Electronic Supplementary Information (ESI)

Synthesis of 1-Azulenyl Ketones by Brønsted Acid Mediated Hydration of 1-Azulenylalkynes

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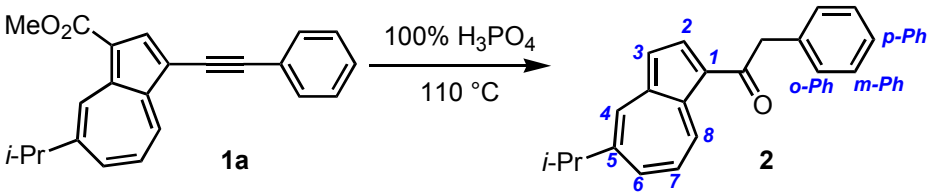
Contents

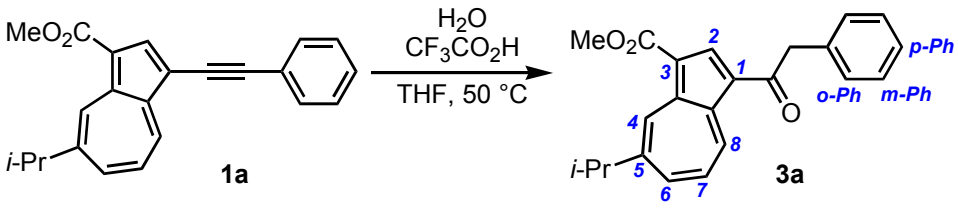
General

Melting points were determined with a Yanagimoto MPS3 micromelting apparatus, and the solvent in the parenthesis shows the solvent used for recrystallization of compound. The HRMS data were obtained with a JEOL JMS-700 or a Bruker Daltonics autoflex Ⅲ TOF/TOF instrument. The IR and UV/Vis spectra were recorded with a JASCO FTIR-4100 and a Shimadzu UV-2550 spectrophotometers. The ^{1}H and ^{13}CNMR spectra were recorded with a JEOL ECA500 spectrometer at 500 and 125 MHz, respectively.



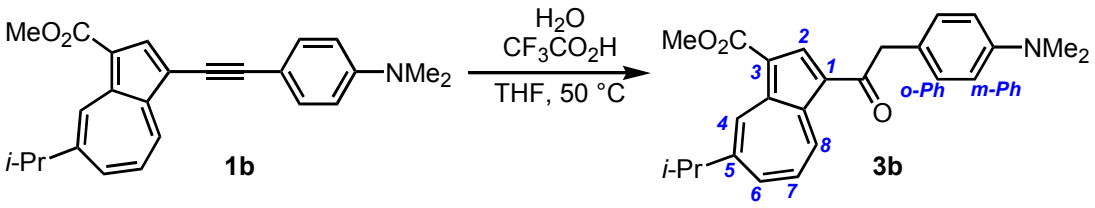
A solution of **1a** (168 mg, 0.51 mmol) in 100% H_3PO_4 (20 mL) was stirred at 110 °C for 30 min. After the reaction mixture was cooled, the reaction mixture was poured into water and extracted with toluene. The crude product was purified by column chromatography on silica gel with toluene/AcOEt (50 : 1) as an eluent to afford **2** (27 mg, 18%) as purple crystals.

M.p. 58−59 °C; IR (AT−IR): ν_{max} = 2960 (w), 2902 (w), 1637 (m), 1575 (w), 1516 (w), 1496 (m), 1464 (w), 1455 (w), 1408 (s), 1396 (s), 1362 (w), 1337 (w), 1325 (w), 1287 (w), 1263 (w), 1211 (w), 1169 (w), 1131 (w), 1092 (m), 1071 (w), 1040 (w), 962 (w), 932 (w), 914 (w), 887 (m), 873 (m), 838 (w), 790 (m), 740 (w), 726 (w), 712 (s), 696 (w), 647 (w), 633 (w), 603 (w) cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ_H = 9.81 (d, 1H, *J* = 10.0 Hz, H_8), 8.43 (s, 1H, H_4), 8.35 (d, 1H, *J* = 4.5 Hz, H_2), 7.77 (d, 1H, *J* = 10.0 Hz, H_6), 7.56 (t, 1H, *J* = 10.0 Hz, H_7), 7.37 (d, 2H, *J* = 7.5 Hz, *o*-Ph), 7.31 (t, 2H, *J* = 7.5 Hz, *m*-Ph), 7.22 (t, 1H, *J* = 7.5 Hz, *p*-Ph), 7.18 (d, 1H, *J* = 4.5 Hz, H_3), 4.36 (s, 2H, CH_2), 3.17 (sept, 1H, *J* = 7.0 Hz, *i*Pr), 1.39 (d, 6H, *J* = 7.0 Hz, *i*Pr) ppm; ^{13}C NMR (125 MHz, $CDCl_3$): δ_C = 194.68, 148.72, 145.39, 140.86, 140.36, 138.97, 138.40, 138.03, 136.40, 129.50, 128.57, 126.52, 123.54, 117.37, 48.01, 38.69, 24.55 ppm; HRMS (MALDI−TOF): Calcd for $C_{21}H_{20}O + H^+$ $[M + H]^+$ 289.1587; found: 289.1582.



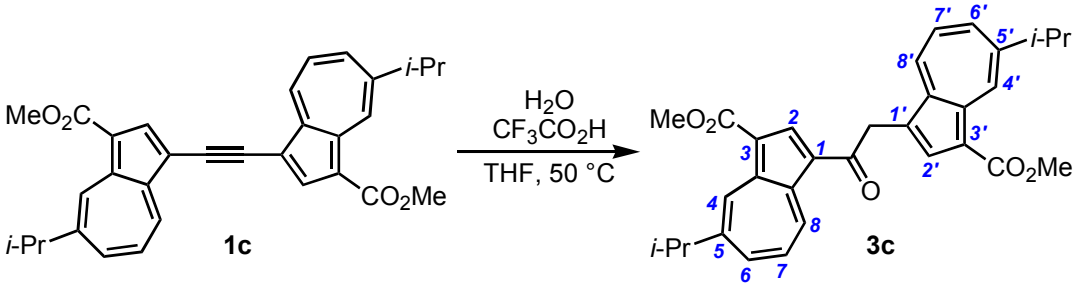
Water (0.5 mL) was added to a solution of **1a** (164 mg, 0.50 mmol) and CF_3CO_2H (0.5 mL) in THF (1 mL). The resulting mixture was stirred at 50 °C for 3 h. The reaction mixture was poured into aq. K_2CO_3. The generated crystal was corrected by filtration. The crystal was dissolved in CH_2Cl_2 and the solution was passed through the short silica gel column to give **3a** (169 mg, 98%) as red crystals.

M.p. 153−155 °C; IR (AT−IR): ν_{max} = 2958 (w), 1686 (m), 1651 (s), 1558 (w), 1523 (w), 1508 (m), 1443 (m), 1418 (s), 1391 (s), 1381 (m), 1282 (w), 1206 (s), 1175 (m), 1157 (m), 1125 (w), 1102 (w), 1081 (m), 1011 (m), 972 (w), 944 (m), 905 (m), 878 (m), 841 (w), 818 (m), 780 (m), 741 (m), 714 (s), 695 (m), 668 (w) cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ_H = 9.93 (d, 1H, *J* = 10.0 Hz), 9.91 (s, 1H, H_4), 8.88 (s, 1H, H_2), 7.95 (d, 1H, *J* = 10.0 Hz, H_6), 7.76 (t, 1H, *J* = 10.0 Hz, H_7), 7.31−7.37 (m, 4H, *o,m*-Ph), 7.24 (t, 1H, *J* = 7.5 Hz, *p*-Ph), 4.37 (s, 2H, CH_2), 3.99 (s, 3H, CO_2Me), 3.28 (sept, 1H, *J* = 7.0 Hz, *i*Pr), 1.44 (d, 6H, *J* = 7.0 Hz, *i*Pr) ppm; ^{13}C NMR (125 MHz, $CDCl_3$): δ_C = 194.99, 165.56, 153.68, 144.84, 144.27, 143.82, 140.87, 139.69, 139.08, 135.75, 132.31, 129.58, 128.64, 126.73, 122.38, 115.05, 51.41, 47.66, 39.35, 24.69 ppm; HRMS (MALDI−TOF): Calcd for $C_{23}H_{22}O_3$ + H^+ $[M + H]^+$ 347.1642; found: 347.1634.



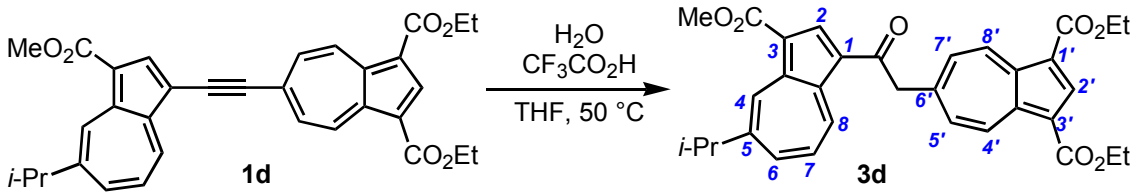
Water (0.5 mL) was added to a solution of **1b** (186 mg, 0.50 mmol) and CF_3CO_2H (0.5 mL) in THF (3 mL). The resulting mixture was stirred at 50 °C for 5 h. The reaction mixture was poured into aq. K_2CO_3. The precipitated crystal was corrected by filtration. The crystal was dissolved in CH_2Cl_2 and the solution was passed through the short silica gel column to give **3b** (161 mg, 83%) as red crystals.

M.p. 133−135 °C; IR (AT−IR): ν_{max} = 2892 (w), 1686 (m), 1661 (s), 1617 (w), 1570 (w), 1558 (w), 1523 (m), 1509 (m), 1473 (w), 1439 (s), 1417 (s), 1391 (s), 1340 (w), 1203 (s), 1178 (m), 1154 (m), 1119 (w), 1099 (w), 1077 (m), 1061 (m), 1013 (m), 980 (w), 947 (w), 906 (m), 880 (w), 822 (m), 803 (m), 775 (m), 738 (w), 713 (w), 689 (w), 658 (w) cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ_H = 9.93 (d, 1H, *J* = 10.0 Hz), 9.89 (d, 1H, *J* = 1.5 Hz, H_4), 8.88 (s, 1H, H_2), 7.93 (d, 1H, *J* = 10.0 Hz, H_6), 7.74 (t, 1H, *J* = 10.0 Hz, H_7), 7.23 (d, 2H, *J* = 8.5 Hz, *o*-Ph), 6.71 (d, 2H, *J* = 8.5 Hz, *m*-Ph), 4.26 (s, 2H, CH_2), 3.98 (s, 3H, CO_2Me), 3.28 (sept, 1H, *J* = 7.0 Hz, *i*Pr), 2.90 (s, 6H, NMe_2), 1.43 (d, 6H, *J* = 7.0 Hz, *i*Pr) ppm; ^{13}C NMR (125 MHz, $CDCl_3$): δ_C = 195.88, 165.62, 153.41, 149.59, 144.73, 144.28, 143.89, 140.68, 139.66, 138.91, 132.11, 130.10, 123.64, 122.52, 114.92, 113.12, 51.36, 46.83, 40.83, 39.32, 24.68 ppm; HRMS (MALDI−TOF): Calcd for $C_{25}H_{27}NO_3^+$ $[M]^+$ 389.1985; found: 389.1975.



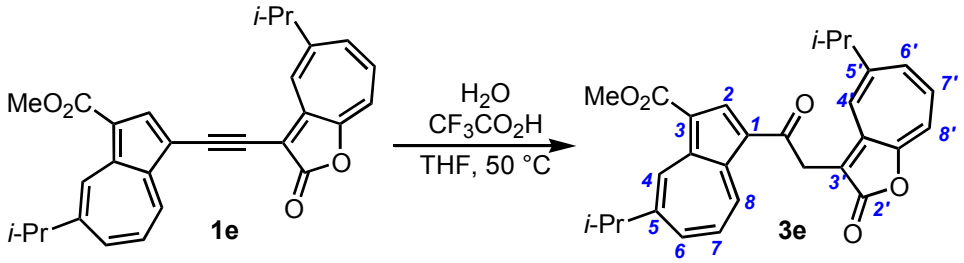
Water (0.5 mL) was added to a solution of **1c** (239 mg, 0.50 mmol) and CF_3CO_2H (0.5 mL) in THF (2 mL). The resulting mixture was stirred at 50 °C for 3 h. The reaction mixture was poured into aq. K_2CO_3. The precipitated crystal was corrected by filtration. The crystal was dissolved in CH_2Cl_2 and the solution was passed through the short silica gel column to give **3c** (196 mg, 79%) as red crystals.

M.p. 182−184 °C; IR (AT−IR): ν_{max} = 2961 (w), 1679 (s), 1657 (m), 1598 (w), 1509 (w), 1454 (m), 1418 (m), 1403 (m), 1380 (m), 1317 (w), 1292 (w), 1222 (s), 1202 (s), 1168 (m), 1131 (m), 1098 (m), 1079 (m), 1055 (m), 992 (w), 950 (w), 908 (w), 876 (m), 857 (w), 820 (w), 809 (w), 775 (m), 742 (w), 700 (w), 689 (w), 677 (w) cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ_H = 9.91−9.89 (m, 2H, $H_{4,8}$), 9.73 (d, 1H, *J* = 1.5 Hz, $H_{4'}$), 8.99 (s, 1H, H_2), 8.48 (d, 1H, *J* = 10.0 Hz, H_8), 8.31 (s, 1H, $H_{2'}$), 7.94 (d, 1H, *J* = 10.0 Hz, H_6), 7.75−7.71 (m, 2H, $H_{7,6'}$), 7.42 (t, 1H, *J* = 10.0 Hz, $H_{7'}$), 4.76 (s, 2H, CH_2), 3.99 (s, 3H, CO_2Me), 3.91 (s, 3H, CO_2Me), 3.29 (sept, 1H, *J* = 7.0 Hz, *i*Pr), 3.21 (sept, 1H, *J* = 7.0 Hz, *i*Pr), 1.43 (d, 6H, *J* = 7.0 Hz, *i*Pr), 1.40 (d, 6H, *J* = 7.0 Hz, *i*Pr) ppm; ^{13}C NMR (125 MHz, $CDCl_3$): δ_C = 194.70, 165.93, 165.58, 153.69, 148.86, 144.83, 144.33, 143.75, 141.82, 141.58, 141.24, 140.87, 139.72, 139.06, 138.25, 137.60, 134.14, 132.28, 126.27, 122.22, 121.83, 115.10, 114.15, 51.39, 50.97, 39.82, 39.32, 39.18, 24.73, 24.66 ppm; HRMS (MALDI−TOF): Calcd for $C_{32}H_{32}O_5^+$ $[M]^+$ 496.2244; found: 496.2242.

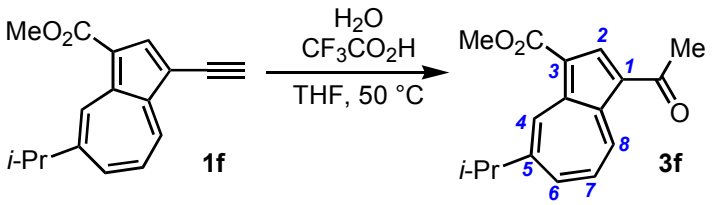


Water (0.5 mL) was added to a solution of **1d** (261 mg, 0.50 mmol) and CF_3CO_2H (0.5 mL) in THF (3 mL). The resulting mixture was stirred at 50 °C for 5 h. The reaction mixture was poured into aq. K_2CO_3. The precipitated crystal was corrected by filtration. The crystal was dissolved in CH_2Cl_2 and the solution was passed through the short silica gel column to give **3d** (242 mg, 89%) as red crystals.

M.p. 207−208 °C; IR (AT−IR): ν_{max} = 2979 (w), 1685 (m), 1650 (w), 1579 (w), 1509 (w), 1434 (s), 1419 (m), 1389 (m), 1352 (w), 1293 (w), 1200 (s), 1179 (m), 1094 (w), 1082 (w), 1042 (m), 1013 (w), 990 (w), 939 (w), 902 (m), 881 (w), 849 (w), 811 (w), 795 (w), 779 (w), 765 (w), 726 (w), 712 (w), 696 (w), 682 (w), 671 (w) cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ_H = 9.94 (d, 1H, *J* = 1.5 Hz, H_4), 9.89 (d, 1H, *J* = 10.0 Hz, H_8), 9.73 (d, 2H, *J* = 10.9 Hz, $H_{4',8'}$), 8.91 (s, 1H, $H_{2'}$), 8.79 (s, 1H, H_2), 7.98 (d, 1H, *J* = 10.0 Hz, H_6), 7.82−7.77 (m, 3H, $H_{7,5',7'}$), 4.71 (s, 2H, CH_2), 4.42 (q, 4H, *J* = 7.1 Hz, CO_2Et), 4.01 (s, 3H, CO_2Me), 3.29 (q, 1H, *J* = 7.0 Hz, *i*Pr), 1.45−1.43 (m, 12H, *i*Pr, CO_2Et) ppm; ^{13}C NMR (125 MHz, $CDCl_3$): δ_C = 192.84, 165.38, 165.11, 154.32, 150.09, 145.13, 144.37, 143.49, 143.15, 143.08, 141.28, 139.72, 139.41, 138.36, 132.76, 121.82, 116.41, 115.41, 60.10, 52.67, 51.51, 39.39, 24.67, 14.67 ppm; HRMS (MALDI−TOF): Calcd for $C_{33}H_{32}O_7 + H^+$ $[M + H]^+$ 541.2221; found: 541.2211.

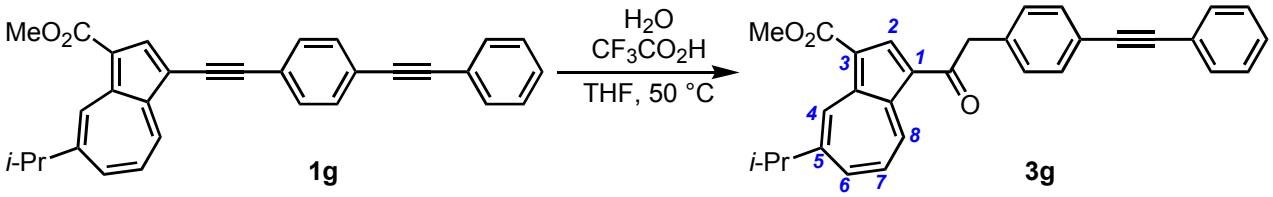


Water (0.5 mL) was added to a solution of **1e** (220 mg, 0.50 mmol) and CF_3CO_2H (0.5 mL) in THF (1 mL). The resulting mixture was stirred at 50 °C for 4 h. The reaction mixture was poured into aq. K_2CO_3 and extracted with CH_2Cl_2. The organic layer was washed with brine, dried over Na_2SO_4, and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel with CH_2Cl_2 to give **3e** (210 mg, 92%) as a brown oil. IR (AT−IR): ν_{max} = 2963 (w), 2873 (w), 1739 (s), 1694 (m), 1648 (m), 1604 (m), 1542 (w), 1508 (m), 1441 (m), 1420 (m), 1393 (m), 1337 (w), 1310 (w), 1279 (w), 1248 (w), 1212 (s), 1178 (m), 1098 (w), 1081 (w), 1058 (w), 1014 (w), 944 (w), 904 (m), 881 (w), 844 (w), 779 (m), 734 (m), 703 (w), 671 (w), 649 (m), 603 (w) cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ_H = 9.92 (d, 1H, *J* = 1.7 Hz, H_4), 9.86 (d, 1H, *J* = 10.0 Hz, H_8), 9.08 (s, 1H, H_2), 7.93 (d, 1H, *J* = 10.0 Hz, H_6), 7.74 (t, 1H, *J* = 10.0 Hz, H_7), 7.32 (s, 1H, $H_{4'}$), 6.88 (dd, 1H, *J* = 11.5, 8.9 Hz, $H_{7'}$), 6.80 (d, 1H, *J* = 8.9 Hz, $H_{8'}$), 6.69 (d, 1H, *J* = 11.5 Hz, $H_{6'}$), 4.23 (s, 2H, CH_2), 3.98 (s, 3H, CO_2Me), 3.27 (sept, 1H, *J* = 7.0 Hz, *i*Pr), 2.80 (sept, 1H, *J* = 7.0 Hz, *i*Pr), 1.42 (d, 6H, *J* = 7.0 Hz, *i*Pr), 1.23 (d, 6H, *J* = 7.0 Hz, *i*Pr) ppm; ^{13}C NMR (125 MHz, $CDCl_3$): δ_C = 192.46, 169.77, 165.58, 157.46, 155.86, 153.77, 149.17, 144.99, 144.30, 144.21, 140.74, 139.26, 139.04, 132.23, 131.66, 131.56, 123.63, 121.89, 115.34, 112.35, 104.29, 51.43, 39.30, 39.05, 35.74, 24.64, 23.20 ppm; HRMS (MALDI−TOF): Calcd for $C_{29}H_{28}O_5^+$ $[M]^+$ 456.1931; found: 456.1930.



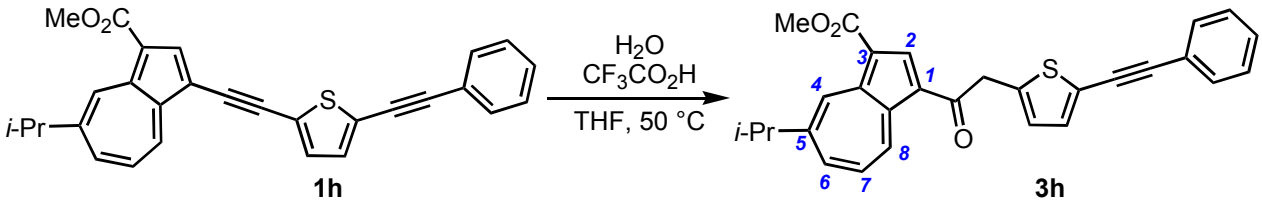
Water (0.5 mL) was added to a solution of **1f** (126 mg, 0.50 mmol) and CF_3CO_2H (0.5 mL) in THF (1 mL). The resulting mixture was stirred at 50 °C for 3 h. The reaction mixture was poured into aq. K_2CO_3. The precipitated crystals were corrected by filtration. The crystal was dissolved in CH_2Cl_2 and the solution was passed through the short silica gel column to give **3f** (109 mg, 81%) as red crystals.

M.p. 98−99 °C; IR (AT−IR): ν_{max} = 2967 (w), 1685 (m), 1644 (s), 1576 (w), 1507 (m), 1440 (m), 1420 (s), 1394 (s), 1374 (w), 1336 (w), 1305 (w), 1284 (w), 1207 (s), 1178 (m), 1146 (w), 1122 (w), 1085 (w), 1056 (w), 1033 (w), 991 (w), 975 (w), 942 (w), 905 (m), 881 (w), 823 (w), 779 (m), 739 (w), 656 (w), 630 (w), 610 (m) cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ_H = 9.92−9.90 (m, 2H, $H_{4,8}$), 8.75 (s, 1H, H_2), 7.95 (d, 1H, *J* = 10.0 Hz, H_6), 7.77 (t, 1H, *J* = 10.0 Hz, H_7), 3.97 (s, 3H, CO_2Me), 3.29 (sept, 1H, *J* = 7.0 Hz, *i*Pr), 2.70 (s, 3H, COMe), 1.44 (d, 6H, *J* = 7.0 Hz, *i*Pr) ppm; ^{13}C NMR (125 MHz, $CDCl_3$): δ_C = 195.47, 165.56, 153.40, 144.62, 144.18, 143.54, 140.72, 139.51, 139.03, 132.13, 123.07, 114.77, 51.34, 39.33, 29.01, 24.68 ppm; HRMS (MALDI−TOF): Calcd for $C_{17}H_{18}O_3$ + H^+ $[M + H]^+$ 271.1329; found: 271.1317.



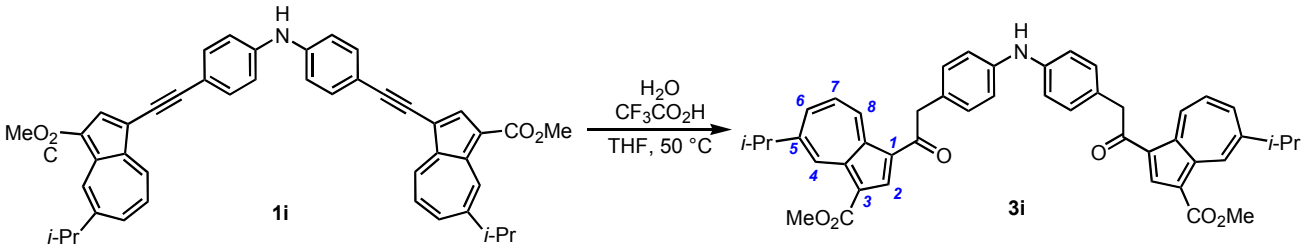
Water (0.5 mL) was added to a solution of **1g** (214 mg, 0.50 mmol) and CF_3CO_2H (0.5 mL) in THF (1 mL). The resulting mixture was stirred at 50 °C for 3 h. The reaction mixture was poured into aq. K_2CO_3. The precipitated crystals were corrected by filtration. The crystal was dissolved in CH_2Cl_2 and the solution was passed through the short silica gel column to give **3g** (202 mg, 91%) as red crystals.

