Supporting Information for

Diastereo- and Enantioselective Formal [3+2] Cycloaddition of Cyclopropyl Ketones and Alkenes via Ti-catalyzed Radical Redox Relay

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Section 1. General information

All reactions were conducted under a nitrogen atmosphere, unless otherwise noted. Flash chromatography was performed using silica gel 60(230-400 mesh) from SiliCycle. Commercial reagents were purchased from Sigma-Aldrich, Alfa Aesar, Acros, TCI, AK Scientific, and Oakwood and used as received with the following exceptions: toluene, dichloromethane, tetrahydrofuran, diethyl ether, and acetonitrile were dried by passing through columns of activated alumina; dimethylformamide was dried by passing through columns of activated molecular sieves. Triethylamine, ethyl acetate and 1,2-dichloroethane were distilled from CaH_2 at 760 torr. Mn powder used in this study was purchased from Alfa Aesar (catalog #10238, ~325 mesh, 99.3% metal basis, apparent density 2.6-3.5 g/cm). Proton nuclear magnetic resonance (^{1}H NMR) spectra and carbon nuclear magnetic resonance (^{13}C NMR) spectra were recorded on Mercury-300 (300 MHz), Inova-400 (400 MHz), Inova-500 (500 MHz) and Inova-600 (600M) spectrometers. Chemical shifts for protons are referenced to residual protium in the NMR solvent ($CHCl_3$ = δ 7.26). Chemical shifts for carbon are referenced to the carbon resonances of the solvent ($CDCl_3$ = δ 77.0). Data are represented as follows: chemical shift, multiplicity (br. s = broad, s= singlet, d = doublet, t = triplet, q = quartet, m = multiplet), coupling constants in Hertz (Hz), integration. Yields determined with ^{1}H NMR used 1,3,5-trimethylbenzene as the internal standard. Infrared (IR) spectra were obtained using a Bruker Hyperion Tensor 27 FTIR spectrometer. The mass spectral data were obtained on a Thermo Fisher Scientific Exactive series DART Mass Spectrometer. Enantiomeric excesses were determined by chiral HPLC of isolated material using a SHIMADZU system with CHIRALPAK® columns and. Optical rotations were measured using a PERKIN-ELMER polarimeter at room temperature in $CHCl_3$.

Abbreviations: ^{t}Bu—*tert*-butyl, DMAP—4-dimethylaminopyridine, DCM—dichloromethane, EtOAc—ethyl acetate, MeCN—acetonitrile, Et_3N—triethylamine, TEMPO—(2,2,6,6-tetramethylpiperidin-1-yl)oxyl, THF—tetrahydrofuran, Ts—*p*-toluenesulfonyl.

Section 2. General procedures for Ti-catalyzed [3+2] cycloaddition and product characterization

Method A. Substrate scope (0.1 mmol scale): In a N_2-filled glovebox, an oven-dried 1.5 dr vial equipped with a magnetic stir bar was charged with Mn (11 mg, 0.2 mmol, 2.0 equiv), $Et_3N{\cdot}HCl$ (27.4 mg, 0.2 mmol, 2.0 equiv) and **3** (8.3 mg, 0.01 mmol, 10 mol %) in 1 mL of EtOAc. The mixture was stirred vigorously for 10 min to allow reduction of the pre-catalyst (Figure S1). Subsequently, the alkene substrate (0.12 mmol, 1.2 equiv) and cyclopropyl ketones (0.10 mmol, 1 equiv) were added, and the resulting mixture was removed from the glovebox and stirred at room temperature (22 ± 1 °C) for 12 h. The reaction mixture was then transferred onto a short Celite column (1-1.5 cm in length, ca. 0.5 g) and flushed through with a mixture of hexanes and ethyl acetate (3:2, 5 mL in total) to remove the inorganic salts and other insoluble solids. The product solution was concentration in vacuo and dissolved in $CDCl_3$ to analyze the dr using ^1H NMR. The pure final product was obtained using flash chromatography on silica gel (5-6 cm in length, ca. 1.5 g).

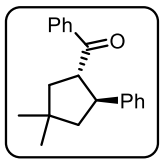
Figure S1. Preactivation of the catalyst. Left: before preactivation, showing red color from catalyst **3**. Right: after preactivation, showing green color of the Ti^{III} active catalyst.

Method B. Scale-up synthesis (1 mmol scale): In a N_2-filled glovebox, an oven-dried 20 mL scintillation vial equipped with a magnetic stir bar was charged with Mn (110 mg, 2.0 mmol, 2.0 equiv), $Et_3N{\cdot}HCl$ (274 mg, 2 mmol, 2.0 equiv) and **3** (42 mg, 0.025 mmol, 2.5 mol %) and EtOAc (10 mL). The mixture was stirred vigorously for 10 min to allow reduction of the pre-catalyst. Subsequently, 3-vinyl-*N*-tosylindole (312 mg, 1.05 mmol, 1.05 equiv) and cyclopropyl ketones **1** (174 mg, 1.0 mmol, 1 equiv) were added, and the resulting mixture stirred at room temperature (22 ± 1 °C) for 60 h. The reaction mixture was then transferred onto a short Celite column (1-1.5 cm in length, ca. 0.5 g) and flushed through with a mixture of hexanes and ethyl acetate (3:2, 5 mL in total) to remove the inorganic salts and other insoluble solids. The product solution was concentration in vacuo and dissolved in $CDCl_3$ to analyze the dr using ^1H NMR. The pure final product was obtained using flash chromatography on silica gel (10 cm in length, ca. 5 g) to obtained the final product **15** (391 mg, 83% yield) as effectively a single diastereomer (dr > 19:1) in 92% ee.

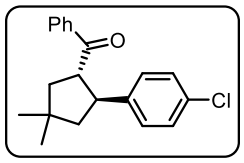
Method C. Low temperature procedure (0.1 mmol scale): In a N_2-filled glovebox, an oven-dried 1.5 dr vial equipped with a magnetic stir bar was charged with Zn (11 mg, 0.2 mmol, 2.0 equiv), $Et_3N{\cdot}HCl$ (27.4 mg, 0.2 mmol, 2.0 equiv) and **3** (8.3 mg, 0.01 mmol, 10 mol %) in 1 mL of EtOAc. The mixture was stirred vigorously at room temperature for 10 min to allow reduction of the pre-catalyst. Then keep this solution under low temperature (in a cold well cooled with isopropanol/dry ice) for 5 min. Subsequently, the alkene substrate (0.12 mmol, 1.2 equiv) and cyclopropyl ketones (0.10 mmol, 1 equiv) were added, and the resulting mixture was removed from the glovebox and stirred at low temperature for 48-50 h. The reaction mixture was then transferred onto a short Celite column (1-1.5 cm in length, ca. 0.5 g) and flushed through with a mixture of hexanes and ethyl acetate (3:2, 5 mL in total) to remove the inorganic salts and other insoluble solids. The product solution was concentration in vacuo and dissolved in $CDCl_3$ to analyze the dr using ^1H NMR. The pure final product was obtained using flash chromatography on silica gel (5-6 cm in length, ca. 1.5 g) to obtained the final product.

*Although all data presented in this work were set up in a glovebox, we have also tested the reaction with standard Schlenk technique using a Schlenk tube as the reaction vessel under air-free conditions and obtained comparable results.

((1*S*,2*S*)-4,4-dimethyl-2-phenylcyclopentyl)(phenyl)methanone (2). Followed Method A, the crude product was purified by column chromatography (1:9, EtOAc/hexanes) to give 27.2 mg (98% yield) of **2** as a white solid. The dr was determined to be >19:1. <u>trans diastereoisomer:</u> 97% ee [AS, hexanes, 0.5 mL/min, 223 nm; t1 = 13.95 min, t2 = 15.24 min]. $[\alpha]_D^{22}$ 0.167 (c0.28, $CHCl_3$). IR (Film): 3058, 3029, 2945, 2924, 2861, 1678, 1598, 1559, 1495, 1447, 1364, 1350, 1282, 1246, 1224, 1204, 1182, 1028, 927, 832, 752, 701; ^1H NMR (500 MHz, $CDCl_3$) δ 7.85 (dd, *J* = 8.3, 1.2 Hz, 2H), 7.53 – 7.50 (m, 1H), 7.41 (t, *J* = 7.7 Hz, 2H), 7.30-7.24 (m, 4H), 7.17-7.14 (m, 1H), 4.02– 3.94 (m, 2H), 2.15 (dd, *J* = 13.0, 9.5 Hz, 1H), 2.07 (dd, *J* = 12.8, 7.1 Hz, 1H), 1.91-1.86(m, 1H), 1.79-1.74 (m, 1H), 1.24 (s, 3H), 1.17 (s, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 201.71, 144.04, 136.97, 132.76, 128.40, 128.39, 128.34, 127.35, 126.12, 54.84, 49.39, 46.77, 46.73, 38.98, 30.56, 29.51; MS (DART) exact mass calculated for [$C_{20}H_{23}O$]: 279.1743, found 279.1751. The characterization data are consistent with literature report.[1]

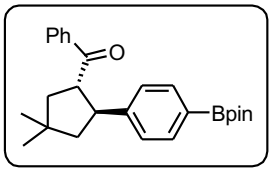


((1*S*,2*S*)-2-(4-chlorophenyl)-4,4-dimethylcyclopentyl)(phenyl)methanone (8). Followed Method A with 5% of catalyst **3**, the crude product was purified by column chromatography (1:9, EtOAc/hexanes) to give 23.4 mg (75% yield) of **8** as a white solid. The dr was determined to be 12:1 trans/cis. <u>trans diastereoisomer:</u> 96% ee [AD, 0.5% iPrOH in hexanes, 1.0 mL/min, 223 nm; t1 = 7.53 min, t2 = 12.71 min]. $[\alpha]_D^{22}$ 0.344 (c0.54, $CHCl_3$). IR (Film): 3083, 3062, 2957, 2927, 2863, 1670, 1596, 1579, 1494, 1446, 1364, 1291, 1242, 1223, 1205, 1180, 1089, 1074, 1012, 836, 825, 793, 758, 701, 663; ^1H NMR (500 MHz, $CDCl_3$) δ 7.83 (dd, *J* = 8.3, 1.1 Hz, 2H), 7.53-7.49 (m, 1H), 7.42-7.38 (m, 2H), 7.19 (s, 4H), 3.97-3.84 (m, 2H), 2.13 (dd, *J* = 13.0, 9.9 Hz, 1H), 2.02 (dd, *J* = 12.7, 7.4 Hz, 1H), 1.81 (dd, *J* = 12.6, 11.7 Hz, 1H), 1.71 (dd, *J* = 13.0, 8.2

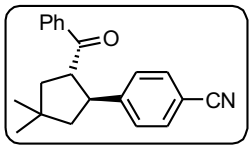


Hz, 1H), 1.21 (s, 3H), 1.13 (s, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 201.38, 142.48, 136.80, 132.94, 131.74, 128.72, 128.49, 128.42, 128.36, 54.90, 49.21, 46.70, 46.00, 38.94, 30.56, 29.53; MS (DART) exact mass calculated for [$C_{20}H_{22}ClO$]: 313.1354, found 313.1361.

