Palladium-catalyzed three-component reaction of 2-alkynylbromobenzene, 2-alkynylaniline, and electrophile: An efficient pathway for the synthesis of diverse 11*H*-indeno[1,2-*c*]quinolines

Xiaolin Pan,[†] Yong Luo,[†] and Jie Wu*[,†,‡]

[†] *Department of Chemistry, Fudan University, 220 Handan Road, Shanghai 200433, China.* [‡] *Jiangxi Key Laboratory of Organic Chemistry, Jiangxi Science & Technology Normal University, Nanchang 330013, China.*

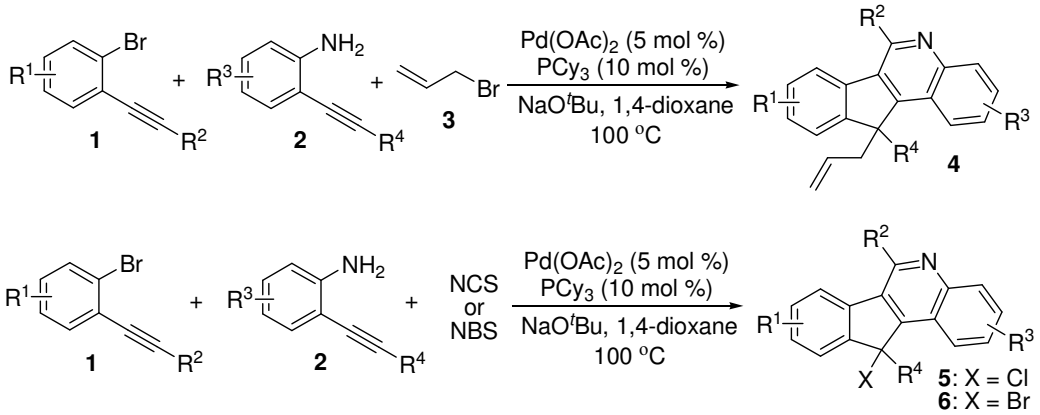
jie_wu@fudan.edu.cn

Supporting Information

General experimental methods:

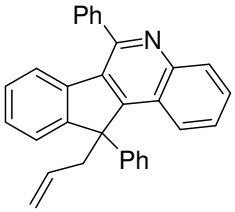
All reactions were performed in reaction tubes. Flash column chromatography was performed using silica gel (60-Å pore size, 32–63 μm, standard grade). Analytical thin–layer chromatography was performed using glass plates pre-coated with 0.25 mm 230–400 mesh silica gel impregnated with a fluorescent indicator (254 nm). Thin layer chromatography plates were visualized by exposure to ultraviolet light. Organic solutions were concentrated on rotary evaporators at ~20 Torr (house vacuum) at 25–35°C. Commercial reagents and solvents were used as received. Nuclear magnetic resonance (NMR) spectra are recorded in parts per million from internal tetramethylsilane on the δ scale. ^{1}H and ^{13}C NMR spectra were recorded in $CDCl_3$ on a Bruker DRX-400 spectrometer operating at 400 MHz and 100 MHz, respectively. All chemical shift values are quoted in ppm and coupling constants quoted in Hz. High resolution mass spectrometry (HRMS) spectra were obtained on a micrOTOF II Instrument. IR spectra were run on a FTIR-360 spectrophotometer.

General experimental procedure for palladium-catalyzed three-component reaction of 2-alkynylbromobenzene, 2-alkynylaniline, and electrophile.

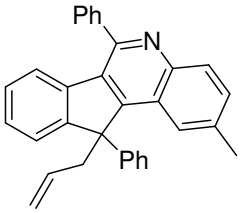


2-Alkynylbromobenzene (0.24 mmol) was added to a mixture of $Pd(OAc)_2$ (5 mol %), tricyclohexylphosphine (10 mol %), *t*-BuONa (0.8 mmol), and 2-alkynylaniline (0.20 mmol) in 1,4-dioxane (2.0 mL). The mixture was heated at 100 °C. After 2-alkynylaniline was consumed completely, an electrophile (allylic bromide, NBS or NCS, 0.3 mmol) was added to the mixture. After completion of the reaction as

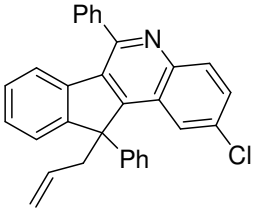
indicated by TLC, the reaction was cooled and the solvent was diluted by EtOAc (10 mL), washed with saturated brine (2 × 10 mL), and dried by anhydrous Na_2SO_4. Evaporation of the solvent followed by purification on silica gel provides the product (11*H*-indeno[1,2-*c*]quinolines **4-6**).



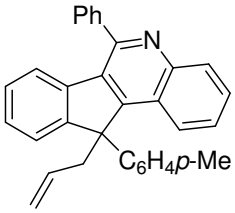
11-Allyl-6,11-diphenyl-11*H*-indeno[1,2-*c*]quinoline (**4a**). IR 3058.3, 2922.9, 2845.6, 1637.9, 1599.9, 1496.0, 1456.7, 1442.5 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 8.24-8.22 (m, 1H), 7.77-7.76 (m, 2H), 7.63-7.56 (m, 5H), 7.37-7.33 (m, 1H), 7.26-7.16 (m, 7H), 7.08-7.04 (m, 1H), 7.00-6.98 (m, 1H), 4.84-4.75 (m, 1H), 4.56-4.47 (m, 2H), 3.58 (d, *J* = 7.2 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 155.8, 155.7, 152.9, 147.2, 142.7, 140.5, 138.4, 132.7, 131.6, 130.4, 128.8, 128.7, 128.6, 127.6, 127.0, 126.9, 126.5, 126.3, 124.0, 123.9, 123.6, 122.8, 117.9, 59.4, 41.3. HRMS (ESI) calcd for $C_{31}H_{23}N$: 410.1909 ($M + H^+$), found: 410.1880.



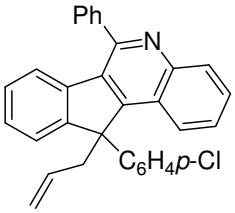
11-Allyl-2-methyl-6,11-diphenyl-11*H*-indeno[1,2-*c*]quinoline (**4b**). IR 3058.7, 2922.9, 2854.0, 1634.6, 1594.9, 1561.3, 1495.0, 1467.1, 1443.0, 1364.9 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 8.12 (d, *J* = 8.8 Hz, 1H), 7.76-7.74 (m, 2H), 7.59-7.54 (m, 3H), 7.44 (d, *J* = 8.8 Hz, 1H), 7.36 (s, 1H), 7.26-7.15 (m, 7H), 7.05 (t, *J* = 7.6 Hz, 1H), 6.99-6.97 (m, 1H), 4.84-4.75 (m, 1H), 4.58-4.48 (m, 2H), 3.58 (dd, *J* = 6.8, 3.2 Hz, 2H), 2.37 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 154.9, 153.0, 147.3, 145.8, 142.8, 140.7, 138.6, 136.2, 132.6, 131.8, 131.1, 130.1, 128.9, 128.8, 128.7, 128.6, 127.5, 126.9, 126.8, 126.3, 124.0, 123.6, 122.8, 117.8, 59.3, 41.1, 22.0. HRMS (ESI) calcd for $C_{32}H_{25}N$: 424.2065 ($M + H^+$), found: 424.2066.



11-Allyl-2-chloro-6,11-diphenyl-11*H*-indeno[1,2-*c*]quinoline (**4c**). IR 3060.6, 2925.5, 2853.5, 1640.7, 1601.3, 1563.4, 1491.8, 1462.3, 1444.3 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 8.15 (d, *J* = 8.8 Hz, 1H), 7.76-7.74 (m, 2H), 7.61-7.53 (m, 5H), 7.29-7.17 (m, 7H), 7.10-7.06 (m, 1H), 7.02-7.00 (m, 1H), 4.85-4.74 (m, 1H), 4.60-4.50 (m, 2H), 3.58-3.54 (m, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.0, 154.9, 153.1, 145.5, 142.0, 140.2, 138.1, 133.5, 132.2, 132.1, 131.4, 129.0, 128.9, 128.8, 128.8, 128.7, 128.0, 127.3, 127.0, 126.3, 124.6, 123.7, 123.0, 122.6, 118.2, 59.4, 41.1. HRMS (ESI) calcd for $C_{31}H_{22}ClN$: 444.1519 ($M + H^+$), found: 444.1503.

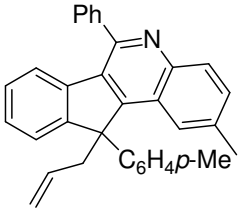


11-Allyl-6-phenyl-11-(p-tolyl)-11*H*-indeno[1,2-*c*]quinoline (**4d**). IR 3059.2, 2921.7, 2847.8, 1634.6, 1561.4, 1509.6, 1491.3, 1466.9, 1436.4, 1366.3 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 8.22 (d, *J* = 8.4 Hz, 1H), 7.77-7.75 (m, 2H), 7.65-7.63 (m, 1H), 7.61-7.55 (m, 3H), 7.35 (t, *J* = 8.0 Hz, 1H), 7.22-7.15 (m, 2H), 7.09-7.06 (m, 6H), 7.00-6.98 (m, 1H), 4.83-4.77 (m, 1H), 4.56-4.46 (m, 2H), 3.56 (d, *J* = 6.8 Hz, 2H), 2.27 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 155.8, 155.07, 153.1, 147.2, 140.6, 139.6, 138.4, 136.5, 132.6, 131.8, 130.4, 129.5, 128.8, 128.8, 128.7, 128.6, 127.6, 126.8, 126.4, 126.2, 124.0, 123.9, 123.5, 122.8, 117.8, 59.1, 41.3, 20.9. HRMS (ESI) calcd for $C_{32}H_{25}N$: 424.2065 ($M + H^+$), found: 424.2070.

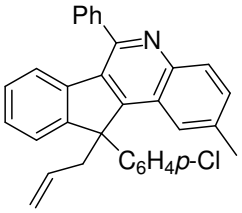


11-Allyl-11-(4-chlorophenyl)-6-phenyl-11*H*-indeno[1,2-*c*]quinoline (**4e**). IR 3061.1,

2923.6, 2852.1, 1640.2, 1565.4, 1491.6, 1463.7, 1444.0 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 8.24 (d, *J* = 8.8 Hz, 1H), 7.76-7.75 (m, 2H), 7.65-7.57 (m, 5H), 7.40-7.36 (m, 1H), 7.23-7.18 (m, 4H), 7.13-7.11 (m, 2H), 7.09-7.05 (m, 1H), 7.00 (d, *J* = 7.6 Hz, 1H), 4.82-4.74 (m, 1H), 4.56-4.48 (m, 2H), 3.54 (d, *J* = 7.2 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 155.8, 155.1, 152.4, 147.2, 141.4, 140.4, 138.4, 132.8, 132.7, 131.3, 130.6, 129.0, 128.9, 128.9, 128.8, 128.7, 127.8, 127.7, 127.1, 126.6, 123.7, 123.5, 122.9, 118.2, 58.9, 41.2. HRMS (ESI) calcd for $C_{31}H_{22}ClN$: 444.1519 ($M + H^+$), found: 444.1508.

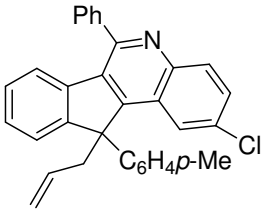


11-Allyl-2-methyl-6-phenyl-11-(p-tolyl)-11*H*-indeno[1,2-*c*]quinoline (**4f**). IR 3057.4, 2921.0, 2855.6, 1640.6, 1622.4, 1561.4, 1497.7.7, 1467.0, 1442.8, 1366.3 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 8.11 (d, *J* = 8.4 Hz, 1H), 7.75 (d, *J* = 6.8 Hz, 2H), 7.58-7.56 (m, 3H), 7.46-7.40 (m, 2H), 7.20-7.14 (m, 2H), 7.09-7.03 (m, 5H), 6.98-6.96 (m, 1H), 4.83-4.75 (m, 1H), 4.57-4.47 (m, 2H), 3.58-3.55 (m, 2H), 2.38 (s, 3H), 2.27 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 155.0, 154.8, 153.1, 145.8, 140.7, 139.7, 138.6, 136.4, 136.2, 132.6, 131.9, 131.1, 130.1, 129.4, 128.9, 128.7, 128.6, 127.5, 126.7, 126.1, 124.0, 123.5, 122.8, 122.7, 117.7, 59.1, 41.1, 22.0, 21.0. HRMS (ESI) calcd for $C_{33}H_{27}N$: 438.2222 ($M + H^+$), found: 438.2208.

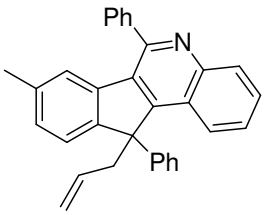


11-Allyl-11-(4-chlorophenyl)-2-methyl-6-phenyl-11*H*-indeno[1,2-*c*]quinoline (**4g**). IR 3060.3, 2921.7, 2854.4, 1643.7, 1622.4, 1561.4, 1492.0, 1467.6, 1442.2, 1364.8 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 8.12 (d, *J* = 8.8 Hz, 1H), 7.74 (d, *J* = 6.4 Hz, 2H), 7.59-7.54 (m, 3H), 7.48-7.45 (m, 1H), 7.32 (s, 1H), 7.24-7.21 (m, 2H), 7.18-7.11 (m, 4H), 7.08-7.04 (m, 1H), 6.99-6.97 (m, 1H), 4.82-4.74 (m, 1H), 4.58-4.48 (m, 2H),

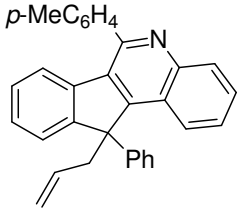
3.56-3.52 (m, 2H), 2.40 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 154.9, 154.2, 152.4, 145.9, 141.5, 140.5, 138.5, 136.5, 132.7, 132.6, 131.4, 131.3, 130.3, 128.9, 128.8, 128.7, 128.6, 127.7, 127.6, 127.0, 123.8, 123.4, 122.9, 122.5, 118.1, 58.8, 41.1, 22.0. HRMS (ESI) calcd for $C_{32}H_{24}ClN$: 458.1676 (M + H^+), found: 458.1678.



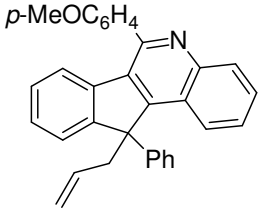
11-Allyl-2-chloro-6-phenyl-11-(p-tolyl)-11*H*-indeno[1,2-*c*]quinoline (**4h**). IR 3051.6, 2925.3, 2855.1, 1643.7, 1608.8, 1563.1, 1491.5, 1462.3, 1444.6, 1362.8 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.14 (d, *J* = 8.8 Hz, 1H), 7.76-7.74 (m, 2H), 7.61-7.53 (m, 5H), 7.21-7.20 (m, 2H), 7.09-7.05(m, 5H), 7.01-6.99 (m, 1H), 4.82-4.74 (m, 1H), 4.59-4.49 (m, 2H), 3.55-3.53 (m, 2H), 2.29 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.0, 155.0, 153.3, 145.5, 140.3, 138.9, 138.0, 136.9, 133.5, 132.1, 132.0, 131.5, 129.7, 129.0, 128.8, 128.7, 128.0, 126.9, 126.1, 124.7, 123.6, 123.0, 122.7, 118.1, 59.2, 41.2, 21.0. HRMS (ESI) calcd for $C_{32}H_{24}ClN$: 458.1676 (M + H^+), found: 458.1670.



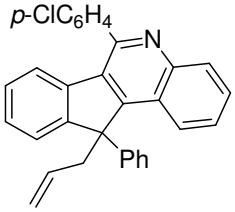
11-Allyl-8-methyl-6,11-diphenyl-11*H*-indeno[1,2-*c*]quinoline (**4i**). IR 3058.2, 2921.8, 2853.8, 1634.6, 1607.1, 1567.6, 1498.3, 1463.3, 1443.8, 1372.8 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.23-8.21 (m, 1H), 7.77-7.75 (m, 2H), 7.62-7.58 (m, 5H), 7.37-7.33 (m, 1H), 7.26-7.18 (m, 5H), 7.10 (d, *J* = 7.6 Hz, 1H), 7.00 (d, *J* = 8.0 Hz, 1H), 6.77 (s, 1H), 4.85-4.79 (m, 1H), 4.57-4.47 (m, 2H), 3.56 (d, *J* = 6.8 Hz, 2H), 2.17 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.0, 155.8, 150.2, 147.2, 143.0, 140.6, 138.6, 136.5, 132.8, 131.9, 130.5, 128.9, 128.8, 128.8, 128.7, 128.6, 128.5, 126.9, 126.4, 126.3, 125.2, 124.0, 123.6, 123.3, 117.8, 59.1, 41.3, 21.6. HRMS (ESI) calcd for $C_{32}H_{25}N$: 424.2065 (M + H^+), found: 424.2057.



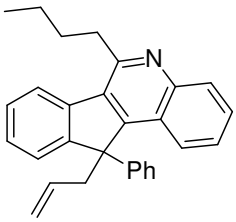
11-Allyl-11-phenyl-6-(p-tolyl)-11*H*-indeno[1,2-*c*]quinoline (**4j**). IR 3060.4, 2922.5, 2853.2, 1640.4, 1608.8, 1582.5, 1500.1, 1464.1, 1445.1, 1414.0 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.22-8.20 (m, 1H), 7.66 (d, *J* = 7.6 Hz, 2H), 7.61-7.59 (m, 2H), 7.39 (d, *J* = 8.0 Hz, 2H), 7.34 (t, *J* = 7.6 Hz, 1H), 7.26-7.18 (m, 7H), 7.09 (s, 2H), 4.83-4.77 (m, 1H), 4.56-4.46 (m, 2H), 3.58 (d, *J* = 7.2 Hz, 2H), 2.50 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 155.9, 155.6, 152.9, 147.3, 142.8, 138.6, 137.7, 132.7, 131.7, 130.4, 129.3, 128.8, 128.7, 127.5, 127.0, 126.8, 126.4, 126.3, 124.0, 123.9, 123.6, 122.9, 117.9, 59.4, 41.3, 21.5. HRMS (ESI) calcd for $C_{32}H_{25}N$: 424.2065 (M + H^+), found: 424.2062.



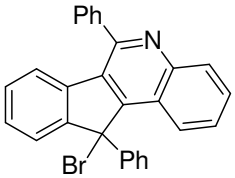
11-Allyl-6-(4-methoxyphenyl)-11-phenyl-11*H*-indeno[1,2-*c*]quinoline (**4k**). IR 3053.7, 2928.3, 2853.7, 1641.5, 1608.9, 1573.1, 1501.7, 1465.1, 1444.3, 1377.8, 1265.1, 1032.4 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.21 (d, *J* = 8.8 Hz, 1H), 7.72 (d, *J* = 8.8 Hz, 2H), 7.60 (d, *J* = 7.6 Hz, 2H), 7.36-7.32 (m, 1H), 7.26-7.19 (m, 7H), 7.13-7.09 (m, 4H), 4.83-4.75 (m, 1H), 4.57-4.47 (m, 2H), 3.94 (s, 3H), 3.58 (d, *J* = 6.8 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.1, 155.7, 155.6, 152.9, 147.3, 142.8, 138.7, 133.1, 132.8, 131.7, 130.4, 130.3, 128.8, 128.7, 127.6, 127.0, 126.9, 126.4, 126.3, 124.0, 123.8, 123.6, 122.9, 117.9, 114.0, 59.4, 41.3, 29.7. HRMS (ESI) calcd for $C_{32}H_{25}NO$: 440.2014 (M + H^+), found: 440.2000.



11-Allyl-6-(4-chlorophenyl)-11-phenyl-11*H*-indeno[1,2-*c*]quinoline (**4l**). IR 3060.8, 2924.4, 2853.6, 1646.7, 1596.6, 1565.3, 1491.4, 1464.8, 1445.0 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.21-8.19 (m, 1H), 7.73 (d, *J* = 8.4 Hz, 2H), 7.63-7.56 (m, 4H), 7.37-7.34 (m, 1H), 7.26-7.18 (m, 7H), 7.13-7.06 (m, 2H), 4.84-4.74 (m, 1H), 4.55-4.46 (m, 2H), 3.58 (d, *J* = 7.2 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.0, 154.4, 152.9, 147.2, 142.6, 139.0, 138.2, 134.9, 132.5, 131.6, 130.4, 129.0, 128.9, 128.8, 127.8, 127.0, 126.9, 126.7, 126.3, 124.0, 123.7, 122.6, 118.0, 59.4, 41.3. HRMS (ESI) calcd for $C_{31}H_{22}ClN$: 444.1519 ($M + H^+$), found: 444.1516.

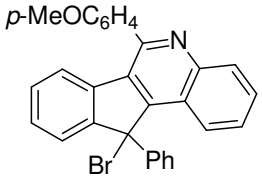


11-Allyl-6-butyl-11-phenyl-11*H*-indeno[1,2-c]quinoline (**4m**). IR 3055.7, 2926.1, 2857.6, 1646.7, 1598.6, 1573.6, 1494.3, 1466.9, 1442.5, 1405.9 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.13 (d, *J* = 8.2 Hz, 1H), 7.92 (d, *J* = 7.8 Hz, 1H), 7.62-7.54 (m, 2H), 7. 44-7.38 (m, 1H), 7.29-7.21 (m, 6H), 7.14-7.12 (m, 2H), 4.69-4.65 (m, 1H), 4.51-4.47 (m, 1H), 4.41-4.39 (m, 1H), 3.55-3.45 (m, 2H), 1.96-1.94 (m, 2H), 1.69-1.61 (m, 3H), 1.26 (s, 1H), 1.07-1.04 (m, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.2, 155.1, 153.2, 147.2, 142.8, 138.8, 128.8, 128.5, 127.5, 127.4, 126.3, 124.0, 123.8, 122.7, 117.8, 59.3, 41.2, 37.9, 30.6, 23.1. HRMS (ESI) calcd for $C_{29}H_{27}N$: 390.2222 ($M + H^+$), found: 390.2236.

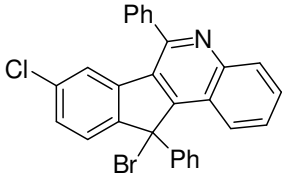


11-Bromo-6,11-diphenyl-11*H*-indeno[1,2-*c*]quinoline (**5a**). IR 3058.8, 2926.0, 2854.5,

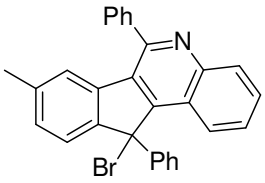
1596.5, 1583.2, 1499.3, 1444.7 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 8.26 (d, *J* = 8.4 Hz, 1H), 7.78-7.75 (m, 3H), 7.68-7.64 (m, 1H), 7.61-7.57 (m, 3H), 7.52-7.42 (m, 4H), 7.28-7.27 (m, 3H), 7.24-7.19 (m, 1H), 7.10-7.06 (m, 1H), 6.99-6.97 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.0, 153.0, 151.3, 148.1, 140.0, 139.1, 135.7, 130.3, 129.6, 129.1, 128.9, 128.8, 128.7, 128.6, 128.5, 128.4, 128.3, 127.1, 126.7, 125.5, 125.1, 122.8, 123.4, 65.5. HRMS (ESI) calcd for $C_{28}H_{18}BrN$: 448.0701 (M + H^+), found: 448.0696.



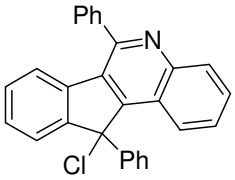
11-Bromo-6-(4-methoxyphenyl)-11-phenyl-11*H*-indeno[1,2-*c*]quinoline (**5b**). IR 3054.4, 2986.1, 2932.0, 1609.0, 1563.1, 1501.9, 1465.4, 1442.4, 1265.2, 1034.0 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 8.25 (d, *J* = 8.4 Hz, 1H), 7.77-7.71 (m, 3H), 7.67-7.63 (m, 1H), 7.51-7.49 (m, 3H), 7.44-7.41 (m, 1H), 7.28-7.27 (m, 3H), 7.25-7.20 (m, 1H), 7.13-7.11 (m, 4H), 3.93 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.3, 155.7, 153.1, 151.3, 148.1, 139.1, 135.9, 132.4, 130. 3, 130.2, 129.8, 129.5, 128.7, 128.6, 128.5, 128.3, 127.1, 126.6, 125.5, 123.4, 122.6, 114.1, 65.6, 55.4. HRMS (ESI) calcd for $C_{29}H_{20}BrNO$: 478.0807 (M + H^+), found: 478.0784.



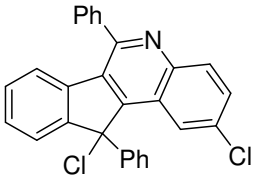
11-Bromo-8-chloro-6,11-diphenyl-11*H*-indeno[1,2-*c*]quinoline (**5c**). IR 3059.6, 2924.7, 2851.9, 1597.2, 1576.5, 1492.1, 1460.4 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 8.27 (d, *J* = 8.8 Hz, 1H), 7.77-7.75 (m, 3H), 7.72-7.67 (m, 1H), 7.63-7.61 (m, 3H), 7.49-7.44 (m, 1H), 7.38 (d, *J* = 8.4 Hz, 3H), 7.30-7.28 (m, 3H), 7.18 (dd, *J* = 8.4, 2.0 Hz, 1H), 6.94 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 155.9, 153.7, 149.5, 148.4, 139.5, 138.5, 137.5, 134.6, 130.4 130.0, 129.4, 128.9, 128.8, 128.7, 128.6, 128.5, 127.0, 126.9, 126.5, 125.1, 123.6, 122.6, 67.0. HRMS (ESI) calcd for $C_{28}H_{17}BrClN$: 482.0311 (M + H^+), found: 482.0305.



11-Bromo-8-methyl-6,11-diphenyl-11*H*-indeno[1,2-*c*]quinoline (**5d**). IR 3058.5, 2924.1, 2852.2, 1610.2, 1567.5, 1492.8, 1469.9, 1444.2, 1369.7 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.25 (d, *J* = 8.4 Hz, 1H), 7.78-7.75 (m, 3H), 7.68-7.64 (m, 1H), 7.61-7.58 (m, 3H), 7.51-7.49 (m, 2H), 7.46-7.42 (m, 1H), 7.36 (d, *J* = 8.0 Hz, 1H) 7.28-7.26 (m, 3H), 7.03 (d, *J* = 7.6 Hz, 1H), 6.77 (s, 1H), 2.16 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.0, 153.4, 148.6, 148.1, 140.1, 139.3, 138.6, 135.9, 130.3, 129.7, 129.5, 129.4, 129.1, 128.8, 128.7, 128.2, 127.0, 126.7, 125.2, 125.1, 124.1, 122.8, 67.0, 21.6. HRMS (ESI) calcd for $C_{29}H_{20}BrN$: 462.0857 ($M + H^+$), found: 462.0849.

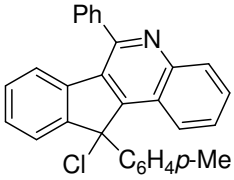


11-Chloro-6,11-diphenyl-11*H*-indeno[1,2-*c*]quinoline (**6a**). IR 3059.7, 2927.0, 2852.6, 1599.4, 1584.3, 1493.3, 1445.4 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.26 (d, *J* = 8.4 Hz, 1H), 7.79-7.77 (m, 3H), 7.68-7.65 (m, 1H), 7.60-7.59 (m, 3H), 7.49-7.40 (m, 4H), 7.30-7.28 (m, 3H), 7.24-7.19 (m, 1H), 7.10 (t, *J* = 7.6 Hz, 1H), 7.00-6.98 (d, *J* = 7.6 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 155.7, 152.9, 150.8, 147.9, 139.7, 139.2, 136.3, 130.6, 130.2, 129.6, 129.2, 128.8, 128.7, 128.6, 128.5, 128.3, 127.1, 126.0, 125.0, 124.7, 123.3, 122.7, 67.0. HRMS (ESI) calcd for $C_{28}H_{18}ClN$: 404.1206 ($M + H^+$), found: 404.1182.

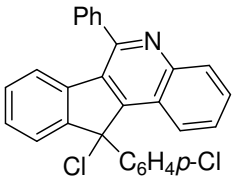


2,11-Dichloro-6,11-diphenyl-11*H*-indeno[1,2-*c*]quinoline (**6b**). IR 3056.5, 2925.3, 2855.3, 1607.1, 1573.6, 1491.3, 1462.5 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.16 (d, *J* = 9.2 Hz, 1H), 7.77-7.73 (m, 3H), 7.61-7.58 (m, 4H), 7.47-7.41 (m, 3H), 7.34-7.31 (m, 3H), 7.26-7.22 (m, 1H), 7.12 (t, *J* = 8.0 Hz, 1H), 7.01 (d, *J* = 7.6 Hz, 1H). ^{13}C

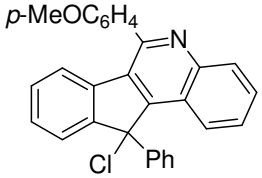
NMR (100 MHz, $CDCl_3$) δ 156.0, 151.2, 150.9, 146.4, 139.6, 138.6, 136.0, 132.9, 131.9, 131.4, 130.5, 129.3, 129.0, 128.9, 128.8, 128.7, 128.5, 125.9, 125.0, 123.5, 123.4, 67.0. HRMS (ESI) calcd for $C_{28}H_{17}Cl_2N$: 438.0816 ($M + H^+$), found: 438.0820.



11-Chloro-6-phenyl-11-(*p*-tolyl)-11*H*-indeno[1,2-*c*]quinoline (**6c**). IR 3058.1, 2926.4, 2853.3, 1608.2, 1570.8, 1509.1, 1467.8, 1446.0, 1360.2 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 8.20 (d, J = 8.4 Hz, 1H), 7.81-7.75 (m, 3H), 7.68-7.65 (m, 1H), 7.60-7.58 (m, 3H), 7.43-7.41 (m, 2H), 7.36-7.34 (m, 2H), 7.24-7.19 (m, 1H), 7.10-7.09 (m, 3H), 7.98-7.97 (m, 1H), 2.30 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 155.8, 152.7, 151.0, 148.1, 140.1, 138.1, 136.3, 136.2, 130.3, 129.5, 129.4, 129.1, 128.9, 128.8, 128.7, 128.6, 127.0, 125.90, 124.9, 124.8, 123.3, 122.8, 73.5, 21.0. HRMS (ESI) calcd for $C_{29}H_{20}ClN$: 418.1363 ($M + H^+$), found: 418.1384.

