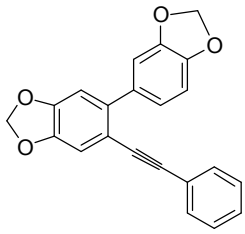


T2-13, new component

^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.50 (s, 1 H), 7.45-7.48 (m, 2 H), 7.35-7.39 (m, 2 H), 7.24-7.26 (m, 2 H), 7.02 (t, J = 8.6 Hz, 2 H), 2.38 (s, 3 H), 2.37 (s, 3 H), 2.36 (s, 3 H), 2.33 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.2 (d, J = 247.7 Hz), 141.3, 138.0, 137.5, 135.8, 135.5, 135.2, 133.8, 133.0 (d, J = 8.1 Hz), 130.7, 130.4, 129.1, 126.6, 119.9 (d, J = 3.4 Hz), 118.3, 115.4 (d, J = 21.7 Hz), 90.0, 89.6, 19.9, 19.8, 19.5, 19.1. HRMS (EI) Calcd for $C_{24}H_{21}F$: $[M]^+$ 328.1627; Found, 328.1621.

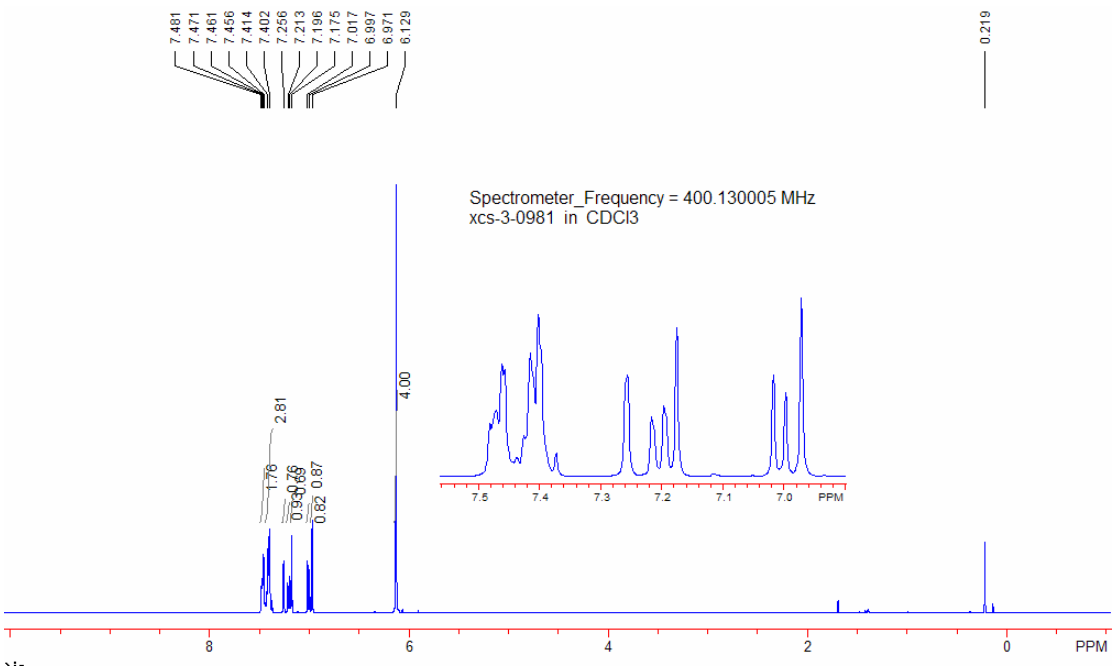


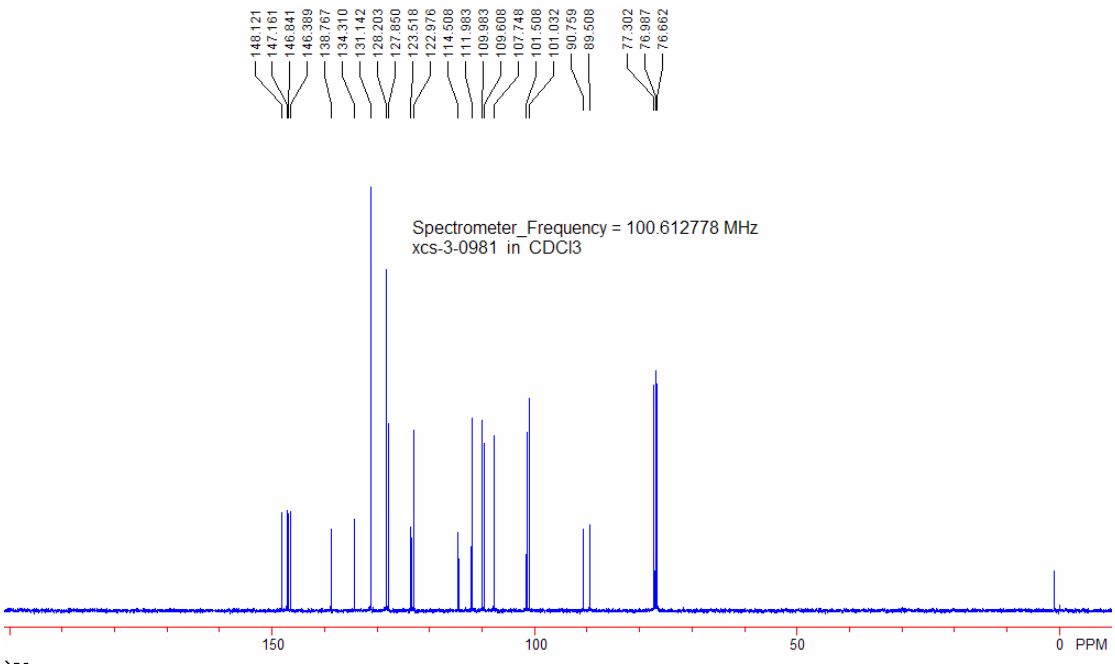


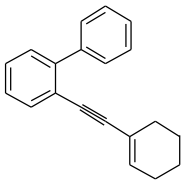


T2-14, new compound

^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.46-7.48 (m, 2 H), 7.40-7.42 (m, 3 H), 7.26 (s, 1 H), 7.20 (d, J = 6.8 Hz, 1 H), 7.18 (s, 1 H), 7.01 (d, J = 8.0 Hz, 1 