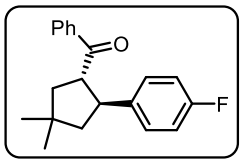
((1*S*,2*S*)-4,4-dimethyl-2-(4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)phenyl)cyclopentyl)(phenyl)methanone (9). Followed Method C, at -25 °C, the crude product was purified by column chromatography (1:9, EtOAc/hexanes) to give 36.8 mg (91% yield) of **9** as a white solid. The dr was determined to be >19:1 dr. trans diastereoisomer: 97% ee [OD, 0.5% iPrOH in hexanes, 1.0 mL/min, 223 nm; t1 = 8.21 min, t2 = 9.53 min]. $[\alpha]_D^{22}$ 0.610 (c1.23, $CHCl_3$). IR (Film): 2980, 2952, 2929, 2864, 1676, 1610, 1447, 1398, 1358, 1321, 1270, 1213, 1202, 1141, 1089, 1013, 962, 859, 927, 757, 707, 676, 637; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.80 – 7.78 (m, 2H), 7.66 (d, *J* = 8.0 Hz, 2H), 7.45 (t, *J* = 7.4 Hz, 1H), 7.35 (t, *J* = 7.7 Hz, 2H), 7.26 – 7.23 (m, 2H), 3.99-3.89 (m, 2H), 2.10 (dd, *J* = 13.0, 9.5 Hz, 1H), 2.00 (dd, *J* = 12.3, 7.2 Hz, 1H), 1.83 (t, *J* = 11.9 Hz, 1H), 1.70 (dd, *J* = 12.7, 7.6 Hz, 1H), 1.28 (s, 12H), 1.18 (s, 3H), 1.11 (s, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 201.61, 147.47, 136.93, 134.91, 132.76, 128.40, 128.35, 126.82, 83.59, 54.71, 49.32, 46.95, 46.76, 39.09, 30.50, 29.47, 24.82, 24.79.MS (DART) exact mass calculated for [$C_{26}H_{34}BO_3$]: 405.2596, found 405.2609.



4-((1*S*,2*S*)-2-benzoyl-4,4-dimethylcyclopentyl)benzonitrile (10). Followed Method C, at -25 °C, the crude product was purified by column chromatography (1:9, EtOAc/hexanes) to give 16.1 mg (53% yield) of **10** as a yellow solid. The dr was determined to be >19:1. trans diastereoisomer: 89% ee [AD, 5% iPrOH in hexanes, 1.0 mL/min, 223 nm; t1 = 6.40 min, t2 = 9.75 min]. $[\alpha]_D^{22}$ 0.499 (c0.97, $CHCl_3$). IR (Film): 2952, 2865, 2226, 1678, 1608, 1596, 1580, 1504, 1463, 1447, 1360, 1319, 1272, 1248, 1205, 1178, 1159, 1090, 1013, 896, 858, 754, 699, 658; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.84 (d, *J* = 7.2 Hz, 2H), 7.52 (d, *J* = 8.4 Hz, 3H), 7.41 (t, *J* = 7.7 Hz, 2H), 7.37 (d, *J* = 8.2 Hz, 2H), 4.04 (dd, *J* = 18.4, 10.8 Hz, 1H), 3.92 – 3.86 (m, 1H), 2.17 (dd, *J* = 13.1, 10.2 Hz, 1H), 2.05 (dd, *J* = 12.6, 7.5 Hz, 1H), 1.83 (t, *J* = 12.2 Hz, 1H), 1.72 (dd, *J* = 13.1, 8.3 Hz, 1H), 1.23 (s, 3H), 1.13 (s, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 200.79, 149.74, 136.48, 133.15, 132.20, 128.58, 128.37, 128.23, 118.99, 109.95, 54.74, 48.84, 46.67, 46.35, 39.10, 30.47, 29.45. MS (DART) exact mass calculated for [$C_{21}H_{22}NO$]: 304.1696, found 304.1704.

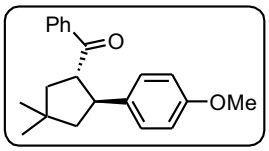


((1*S*,2*S*)-2-(4-fluorophenyl)-4,4-dimethylcyclopentyl)(phenyl)methanone (11). Followed Method A, the crude product was purified by column chromatography (1:9, EtOAc/hexanes) to give 25.2 mg (85% yield) of **11** as a yellow solid. The dr was determined to be 12:1 trans/cis. trans diastereoisomer: 94% ee [AS, hexanes, 0.3 mL/min, 223 nm; t1 = 24.23 min, t2 = 26.05 min]. $[\alpha]_D^{22}$ 0.538 (c0.91, $CHCl_3$). IR (Film): 2952, 2929, 2864, 1676, 1597, 1580, 1509, 1447, 1366, 1285, 1222, 1158, 1014, 832, 792, 699, 661; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.83 (dd, *J* = 8.3, 1.2 Hz, 2H), 7.52-7.49 (m, 1H), 7.41-7.38 (m, 2H), 7.23-7.20 (m, 2H), 6.91 (t, *J* = 8.7 Hz, 2H), 3.97-3.85 (m, 2H), 2.12 (dd, *J* = 13.0, 9.8 Hz, 1H), 2.02 (dd, *J* = 12.9, 7.1 Hz, 1H), 1.84-1.79 (m, 1H), 1.72



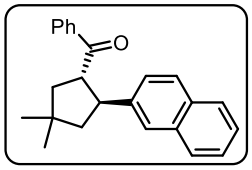
(dd, *J* = 12.8, 8.4 Hz, 1H), 1.22 (s, 3H), 1.13 (s, 3H).13C NMR (126 MHz, $CDCl_3$) δ 201.55, 162.27, 160.33, 139.58 (d, *J* = 3.2 Hz), 136.88, 132.88, 128.70 (d, *J* = 7.8 Hz), 128.41 (d, *J* = 13.0 Hz), 115.05 (d, *J* = 21.0 Hz), 55.04, 49.41, 46.66, 46.01, 38.86, 30.60, 29.56.MS (DART) exact mass calculated for [$C_{20}H_{22}FO$]: 297.1649, found 297.1659.

((1*S*,2*S*)-2-(4-methoxyphenyl)-4,4-dimethylcyclopentyl)(phenyl)methanone (12).



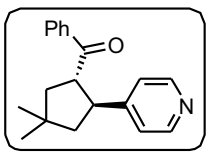
Followed Method A, the crude product was purified by column chromatography (1:9, EtOAc/hexanes) to give 27.4 mg (89% yield) of **12** as a white solid. The dr was determined to be >19:1. trans diastereoisomer: 96% ee [AD, 0.5% iPrOH in hexanes, 1.0 mL/min, 223 nm; t1 = 10.77 min, t2 = 23.35 min]. $[\alpha]_D^{22}$ 0.982 (c1.91, $CHCl_3$). IR (Film): 2950, 2932, 2863, 2834, 1677, 1611, 1580, 1512, 1462, 1447, 1365, 1282, 1244, 1204, 1177, 1035, 1012, 827, 775, 699, 659; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.84-7.82 (m, 2H), 7.51-7.47 (m, 1H), 7.40-7.37 (m, 2H), 7.18 (d, *J* = 8.7 Hz, 2H), 6.78 (d, *J* = 8.7 Hz, 2H), 3.94-3.86 (m, 2H), 3.74 (s, 3H), 2.10 (dd, *J* = 13.0, 9.4 Hz, 1H), 2.01 (dd, *J* = 12.7, 6.7 Hz, 1H), 1.85-1.80 (m, 1H), 1.73 (dd, *J* = 12.8, 7.5 Hz, 1H), 1.21 (s, 3H), 1.14 (s, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 201.88, 157.89, 137.03, 136.05, 132.72, 128.38, 128.37, 128.23, 113.72, 55.19, 55.03, 49.49, 46.69, 46.11, 38.81, 30.62, 29.58. MS (DART) exact mass calculated for [$C_{21}H_{25}O_2$]: 309.1849, found 309.8157.

((1*S*,2*S*)-4,4-dimethyl-2-(naphthalen-2-yl)cyclopentyl)(phenyl)methanone (13).



Followed Method A, the crude product was purified by column chromatography (1:9, EtOAc/hexanes) to give 30.2 mg (92% yield) of **13** as a white solid. The dr was determined to be >19:1. trans diastereoisomer: 94% ee [IA, 2.0% iPrOH in hexanes, 1.0 mL/min, 223 nm; t1 = 7.47 min, t2 = 11.99 min]. $[\alpha]_D^{22}$ 0.46 (c0.97, $CHCl_3$). IR (Film): 3057, 3021, 2948, 2928, 2862, 1670, 1598, 1579, 1508, 1447, 1363, 1298, 1242, 1212, 1022, 1002, 902, 865, 828, 746, 700; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.85 (dd, *J* = 8.4, 1.3 Hz, 2H), 7.75 (t, *J* = 7.9 Hz, 3H), 7.70 (d, *J* = 1.7 Hz, 1H), 7.49-7.35 (m, 6H), 4.20-4.14 (m, 1H), 4.09-4.03 (m, 1H), 2.19 (dd, *J* = 13.0, 10.1 Hz, 1H), 2.12 (dd, *J* = 12.8, 7.4 Hz, 1H), 2.02-1.97 (m, 1H), 1.79 (dd, *J* = 13.3, 8.4 Hz, 1H), 1.27 (s, 3H), 1.19 (s, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 201.69, 141.44, 136.94, 133.44, 132.78, 132.16, 128.40, 128.37, 127.99, 127.58, 127.45, 125.93, 125.82, 125.67, 125.19, 54.78, 49.35, 46.83, 39.12, 30.57, 29.52. MS (DART) exact mass calculated for [$C_{24}H_{25}O$]: 329.1900, found 329.1912.

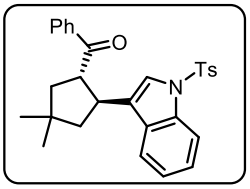
((1*S*,2*S*)-4,4-dimethyl-2-(pyridin-4-yl)cyclopentyl)(phenyl)methanone (14). Followed



Method A, the crude product was purified by column chromatography (2:3, EtOAc/hexanes) to give 24.3 mg (87% yield) of **14** as a yellow solid. The dr was determined to be >19:1. trans diastereoisomer: 79% ee [IA, 12% iPrOH in hexanes, 1.2 mL/min, 223 nm; t1 = 7.29 min, t2 = 13.45 min]. $[\alpha]_D^{22}$ 0.010 (c0.49, $CHCl_3$). IR (Film): 3057, 3025, 2952, 2865, 1680, 1597, 1580, 1448, 1366, 1251, 1208, 1013, 818, 748, 702; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.43 (d, *J* = 6.1 Hz, 2H), 7.86 (d, *J* = 7.1 Hz, 2H), 7.53 (t, *J* = 7.4 Hz, 1H), 7.42 (t, *J* = 7.8 Hz, 2H), 7.16 (d, *J* = 6.2 Hz, 2H), 3.99 (dd, *J* = 18.2, 10.6 Hz, 1H), 3.93-3.87 (m, 1H), 2.16 (dd, *J* = 13.1, 10.1 Hz, 1H), 2.05 (ddd, *J* = 12.7, 7.5, 1.0 Hz, 1H), 1.83

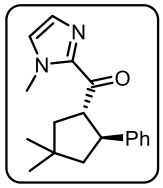
(t, *J* = 12.1 Hz, 1H), 1.72 (ddd, *J* = 13.0, 8.2, 1.0 Hz, 1H), 1.22 (s, 3H), 1.13 (s, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 200.82, 153.06, 149.77, 136.50, 133.12, 128.58, 128.38, 122.72, 54.20, 48.26, 46.68, 45.42, 39.16, 30.37, 29.36. MS (DART) exact mass calculated for [$C_{19}H_{22}NO$]: 280.1696, found 280.1698.

