SUPPORTING INFORMATION

An efficient protocol for the synthesis of novel spiro[acenaphthylene-1,2'-pyrrolidin]-2-one compounds

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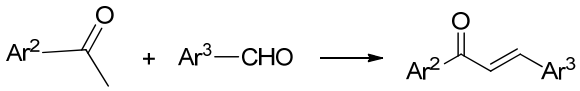
Experimental

^{1}H-NMR spectra and ^{13}C-NMR spectra were recorded on a Bruker Avance III 500 MHz spectrometer, using $CDCl_3$ as solvent (500 MHz for ^{1}H or 126 MHz for ^{13}C, respectively). IR spectra (KBr) were recorded on a Nicolet 6700 spectrometer. Melting points were taken on Büchi M-560 apparatus in open capillary tubes and are uncorrected. HRMS were carried out on DECAX-60000 LCQ Deca XP. X-ray crystallographic intensity data were collected using Bruker SMART APEX II instrument. The reaction mixture was monitored by TLC on silica gel plates (60 F-254). All chemicals were purchased from Aladdin (Shanghai, China) chemical company.

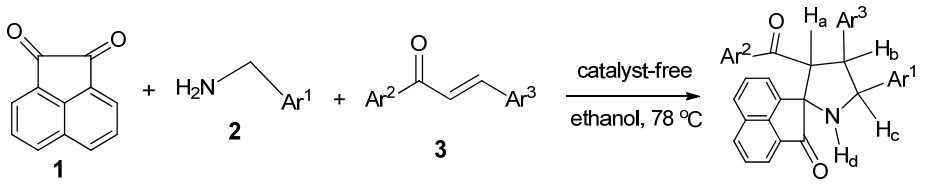
General procedure for the synthesis of chalcones 3



A solution of 0.01 mol of aryl aldehyde and 0.01 mol of acetophenone in 10 mL of ethanol was taken in a 25-mL flask equipped with a magnetic stirring bar. To this solution 10 mL of 2 M NaOH solution was then added with the help of a dropping

funnel keeping the flask an in ice water bath. Then, the reaction mixture was stirred for 4-5 h at room temperature, subsequently the crude product was filtered and recrystallized from ethanol.

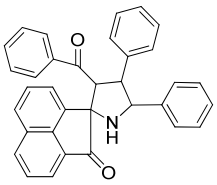
General procedure for preparation of spiro[acenaphthylene-1,2'-pyrrolidin]-2-ones 4



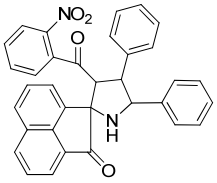
A mixture of acenaphthenequinone **1** (0.5 mmol), arylmethyl amine **2** (0.5 mmol) and chalcone **3** (0.5 mmol) in ethanol (5 mL) was stirred at reflux for 90 min, as indicated by TLC. After completion of the reaction, the mixture was cooled to room temperature. Then the precipitate formed in the reaction mixture was filtered and recrystallized from ethanol to obtain the pure product.

A single crystal of **4a** was obtained by slow evaporation of DMF/H_2O/DCM mixtures. X-ray crystallographic intensity data were collected using Bruker SMART APEX II detector, T = 296(2) K, Wavelength = 0.71073 Å. Crystallographic data for **4a**: $C_{34}H_{25}NO_2$, M = 497.55 g·mol^{-1}, space group: P -1, a = 9.0747(6) Å, b = 10.0321(6) Å, c = 14.3157(9) Å, α = 96.556(2) °, β = 90.976(2) °, γ = 103.110(2) °, V = 1259.77(14) Å^3, Z = 2, Mu = 0.078 mm^{-1}, h = -11~11, k = -13~13, l = -18~18, R = 0.0447, wR2 = 0.0923, CCDC reference number: 1045858.

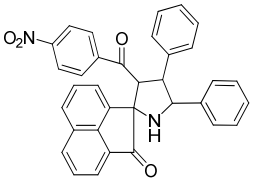
Spectroscopic data



3'-benzoyl-4',5'-diphenyl-2*H*-spiro[acenaphthylene-1,2'-pyrrolidin]-2-one (4a). Yellow powder; m.p. 218–220 °C; IR (KBr, ν, cm^{-1}): 3317, 3060, 1707, 1685, 1601, 1281, 783, 699; ^{1}H-NMR (500 MHz, $CDCl_3$) δ 7.89 (dd, *J* = 7.5, 2.2 Hz, 2H), 7.64 (t, *J* = 7.1 Hz, 2H), 7.58 (dt, *J* = 7.2, 5.1 Hz, 2H), 7.51 (d, *J* = 7.4 Hz, 2H), 7.43 (d, *J* = 7.1 Hz, 2H), 7.31 – 7.28 (m, 4H), 7.26 – 7.17 (m, 2H), 7.13 (d, *J* = 7.3 Hz, 2H), 7.00 (t, *J* = 7.4 Hz, 1H), 6.82 (t, *J* = 7.8 Hz, 2H), 5.25 (d, *J* = 10.5 Hz, 1H), 4.89 (d, *J* = 10.5 Hz, 1H), 4.42 (t, *J* = 10.5 Hz, 1H), 2.80 (s, 1H). ^{13}C-NMR (126 MHz, $CDCl_3$) δ 208.4, 197.8, 141.5, 140.7, 139.3, 139.1, 136.9, 132.1, 131.8, 131.2, 129.9, 128.7, 128.5, 128.5, 128.3, 127.9, 127.7, 127.6, 127.2, 127.1, 126.9, 124.8, 122.8, 121.7, 72.4, 68.4, 62.7, 55.7. HRMS (ESI): Calculated for $C_{34}H_{26}NO_2$ $[M+H]^+$: 480.1964; Found: 480.1967.

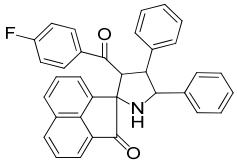


3'-(2-nitrobenzoyl)-4',5'-diphenyl-2*H*-spiro[acenaphthylene-1,2'-pyrrolidin]-2-one (4b). Yellow powder; m.p. 205–207 °C; IR (KBr, ν, cm^{-1}): 3328, 3062, 1715, 1676, 1596, 1256, 774, 697; ^{1}H-NMR (500 MHz, $CDCl_3$) δ 8.07 (d, *J* = 8.0 Hz, 1H), 7.95 – 7.87 (m, 2H), 7.82 (d, *J* = 8.2 Hz, 1H), 7.76 (d, *J* = 6.8 Hz, 1H), 7.63 (t, *J* = 8.1 Hz, 2H), 7.42 (d, *J* = 7.2 Hz, 2H), 7.33 (d, *J* = 7.0 Hz, 4H), 7.25 (dd, *J* = 16.4, 9.2 Hz, 5H), 7.07 (t, *J* = 7.8 Hz, 1H), 6.70 (t, *J* = 7.6 Hz, 1H), 5.03 (d, *J* = 10.4 Hz, 1H), 4.58 (d, *J* = 11.3 Hz, 1H), 4.23 (t, *J* = 10.9 Hz, 1H), 2.79 (s, 1H). ^{13}C-NMR (126 MHz, $CDCl_3$) δ 206.7, 197.2, 146.3, 142.0, 140.7, 139.9, 137.7, 134.9, 132.2, 131.8, 130.6, 130.5, 130.3, 129.2, 128.6, 128.4, 128.3, 128.1, 128.1, 127.6, 127.2, 126.9, 125.2, 123.5, 122.9, 122.0, 72.5, 68.9, 65.8, 57.0. HRMS (ESI): Calculated for $C_{34}H_{25}N_2O_4$ $[M+H]^+$: 525.1814; Found: 525.1797.

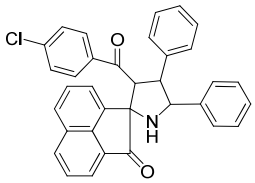


3'-(4-nitrobenzoyl)-4',5'-diphenyl-2*H*-spiro[acenaphthylene-1,2'-pyrrolidin]-2-one (4c). Yellow powder; m.p. 201–202 °C; IR (KBr, ν, cm^{-1}): 3312, 3056, 1724, 1688, 1614, 1291, 786, 699; ^{1}H-NMR (500 MHz, $CDCl_3$) δ 7.89 (dd, *J* = 11.3, 7.6 Hz, 2H), 7.67 (dd, *J* = 7.0, 2.0 Hz, 1H), 7.60 (dd, *J* = 10.9, 6.9 Hz, 5H), 7.51 (d, *J* = 7.3 Hz, 2H), 7.42 (d, *J* = 6.9 Hz, 2H), 7.34 – 7.28 (m, 4H), 7.26 – 7.17 (m, 4H), 5.27 (d, *J* = 10.5 Hz, 1H), 4.83 (d, *J* = 10.5 Hz, 1H), 4.35 (t, *J* = 10.5 Hz, 1H), 2.81 (s, 1H). ^{13}C-NMR (126 MHz, $CDCl_3$) δ 208.0, 196.6, 149.2, 141.3, 141.2, 140.3, 138.8, 138.7, 132.0, 131.0, 129.9, 128.8, 128.7, 128.5, 128.3, 128.2, 127.9, 127.7, 127.1, 127.0, 125.1, 122.9, 122.6, 122.0,

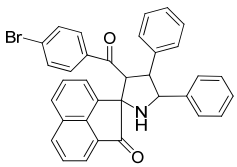
72.1, 68.3, 63.6, 55.5. HRMS (ESI): Calculated for $C_{34}H_{25}N_2O_4$ $[M+H]^+$: 525.1814; Found: 525.1808.



3'-(4-fluorobenzoyl)-4',5'-diphenyl-2*H*-spiro[acenaphthylene-1,2'-pyrrolidin]-2-one (4d). Yellow powder; m.p. 132–135 °C; IR (KBr, ν, cm^{-1}): 3342, 3060, 1714, 1681, 1595, 1233, 778, 699; ^{1}H-NMR (500 MHz, $CDCl_3$) δ 7.92 (dd, *J* = 7.5, 4.5 Hz, 2H), 7.68 – 7.56 (m, 4H), 7.51 (d, *J* = 7.3 Hz, 2H), 7.43 (d, *J* = 7.1 Hz, 2H), 7.34 – 7.27 (m, 2H), 7.26 – 7.14 (m, 4H), 6.50 (t, *J* = 8.6 Hz, 2H), 5.25 (d, *J* = 10.5 Hz, 1H), 4.83 (d, *J* = 10.5 Hz, 1H), 4.40 (t, *J* = 10.5 Hz, 1H), 2.80 (s, 1H). ^{13}C-NMR (126 MHz, $CDCl_3$) δ 208.3, 196.1, 164.8 (d, *J* = 254.8 Hz), 141.0 (d, *J* = 110.9 Hz), 139.2, 138.9, 133.4, 131.9, 131.1, 129.9, 129.8, 129.7, 128.7, 128.6, 128.5, 128.3, 128.0, 127.6, 127.1, 126.9, 124.8, 122.8, 121.7, 114.7 (d, *J* = 21.9 Hz), 72.3, 68.3, 62.7, 55.7. HRMS (ESI): Calculated for $C_{34}H_{25}FNO_2$ $[M+H]^+$: 498.1869; Found: 498.1870.

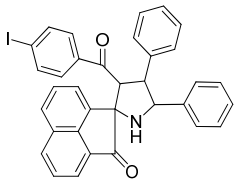


3'-(4-chlorobenzoyl)-4',5'-diphenyl-2*H*-spiro[acenaphthylene-1,2'-pyrrolidin]-2-one (4e). Yellow powder; m.p. 155–158 °C; IR (KBr, ν, cm^{-1}): 3342, 3060, 1717, 1686, 1587, 1281, 781, 702; ^{1}H-NMR (500 MHz, $CDCl_3$) δ 7.96 – 7.89 (m, 2H), 7.69 – (m, 4H), 7.50 (d, *J* = 7.2 Hz, 2H), 7.42 (d, *J* = 6.9 Hz, 2H), 7.32 – 7.28 (m, 3H), 7.27 – 7.18 (m, 3H), 7.06 (d, *J* = 8.6 Hz, 2H), 6.79 (d, *J* = 8.6 Hz, 2H), 5.24 (d, *J* = 10.5 Hz, 1H), 4.81 (d, *J* = 10.5 Hz, 1H), 4.38 (t, *J* = 10.5 Hz, 1H), 2.78 (s, 1H). ^{13}C-NMR (126 MHz, $CDCl_3$) δ 208.2, 196.6, 141.4, 140.5, 139.1, 138.9, 138.6, 135.3, 132.0, 131.0, 130.0, 128.7, 128.6, 128.5, 128.5, 128.3, 128.0, 127.9, 127.6, 127.1, 127.0, 124.9, 122.8, 121.8, 72.3, 68.3, 62.8, 55.7. HRMS (ESI): Calculated for $C_{34}H_{25}ClNO_2$ $[M+H]^+$: 514.1574; Found: 514.1553.

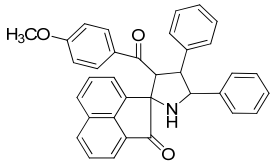


3'-(4-bromobenzoyl)-4',5'-diphenyl-2*H*-spiro[acenaphthylene-1,2'-pyrrolidin]-2-one (4f). Yellow powder; m.p. 176–178 °C; IR (KBr, ν, cm^{-1}): 3327, 3056, 1712, 1680, 1583, 1280, 781, 698; ^{1}H-NMR (500 MHz, $CDCl_3$) δ 7.93 (dd, *J* = 12.6, 7.6 Hz, 2H), 7.72 – 7.55 (m, 4H), 7.50 (d, *J* = 7.5 Hz, 2H), 7.42 (d, *J* = 7.2 Hz, 2H), 7.30 (d, *J* = 7.6 Hz, 2H), 7.28 – 7.17 (m, 4H), 6.96 (q, *J* = 8.7 Hz, 4H), 5.24 (d, *J* = 10.5 Hz, 1H), 4.80 (d, *J* = 10.5 Hz, 1H), 4.38 (t, *J* = 10.5 Hz, 1H), 2.78 (s, 1H). ^{13}C-NMR

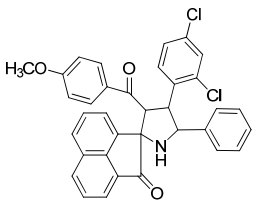
(126 MHz, $CDCl_3$) δ 208.28, 196.8, 141.4, 140.6, 139.1, 138.9, 135.7, 132.0, 131.1, 130.8, 130.0, 128.7, 128.6, 128.6, 128.5, 128.3, 128.0, 127.6, 127.3, 127.1, 127.0, 124.9, 122.8, 121.8, 72.3, 68.3, 62.9, 55.7. HRMS (ESI): Calculated for $C_{34}H_{25}BrNO_2$ $[M+H]^+$: 558.1069; Found: 558.1060.



3'-(4-iodobenzoyl)-4',5'-diphenyl-2*H*-spiro[acenaphthylene-1,2'-pyrrolidin]-2-one (4g). Yellow powder; m.p. 196–198 °C; IR (KBr, ν, cm^{-1}): 3313, 3054, 1708, 1689, 1574, 1255, 794, 700; ^{1}H-NMR (500 MHz, $CDCl_3$) δ 7.93 (dd, *J* = 18.8, 7.5 Hz, 2H), 7.72 – 7.63 (m, 2H), 7.63 – 7.55 (m, 2H), 7.49 (d, *J* = 7.5 Hz, 2H), 7.42 (d, *J* = 7.2 Hz, 2H), 7.30 (d, *J* = 7.6 Hz, 3H), 7.27 – 7.13 (m, 5H), 6.80 (d, *J* = 8.2 Hz, 2H), 5.23 (d, *J* = 10.5 Hz, 1H), 4.78 (d, *J* = 10.5 Hz, 1H), 4.36 (t, *J* = 10.5 Hz, 1H), 2.80 (s, 1H). ^{13}C-NMR (126 MHz, $CDCl_3$) δ 208.2, 197.2, 141.4, 140.5, 139.1, 138.9, 136.8, 136.2, 132.0, 131.1, 130.0, 128.7, 128.6, 128.5, 128.4, 128.3, 128.0, 127.6, 127.1, 127.0, 125.0, 122.8, 121.8, 72.3, 68.3, 62.9, 55.7. HRMS (ESI): Calculated for $C_{34}H_{25}INO_2$ $[M+H]^+$: 606.0930; Found: 606.0896.