H), 6.97 (s, 1 H), 6.13 (s, 4 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 148.1, 147.2, 146.8, 146.4, 138.8, 134.3, 131.1, 128.2, 127.8, 123.5, 123.0, 114.5, 112.0, 110.0, 109.6, 107.7, 101.5, 101.0, 90.8, 89.5. HRMS (EI) Calcd for $C_{22}H_{14}O_4$: $[M]^+$ 342.0892; Found, 342.0898.

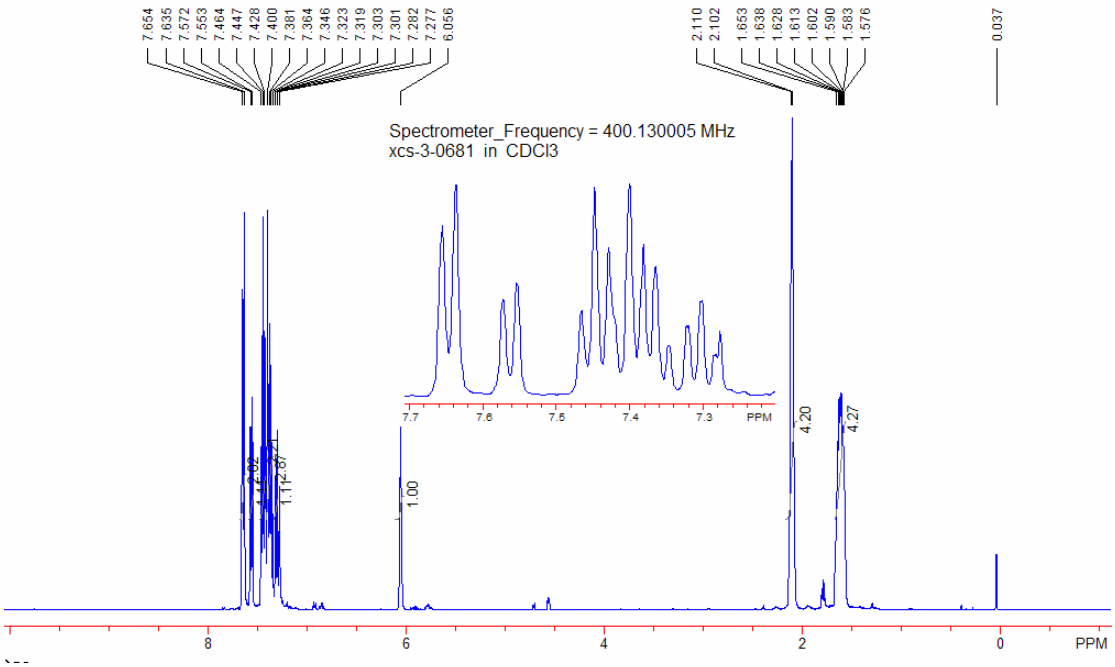


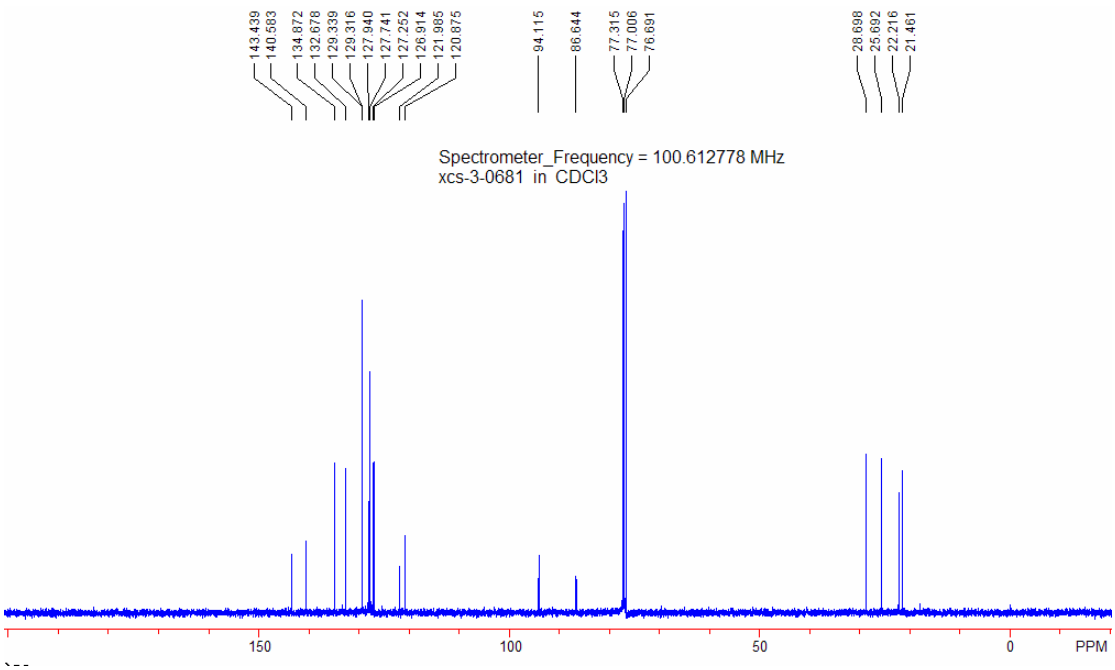


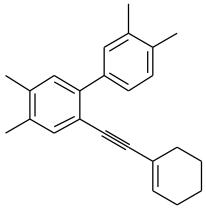


T2-15, 851901-88-7, Ref. 5

^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.64 (d, J = 7.6 Hz, 2 H), 7.56 (d, J = 7.6 Hz, 1 H), 7.45 (t, J = 7.2 Hz, 2 H), 7.35-7.40 (m, 3 H), 7.30 (t, J = 8.2 Hz, 1 H), 6.06 (s, 1 H), 2.10-2.11 (m, 4 H), 1.58-1.65 (m, 4 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.4, 140.6, 134.9, 132.7, 129.34, 129.32, 127.9, 127.7, 127.2, 126.9, 122.0, 120.9, 94.1, 86.6, 28.7, 26.7, 22.2, 21.5. HRMS (EI) Calcd for $C_{20}H_{18}$: $[M]^+$ 258.1409; Found, 258.1405.