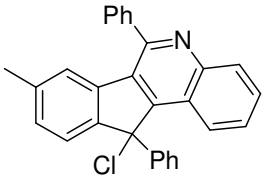


11-Chloro-11-(4-chlorophenyl)-6-phenyl-11*H*-indeno[1,2-*c*]quinoline (**6d**). IR 3058.1, 2924.4, 2847.8, 1582.7, 1579.7, 1491.3, 1451.7 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 8.24 (d, J = 9.2 Hz, 1H), 7.77-7.67 (m, 4H), 7.61-7.59 (m, 3H), 7.48-7.38 (m, 4H), 7.29-7.21 (m, 3H), 7.15-7.11 (m, 1H), 7.00 (d, J = 8.0 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 155.8, 152.1, 150.4, 148.1, 139.9, 138.0, 136.4, 134.3, 130.5, 129.7, 129.2, 129.0, 128.9, 128.8, 128.7, 127.5, 127.2, 124.9, 124.5, 123.4, 122.5, 72.9. HRMS (ESI) calcd for $C_{28}H_{17}Cl_2N$: 438.0816 ($M + H^+$), found: 438.0817.

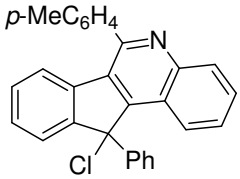


11-Chloro-6-(4-methoxyphenyl)-11-phenyl-11*H*-indeno[1,2-*c*]quinoline (**6e**). IR 3061.4, 2927.4, 2852.7, 1608.0, 1572.2, 1501.3, 1445.1, 1366.0, 1249.3, 1030.9 cm^{-1}.

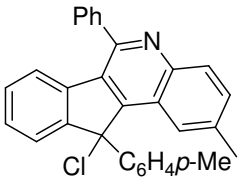
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.22 (d, *J* = 8.4 Hz, 1H), 7.77-7.71 (m, 3H), 7.67-7.63 (m, 1H), 7.49-7.46 (m, 2H), 7.42-7.38 (m, 2H), 7.30-7.28 (m, 3H), 7.25-7.20 (m, 1H), 7.14-7.11 (m, 4H), 3.94 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.3, 155.6, 152.6, 150.8, 148.2, 139.3, 136.6, 132.5, 130.7, 130.3, 129.5, 128.8, 128.7, 128.5, 128.2, 126.9, 126.0, 125.0, 124.7, 123.4, 122.5, 114.1, 73.5, 55.4. HRMS (ESI) calcd for $C_{29}H_{20}ClNO$: 434.1312 (M + H^+), found: 434.1340.



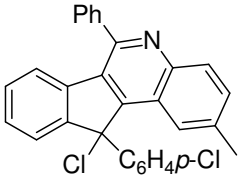
11-Chloro-8-methyl-6,11-diphenyl-11*H*-indeno[1,2-*c*]quinoline (**6f**). IR 3058.3, 2925.5, 2853.2, 1604.1, 1573.6, 1488.2, 1466.9, 1445.2, 1369.4 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.23 (d, *J* = 8.4 Hz, 1H), 7.77-7.76 (m, 3H), 7.69-7.64 (m, 1H), 7.61-7.59 (m, 3H), 7.48-7.42 (m, 3H), 7.30-7.25 (m, 4H), 7.04 (d, *J* = 7.6 Hz, 1H), 2.17 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 155.8, 153.1, 148.1, 148.0, 140.0, 139.5, 138.8, 136.6, 130.7, 130.3, 129.5, 129.4, 129.1, 128.9, 128.7, 128.6, 128.2, 127.0, 126.0, 124.7, 124.6, 124.1, 122.7, 73.5, 21.6. HRMS (ESI) calcd for $C_{29}H_{20}ClN$: 418.1363 (M + H^+), found: 418.1367.



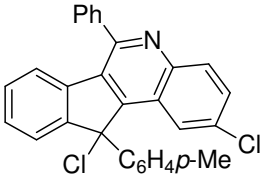
11-Chloro-11-phenyl-6-(p-tolyl)-11*H*-indeno[1,2-*c*]quinoline (**6g**). IR 3059.4, 2923.3, 2854.1, 1610.2, 1570.6, 1500.9, 1467.9, 1445.7, 1366.0 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.22 (d, *J* = 8.4 Hz, 1H), 7.76 (d, *J* = 8.0 Hz, 1H), 7.67-7.63 (m, 3H), 7.49-7.46 (m, 2H), 7.42-7.39 (m, 4H), 7.31-7.28 (m, 3H), 7.24-7.19 (m, 1H), 7.14-7.07 (m, 2H), 2.51 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.0, 152.6, 150.8, 148.2, 139.3, 139.0, 137.1, 136.6, 130.6, 130.3, 129.5, 129.4, 128.8, 128.7, 128.5, 128.2, 126.9, 126.0, 125.0, 124.7, 123.4, 122.6, 73.5, 21.5. HRMS (ESI) calcd for $C_{29}H_{20}ClN$: 418.1363 (M + H^+), found: 418.1365.



11-Chloro-2-methyl-6-phenyl-11-(p-tolyl)-11*H*-indeno[1,2-*c*]quinoline (**6h**). IR 3056.4, 2924.5, 2854.6, 1628.5, 1570.5, 1494.3, 1466.9, 1442.5, 1366.3 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 8.12 (d, *J* = 8.8 Hz, 1H), 7.76-7.74 (m, 2H), 7.58-7.55 (m, 4H), 7.49 (d, *J* = 8.8 Hz, 1H), 7.41 (d, *J* = 7.6 Hz, 1H), 7.35 (d, *J* = 8.0 Hz, 2H), 7.19 (t, *J* = 7.6 Hz, 1H), 7.10-7.06 (m, 3H), 6.96 (d, *J* = 7.6 Hz, 1H), 2.40 (s, 3H), 2.30 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 154.8, 151.8, 151.0, 146.8, 140.2, 138.0, 137.0, 136.4, 136.3, 131.9, 130.4, 130.0, 129.4, 128.9, 128.8, 128.7, 128.6, 128.4, 125.9, 124.9, 123.5, 123.2, 122.8, 73.6, 22.1, 21.0. HRMS (ESI) calcd for $C_{30}H_{22}ClN$: 432.1519 ($M + H^+$), found: 432.1508.

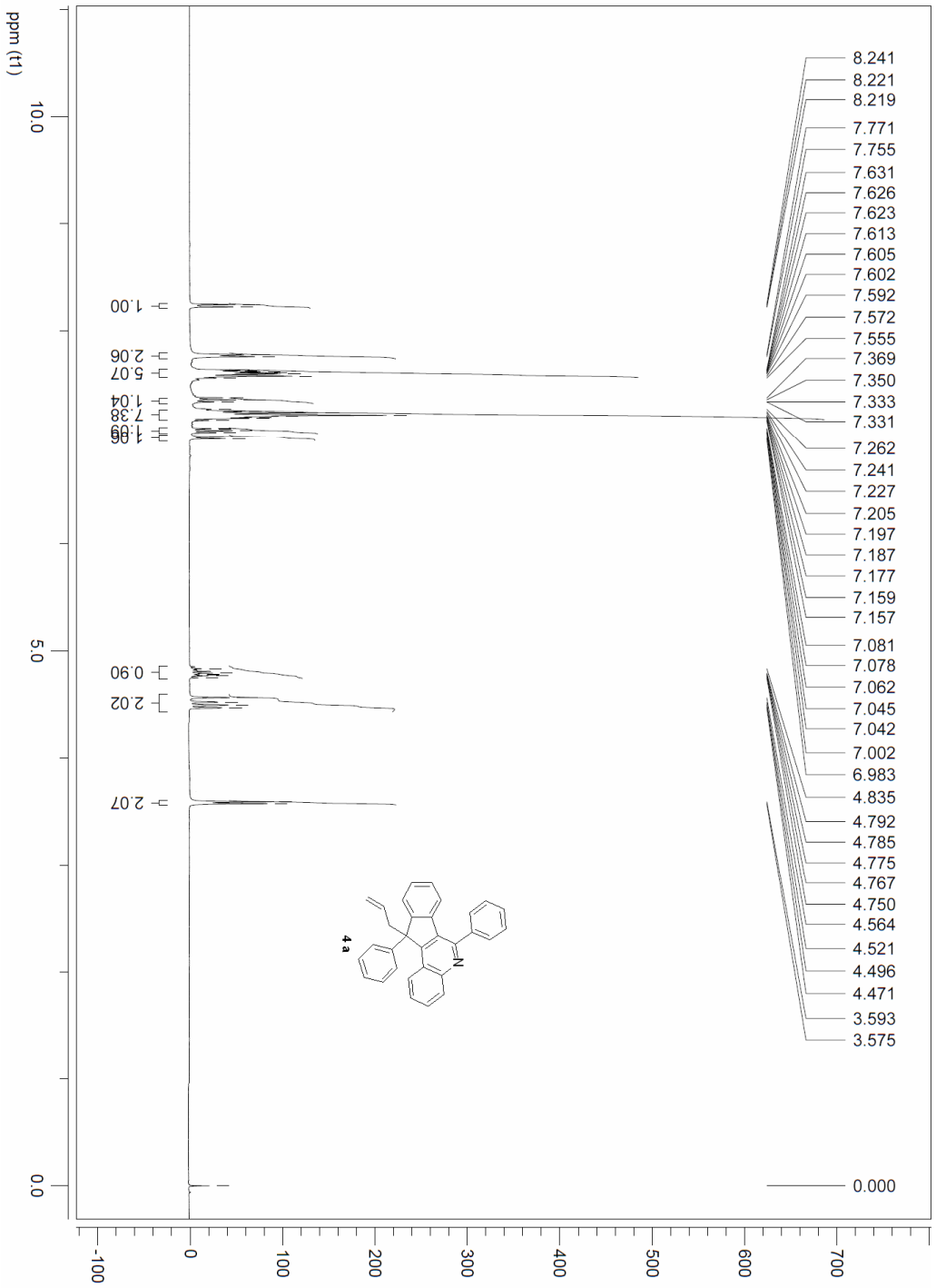


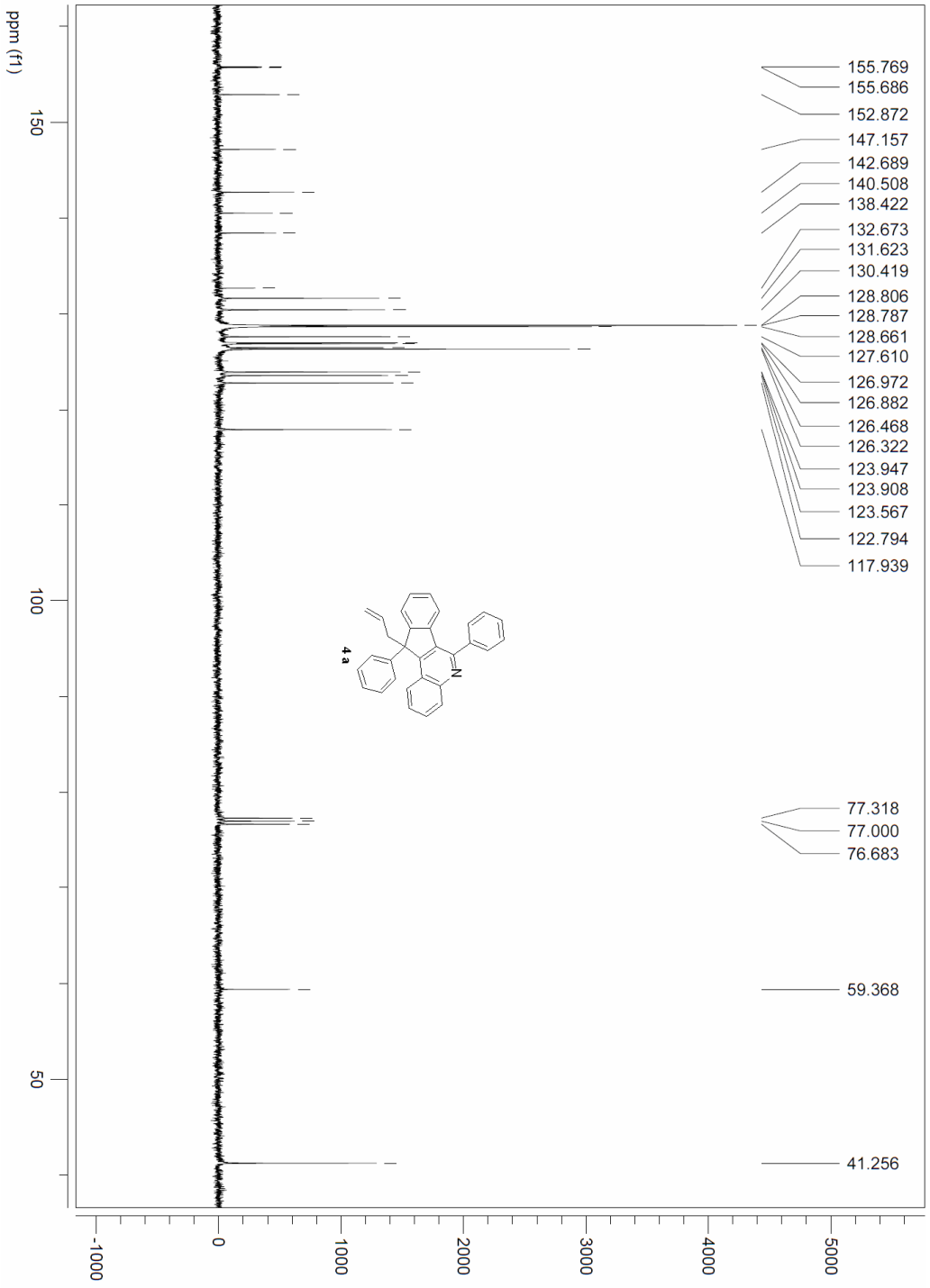
11-Chloro-11-(4-chlorophenyl)-2-methyl-6-phenyl-11*H*-indeno[1,2-*c*]quinoline (**6i**). IR 3058.5, 2924.9, 2853.6, 1588.0, 1569.1, 1490.0, 1468.3, 1444.7, 1366.1 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 8.14 (d, *J* = 8.8 Hz, 1H), 7.76-7.74 (m, 2H), 7.60-7.58 (m, 3H), 7.53-7.48 (m, 2H), 7.42-7.37 (m, 3H), 7.29-7.20 (m, 3H), 7.13-7.09 (m, 1H), 6.98 (d, *J* = 7.6 Hz, 1H), 2.43 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 154.8, 150.4, 147.3, 146.8, 139.9, 138.1, 137.4, 136.5, 134.2, 132.1, 130.1, 129.1, 129.0, 128.9, 128.8, 128.7, 128.6, 127.5, 124.8, 123.4, 123.1, 122.6, 67.0, 22.1. HRMS (ESI) calcd for $C_{29}H_{19}Cl_2N$: 452.0973 ($M + H^+$), found: 452.0971.

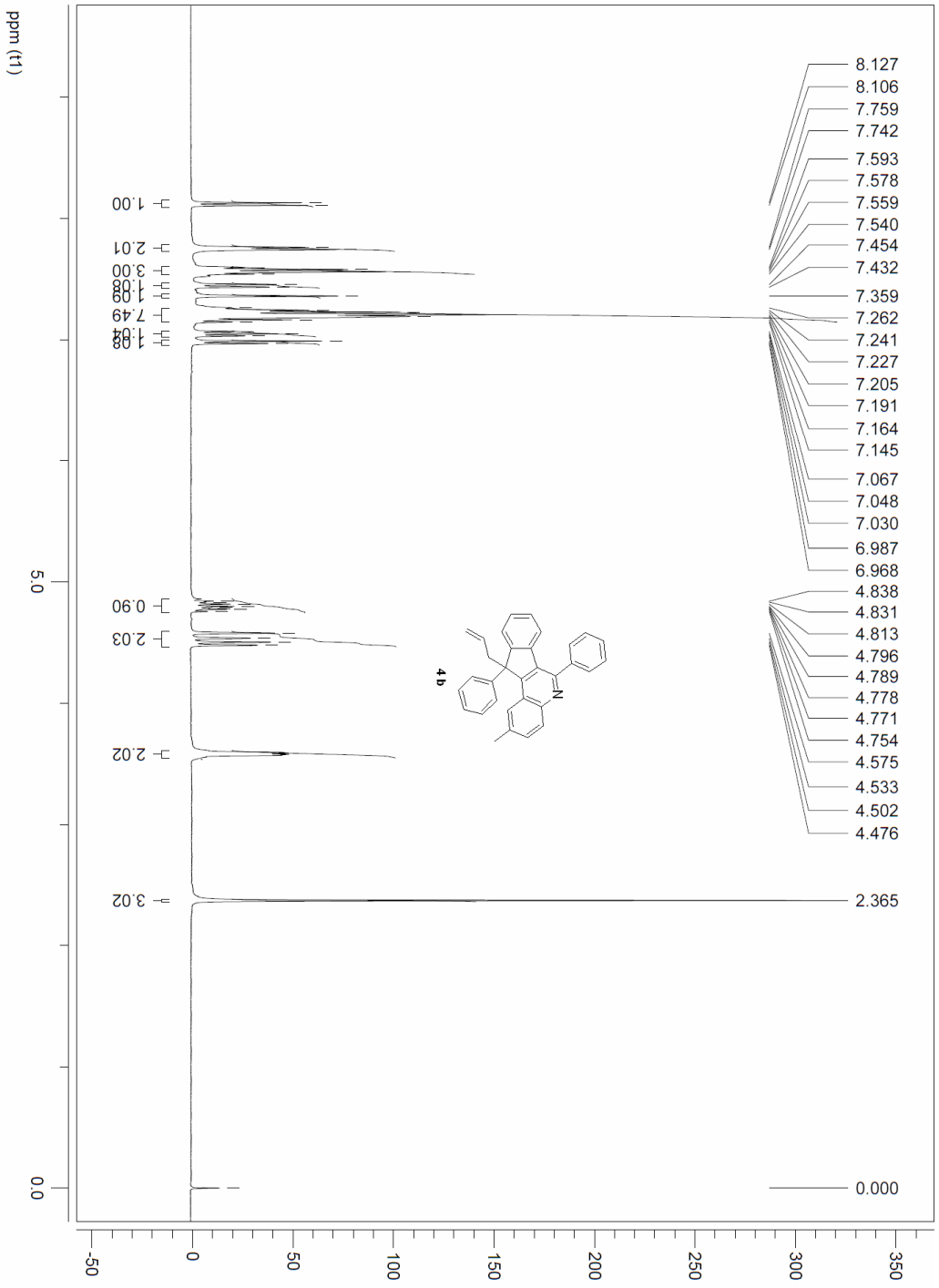


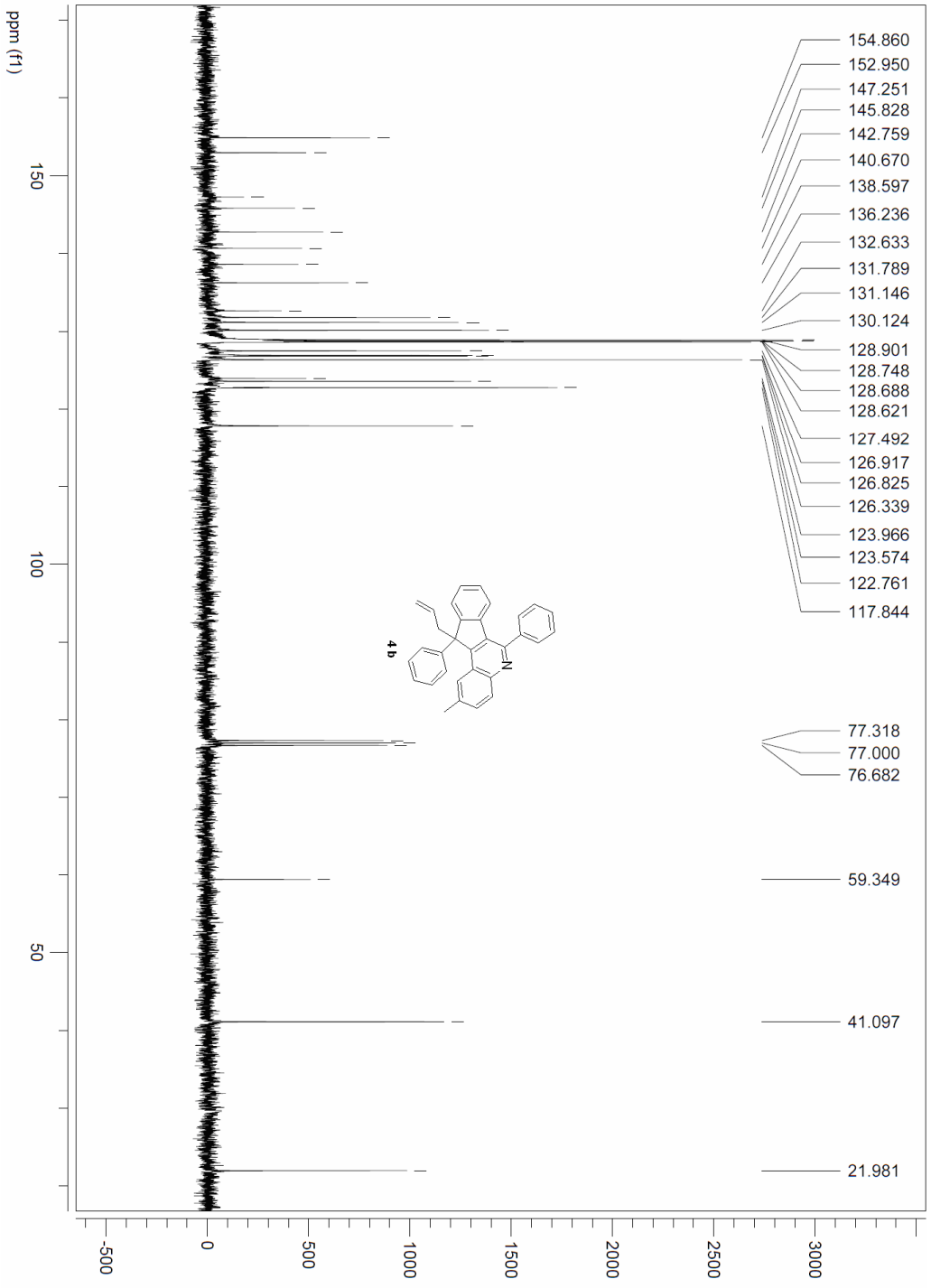
2,11-Dichloro-6-phenyl-11-(p-tolyl)-11*H*-indeno[1,2-*c*]quinoline (**6j**). IR 3056.1, 2925.8, 2852.8, 1613.2, 1566.4, 1491.7, 1462.2, 1445.3, 1364.6 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ 8.15 (d, *J* = 9.2 Hz, 1H), 7.78-7.75 (m, 3H), 7.60-7.58 (m, 4H), 7.41

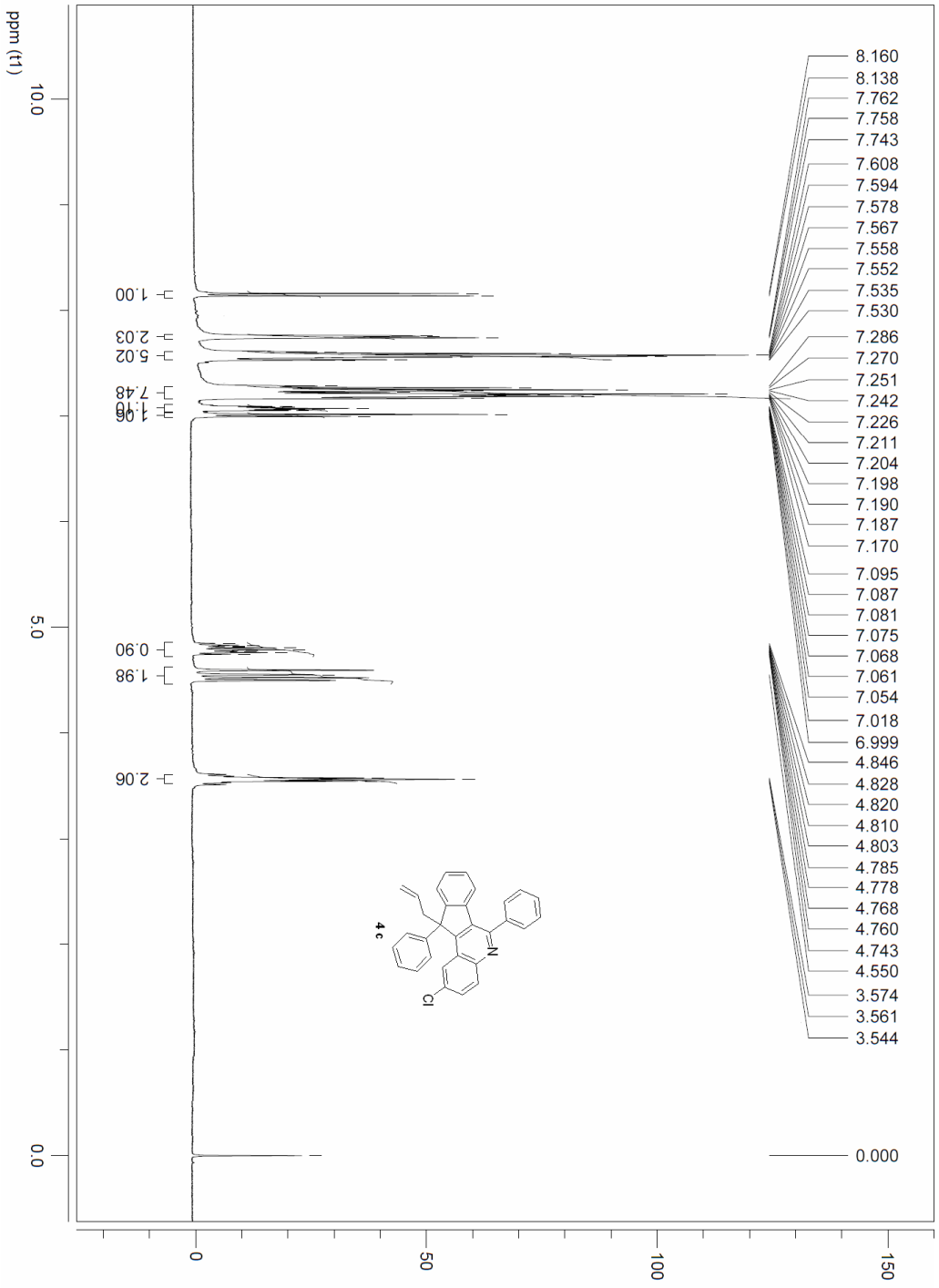
(d, *J* = 7.6 Hz, 1H), 7.33 (d, *J* = 8.0 Hz, 2H), 7.24-7.21 (m, 1H), 7.12-7.08 (m, 3H), 7.00 (d, *J* = 8.0 Hz, 1H), 2.31 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.0, 151.9, 151.1, 146.4, 139.7, 138.3, 135.9, 135.7, 132.8, 131.9, 131.3, 130.5, 129.6, 129.2, 128.9, 128.8, 128.7, 125.8, 125.0, 123.4, 67.0, 21.0. HRMS (ESI) calcd for $C_{29}H_{19}Cl_2N$: 452.0973 ($M + H^+$), found: 452.0983.