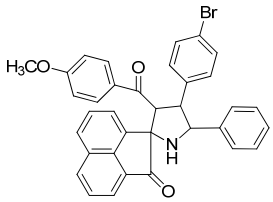


3'-(4-methoxybenzoyl)-4',5'-diphenyl-2*H*-spiro[acenaphthylene-1,2'-pyrrolidin]-2-one (4h). Yellow powder; m.p. 125–127 °C; IR (KBr, ν, cm^{-1}): 3334, 3060, 1715, 1675, 1600, 1261, 787, 696; ^{1}H-NMR (500 MHz, $CDCl_3$) δ 7.95 – 7.90 (m, 2H), 7.66 (dd, *J* = 7.4, 5.3 Hz, 2H), 7.63 – 7.56 (m, 2H), 7.50 (d, *J* = 7.3 Hz, 2H), 7.43 (d, *J* = 7.1 Hz, 2H), 7.29 (s, 1H), 7.28 – 7.21 (m, 4H), 7.18 (d, *J* = 8.7 Hz, 3H), 6.33 (d, *J* = 8.8 Hz, 2H), 5.23 (d, *J* = 10.5 Hz, 1H), 4.85 (d, *J* = 10.5 Hz, 1H), 4.43 (t, *J* = 10.5 Hz, 1H), 3.58 (s, 3H), 2.78 (s, 1H). ^{13}C-NMR (126 MHz, $CDCl_3$) δ 195.9, 162.7, 141.6, 140.6, 139.4, 139.1, 131.8, 131.2, 130.1, 130.0, 129.5, 128.7, 128.5, 128.3, 127.8, 127.6, 127.2, 126.8, 124.7, 122.9, 121.6, 112.9, 72.5, 68.3, 62.1, 55.9, 55.2. HRMS (ESI): Calculated for $C_{35}H_{28}NO_3$ $[M+H]^+$: 510.2069; Found: 510.2063.

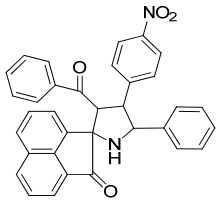


4'-(2,4-dichlorophenyl)-3'-(4-methoxybenzoyl)-5'-phenyl-2*H*-spiro[acenaphthylene-1,2'-pyrrolidin]-2-one (4i). Yellow powder; m.p. 134–136 °C; IR (KBr, ν, cm^{-1}): 3307, 3059, 1713, 1674, 1599, 1257, 783, 699; ^{1}H-NMR (500 MHz, $CDCl_3$) δ 7.93 (t, *J* = 7.4 Hz, 2H), 7.88 (d, *J* = 8.5 Hz, 1H), 7.69

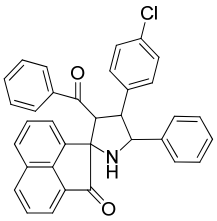
– 7.59 (m, 3H), 7.58 – 7.52 (m, 1H), 7.44 (d, *J* = 6.7 Hz, 2H), 7.32 – 7.26 (m, 5H), 7.20 (d, *J* = 8.8 Hz, 2H), 6.33 (d, *J* = 8.8 Hz, 2H), 5.16 (d, *J* = 10.4 Hz, 1H), 5.08 (t, *J* = 10.2 Hz, 1H), 4.85 (d, *J* = 10.0 Hz, 1H), 3.57 (s, 3H), 2.78 (s, 1H). ^{13}C-NMR (126 MHz, $CDCl_3$) δ 208.1, 195.5, 162.8, 141.6, 139.6, 138.5, 135.9, 135.8, 132.8, 131.9, 131.0, 130.1, 130.0, 129.8, 129.6, 129.5, 128.7, 128.3, 127.8, 127.8, 127.4, 127.0, 124.9, 123.0, 121.7, 112.9, 72.6, 68.9, 61.5, 55.1, 51.3. HRMS (ESI): Calculated for $C_{35}H_{26}Cl_2NO_3$ $[M+H]^+$: 578.1290; Found: 578.1277.



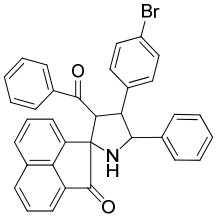
4'-(4-bromophenyl)-3'-(4-methoxybenzoyl)-5'-phenyl-2*H*-spiro[acenaphthylene-1,2'-pyrrolidin]-2-one (4j). Yellow powder; m.p. 139–141 °C; IR (KBr, ν, cm^{-1}): 3411, 3052, 1702, 1692, 1582, 1249, 783, 698; ^{1}H-NMR (500 MHz, $CDCl_3$) δ 7.93 (dd, *J* = 7.6, 1.8 Hz, 2H), 7.67 – 7.55 (m, 4H), 7.43 – 7.36 (m, 6H), 7.30 (d, *J* = 6.9 Hz, 2H), 7.25 (d, *J* = 7.0 Hz, 1H), 7.17 (d, *J* = 8.9 Hz, 2H), 6.33 (d, *J* = 8.9 Hz, 2H), 5.18 (d, *J* = 10.5 Hz, 1H), 4.75 (d, *J* = 10.5 Hz, 1H), 4.39 (t, *J* = 10.5 Hz, 1H), 3.58 (s, 3H), 2.80 (s, 1H). ^{13}C-NMR (126 MHz, $CDCl_3$) δ 208.3, 195.7, 162.9, 141.6, 140.3, 138.9, 138.6, 131.9, 131.6, 131.1, 130.2, 130.0, 130.0, 129.5, 128.7, 128.4, 127.8, 127.8, 127.1, 124.8, 122.9, 121.7, 120.8, 113.0, 72.4, 68.1, 62.0, 55.4, 55.2. HRMS (ESI): Calculated for $C_{35}H_{27}BrNO_3$ $[M+H]^+$: 588.1174; Found: 588.1153.



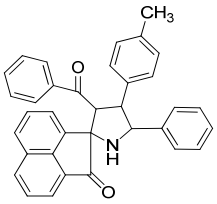
3'-benzoyl-4'-(4-nitrophenyl)-5'-phenyl-2*H*-spiro[acenaphthylene-1,2'-pyrrolidin]-2-one (4k). Yellow powder; m.p. 229–231 °C; IR (KBr, ν, cm^{-1}): 3333, 3046, 1714, 1684, 1605, 1280, 781, 696; ^{1}H-NMR (500 MHz, $CDCl_3$) δ 8.15 (d, *J* = 8.7 Hz, 2H), 7.91 (dd, *J* = 10.7, 7.5 Hz, 2H), 7.71 – 7.56 (m, 6H), 7.41 (d, *J* = 6.7 Hz, 2H), 7.30 (t, *J* = 7.0 Hz, 2H), 7.26 (s, 1H), 7.15 – 7.09 (m, 2H), 7.01 (t, *J* = 7.4 Hz, 1H), 6.82 (t, *J* = 7.8 Hz, 2H), 5.27 (d, *J* = 10.5 Hz, 1H), 4.83 (d, *J* = 10.4 Hz, 1H), 4.52 (t, *J* = 10.4 Hz, 1H), 2.82 (s, 1H). ^{13}C-NMR (126 MHz, $CDCl_3$) δ 208.1, 197.3, 147.3, 147.1, 141.6, 139.7, 138.4, 136.4, 132.5, 132.0, 131.0, 130.0, 129.4, 128.7, 128.5, 128.1, 128.0, 127.7, 127.1, 127.0, 125.0, 123.8, 122.8, 121.9, 72.2, 68.3, 62.4, 55.6. HRMS (ESI): Calculated for $C_{34}H_{25}N_2O_4$ $[M+H]^+$: 525.1814; Found: 525.1792.



3'-benzoyl-4'-(4-chlorophenyl)-5'-phenyl-2*H*-spiro[acenaphthylene-1,2'-pyrrolidin]-2-one (4l). Yellow powder; m.p. 212–214 °C; IR (KBr, ν, cm^{-1}): 3321, 3061, 1711, 1678, 1610, 1271, 789, 701; ^{1}H-NMR (500 MHz, $CDCl_3$) δ 7.89 (dd, *J* = 7.4, 5.5 Hz, 2H), 7.66 – 7.55 (m, 4H), 7.44 (dd, *J* = 12.8, 7.8 Hz, 4H), 7.30 (t, *J* = 7.2 Hz, 2H), 7.26 (d, *J* = 8.5 Hz, 3H), 7.15 – 7.10 (m, 2H), 7.01 (t, *J* = 7.4 Hz, 1H), 6.83 (t, *J* = 7.8 Hz, 2H), 5.20 (d, *J* = 10.5 Hz, 1H), 4.81 (d, *J* = 10.5 Hz, 1H), 4.38 (t, *J* = 10.5 Hz, 1H), 2.80 (s, 1H). ^{13}C-NMR (126 MHz, $CDCl_3$) δ 208.3, 197.6, 141.5, 140.3, 138.8, 137.9, 136.7, 132.7, 132.3, 131.8, 131.1, 129.9, 129.8, 128.7, 128.7, 128.3, 127.9, 127.8, 127.6, 127.1, 127.1, 124.8, 122.8, 121.7, 72.2, 68.2, 62.6, 55.2. HRMS (ESI): Calculated for $C_{34}H_{25}ClNO_2$ $[M+H]^+$: 514.1574; Found: 514.1568.

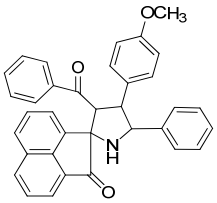


3'-benzoyl-4'-(4-bromophenyl)-5'-phenyl-2*H*-spiro[acenaphthylene-1,2'-pyrrolidin]-2-one (4m). Yellow powder; m.p. 207–209 °C; IR (KBr, ν, cm^{-1}): 3413, 3049, 1708, 1689, 1574, 1235, 784, 697; ^{1}H-NMR (500 MHz, $CDCl_3$) δ 7.89 (dd, *J* = 7.5, 4.8 Hz, 2H), 7.67 – 7.54 (m, 4H), 7.45 – 7.37 (m, 6H), 7.30 (d, *J* = 6.8 Hz, 2H), 7.25 (s, 1H), 7.12 (d, *J* = 7.4 Hz, 2H), 7.01 (t, *J* = 7.4 Hz, 1H), 6.83 (t, *J* = 7.7 Hz, 2H), 5.20 (d, *J* = 10.5 Hz, 1H), 4.80 (d, *J* = 10.5 Hz, 1H), 4.37 (t, *J* = 10.5 Hz, 1H), 2.77 (s, 1H). ^{13}C-NMR (126 MHz, $CDCl_3$) δ 208.2, 197.6, 141.5, 140.3, 138.8, 138.4, 136.7, 132.3, 131.8, 131.7, 131.1, 130.2, 129.9, 128.7, 128.4, 127.9, 127.8, 127.6, 127.1, 127.1, 124.9, 122.8, 121.7, 120.8, 72.2, 68.2, 62.5, 55.2. HRMS (ESI): Calculated for $C_{34}H_{25}BrNO_2$ $[M+H]^+$: 558.1069; Found: 558.1040.

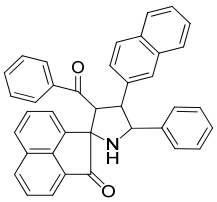


3'-benzoyl-5'-phenyl-4'-(p-tolyl)-2*H*-spiro[acenaphthylene-1,2'-pyrrolidin]-2-one (4n). Yellow powder; m.p. 219–222 °C; IR (KBr, ν, cm^{-1}): 3327, 3059, 1717, 1677, 1592, 1282, 789, 699; ^{1}H-NMR (500 MHz, $CDCl_3$) δ 7.88 (dd, *J* = 7.5, 2.8 Hz, 2H), 7.67 – 7.62 (m, 2H), 7.61 – 7.55 (m, 2H), 7.43 (dd, *J* = 21.0, 7.6 Hz, 4H), 7.31 – 7.28 (m, 2H), 7.25 (d, *J* = 7.1 Hz, 1H), 7.12 (dd, *J* = 17.3, 7.7 Hz, 4H), 7.00 (t, *J* = 7.4 Hz, 1H), 6.82 (t, *J* = 7.7 Hz, 2H), 5.23 (d, *J* = 10.5 Hz, 1H), 4.88 (d, *J* = 10.5 Hz, 1H), 4.40 (t, *J* = 10.5 Hz, 1H), 2.77 (s, 1H), 2.29 (s, 3H). ^{13}C-NMR (126 MHz, $CDCl_3$) δ 208.3,

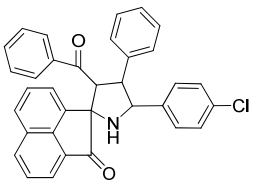
197.8, 141.5, 140.8, 139.2, 137.0, 136.3, 136.2, 132.1, 131.7, 131.2, 129.9, 129.2, 128.7, 128.3, 128.2, 127.8, 127.6, 127.5, 127.2, 127.2, 124.7, 122.8, 121.6, 72.3, 68.3, 62.8, 55.3, 21.0. HRMS (ESI): Calculated for $C_{35}H_{28}NO_2$ $[M+H]^+$: 494.2120; Found: 494.2117.



3'-benzoyl-4'-(4-methoxyphenyl)-5'-phenyl-2*H*-spiro[acenaphthylene-1,2'-pyrrolidin]-2-one (4o). Yellow powder; m.p. 201–203 °C; IR (KBr, ν, cm^{-1}): 3345, 3053, 1708, 1684, 1593, 1267, 778, 698; ^{1}H-NMR (500 MHz, $CDCl_3$) δ 7.88 (d, *J* = 7.4 Hz, 2H), 7.64 (dd, *J* = 7.4, 3.9 Hz, 2H), 7.58 (t, *J* = 7.3 Hz, 2H), 7.43 (dd, *J* = 7.7, 5.7 Hz, 4H), 7.31 – 7.28 (m, 2H), 7.25 (d, *J* = 7.1 Hz, 1H), 7.13 (d, *J* = 7.3 Hz, 2H), 7.00 (t, *J* = 7.4 Hz, 1H), 6.82 (t, *J* = 7.8 Hz, 4H), 5.20 (d, *J* = 10.5 Hz, 1H), 4.84 (d, *J* = 10.6 Hz, 1H), 4.37 (t, *J* = 10.5 Hz, 1H), 3.75 (s, 3H), 2.81 (s, 1H). ^{13}C-NMR (126 MHz, $CDCl_3$) δ 208.4, 197.9, 158.5, 141.5, 140.8, 139.1, 137.0, 132.1, 131.7, 131.2, 131.2, 129.9, 129.4, 128.7, 128.2, 127.8, 127.6, 127.5, 127.2, 127.1, 124.7, 122.8, 121.6, 114.0, 72.3, 68.3, 62.7, 55.1, 55.0. HRMS (ESI): Calculated for $C_{35}H_{28}NO_3$ $[M+H]^+$: 510.2069; Found: 510.2049.

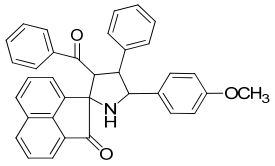


3'-benzoyl-4'-(naphthalen-2-yl)-5'-phenyl-2H-spiro[acenaphthylene-1,2'-pyrrolidin]-2-one (4p). Yellow powder; m.p. 183–185 °C; IR (KBr, ν, cm^{-1}): 3336, 3053, 1711, 1676, 1579, 1237, 778, 698; ^{1}H-NMR (500 MHz, $CDCl_3$) δ 7.96 (d, *J* = 7.0 Hz, 1H), 7.90 (d, *J* = 8.1 Hz, 1H), 7.73 (dd, *J* = 14.2, 7.5 Hz, 3H), 7.67 – 7.55 (m, 5H), 7.47 – 7.39 (m, 4H), 7.19 – 7.11 (m, 6H), 6.97 (t, *J* = 7.4 Hz, 1H), 6.79 (t, *J* = 7.8 Hz, 2H), 5.51 (d, *J* = 9.4 Hz, 1H), 5.39 (t, *J* = 8.9 Hz, 1H), 5.10 (d, *J* = 9.2 Hz, 1H), 2.91 (s, 1H). ^{13}C- NMR (126 MHz, $CDCl_3$) δ 208.49, 198.1, 141.6, 140.7, 138.8, 136.8, 136.4, 133.9, 132.6, 132.1, 131.8, 131.1, 130.0, 128.7, 128.4, 128.3, 128.2, 127.9, 127.8, 127.5, 127.3, 127.2, 126.8, 125.8, 125.5, 125.3, 124.8, 123.8, 123.0, 121.7, 72.7, 69.6, 63.5, 58.4. HRMS (ESI): Calculated for $C_{38}H_{28}NO_2$ $[M+H]^+$: 530.2120; Found: 530.2102.

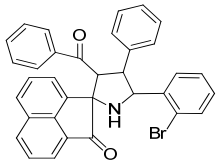


3'-benzoyl-5'-(4-chlorophenyl)-4'-phenyl-2*H*-spiro[acenaphthylene-1,2'-pyrrolidin]-2-one (4q). Yellow powder; m.p. 198–200 °C; IR (KBr, ν, cm^{-1}): 3340, 3062, 1711, 1664, 1600, 1267, 781, 699; ^{1}H-NMR (500 MHz, $CDCl_3$) δ 7.89 (d, *J* = 8.2 Hz, 2H), 7.65 – 7.48 (m, 4H), 7.49 (d, *J* = 7.2 Hz, 2H),

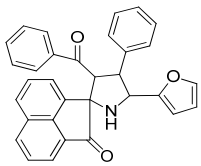
7.37 – 7.28 (m, 4H), 7.26 – 7.19 (m, 3H), 7.14 – 7.09 (m, 2H), 7.00 (t, *J* = 7.4 Hz, 1H), 6.81 (t, *J* = 7.8 Hz, 2H), 5.24 (d, *J* = 10.4 Hz, 1H), 4.85 (d, *J* = 10.5 Hz, 1H), 4.31 (t, *J* = 10.5 Hz, 1H), 2.77 (s, 1H). ^{13}C-NMR (126 MHz, $CDCl_3$) δ 208.5, 197.5, 141.5, 139.4, 138.9, 138.9, 136.8, 133.2, 132.2, 131.8, 131.1, 129.9, 128.7, 128.6, 128.5, 128.4, 127.8, 127.6, 127.1, 127.1, 124.8, 122.9, 121.6, 72.2, 67.6, 62.5, 55.8. HRMS (ESI): Calculated for $C_{34}H_{25}ClNO_2$ $[M+H]^+$: 514.1574; Found: 514.1556.