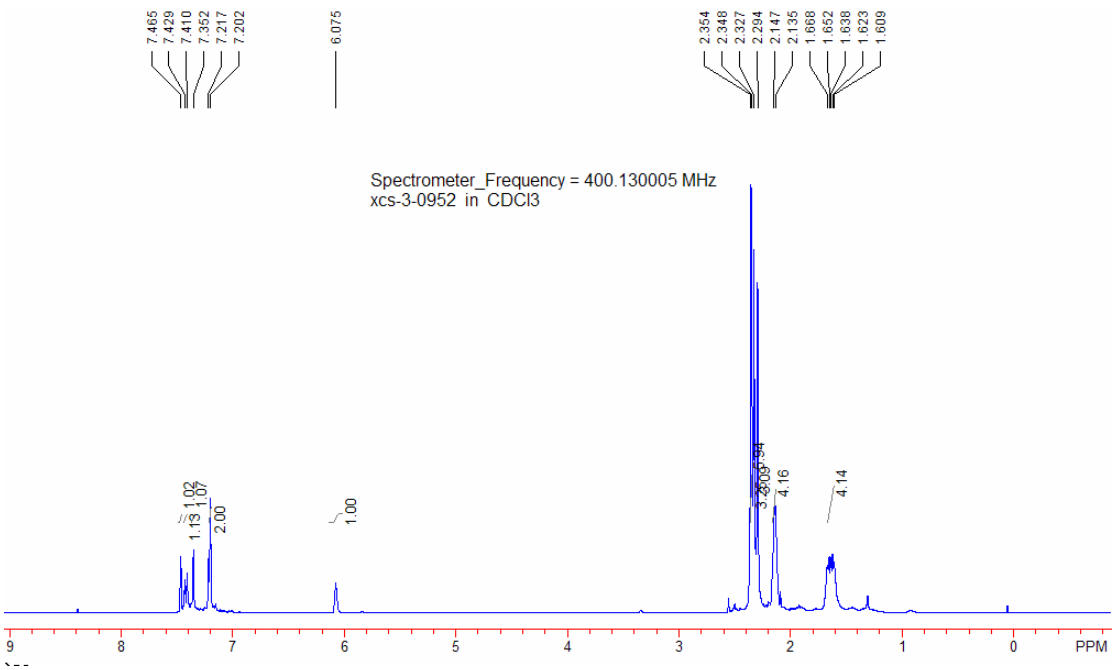


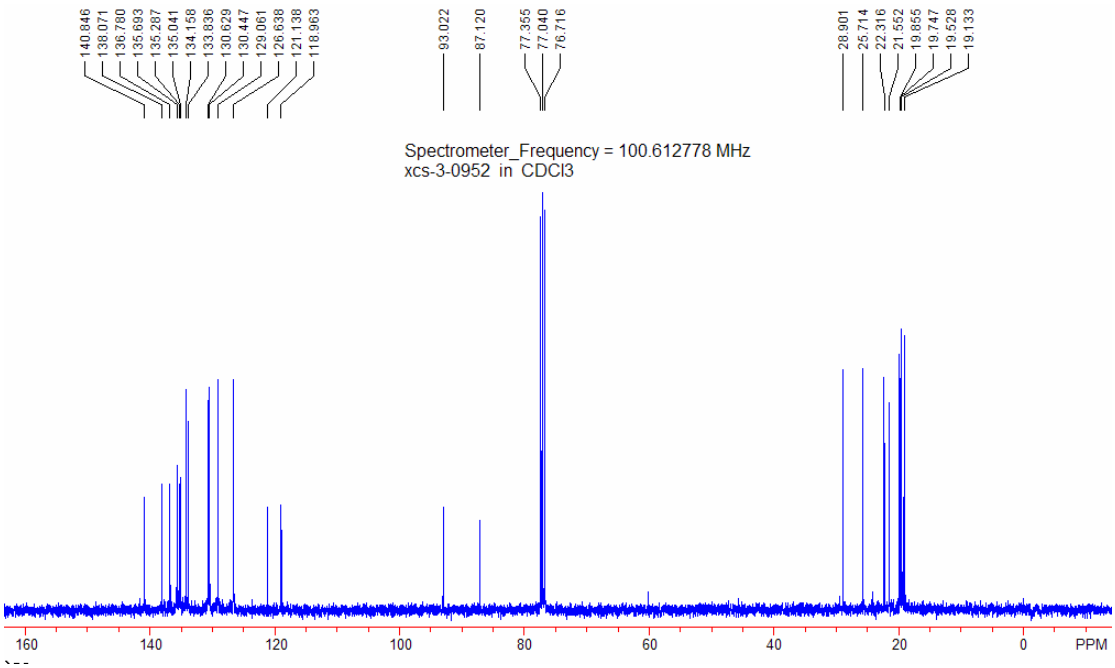


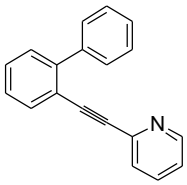


T2-16, new compound

^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.46 (s, 1 H), 7.42 (d, *J* = 7.6 Hz, 1 H), 7.35 (s, 1 H), 7.21 (d, *J* = 6.0 Hz, 1 H), 7.20 (s, 1 H), 6.08 (s, 1 H), 2.35 (s, 3 H), 2.34 (s, 3 H), 2.33 (s, 3 H), 2.29 (s, 3 H), 2.14-2.15 (m, 4 H), 1.61-1.67 (m, 4 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.8, 138.1, 136.8, 135.7, 135.3, 135.0, 134.2, 133.8, 130.6, 130.4, 129.1, 126.6, 121.1, 118.9, 93.0, 87.1, 28.9, 25.7, 22.3, 21.6, 19.8, 19.7, 19.5, 19.1. HRMS (EI) Calcd for $C_{24}H_{26}$: $[M]^+$ 314.2035; Found, 314.2034.