((1*S*,2*S*)-4,4-dimethyl-2-(1-tosyl-1*H*-indol-3-yl)cyclopentyl)(phenyl)methanone (15).

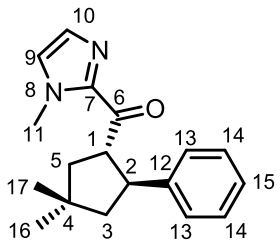


Followed Method A, the crude product was purified by column chromatography (1:5, EtOAc/hexanes) to give 42.9 mg (91% yield) of **15** as a white solid. The dr was determined to be >19:1. trans diastereoisomer: 98% ee [AD, 6.0% iPrOH in hexanes, 1.0 mL/min, 223 nm; t1 = 6.74 min, t2 = 10.01 min]. $[\alpha]_D^{22}$ 0.509 (c1.98, $CHCl_3$). IR (Film): 2952, 2933, 2866, 1677, 1597, 1580, 1447, 1367, 1306, 1280, 1253, 1207, 1187, 1173, 1124, 1095, 1019, 977, 909, 812, 745, 733, 703, 676; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.89 (d, *J* = 8.3 Hz, 1H), 7.84 (dd, *J* = 8.3, 1.1 Hz, 2H), 7.62 (d, *J* = 8.4 Hz, 2H), 7.55 (d, *J* = 7.9 Hz, 1H), 7.52-7.49 (m, 1H), 7.38 (t, *J* = 7.8 Hz, 2H), 7.34 (s, 1H), 7.23 (d, *J* = 8.3 Hz, 1H), 7.18-7.15 (m, 1H), 7.12 (d, *J* = 8.0 Hz, 2H), 4.19-4.13 (m, 1H), 4.05-4.00 (m, 1H), 2.30 (s, 3H), 2.18 – 2.08 (m, 2H), 1.92-1.87 (m, 1H), 1.75 (dd, *J* = 13.0, 7.9 Hz, 1H), 1.21 (s, 3H), 1.15 (s, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 201.73, 144.60, 136.84, 135.45, 135.13, 132.94, 130.53, 129.71, 128.49, 128.35, 126.66, 126.25, 124.55, 122.99, 121.87, 120.39, 113.61, 53.09, 48.03, 46.65, 39.43, 37.67, 30.39, 29.17, 21.52. MS (DART) exact mass calculated for [$C_{29}H_{30}NO_3S$]: 472.1941, found 472.1958.

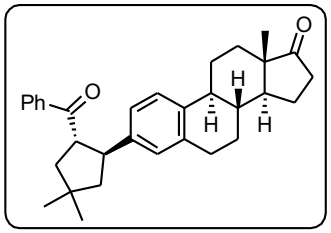
((1*S*,2*S*)-4,4-dimethyl-2-phenylcyclopentyl)(1-methyl-1*H*-imidazol-2-yl)methanone



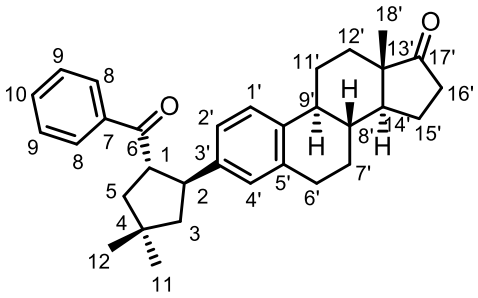
(16). Followed Method A, the crude product was purified by column chromatography (1:9, EtOAc/Hexanes) to give 25.9 mg (92% yield) of **16** as a white solid. The dr was determined to be 6:1 trans/cis. trans diastereoisomer: 88% ee [IA, 0.5% iPrOH in hexanes, 1.0 mL/min, 223 nm; t1 = 19.15 min, t2 = 22.66 min]. $[\alpha]_D^{22}$ 0.801 (c2.49, $CHCl_3$). IR (Film): 3028, 2951, 2865, 1669, 1494, 1462, 1406, 1365, 1289, 1222, 1154, 1078, 1019, 906, 890, 821, 760, 689; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.31-7.29 (m, 2H), 7.22 (t, *J* = 7.7 Hz, 2H), 7.13-7.09 (m, 2H), 6.94 (s, 1H), 4.49-4.43 (m, 1H), 3.93 (s, 3H), 3.83 (dd, *J* = 22.6, 7.5 Hz, 1H), 2.25 (dd, *J* = 12.9, 9.7 Hz, 1H), 2.01 (dd, *J* = 12.6, 7.5 Hz, 1H), 1.78 (t, *J* = 12.3 Hz, 1H), 1.66 (dd, *J* = 12.9, 9.2 Hz, 1H), 1.20 (s, 3H), 1.14 (s, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 194.24, 143.71, 143.14, 129.02, 128.23, 127.46, 126.85, 125.99, 54.28, 50.33, 47.05, 46.69, 38.48, 36.16, 30.69, 30.21.MS (DART) exact mass calculated for [$C_{20}H_{23}N_2O$]: 283.1805, found 283.1814.



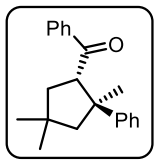
Assignment based on 1D 1H supported by COSY. Major product assigned as trans based on: ROE between H1, H3' (top), H5' (top), and Me17 defines "top". ROE from H2, H3'' (bottom), and H5'' (bottom) to Me16 gives "bottom".

(8*R*,9*S*,13*S*,14*S*)-3-((1*S*,2*S*)-2-benzoyl-4,4-dimethylcyclopentyl)-13-methyl-6,7,8,9,11,12,13,14,15,16-decahydro-17*H*-cyclopenta[*a*]phenanthren-17-one (17). 

Followed Method A, the crude product was purified by column chromatography (1:5, EtOAc/hexanes) to give 41.8 mg (92% yield) of **17** as a white solid. The dr was determined to be >19:1 trans/cis. trans diastereoisomer: 95% de [AD, 3.0% iPrOH in hexanes, 1.0 mL/min, 223 nm; t1 = 8.11 min, t2 = 9.65 min]. $[\alpha]_D^{22}$ 0.322 (c0.32, $CHCl_3$). IR (Film): 2930, 2864, 1738, 1681, 1490, 1448, 1369, 1254, 1207, 1083, 1053, 1038, 1008, 822, 757, 702; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.86 (dd, *J* = 8.4, 1.4 Hz, 2H), 7.50 (t, *J* = 7.4 Hz, 1H), 7.40 (t, *J* = 7.7 Hz, 2H), 7.17 (dd, *J* = 8.1, 1.0 Hz, 1H), 7.07 (dd, *J* = 8.1, 2.0 Hz, 1H), 6.98 (d, *J* = 1.9 Hz, 1H), 3.98-3.88 (m, 2H), 2.84 (dd, *J* = 9.9, 4.9 Hz, 2H), 2.51-2.46 (m, 1H), 2.39-2.35 (m, 1H), 2.24-2.21 (m, 1H), 2.16-2.11 (m, 2H), 2.06-1.92 (m, 4H), 1.86 – 1.81 (m, 1H), 1.69 (dd, *J* = 13.3, 7.6 Hz, 1H), 1.63-1.56 (m, 2H), 1.51-1.36 (m, 4H), 1.21 (s, 3H), 1.11 (s, 3H), 0.88 (s, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 201.58, 141.56, 137.48, 136.97, 136.26, 132.72, 128.44, 128.38, 128.28, 125.35, 124.55, 54.74, 50.48, 49.46, 47.98, 46.81, 45.83, 44.28, 38.98, 38.15, 35.84, 31.57, 30.53, 29.45, 29.38, 26.52, 25.64, 21.55, 13.82.MS (DART) exact mass calculated for $[C_{32}H_{39}O_2]$: 455.2945, found 455.2957.

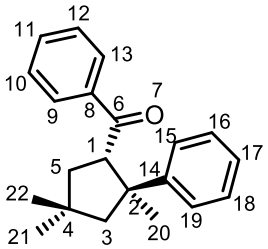


Assignments were based on 1D 1H supported by COSY and HSQC. Major product trans: ROE from H1, H3' (top), H5' (top) to H12 defines "top". ROE from H11 to H3'' (bottom), H5'' (bottom) and H2 defines "bottom" and shows that H2 is trans to H1.

phenyl((1*S*,2*S*)-2,4,4-trimethyl-2-phenylcyclopentyl)methanone (19). 

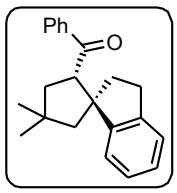
Followed Method A, the crude product was purified by column chromatography (1:9, EtOAc/hexanes) to give 28.0 mg (96% yield) of **18** as a yellow oil. The dr was determined to be >19:1. trans diastereoisomer: 96% ee [AD, 0.5% iPrOH in hexanes, 1.0 mL/min, 223 nm; t1 = 5.16 min, t2 = 5.99 min]. $[\alpha]_D^{22}$ 0.745 (c2.12, $CHCl_3$). IR (Film): 057, 3025, 2952, 2867, 1673, 1597, 1580, 1496, 1464, 1446, 1380, 1367, 1311, 1246, 1206, 1180, 1009, 830, 759, 728, 691; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.47 (dd, *J* = 8.4, 1.2 Hz, 2H), 7.39-7.35 (m, 1H), 7.28 – 7.26 (m, 2H), 7.22-7.16 (m, 4H), 7.14-7.11 (m, 1H), 4.20 (dd, *J* = 12.4, 6.3 Hz, 1H), 2.45 (t, *J* = 12.7 Hz, 1H), 2.30 (d, *J* = 13.8 Hz, 1H), 1.92 (d, *J* = 13.9 Hz, 1H), 1.81 (dd, *J* = 13.1, 6.2 Hz, 1H), 1.39 (s, 3H), 1.29 (d, *J* = 1.7 Hz, 6H).^{13}C NMR (126 MHz, $CDCl_3$) δ

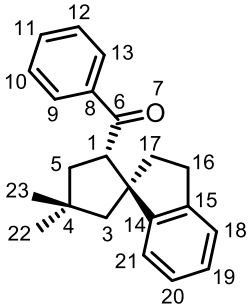
201.94, 149.02, 138.04, 132.14, 128.18, 128.09, 127.90, 126.26, 125.72, 58.54, 57.55, 51.09, 44.39, 36.38, 31.91, 31.79, 24.13. MS (DART) exact mass calculated for [$C_{21}H_{25}O$]: 293.1900, found 293.1906.



Assignments were based on 1D 1H supported by COSY and HSQC. Major product trans: ROE from H1, H3' (top), H5' (top) to H22 defines "top". ROE from H20 to H3'' (bottom), H5'' (bottom) and H21 defines "bottom" and shows that H1 is cis to Me20.