M.p. 198−200 °C; IR (AT−IR): ν_{max} = 2963 (w), 2218 (w), 1687 (m), 1650 (m), 1506 (m), 1485 (w), 1440 (m), 1421 (m), 1389 (m), 1308 (w), 1212 (s), 1178 (m), 1155 (m), 1138 (w), 1097 (m), 1081 (w), 1058 (m), 1013 (w), 980 (w), 943 (w), 903 (m), 881 (w), 835 (w), 826 (w), 801 (w), 782 (m), 771 (m), 757 (m), 692 (w), 674 (w), 666 (w), 658 (w) cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ_H = 9.93 (m, 2H, $H_{4,8}$), 8.86 (s, 1H, H_2), 7.97 (d, 1H, *J* = 10.0 Hz, H_6), 7.78 (t, 1H, *J* = 10.0 Hz, H_7), 7.52−7.49 (m, 4H, Ph), 7.35−7.31 (m, 5H, Ph), 4.38 (s, 2H, CH_2), 3.99 (s, 3H, CO_2Me), 3.29 (sept, 1H, *J* = 7.0 Hz, *i*Pr), 1.44 (d, 6H, *J* = 7.0 Hz, *i*Pr) ppm; ^{13}C NMR (125 MHz, $CDCl_3$): δ_C = 194.41, 165.51, 153.82, 144.89, 144.29, 143.75, 140.96, 139.68, 139.15, 136.08, 132.40, 131.87, 131.66, 129.62, 128.38, 128.22, 123.44, 122.24, 121.71, 115.13, 89.43, 89.35, 51.43, 47.56, 39.36, 24.69 ppm; HRMS (MALDI−TOF): Calcd for $C_{31}H_{26}O_3$ + H^+ $[M + H]^+$ 447.1955; found: 447.1964.



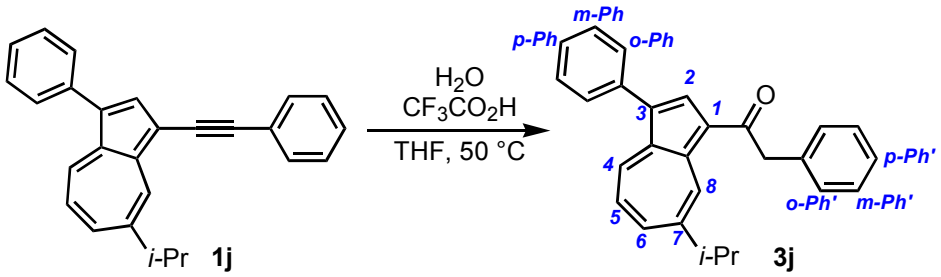
Water (0.5 mL) was added to a solution of **1h** (217 mg, 0.50 mmol) and CF_3CO_2H (0.5 mL) in THF (1 mL). The resulting mixture was stirred at 50 °C for 3 h. The reaction mixture was poured into aq. K_2CO_3. The precipitated crystals were corrected by filtration. The crystal was dissolved in CH_2Cl_2 and the solution was passed through the short silica gel column to give **3h** (208 mg, 92%) as red crystals.

M.p. 223−224 °C; IR (AT−IR): ν_{max} = 2955 (w), 2203 (w), 1686 (m), 1651 (m), 1597 (w), 1573 (w), 1508 (w), 1442 (m), 1420 (m), 1393 (m), 1308 (w), 1275 (w), 1211 (s), 1176 (m), 1160 (m), 1139 (w), 1096 (w), 1057 (m), 1037 (w), 1009 (w), 972 (w), 940 (w), 903 (m), 883 (w), 857 (w), 818 (m), 778 (m), 756 (m), 734 (w), 691 (m), 667 (w), 656 (w) cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ_H = 9.95 (m, 2H, $H_{4,8}$), 8.85 (s, 1H, H_2), 7.99 (d, 1H, *J* = 10.0 Hz, H_6), 7.81 (t, 1H, *J* = 10.0 Hz, H_7), 7.48 (dd, 2H, *J* = 7.5, 2.0 Hz, *m*-Ph), 7.35−7.31 (m, 3H, *o,p*-Ph), 7.15 (d, 1H, *J* = 3.5 Hz, $H_{3'}$ or $H_{4'}$ of Th), 6.89 (d, 1H, *J* = 3.5 Hz, $H_{3'}$ or $H_{4'}$ of Th), 4.55 (s, 2H, CH_2), 4.00 (s, 3H, CO_2Me), 3.30 (sept, 1H, *J* = 7.0 Hz, *i*Pr), 1.45 (d, 6H, *J* = 7.0 Hz, *i*Pr) ppm; ^{13}C NMR (125 MHz, $CDCl_3$): δ_C = 192.34, 165.44, 154.06, 145.04, 144.40, 143.55, 141.11, 139.73, 139.24, 139.07, 132.57, 131.82, 131.42, 128.38, 128.31, 126.63, 123.15, 122.81, 121.49, 115.24, 92.93, 83.00, 51.44, 41.84, 39.38, 24.68 ppm; HRMS (MALDI−TOF): Calcd for $C_{29}H_{24}O_3S + H^+$ $[M + H]^+$ 453.1519; found: 453.1537.



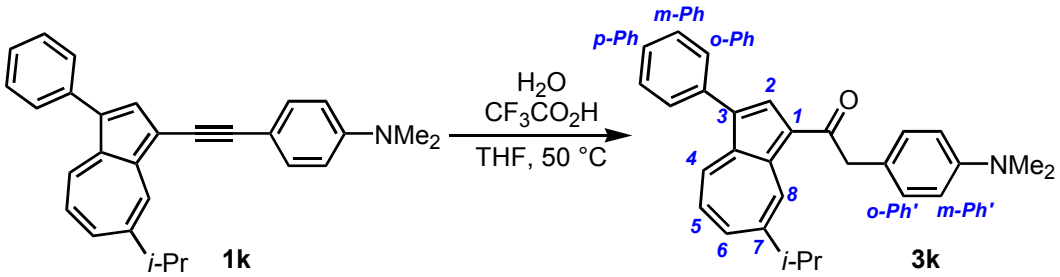
Water (1 mL) was added to a solution of **1h** (200 mg, 0.30 mmol) and CF_3CO_2H (1 mL) in THF (2 mL). The resulting mixture was stirred at 50 °C for 5 h. The reaction mixture was poured into aq. K_2CO_3 and extracted with CH_2Cl_2. The organic layer was washed with brine, dried over Na_2SO_4, and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel with hexane/AcOEt (3 : 1) to give **3g** (157 mg, 72%) as a brown oil.

IR (AT−IR): ν_{max} = 3368 (w), 2971 (w), 1693 (m), 1654 (w), 1637 (w), 1607 (w), 1508 (s), 1442 (m), 1419 (m), 1393 (m), 1355 (w), 1313 (w), 1213 (s), 1177 (m), 1157 (w), 1097 (w), 1080 (w), 1057 (w), 1013 (w), 942 (w), 908 (m), 880 (w), 810 (w), 779 (m), 731 (s), 689 (w), 668 (w) cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ_H = 9.93 (d, 2H, *J* = 10.0 Hz, H_8), 9.90 (d, 2H, *J* = 1.0 Hz, H_4), 8.87 (s, 2H, H_2), 7.93 (d, 2H, *J* = 10.0 Hz, H_6), 7.74 (t, 2H, *J* = 10.0 Hz, H_7), 7.22 (d, 4H, *J* = 8.5 Hz, *m*-Ph), 7.01 (d, 4H, *J* = 8.5 Hz, *p*-Ph), 5.70 (br s, 1H, NH), 4.29 (s, 4H, CH_2), 3.98 (s, 6H, CO_2Me), 3.28 (sept, 2H, *J* = 7.0 Hz, *i*Pr), 1.43 (d, 12H, *J* = 7.0 Hz, *i*Pr) ppm; ^{13}C NMR (125 MHz, $CDCl_3$): δ_C = 195.37, 165.53, 153.53, 144.75, 144.23, 143.78, 141.90, 140.76, 139.63, 138.95, 132.21, 130.37, 127.92, 122.35, 117.99, 114.95, 51.36, 46.92, 39.28, 24.64 ppm; HRMS (MALDI−TOF): Calcd for $C_{46}H_{43}NO_6$ + Ag^+ $[M + Ag]^+$ 812.2136; found: 812.2137.



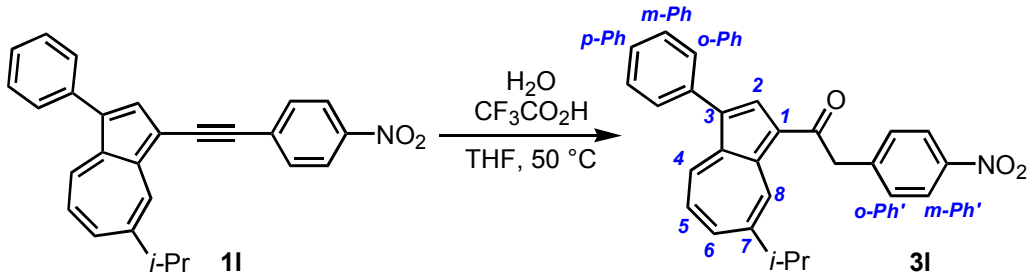
Water (0.5 mL) was added to a solution of **1j** (173 mg, 0.50 mmol) and CF_3CO_2H (0.5 mL) in THF (1 mL). The resulting mixture was stirred at 50 °C for 3 h. The reaction mixture was poured into water. The precipitated crystals were corrected by filtration. The crystal was dissolved in CH_2Cl_2 and the solution was passed through the short silica gel column to give **3j** (123 mg, 71%) as purple crystals.

M.p. 102−104 °C; IR (AT−IR): ν_{max} = 2960 (w), 1643 (m), 1600 (w), 1570 (w), 1525 (w), 1493 (w), 1426 (s), 1385 (m), 1365 (m), 1310 (w), 1265 (w), 1210 (m), 1196 (m), 1170 (w), 1115 (w), 1076 (w), 1031 (w), 949 (w), 903 (m), 883 (w), 843 (w), 803 (m), 774 (m), 764 (w), 740 (m), 719 (m), 706 (s), 696 (m), 686 (w), 661 (w) cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ_H = 10.11 (s, 1H, H_8), 8.57 (d, 1H, *J* = 10.0 Hz, H_4), 8.47 (s, 1H, H_2), 7.78 (d, 1H, *J* = 10.0 Hz, H_6), 7.59 (d, 2H, *J* = 7.5 Hz, *o*-Ph or *o*-Ph'), 7.53 (t, 2H, *J* = 7.5 Hz, *m*-Ph or *m*-Ph'), 7.45−7.40 (m, 4H, H_5, *o*-Ph or *o*-Ph', *p*-Ph or *p*-Ph'), 7.36 (t, 2H, *J* = 7.5 Hz, *m*-Ph or *m*-Ph'), 7.27 (t, 1H, *J* = 7.5 Hz, *p*-Ph or *p*-Ph'), 4.44 (s, 2H, CH_2), 3.24 (t, 1H, *J* = 7.0 Hz, *i*Pr), 1.42 (d, 6H, *J* = 7.0 Hz, *i*Pr) ppm; ^{13}C NMR (125 MHz, $CDCl_3$): δ_C = 194.67, 151.36, 141.84, 140.78, 140.42, 140.37, 138.99, 136.57, 136.19, 135.52, 130.05, 129.67, 129.65, 128.83, 128.62, 127.84, 126.92, 126.61, 122.30, 48.03, 39.22, 24.71 ppm; HRMS (MALDI−TOF): Calcd for $C_{27}H_{24}O + H^+$ $[M + H]^+$ 365.1900; found: 365.1911.



Water (0.5 mL) was added to a solution of **1k** (195 mg, 0.50 mmol) and CF_3CO_2H (0.5 mL) in THF (1 mL). The resulting mixture was stirred at 50 °C for 3 h. The reaction mixture was poured into water. The precipitated crystal was corrected by filtration. The crystal was dissolved in CH_2Cl_2 and the solution was passed through the short silica gel column to give **3k** (167 mg, 82%) as brown crystals.

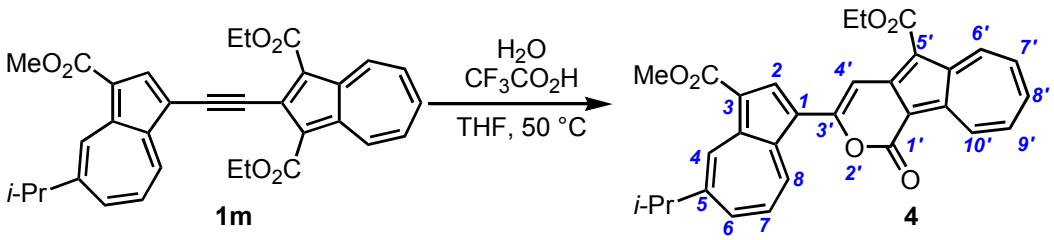
M.p. 137−139 °C; IR (AT−IR): ν_{max} = 2961 (w), 2927 (w), 1649 (m), 1617 (m), 1573 (w), 1524 (s), 1489 (w), 1465 (w), 1424 (s), 1389 (w), 1381 (m), 1364 (m), 1348 (m), 1309 (w), 1265 (w), 1228 (w), 1196 (m), 1169 (w), 1118 (w), 1071 (w), 1029 (m), 998 (w), 950 (w), 923 (w), 903 (m), 879 (w), 844 (w), 800 (s), 772 (s), 762 (w), 738 (w), 707 (s), 697 (w), 681 (w), 664 (w), 641 (w), 632 (w), 618 (w) cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ_H = 10.09 (s, 1H, H_8), 8.54 (d, 1H, *J* = 10.0 Hz, H_4), 8.46 (s, 1H, H_2), 7.75 (d, 1H, *J* = 10.0 Hz, H_6), 7.58 (d, 2H, *J* = 7.6 Hz, *o*-Ph), 7.51 (t, 2H, *J* = 7.6 Hz, *m*-Ph), 7.42−7.38 (m, 2H, H_5, *p*-Ph), 7.25 (d, 2H, *J* = 8.3 Hz, *o*-Ph'), 6.74 (d, 2H, *J* = 8.3 Hz, *m*-Ph'), 4.32 (s, 2H, CH_2), 3.21 (t, 1H, *J* = 7.0 Hz, *i*Pr), 2.91 (s, 6H, NMe_2), 1.40 (d, 6H, *J* = 7.0 Hz, *i*Pr) ppm; ^{13}C NMR (125 MHz, $CDCl_3$): δ_C = 195.67, 151.15, 149.60, 141.84, 140.63, 140.51, 140.46, 138.88, 136.73, 135.41, 130.22, 129.95, 129.73, 128.84, 127.64, 126.88, 124.19, 122.47, 113.23, 47.19, 40.89, 39.23, 24.71 ppm; HRMS (MALDI−TOF): Calcd for $C_{29}H_{29}NO^+$ $[M]^+$ 407.2244; found: 407.2243.



1l **3l**

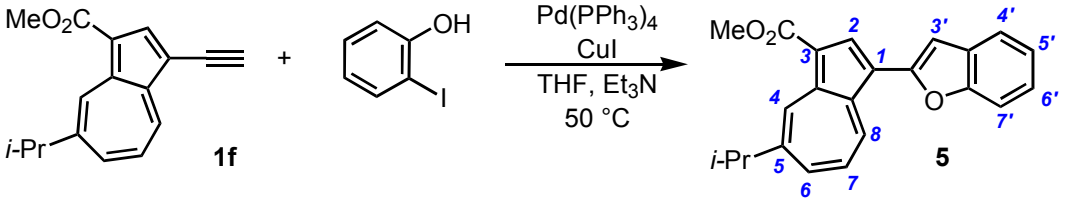
Water (0.5 mL) was added to a solution of **1l** (100 mg, 0.26 mmol) and CF_3CO_2H (0.5 mL) in THF (1.5 mL). The resulting mixture was stirred at 50 °C for 4 h. The reaction mixture was poured into aq. K_2CO_3. The precipitated crystals were corrected by filtration. The crystal was dissolved in CH_2Cl_2 and the solution was passed through the short silica gel column to give **3l** (101 mg, 97%) as brown crystals.

M.p. 141−143 °C; IR (AT−IR): ν_{max} = 2966 (w), 1638 (m), 1599 (w), 1575 (w), 1509 (s), 1490 (w), 1467 (w), 1430 (m), 1419 (m), 1382 (w), 1364 (m), 1341 (s), 1309 (w), 1212 (w), 1199 (m), 1176 (w), 1142 (w), 1109 (w), 1062 (w), 1028 (w), 949 (w), 906 (m), 880 (m), 859 (m), 815 (w), 802 (m), 768 (m), 740 (w), 724 (m), 705 (s), 688 (w), 667 (m), 654 (w) cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ_H = 10.07 (d, 1H, *J* = 1.1 Hz, H_8), 8.59 (d, 1H, *J* = 10.0 Hz, H_4), 8.42 (s, 1H, H_2), 8.20 (d, 2H, *J* = 8.6 Hz, *m*-Ph'), 7.81 (d, 1H, *J* = 10.0 Hz, H_6), 7.59 (d, 2H, *J* = 7.5 Hz, *m*-Ph), 7.51−7.54 (m, 4H, *o*-Ph, *o*-Ph'), 7.48 (t, 1H, *J* = 10.0 Hz, H_5), 7.41 (t, 1H, *J* = 7.5 Hz, *p*-Ph), 4.54 (s, 2H, CH_2), 3.23 (sept, 1H, *J* = 7.0 Hz, *i*Pr), 1.41 (d, 6H, *J* = 7.0 Hz, *i*Pr) ppm; ^{13}C NMR (125 MHz, $CDCl_3$): δ_C = 192.49, 151.91, 146.84, 143.78, 141.96, 141.20, 140.34, 139.86, 139.41, 136.26, 135.84, 130.67, 130.38, 129.60, 128.88, 128.36, 127.09, 123.69, 121.70, 47.37, 39.23, 24.69 ppm; HRMS (MALDI−TOF): Calcd for $C_{27}H_{23}NO_3$ + H^+ $[M + H]^+$ 410.1751; found: 410.1745.



Water (0.5 mL) was added to a solution of **1m** (261 mg, 0.50 mmol) and CF_3CO_2H (0.5 mL) in THF (3 mL). The resulting mixture was stirred at 50 °C for 5 h. The reaction mixture was poured into aq. K_2CO_3. The precipitated crystals were corrected by filtration. The crystal was dissolved in CH_2Cl_2 and the solution was passed through the short silica gel column to give **4** (223 mg, 90%) as red crystals.

M.p. 245−246 °C; IR (AT−IR): ν_{max} = 2954 (w), 1686 (s), 1596 (m), 1586 (m), 1576 (m), 1523 (m), 1498 (s), 1466 (m), 1442 (m), 1419 (m), 1385 (m), 1332 (w), 1283 (w), 1251 (m), 1212 (s), 1151 (m), 1103 (w), 1087 (m), 1035 (m), 988 (w), 968 (w), 939 (w), 906 (w), 895 (w), 874 (w), 863 (w), 833 (m), 807 (w), 789 (m), 772 (m), 759 (w), 733 (w), 714 (w), 702 (w), 677 (w), 665 (m) cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ_H = 9.87 (s, 1H, H_4), 9.75−9.72 (m, 2H, $H_{6',10'}$), 9.46 (d, 1H, *J* = 10.0 Hz, H_8), 8.88 (s, 1H, H_2), 8.06 (s, 1H, $H_{4'}$), 7.93−7.82 (m, 4H, $H_{6,7',8',9'}$), 7.67 (t, 1H, *J* = 10.0 Hz, H_7), 4.57 (q, 2H, *J* = 7.2 Hz, CO_2Et), 4.00 (s, 3H, CO_2Me), 3.28 (sept, 1H, *J* = 7.0 Hz, *i*Pr), 1.58 (t, 3H, *J* = 7.2 Hz, CO_2Et), 1.46 (d, 6H, *J* = 7.0 Hz, *i*Pr) ppm; ^{13}C NMR (125 MHz, $CDCl_3$): δ_C = 165.68, 165.55, 160.11, 158.07, 151.74, 151.13, 147.89, 144.45, 144.03, 140.80, 140.71, 140.00, 138.94, 138.90, 137.38, 137.30, 136.81, 133.17, 129.48, 119.15, 116.18, 109.58, 107.13, 101.12, 60.36, 51.39, 39.18, 24.68, 14.80 ppm, One signal is overlapped with other signal. HRMS (MALDI−TOF): Calcd for $C_{31}H_{26}O_6^+$ $[M]^+$ 494.1724; found: 494.1715.



To a degassed solution of **1f** (103 mg, 0.41 mmol), 2-iodophenol (152 mg, 0.69 mmol), and CuI (11 mg, 0.058 mmol) in triethylamine (2 mL) and THF (2 mL) was added tetrakis(triphenylphosphine)palladium(0) (16 mg, 0.014 mmol). The resulting mixture was stirred at 50 °C for 18 h under an Ar atmosphere. The reaction mixture was poured into a 10% NH_4Cl solution and extracted with hexane. The organic layer was washed with brine, dried over Na_2SO_4, and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel with hexane/AcOEt (10 : 1) to give **5** (77 mg, 55%) as green crystals.

M.p. 129−131 °C; IR (AT−IR): ν_{max} = 2959 (w), 1693 (m), 1573 (w), 1524 (w), 1447 (m), 1386 (w), 1303 (w), 1259 (w), 1237 (w), 1208 (s), 1169 (w), 1125 (w), 1091 (w), 1012 (w), 964 (w), 929 (w), 898 (m), 800 (m), 776 (m), 749 (m), 738 (m) cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ_H = 9.80 (d, 1H, *J* = 1.7 Hz, H_4), 9.12 (d, 1H, *J* = 10.0 Hz, H_8), 8.74 (s, 1H, H_2), 7.80 (d, 1H, *J* = 10.0 Hz, H_6), 7.61 (d, 1H, *J* = 7.5 Hz, $H_{4'}$), 7.57 (d, 1H, *J* = 7.5 Hz, $H_{7'}$), 7.52 (t, 1H, *J* = 10.0 Hz, H_7), 7.30−7.24 (m, 2H, $H_{5',6'}$), 7.01 (s, 1H, $H_{3'}$), 3.99 (s, 3H, CO_2Me), 3.24 (sept, 1H, *J* = 7.0 Hz, *i*Pr), 1.45 (d, 6H, *J* = 7.0 Hz, *i*Pr) ppm; ^{13}C NMR (125 MHz, $CDCl_3$): δ_C = 165.70, 154.64, 153.89, 150.23, 142.69, 139.56, 139.27, 139.22, 138.52, 136.31, 129.41, 127.89, 123.71, 122.98, 120.50, 117.47, 115.54, 110.98, 102.01, 51.27, 39.14, 24.67 ppm; HRMS (MALDI−TOF): Calcd for $C_{23}H_{20}O_3^+$ $[M]^+$ 344.1407; found: 344.1412.

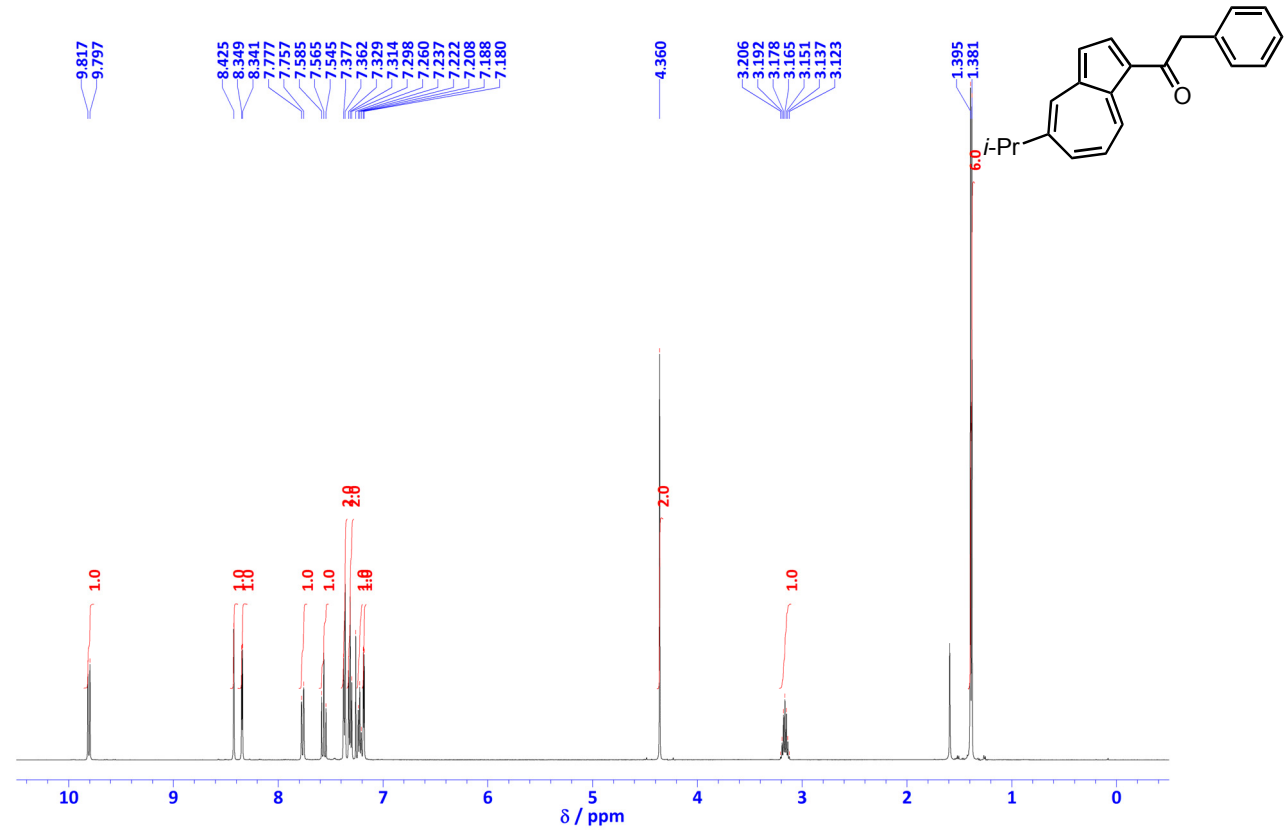


Figure S1. ^{1}H NMR spectrum of **2** in $CDCl_3$ (500 MHz).