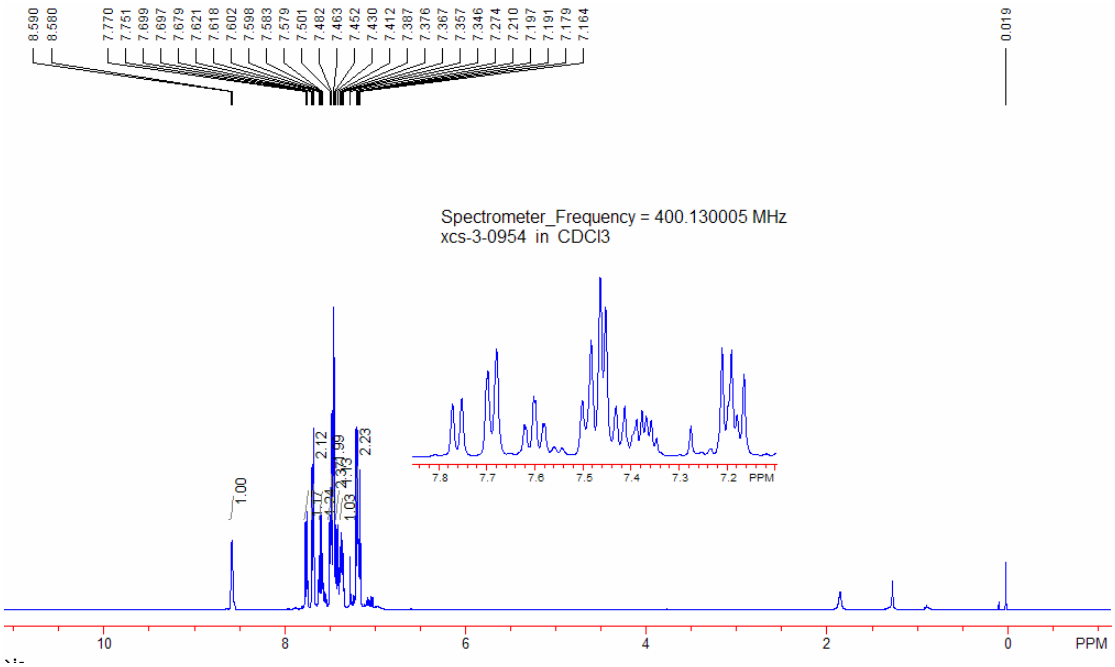


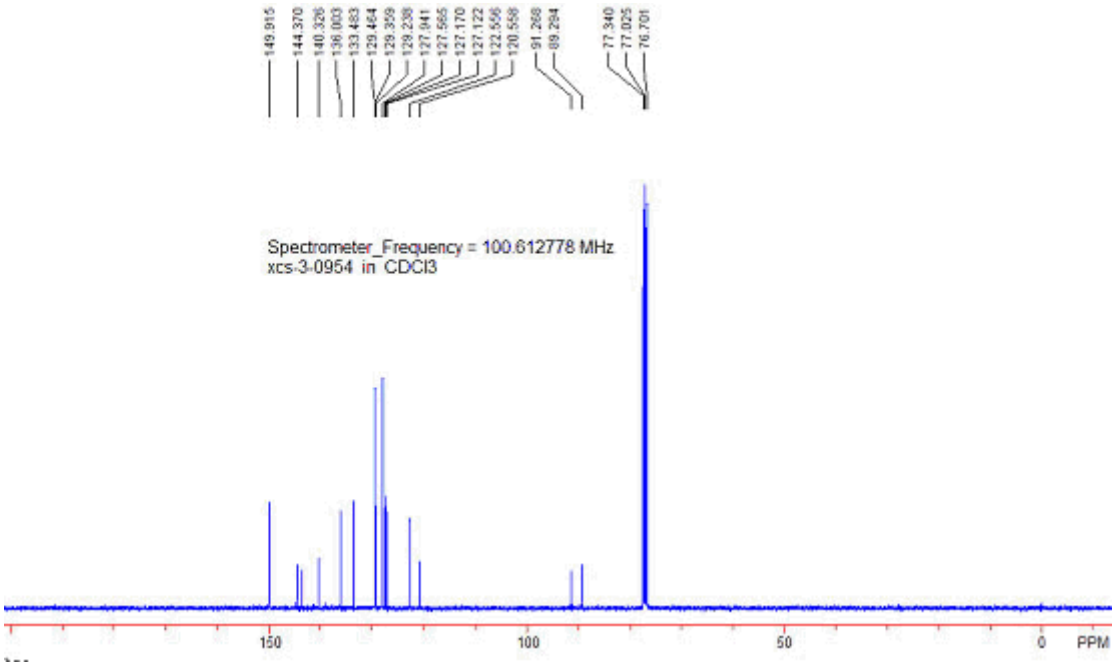


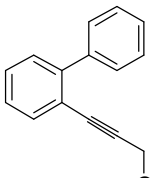


T2-17, new compound

^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 8.58 (d, *J* = 4.0 Hz, 1 H), 7.76 (d, *J* = 7.6 Hz, 1 H), 7.69 (d, *J* = 7.2 Hz, 2 H), 7.60 (t, *J* = 7.6 Hz, 1 H), 7.49 (d, *J* = 7.6 Hz, 2 H), 7.45 (d, *J* = 4.4 Hz, 2 H), 7.42 (d, *J* = 7.2 Hz, 1 H), 7.37 (m, 1 H), 7.20 (d, *J* = 7.6 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 149.9, 144.4, 140.3, 136.0, 133.5, 129.5, 129.4, 129.2, 127.9, 127.6, 127.2, 127.1, 122.6, 120.6, 91.3, 89.3. HRMS (EI) Calcd for $C_{19}H_{13}N$: $[M]^+$ 255.1048; Found, 255.1041.