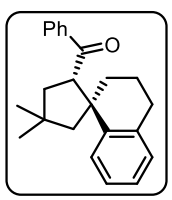
((1*S*,5*S*)-3,3-dimethyl-2',3'-dihydrospiro[cyclopentane-1,1'-inden]-5-yl)(phenyl)methanone (20). Followed Method A, the crude product was purified by column chromatography (1:9, EtOAc/hexanes) to give 24.9 mg (82% yield) of **19** as a yellow oil. The dr was determined to be >19:1 dr. <u>trans diastereoisomer:</u> 96% ee [AD, 0.2% iPrOH in hexanes, 1.0 mL/min, 223 nm; t1 = 6.09 min, t2 = 7.07 min]. $[\alpha]_D^{22}$ 1.805 (c1.78, $CHCl_3$). IR (Film): 2950, 2930, 2863, 1669, 1596, 1580, 1478, 1457, 1447, 1365, 1291, 1244, 1226, 1209, 1026, 1003, 982, 754, 730, 718, 689; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.43 (d, *J* = 7.6 Hz, 1H), 7.38 (dd, *J* = 8.4, 1.2 Hz, 2H), 7.31-7.28 (m, 1H), 7.25-7.22 (m, 1H), 7.10-7.07 (m, 2H), 7.01 (td, *J* = 7.4, 1.0 Hz, 1H), 6.80 (d, *J* = 7.5 Hz, 1H), 3.97 (dd, *J* = 12.1, 6.4 Hz, 1H), 2.64 (ddd, *J* = 13.0, 7.9, 1.8 Hz, 1H), 2.57 (dd, *J* = 16.5, 9.1 Hz, 1H), 2.43 (t, *J* = 12.6 Hz, 1H), 2.33 (d, *J* = 13.7 Hz, 1H), 2.27-2.20 (m, 1H), 1.88-1.78 (m, 2H), 1.70 (dd, *J* = 13.1, 6.4 Hz, 1H), 1.27 (s, 3H), 1.25 (s, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 201.62, 148.79, 143.78, 137.37, 132.17, 128.00, 127.66, 126.83, 126.45, 124.50, 122.54, 60.66, 57.86, 56.94, 44.43, 36.97, 36.45, 31.50, 31.24, 31.04. MS (DART) exact mass calculated for [$C_{22}H_{25}O$]: 305.1900, found 305.1907.





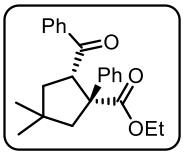
Assignments were based on 1D 1H supported by COSY and HSQC. Major product trans: ROE from H1, H3' (top), H5' (top) to H23 defines "top". ROE from H22 to H3'' (bottom), H5'' (bottom) and H17'' defines "bottom" and shows that Ph14 is trans to H1.

((1*S*,5*S*)-3,3-dimethyl-3',4'-dihydro-2'*H*-spiro[cyclopentane-1,1'-naphthalen]-5-yl)(phenyl)methanone (20). Followed Method A, the crude product was purified by column chromatography (1:9, EtOAc/hexanes) to give 25.8 mg (81% yield) of **20** as a yellow oil. The dr was determined to be >19:1.

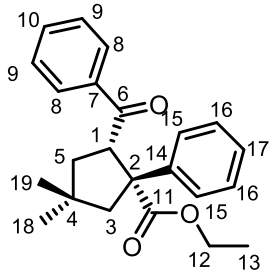


trans diastereoisomer: 90% ee [AD, 0.5% iPrOH in hexanes, 1.0 mL/min, 223 nm; t1 = 6.14 min, t2 = 7.10 min]. $[\alpha]_D^{22}$ 1.378 (c3.12, CH_2Cl_2). IR (Film): 2949, 2932, 2866, 1671, 1597, 1579, 1488, 1446, 1365, 1314, 1280, 1236, 1205, 1181, 1008, 993,973, 861, 831, 754, 732, 718, 690; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.65 (d, *J* = 7.9 Hz, 1H), 7.40 (dd, *J* = 8.4, 1.2 Hz, 2H), 7.30-7.24 (m, 2H), 7.10-7.06 (m, 2H), 7.02-6.99 (m, 1H), 6.77 (d, *J* = 8.2 Hz, 1H), 4.28 (dd, *J* = 12.5, 6.2 Hz, 1H), 2.56 – 2.45 (m, 2H), 2.26 – 2.20 (m, 1H), 2.11 (d, *J* = 14.1 Hz, 1H), 2.00 (d, *J* = 14.1 Hz, 1H), 1.87 (dd, *J* = 16.8, 9.3 Hz, 1H), 1.78 – 1.68 (m, 2H), 1.53-1.44 (m, 2H), 1.31 (s, 3H), 1.24 (s, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 202.75, 142.99, 138.11, 138.05, 131.92, 128.97, 128.27, 127.83, 127.67, 126.14, 125.41, 61.34, 59.27, 51.27, 43.57, 36.26, 33.94, 31.96, 31.92, 30.42, 20.14.MS (DART) exact mass calculated for [$C_{23}H_{27}O$]: 319.2056, found 319.2068.

ethyl (1*R*,2*S*)-2-benzoyl-4,4-dimethyl-1-phenylcyclopentane-1-carboxylate (21).

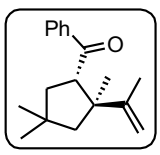


Followed Method A, the crude product was purified by column chromatography (1:9, EtOAc/hexanes) to give 30.5 mg (87% yield) of **21** as a white solid. The dr was determined to be 9:1 cis/trans. cis diastereoisomer: 80% ee [AD, 2.0% iPrOH in hexanes, 1.0 mL/min, 223 nm; t1 = 9.13 min, t2 = 16.87 min]. $[\alpha]_D^{22}$ 0.512 (c2.54, $CHCl_3$). IR (Film): 2955, 2903, 2868, 1728, 1683, 1596, 1580, 1498, 1447, 1365, 1244, 1219, 1171, 1120, 1058, 1011, 756, 737, 696; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.99 (dd, *J* = 8.3, 1.2 Hz, 2H), 7.56 (dd, *J* = 7.5, 2.1 Hz, 3H), 7.48 (t, *J* = 7.6 Hz, 2H), 7.35 (t, *J* = 7.7 Hz, 2H), 7.28-7.24 (m, 1H), 4.74 (dd, *J* = 9.1, 3.6 Hz, 1H), 4.06-3.93 (m, 2H), 2.94 (d, *J* = 13.8 Hz, 1H), 2.42 (dd, *J* = 13.8, 1.0 Hz, 1H), 2.13 (dd, *J* = 13.7, 9.1 Hz, 1H), 1.94 (dd, *J* = 13.7, 3.7 Hz, 1H), 1.04-1.01 (m, 6H), 0.79 (s, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 201.32, 174.84, 142.05, 136.48, 132.80, 128.56, 128.50, 128.43, 126.96, 126.50, 61.04, 60.61, 54.19, 50.32, 44.63, 38.00, 32.10, 31.82, 13.80.MS (DART) exact mass calculated for [$C_{23}H_{27}O_3$]: 351.1955, found 351.1966.



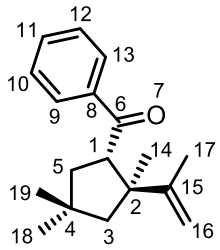
Assignment of aliphatics based on 1D 1H supported by COSY. Assignment of aromatics based on COSY. Assignment of Me's based on ROESY. Major product assigned as cis based on: ROE between H1, H3' (top), H5' (top) and a single Me (19) defines "top". ROE from H3'' (bottom) and H5'' (bottom) to Me (18) gives "bottom". Strong ROE from H15 to H1, H3' and H5' indicate C-2 phenyl is on top.

phenyl((1*S*,2*S*)-2,4,4-trimethyl-2-(prop-1-en-2-yl)cyclopentyl)methanone (22).



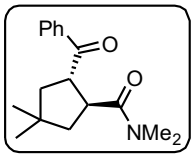
Followed Method A, the crude product was purified by column chromatography (1:9, EtOAc/hexanes) to give 23.0 mg (90% yield) of **22** as a yellow oil. The dr was determined to be 4:1 dr. trans diastereoisomer: 96% ee [AS, 0.1% iPrOH in hexanes, 1.0 mL/min, 223 nm; t1 = 6.09 min, t2 = 7.08 min]. $[\alpha]_D^{22}$ 0.111 (c1.26, $CHCl_3$). IR (Film): 3085, 3060, 2953,

2867, 1678, 1636, 1597, 1462, 1447, 1370, 1225, 1207, 1180, 1015, 1003, 974, 889, 833, 729, 711, 691, 669; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.83 (dd, *J* = 8.3, 1.2 Hz, 2H), 7.53 – 7.49 (m, 1H), 7.45 – 7.40 (m, 2H), 4.61 – 4.59 (m, 2H), 4.04 (dd, *J* = 12.1, 6.5 Hz, 1H), 2.24 (t, *J* = 12.5 Hz, 1H), 1.90 (d, *J* = 13.6 Hz, 1H), 1.78 (d, *J* = 1.2 Hz, 3H), 1.73 (dd, *J* = 13.0, 6.4 Hz, 1H), 1.50 (d, *J* = 13.6 Hz, 1H), 1.19 (d, *J* = 5.8 Hz, 6H), 1.14 (s, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 202.56, 150.72, 139.01, 132.43, 128.28, 127.95, 110.38, 54.46, 52.49, 52.25, 44.59, 36.26, 31.89, 31.63, 23.35, 20.50. MS (DART) exact mass calculated for [$C_{18}H_{25}O$]: 257.1900, found 257.1906.

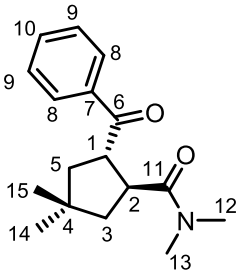


Assignments were based on COSY and ROESY. In major diasteromer ROE observed between H1 and H19 and very weak ROE between H1 and H14. In minor, strong ROE H1 to H14 and very weak H1 to H19. This indicates C14 is syn to carbonyl in the major isomer. In major, ROE H1 to H3' and H19 to H3', so H3' is "top" and H3'' is "bottom". Strong ROE from H3'' (bottom) to H14. ROE from H1 to H16. Minor: H1 to H14; H1 to H19 (weak), H5' (top) to H19 and H14, H5'' (bottom) to H18 and H16 so the vinyl group is bottom.

(1*S*,2*S*)-2-benzoyl-*N*,*N*,4,4-tetramethylcyclopentane-1-carboxamide (23). Followed

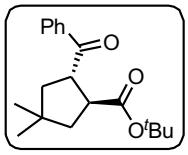


Method A, the crude product was purified by column chromatography (1:9, methanol/DCM) to give 24.8 mg (91% yield) of **23** as a yellow oil. The dr was determined to be 11:1. <u>trans diastereoisomer:</u> 96% ee [AD, 12% iPrOH in hexanes, 1.0 mL/min, 223 nm; t1 = 4.04 min, t2 = 5.20 min]. $[\alpha]_D^{22}$ 0.051 (c0.28, $CHCl_3$). IR (Film): 2952,2931,2866, 1677, 1639, 1580, 1496, 1463, 1448, 1416, 1367, 1255, 1220, 1139, 1016, 884, 826, 776, 701; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.98 (dd, *J* = 8.3, 1.4 Hz, 2H), 7.53 (t, *J* = 7.4 Hz, 1H), 7.44 (t, *J* = 7.7 Hz, 2H), 4.52-4.46 (m, 1H), 3.87-3.81 (m, 1H), 3.09 (s, 3H), 2.91 (s, 3H), 2.07 (dd, *J* = 12.7, 9.8 Hz, 1H), 1.89 (dd, *J* = 12.4, 8.7 Hz, 1H), 1.68 (dd, *J* = 12.5, 9.9 Hz, 1H), 1.59-1.57 (m, 1H), 1.15 (s, 3H), 1.04 (s, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 202.15, 174.52, 136.63, 132.95, 128.69, 128.48, 50.33, 45.98, 45.13, 42.65, 40.06, 37.26, 35.75, 29.47, 29.22. MS (DART) exact mass calculated for [$C_{17}H_{23}NO_2$]: 274.1802, found 274.1803.