3'-benzoyl-5'-(4-methoxyphenyl)-4'-phenyl-2*H*-spiro[acenaphthylene-1,2'-pyrrolidin]-2-one (4r). Yellow powder; m.p. 206–208 °C; IR (KBr, ν, cm^{-1}): 3355, 3052, 1715, 1663, 1586, 1246, 784, 700; ^{1}H-NMR (500 MHz, $CDCl_3$) δ 7.88 (t, *J* = 7.1 Hz, 2H), 7.63 (t, *J* = 7.0 Hz, 2H), 7.57 (dd, *J* = 12.8, 7.3 Hz, 2H), 7.52 (d, *J* = 7.4 Hz, 2H), 7.37 (d, *J* = 8.6 Hz, 2H), 7.30 (d, *J* = 7.5 Hz, 2H), 7.21 – 7.12 (m, 3H), 6.99 (t, *J* = 7.4 Hz, 1H), 6.82 (dd, *J* = 8.0, 4.8 Hz, 4H), 5.20 (d, *J* = 10.5 Hz, 1H), 4.88 (d, *J* = 10.5 Hz, 1H), 4.39 (t, *J* = 10.5 Hz, 1H), 3.77 (s, 3H), 2.72 (s, 1H). ^{13}C-NMR (126 MHz, $CDCl_3$) δ 208.3, 197.8, 159.1, 141.5, 139.4, 139.1, 136.9, 132.6, 132.1, 131.7, 131.2, 129.9, 128.7, 128.5, 128.5, 128.2, 127.8, 127.6, 127.2, 126.8, 124.7, 122.8, 121.6, 113.7, 72.2, 67.9, 62.6, 55.6, 55.1. HRMS (ESI): Calculated for $C_{35}H_{28}NO_3$ $[M+H]^+$: 510.2069; Found: 510.2058.

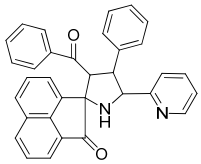


3'-benzoyl-5'-(2-bromophenyl)-4'-phenyl-2*H*-spiro[acenaphthylene-1,2'-pyrrolidin]-2-one (4s). Yellow powder; m.p. 191–193 °C; IR (KBr, ν, cm^{-1}): 3329, 3048, 1711, 1688, 1596, 1281, 788, 697; ^{1}H-NMR (500 MHz, $CDCl_3$) δ 8.05 – 7.81 (m, 4H), 7.64 – 7.54 (m, 6H), 7.45 – 7.35 (m, 2H), 7.22 – 6.98 (m, 6H), 6.83 (t, *J* = 7.3 Hz, 2H), 5.81 (d, *J* = 10.6 Hz, 1H), 4.91 (d, *J* = 10.3 Hz, 1H), 4.60 (t, *J* = 10.4 Hz, 1H), 2.89 (s, 1H). ^{13}C-NMR (126 MHz, $CDCl_3$) δ 208.1, 197.7, 141.5, 139.4, 138.9, 138.5, 136.8, 132.8, 132.2, 131.7, 131.1, 129.9, 129.0, 128.8, 128.7, 128.5, 128.1, 127.8, 127.7, 127.6, 127.2, 127.0, 125.1, 124.8, 122.9, 121.7, 72.0, 65.7, 62.0, 54.2. HRMS (ESI): Calculated for $C_{34}H_{25}BrNO_2$ $[M+H]^+$: 558.1069; Found: 558.1046.



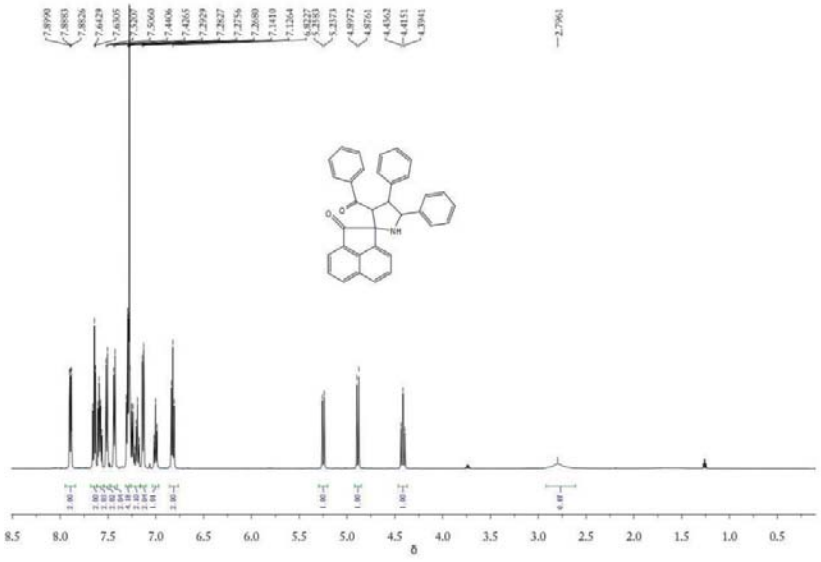
3'-benzoyl-5'-(furan-2-yl)-4'-phenyl-2*H*-spiro[acenaphthylene-1,2'-pyrrolidin]-2-one (4t). Yellow powder; m.p. 187–188 °C; IR (KBr, ν, cm^{-1}): 3327, 3055, 1710, 1677, 1595, 1244, 786, 701; ^{1}H-NMR (500 MHz, $CDCl_3$) δ 7.88 (t, *J* = 7.1 Hz, 2H), 7.65 (dd, *J* = 13.2, 7.5 Hz, 2H), 7.57 (dd, *J* =

14.2, 7.2 Hz, 4H), 7.41 – 7.31 (m, 3H), 7.23 – 7.13 (m, 3H), 7.02 (t, *J* = 7.4 Hz, 1H), 6.85 (t, *J* = 7.8 Hz, 2H), 6.31 – 6.22 (m, 2H), 5.18 (d, *J* = 10.8 Hz, 1H), 4.91 (d, *J* = 10.8 Hz, 1H), 4.72 (t, *J* = 10.8 Hz, 1H) 2.91 (s, 1H).^{13}C-NMR (126 MHz, $CDCl_3$) δ 206.7, 197.5, 152.7, 142.2, 141.5, 139.1, 138.4, 136.8, 132.2, 131.7, 131.1, 129.9, 128.6, 128.1, 127.9, 127.7, 127.2, 127.0, 125.0, 122.6, 121.9, 110.2, 107.7, 72.8, 62.7, 62.3, 53.3. HRMS (ESI): Calculated for $C_{32}H_{24}NO_3$ $[M+H]^+$: 470.1756; Found: 470.1738.



3'-benzoyl-4'-phenyl-5'-(pyridin-2-yl)-2*H*-spiro[acenaphthylene-1,2'-pyrrolidin]-2-one (4u). Yellow powder; m.p. 186–187 °C; IR (KBr, ν, cm^{-1}): 3332, 3054, 1707, 1667, 1602, 1258, 782, 699; ^{1}H-NMR (500 MHz, $CDCl_3$) δ 8.60 (d, *J* = 4.2 Hz, 1H), 7.93 – 7.86 (m, 2H), 7.70 (dd, *J* = 17.4, 7.5 Hz, 2H), 7.63 – 7.56 (m, 2H), 7.52 (d, *J* = 7.3 Hz, 2H), 7.46 (t, *J* = 7.6 Hz, 1H), 7.32 (t, *J* = 7.6 Hz, 2H), 7.23 – 7.12 (m, 4H), 7.01 (t, *J* = 7.4 Hz, 1H), 6.84 (dd, *J* = 13.3, 5.7 Hz, 3H), 5.09 (d, *J* = 10.6 Hz, 1H), 5.05 (d, *J* = 11.0 Hz, 1H), 4.42 (t, *J* = 10.8 Hz, 1H), 4.09 (s, 1H). ^{13}C-NMR (126 MHz, $CDCl_3$) δ 206.56, 197.8, 158.1, 149.3, 141.6, 139.2, 138.5, 137.0, 136.0, 132.1, 131.5, 131.4, 130.0, 128.6, 128.3, 127.9, 127.6, 127.2, 126.9, 125.0, 122.8, 122.7, 122.6, 121.9, 73.3, 70.2, 63.4, 57.6. HRMS (ESI): Calculated for $C_{33}H_{25}N_2O_2$ $[M+H]^+$: 481.1916; Found: 481.1899.

4a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7.4265
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7.2756
7.2680
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7.1264
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4.8761
4.4562
4.4151
4.3941
2.7961
O
O
NH
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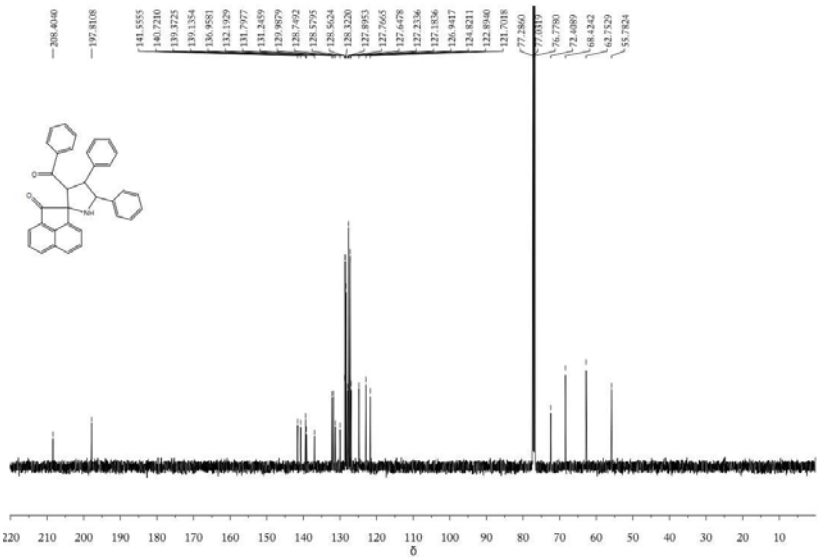
δ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127.1836
126.9417
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122.8940
121.7018
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77.0319
76.7780
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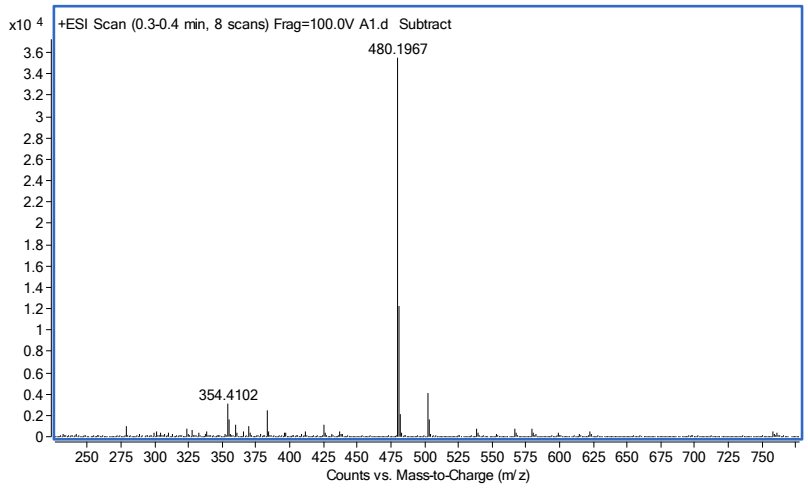
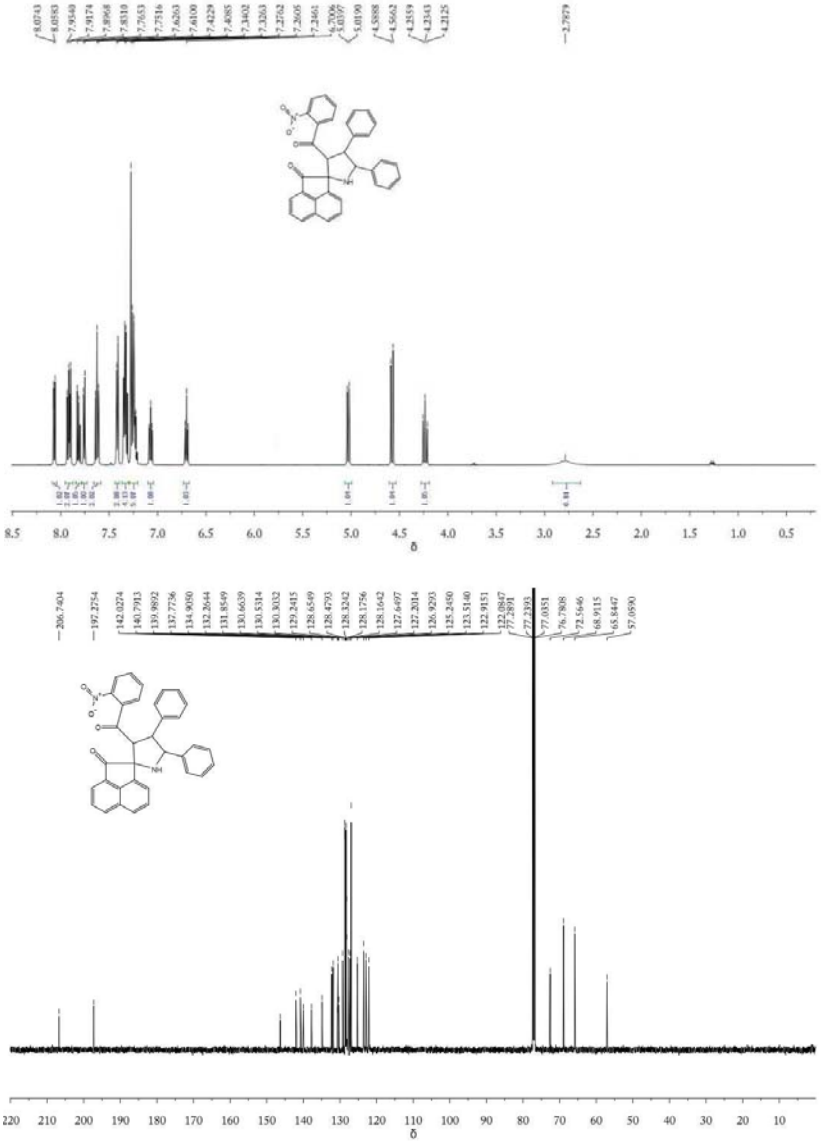
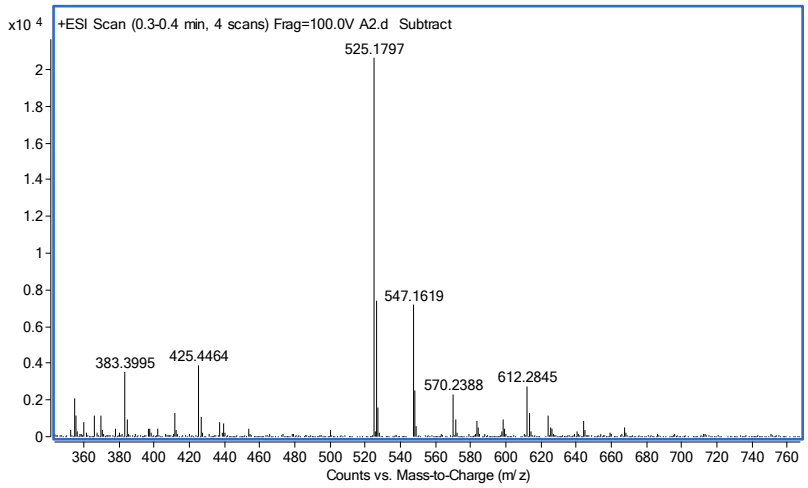
O
O
NH
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
δ


x10 4
+ESI Scan (0.3-0.4 min, 8 scans) Frag=100.0V A1.d Subtract
480.1967
354.4102
Counts vs. Mass-to-Charge (m/z)