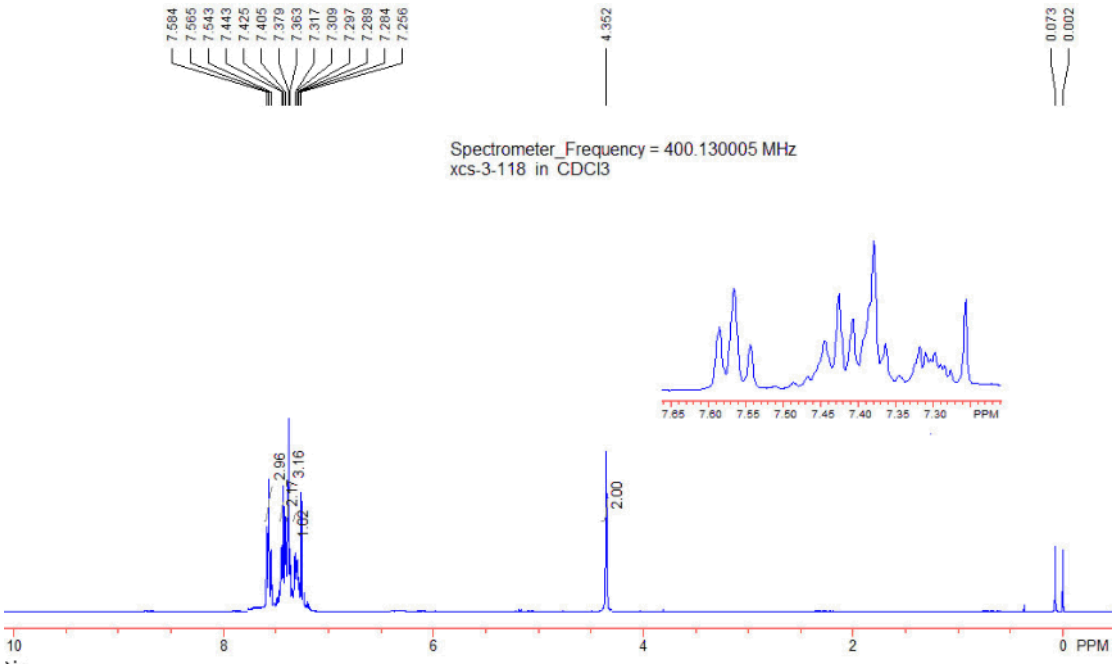


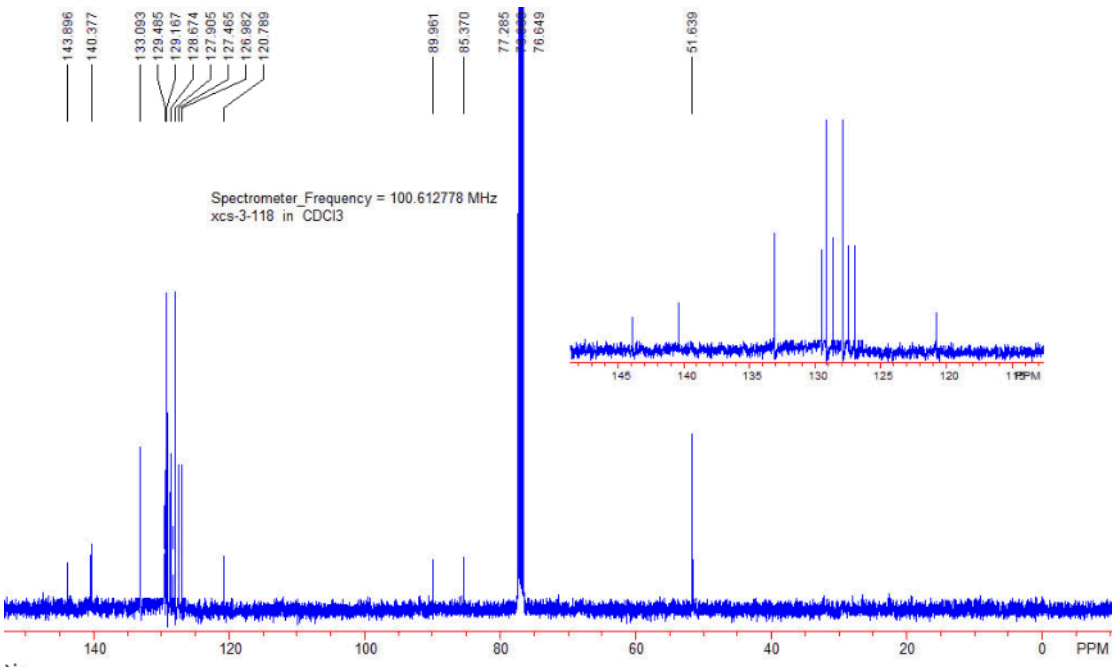


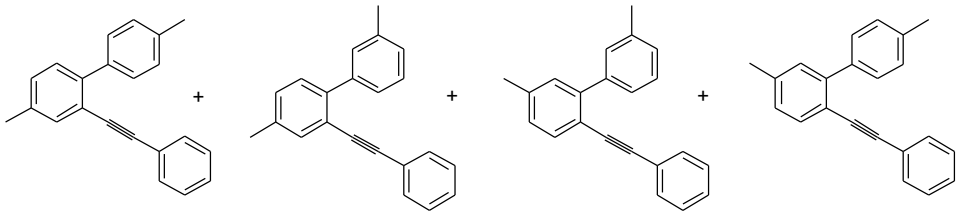


T2-18, 1001920-52-0, Ref. 6

^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.57 (d, *J* = 7.6 Hz, 2 H), 7.55 (d, *J* = 8.8 Hz, 1 H), 7.43 (t, *J* = 7.6 Hz, 2 H), 7.36-7.40 (m, 3 H), 7.30 (m, 1 H), 4.35 (s, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.9, 140.4, 133.1, 129.5, 129.2, 128.7, 127.9, 127.5, 126.9, 120.8, 89.9, 85.4, 51.6. MS (EI): m/z: 208 [M^+], 190, 178, 165, 152, 94.