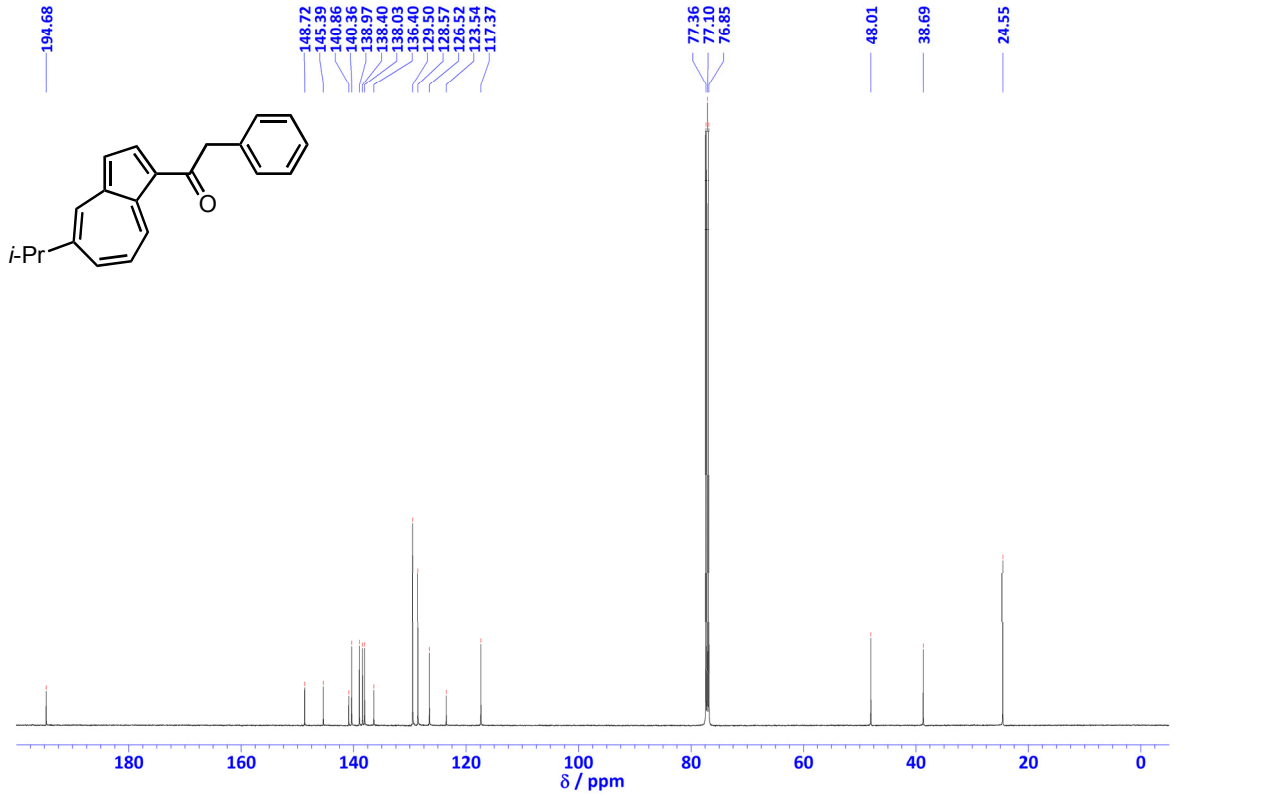


Figure S2. ^{13}C NMR spectrum of **2** in $CDCl_3$ (125 MHz).

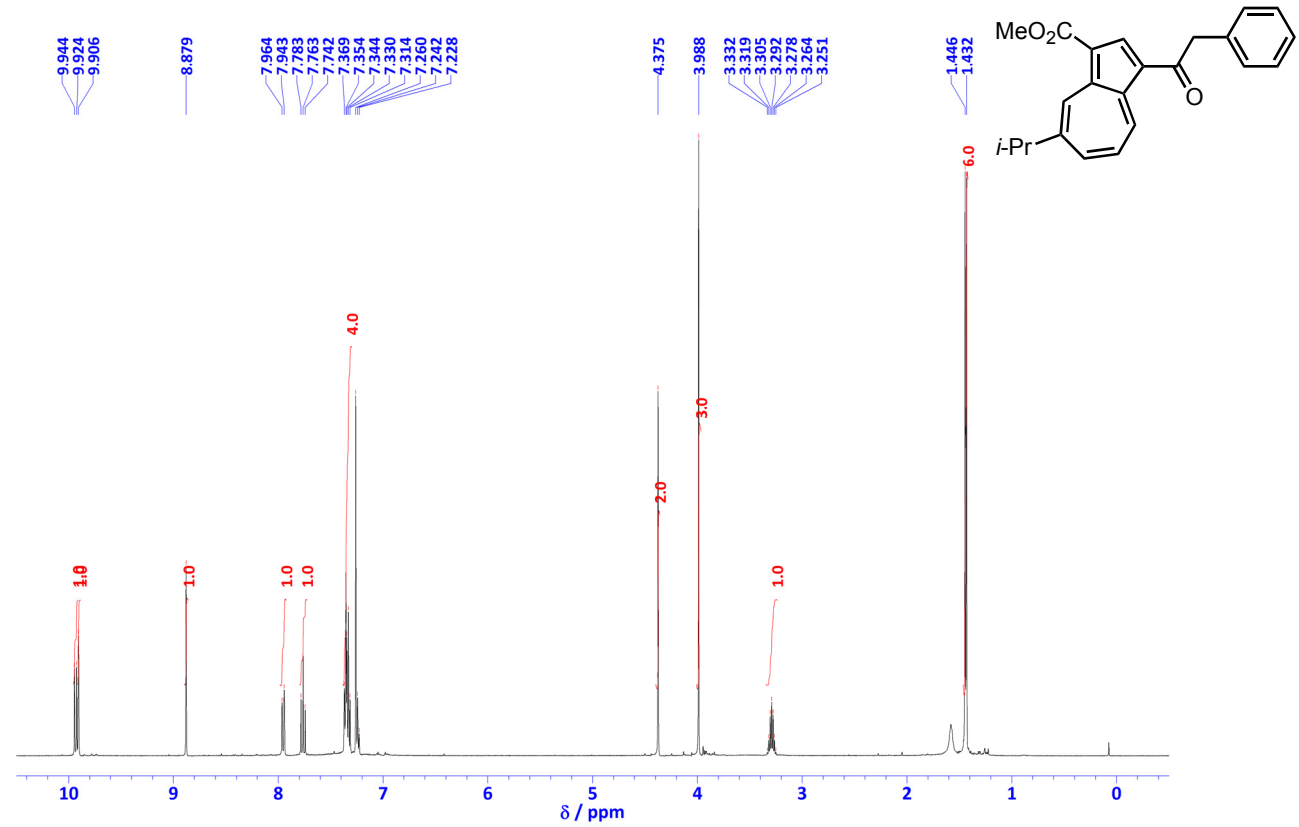


Figure S3. ^{1}H NMR spectrum of **3a** in $CDCl_3$ (500 MHz).

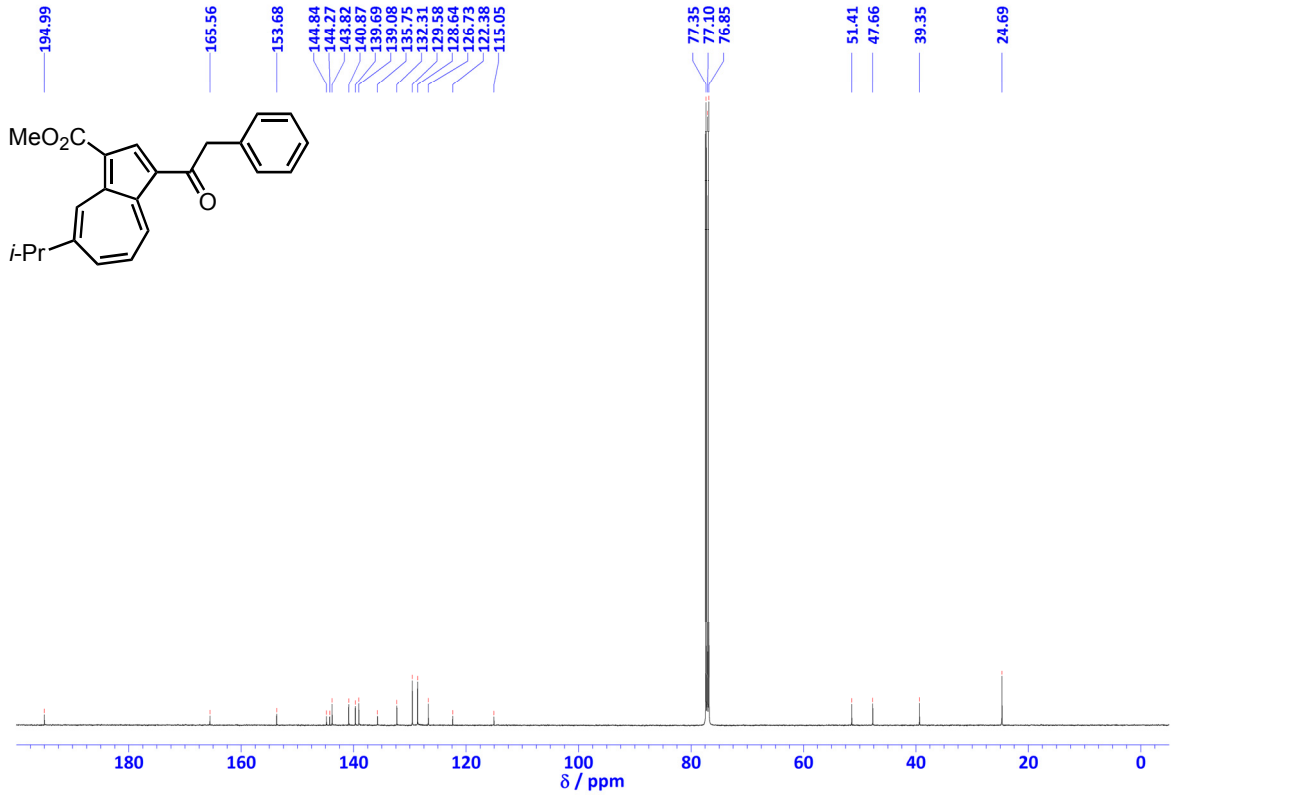


Figure S4. ^{13}C NMR spectrum of **3a** in $CDCl_3$ (125 MHz).

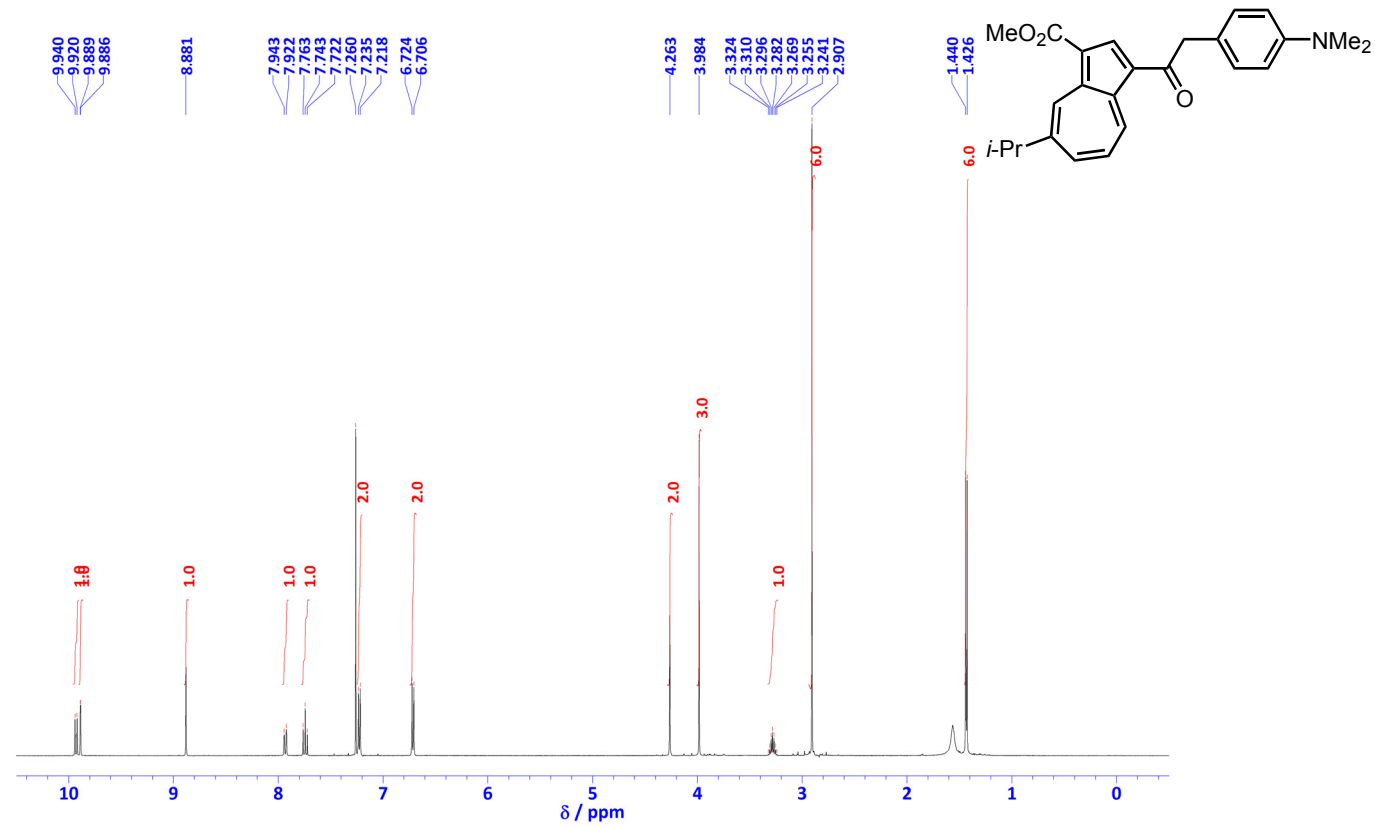


Figure S5. ^{1}H NMR spectrum of **3b** in $CDCl_3$ (500 MHz).

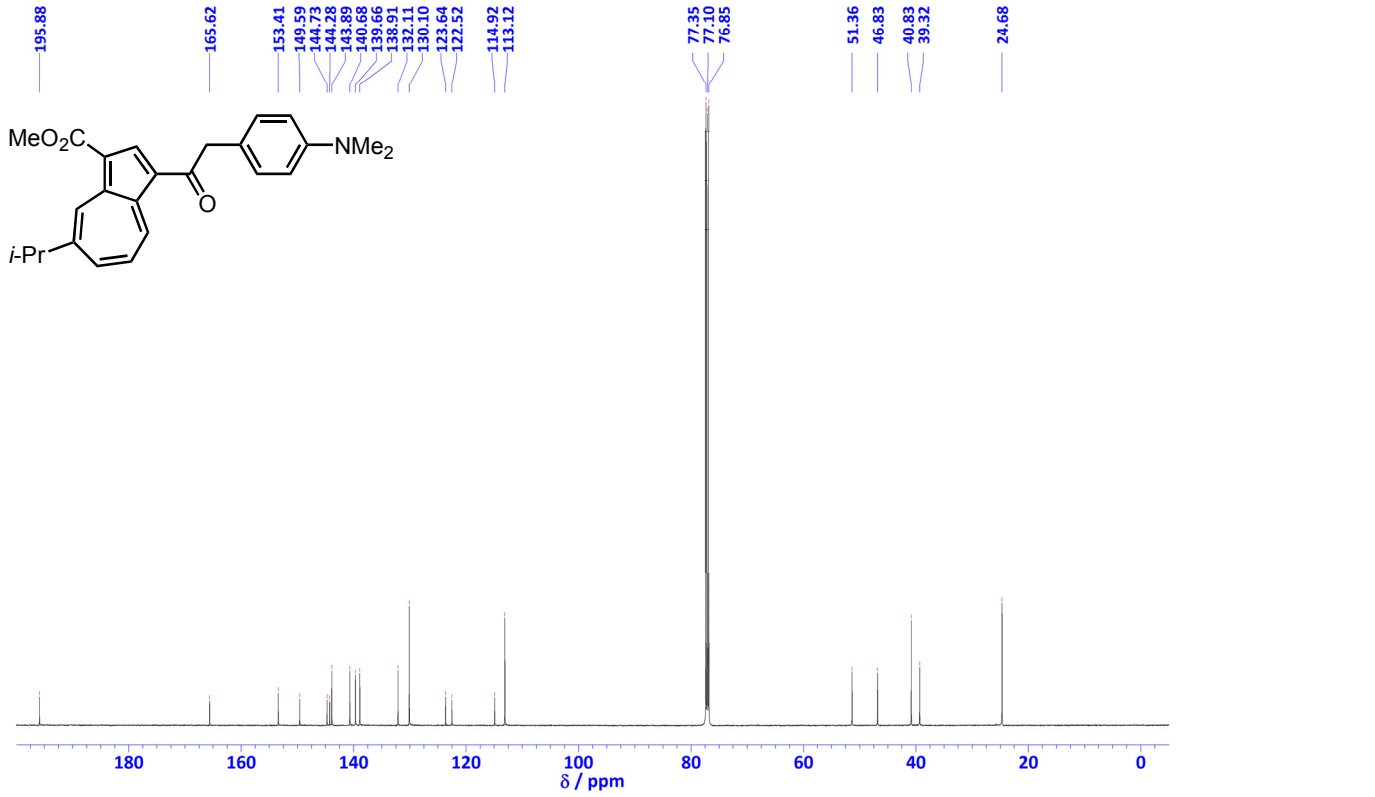


Figure S6. ^{13}C NMR spectrum of **3b** in $CDCl_3$ (125 MHz).

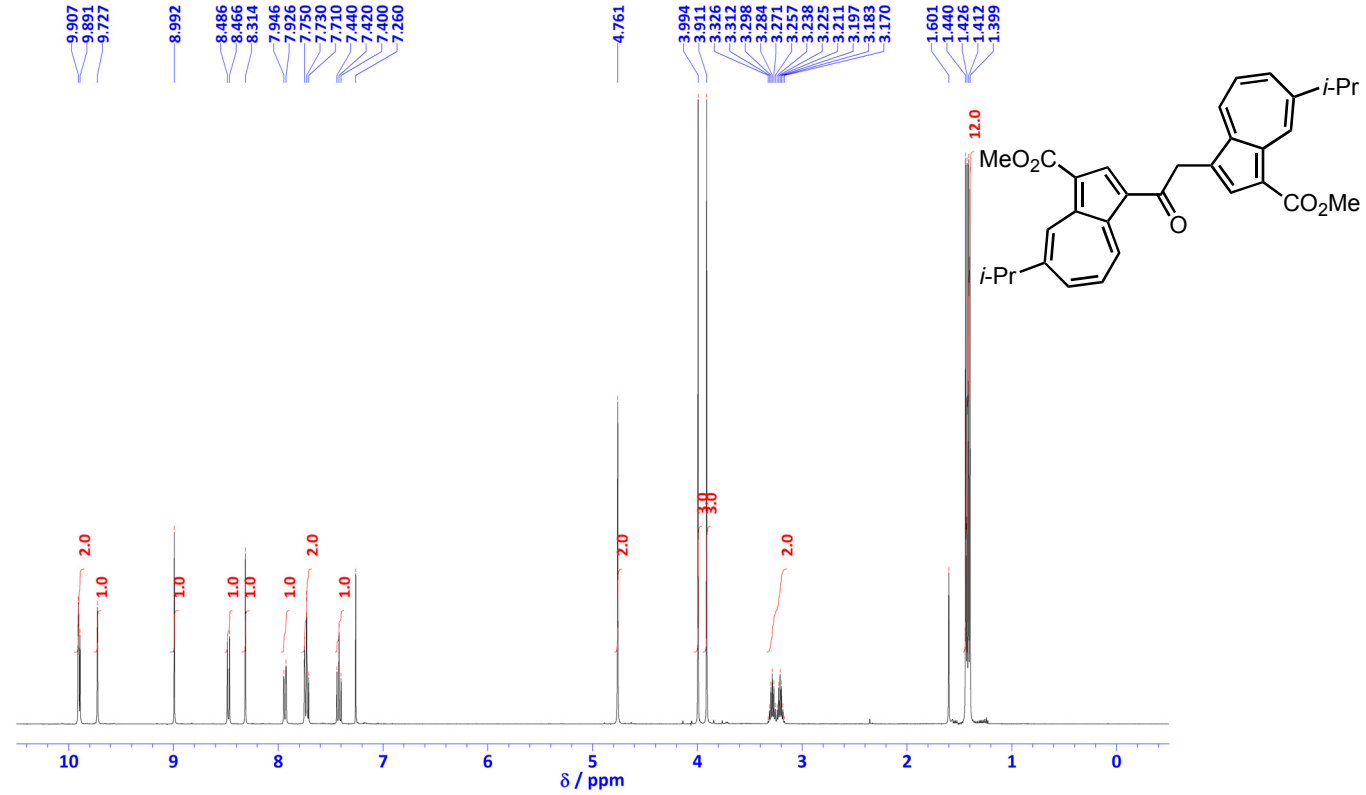


Figure S7. ^{1}H NMR spectrum of **3c** in $CDCl_3$ (500 MHz).

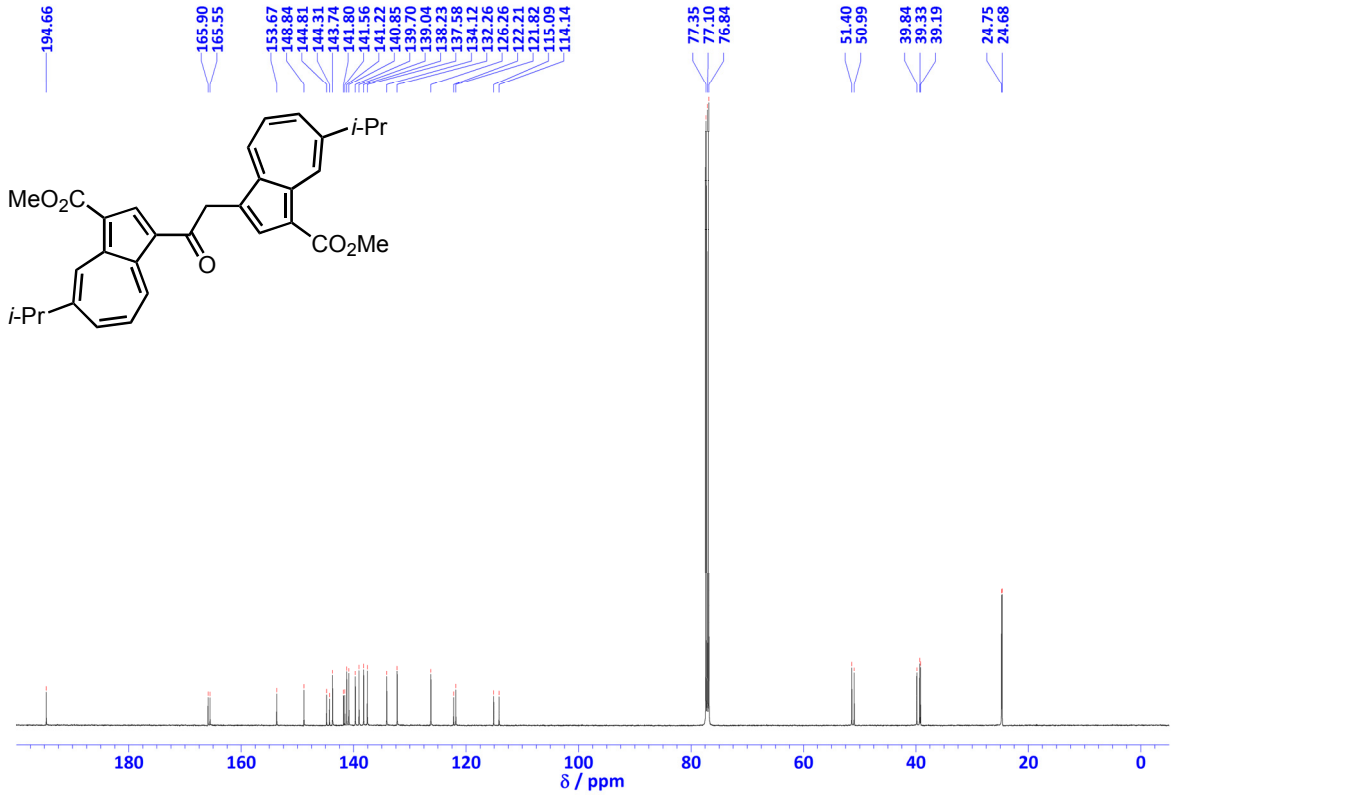


Figure S8. ^{13}C NMR spectrum of **3c** in $CDCl_3$ (125 MHz).