4b




x10 4
+ESI Scan (0.3-0.4 min, 4 scans) Frag=100.0V A2.d Subtract
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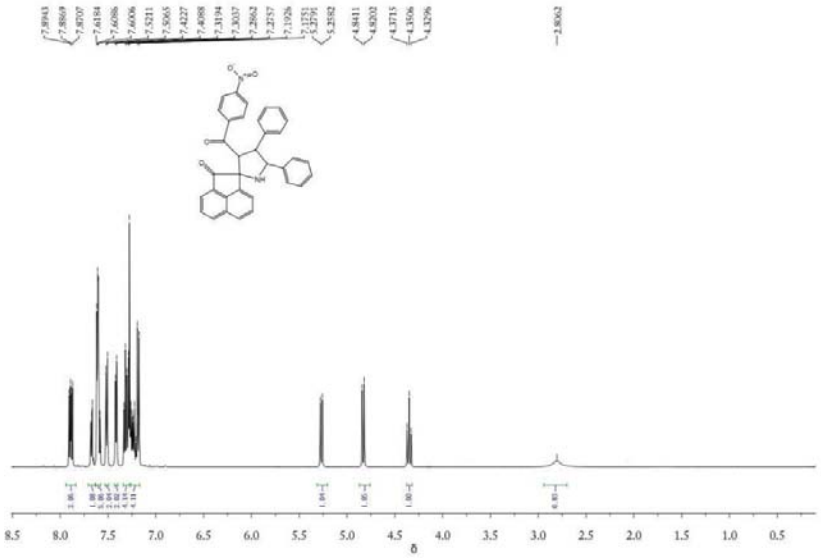
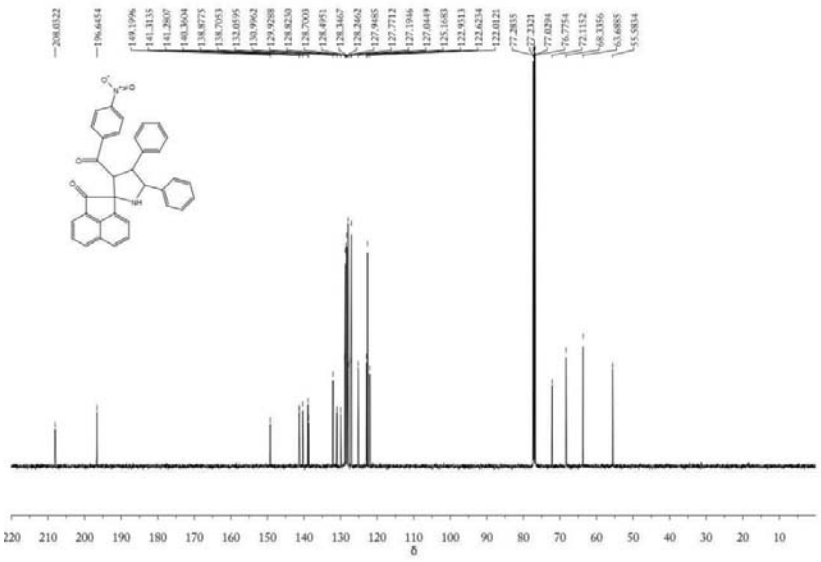
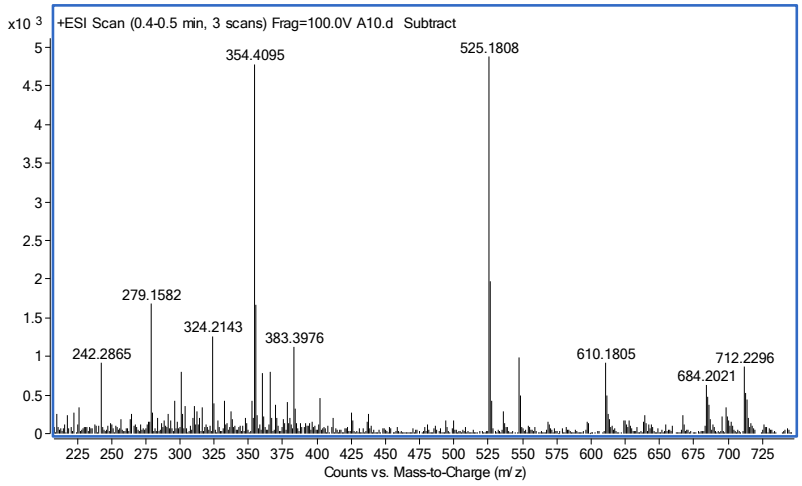
383.3995
425.4464
570.2388
612.2845
Counts vs. Mass-to-Charge (m/z)

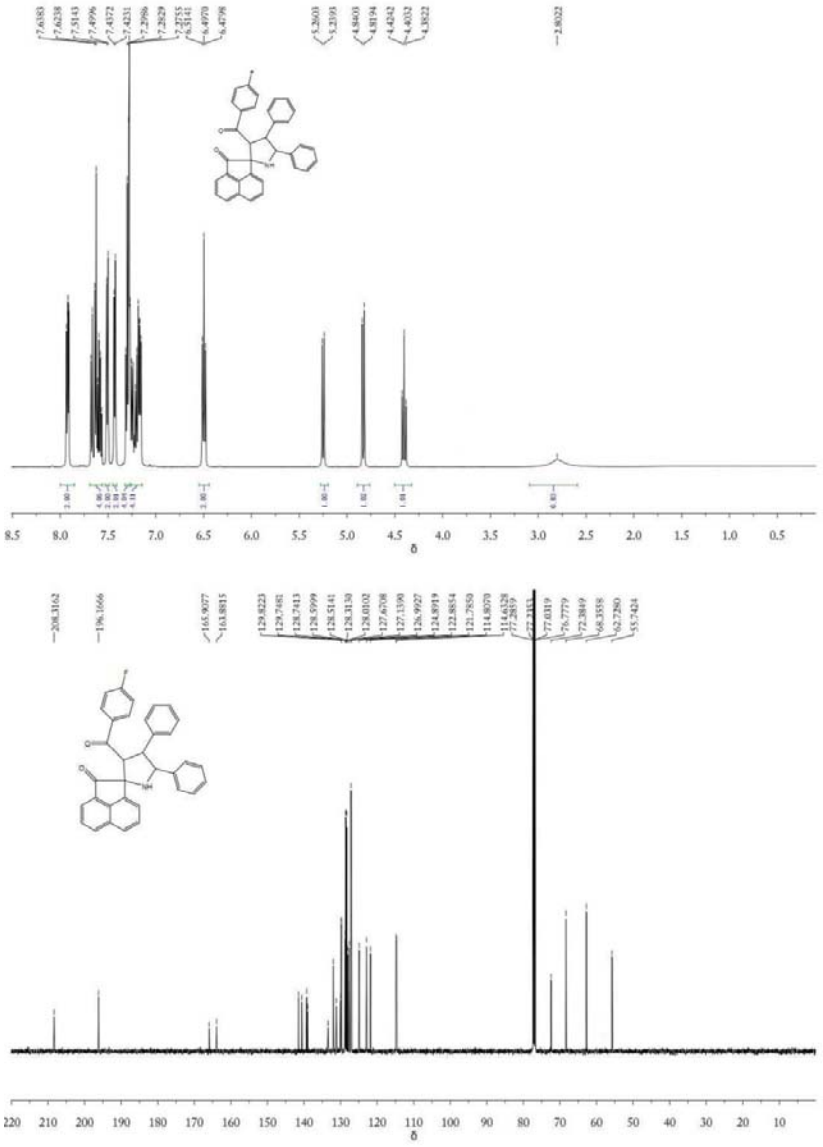
4c

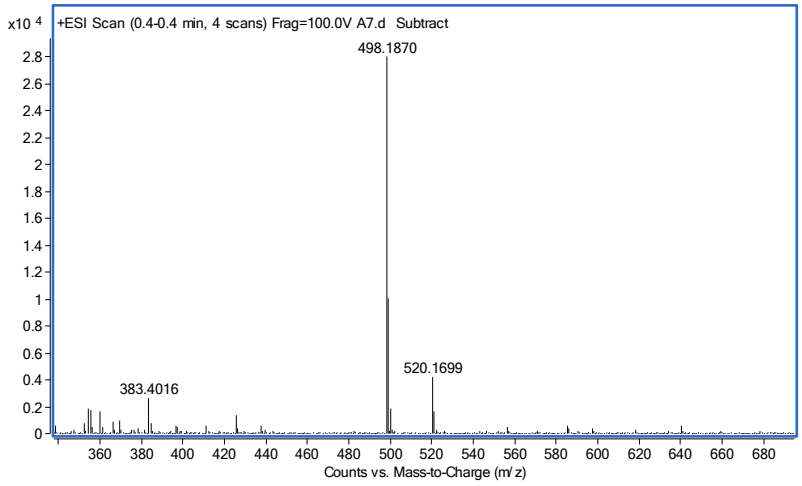




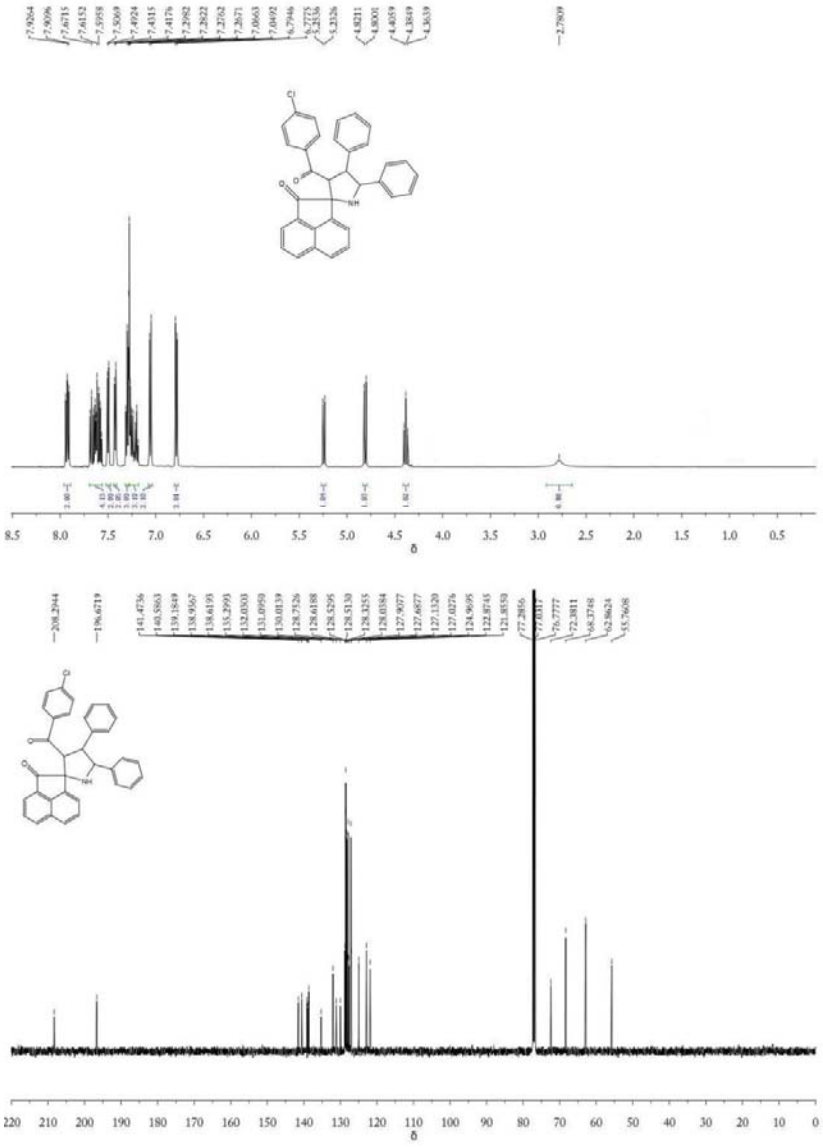

x10 3
+ESI Scan (0.4-0.5 min, 3 scans) Frag=100.0V A10.d Subtract
354.4095
525.1808
279.1582
324.2143
383.3976
242.2865
610.1805
712.2296
684.2021
Counts vs. Mass-to-Charge (m/z)

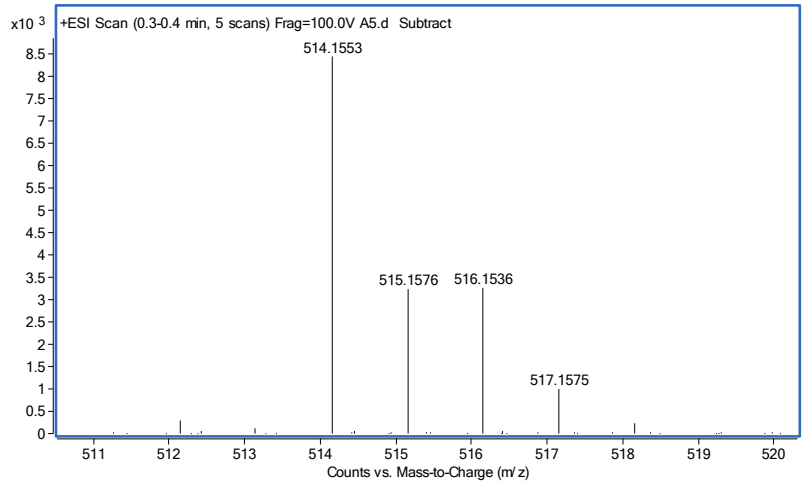
4d


δ
δ

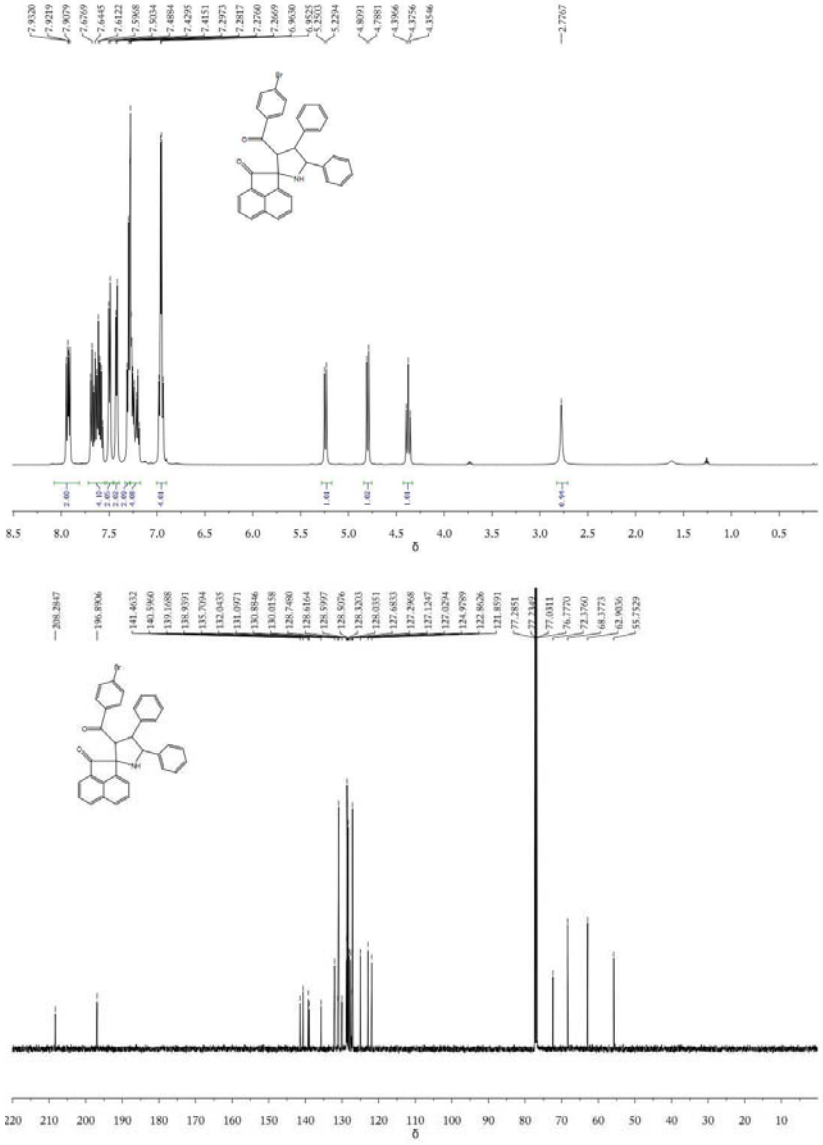

x10 4
+ESI Scan (0.4-0.4 min, 4 scans) Frag=100.0V A7.d Subtract
498.1870
520.1699
383.4016
Counts vs. Mass-to-Charge (m/z)