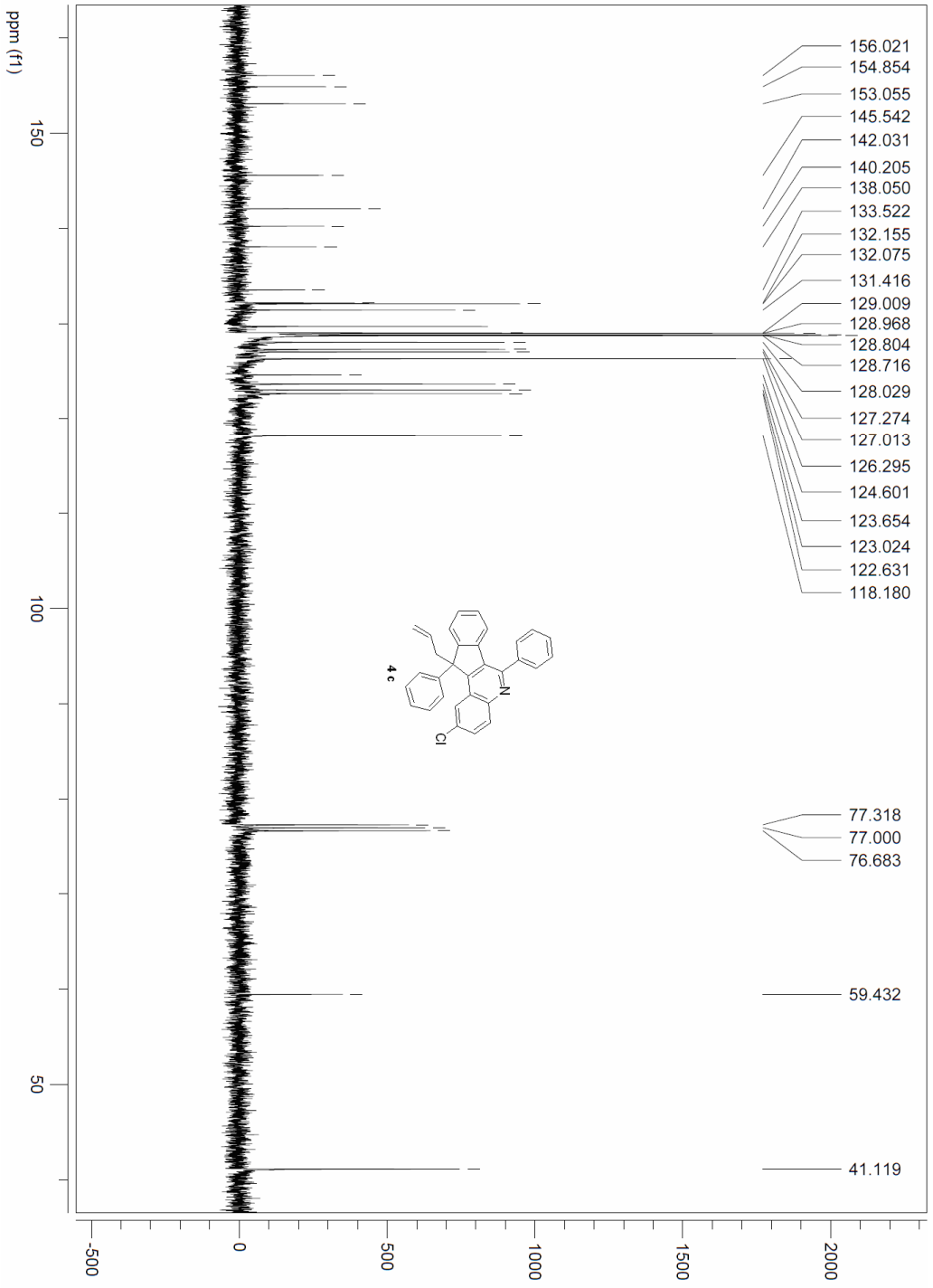


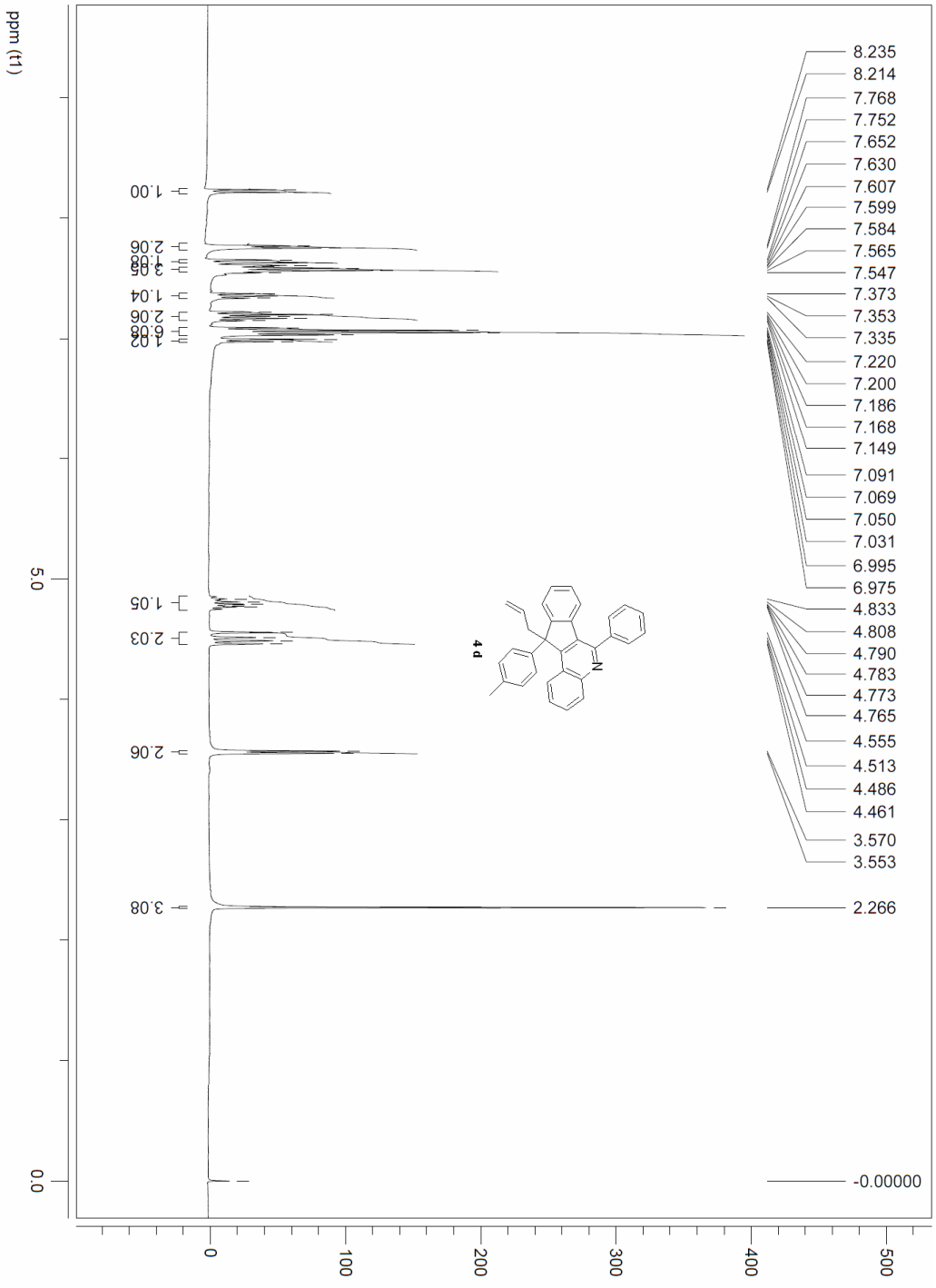


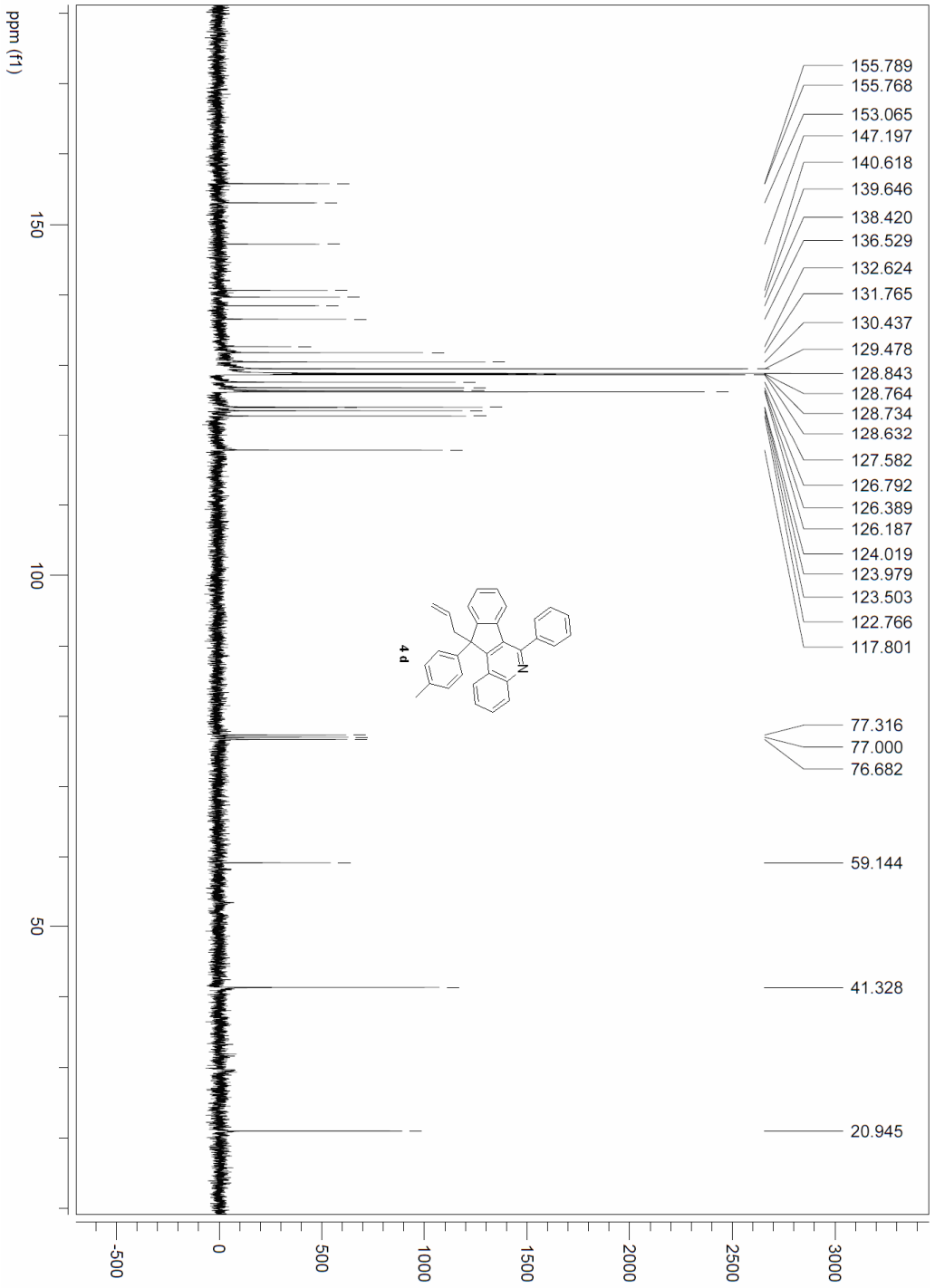


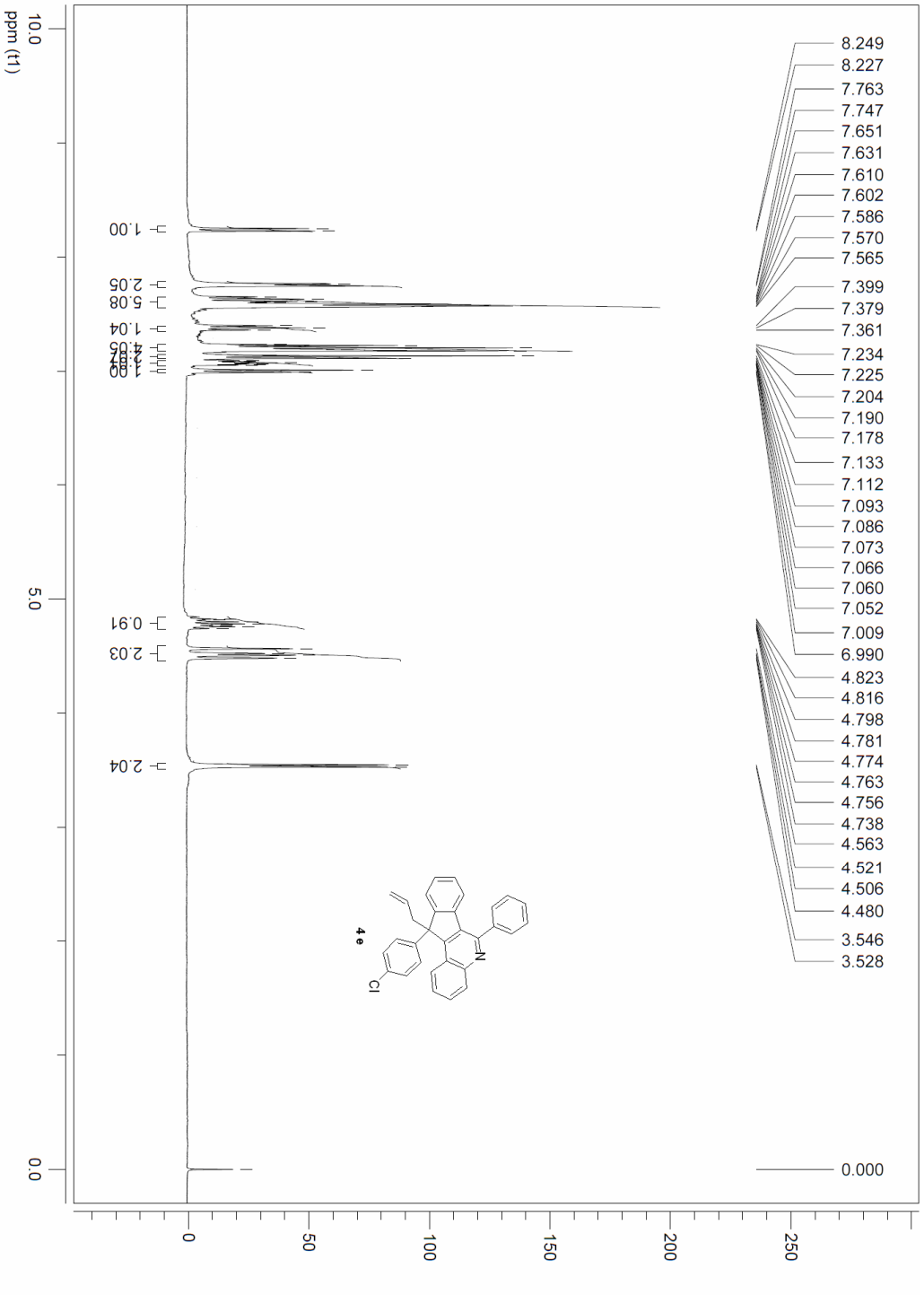


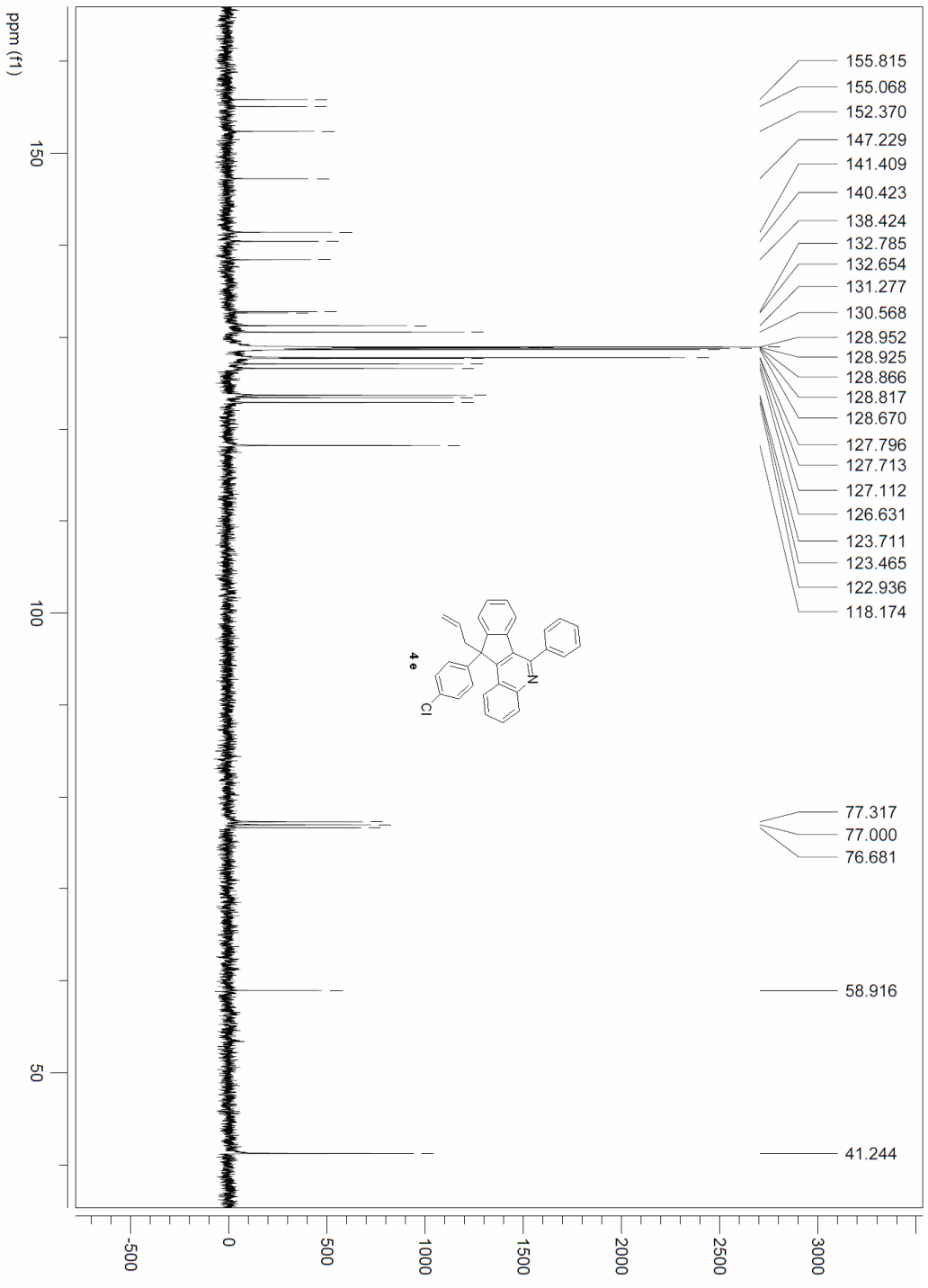


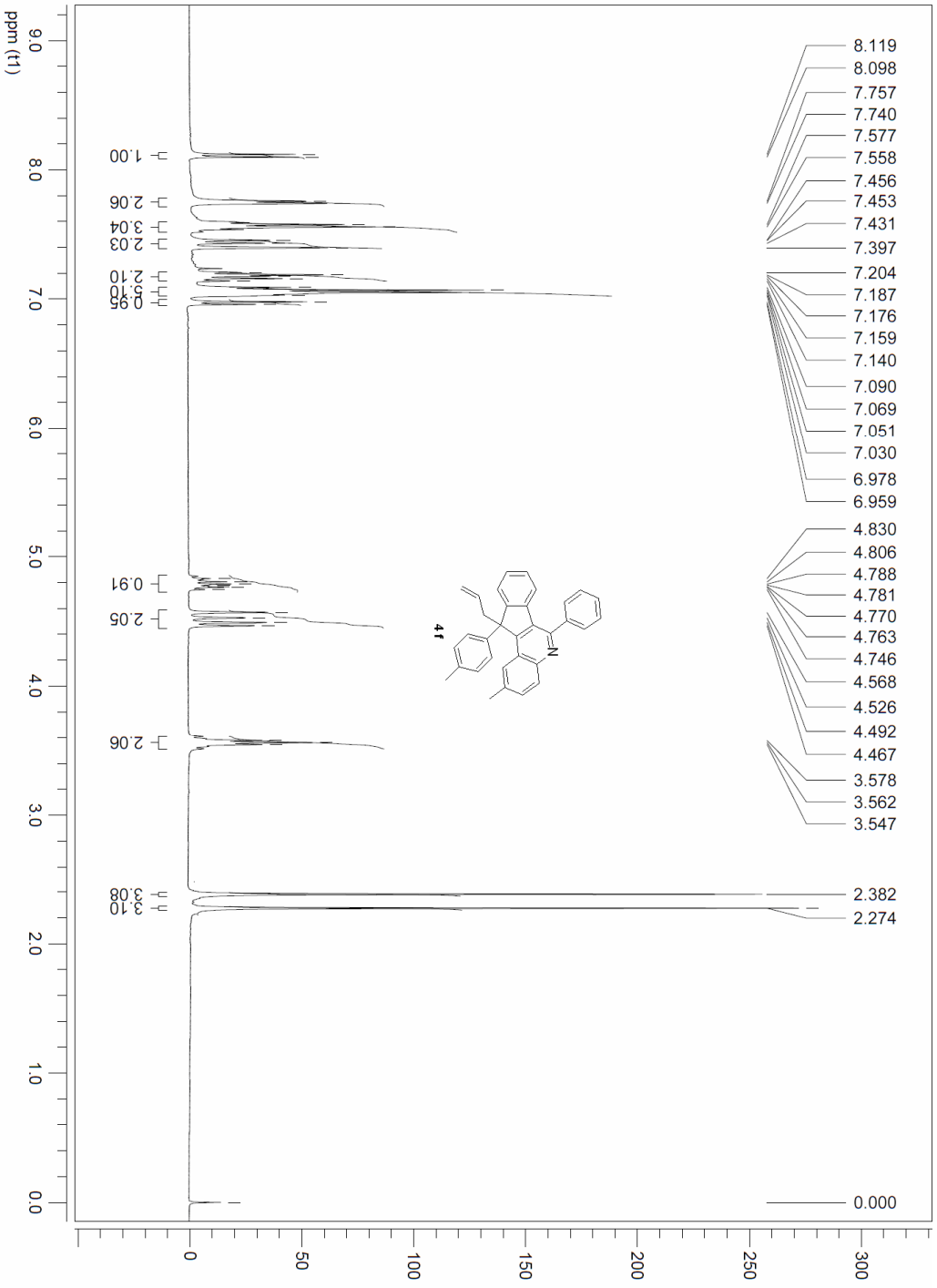


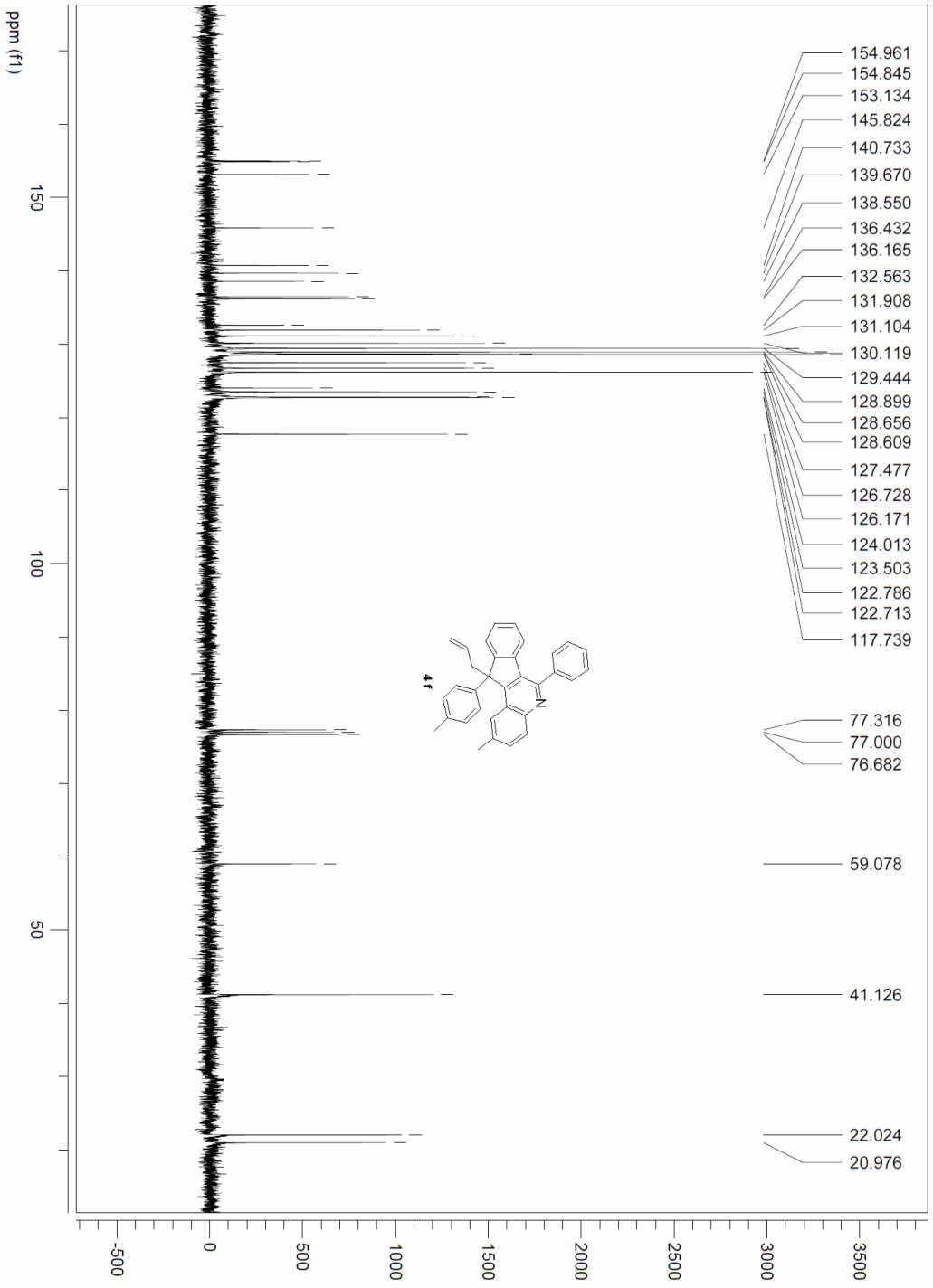

ppm (t1)
5.0
0.0
1.00
2.06
3.08
1.04
2.06
6.08
1.02
1.05
2.03
2.06
3.08
4d
8.235
8.214
7.768
7.752
7.652
7.630
7.607
7.599
7.584
7.565
7.547
7.373
7.353
7.335
7.220
7.200
7.186
7.168
7.149
7.091
7.069
7.050
7.031
6.995
6.975
4.833
4.808
4.790
4.783
4.773
4.765
4.555
4.513
4.486
4.461
3.570
3.553
2.266
-0.00000
0
100
200
300
400
500

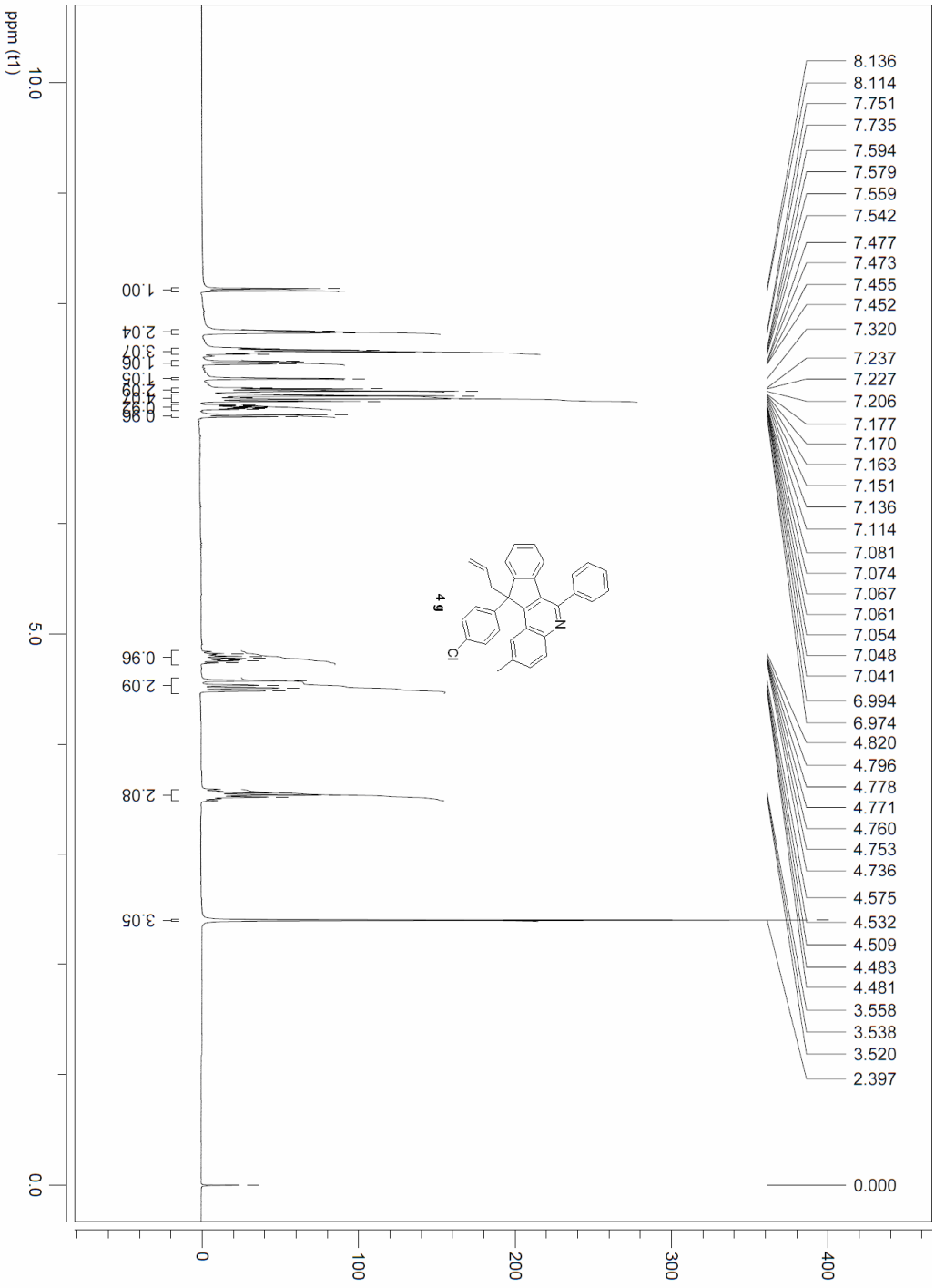


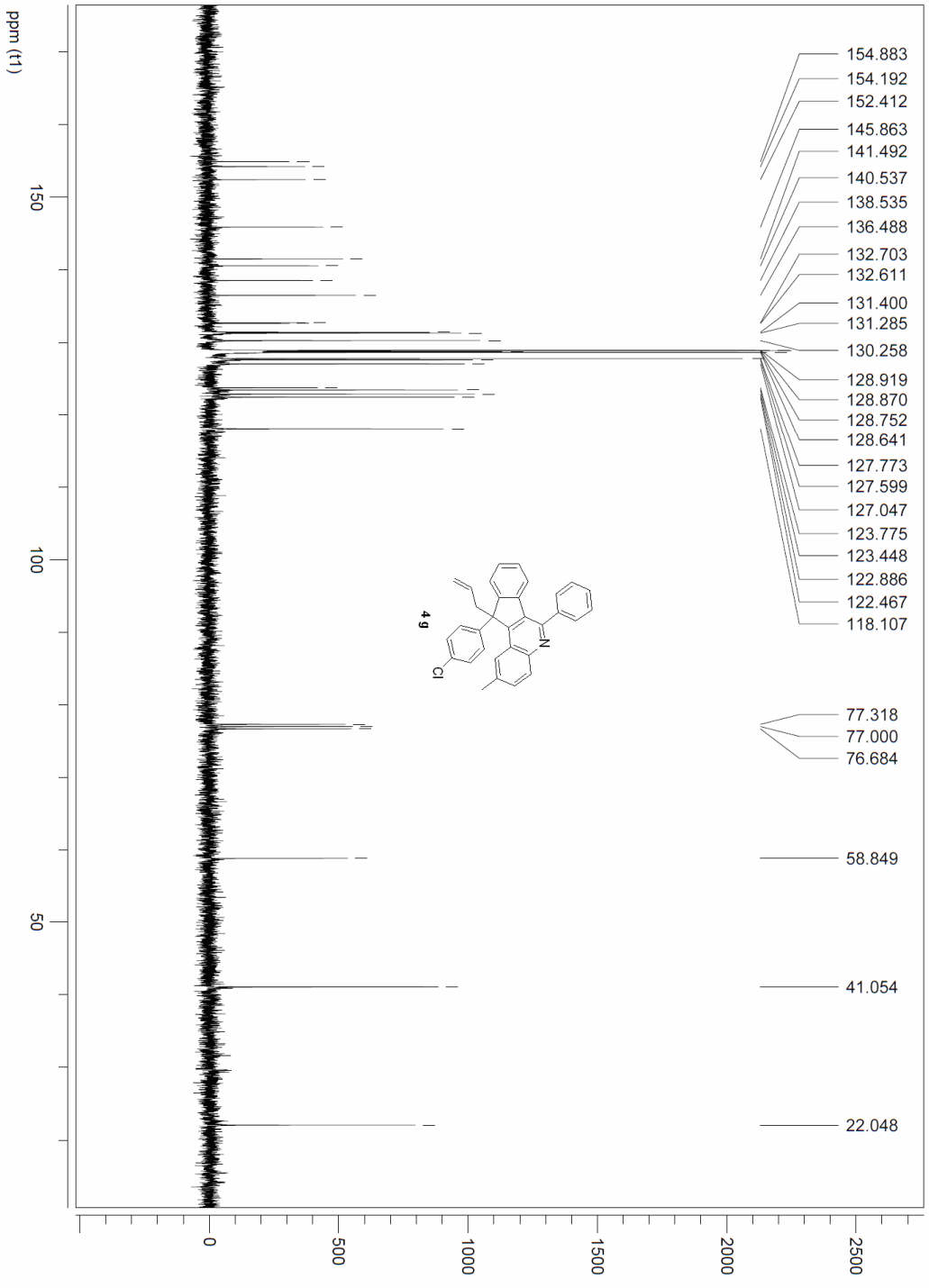

ppm (t1)
10.0
5.0
0.0
1.00
2.05
5.08
1.04
4.05
1.00
0.91
2.03
2.04
8.249
8.227
7.763
7.747
7.651
7.631
7.610
7.602
7.586
7.570
7.565
7.399
7.379
7.361
7.234
7.225
7.204
7.190
7.178
7.133
7.112
7.093
7.086
7.073
7.066
7.060
7.052
7.009
6.990
4.823
4.816
4.798
4.781
4.774
4.763
4.756
4.738
4.563
4.521
4.506
4.480
3.546
3.528
0.000
4e
Cl
N
0
50
100
150
200
250