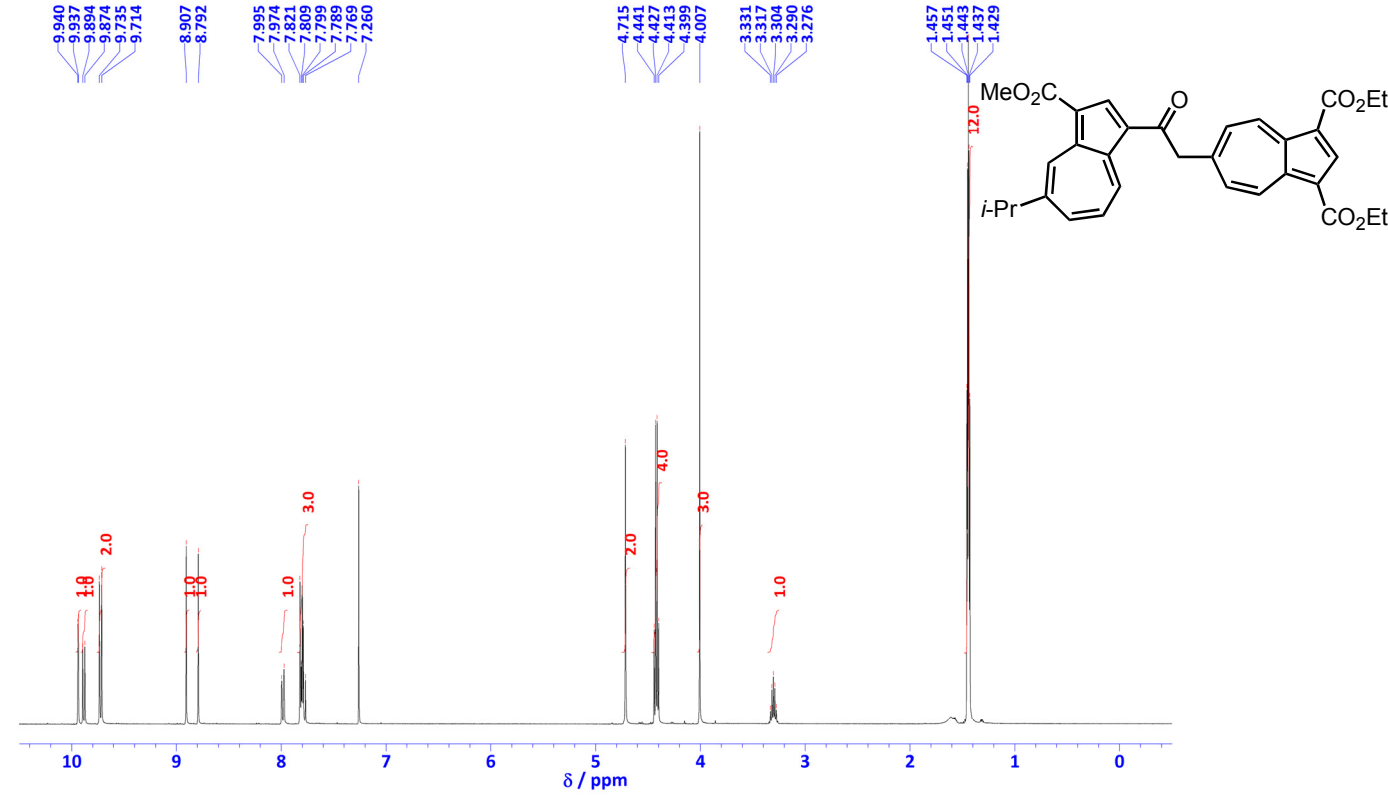


Figure S9. ^{1}H NMR spectrum of **3d** in $CDCl_3$ (500 MHz).

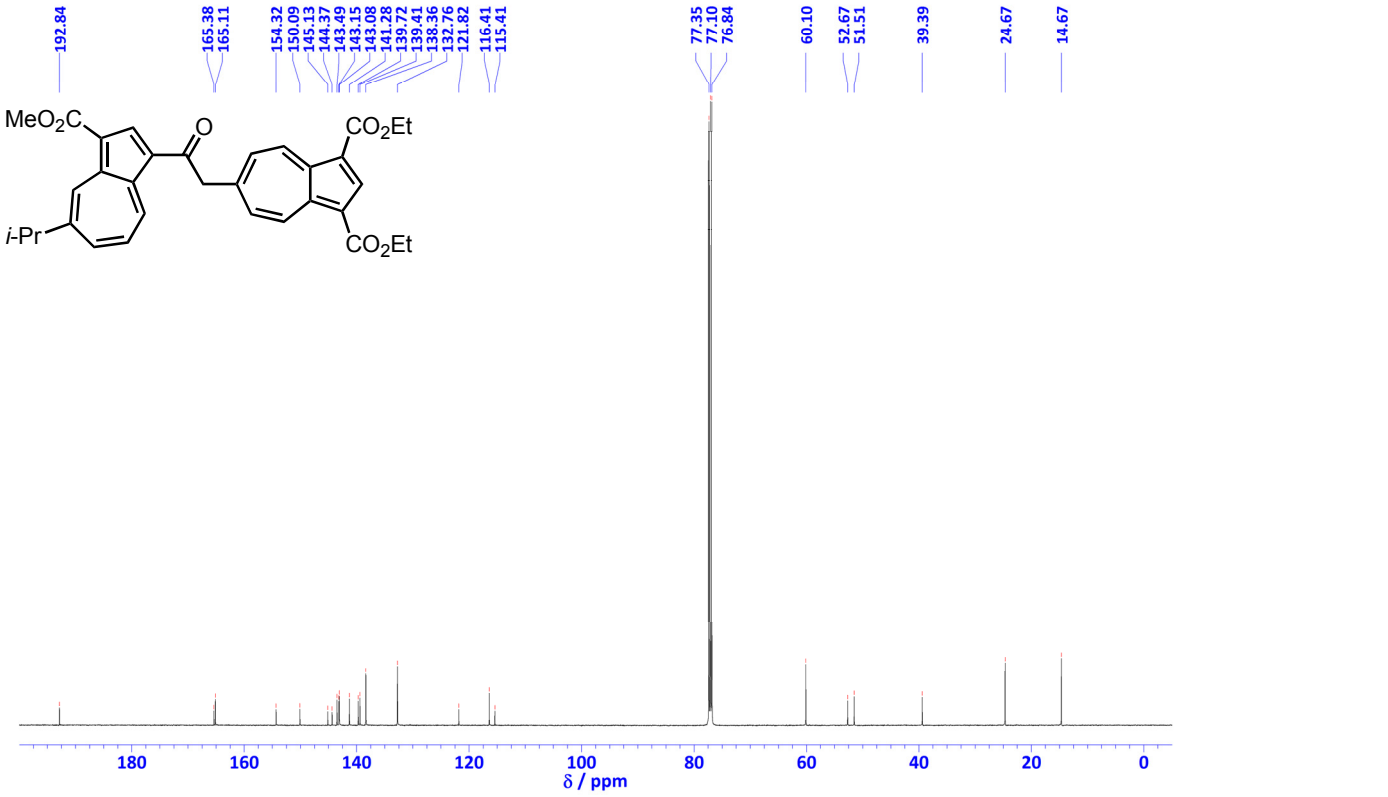


Figure S10. ^{13}C NMR spectrum of **3d** in $CDCl_3$ (125 MHz).

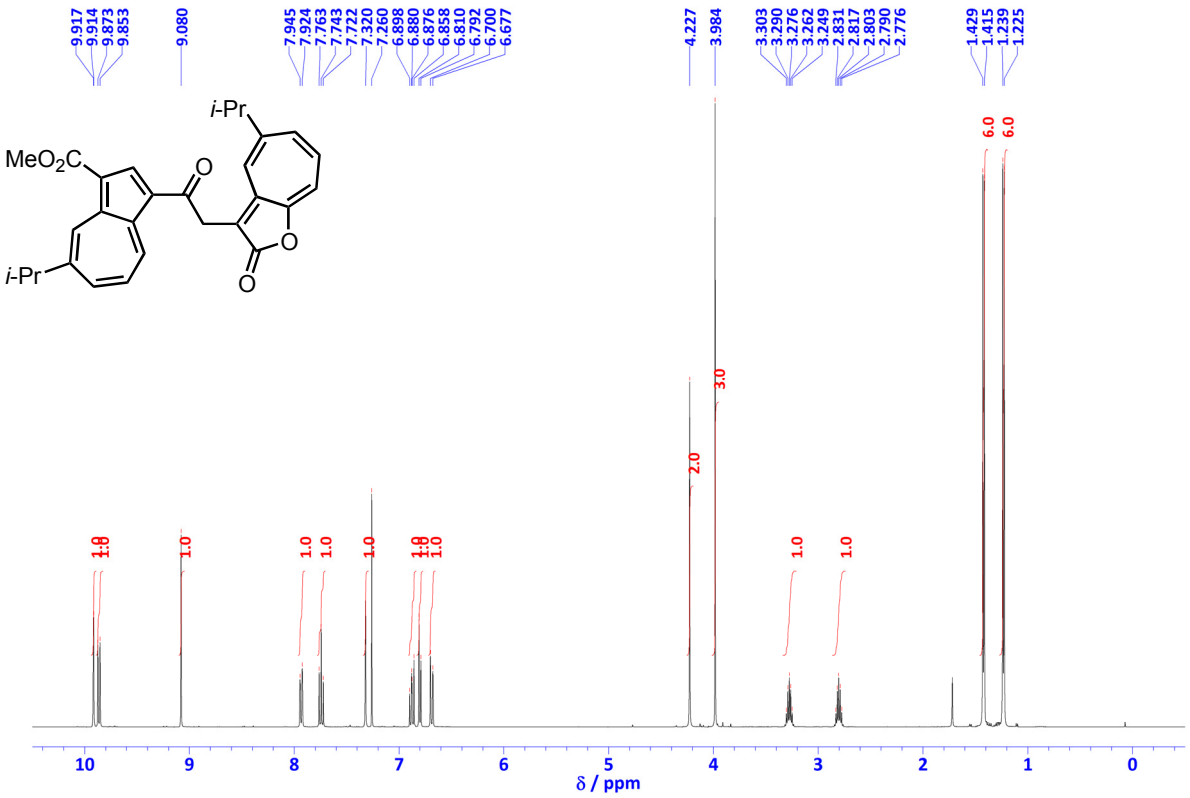


Figure S11. ^{1}H NMR spectrum of **3e** in $CDCl_3$ (500 MHz).

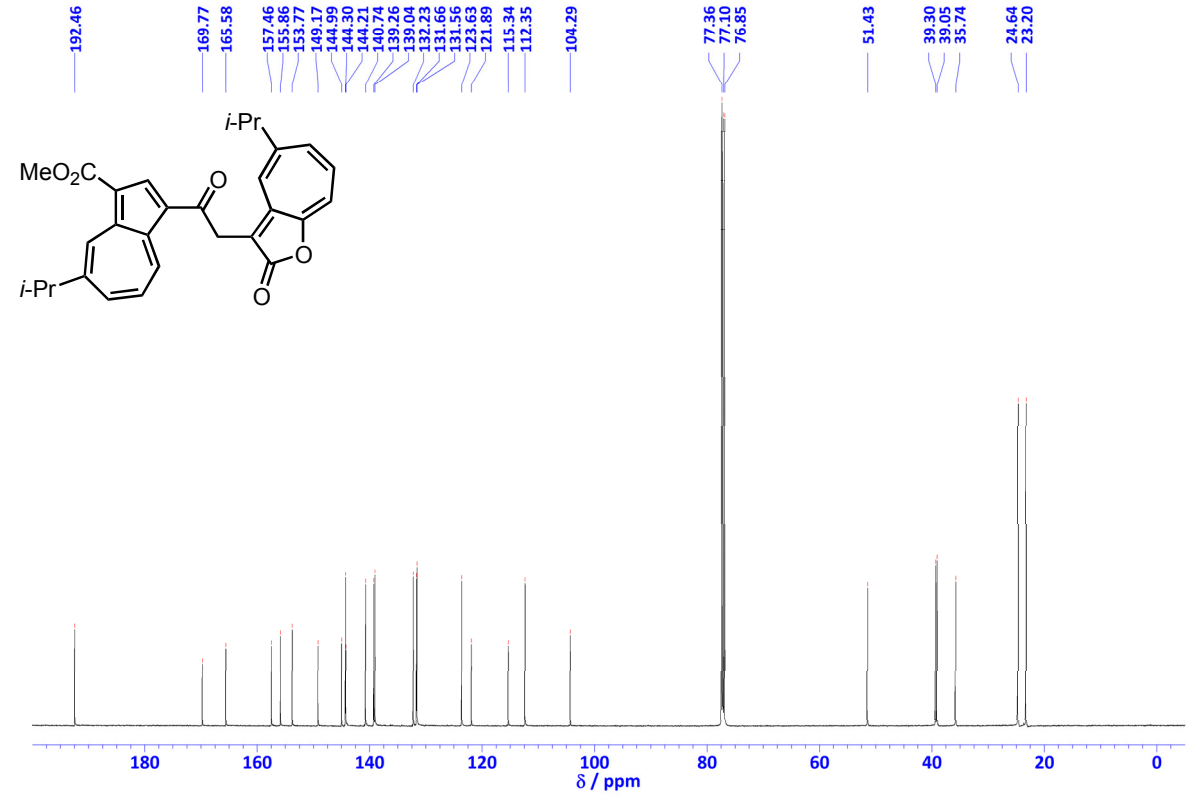


Figure S12. ^{13}C NMR spectrum of **3e** in $CDCl_3$ (125 MHz).

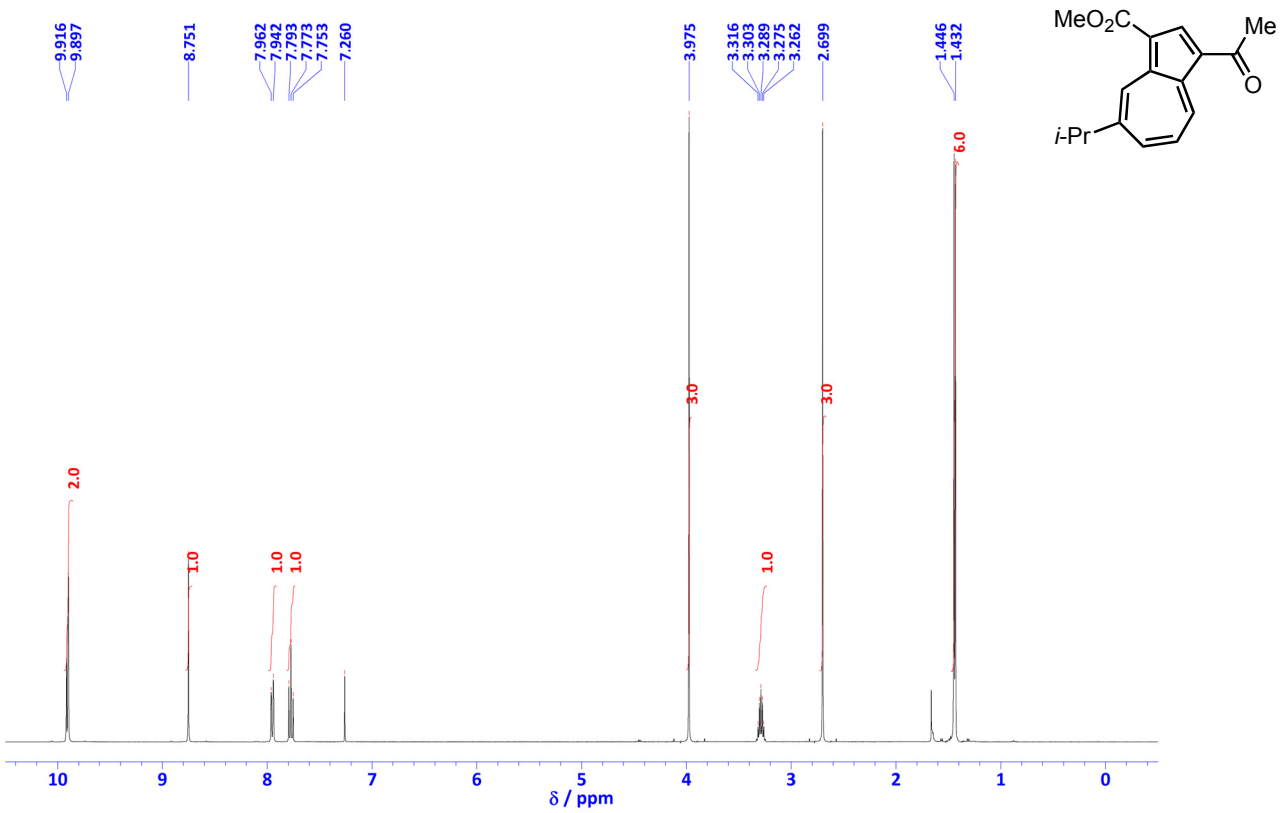


Figure S13. ^{1}H NMR spectrum of **3f** in $CDCl_3$ (500 MHz).

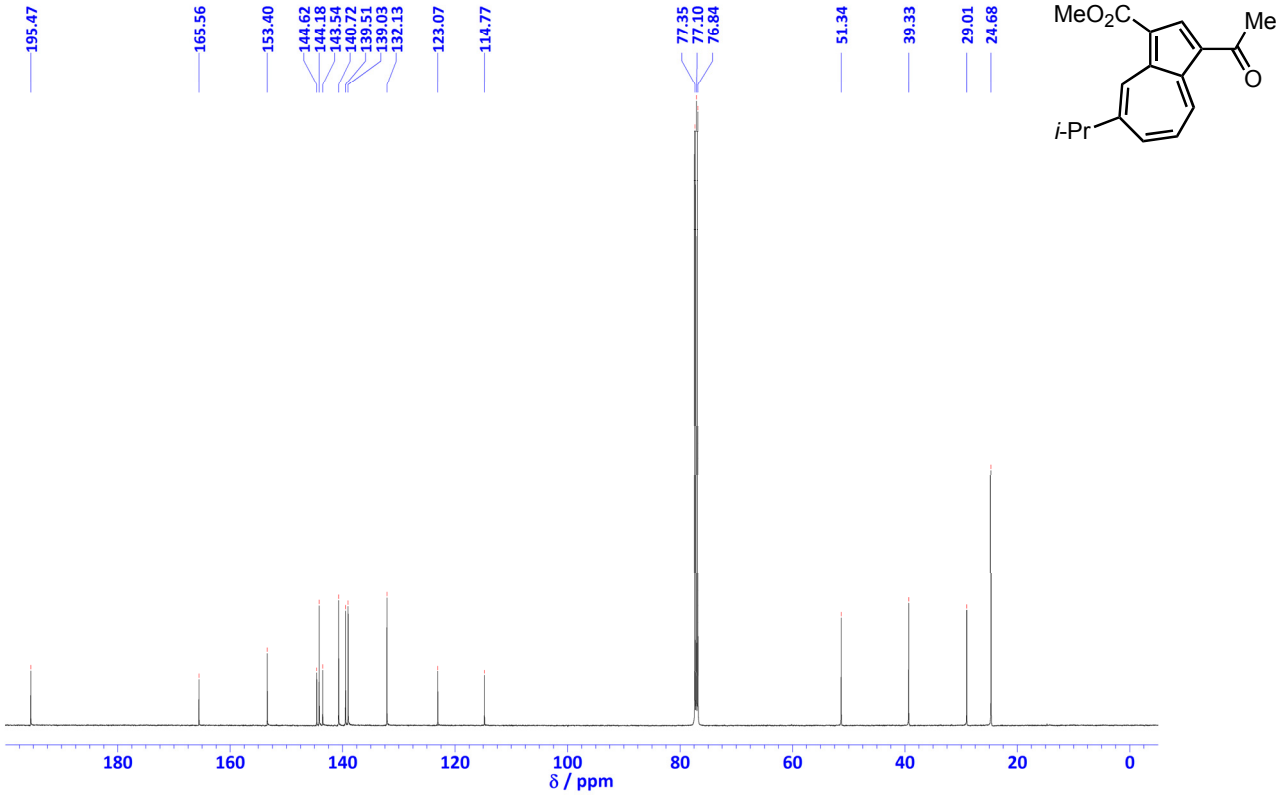


Figure S14. ^{13}C NMR spectrum of **3f** in $CDCl_3$ (125 MHz).

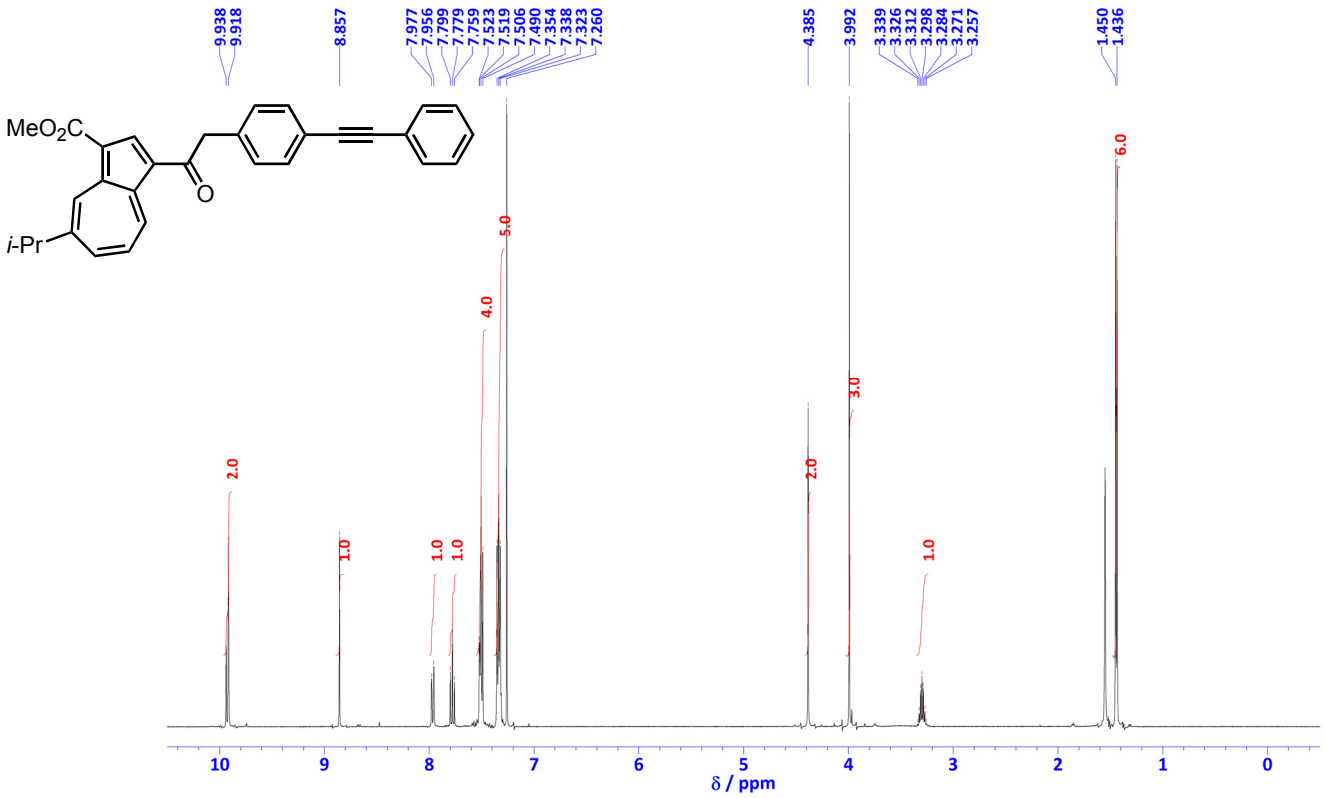


Figure S15. ^{1}H NMR spectrum of **3g** in $CDCl_3$ (500 MHz).