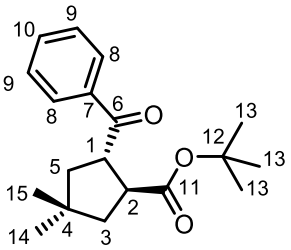


Assignments were based on 1D 1H supported by COSY and HSQC. Major product trans: ROE from H1, H3' (top), H5' (top) to H15 defines "top". ROE from H14 to H3'' (bottom), H5'' (bottom) and H2 defines "bottom" and shows that H2 is trans to H1.

***tert*-butyl (1*S*,2*S*)-2-benzoyl-4,4-dimethylcyclopentane-1-carboxylate (24).** Followed

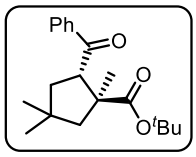


Method C, at -35 °C for 50 h, the crude product was purified by column chromatography (1:9, EtOAc/hexanes) to give 27.5 mg (91% yield) of **24** as a yellow oil. The dr was determined to be >19:1. trans diastereoisomer: 73% ee [IA, 0.5% iPrOH in hexanes, 1.0 mL/min, 223 nm; t1 = 7.44 min, t2 = 8.06 min]. $[\alpha]_D^{22}$ 0.305 (c1.89, CH_2Cl_2). IR (Film): 2955, 2933, 2868, 1721, 1682, 1597, 1581, 1559, 1448, 1391, 1367, 1315, 1293, 1252, 1232, 1208, 1151, 1014, 981, 849, 773, 700, 659; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.99-7.97 (m, 2H), 7.55 (t, *J* = 7.4 Hz, 1H), 7.46 (t, *J* = 7.7 Hz, 2H), 4.22 (q, *J* = 8.7 Hz, 1H), 3.55 (q, *J* = 8.8 Hz, 1H), 2.00-1.90 (m, 2H), 1.78 (dd, *J* = 12.7, 8.9 Hz, 1H), 1.62-1.57 (m, 1H), 1.36 (s, 9H), 1.10 (s, 3H), 1.03 (s, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 201.45, 174.63, 136.78, 132.92, 128.56, 128.51, 80.34, 48.99, 46.58, 45.94, 44.61, 39.94, 29.07, 28.78, 27.98.MS (DART) exact mass calculated for [$C_{19}H_{27}O_3$]: 303.1955, found 303.1964.

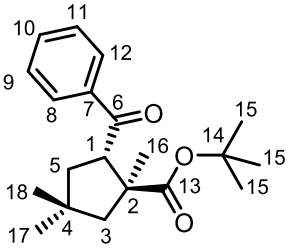


Assignments were based on 1D 1H supported by COSY and HSQC. Major product trans: ROE from H1, H3' (top), H5' (top) to H15 defines "top". ROE from H14 to H3'' (bottom), H5'' (bottom) and H2 defines "bottom" and shows that H2 is trans to H1.

***tert*-butyl (1*S*,2*S*)-2-benzoyl-1,4,4-trimethylcyclopentane-1-carboxylate (25).**

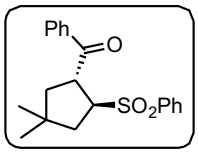


Followed Method A, the crude product was purified by column chromatography (1:9, EtOAc/hexanes) to give 30.0 mg (95% yield) of **25** as a yellow oil. The dr was determined to be >19:1. trans diastereoisomer: 65% ee [AD, 0.5% iPrOH in hexanes, 1.0 mL/min, 223 nm; t1 = 3.70 min, t2 = 4.29 min]. $[\alpha]_D^{22}$ 0.978 (c3.23, $CHCl_3$). IR (Film): 2954, 2934, 2868, 1715, 1677, 1597, 1581, 1457, 1448, 1367, 1325, 1245, 1219, 1147, 1012, 978, 849, 738, 706, 690, 667; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.02 (dd, *J* = 8.4, 1.3 Hz, 2H), 7.54 – 7.50 (m, 1H), 7.42 (t, *J* = 7.6 Hz, 2H), 4.65 (dd, *J* = 11.4, 6.8 Hz, 1H), 2.22 (dd, *J* = 12.8, 11.5 Hz, 1H), 2.12 (dd, *J* = 13.4, 1.7 Hz, 1H), 1.66 (ddd, *J* = 12.9, 6.9, 1.7 Hz, 1H), 1.53 (d, *J* = 13.4 Hz, 1H), 1.38 (s, 9H), 1.14 (s, 3H), 1.10 (s, 3H), 1.02 (s, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 201.81, 176.84, 138.26, 132.76, 128.58, 128.42, 80.62, 54.95, 53.35, 50.71, 43.67, 37.76, 30.29, 28.95, 27.80, 22.48.MS (DART) exact mass calculated for [$C_{20}H_{29}O_3$]: 317.2111, found 317.2120.



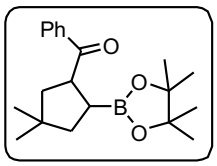
Assignment of rings and tBu from 1D 1H supported by COSY. Assignment of Me's from ROESY. Water overlapped with one line in H3", doublet confirmed by HSQC. Assigned as trans based on: H1, H3' (top) and H5' (top) to Me18; H5'' (bottom) and H3'' (bottom) to two methyls (Me16 and 17). In COSY Me17 showed weak correlations to both H3' and H5', Me16 couples to only H3'.

((1*R*,2*S*)-4,4-dimethyl-2-(phenylsulfonyl)cyclopentyl)(phenyl)methanone (26).

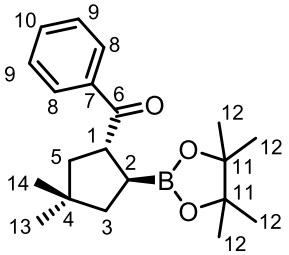


Followed Method C, at -25 °C, the crude product was purified by column chromatography (2:3, EtOAc/hexanes) to give 28.6 mg (81% yield) of **26** as a white solid. The dr was determined to be >19:1. trans diastereoisomer: 51% ee [AD, 6% iPrOH in hexanes, 1.0 mL/min, 250 nm; t1 = 10.92 min, t2 = 14.14 min]. $[\alpha]_D^{22}$ 0.036 (c0.48, $CHCl_3$). IR (Film): 3060, 2958, 2869, 1683, 1596, 1582, 1559, 1447, 1306, 1238, 1147, 1087, 1010, 974, 768, 744, 721, 700, 688, 646; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.82 (dd, *J* = 16.5, 8.3 Hz, 4H), 7.57-7.50 (m, 2H), 7.45-7.39 (m, 4H), 4.65-4.60 (m, 1H), 4.38-4.33 (m, 1H), 2.21-2.15 (m, 2H), 1.90 (dd, *J* = 13.0, 8.8 Hz, 1H), 1.58 (dd, *J* = 13.4, 7.3 Hz, 1H), 1.18 (s, 3H), 0.96 (s, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 198.31, 138.67, 135.36, 133.52, 133.37, 129.07, 128.57, 128.47, 128.32, 64.53, 47.09, 46.33, 40.81, 40.48, 28.70, 28.02. MS (DART) exact mass calculated for [$C_{20}H_{23}O_3S$]: 343.1362, found 343.1374.

((1*S*,2*S*)-4,4-dimethyl-2-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)cyclopentyl)(phenyl)methanone (27).



Followed Method C, at -25 °C, the crude product was purified by column chromatography (1:9, EtOAc/hexanes) to give 25.9 mg (79% yield) of **27** as a yellow oil. The dr was determined to be >19:1. trans diastereoisomer: 46% ee [AD, 0.5% iPrOH in hexanes, 1.0 mL/min, 223 nm; t1 = 5.36 min, t2 = 7.56 min]. $[\alpha]_D^{22}$ 0.211 (c1.16, $CHCl_3$). IR (Film): 2976, 2951, 2932, 2865, 1681, 1597, 1581, 1466, 1448, 1379, 1315, 1232, 1213, 1142, 1009, 971, 911, 589, 770, 698, 669; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.02–8.00 (m, 2H), 7.54-7.50 (m, 1H), 7.43 (t, *J* = 7.6 Hz, 2H), 3.97 (q, *J* = 8.9 Hz, 1H), 2.03 (q, *J* = 9.1 Hz, 1H), 1.83 (dd, *J* = 12.7, 9.2 Hz, 1H), 1.75 (dd, *J* = 12.3, 9.2 Hz, 1H), 1.67 (dd, *J* = 12.7, 8.6 Hz, 1H), 1.52 (dd, *J* = 12.3, 9.2 Hz, 1H), 1.19 (d, *J* = 2.9 Hz, 12H), 1.07 (s, 3H), 1.02 (s, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 202.95, 137.33, 132.49, 128.62, 128.30, 83.20, 48.86, 46.06, 43.66, 40.69, 29.01, 28.76, 24.73, 24.63.MS (DART) exact mass calculated for [$C_{20}H_{30}BO_3$]: 329.2283, found 329.2294.



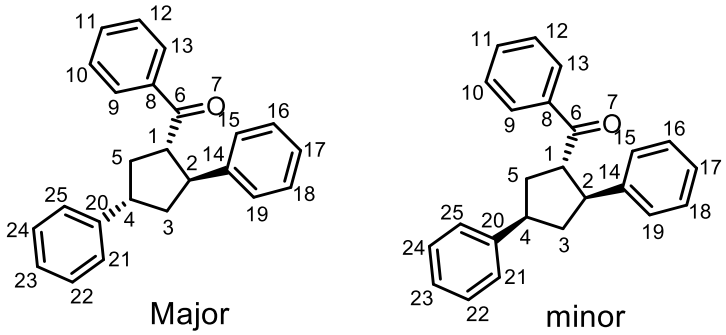
Assignments were based on 1D 1H supported by COSY and HSQC. Major product trans: ROE from H1, H3' (top), H5' (top) to H14 defines "top". ROE from H13 to H3'' (bottom), H5'' (bottom) and H2 defines "bottom" and shows that H2 is trans to H1.