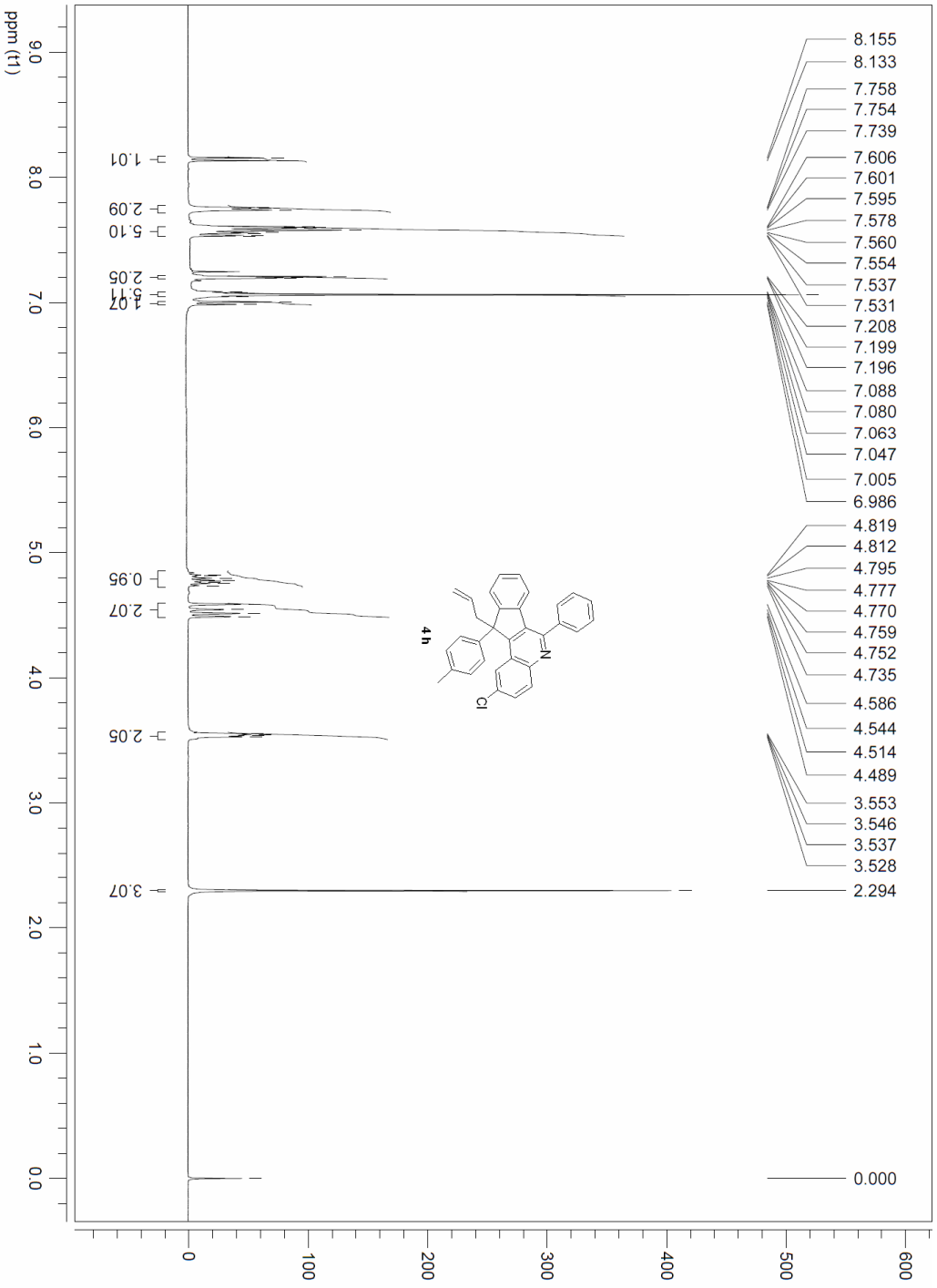


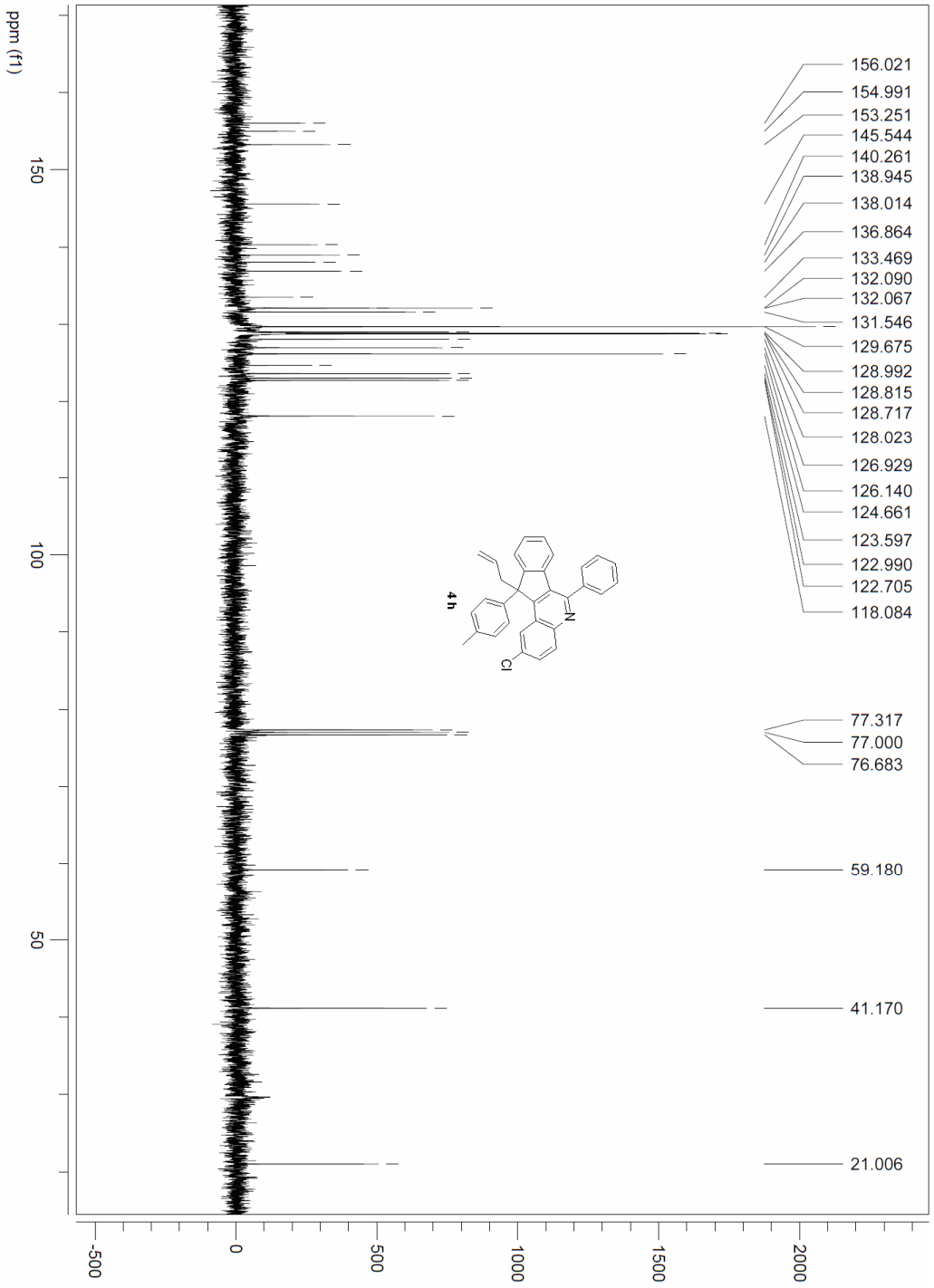


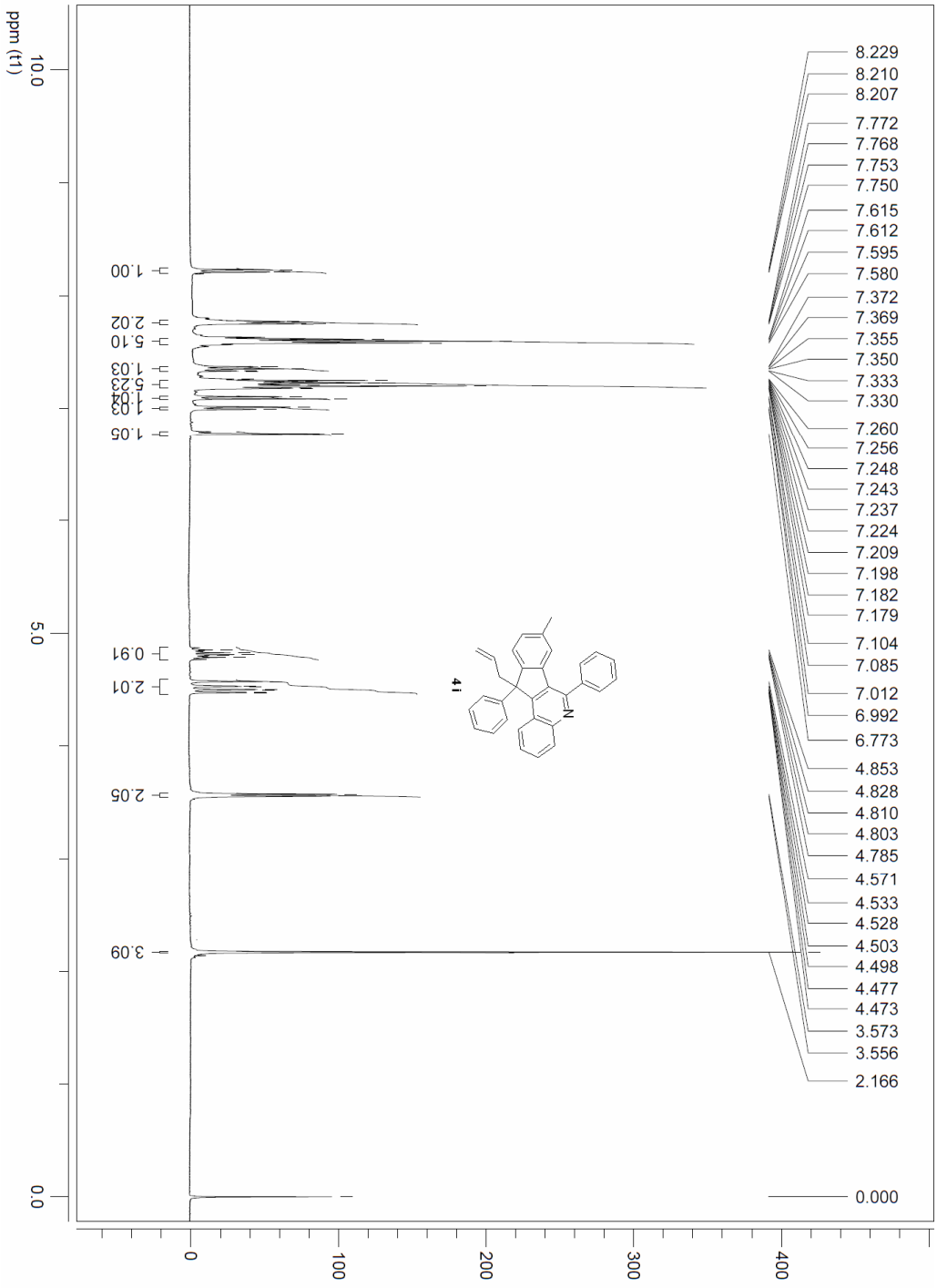


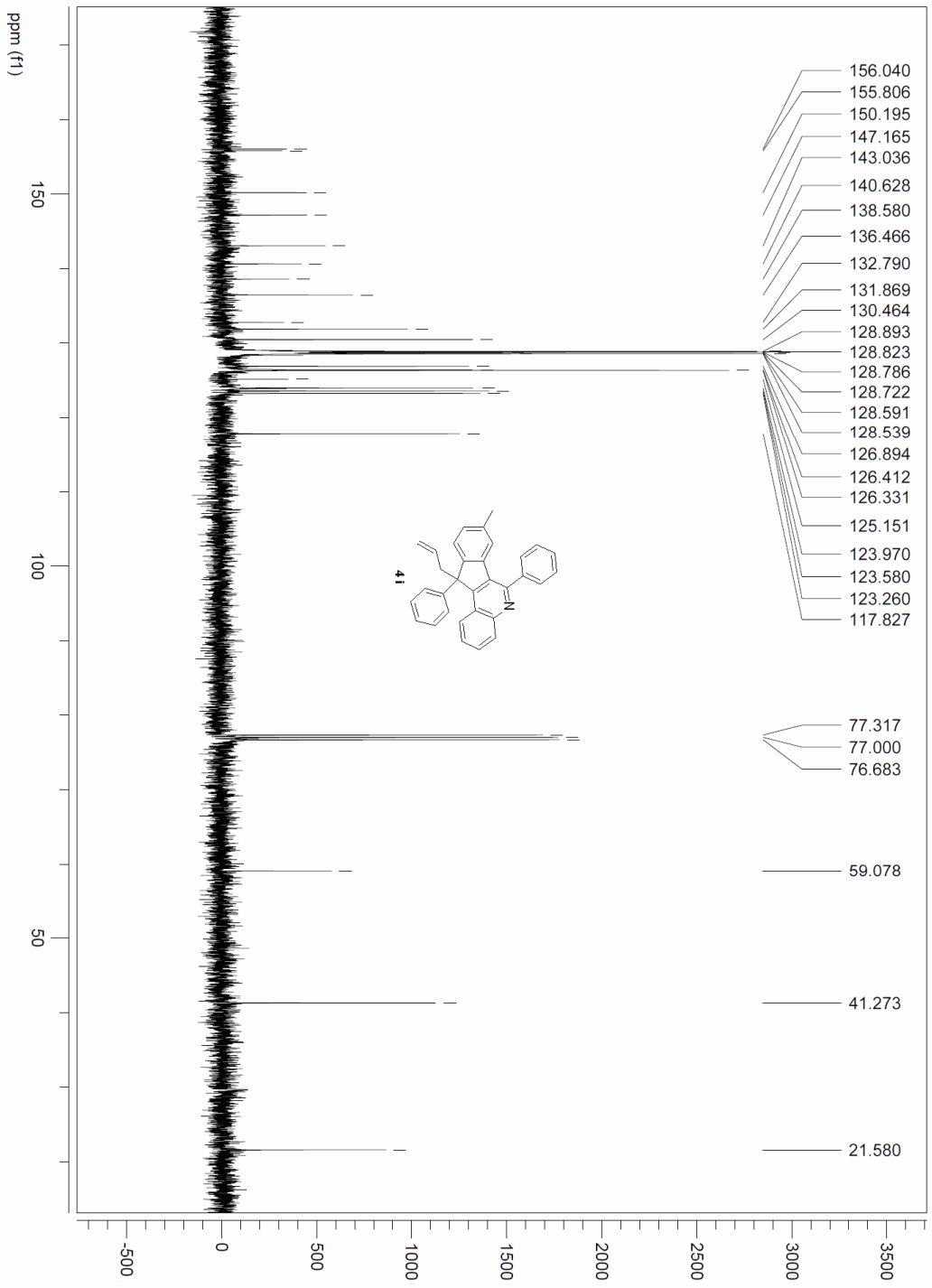

ppm (t1)
10.0
5.0
0.0
1.00
2.04
3.07
1.06
1.05
0.96
2.09
2.08
3.05
4g
Cl
N
8.136
8.114
7.751
7.735
7.594
7.579
7.559
7.542
7.477
7.473
7.455
7.452
7.320
7.237
7.227
7.206
7.177
7.170
7.163
7.151
7.136
7.114
7.081
7.074
7.067
7.061
7.054
7.048
7.041
6.994
6.974
4.820
4.796
4.778
4.771
4.760
4.753
4.736
4.575
4.532
4.509
4.483
4.481
3.558
3.538
3.520
2.397
0.000
0
100
200
300
400