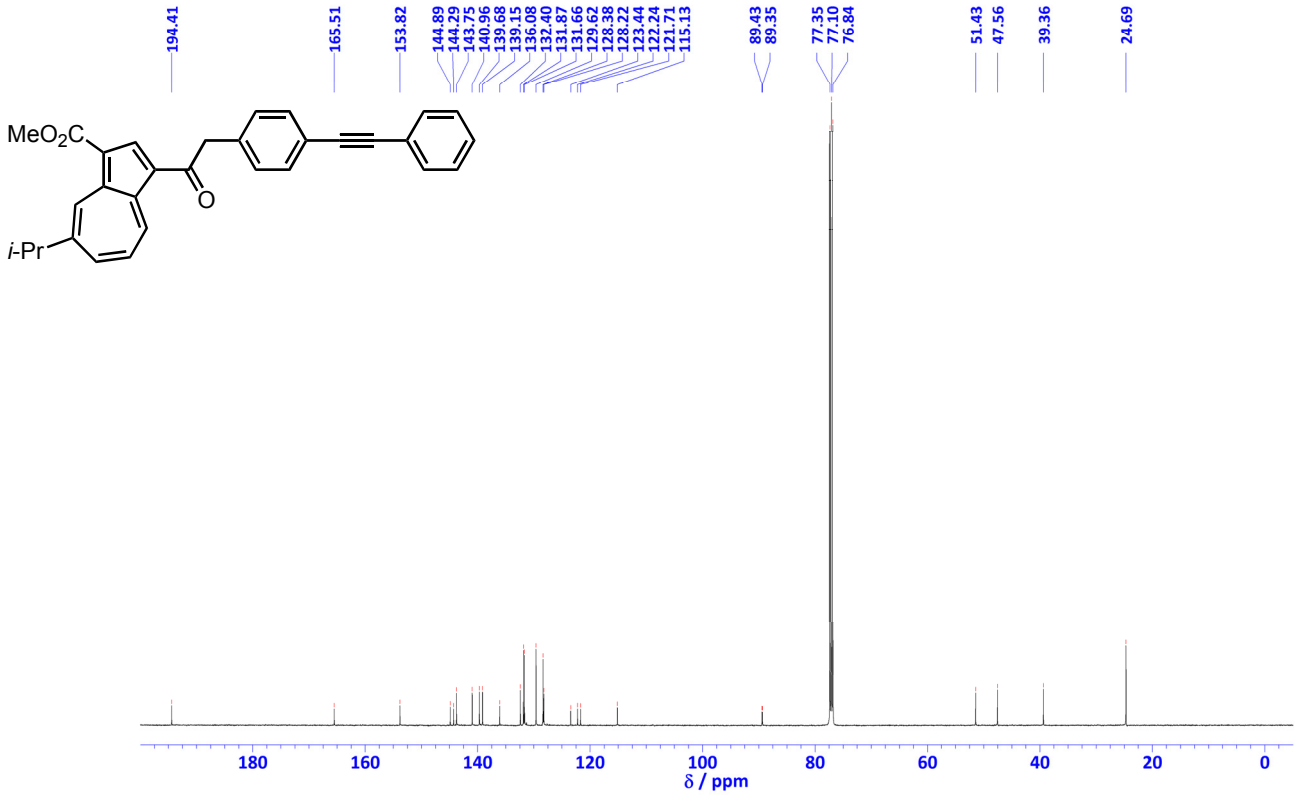


Figure S16. ^{13}C NMR spectrum of **3g** in $CDCl_3$ (125 MHz).

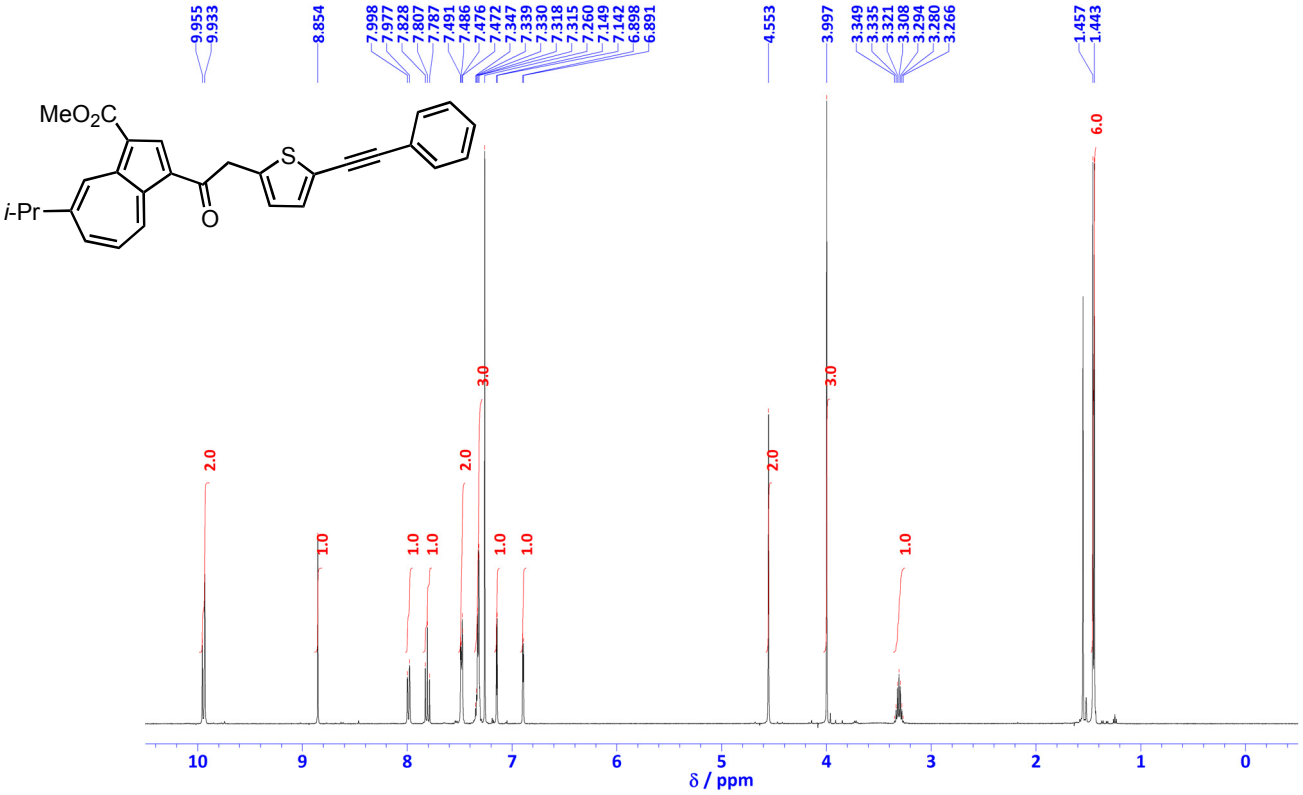


Figure S17. ^{1}H NMR spectrum of **3h** in $CDCl_3$ (500 MHz).

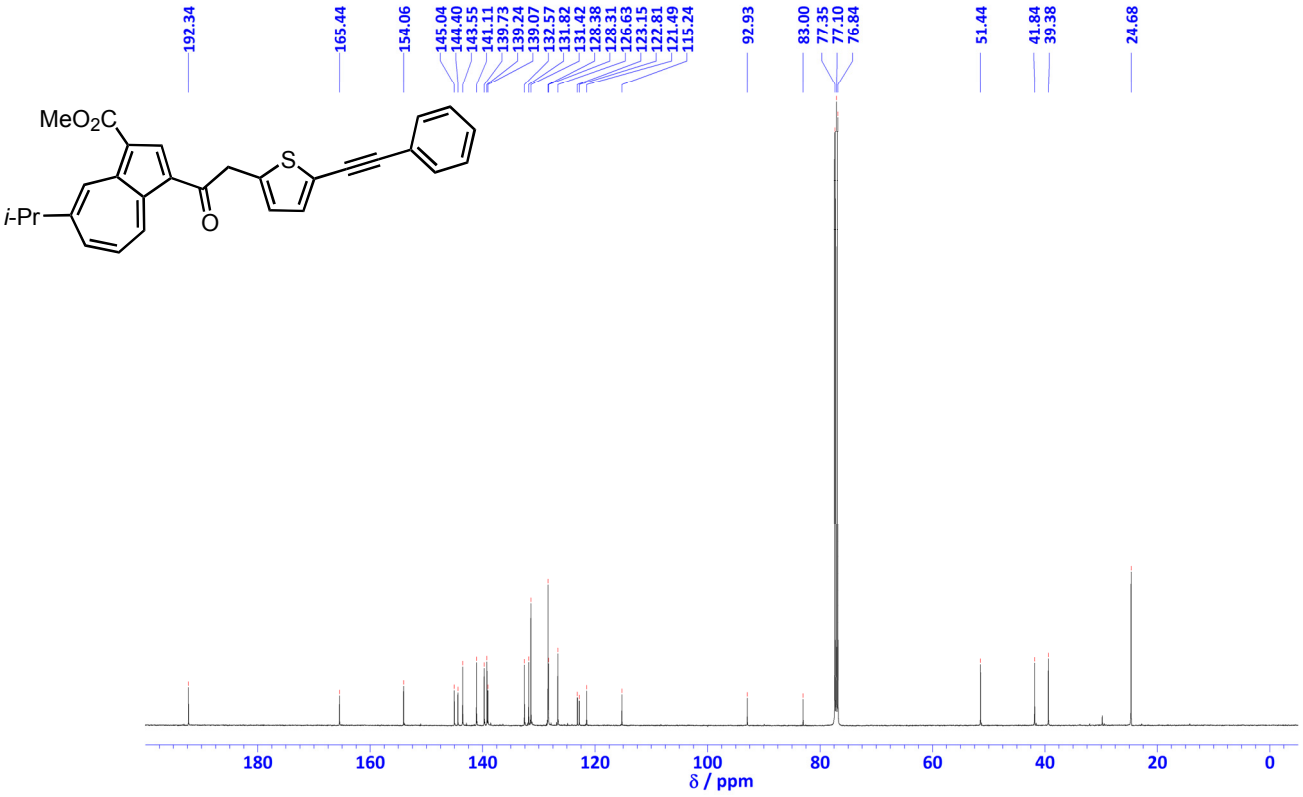


Figure S18. ^{13}C NMR spectrum of **3h** in $CDCl_3$ (125 MHz).

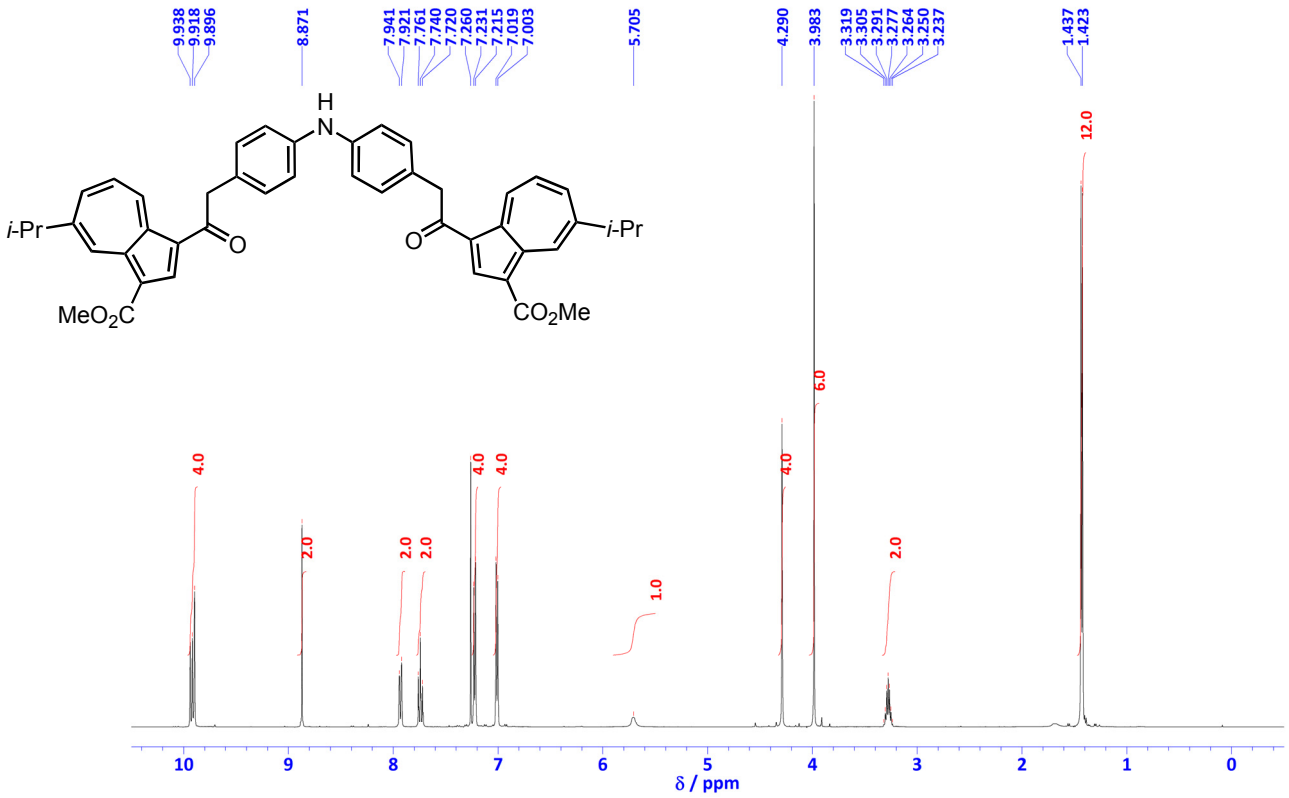


Figure S19. ^{1}H NMR spectrum of **3i** in $CDCl_3$ (500 MHz).

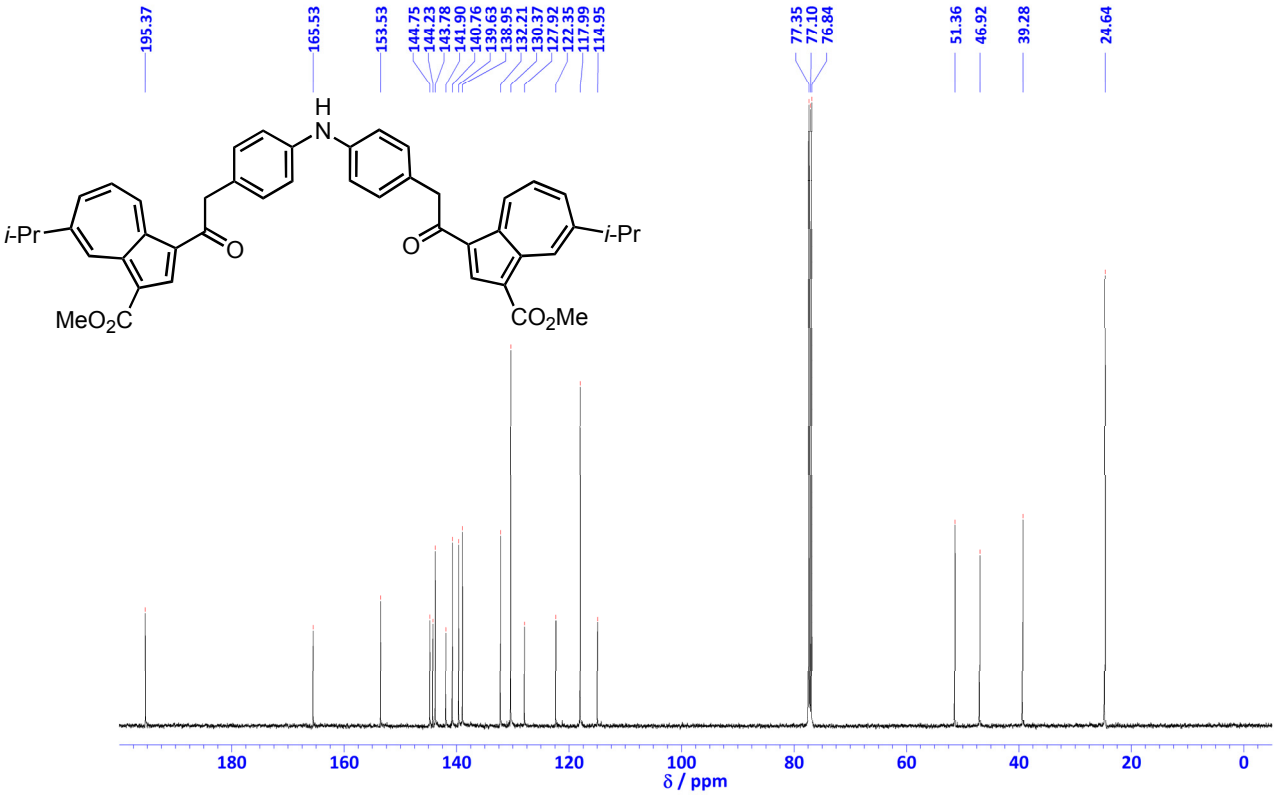


Figure S20. ^{13}C NMR spectrum of **3i** in $CDCl_3$ (125 MHz).

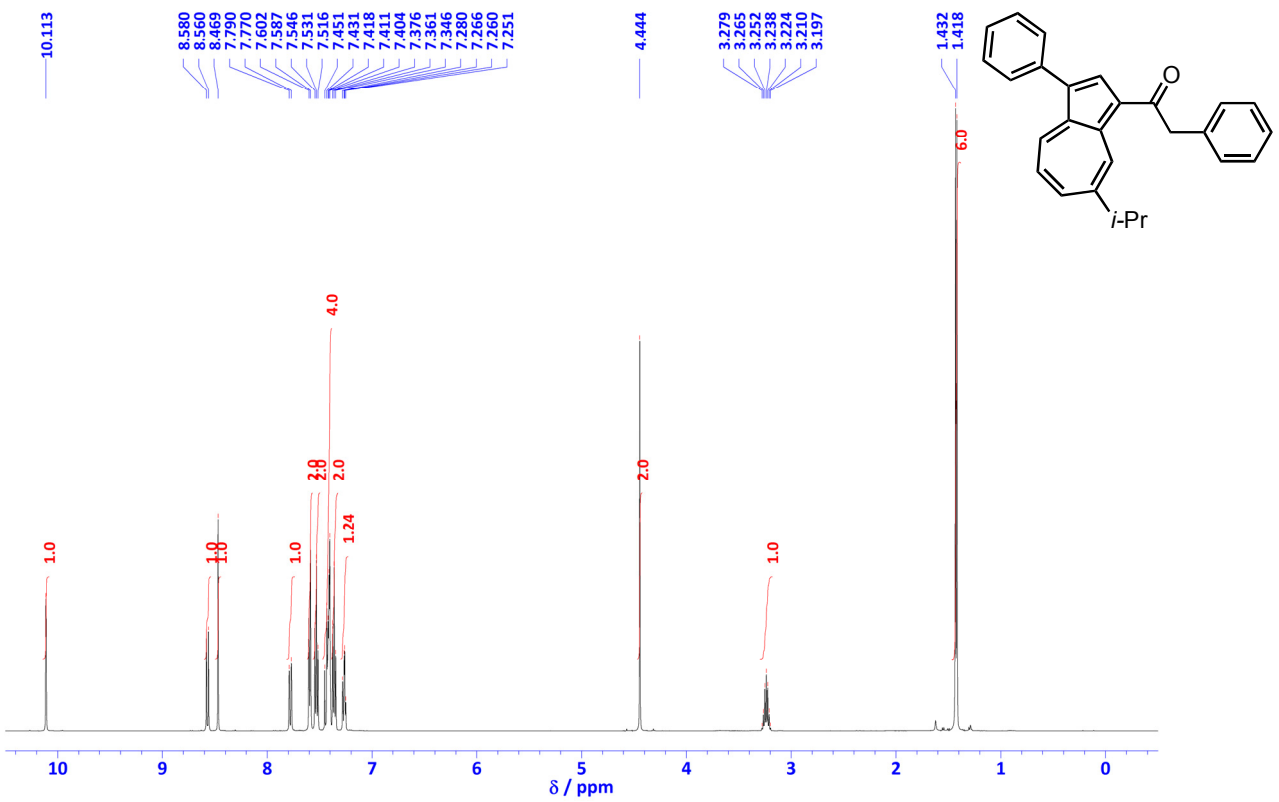


Figure S21. ^{1}H NMR spectrum of **3j** in $CDCl_3$ (500 MHz).

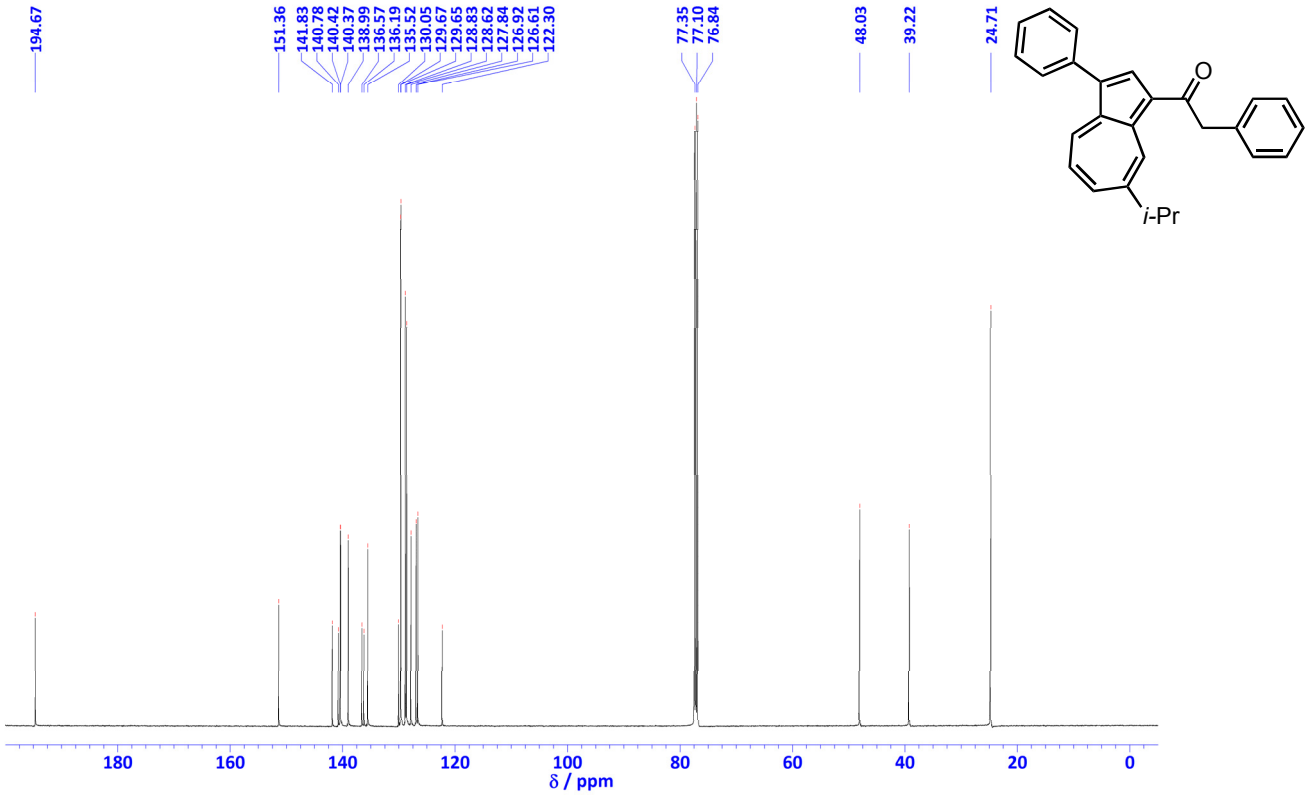


Figure S22. ^{13}C NMR spectrum of **3j** in $CDCl_3$ (125 MHz).