(4,4-dimethyl-2,2-diphenylcyclopentyl)(phenyl)methanone (28). Followed Method C, at -25 °C, the crude product was purified by column chromatography (1:9, EtOAc/hexanes) to give 31.9 mg (90% yield) of **28** as a white solid: 45% ee [AD, 1.0% iPrOH in hexanes, 1.0 mL/min, 223 nm; t1 = 3.82 min, t2 = 4.72 min]. $[\alpha]_D^{22}$ 0.898 (c3.27, $CHCl_3$). IR (Film): 3058, 3025, 2935, 2866, 2097, 1677, 1596, 1580, 1492, 1446, 1362, 1265, 1218, 1173, 1118, 1034, 974, 915, 769, 748, 696, 644; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.74-7.72 (m, 2H), 7.45 (dd, *J* = 7.4, 3.7 Hz, 3H), 7.35 (t, *J* = 7.7 Hz, 2H), 7.30 (t, *J* = 7.8 Hz, 2H), 7.15 (t, *J* = 7.3 Hz, 1H), 7.09 (d, *J* = 7.3 Hz, 2H), 7.01 (t, *J* = 7.7 Hz, 2H), 6.92 (t, *J* = 7.3 Hz, 1H), 5.17 (d, *J* = 8.8 Hz, 1H), 3.28 (d, *J* = 12.6 Hz, 1H), 2.44 (dd, *J* = 12.7, 1.4 Hz, 1H), 2.23 (dd, *J* = 13.9, 8.8 Hz, 1H), 1.98 (dd, *J* = 13.9, 1.7 Hz, 1H), 1.22 (s, 3H), 0.67 (s, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 202.92, 148.59, 147.12, 138.45, 132.16, 128.30, 128.22, 127.96, 127.74, 127.30, 126.74, 125.70, 125.33, 59.74, 53.37, 51.84, 44.07, 38.11, 32.22, 31.81.MS (DART) exact mass calculated for [$C_{26}H_{27}O$]: 355.2056, found 355.2067.

1-((1*S*,2*S*)-4,4-dimethyl-2-phenylcyclopentyl)ethan-1-one (29). Followed Method A, the crude product was purified by column chromatography (1:9, EtOAc/hexanes) to give 17.7 mg (82% yield) of **29** as a yellow oil. The dr was determined to be 5:1. <u>trans diastereoisomer</u>: 13% ee [AD, 0.3% iPrOH in hexanes, 1.0 mL/min, 220 nm; t1 = 6.19 min, t2 = 6.82 min]. $[\alpha]_D^{22}$ 0.025 (c0.49, $CHCl_3$). IR (Film): 2951, 2930, 2903, 2864, 1707, 1584, 1494, 1452, 1365, 1356, 1235, 1166, 859, 761, 747, 699; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.30-7.24 (m, 5H), 3.52-3.46 (m, 1H), 3.16 (q, J = 9.3 Hz, 1H), 1.98-1.95 (m, 4H), 1.92-1.90 (m, 1H), 1.79-1.76 (m, 1H), 1.72-1.68 (m, 1H), 1.16 (s, 3H), 1.10 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 210.23, 143.89, 128.51, 127.25, 126.33, 60.14, 50.32, 47.94, 44.34, 38.39, 30.53, 29.96, 29.71. MS (DART) exact mass calculated for [$C_{15}H_{21}O$]: 217.1587, found 217.1593.

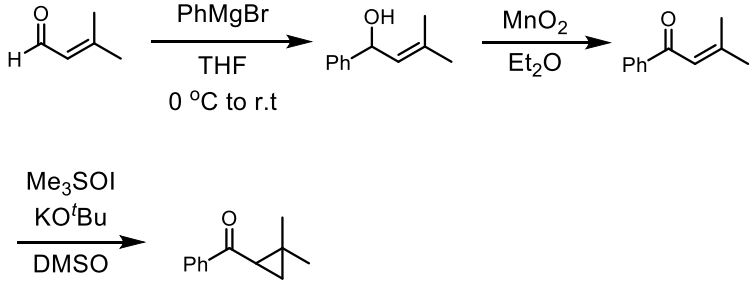
((1*S*,2*S*,4*S*)-2,4-diphenylcyclopentyl)(phenyl)methanone (30). Followed Method C, at 0 °C for 48 h, the crude product was purified by column chromatography (1:9, EtOAc/hexanes) to give 30.3 mg (93% yield) of **30** as a yellow oil. The dr was determined to be 2:1 dr. Only two diasteremers were observed with crude ^{1}H NMR. <u>major diastereoisomer:</u> 79% ee [AD, 1.0% iPrOH in hexanes, 1.0 mL/min, 223 nm; t1 = 13.54 min, t2 = 24.87 min]. <u>minor diastereoisomer:</u> 93% ee [AD, 1.0% iPrOH in hexanes, 1.0 mL/min, 223 nm; t1 = 12.49

min, t2 = 17.04 min]. $[\alpha]_D^{22}$ 0.288 (c0.93, $CHCl_3$). IR (Film): 3060, 3027, 2950, 2868, 1678, 1598, 1580, 1494, 1448, 1368, 1347, 1262, 1218, 1180, 1030, 1004, 754, 698; Major: ^{1}H NMR (599 MHz, $CDCl_3$) δ 4.09-4.05 (m, 1H), 3.96 (q, J = 8.3 Hz, 1H), 3.62-3.56 (m, 1H), 2.61 (dq, J = 13.5, 6.8 Hz, 1H), 2.43 – 2.33 (m, 2H), 2.21-2.13 (m,1H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 201.41, 145.27, 144.65, 136.95, 128.58, 128.47, 128.46, 128.46, 128.41, 127.26, 127.11, 126.27, 126.25, 55.62, 47.43, 45.45, 42.30, 40.56. MS (DART) exact mass calculated for $[C_{24}H_{23}O]$: 327.1743, found 327.1752.



In major, H-1 gives ROEs to H4 and H5' (top), whereas H2 gives ROE to H5'' (H3' and H3'' are overlapped so ROEs are unclear) indicating that H1 is on the same face as H4 and opposite to H2. In minor, a strong ROE is observed between H2 and H4 while no ROE is present between H1 and H4 indicating that the C4 stereogenic center is inverted relative to major. ROE correlations to H-5s and H-3s are obscured by TOCSY artifacts.

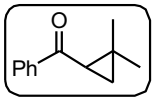
Section 3. Preparation and characterization of catalysts and substrates



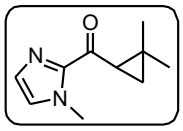
Method D. Representative procedure:[1] To a solution of 3-methyl-2-butenal (2.52 g, 30 mmol, 1.0 equiv) in THF (50 mL), PhMgBr (11 mL, 33 mmol, 1.1 equiv) was added at 0 °C. The mixture was then stirred for 2 h at room temperature. Subsequently, the reaction was quenched with water (100 mL) and extracted with EtOAc (3 times). The combined organic layers were washed with brine, dried over Na_2SO_4 and concentrated in vacuo. The crude product was purified by column chromatography on silica gel (20% EtOAc in hexanes) to afford 4.37 g of 3-methyl-1-phenylbut-2-en-1-ol (90% yield).

To a solution of 3-methyl-1-phenylbut-2-en-1-ol (3.24 g, 20 mmol, 1 equiv) in Et_2O (120 mL) was added MnO_2 (activated, 17.4 g, 200 mmol, 10 equiv). The mixture was then stirred for 12 h at room temperature. Subsequently, the reaction was filtered and the solvent was removed. The crude product was purified by column chromatography on silica gel (10% EtOAc in hexanes) to afford 2.56 g of 3-methyl-1-phenylbut-2-en-1-one (80% yield).

A flame-dried 100 mL flask was charged with KO^{t}Bu (1.34 g, 12 mmol, 1.2 equiv) and trimethylsulfoxonium iodide (2.64 g, 12 mmol, 1.2 equiv), DMSO (40 mL) was then added dropwise to the flask, the reaction mixture was stirred for an additional 15 min, during which the solution became clear. 3-Methyl-1-phenylbut-2-en-1-one (1.6 g, 10 mmol, 1.0 equiv) in 20 mL of DMSO was added in one portion via syringe. The reaction mixture was allowed to stir for 4 h at room temperature, then quenched by addition of water and the mixture extracted three times with Et_2O. The combined organic layers were dried over Na_2SO_4, and volatiles were removed under reduced pressure to yield the crude product. The crude product was purified by column chromatograph on silica gel (10% EtOAc in hexanes) to afford 1.65 g of 2,2-dimethylcyclopropyl(phenyl)methanone (95% yield).

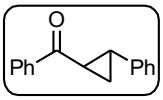


(2,2-dimethylcyclopropyl)(phenyl)methanone (1).[1] ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.96-7.93 (m, 2H), 7.58-7.52 (m, 1H), 7.47 (t, J = 7.2 Hz, 2H), 2.48 (dd, J = 7.5, 5.6 Hz, 1H), 1.52 (dd, J = 5.6, 4.1 Hz, 1H), 1.36 (s, 3H), 1.09 (s, 3H), 0.96 (dd, J = 7.5, 4.1 Hz, 1H). Characterization data consistent with literature.[1]

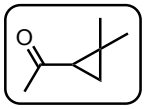


(2,2-dimethylcyclopropyl)(1-methyl-1*H*-imidazol-2-yl)methanone. The synthesis of the precursor prior to oxidation, 3-methyl-1-(1-methyl-1*H*-imidazol-2-yl)but-2-en-1-ol, was conducted using a modified literature procedure from 3-methyl-2-butenal and 1-methylimidazole.[2]

Subsequent MnO_2 oxidation followed by cyclopropanation (see Method D) furnished the desired substrate. ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.15 (d, *J* = 1.0 Hz, 1H), 7.00 (d, *J* = 1.0 Hz, 1H), 3.99 (s, 3H), 3.16 (dd, *J* = 7.8, 5.7 Hz, 1H), 1.39 (dd, *J* = 5.7, 3.7 Hz, 1H), 1.30 (s, 3H), 1.19 (s, 3H), 1.02 (dd, *J* = 7.8, 3.7 Hz, 1H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 190.58, 144.61, 128.86, 126.46, 36.28, 32.07, 28.37, 27.31, 24.22, 18.19.



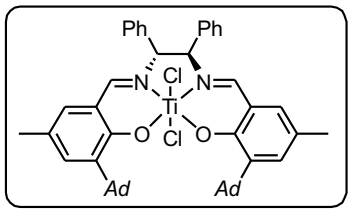
***trans*-phenyl(2-phenylcyclopropyl)methanone.**[3] ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.01-7.98 (m, 2H), 7.56 (t, *J* = 7.3 Hz, 1H), 7.46 (t, *J* = 7.4 Hz, 2H), 7.32 (t, *J* = 7.1 Hz, 2H), 7.23-7.17 (m, 3H), 2.94-2.88 (m, 1H), 2.74-2.67 (m, 1H), 1.96-1.90 (m, 1H), 1.59-1.53 (m, 1H). Characterization data consistent with literature.[3]



1-(2,2-dimethylcyclopropyl)ethan-1-one. ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.24 (s, 3H), 1.86 (dd, *J* = 7.6, 5.5 Hz, 1H), 1.24 (dd, *J* = 5.6, 4.1 Hz, 1H), 1.20 (s, 3H), 1.09 (s, 3H), 0.82 (dd, *J* = 7.6, 4.0 Hz, 1H).

Method E. Synthesis of salen ligand for catalyst **3**: In an oven-dried round bottom flask, 3-(adamantan-1-yl)-5-methylsalicylaldehyde (540 mg, 2.0 mmol, 2.0 equiv; synthesized according to ref. [4]) and (1*R*,2*R*)-1,2-diphenylethane-1,2-diamine (212 mg, 1.0 mmol, 1 equiv) were dissolved in EtOH (5.0 mL). The reaction was refluxed overnight (ca. 10 h) and then cooled to room temperature. The precipitate was collected via vacuum filtration and washed with hexanes to yield the desired salen ligand (614 mg, 86% yield) as a yellow solid.