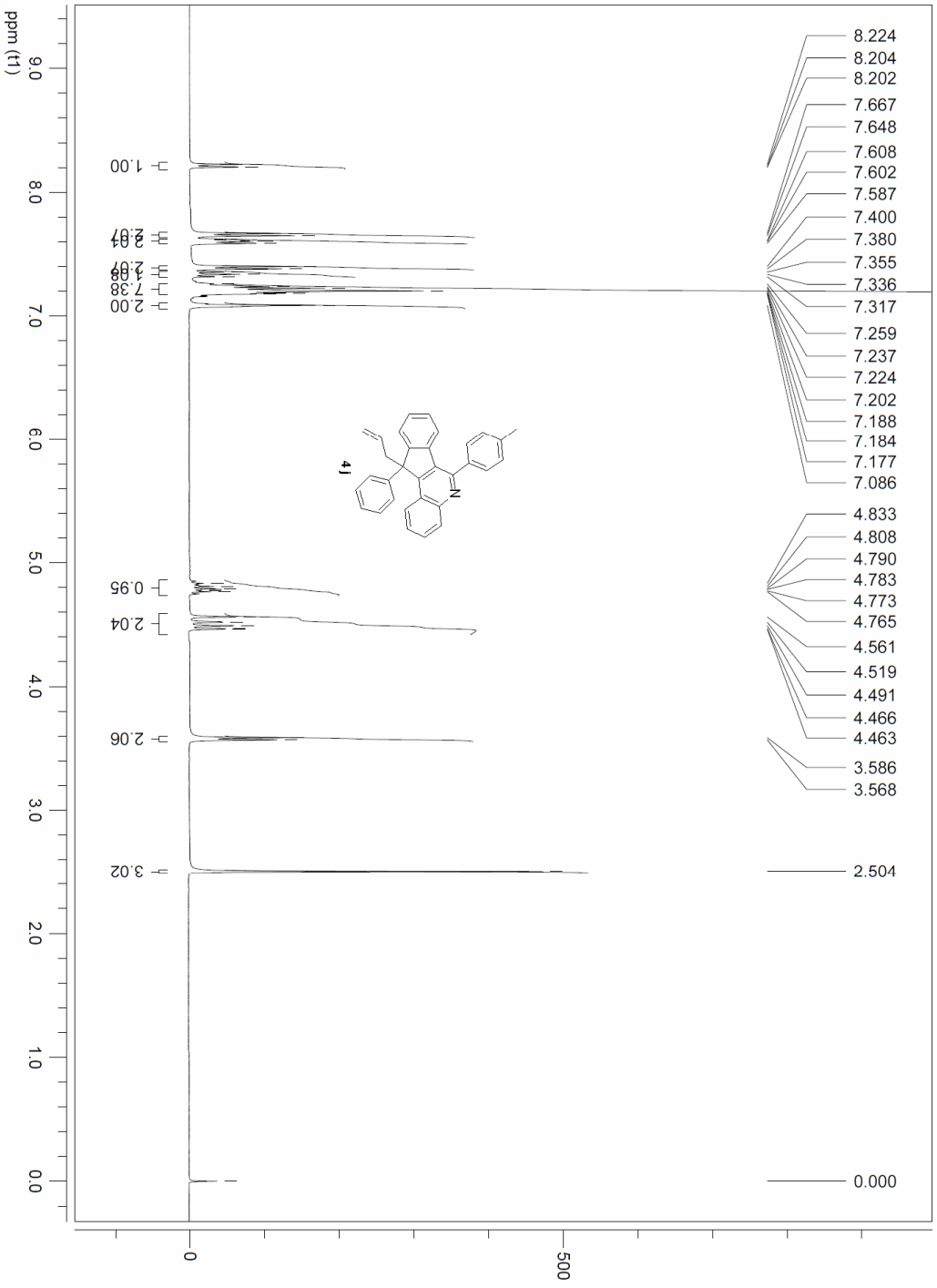


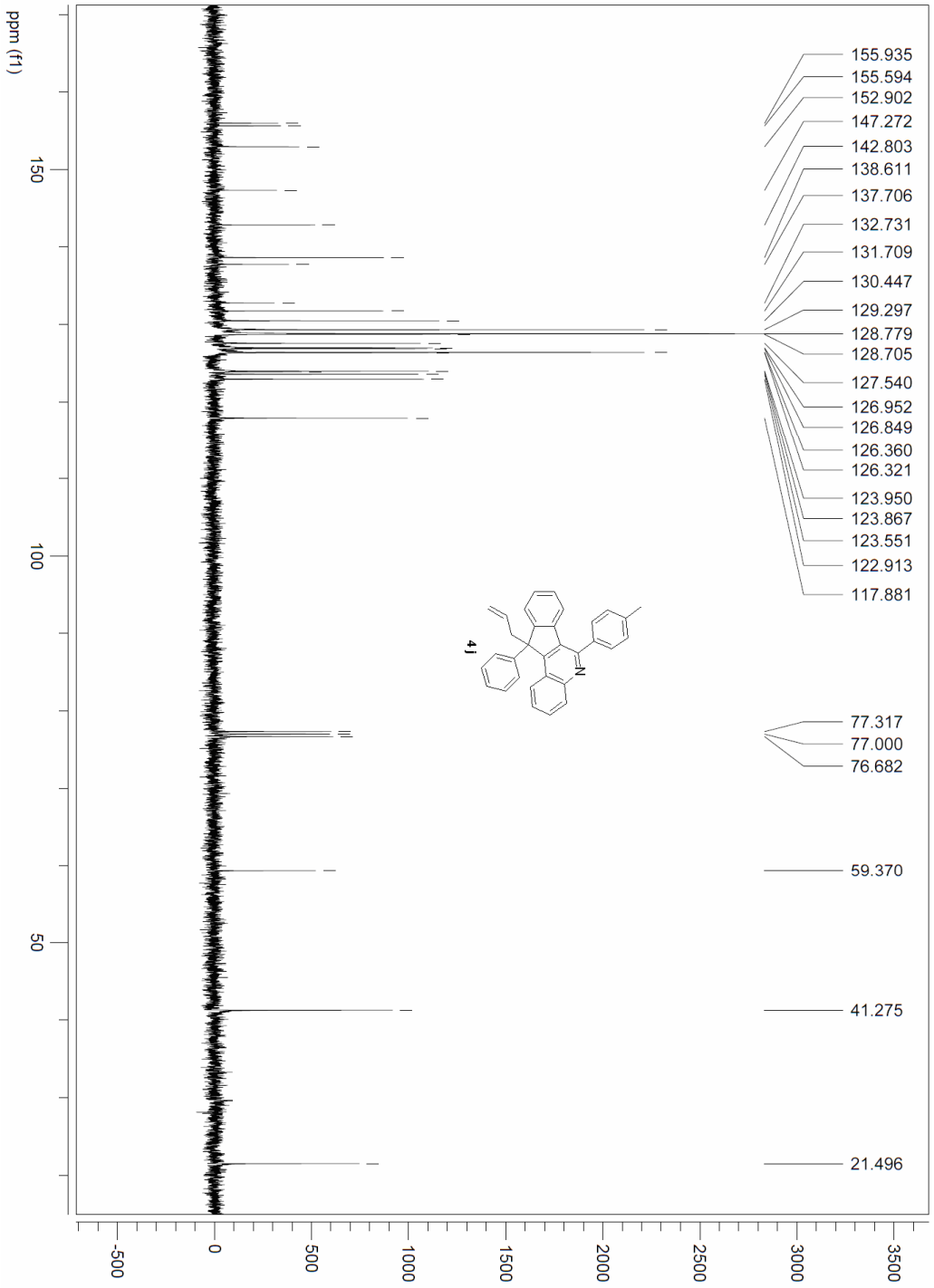


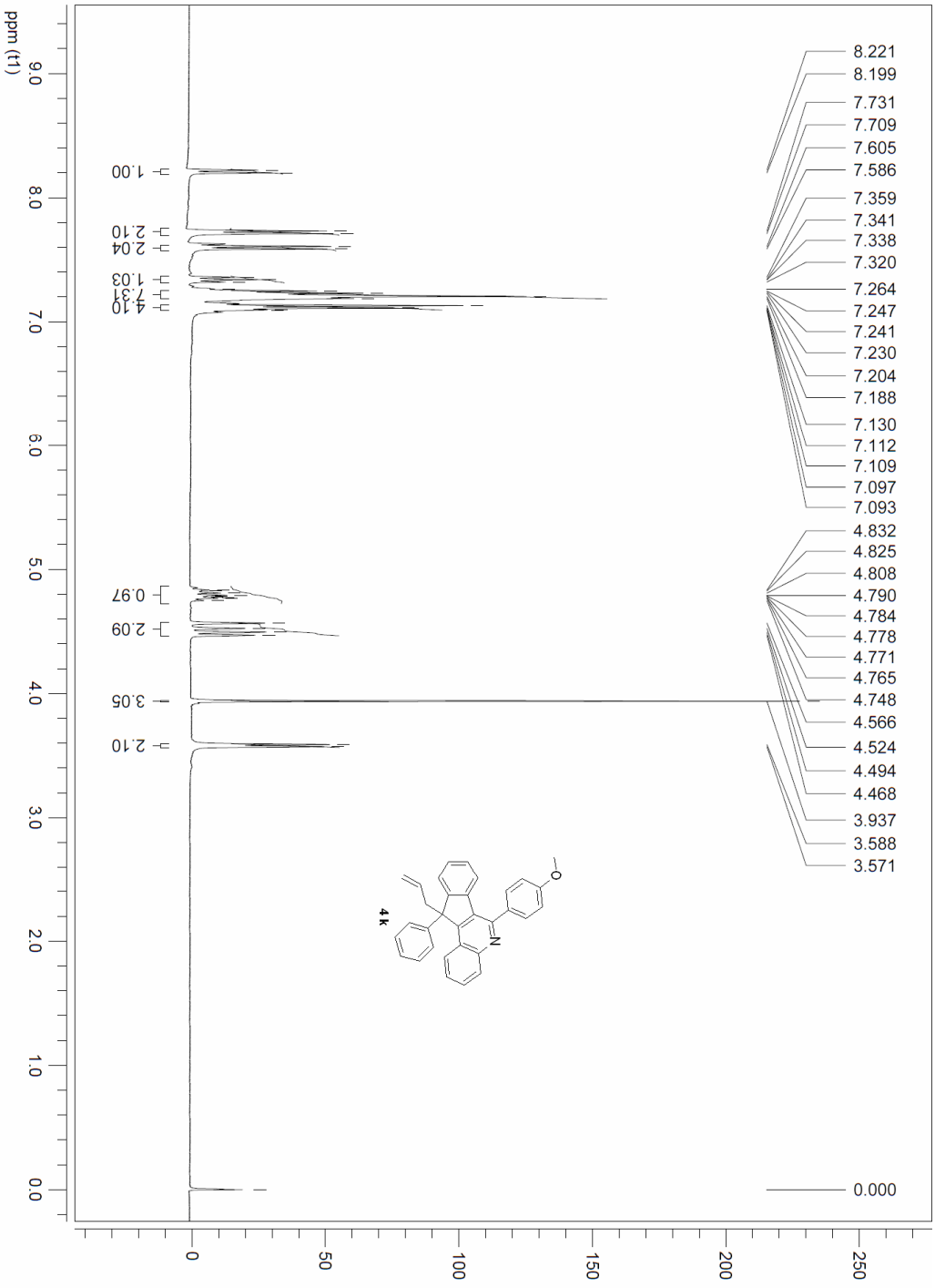


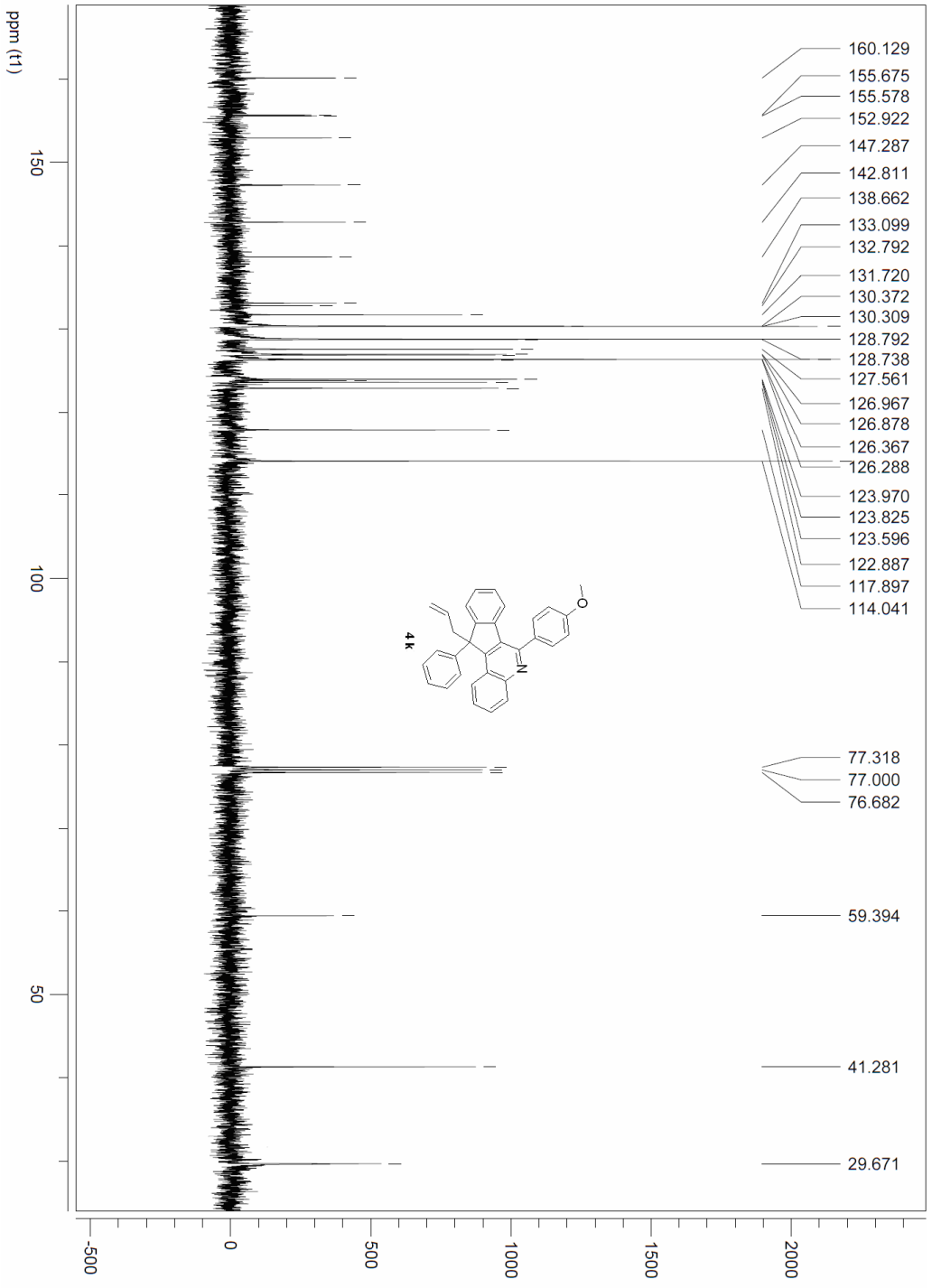


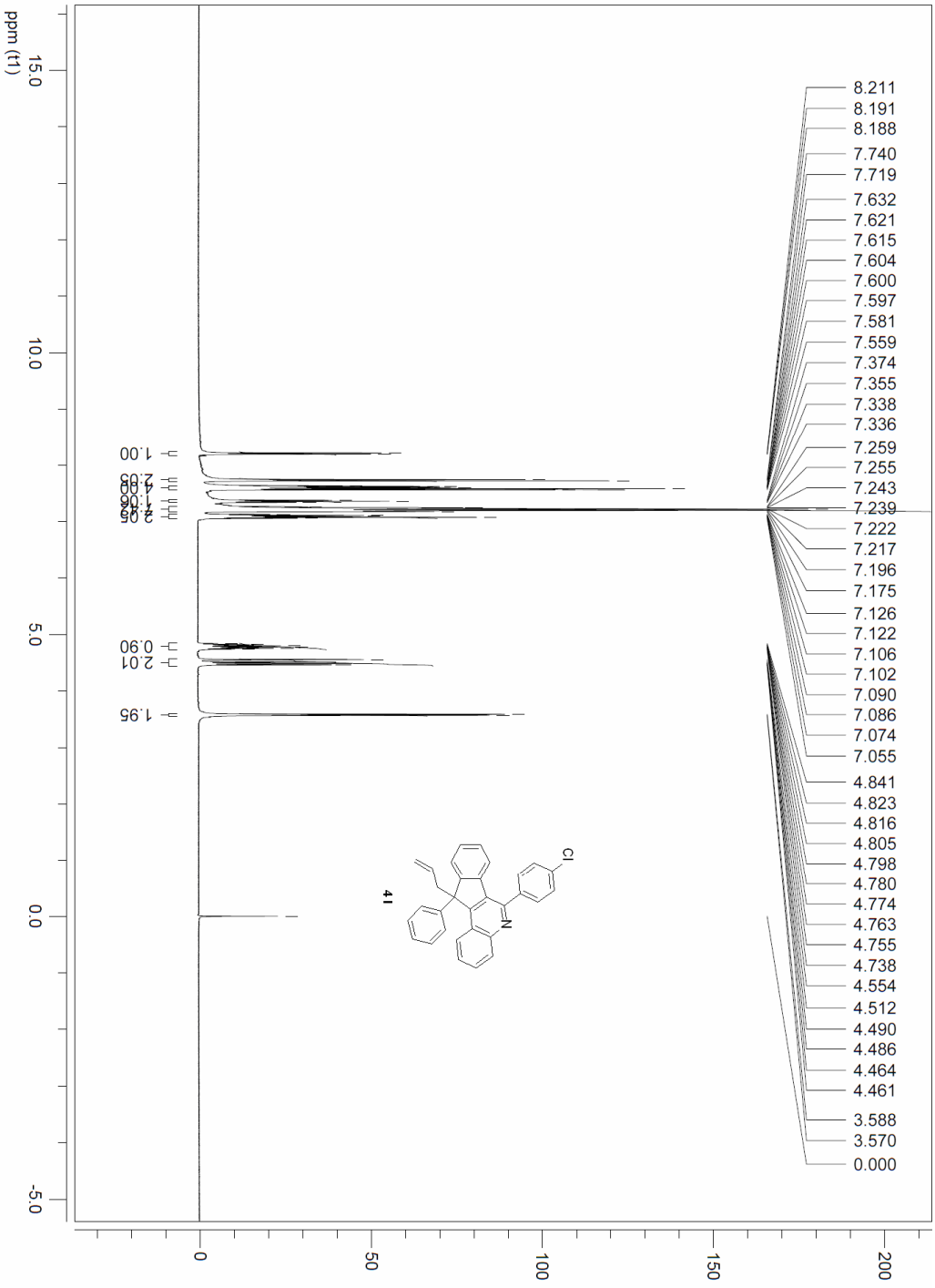

ppm (f1)
150
100
50
-500
0
500
1000
1500
2000
2500
3000
3500
156.040
155.806
150.195
147.165
143.036
140.628
138.580
136.466
132.790
131.869
130.464
128.893
128.823
128.786
128.722
128.591
128.539
126.894
126.412
126.331
125.151
123.970
123.580
123.260
117.827
77.317
77.000
76.683
59.078
41.273
21.580
4i
N

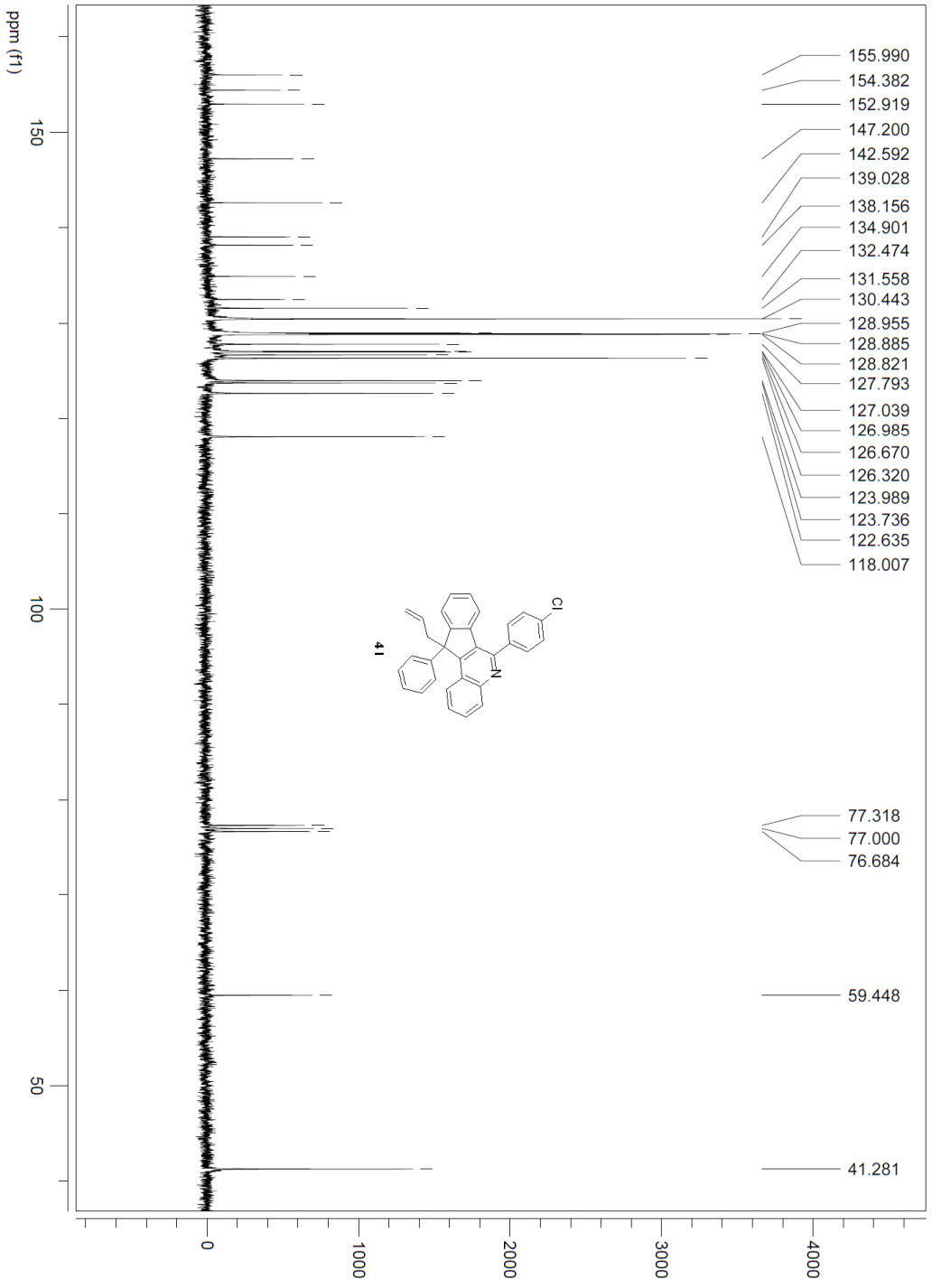


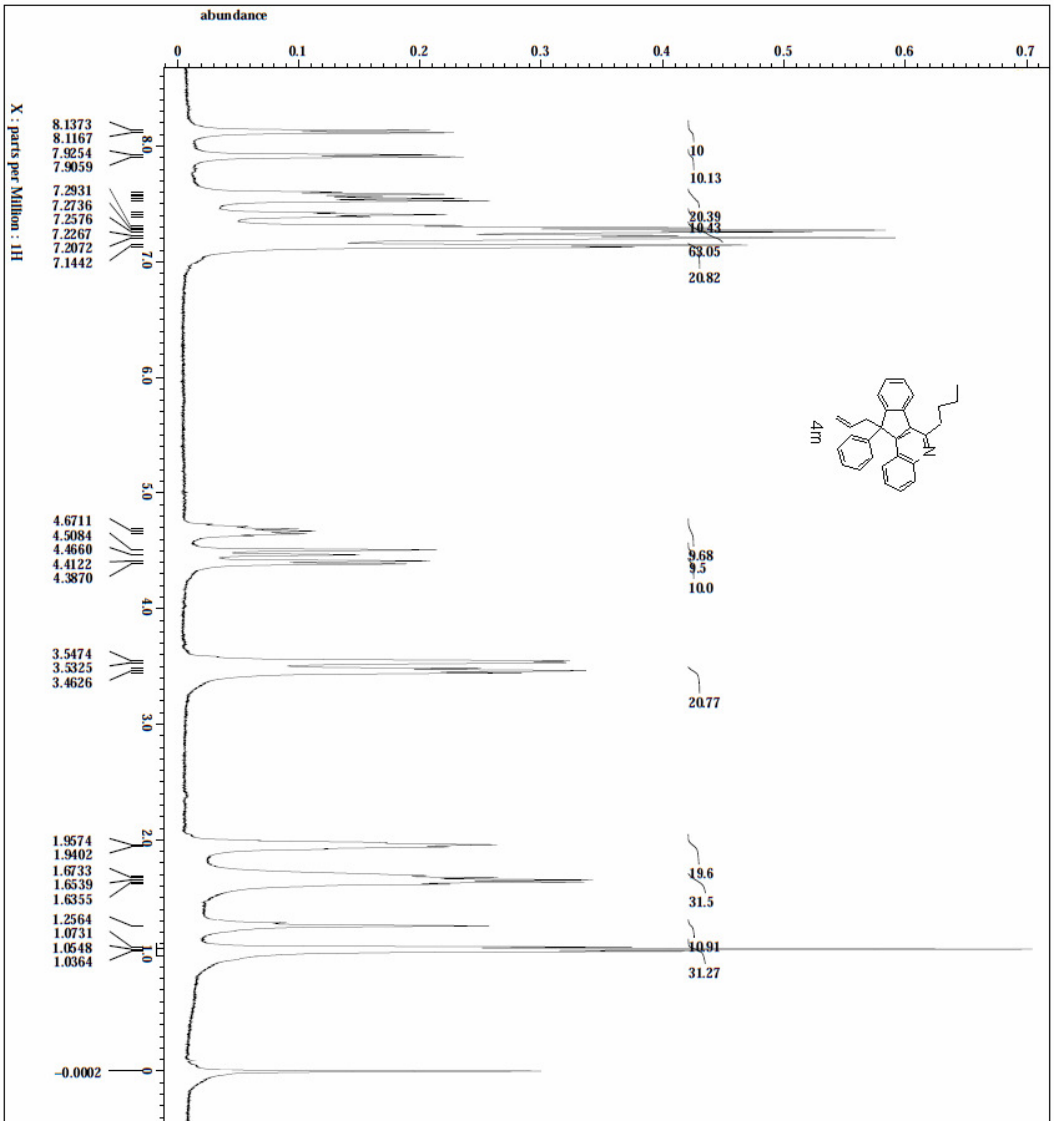

ppm (f1)
150
100
50
-500
0
500
1000
1500
2000
2500
3000
3500
155.935
155.594
152.902
147.272
142.803
138.611
137.706
132.731
131.709
130.447
129.297
128.779
128.705
127.540
126.952
126.849
126.360
126.321
123.950
123.867
123.551
122.913
117.881
77.317
77.000
76.682
59.370
41.275
21.496
4j
N