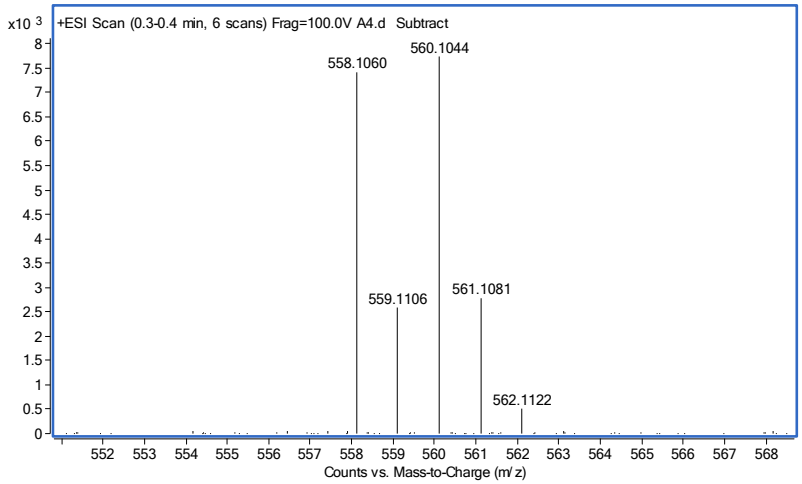
4e


δ
δ

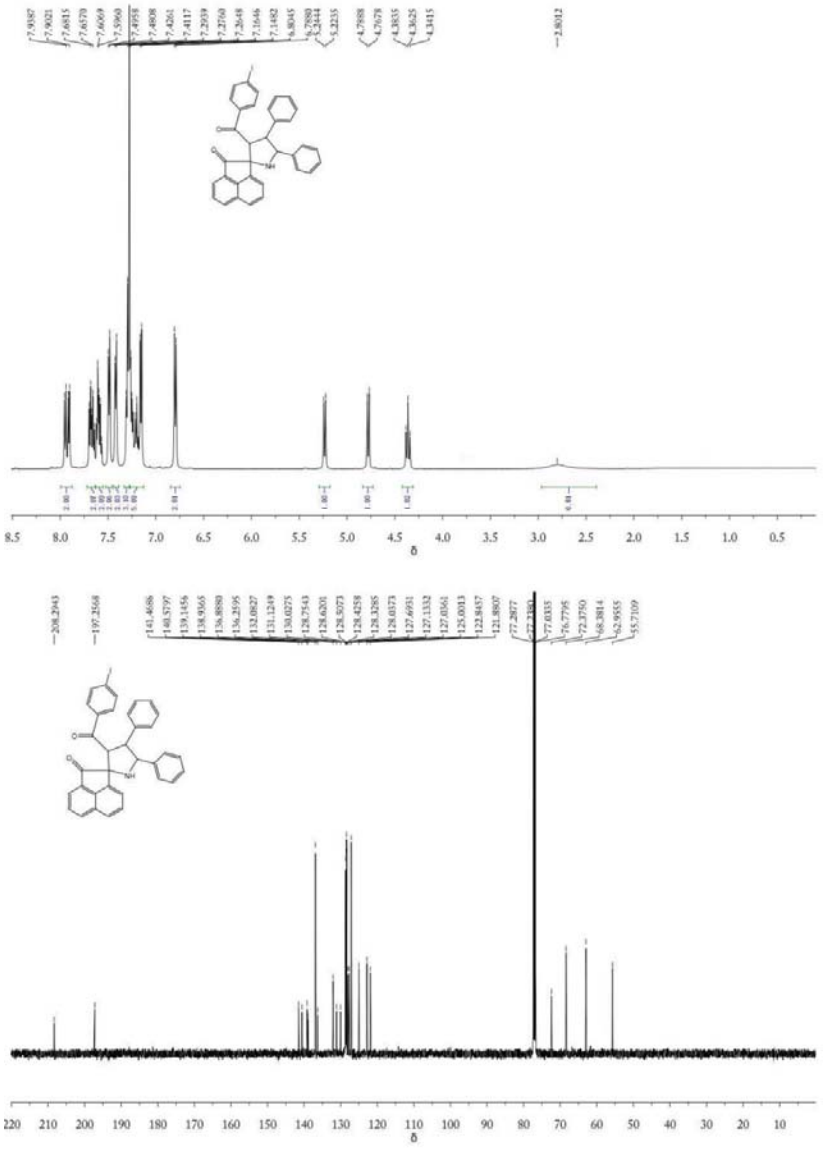

x10 3
+ESI Scan (0.3-0.4 min, 5 scans) Frag=100.0V A5.d Subtract
514.1553
515.1576
516.1536
517.1575
Counts vs. Mass-to-Charge (m/z)

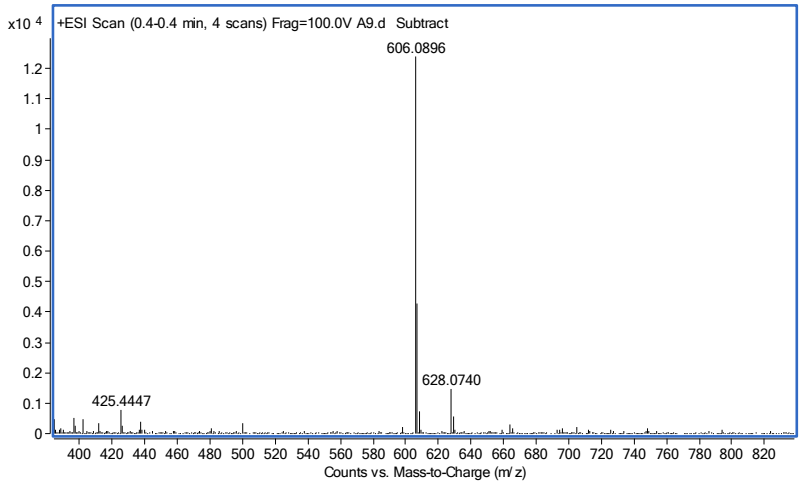
4f



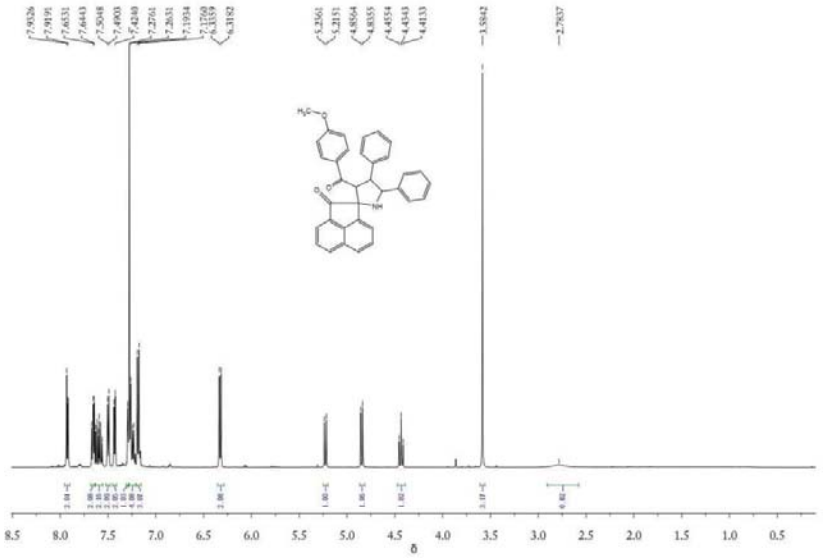

x10 3
+ESI Scan (0.3-0.4 min, 6 scans) Frag=100.0V A4.d Subtract
558.1060
560.1044
559.1106
561.1081
562.1122
Counts vs. Mass-to-Charge (m/z)

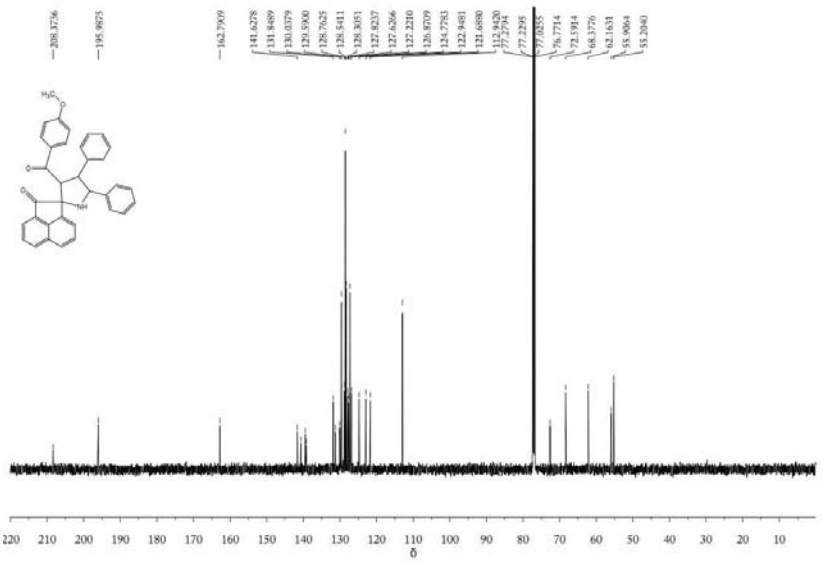
4g

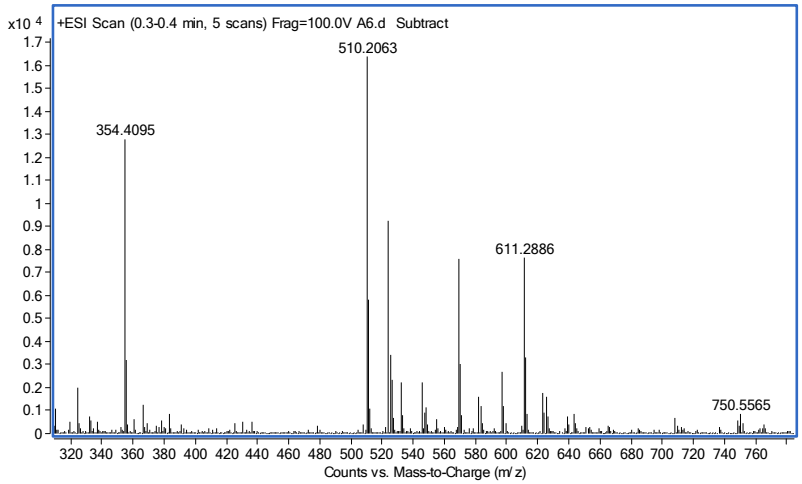



x10 4
+ESI Scan (0.4-0.4 min, 4 scans) Frag=100.0V A9.d Subtract
606.0896
628.0740
425.4447
Counts vs. Mass-to-Charge (m/z)

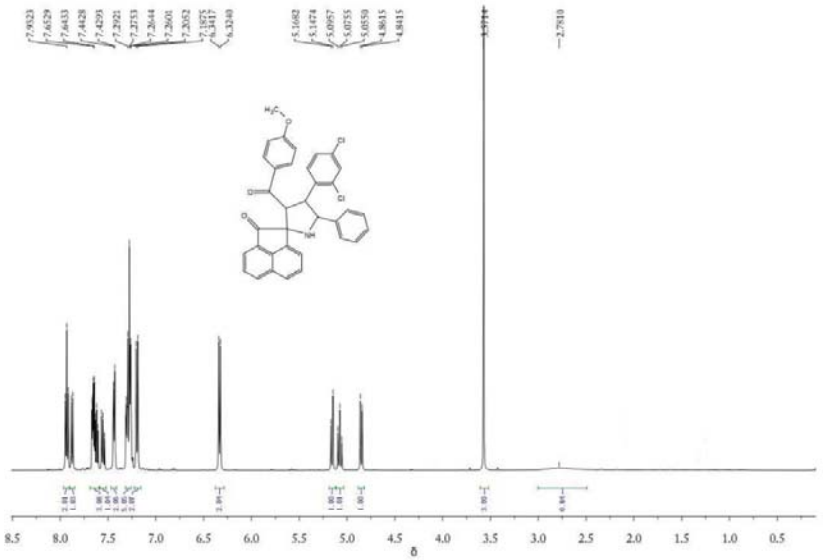
4h

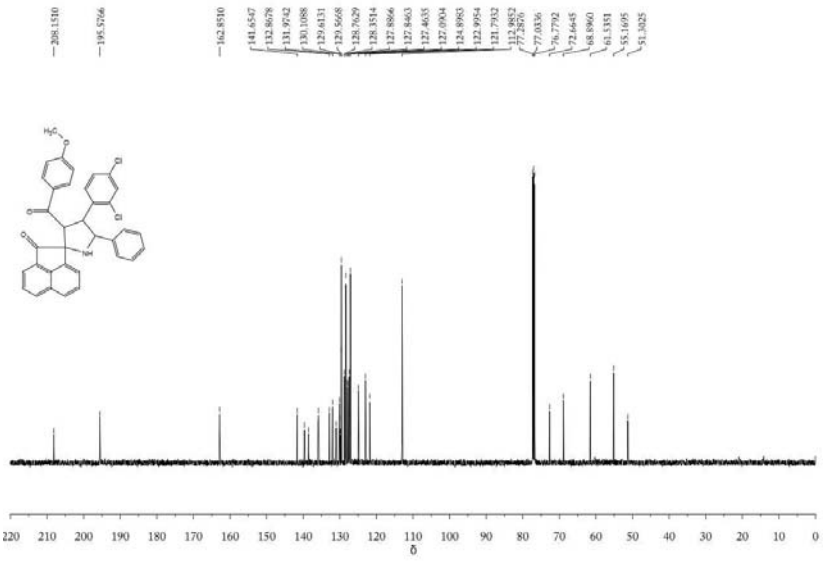


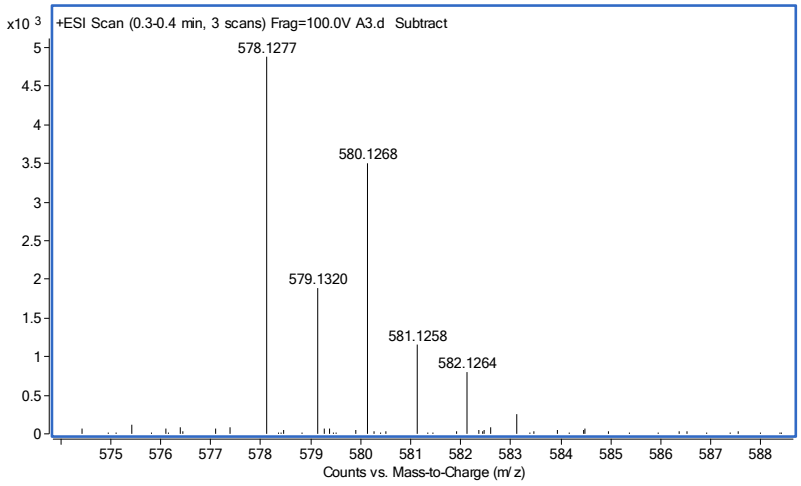



x10 4
+ESI Scan (0.3-0.4 min, 5 scans) Frag=100.0V A6.d Subtract
510.2063
354.4095
611.2886
750.5565
Counts vs. Mass-to-Charge (m/z)

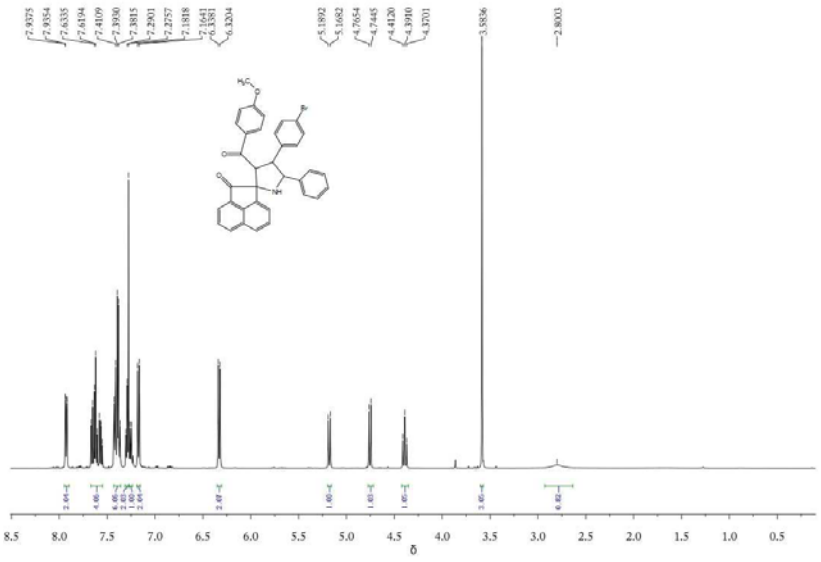
4i

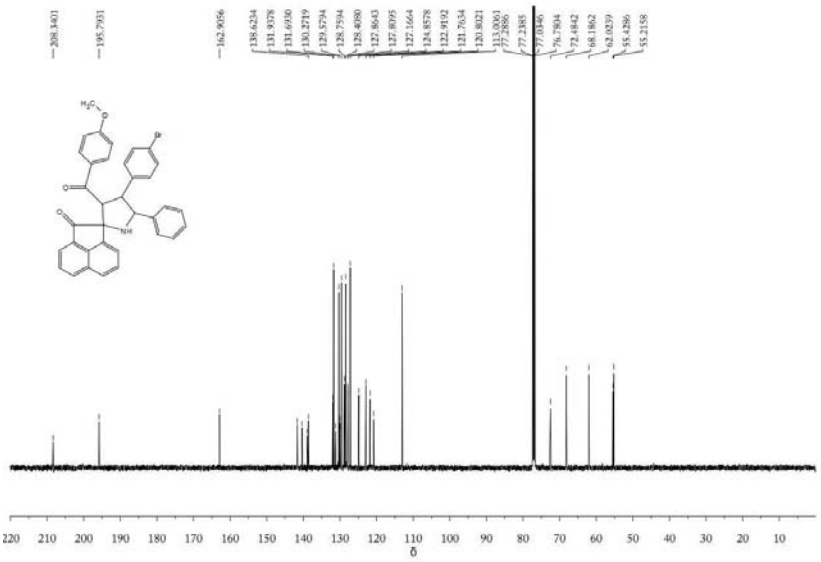


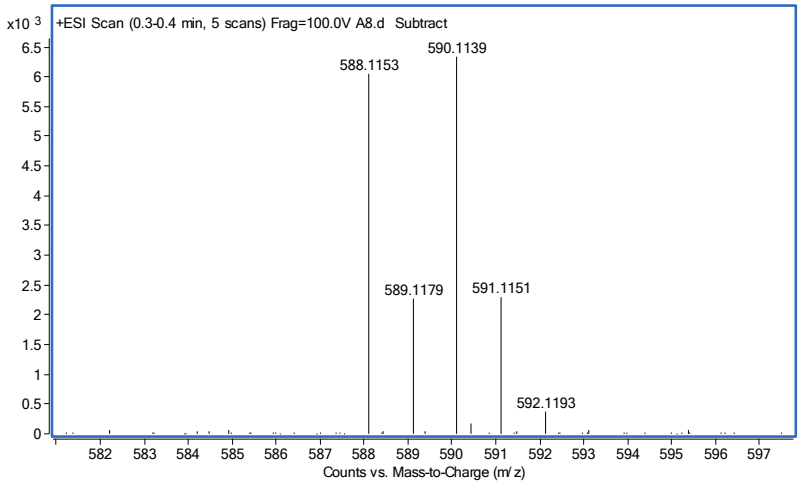



+ESI Scan (0.3-0.4 min, 3 scans) Frag=100.0V A3.d Subtract
x10 3
578.1277
580.1268
579.1320
581.1258
582.1264
Counts vs. Mass-to-Charge (m/z)