Synthesis of catalyst **3** (*this procedure was conducted on a bench top using standard Schlenk technique*):[5] In an oven-dried round bottom flask, the salen ligand (358 mg, 0.5 mmol, 1 equiv) was dissolved in THF (5 mL) to afford a yellow solution, which was cooled to -78 °C under N_2. Then $TiCl_4$ solution (1.0 M in toluene; 0.5 mL, 0.5 mmol, 1.0 equiv) was added carefully into the above solution at -78 °C. This red suspension was heated under reflux for 3 h. After the reaction was cooled to room temperature, the dark red solid was filtered off and washed with diethyl ether to afford catalyst **3**.

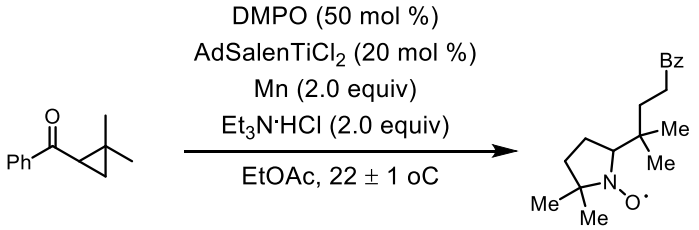


Catalyst 3. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.82 (d, *J* = 0.9 Hz, 2H), 7.33 (d, *J* = 2.2 Hz, 2H), 7.28-7.27 (m, 6H), 7.12-7.11 (m, 4H), 6.80 (d, *J* = 2.1 Hz, 2H), 5.55 (s, 2H), 2.25-2.22 (m, 18H), 2.13-2.11 (m, 6H), 1.84-1.81 (m, 6H), 1.77-1.74 (m, 6H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 164.81, 160.82, 137.60, 136.15, 135.97, 133.72, 131.34, 129.23, 128.95, 126.24, 41.67, 37.80, 36.93, 28.90, 20.48. MS (DART) exact mass calculated for [$C_{50}H_{54}N_2O_2TiCl$]: 797.3348, found 797.3359.

Section 4. Mechanistic studies

General information: ESR spectra were recorded on a Bruker ELEXYS-II E500 spectrometer at National Biomedical Center for Advanced Electron Spin Resonance Technology(ACERT) at a microwave frequency of 9.32 GHz, microwave power of 0.63 mW, and modulation amplitude of 2 G (0.4 G for the experiment described in Section 5). Samples were prepared in a N_2-filled glovebox.

Spin trapping with DMPO[6]



In a N_2-filled glovebox, an oven-dried 1.5 dr vial equipped with a magnetic stir bar was charged with Mn (5.5 mg, 0.10 mmol, 2.0 equiv), **3** (8.3 mg, 0.01, 20 mol%), $Et_3N{\cdot}HCl$ (13.7 mg, 0.1 mmol, 2.0 equiv) and EtOAc (0.5 mL). The mixture was stirred vigorously for 10 min to allow reduction of the pre-catalyst. Subsequently, **1** (8.7 mg, 0.050 mmol, 1 equiv), and DMPO (2.8 mg, 0.025 mmol, 50 mol%) were added, and the resulting mixture was stirred at room temperature (22 ± 1 °C) for 0.5 h. Subsequently, the supernatant was analyzed by ESR and mass spectrometry (DART). ESR spectrum showed an average *g* value of 2.0061 with two hyperfine splittings of 17.2 G (assigned to the nitroxide nitrogen) and 14.5 G (assigned to the α-hydrogen). High-resolution mass spectrum showed a molecular weight (M_w) of 288.19664 (1.04%), corresponding to nitroxide product **31** (calculated for M^+: M_w = 289.19635; ionization by losing an electron to form the oxoammonium ion).

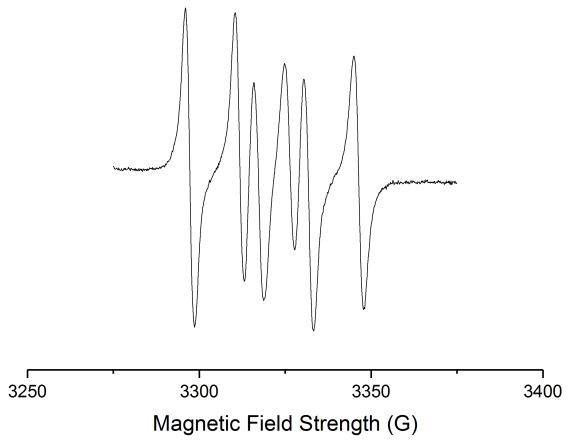


Figure S1. ESR spectrum of the reaction mixture in the presence of DMPO. Data are consistent with structurally analogous nitroxyl radicals in ref. [6].

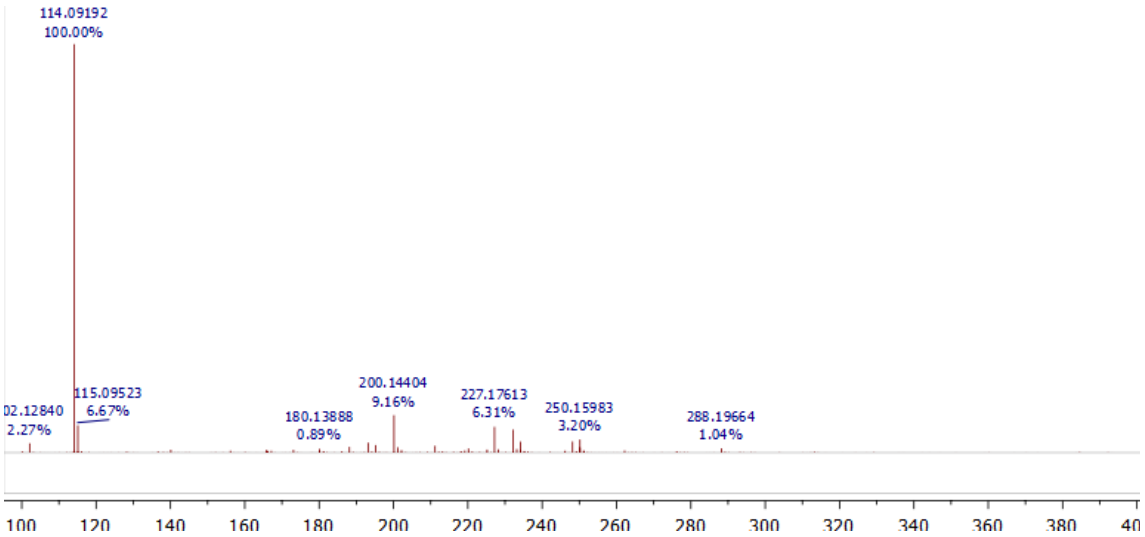


Figure S2. MS data of the reaction mixture in the presence of DMPO.

ESR spectral data of catalysts

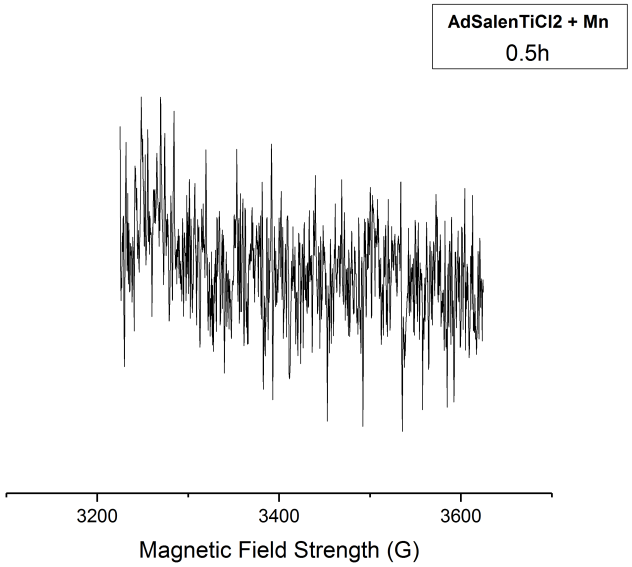


Figure S3. ESR spectrum of **3** (20 mM) and Mn (10 equiv) in EtOAc for **0.5 h**

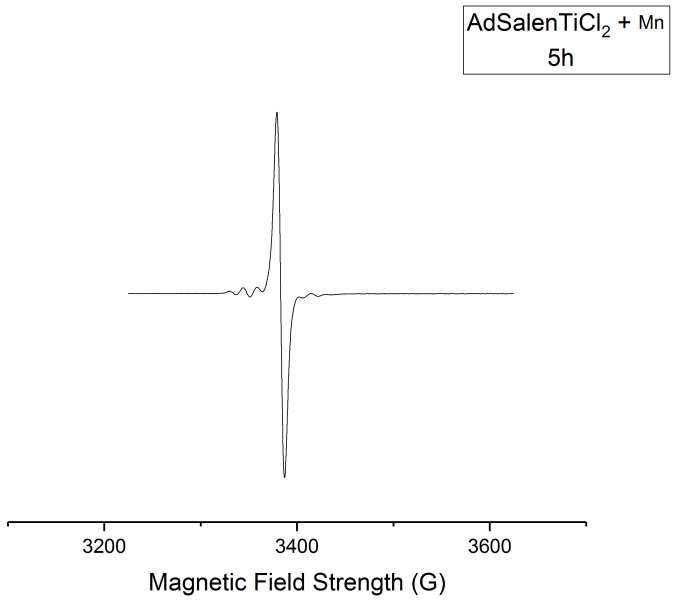


Figure S4. ESR spectrum of **3** (20 mM) and Mn (10 equiv) in EtOAc for **5 h**. Data are consistent with our previous analysis of Ti(III) complexes.[7]

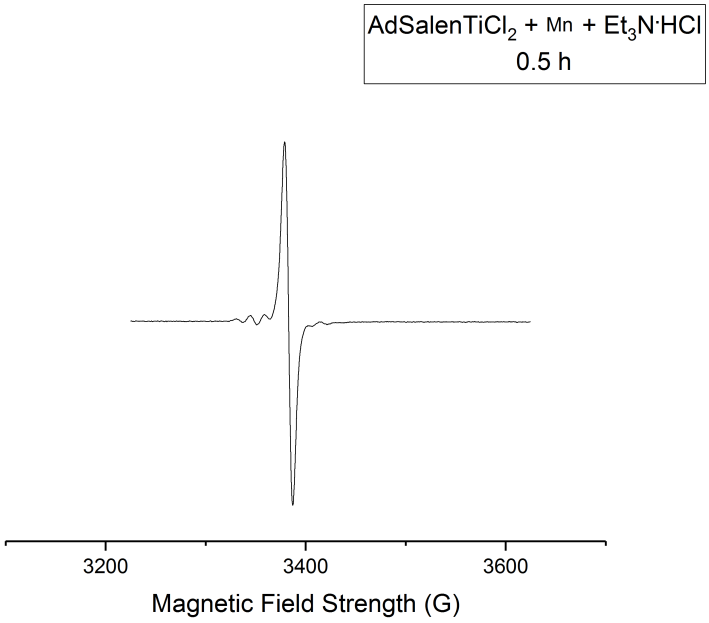


Figure S5. ESR spectrum of **3** (20 mM), $Et_3N{\cdot}HCl$ (200 mM) and Mn (10 equiv) in EtOAc for **0.5 h**

Section 5. X-ray crystallographic data

General information: Low-temperature X-ray diffraction data for **2** (CCDC-1589640) and **17** (CCDC-1589641) were collected on a Rigaku XtaLAB Synergy diffractometer coupled to a RigakuHypix detector with Cu Kα radiation (λ =1.54184 Å), from a PhotonJet micro-focus X-ray source at 100 K. The diffraction images were processed and scaled using the CrysAlisPro software.[8] The structures were solved through intrinsic phasing using SHELXT[9] and refined against F^2 on all data by full-matrix least squares with SHELXL[10] following established refinement strategies.[11] All non-hydrogen atoms were refined anisotropically. All hydrogen atoms bound to carbon were included in the model at geometrically calculated positions and refined using a riding model. The isotropic displacement parameters of all hydrogen atoms were fixed to 1.2 times the Ueq value of the atoms they are linked to (1.5 times for methyl groups). Details of the data quality and a summary of the residual values of the refinements are listed in Tables S1-S2.