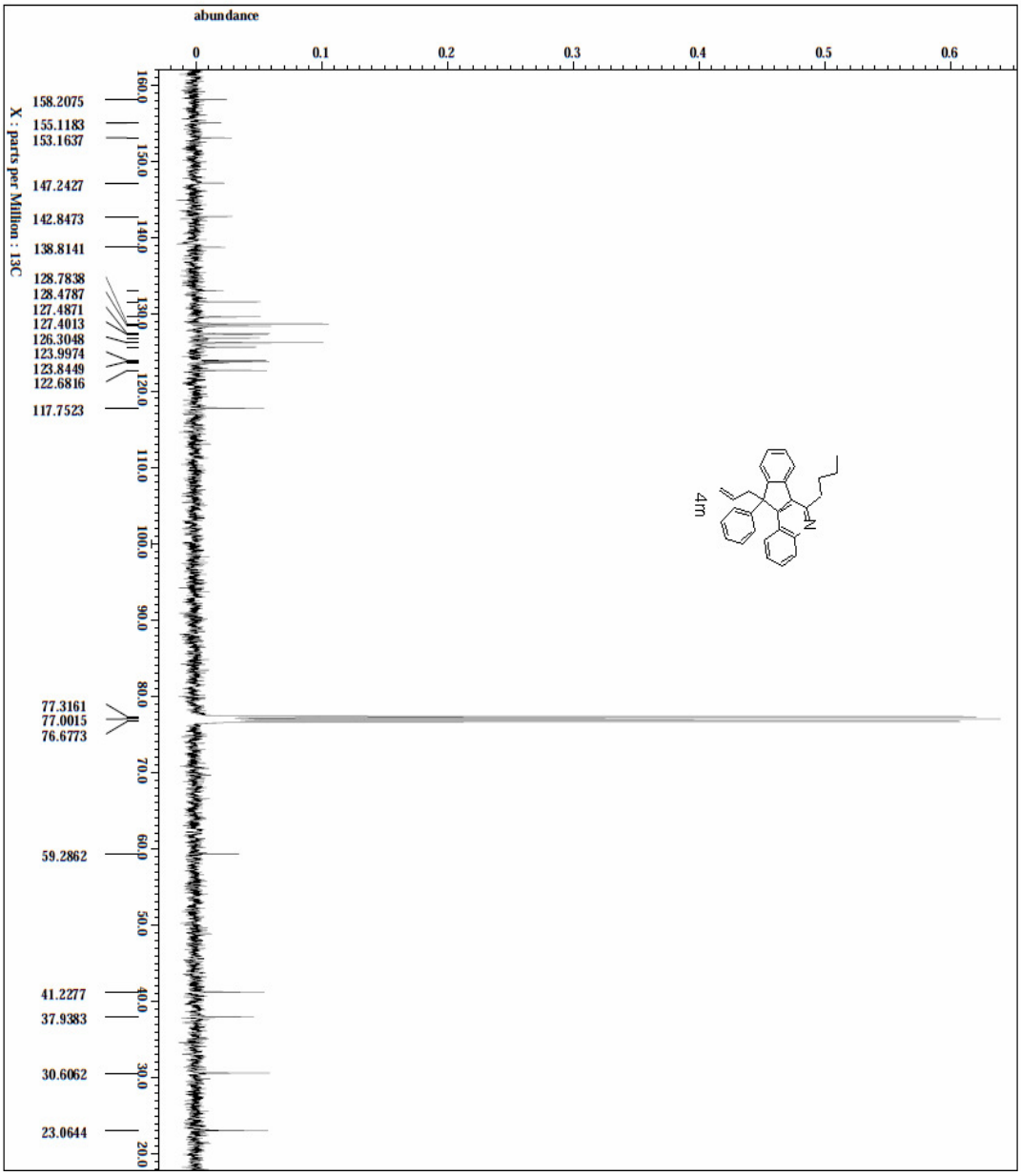


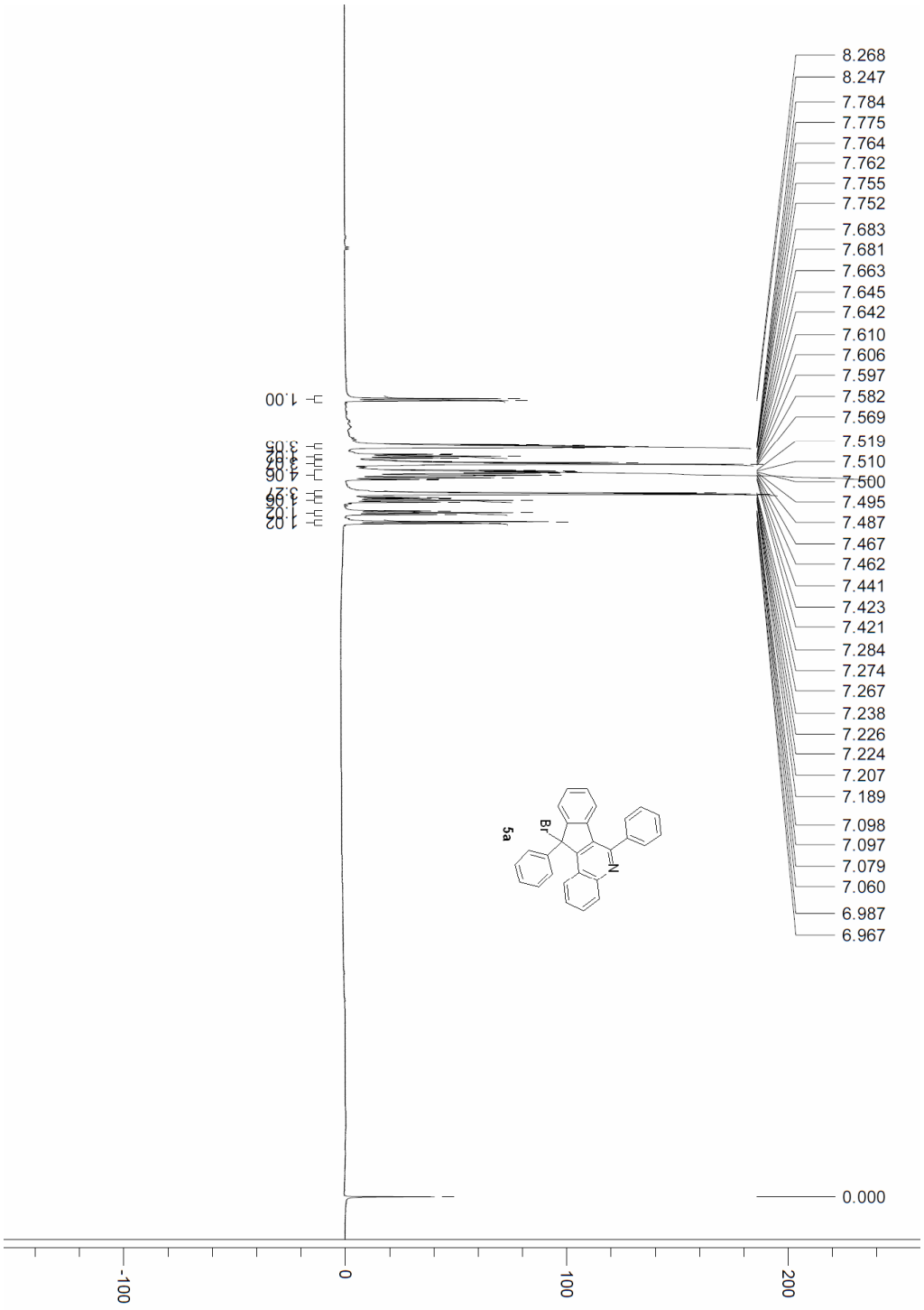


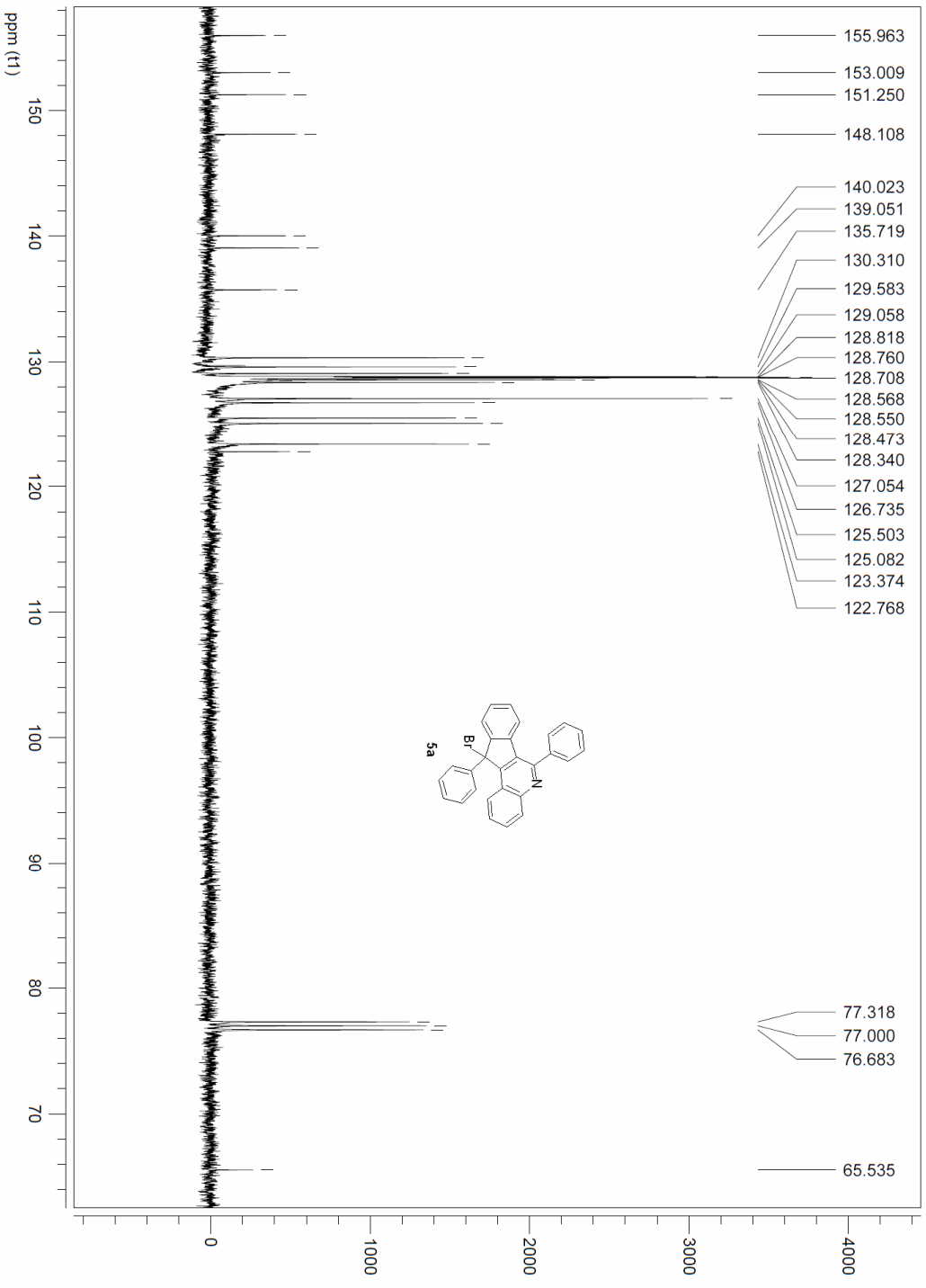


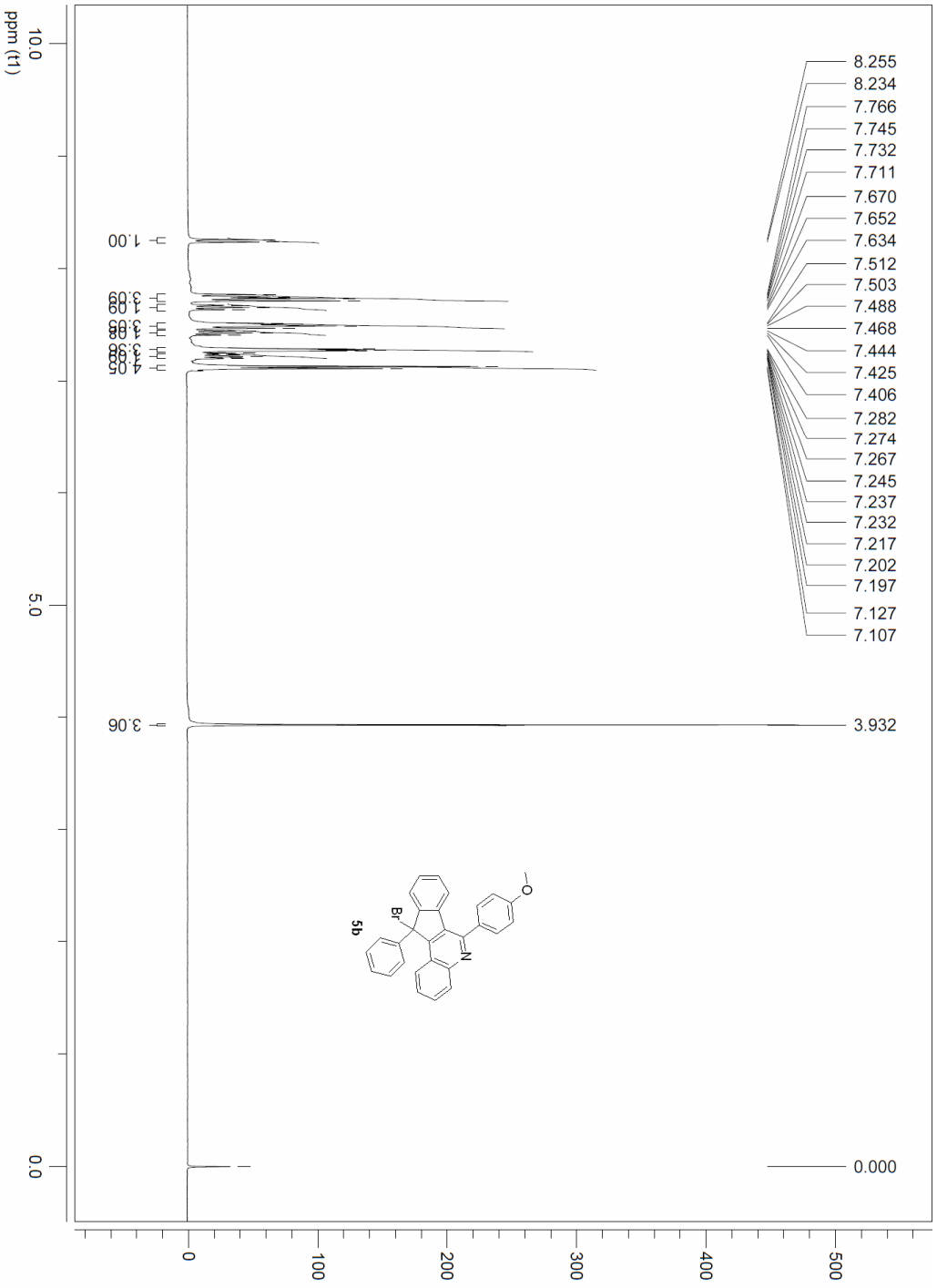


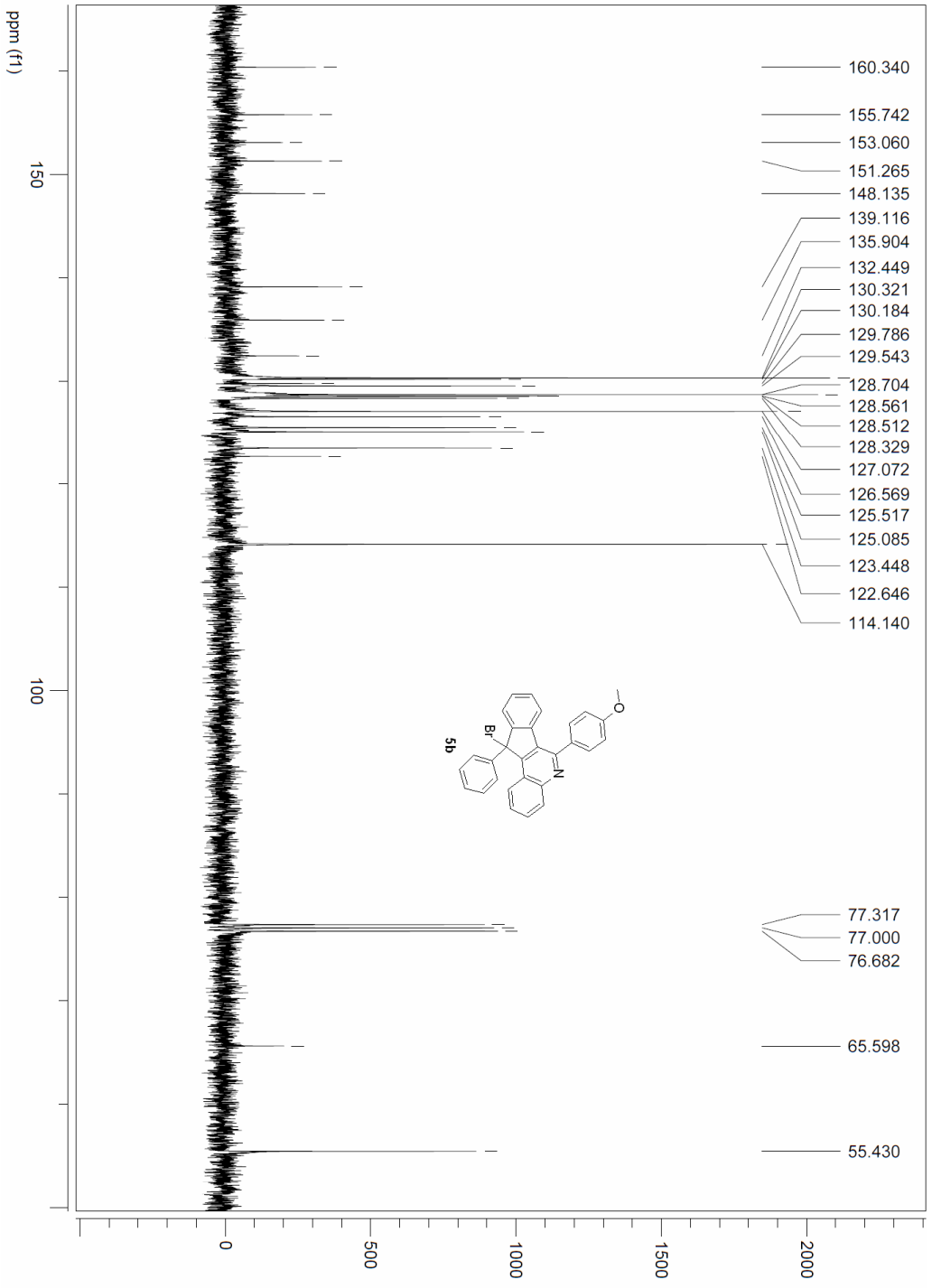


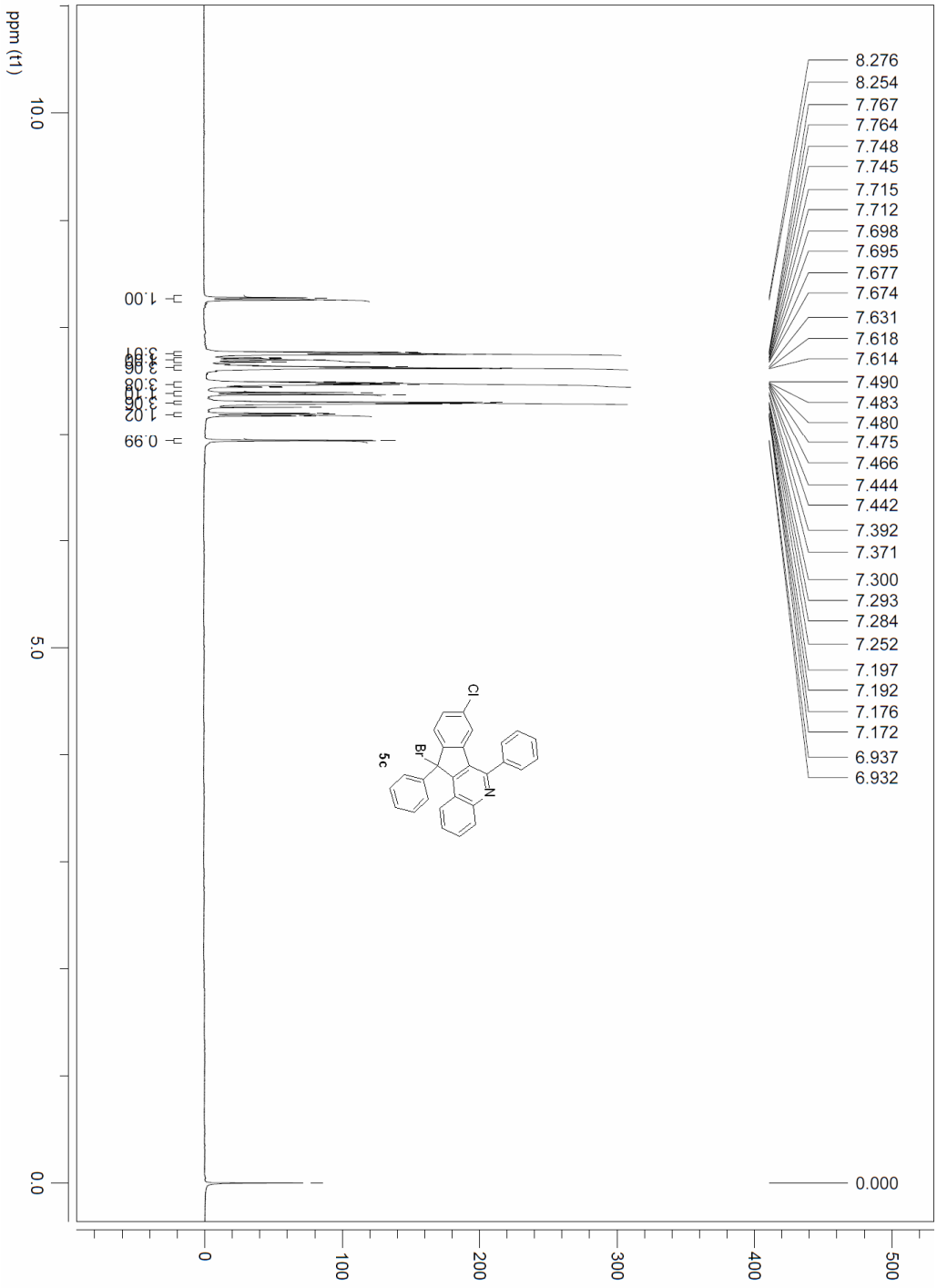


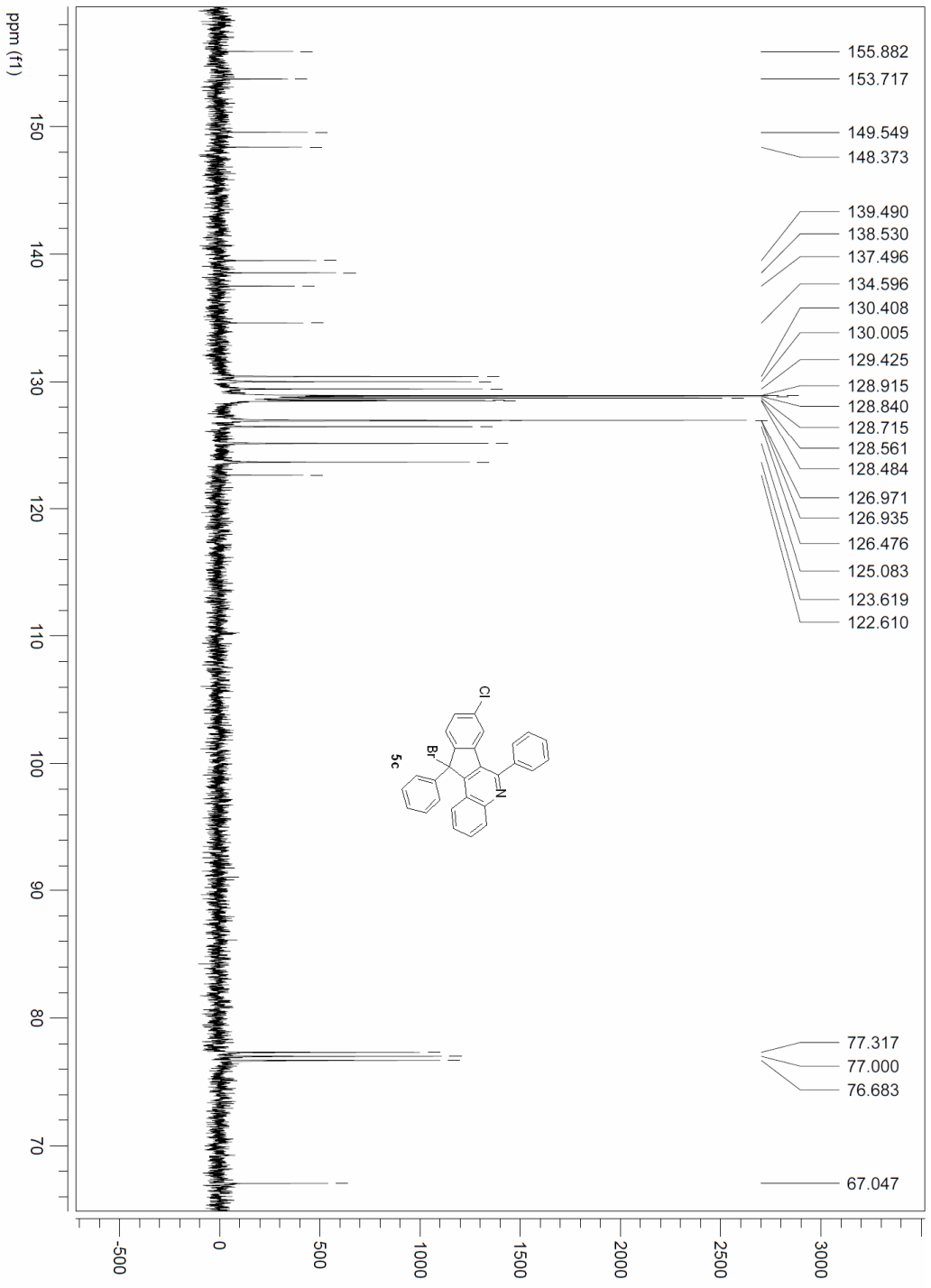


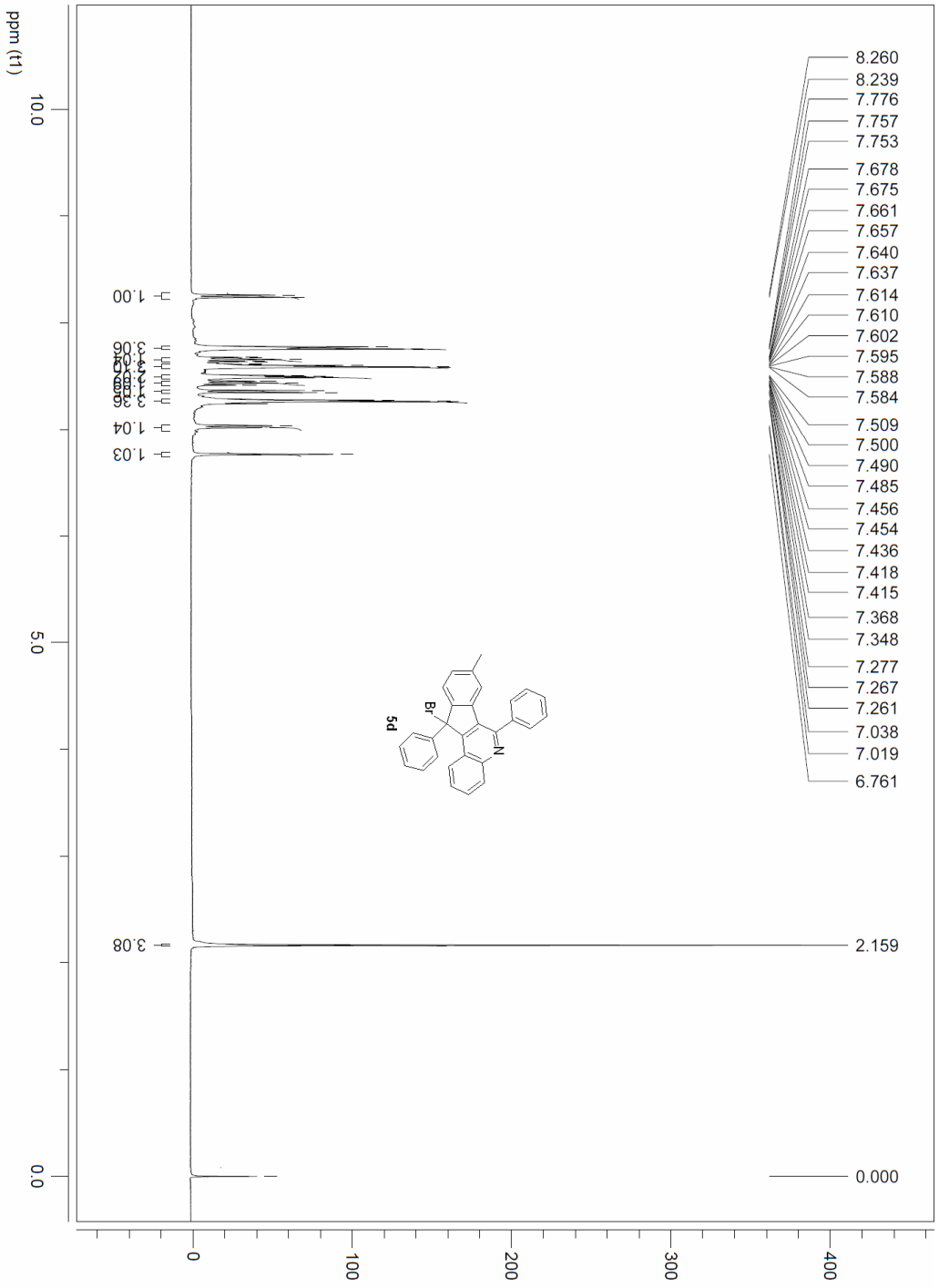


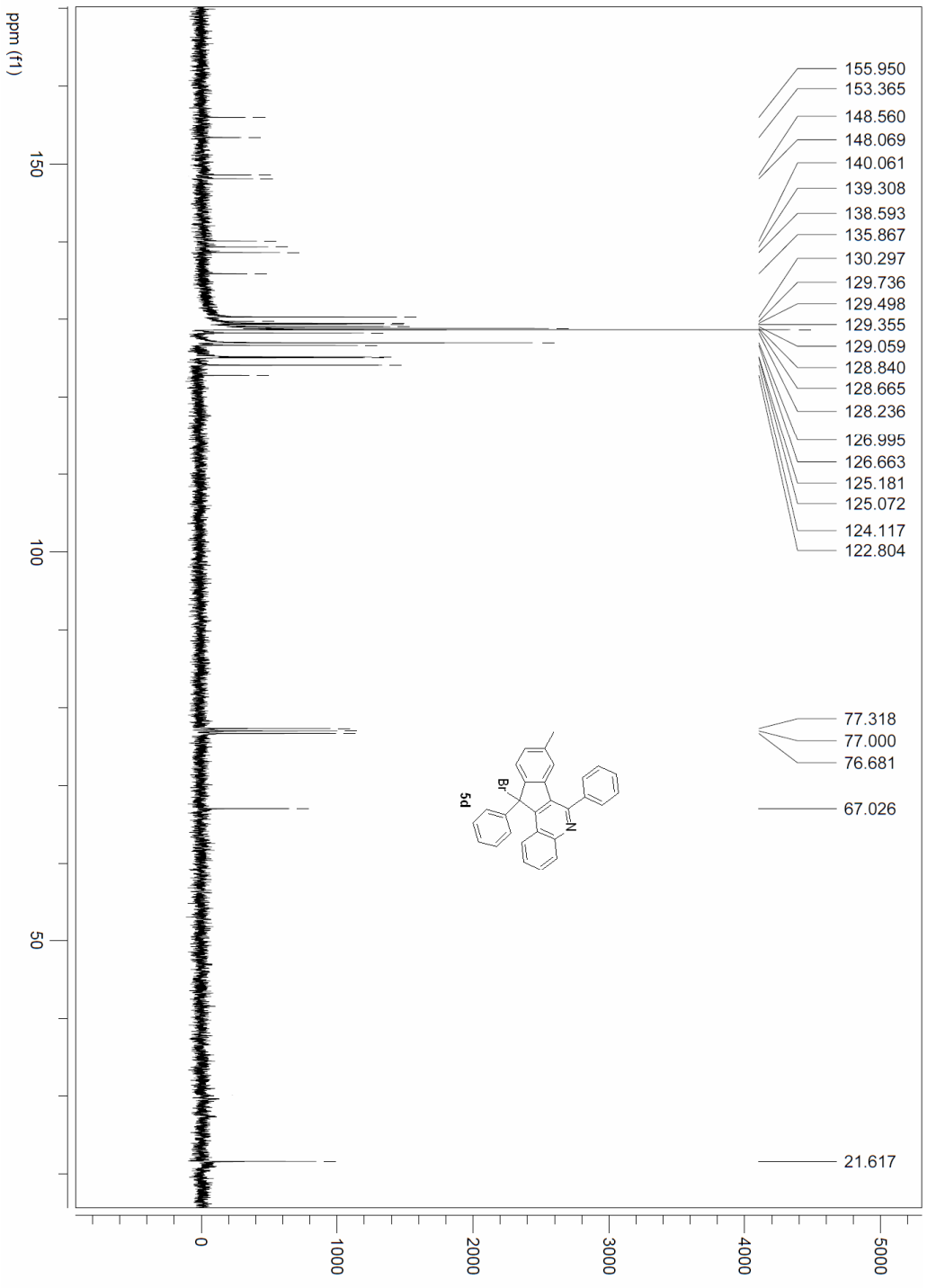


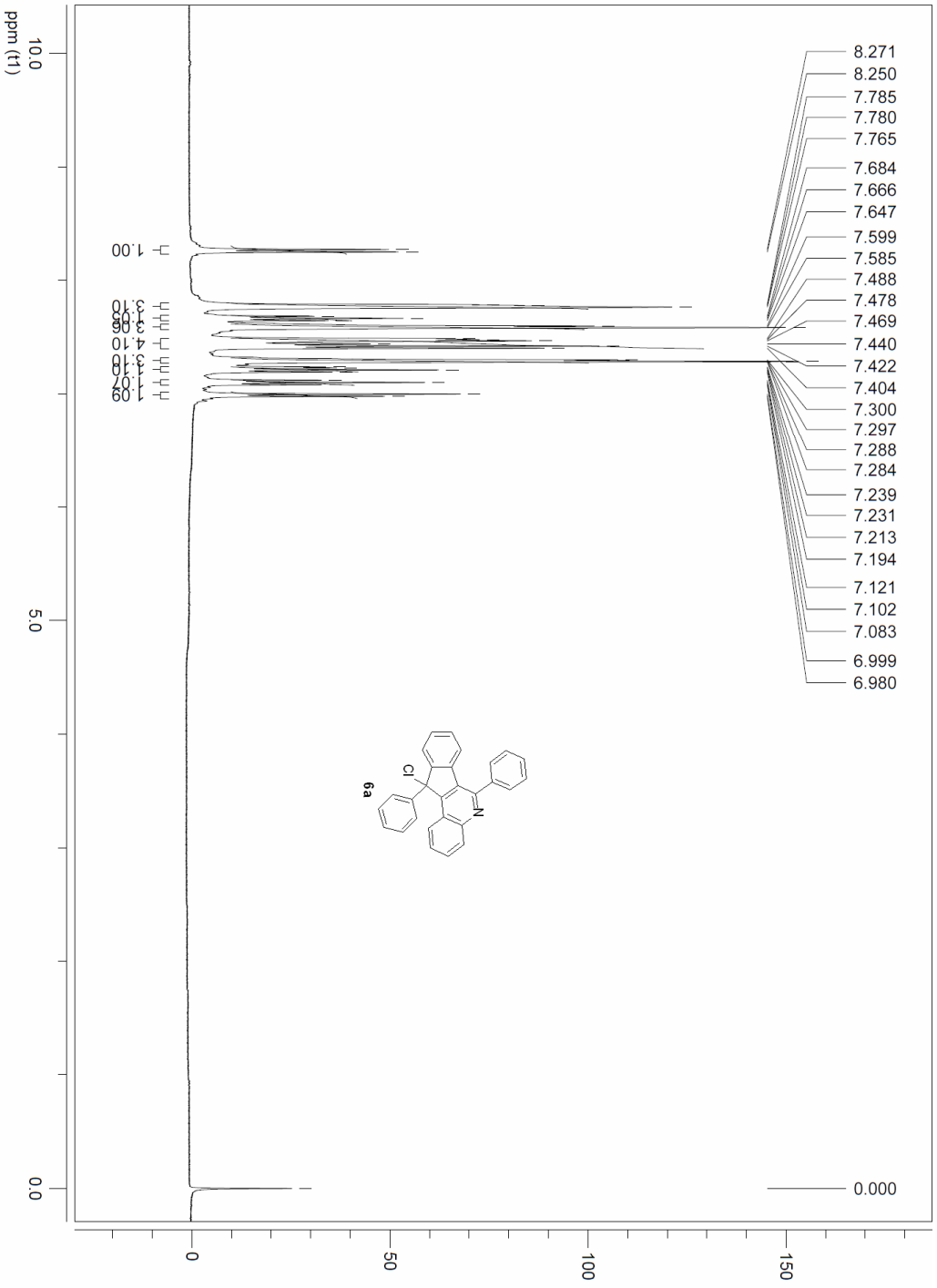


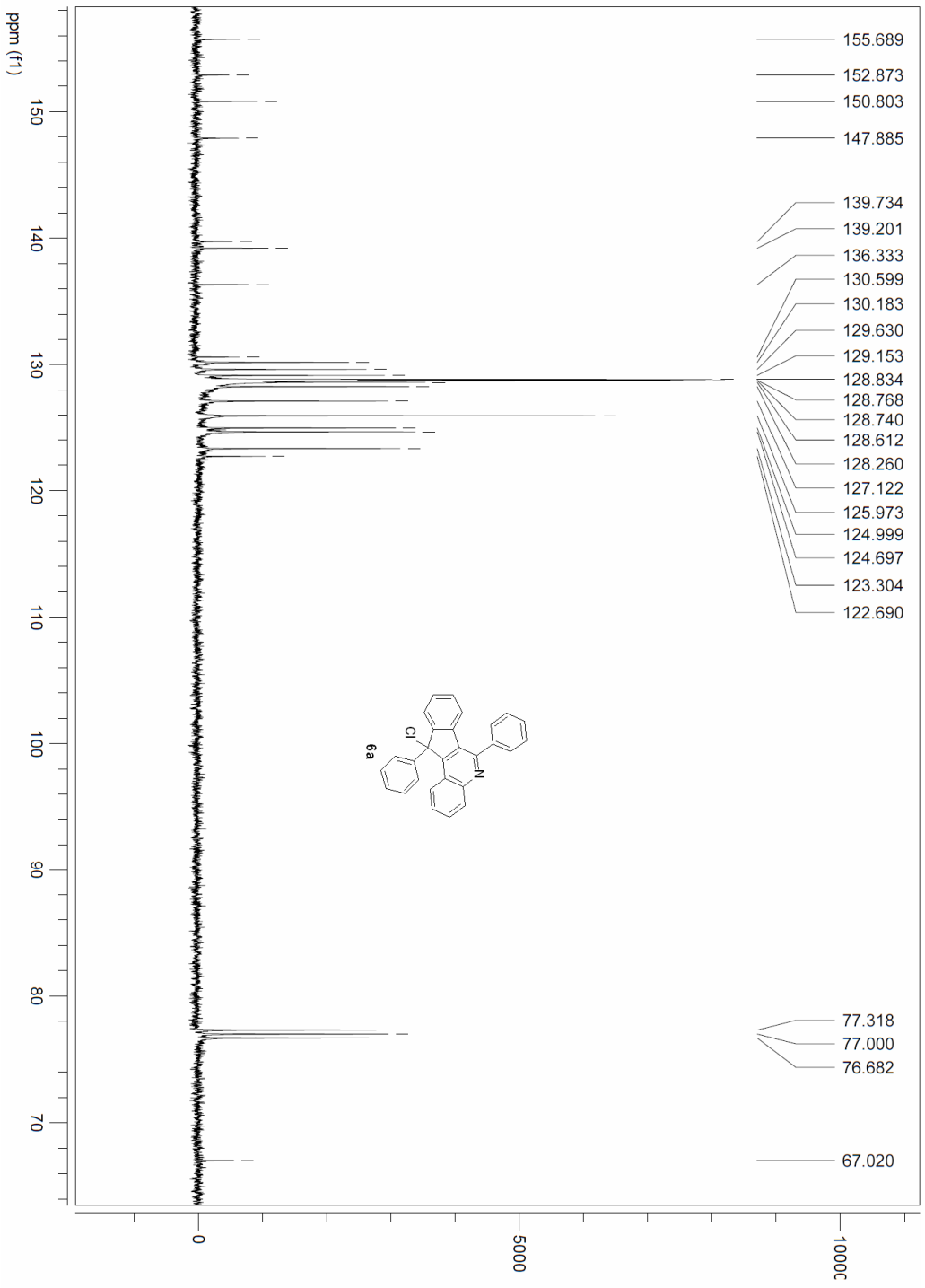

ppm (t1)
10.0
5.0
0.0
0
100
200
300
400
500
1.00
0.99
8.276
8.254
7.767
7.764
7.748
7.745
7.715
7.712
7.698
7.695
7.677
7.674
7.631
7.618
7.614
7.490
7.483
7.480
7.475
7.466
7.444
7.442
7.392
7.371
7.300
7.293
7.284
7.252
7.197
7.192
7.176
7.172
6.937
6.932
0.000
Cl
Br
N
5c

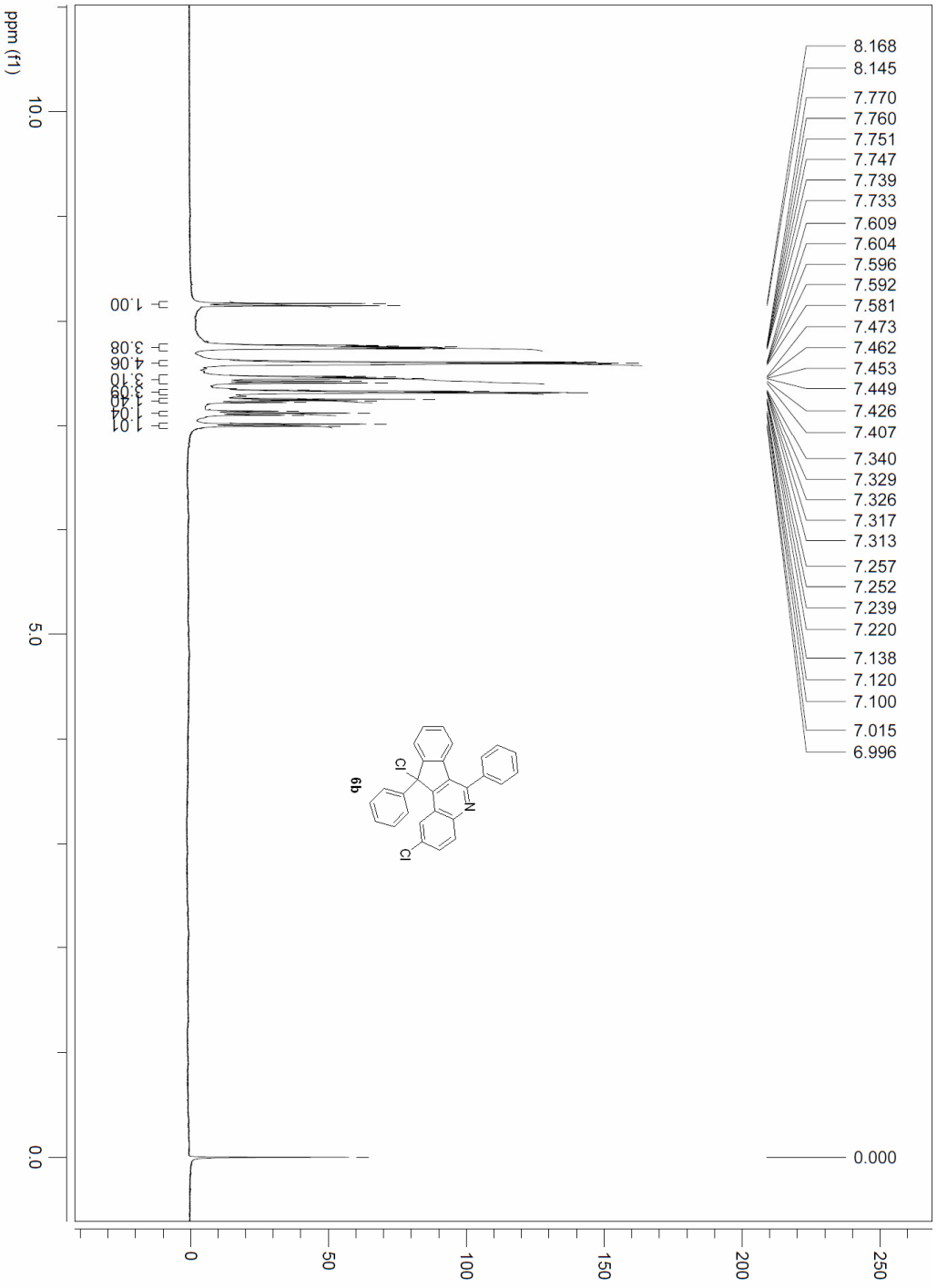


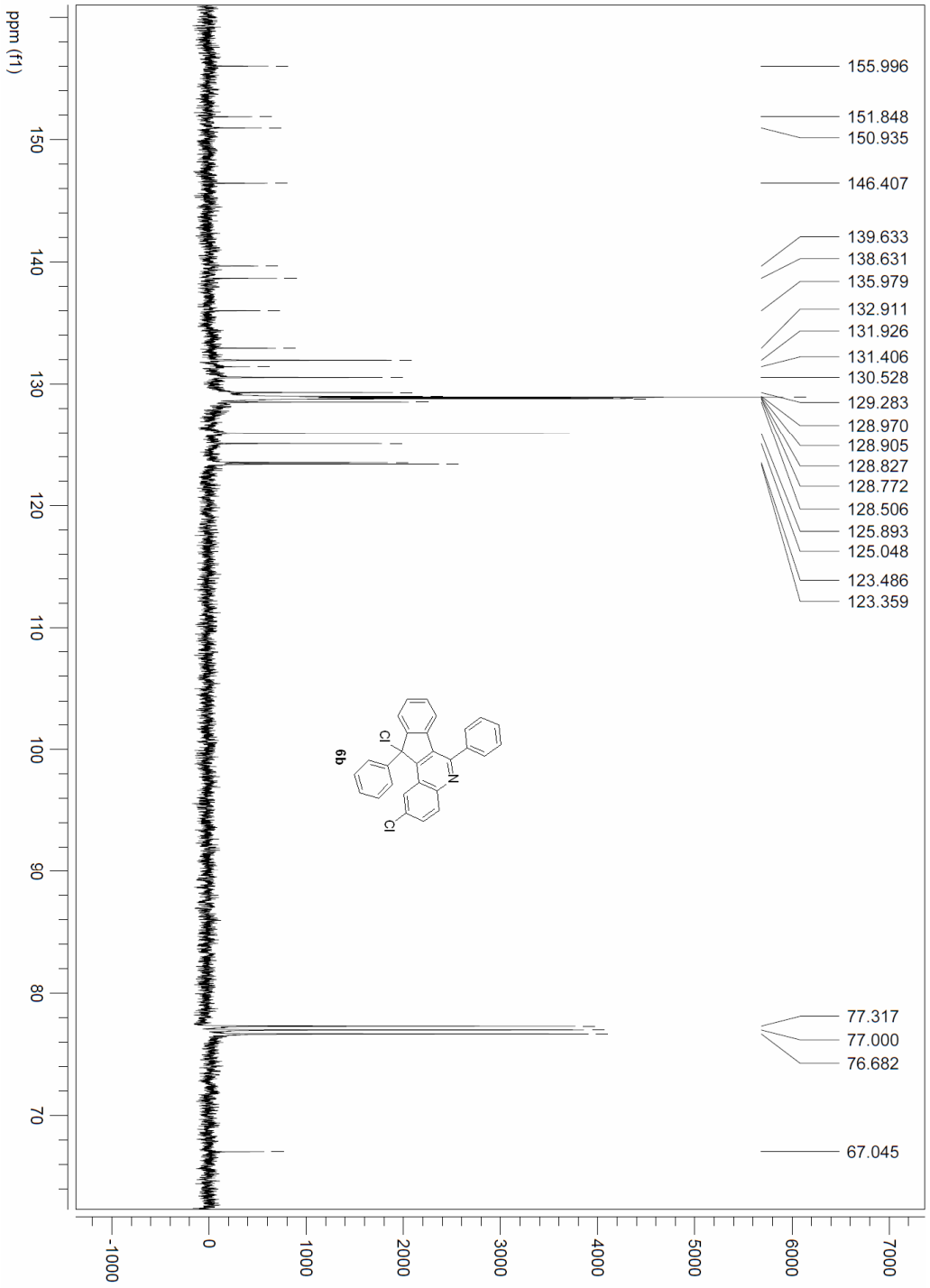

ppm (t1)
10.0
5.0
0.0
0
100
200
300
400
1.00
3.06
1.04
1.03
3.08
2.159
0.000
8.260
8.239
7.776
7.757
7.753
7.678
7.675
7.661
7.657
7.640
7.637
7.614
7.610
7.602
7.595
7.588
7.584
7.509
7.500
7.490
7.485
7.456
7.454
7.436
7.418
7.415
7.368
7.348
7.277
7.267
7.261
7.038
7.019
6.761
Br
N
5d