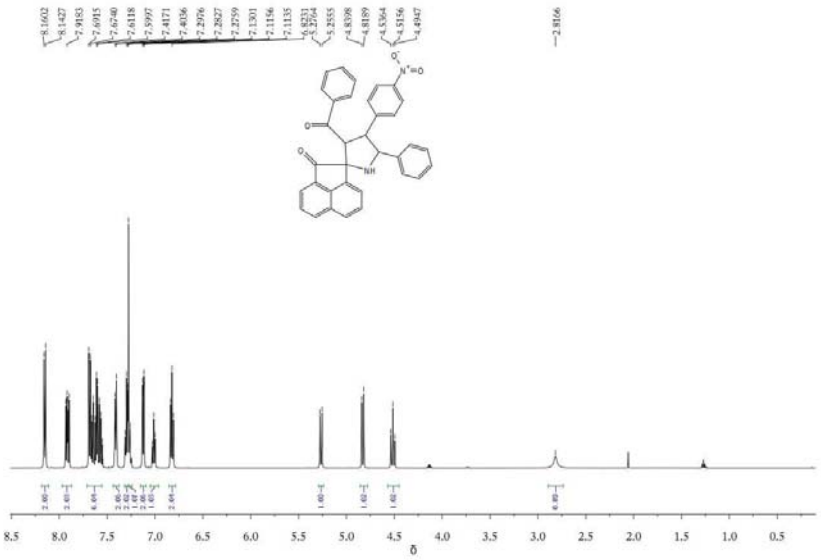
4j

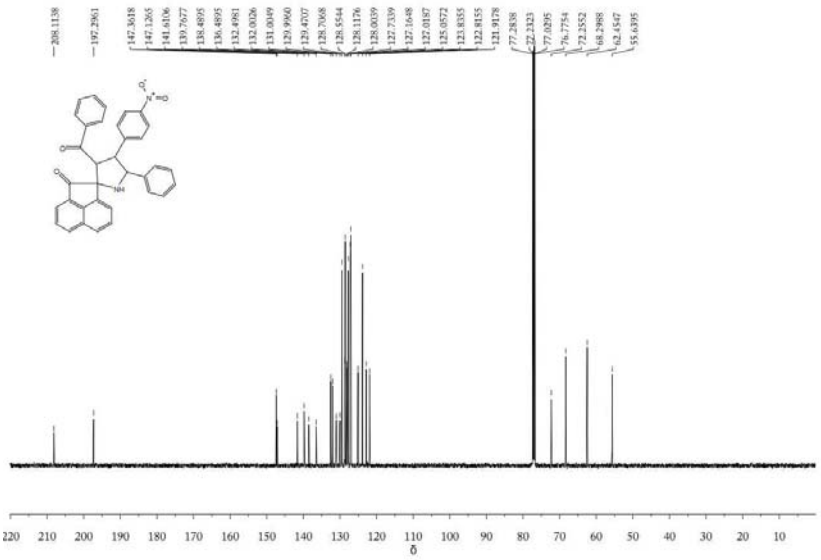


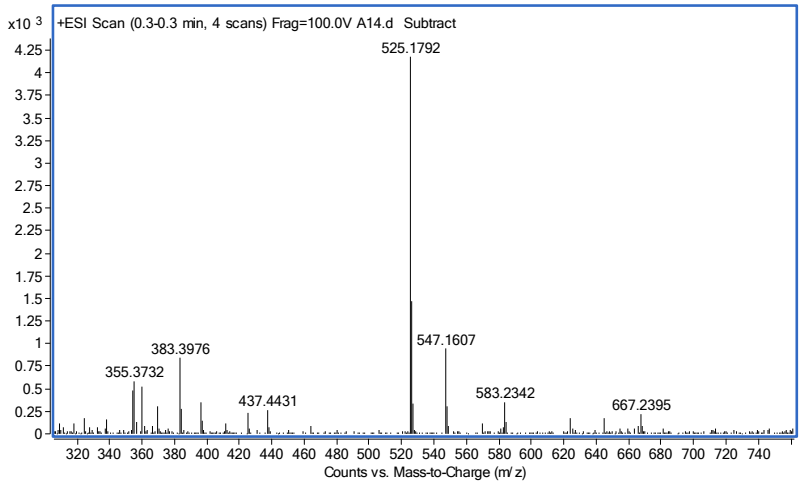



x10 3
+ESI Scan (0.3-0.4 min, 5 scans) Frag=100.0V A8.d Subtract
588.1153
590.1139
589.1179
591.1151
592.1193
Counts vs. Mass-to-Charge (m/z)

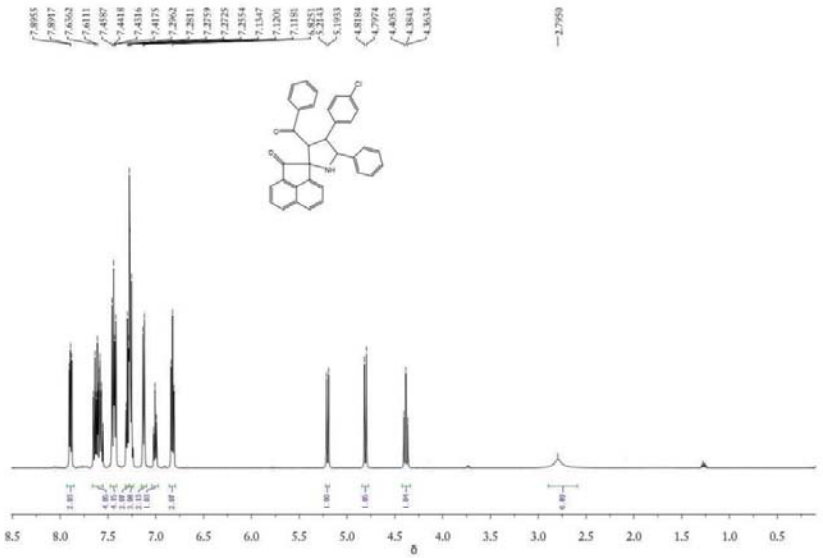
4k

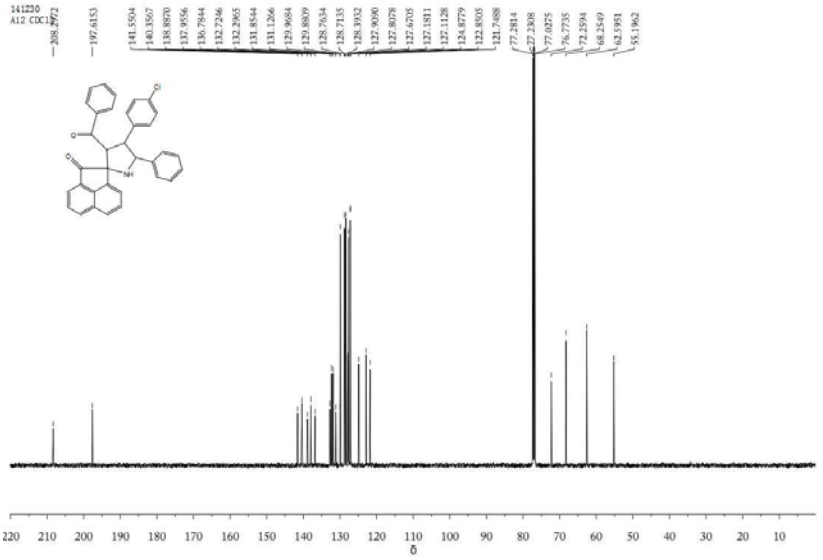


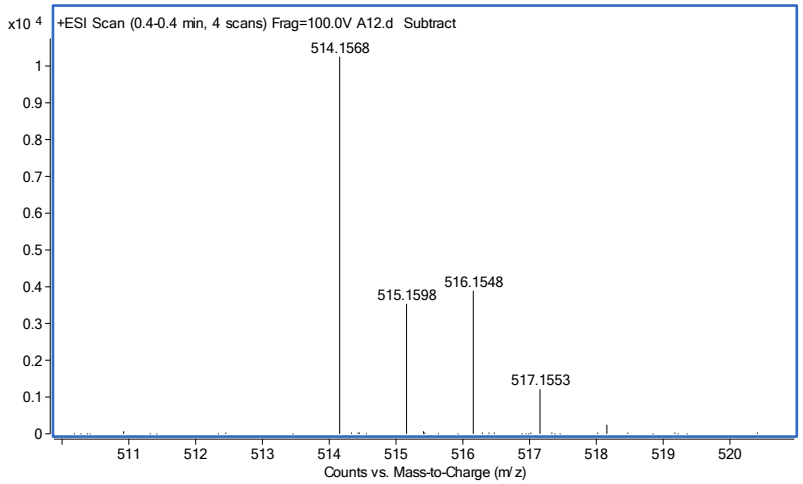



x10 3
+ESI Scan (0.3-0.3 min, 4 scans) Frag=100.0V A14.d Subtract
525.1792
547.1607
383.3976
355.3732
437.4431
583.2342
667.2395
Counts vs. Mass-to-Charge (m/z)

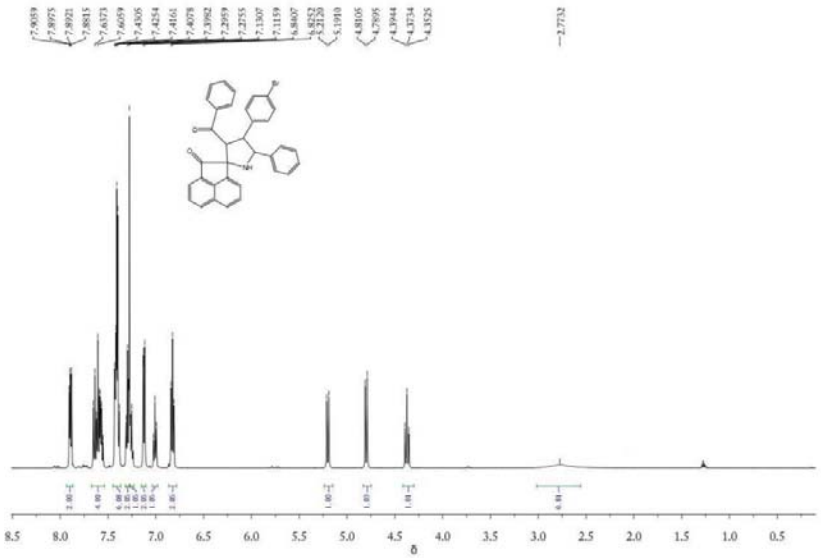
4l

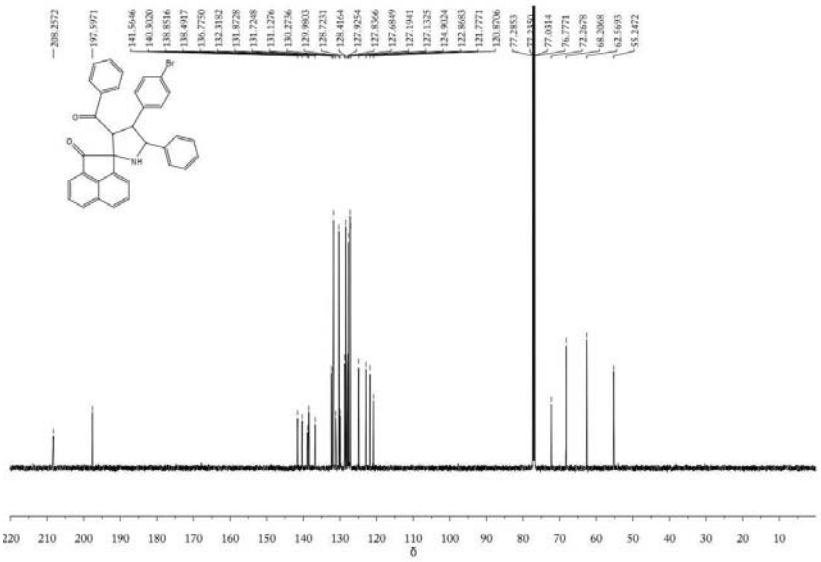


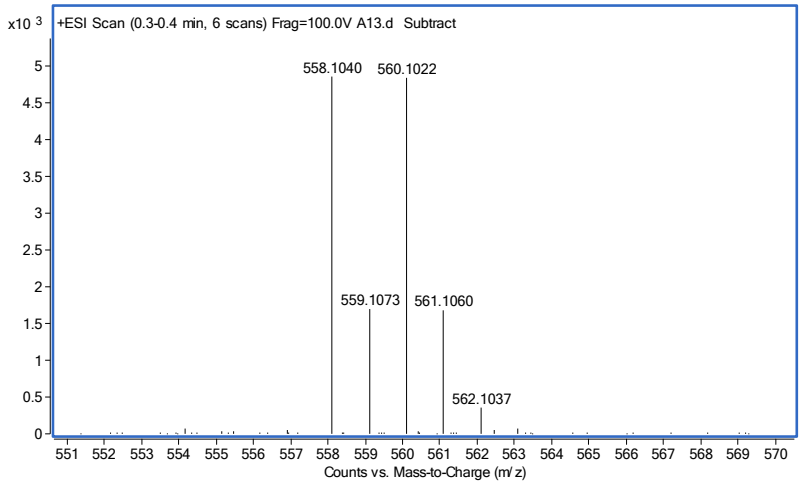



x10 4
+ESI Scan (0.4-0.4 min, 4 scans) Frag=100.0V A12.d Subtract
514.1568
515.1598
516.1548
517.1553
Counts vs. Mass-to-Charge (m/z)