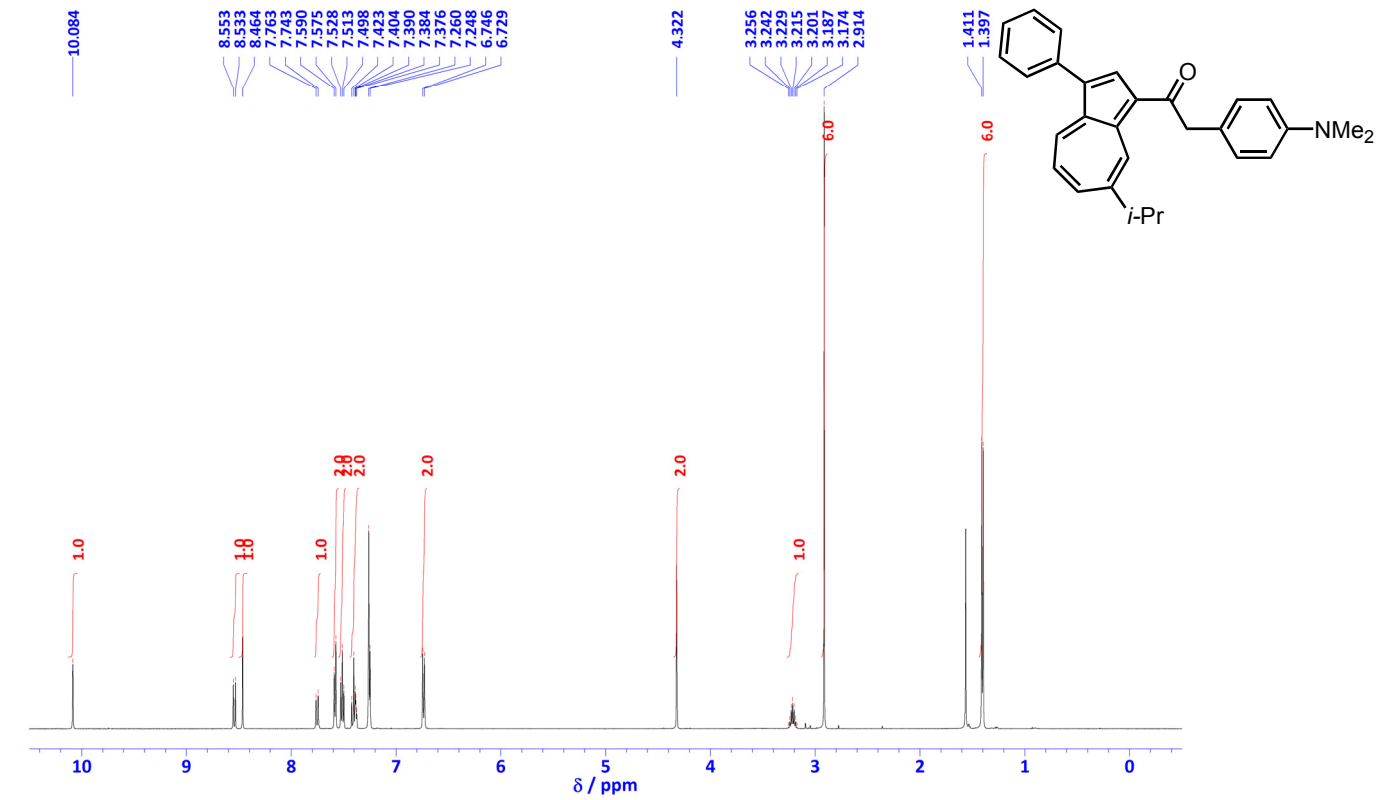


Figure S23. ^{1}H NMR spectrum of **3k** in $CDCl_3$ (500 MHz).

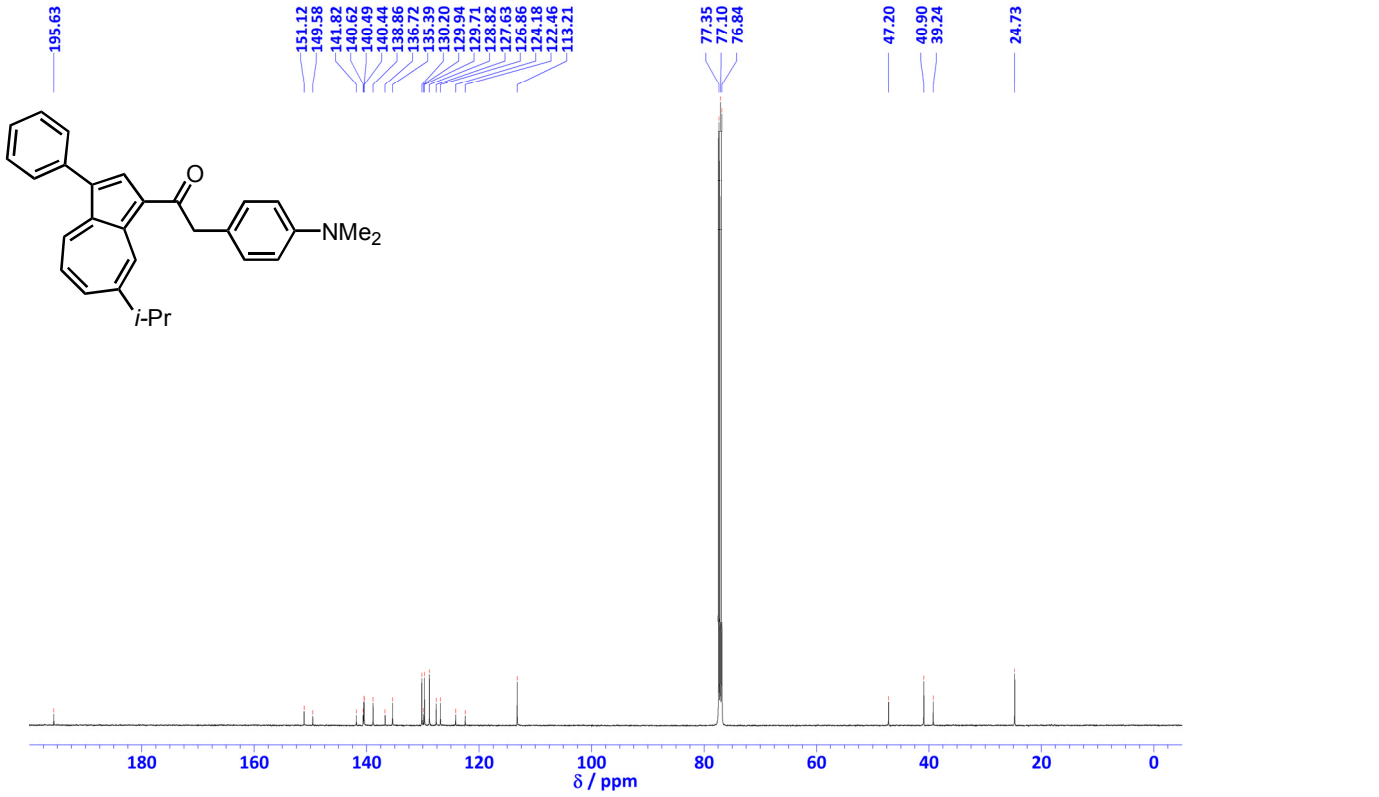


Figure S24. ^{13}C NMR spectrum of **3k** in $CDCl_3$ (125 MHz).

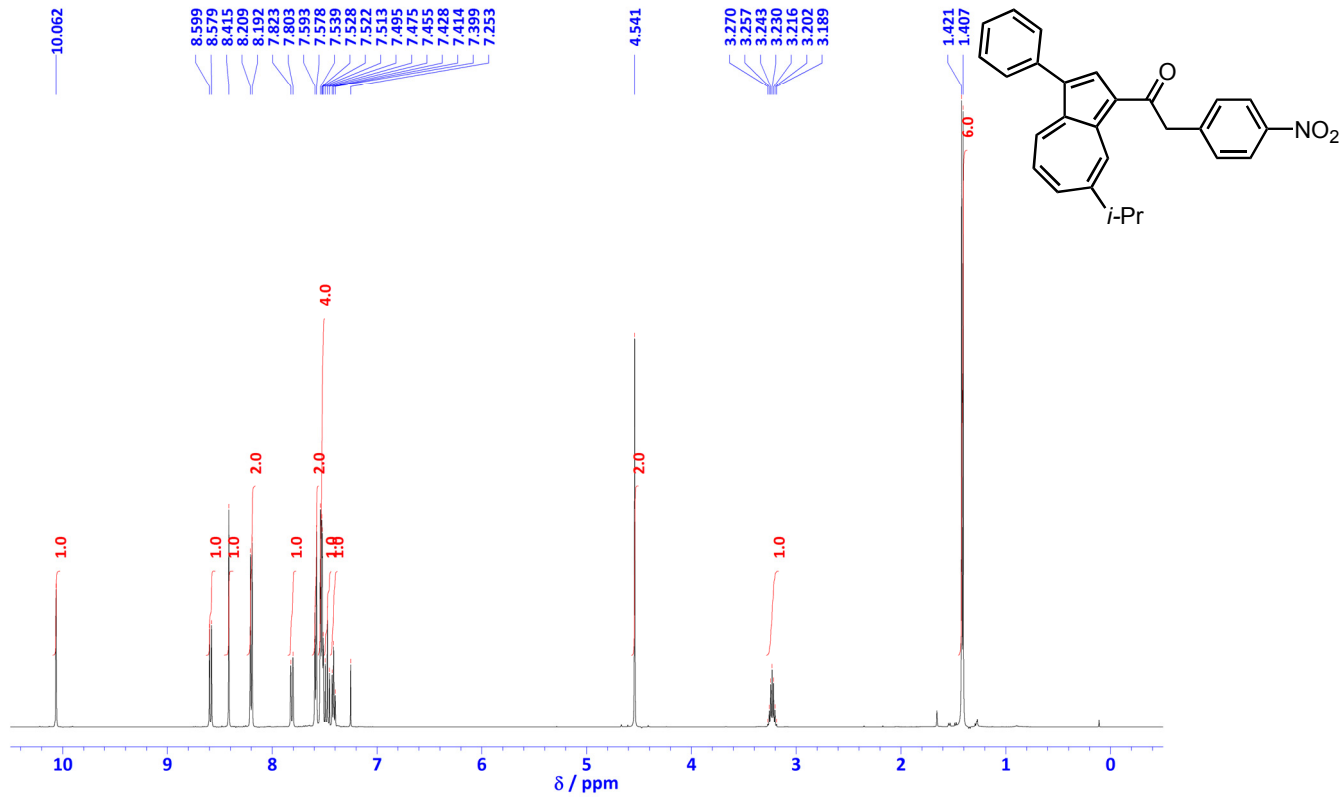


Figure S25. ^{1}H NMR spectrum of **3l** in $CDCl_3$ (500 MHz).

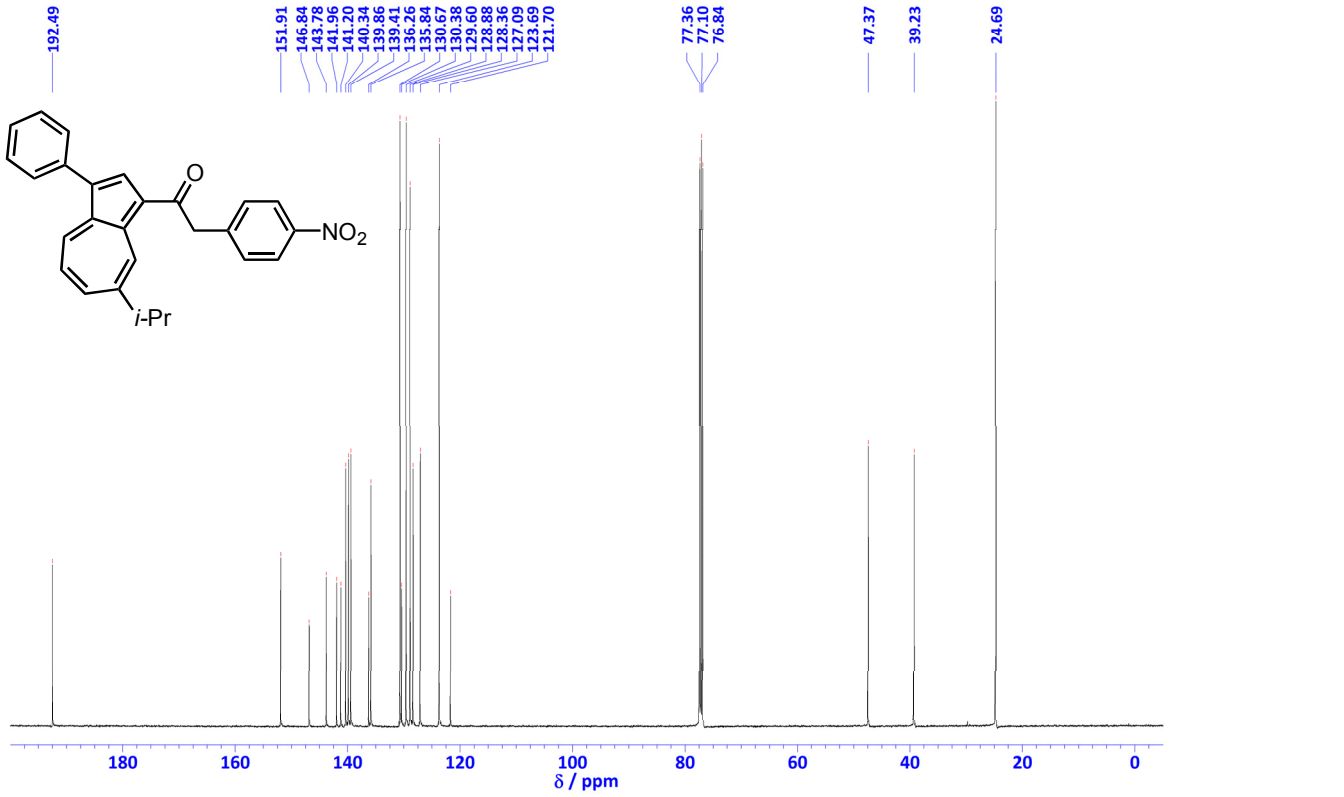


Figure S26. ^{13}C NMR spectrum of **3l** in $CDCl_3$ (125 MHz).

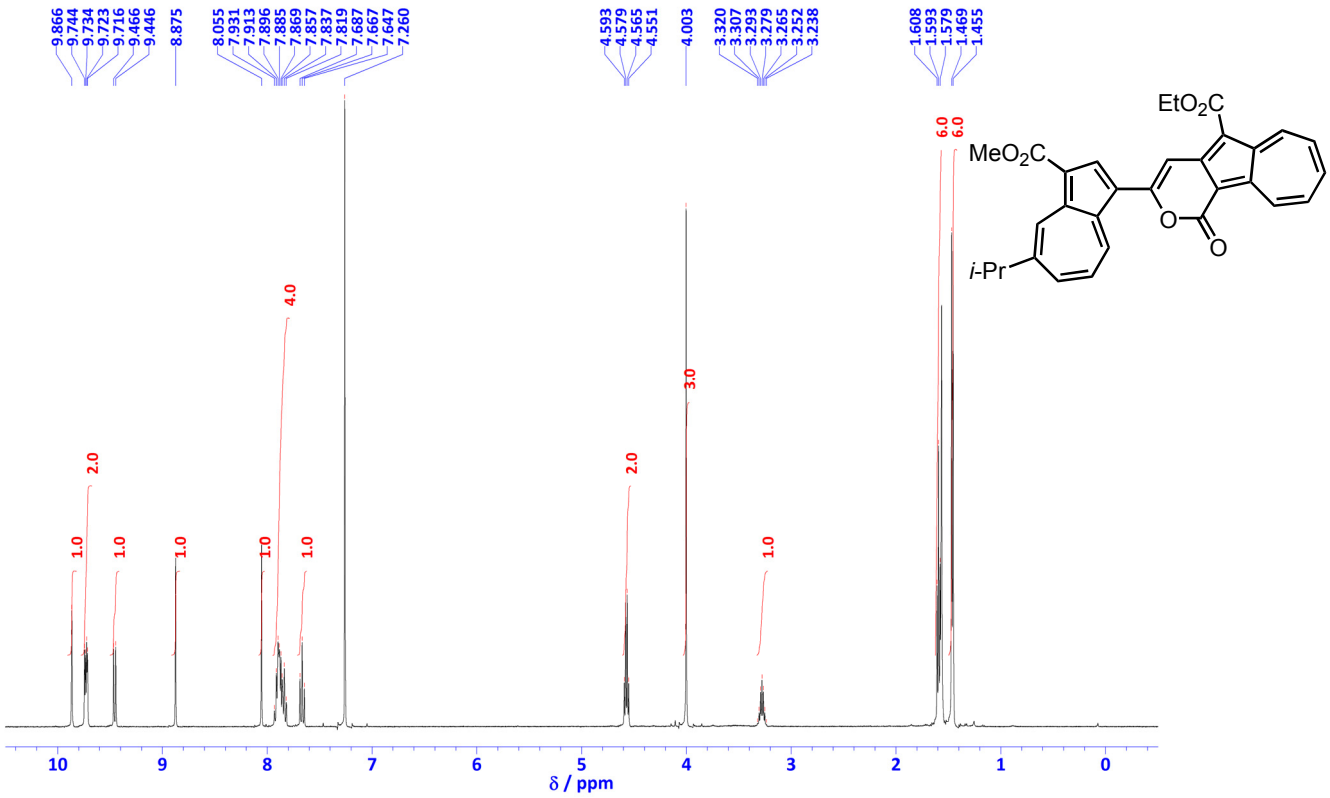


Figure S27. ^{1}H NMR spectrum of **4** in $CDCl_3$ (500 MHz).

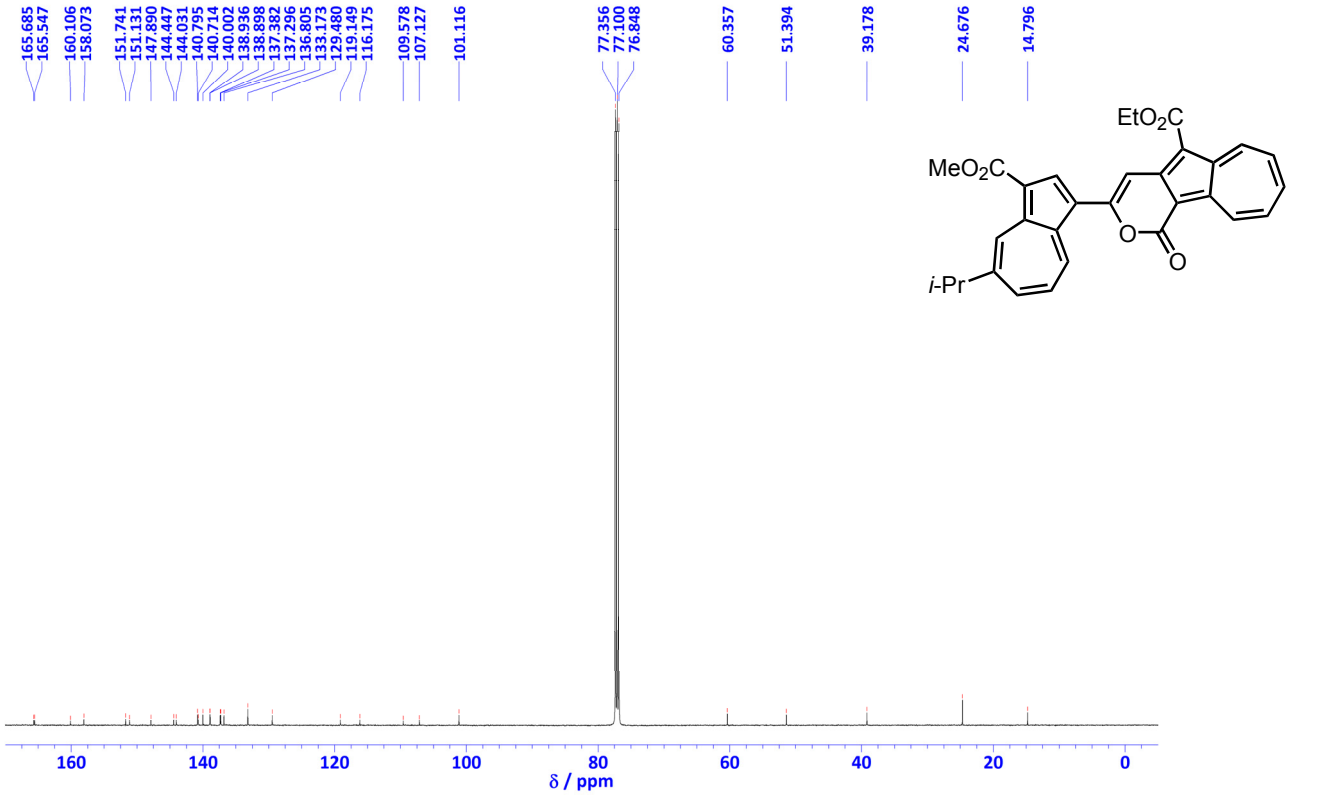


Figure S28. ^{13}C NMR spectrum of **4** in $CDCl_3$ (125 MHz).

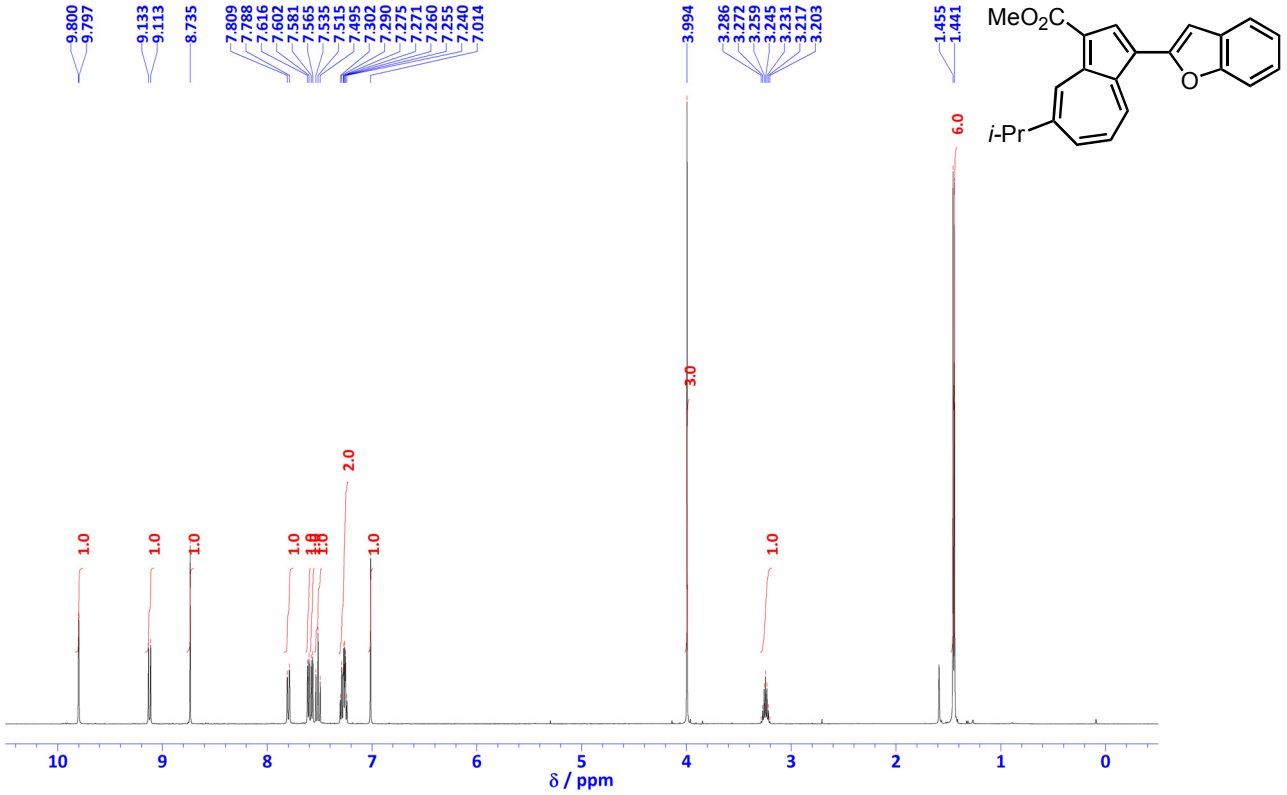


Figure S29. ^{1}H NMR spectrum of **5** in $CDCl_3$ (500 MHz).