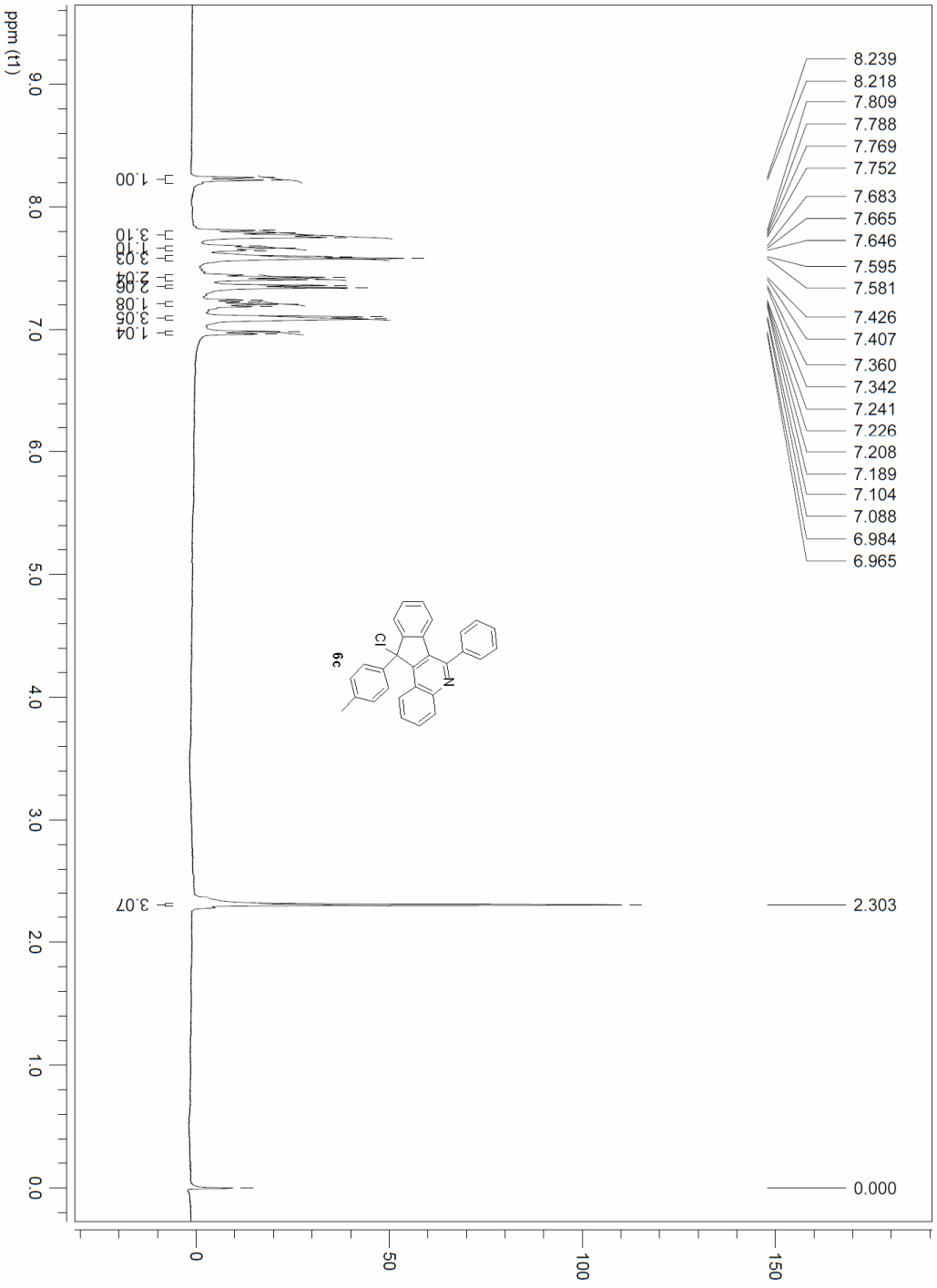

ppm (f1)
150
100
50
0
1000
2000
3000
4000
5000
155.950
153.365
148.560
148.069
140.061
139.308
138.593
135.867
130.297
129.736
129.498
129.355
129.059
128.840
128.665
128.236
126.995
126.663
125.181
125.072
124.117
122.804
77.318
77.000
76.681
67.026
21.617
Br
N
5q

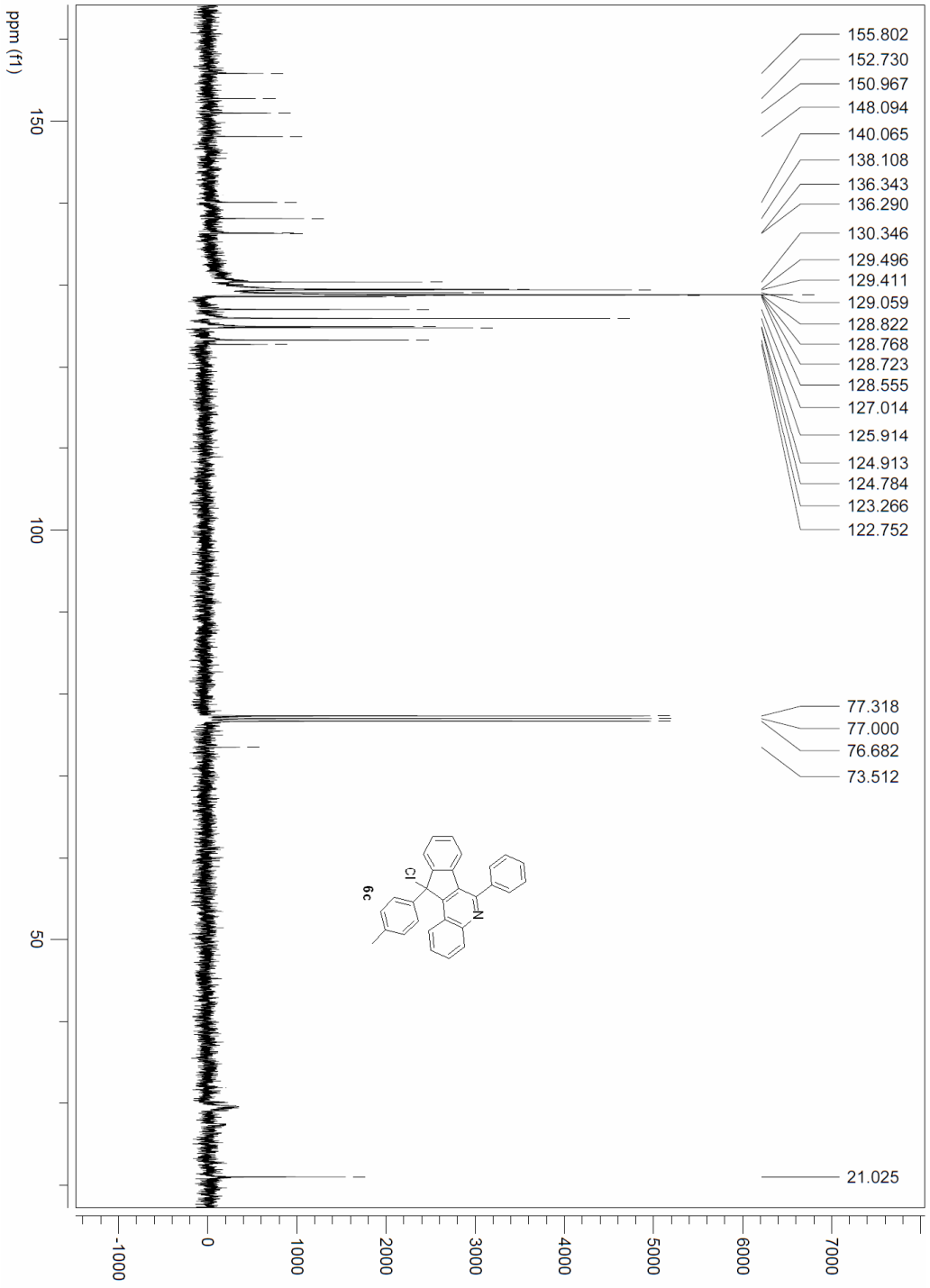

ppm (t1)
10.0
5.0
0.0
0
50
100
150
1.00
3.10
3.06
3.06
4.10
3.10
1.10
1.07
1.09
8.271
8.250
7.785
7.780
7.765
7.684
7.666
7.647
7.599
7.585
7.488
7.478
7.469
7.440
7.422
7.404
7.300
7.297
7.288
7.284
7.239
7.231
7.213
7.194
7.121
7.102
7.083
6.999
6.980
0.000
Cl
N
6a

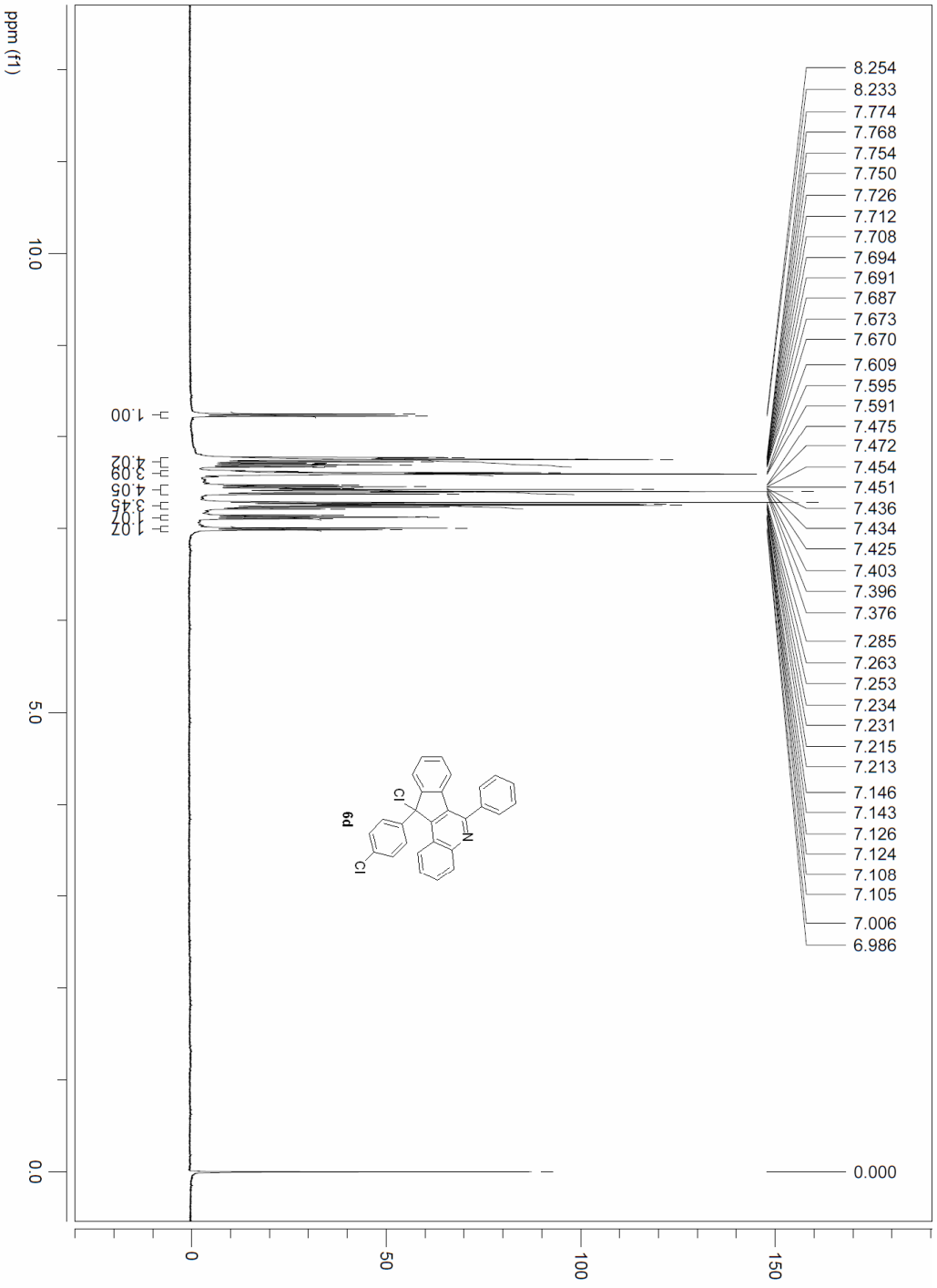


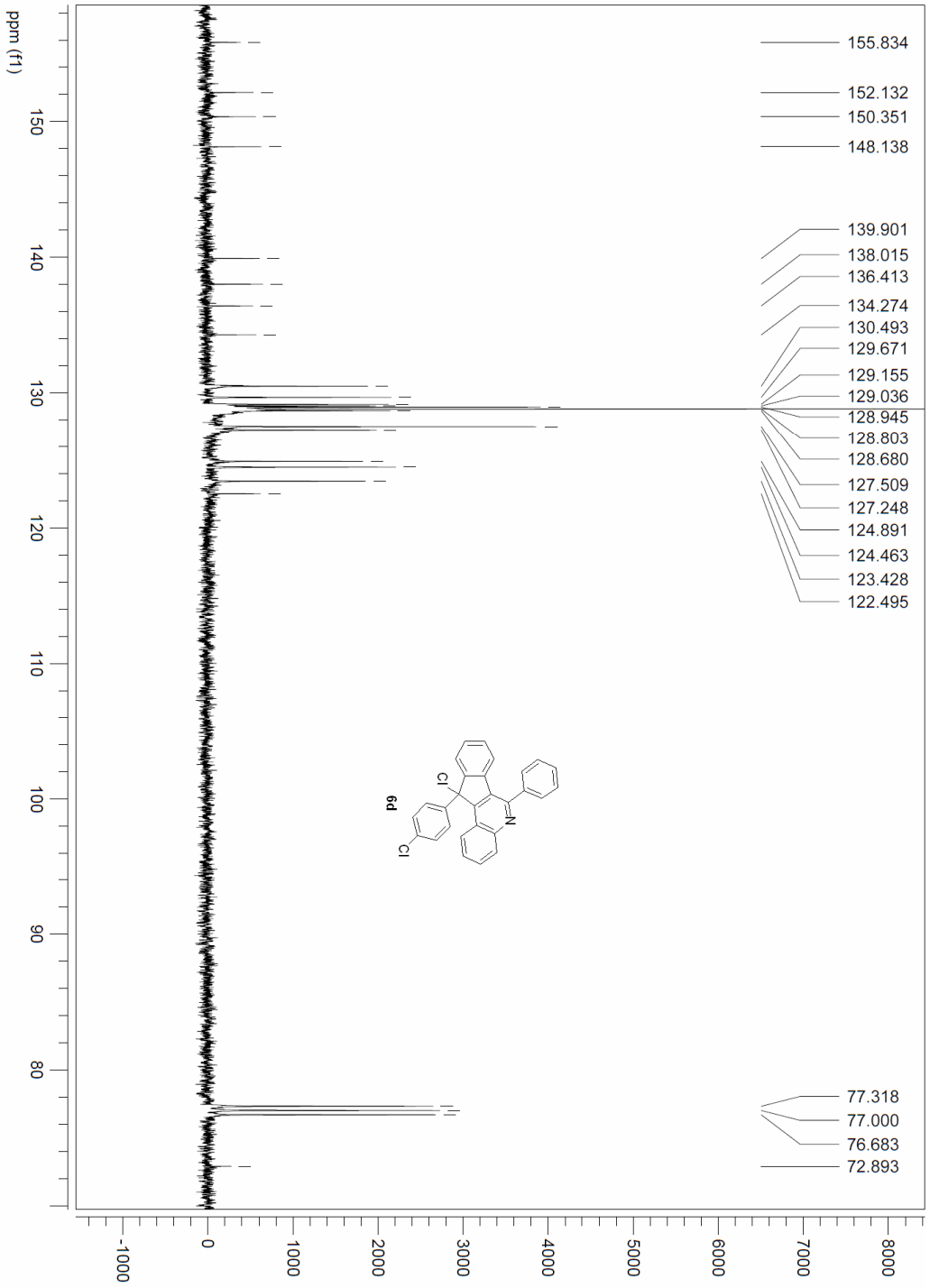

ppm (f1)
10.0
5.0
0.0
0
50
100
150
200
250
1.00
3.08
4.06
8.168
8.145
7.770
7.760
7.751
7.747
7.739
7.733
7.609
7.604
7.596
7.592
7.581
7.473
7.462
7.453
7.449
7.426
7.407
7.340
7.329
7.326
7.317
7.313
7.257
7.252
7.239
7.220
7.138
7.120
7.100
7.015
6.996
0.000
6b
Cl
N
Cl

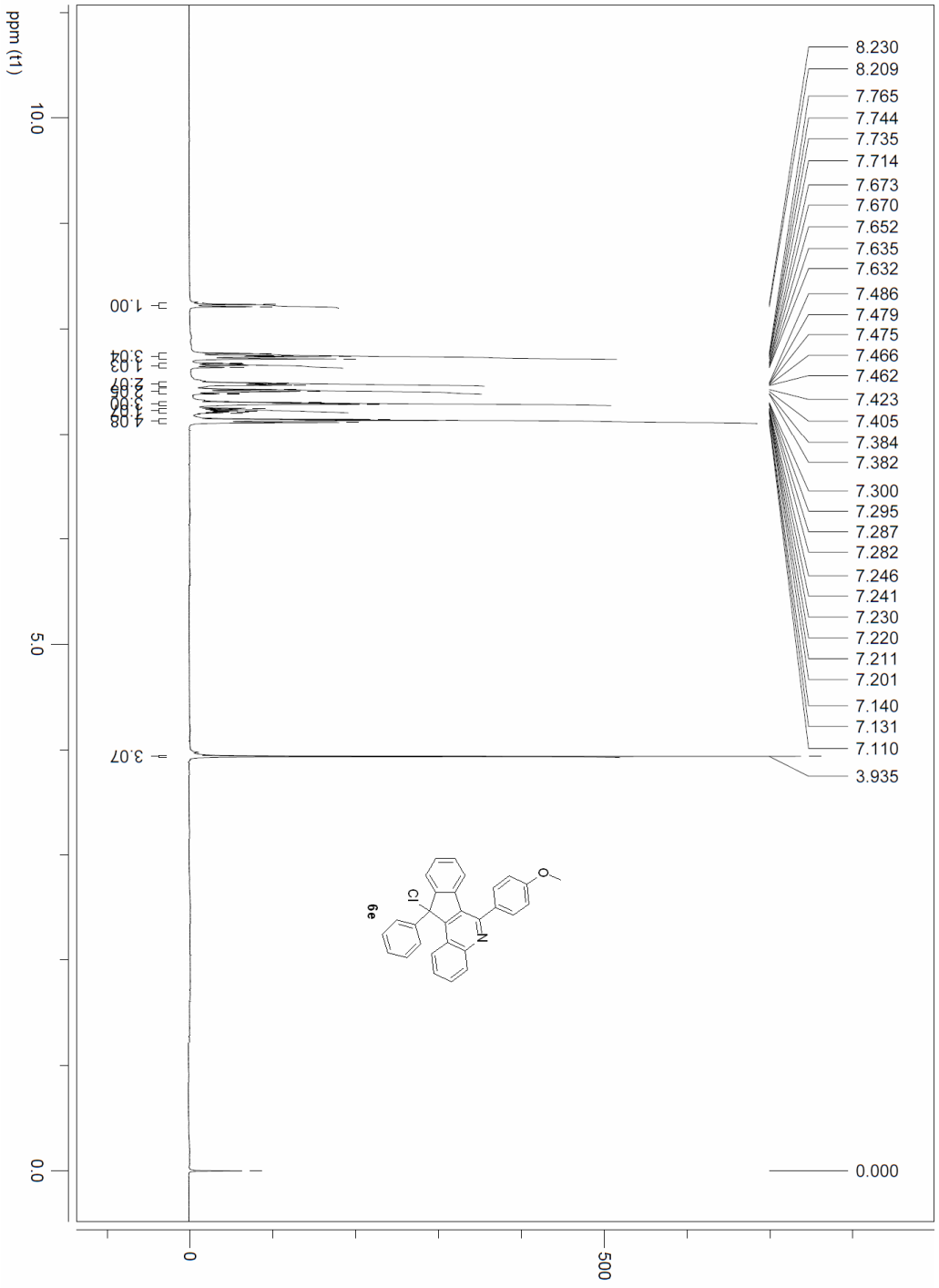


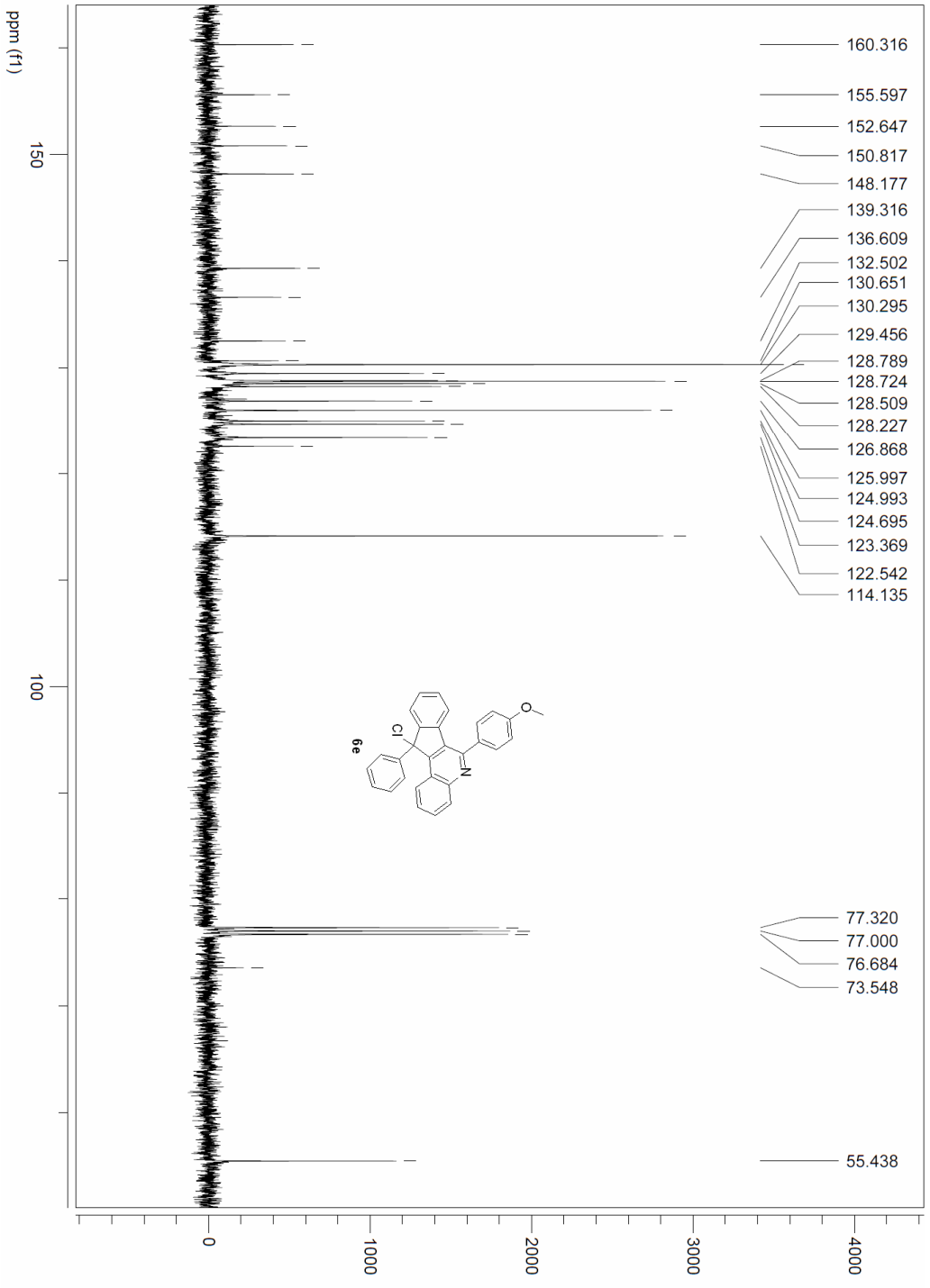


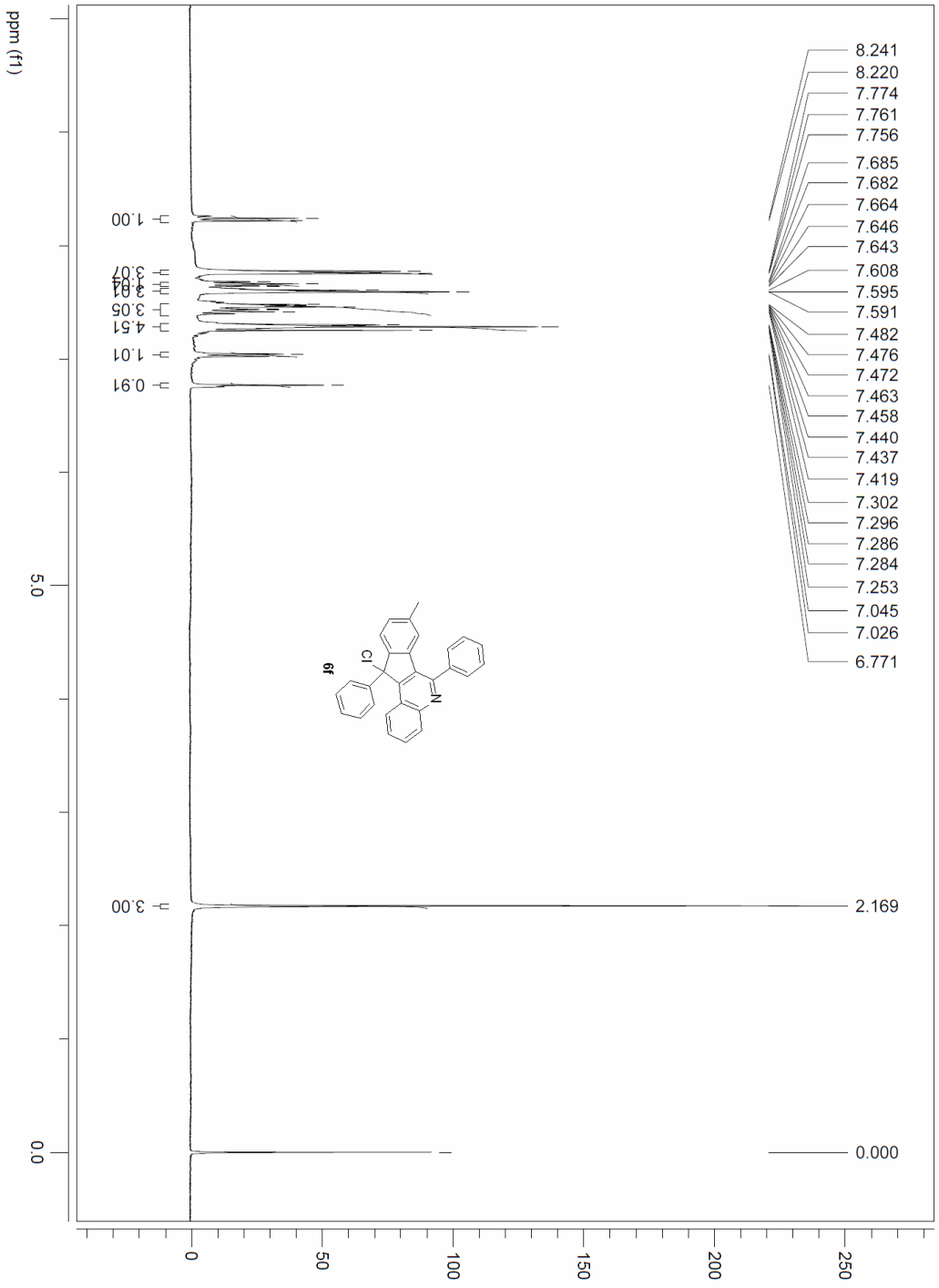


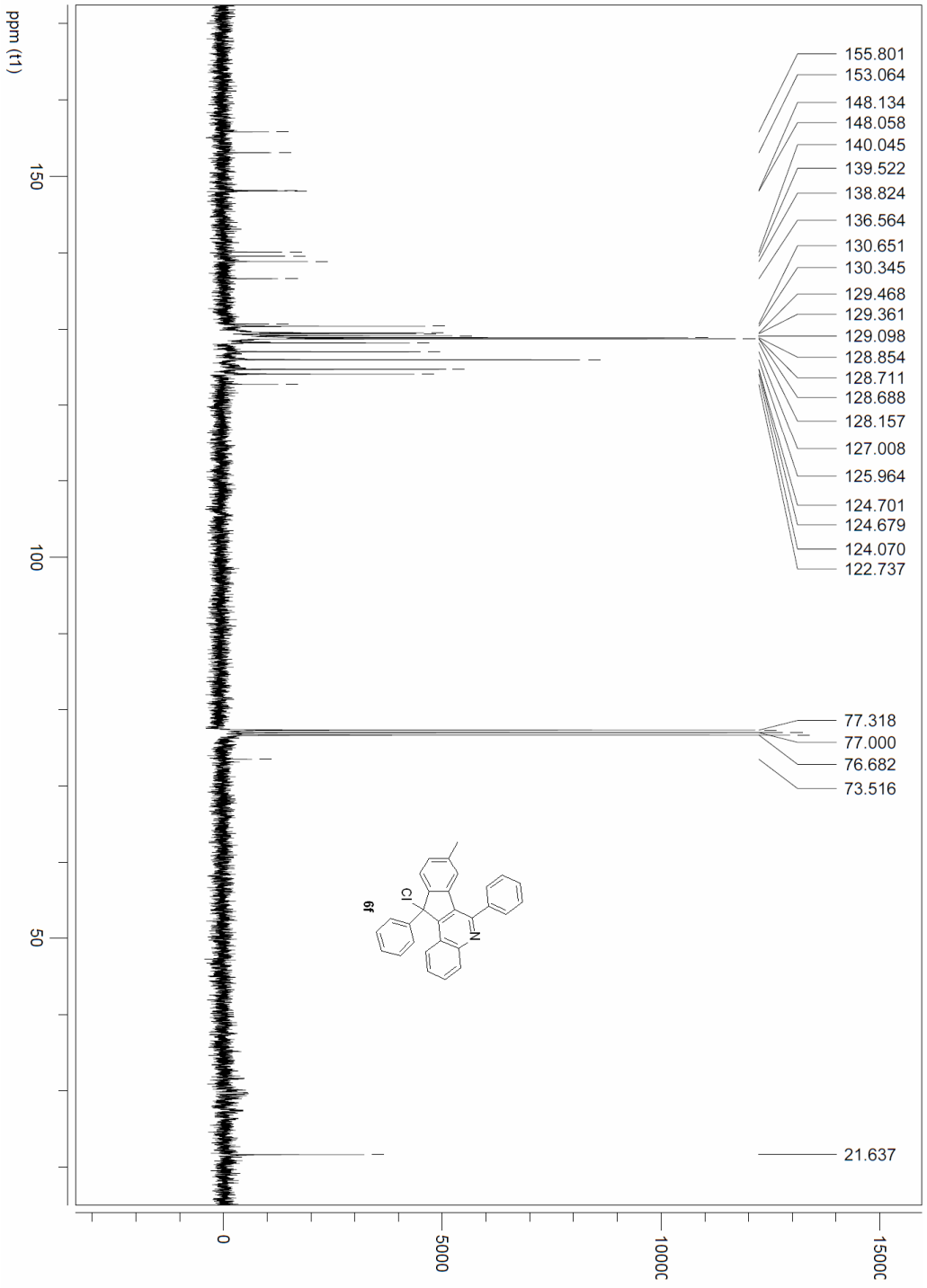

ppm (f1)
10.0
5.0
0.0
0
50
100
150
1.00
2.02
3.09
4.05
3.45
2.07
1.02
8.254
8.233
7.774
7.768
7.754
7.750
7.726
7.712
7.708
7.694
7.691
7.687
7.673
7.670
7.609
7.595
7.591
7.475
7.472
7.454
7.451
7.436
7.434
7.425
7.403
7.396
7.376
7.285
7.263
7.253
7.234
7.231
7.215
7.213
7.146
7.143
7.126
7.124
7.108
7.105
7.006
6.986
0.000
6d
Cl
Cl
N