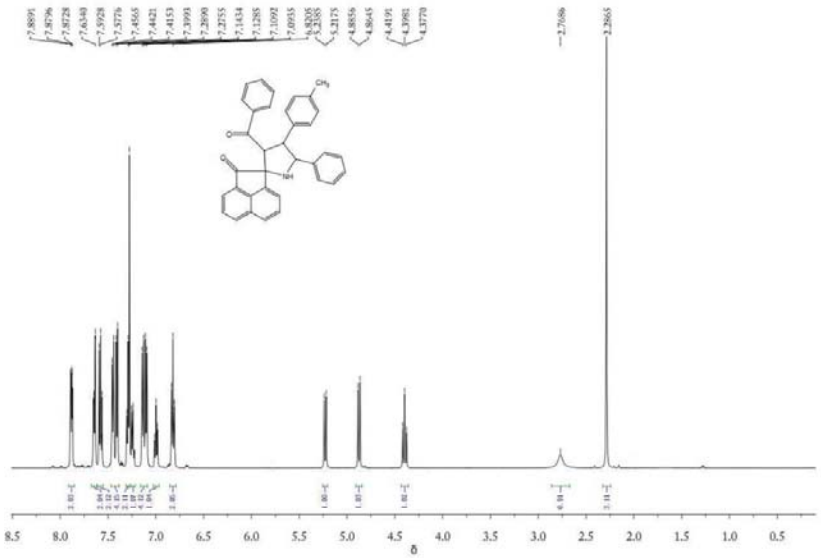
4m

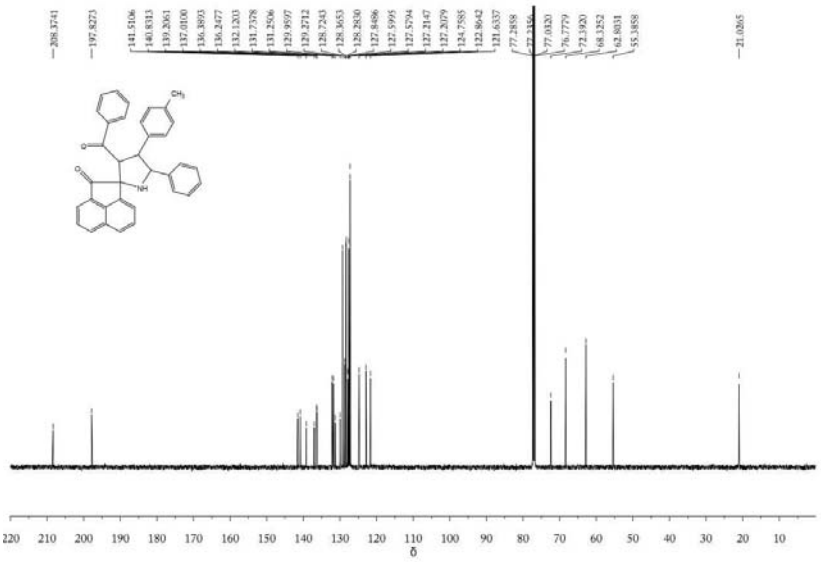


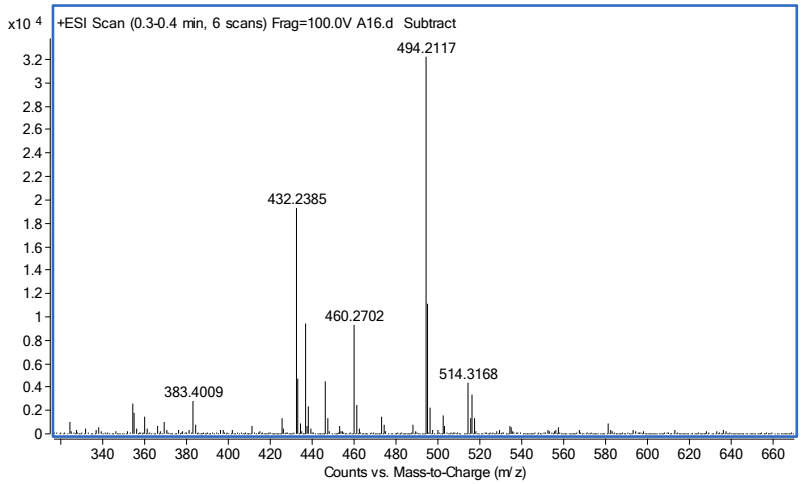


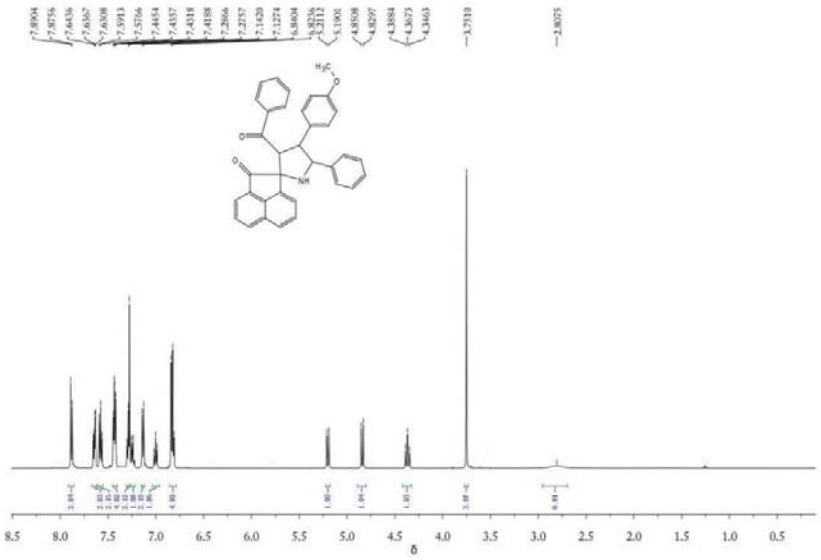

x10 3
+ESI Scan (0.3-0.4 min, 6 scans) Frag=100.0V A13.d Subtract
558.1040
560.1022
559.1073
561.1060
562.1037
Counts vs. Mass-to-Charge (m/z)

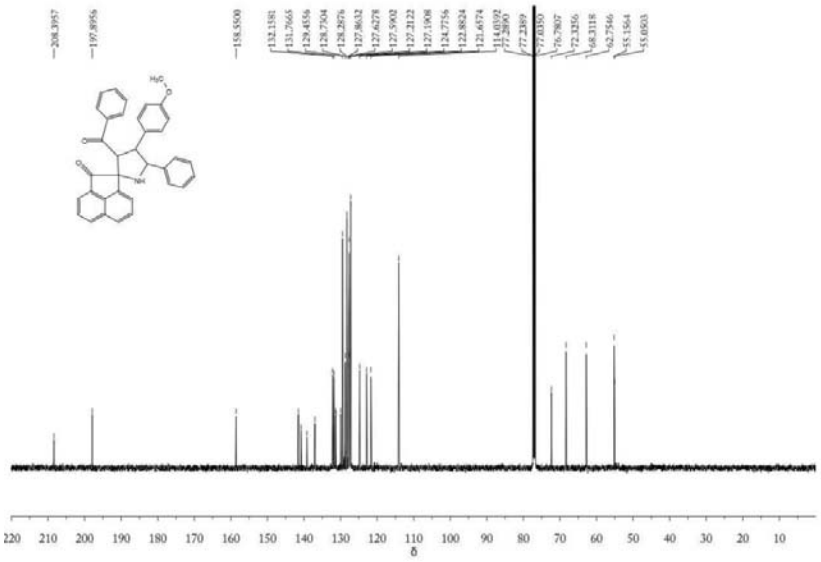
4n

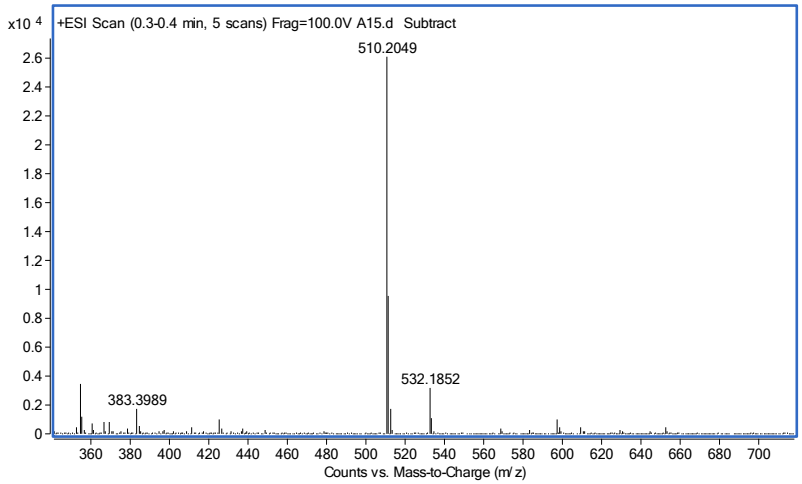




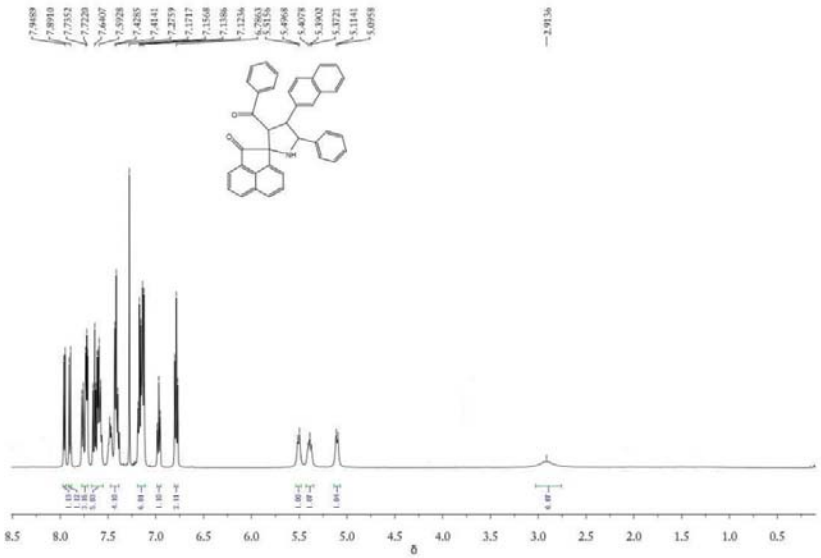

x10 4
+ESI Scan (0.3-0.4 min, 6 scans) Frag=100.0V A16.d Subtract
494.2117
432.2385
460.2702
514.3168
383.4009
Counts vs. Mass-to-Charge (m/z)

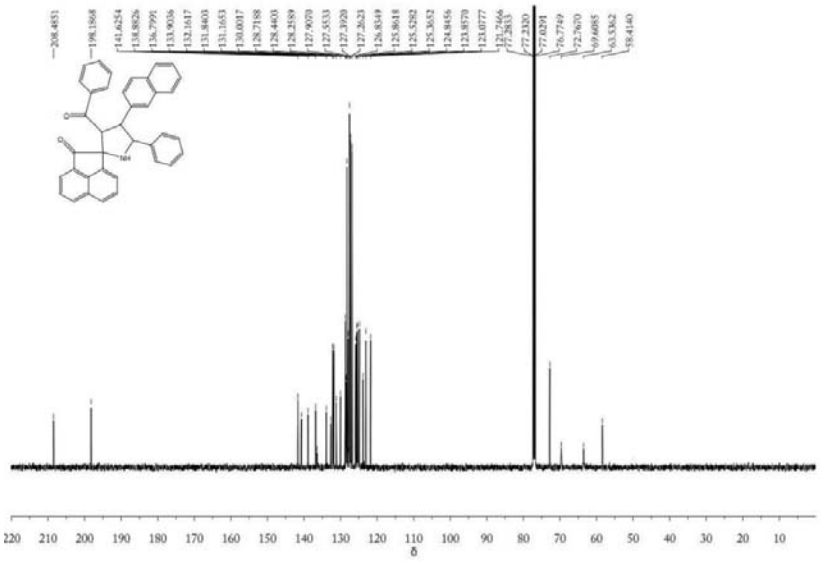


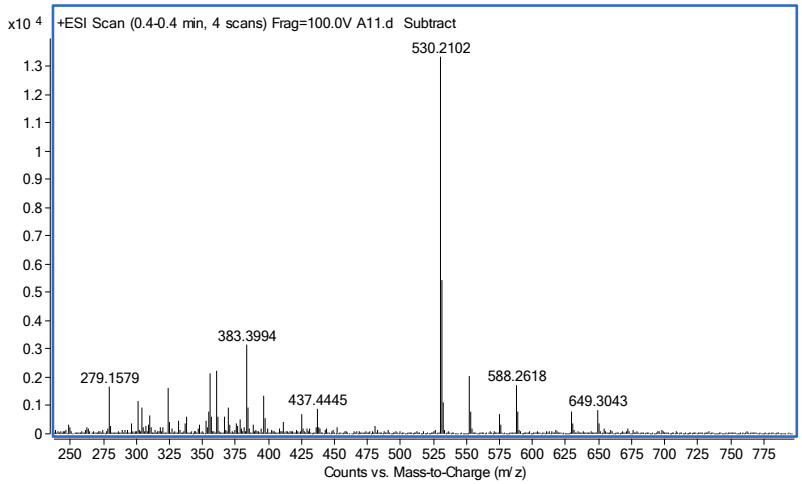



x10 4
+ESI Scan (0.3-0.4 min, 5 scans) Frag=100.0V A15.d Subtract
510.2049
532.1852
383.3989
Counts vs. Mass-to-Charge (m/z)

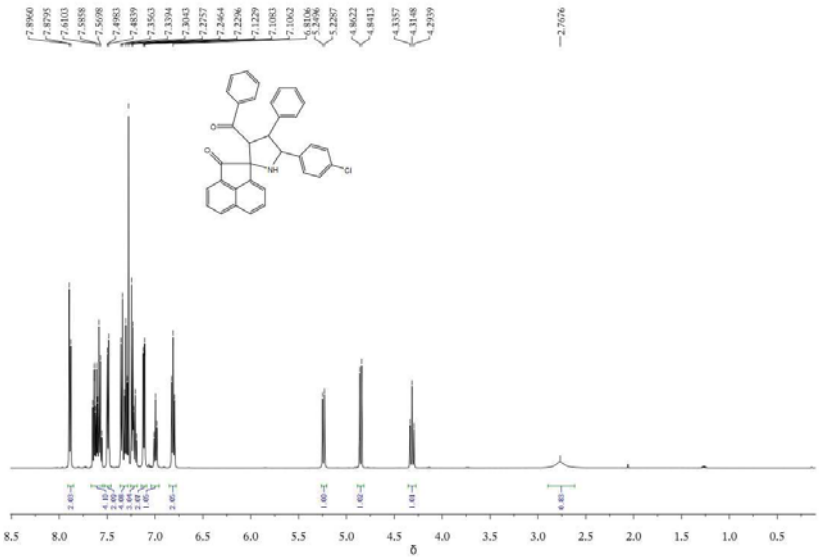
4p

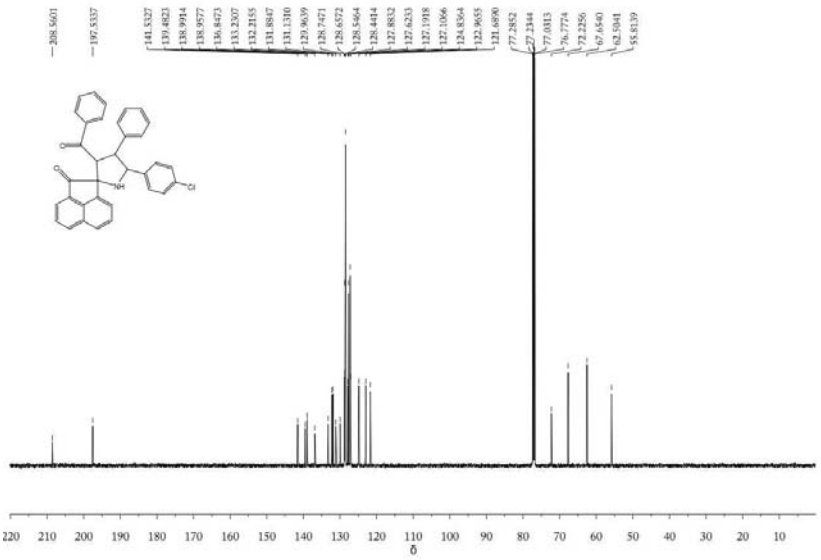


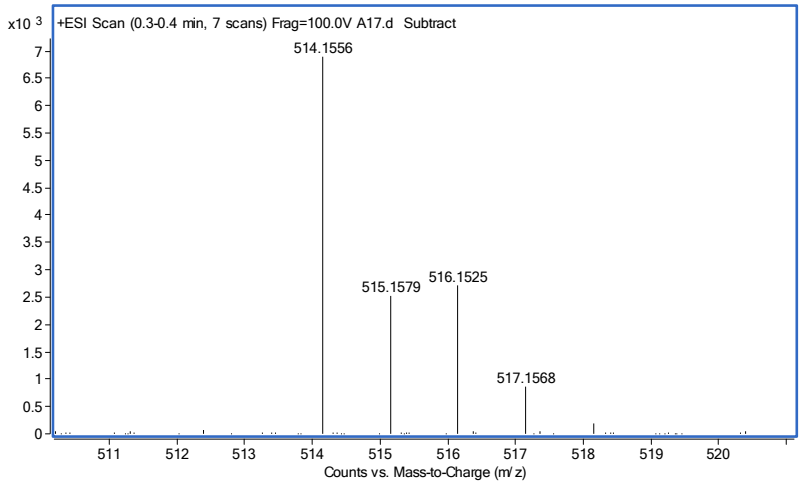



x10 4
+ESI Scan (0.4-0.4 min, 4 scans) Frag=100.0V A11.d Subtract
530.2102
383.3994
279.1579
437.4445
588.2618
649.3043
Counts vs. Mass-to-Charge (m/z)