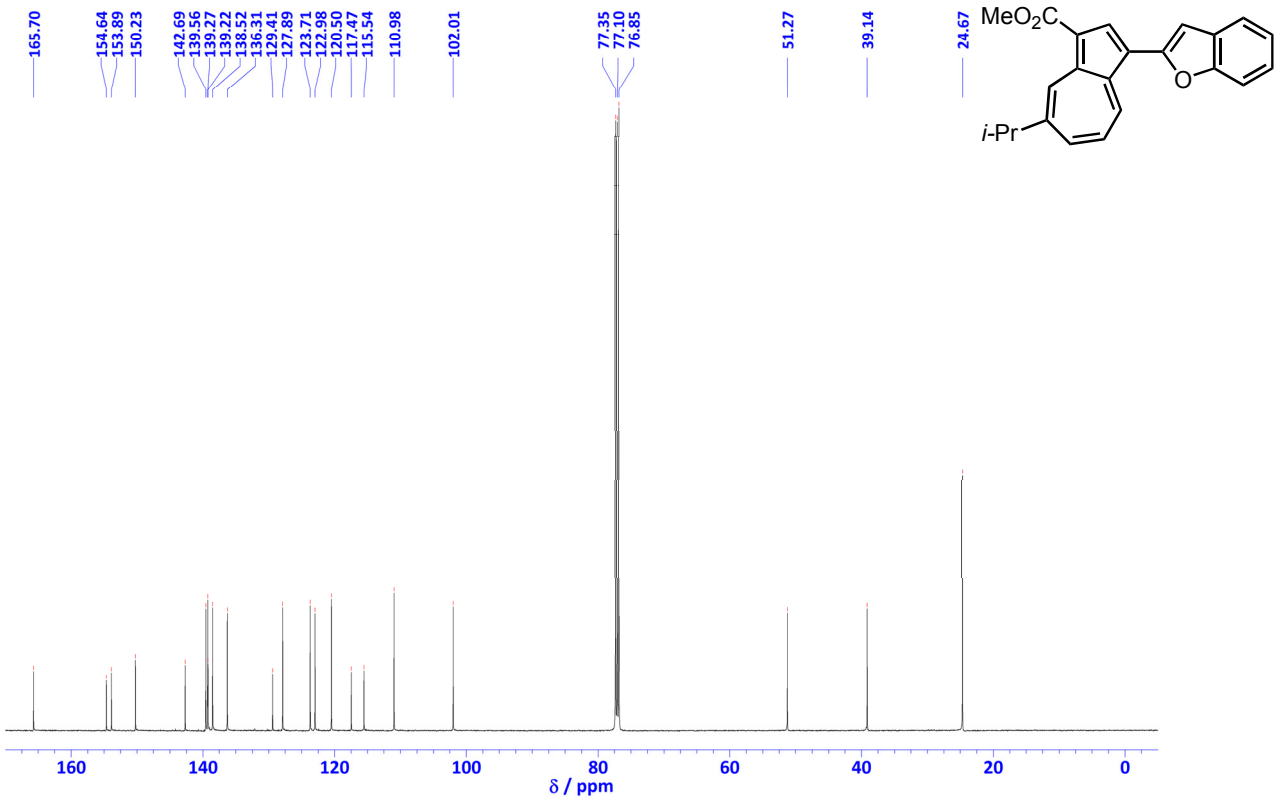


Figure S30. ^{13}C NMR spectrum of **5** in $CDCl_3$ (125 MHz).

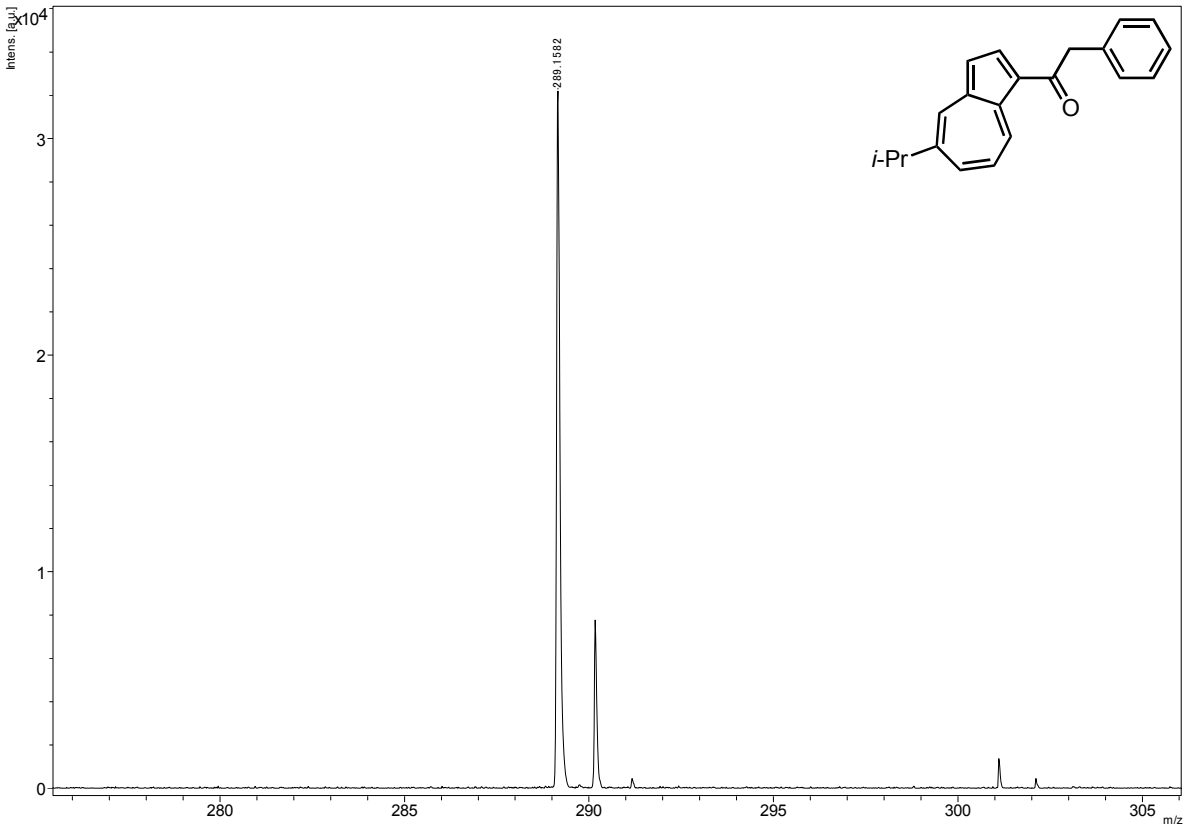


Figure S31. HRMS of **2** (MALDI-TOF).

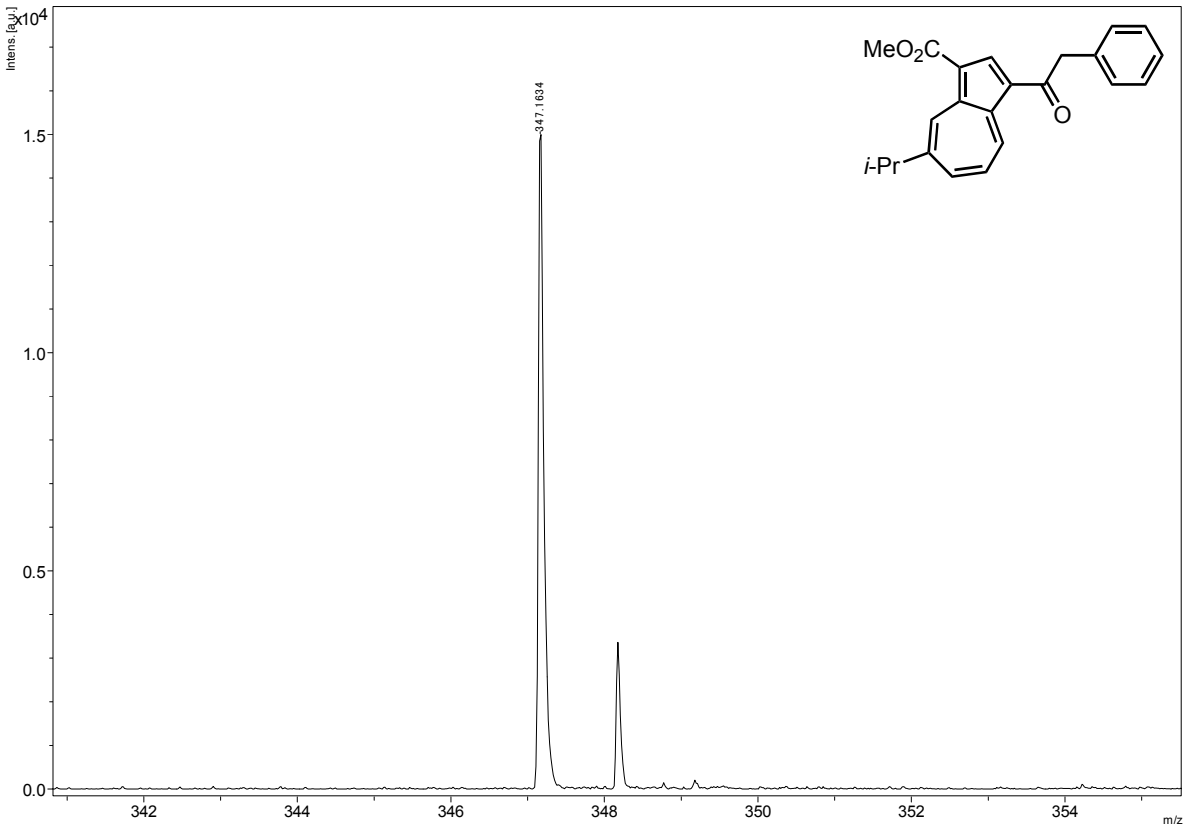


Figure S32. HRMS of **3a** (MALDI-TOF).

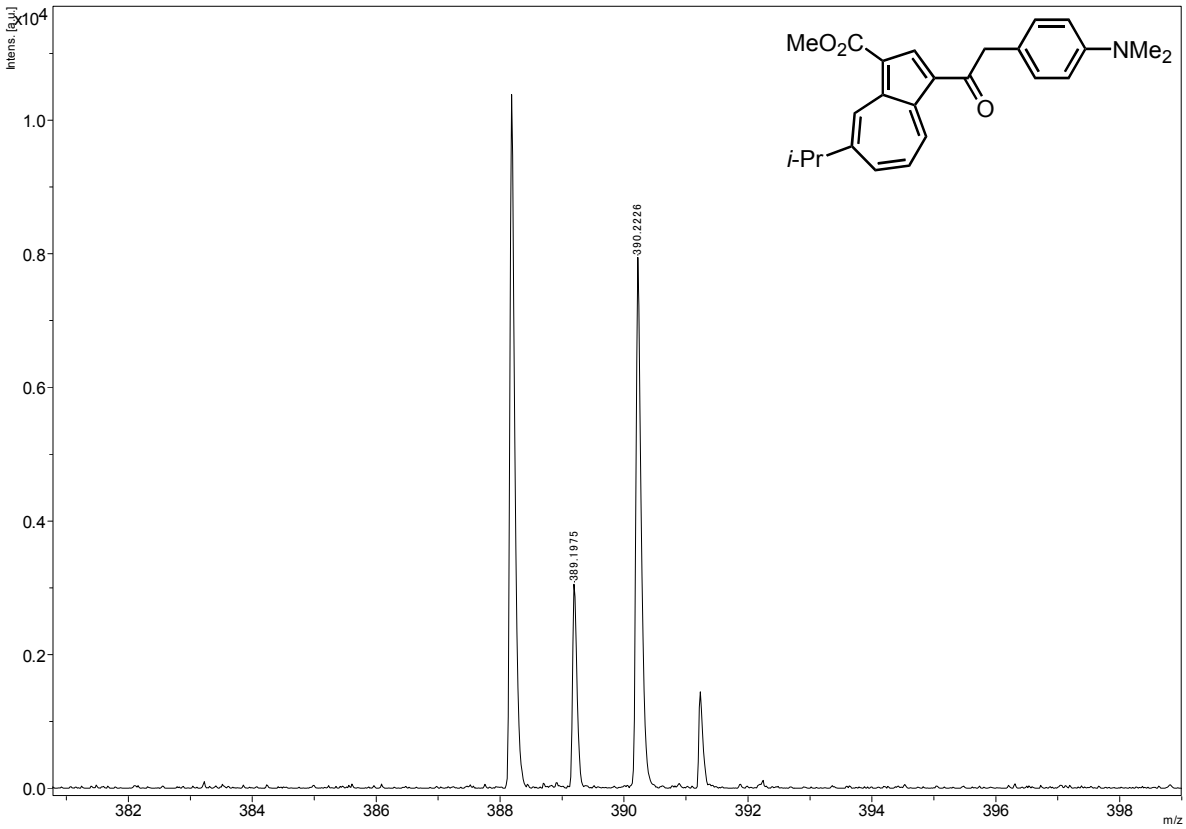


Figure S33. HRMS of **3b** (MALDI-TOF).

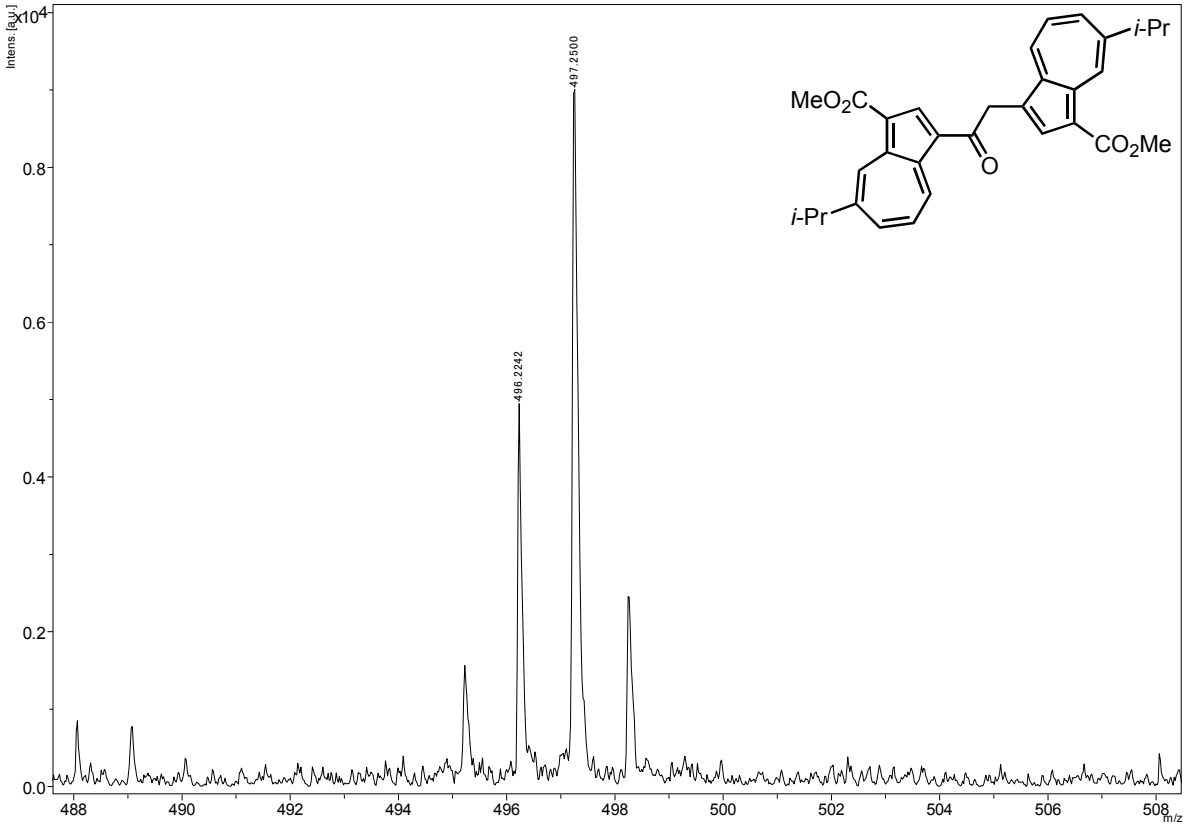


Figure S34. HRMS of **3c** (MALDI-TOF).

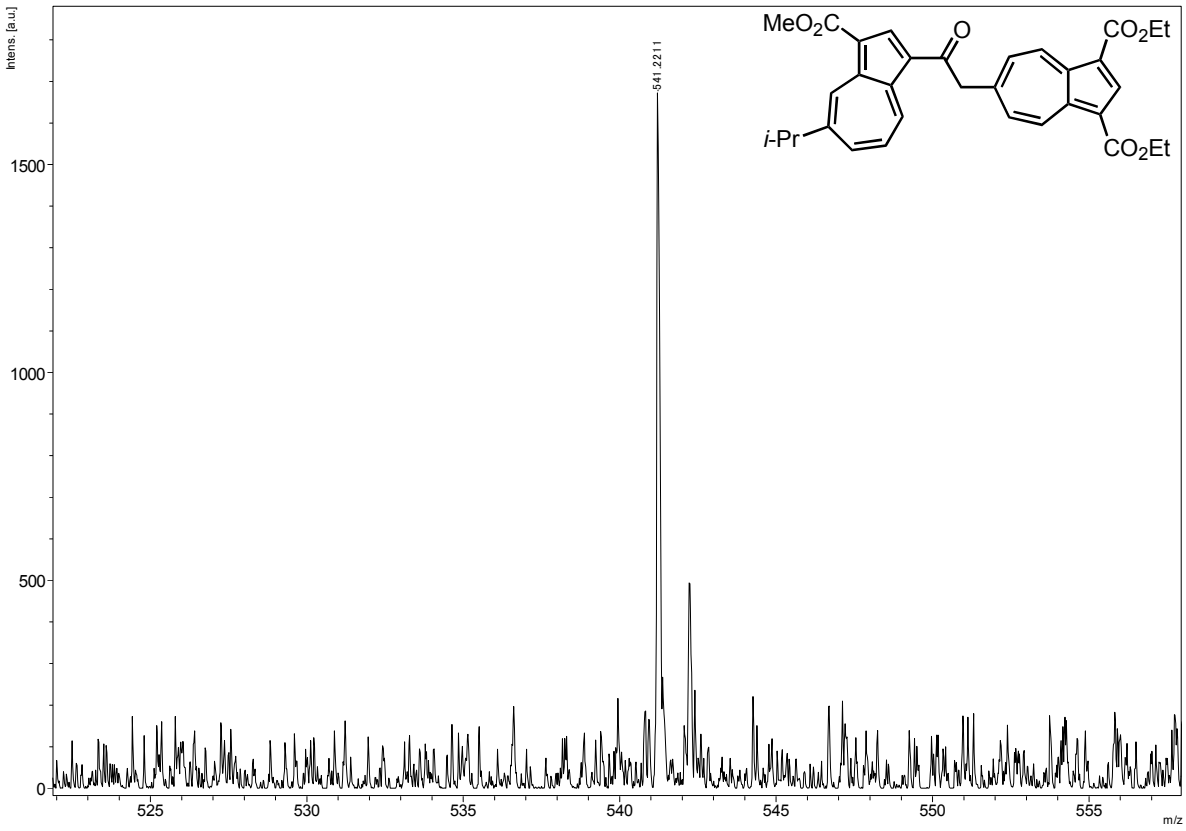


Figure S35. HRMS of **3d** (MALDI-TOF).

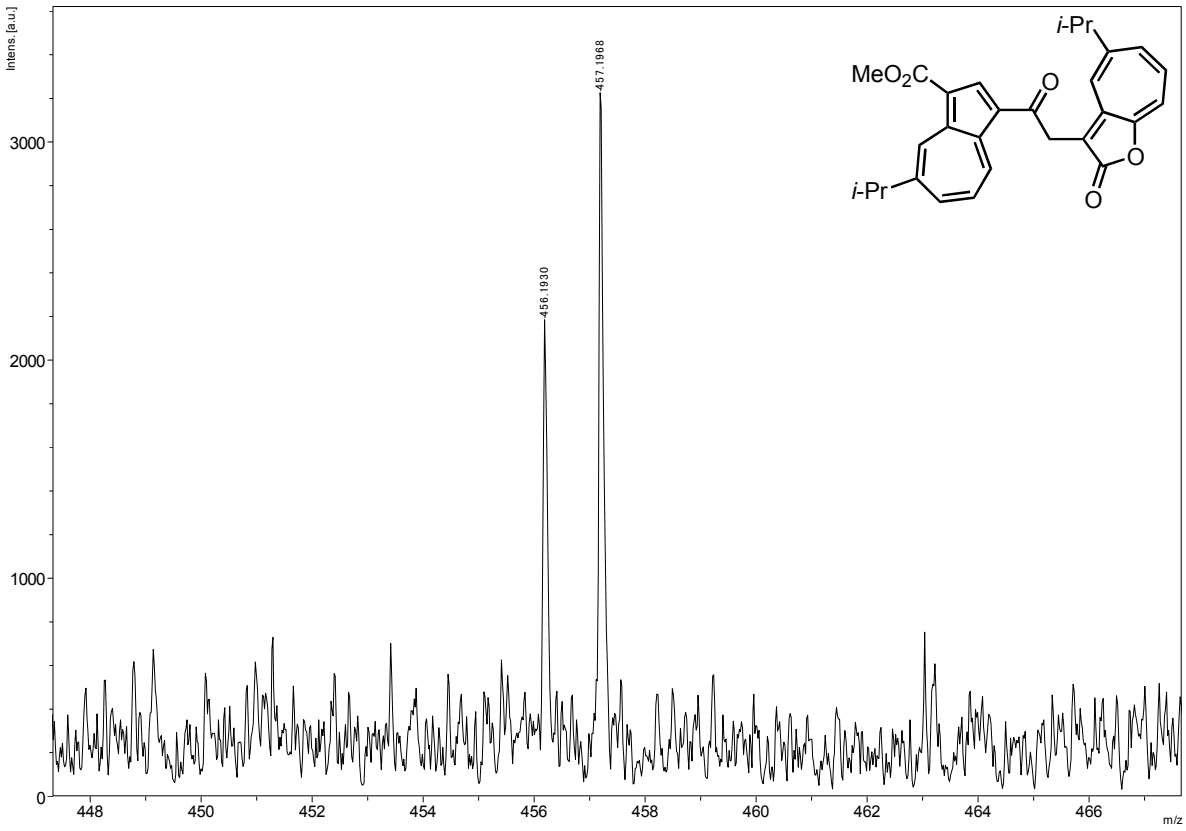


Figure S36. HRMS of **3e** (MALDI-TOF).

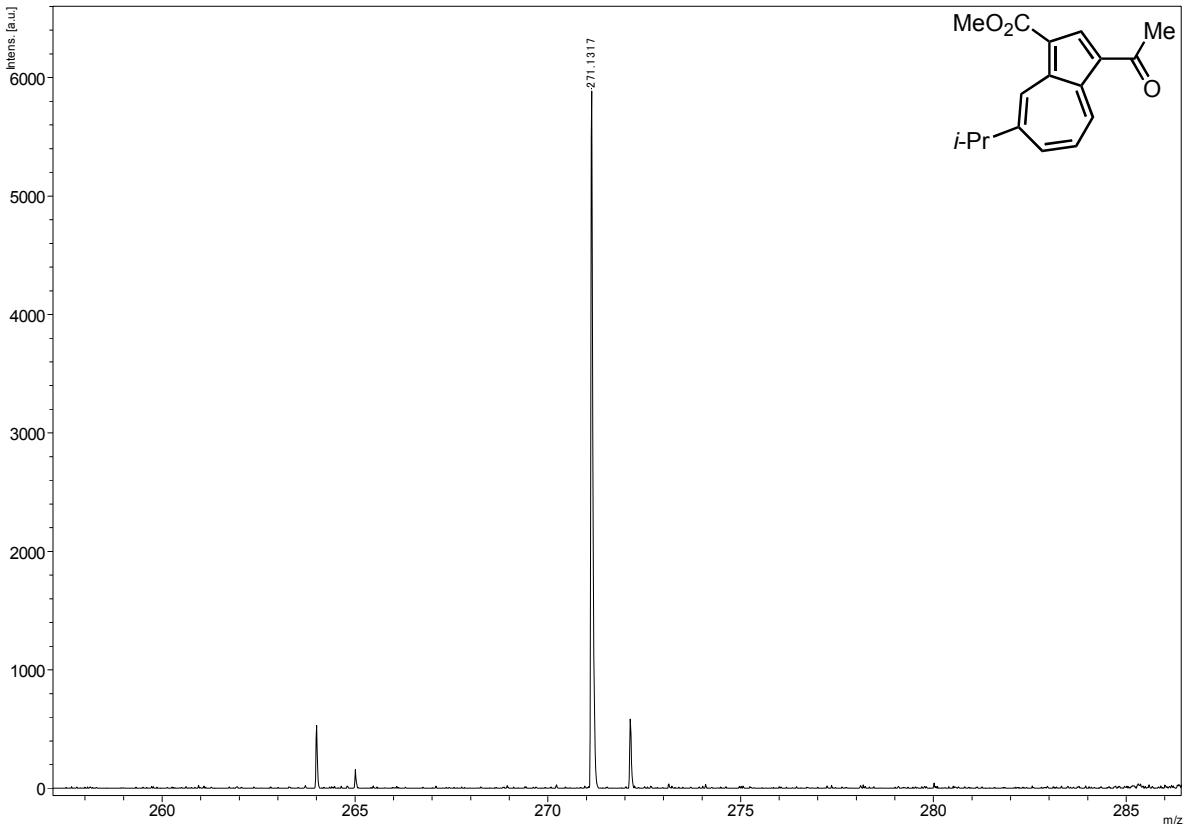


Figure S37. HRMS of **3f** (MALDI-TOF).