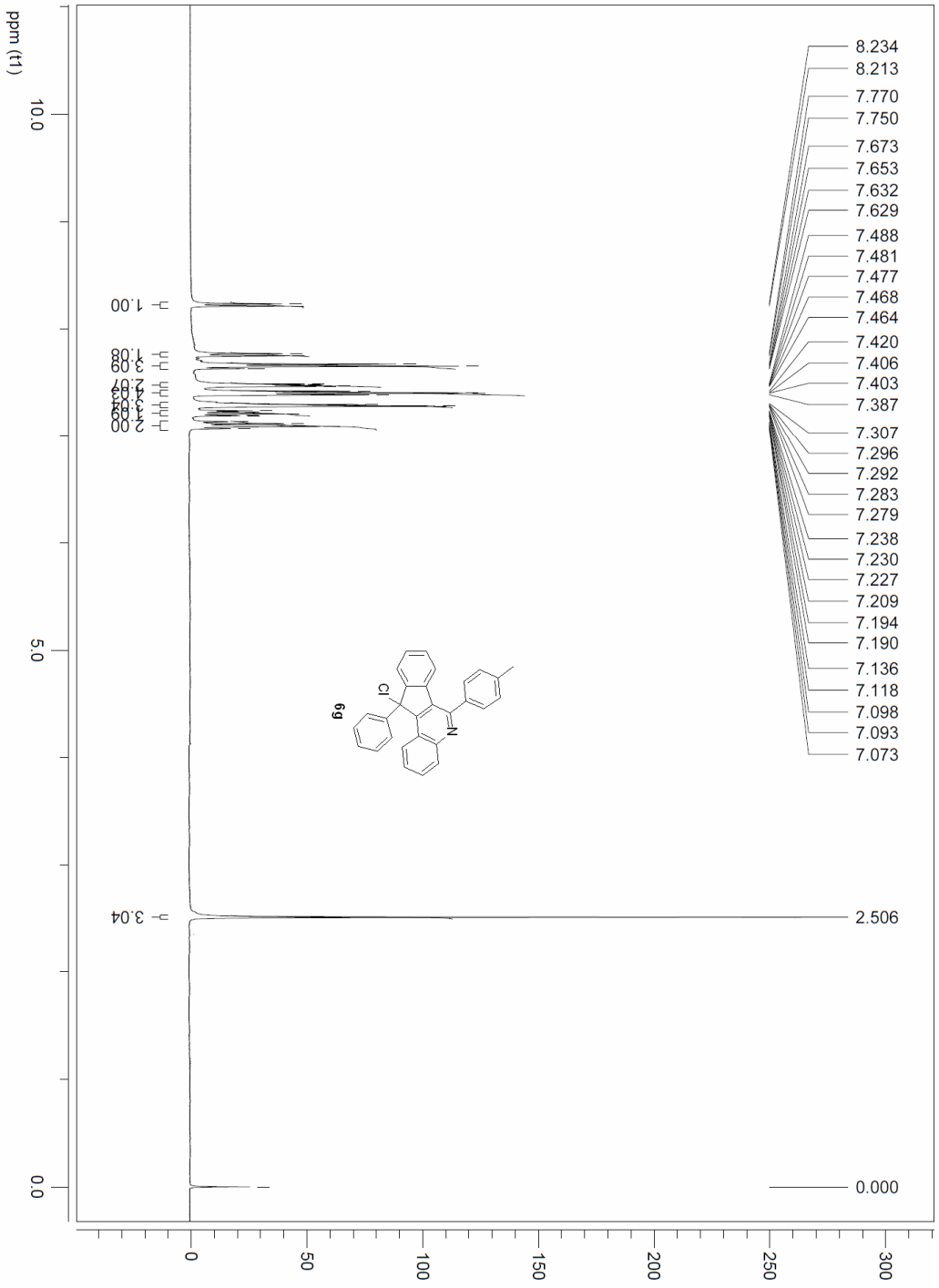


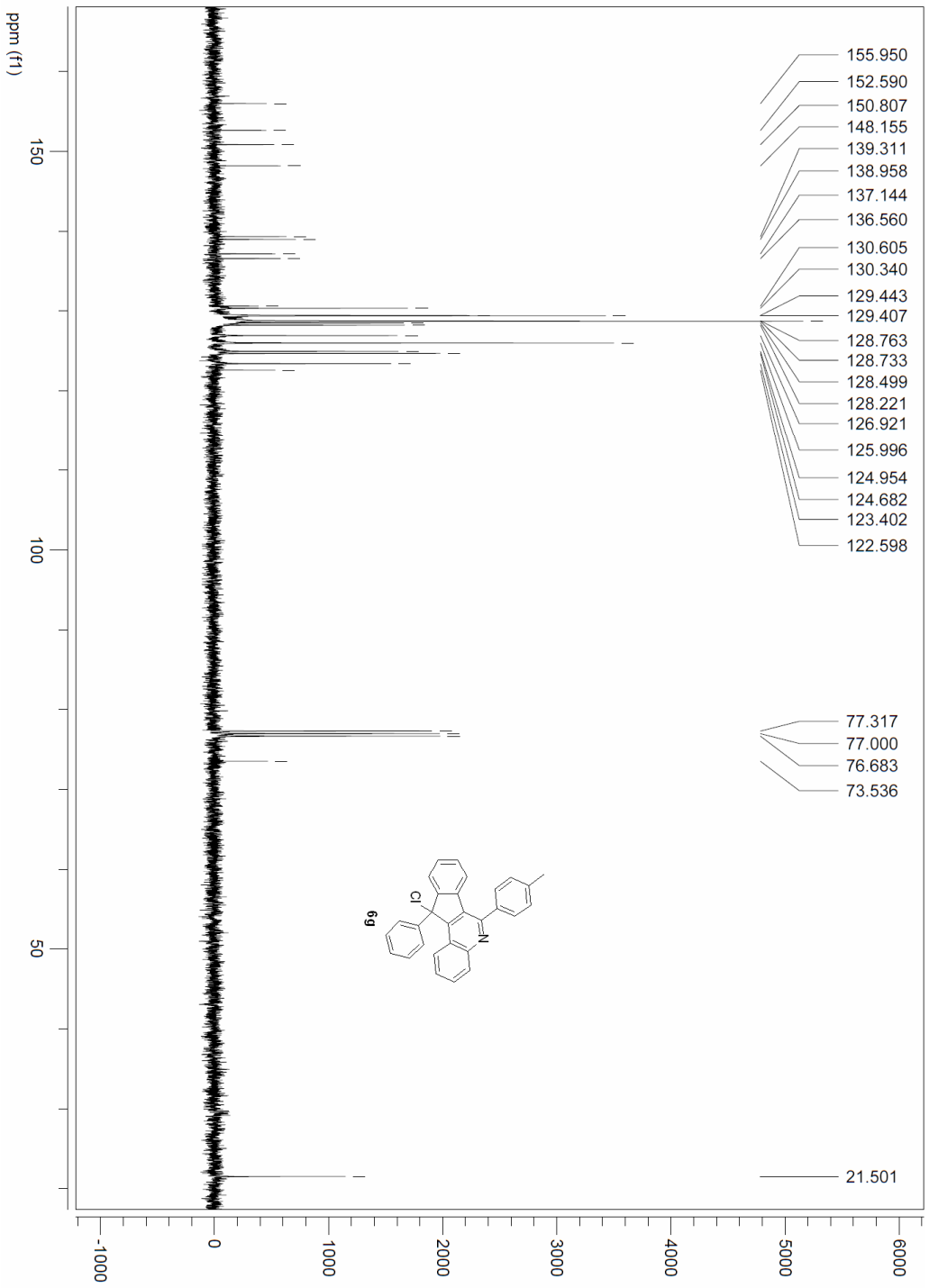

ppm (t1)
10.0
5.0
0.0
0
500
1.00
3.07
8.230
8.209
7.765
7.744
7.735
7.714
7.673
7.670
7.652
7.635
7.632
7.486
7.479
7.475
7.466
7.462
7.423
7.405
7.384
7.382
7.300
7.295
7.287
7.282
7.246
7.241
7.230
7.220
7.211
7.201
7.140
7.131
7.110
3.935
0.000
6e
Cl
N
O

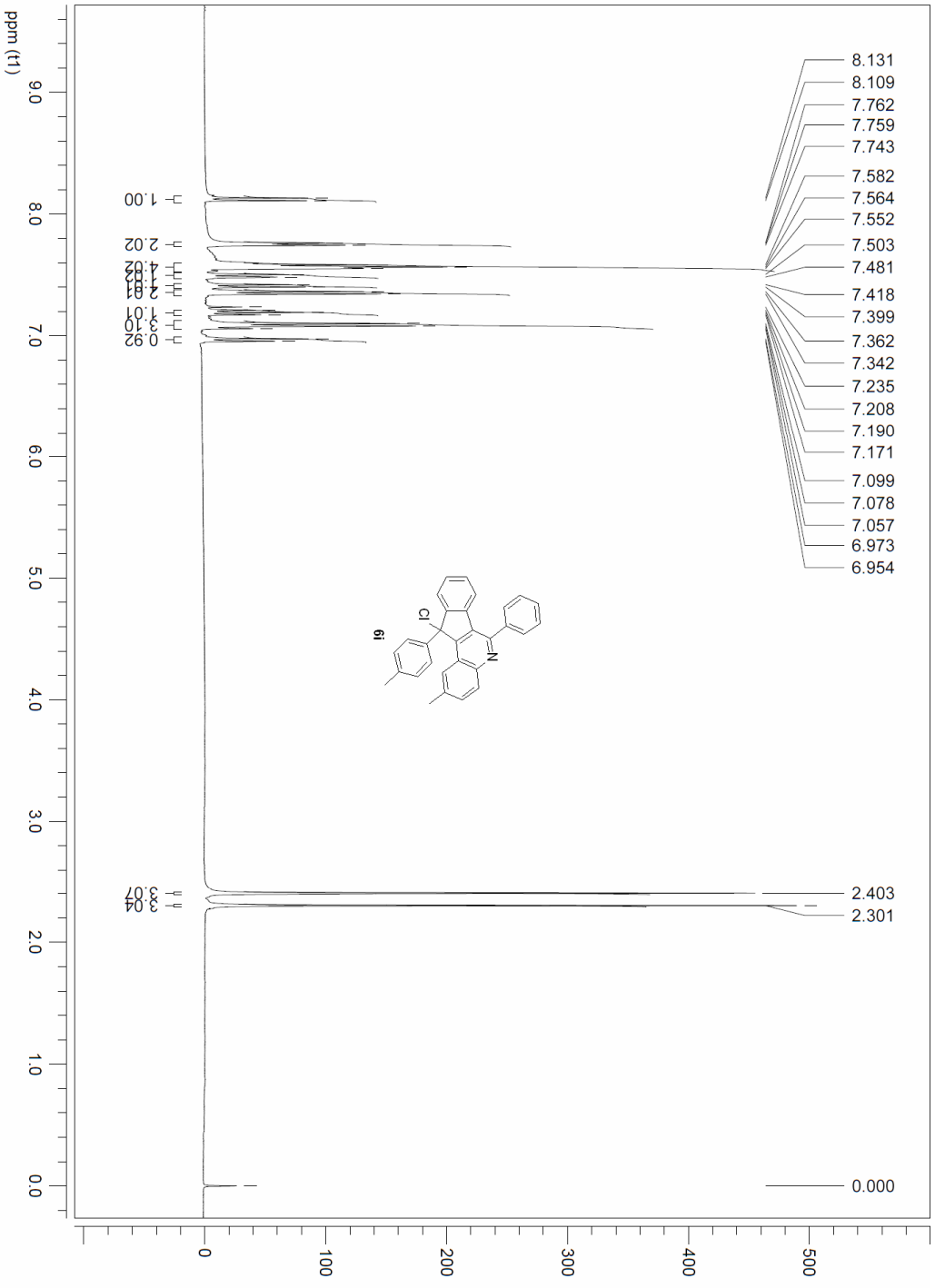


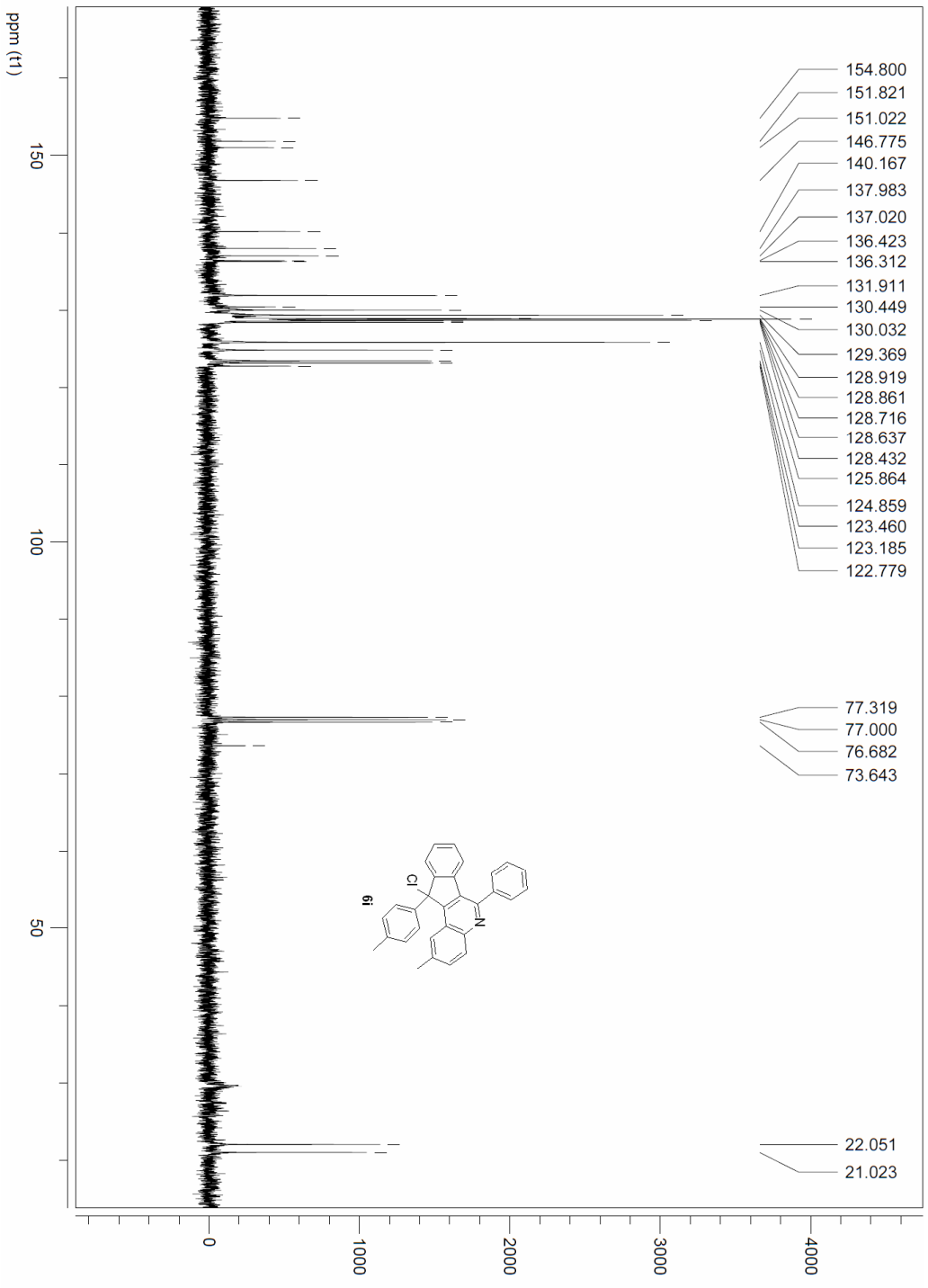


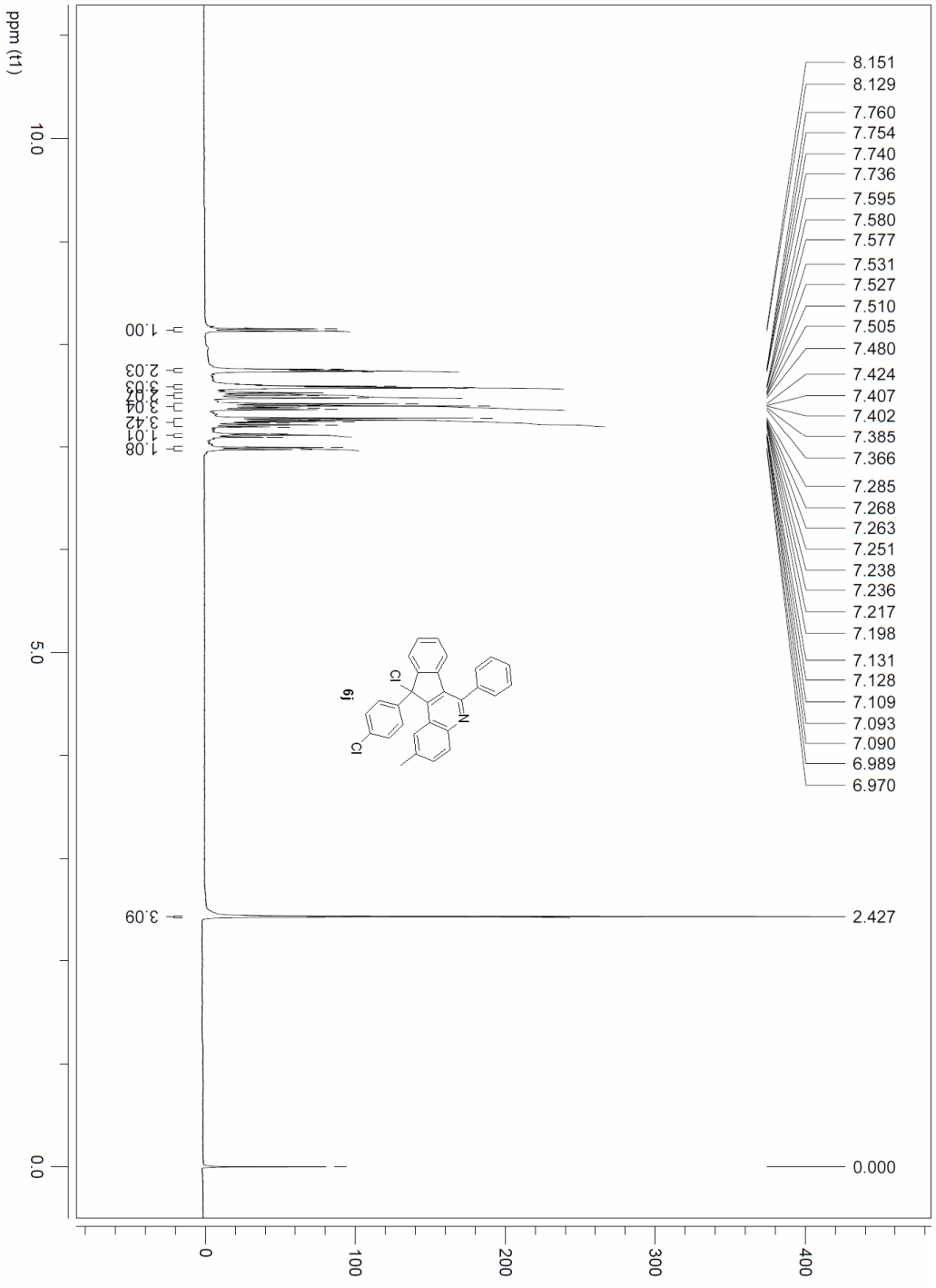


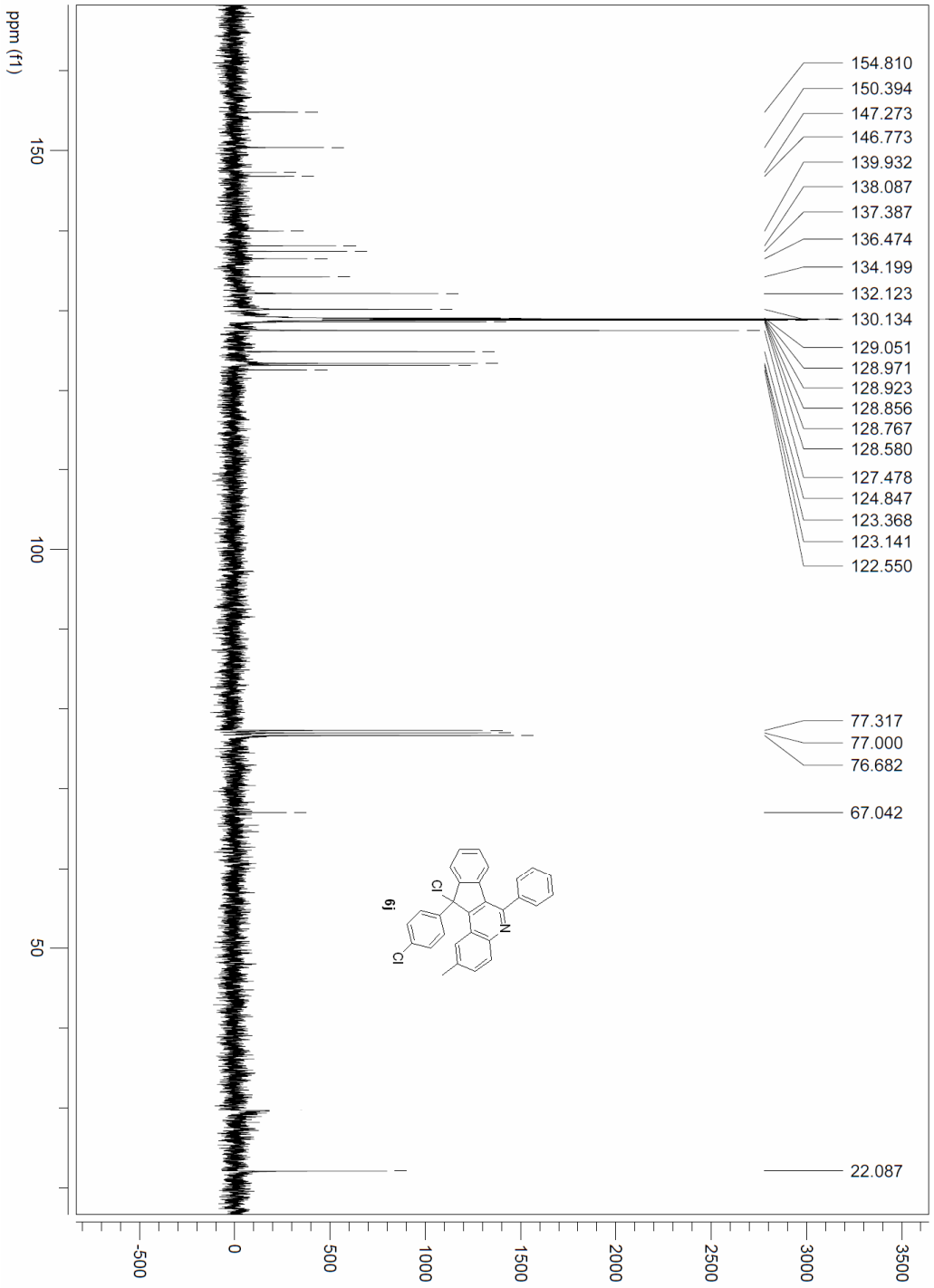


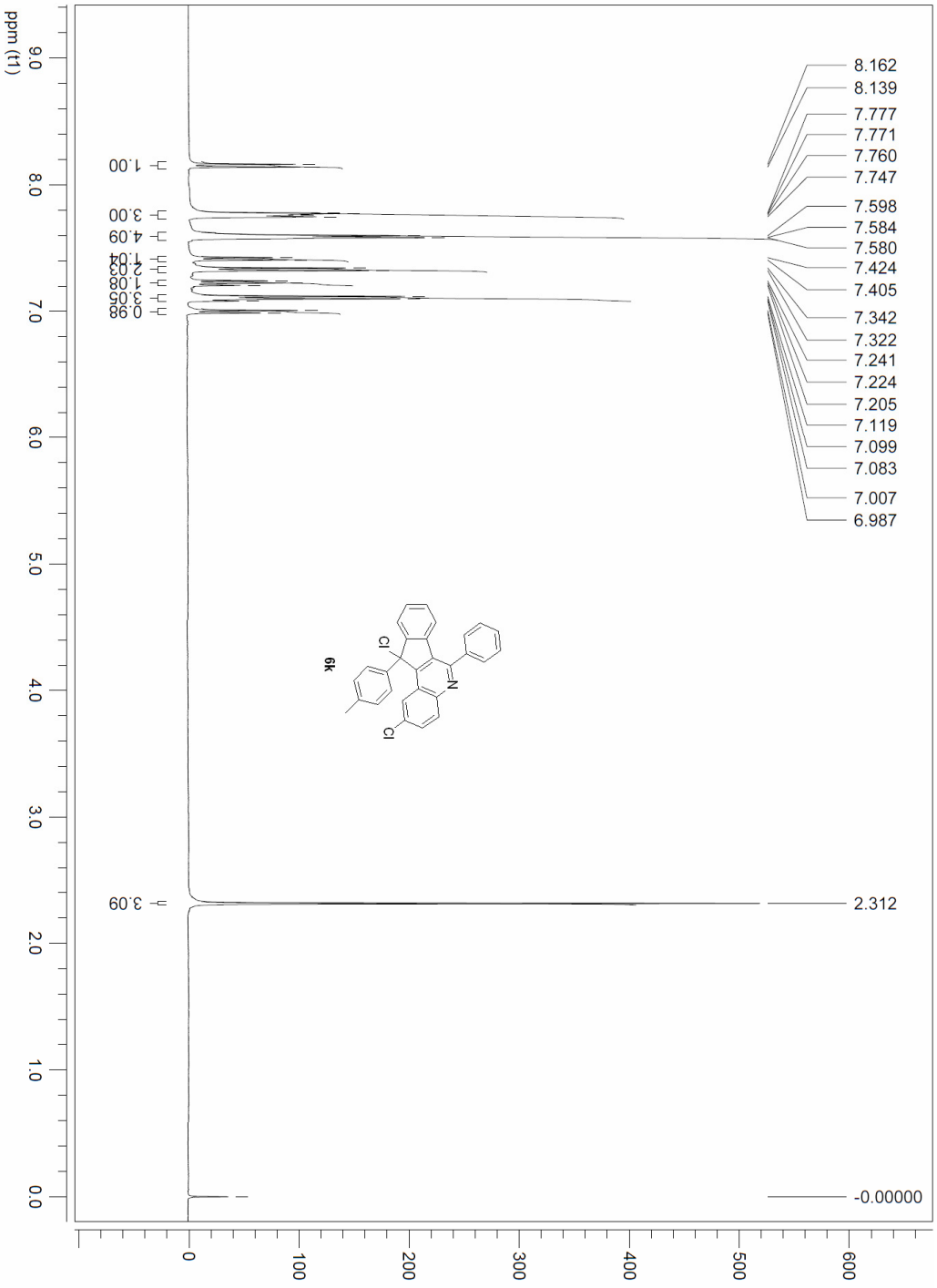







ppm (t1)
10.0
5.0
0.0
0
100
200
300
400
1.00
2.03
3.09
1.08
1.01
3.42
3.04
3.07
3.03
2.427
8.151
8.129
7.760
7.754
7.740
7.736
7.595
7.580
7.577
7.531
7.527
7.510
7.505
7.480
7.424
7.407
7.402
7.385
7.366
7.285
7.268
7.263
7.251
7.238
7.236
7.217
7.198
7.131
7.128
7.109
7.093
7.090
6.989
6.970
0.000
6j
Cl
Cl
N




ppm (t1)
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
100
200
300
400
500
600
1.00
3.00
4.09
1.04
2.03
1.08
3.05
0.98
3.09
8.162
8.139
7.777
7.771
7.760
7.747
7.598
7.584
7.580
7.424
7.405
7.342
7.322
7.241
7.224
7.205
7.119
7.099
7.083
7.007
6.987
2.312
-0.00000
6k
Cl
N
Cl