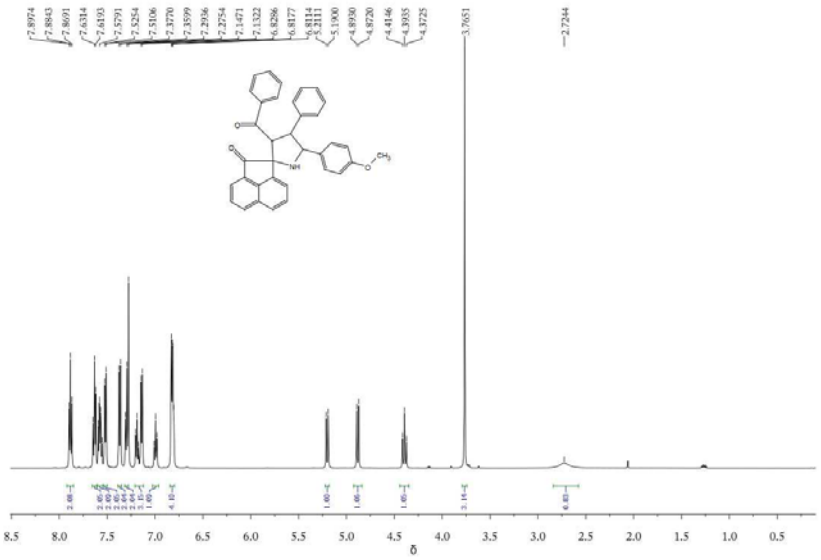
4q

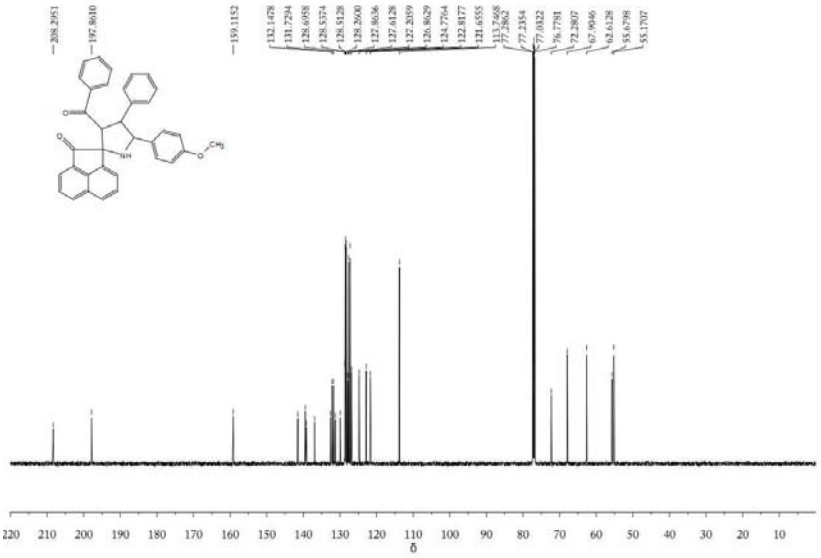


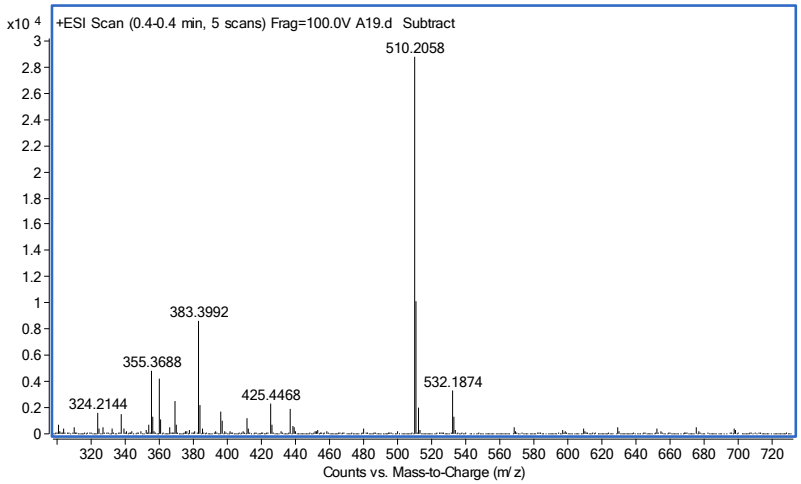



+ESI Scan (0.3-0.4 min, 7 scans) Frag=100.0V A17.d Subtract
514.1556
515.1579
516.1525
517.1568
Counts vs. Mass-to-Charge (m/z)

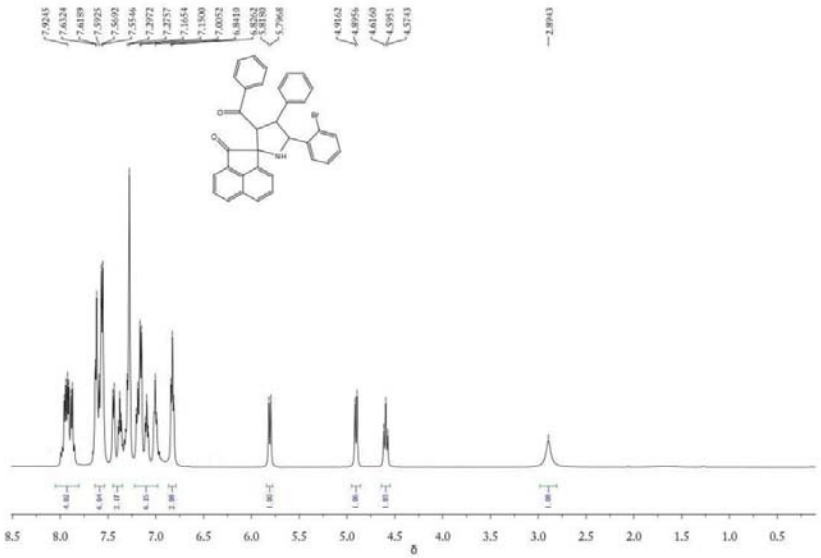
4r

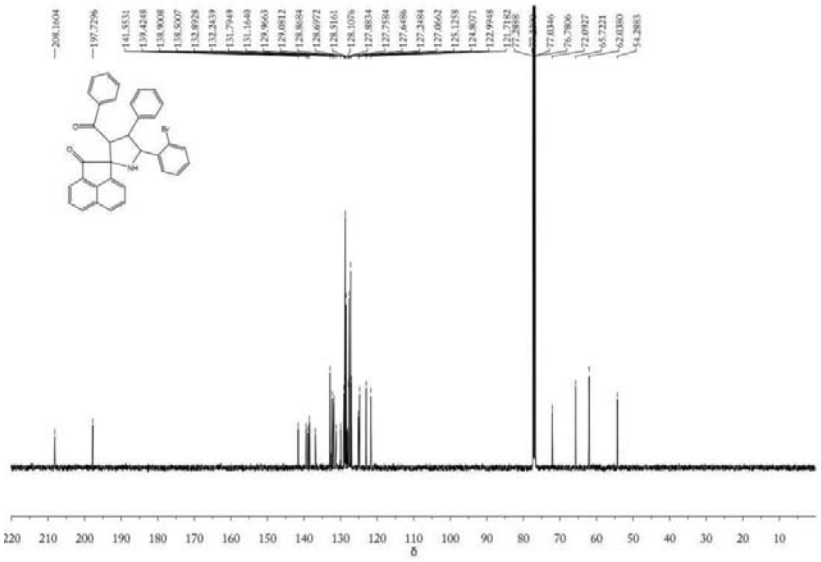


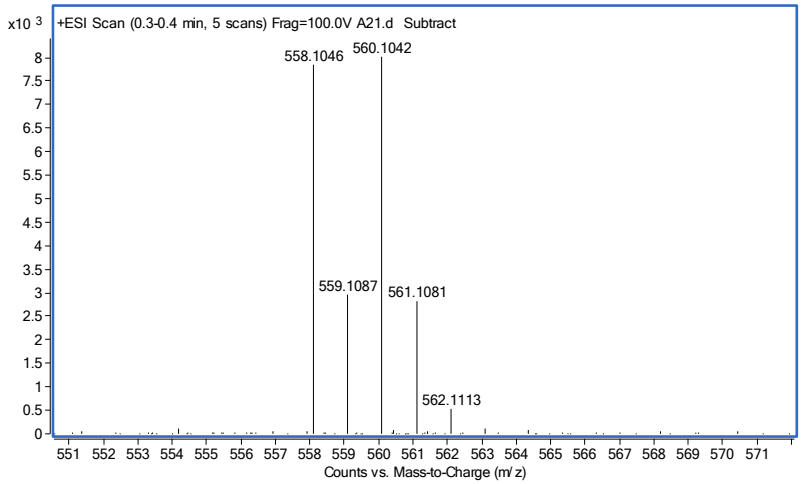



+ESI Scan (0.4-0.4 min, 5 scans) Frag=100.0V A19.d Subtract
x10 4
510.2058
383.3992
355.3688
532.1874
425.4468
324.2144
Counts vs. Mass-to-Charge (m/z)

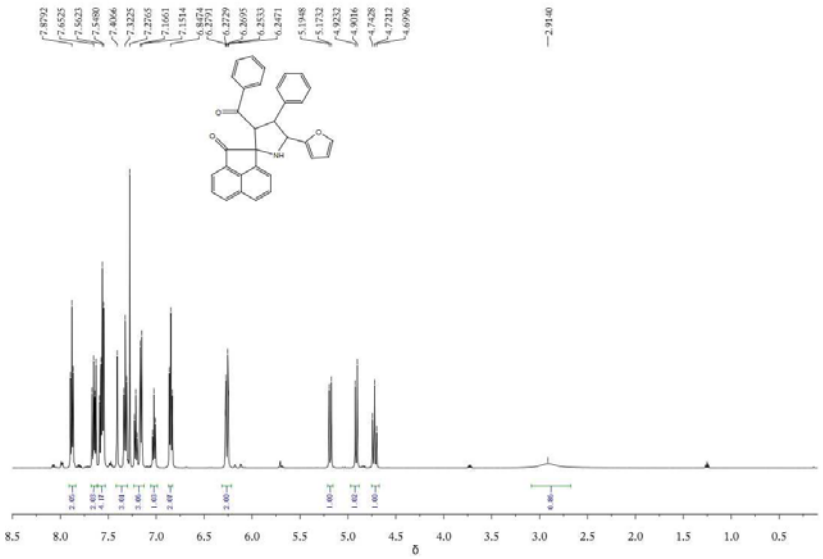
4s

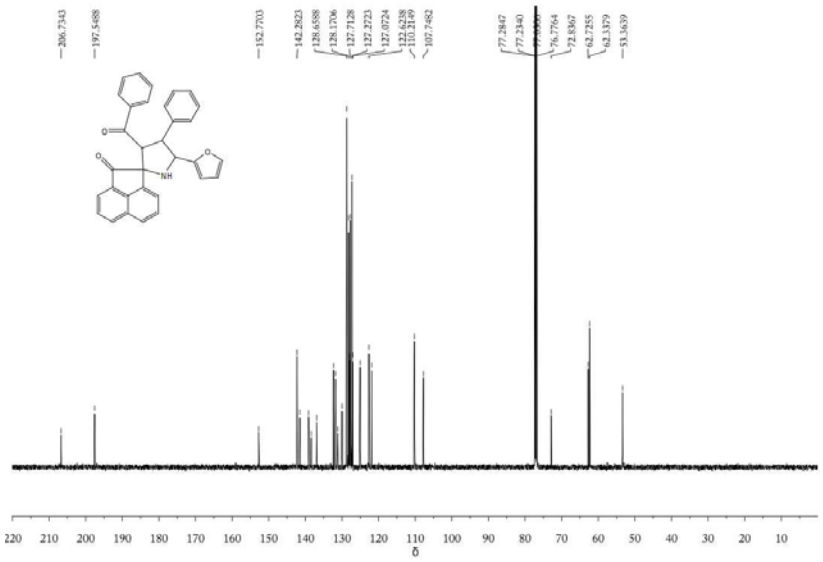


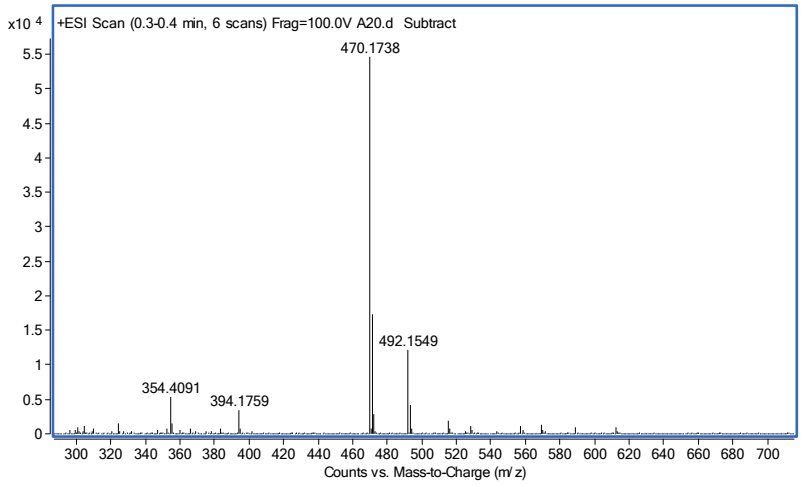



x10 3
+ESI Scan (0.3-0.4 min, 5 scans) Frag=100.0V A21.d Subtract
558.1046
560.1042
559.1087
561.1081
562.1113
Counts vs. Mass-to-Charge (m/z)

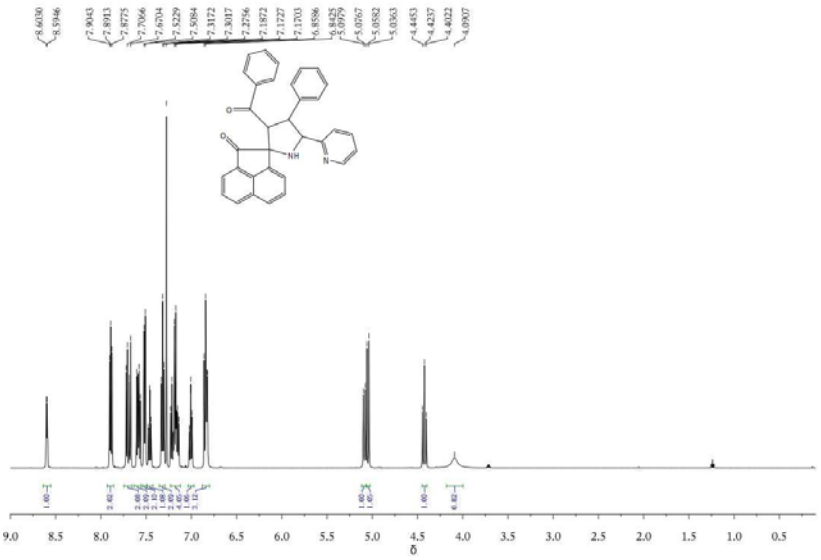
4t

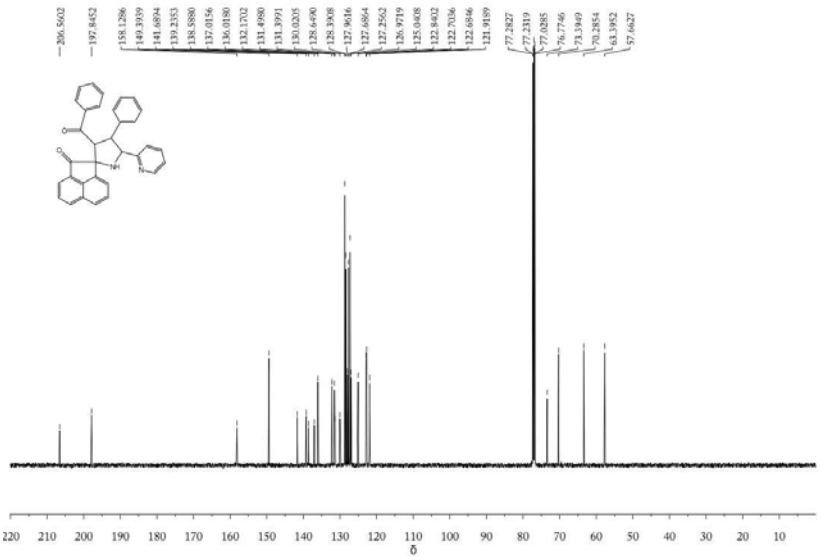


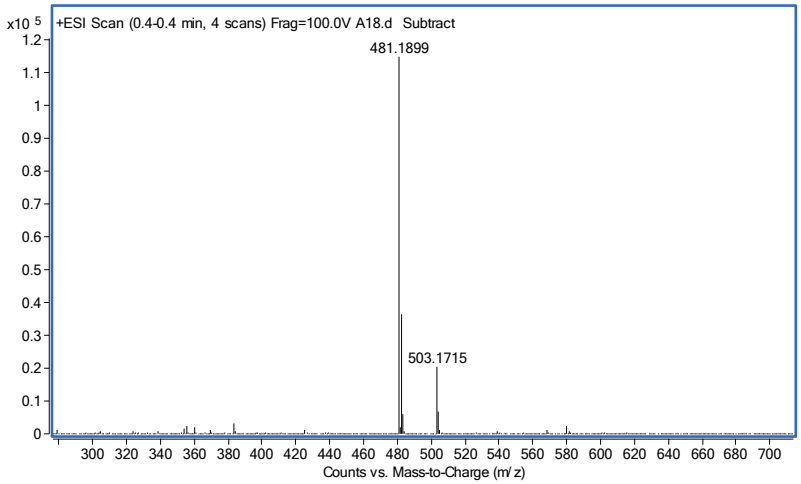



x10 4
+ESI Scan (0.3-0.4 min, 6 scans) Frag=100.0V A20.d Subtract
470.1738
492.1549
354.4091
394.1759
Counts vs. Mass-to-Charge (m/z)

4u






x10 5
+ESI Scan (0.4-0.4 min, 4 scans) Frag=100.0V A18.d Subtract
481.1899
503.1715
Counts vs. Mass-to-Charge (m/z)