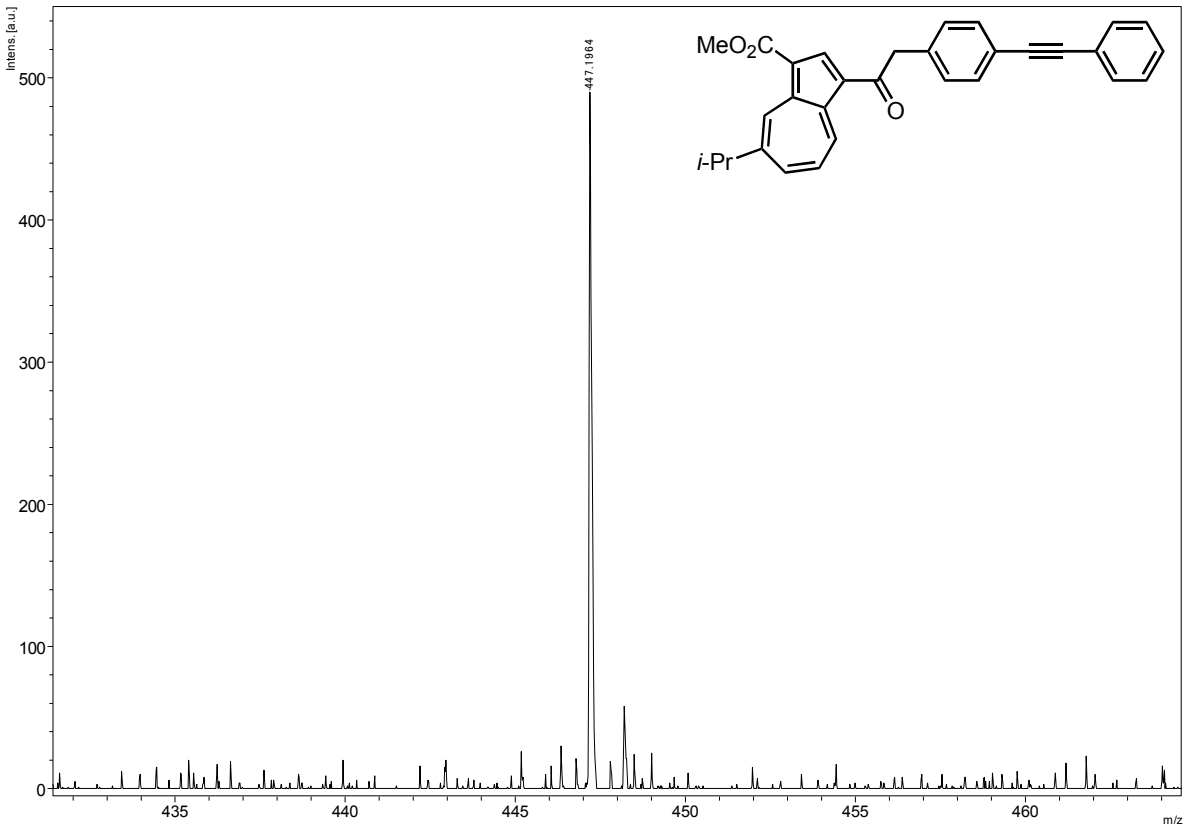


Figure S38. HRMS of **3g** (MALDI-TOF).

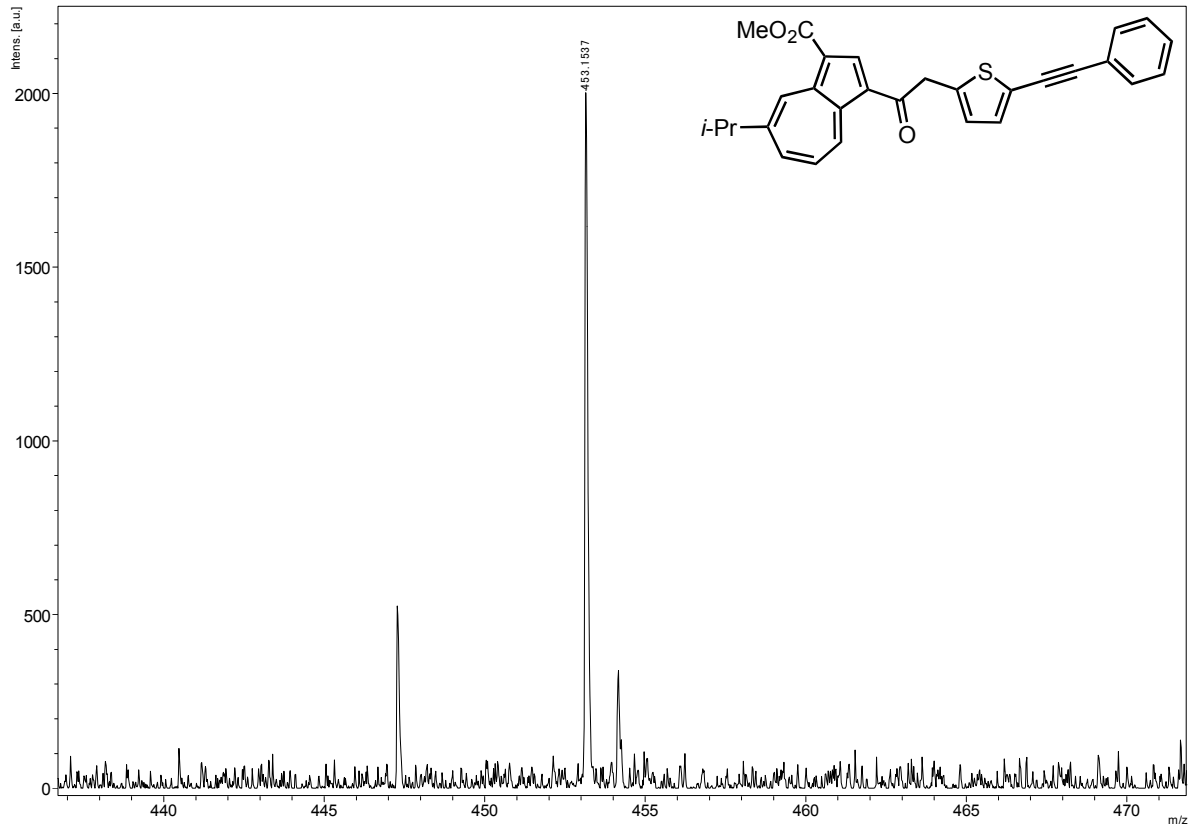


Figure S39. HRMS of **3h** (MALDI-TOF).

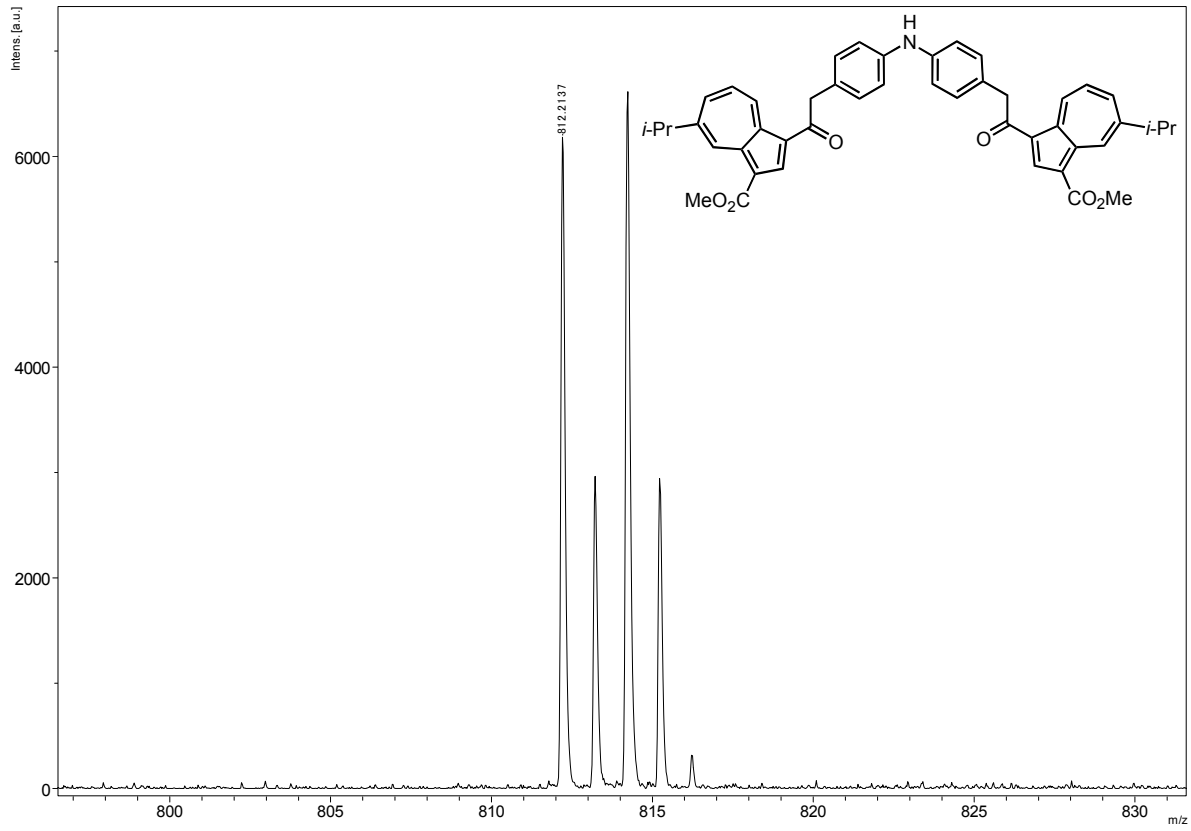


Figure S40. HRMS of **3i** (MALDI-TOF).

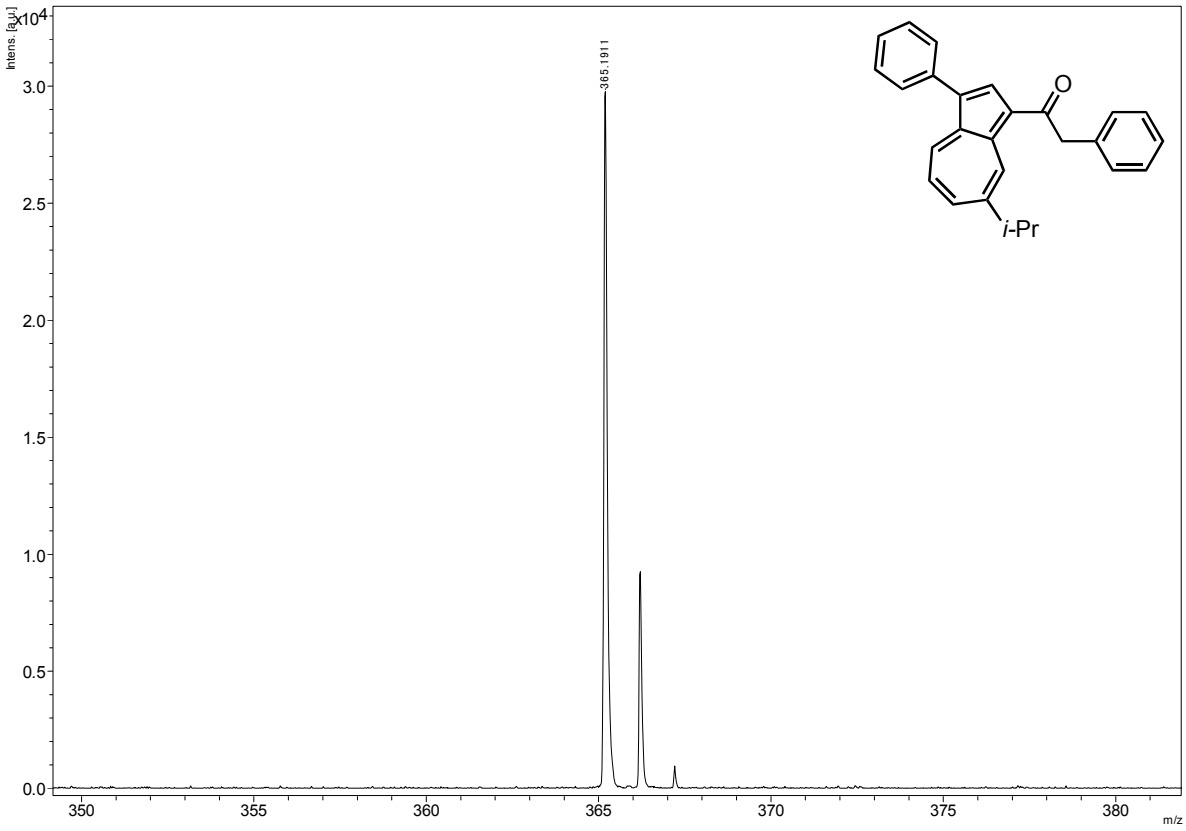


Figure S41. HRMS of **3j** (MALDI-TOF).

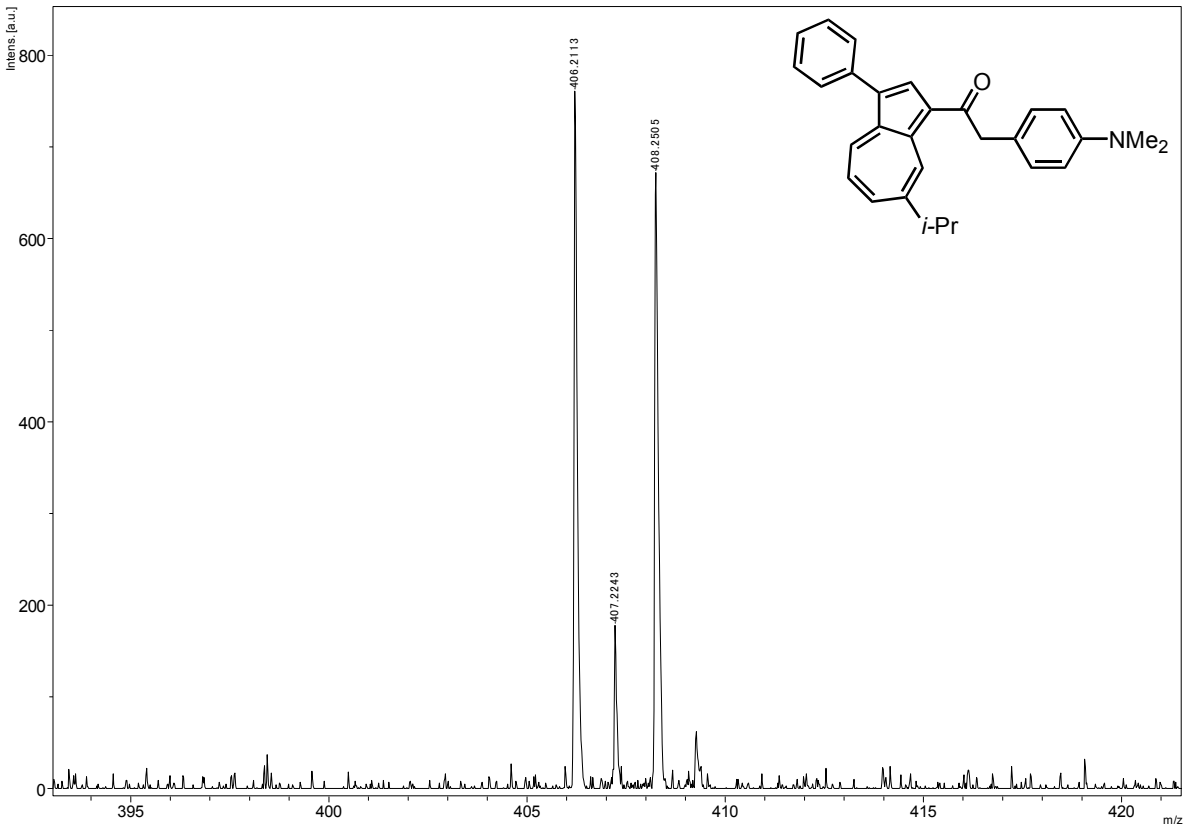


Figure S42. HRMS of **3k** (MALDI-TOF).

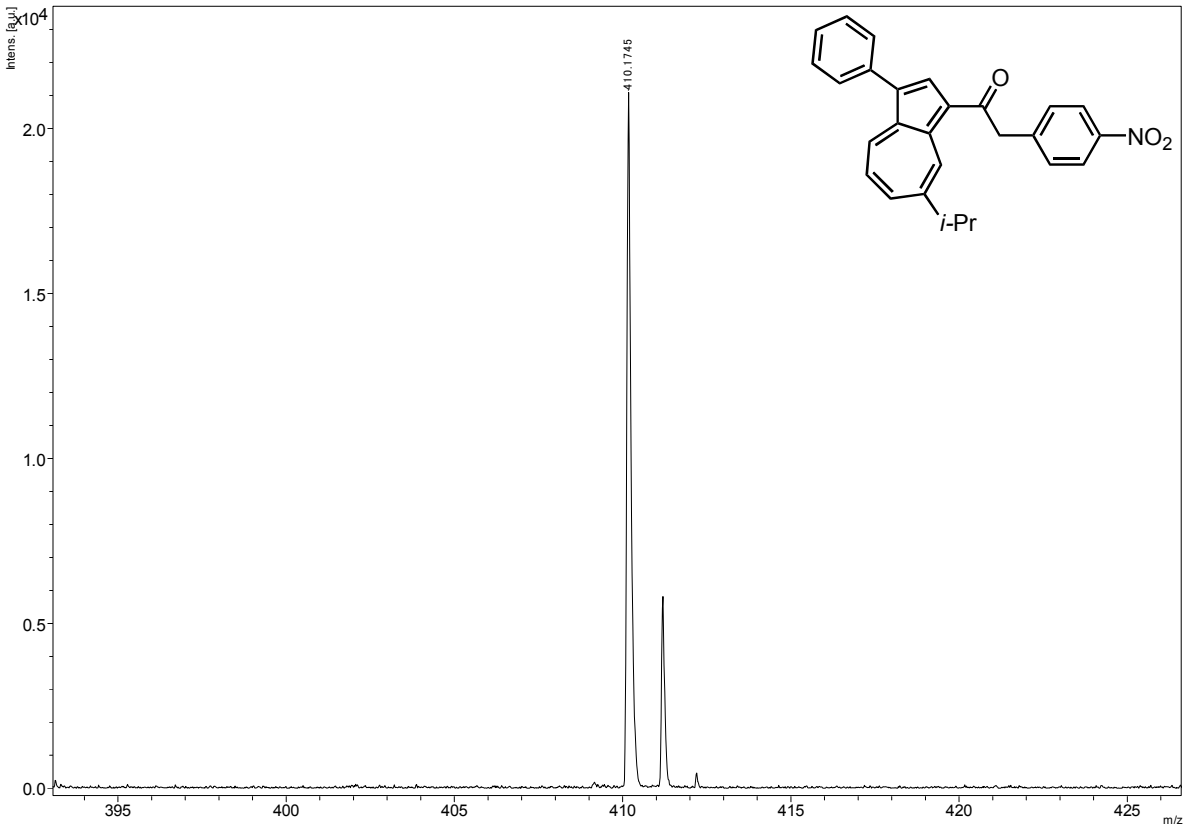


Figure S43. HRMS of **3l** (MALDI-TOF).

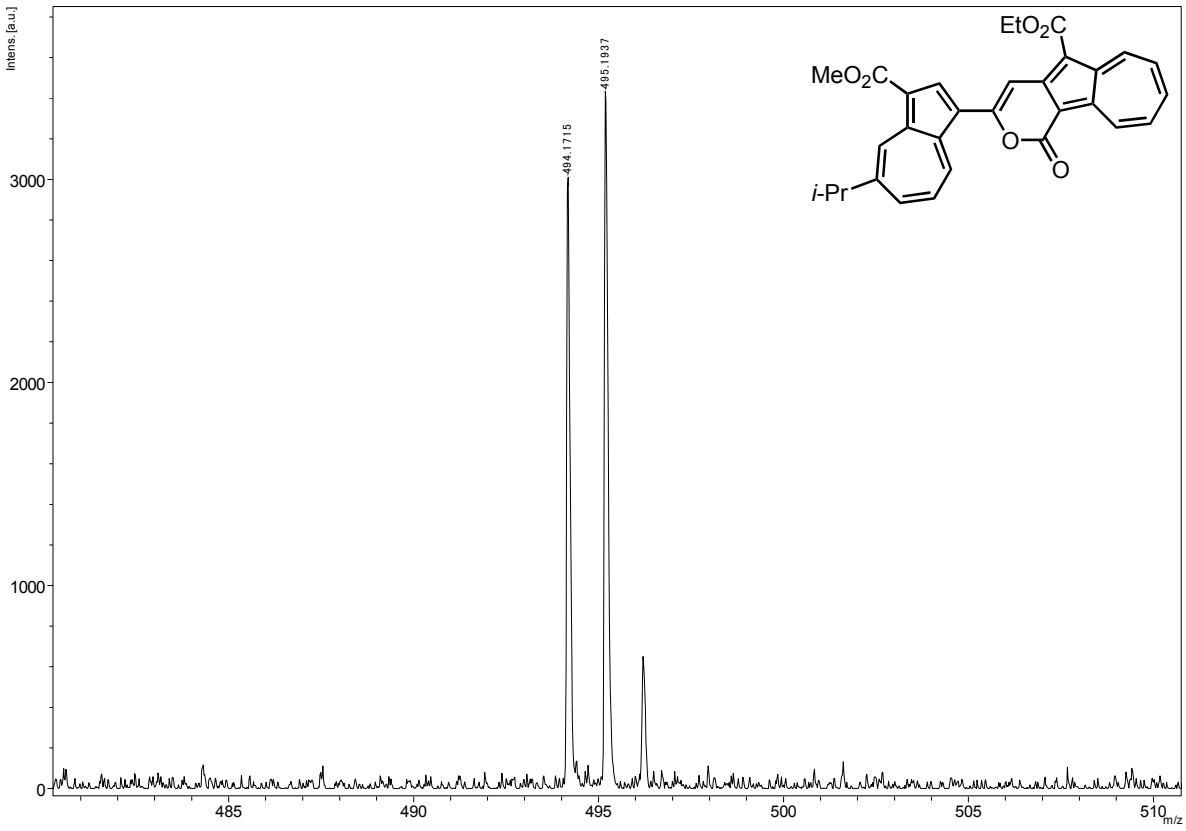


Figure S44. HRMS of **4** (MALDI-TOF).

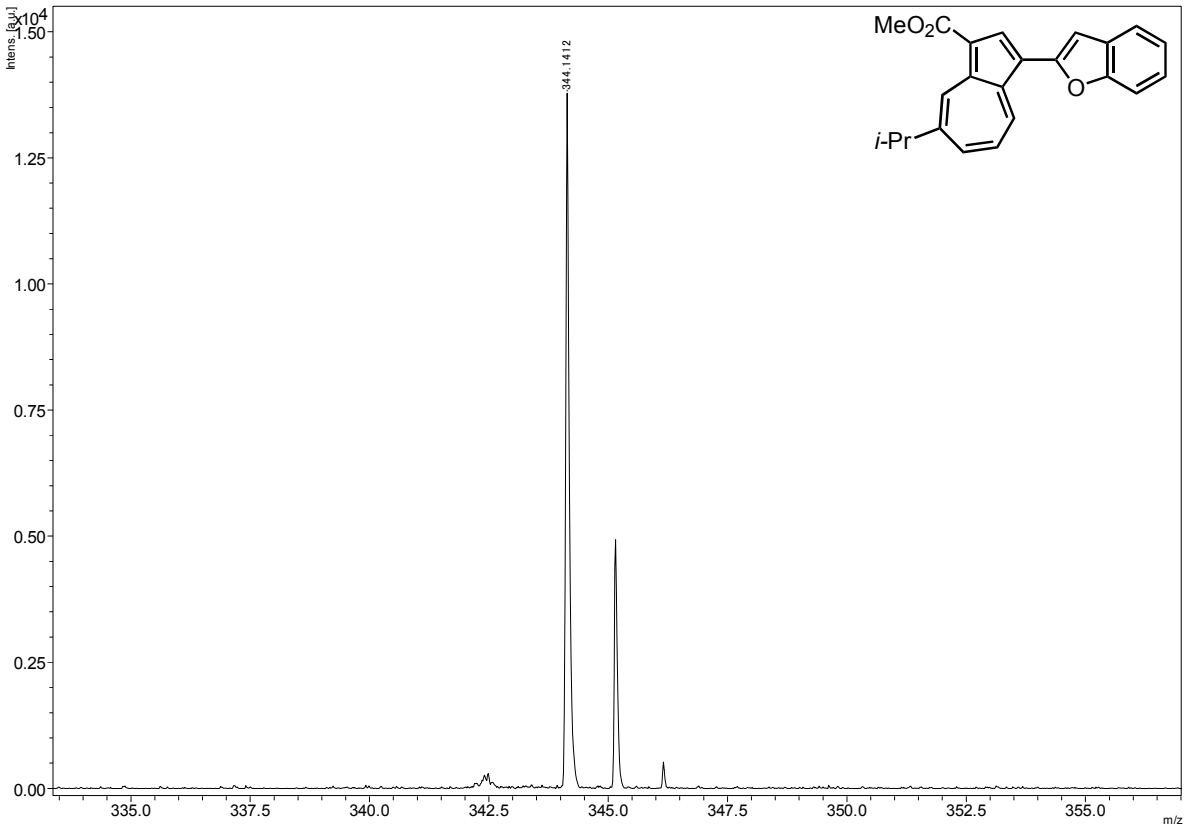


Figure S45. HRMS of **5** (MALDI-TOF).