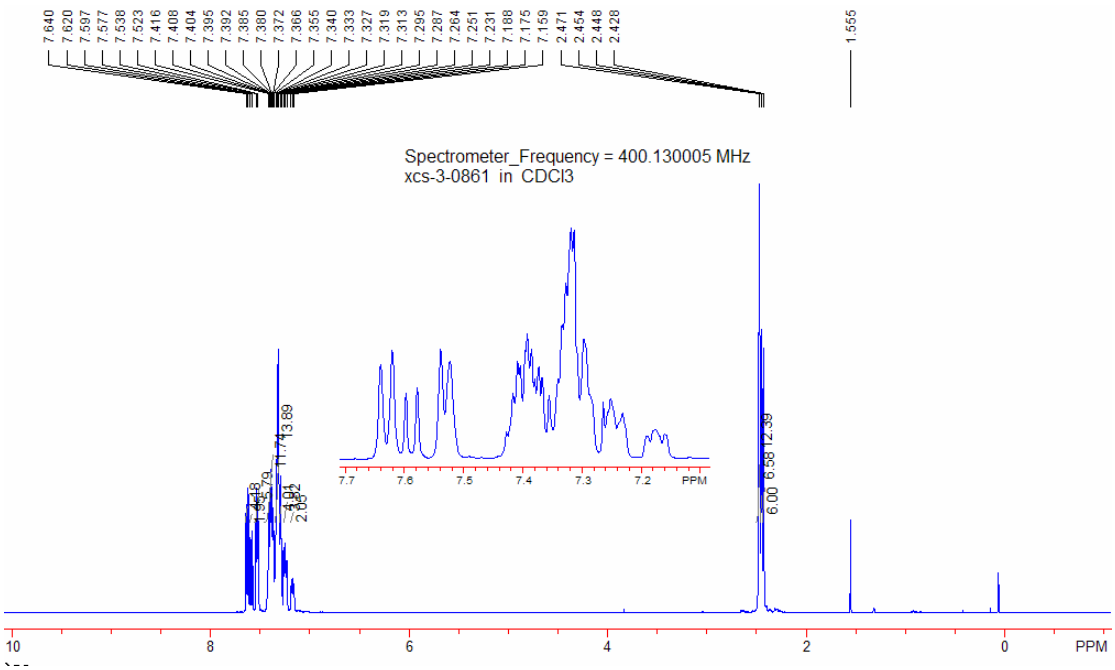


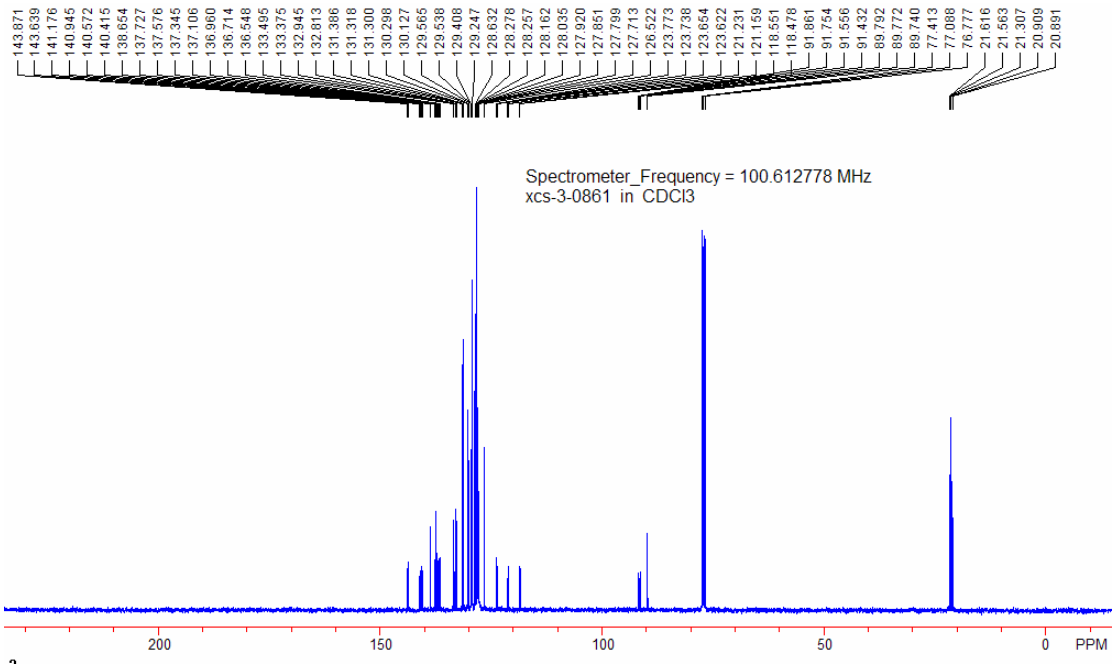


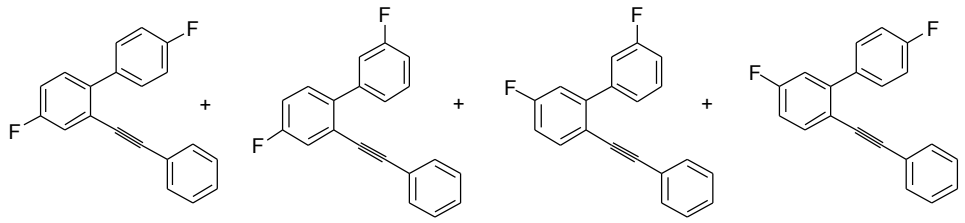
Scheme 3-1

223114-17-8, Ref. 7 new compound new compound 223114-14-5, Ref. 7

^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.63 (d, J = 8.0 Hz, 4 H), 7.59 (d, J = 8.0 Hz, 2 H), 7.52-7.54 (m, 6 H), 7.37-7.43 (m, 12 H), 7.29-7.34 (m, 14 H), 7.26-7.29 (m, 4 H), 7.23-7.26 (m, 4 H), 7.16-7.19 (m, 2 H), 2.46-2.47 (m, 12 H), 2.45-2.46 (m, 6 H), 2.43-2.44 (m, 6 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.9, 143.6, 141.2, 140.9, 140.6, 140.4, 138.6, 137.7, 137.6, 137.3, 137.1, 137.0, 136.7, 136.5, 133.5, 133.4, 132.9, 132.8, 131.4, 131.3, 130.3, 130.1, 129.6, 129.5, 129.4, 129.2, 128.6, 128.3, 128.2, 128.1, 128.0, 127.9, 127.8, 127.7, 126.5, 123.8, 123.7, 123.6, 121.2, 121.1, 118.6, 118.5, 91.9, 91.8, 91.6, 91.4, 89.8, 89.7, 21.6, 21.5, 21.3, 20.9, 20.8. HRMS (EI) Calcd for $C_{22}H_{18}$: $[M]^+$ 282.1409; Found, 282.1406.

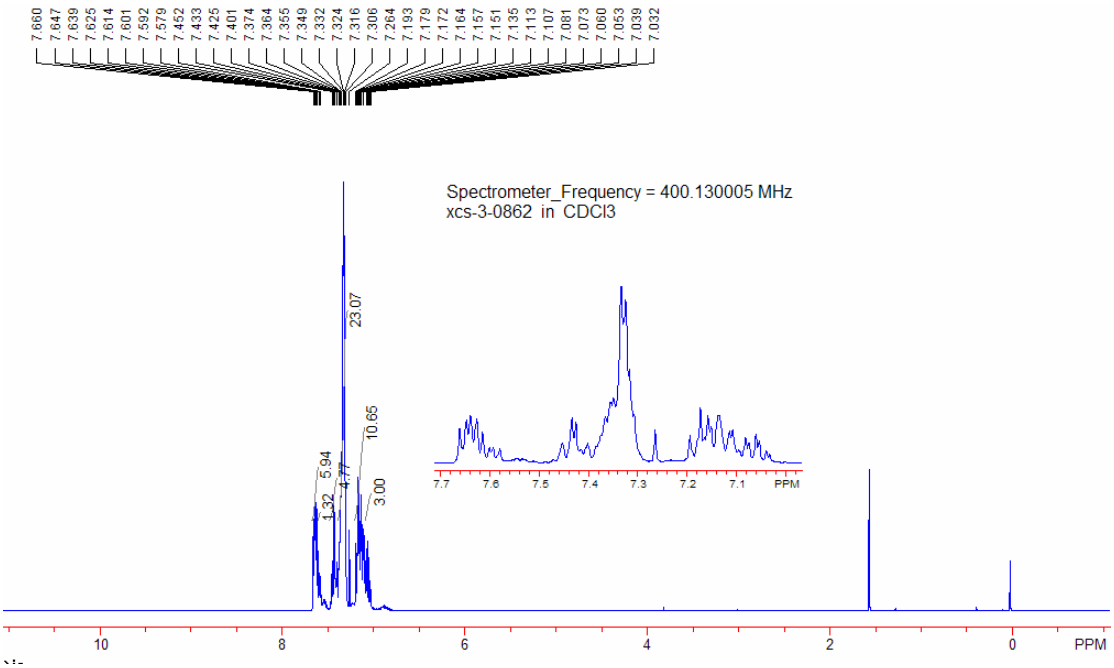


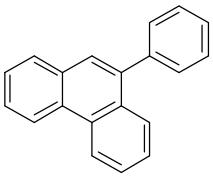




Scheme 3-2, new compounds

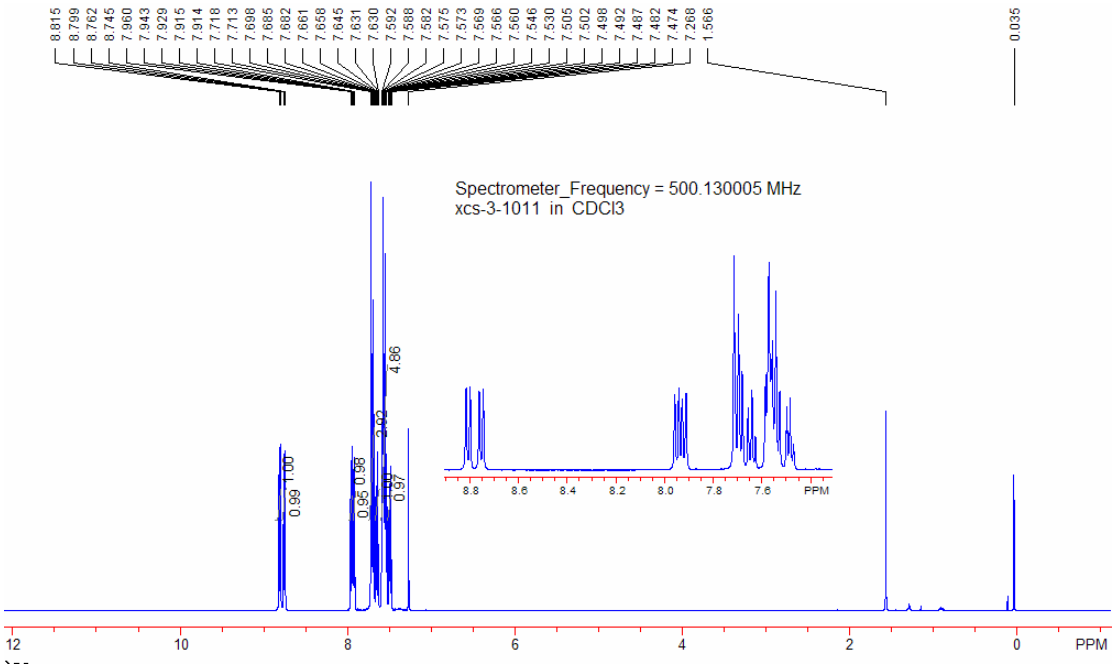
^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.61-7.66 (m, 6 H), 7.59 (d, J = 7.6 Hz, 1 H), 7.40-7.45 (m, 5 H), 7.31-7.37 (m, 23 H), 7.11-7.19 (m, 10 H), 7.03-7.08 (m, 3 H); HRMS (EI) Calcd for $C_{20}H_{12}F_2$: $[M]^+$ 290.0907; Found, 290.0899.

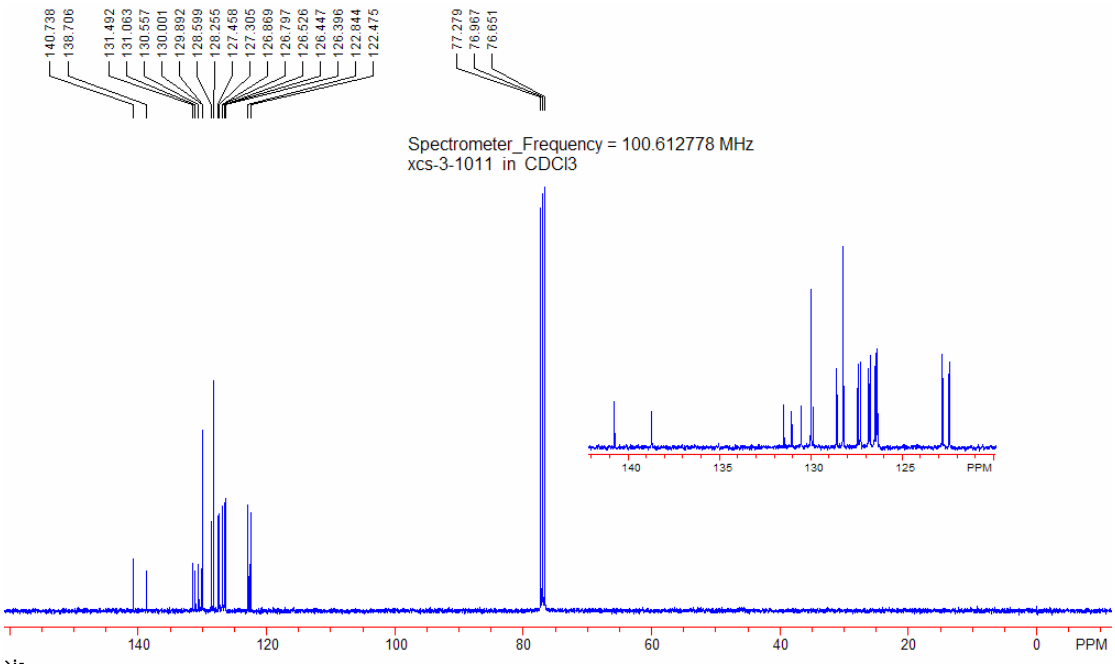




Scheme 4, 844-20-2, Ref. 4

^{1}H NMR (500 MHz, $CDCl_3$, TMS) δ 8.80 (d, J = 8.0 Hz, 1 H), 8.75 (d, J = 8.5 Hz, 1 H), 7.95 (d, J = 8.5 Hz, 1 H), 7.92 (d, J = 7.5 Hz, 1 H), 7.68-7.72 (m, 3 H), 7.64 (t, J = 7.5 Hz, 1 H), 7.53-7.59 (m, 5 H), 7.49 (t, J = 7.0 Hz, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.7, 138.7, 131.5, 131.1, 130.6, 130.0, 129.9, 128.6, 128.2, 127.4, 127.3, 126.9, 126.8, 126.5, 126.4, 126.3, 122.8, 122.5. MS (EI): m/z (%): 254 (100) [M^+], 126 (30), 113 (15).





References

(1) Y. Himeshima, T. Sonoda and H. Kobayashi, *Chem. Lett*., 1983, 1211-1214.

(2) Y. Wang and D. J. Burton, *Org. Lett.,* 2006, **8**, 5295-5298.

(3) T. Hirao, T. Takada and A. Ogawa, *J. Org. Chem.*, 2000, **65**, 1511-1515.

(4) K. Kanno, Y.-H. Liu, A. Lesato, K. Nakajima and T. Takahashi, *Org. Lett*. 2005, **7**, 5453-5456.

(5) T.-L. Yao, M. A. Campo and R. C. Larock, *J. Org. Chem.*, 2005, **70**, 3511-3517.

(6) S. Djurdjevic and J. R. Green, *Org. Lett.,* 2007, **9**, 5505-5508.

(7) S. Watanabe, K. Yamamoto, Y. Itagaki, T. Iwamura, T. Iwama and T. Kataoka *Tetrahedron,* 2000, **56**, 855-863.