The crystals of both **2** and **17** were obtained via slow evaporation of a concentrated Et_2O solution of the corresponding compound at 4 °C.

Table S1. Crystal data and structure refinement for **2**.

Identification code	rwh10_abs	
Empirical formula	C20 H22 O	
Formula weight	278.37	
Temperature	100.00(10) K	
Wavelength	1.54184 Å	
Crystal system	Monoclinic	
Space group	P 1 21 1	
Unit cell dimensions	a = 5.84080(10) Å	α= 90°.
	b = 16.7324(4) Å	β= 92.485(2)°.
	c = 7.8935(2) Å	γ = 90°.
Volume	770.71(3) $Å^3$	
Z	2	
Density (calculated)	1.200 Mg/m^3	
Absorption coefficient	0.549 mm^{-1}	
F(000)	300	
Crystal size	0.236 x 0.179 x 0.127 mm^3	
Theta range for data collection	5.287 to 70.012°.	
Index ranges	-7<=h<=7, -20<=k<=20, -9<=l<=9	
Reflections collected	31128	
Independent reflections	2923 [R(int) = 0.0252]	

Completeness to theta = 67.684°	100.0 %
Absorption correction	Gaussian
Max. and min. transmission	1.000 and 0.563
Refinement method	Full-matrix least-squares on F^2
Data / restraints / parameters	2923 / 1 / 192
Goodness-of-fit on F^2	1.069
Final R indices [I>2sigma(I)]	R1 = 0.0265, wR2 = 0.0706
R indices (all data)	R1 = 0.0266, wR2 = 0.0715
Absolute structure parameter	-0.04(5)
Extinction coefficient	n/a
Largest diff. peak and hole	0.161 and -0.168 e.Å^{-3}

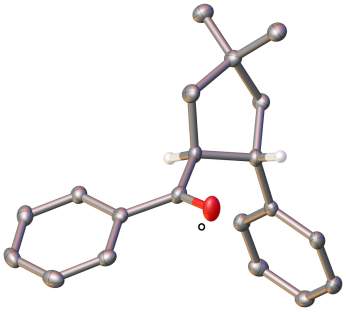


Figure S6. ORTEP drawing of **2** with 30% probability thermal ellipsoids. Hydrogen atoms have been omitted for clarity.

Table S2. Crystal data and structure refinement for **17**.

Identification code	rwh11_abs	
Empirical formula	C32 H38 O2	
Formula weight	454.62	
Temperature	100.00(10) K	
Wavelength	1.54184 Å	
Crystal system	Monoclinic	
Space group	P 1 21 1	
Unit cell dimensions	a = 13.24067(7) Å	α= 90°.
	b = 7.76255(4) Å	β= 91.3423(5)°.
	c = 24.83830(13) Å	γ = 90°.
Volume	2552.21(2) Å^3	
Z	4	
Density (calculated)	1.183 Mg/m^3	
Absorption coefficient	0.550 mm^{-1}	

F(000)	984
Crystal size	0.168 x 0.099 x 0.05 mm^3
Theta range for data collection	1.779 to 70.065°.
Index ranges	-16<=h<=16, -9<=k<=9, -30<=l<=30
Reflections collected	94575
Independent reflections	9697 [R(int) = 0.0338]
Completeness to theta = 67.684°	100.0 %
Absorption correction	Gaussian
Max. and min. transmission	1.000 and 0.851
Refinement method	Full-matrix least-squares on F^2
Data / restraints / parameters	9697 / 1 / 619
Goodness-of-fit on F^2	1.027
Final R indices [I>2sigma(I)]	R1 = 0.0315, wR2 = 0.0822
R indices (all data)	R1 = 0.0318, wR2 = 0.0824
Absolute structure parameter	0.00(5)
Extinction coefficient	n/a
Largest diff. peak and hole	0.263 and -0.181 e.$Å^{-3}$

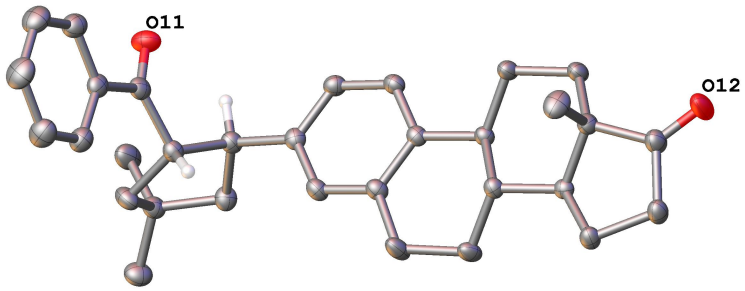


Figure S7. ORTEP drawing of **17** with 30% probability thermal ellipsoids. Hydrogen atoms have been omitted for clarity.

Section 6. References

1. Amador, A. G.; Sherbrook, E. M.; Yoon, T. P. *J. Am. Chem. Soc.* **2016**, *138*, 4722–4725.
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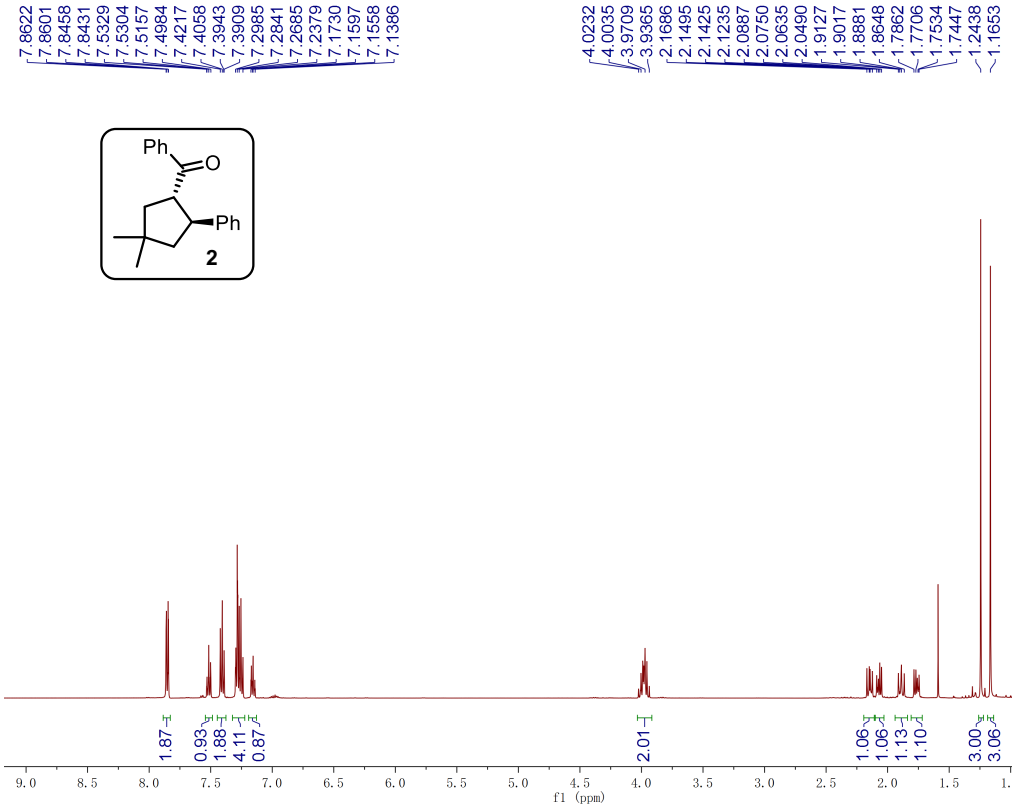
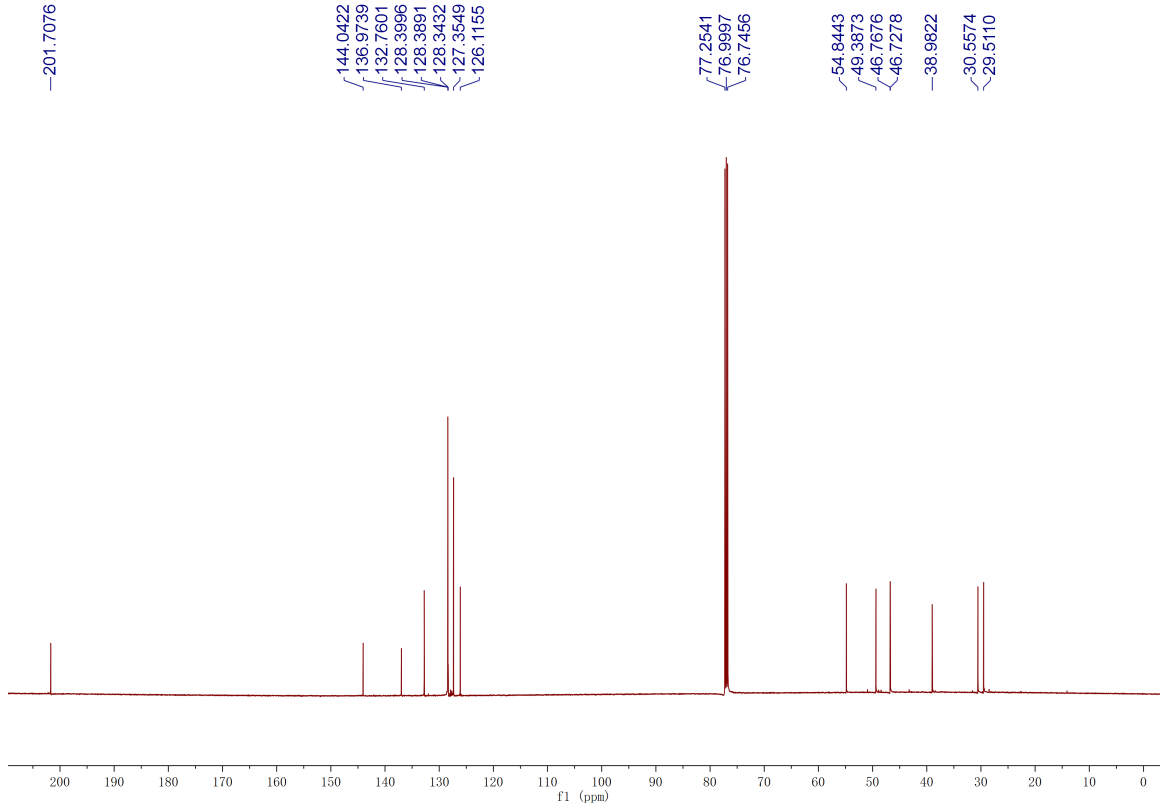
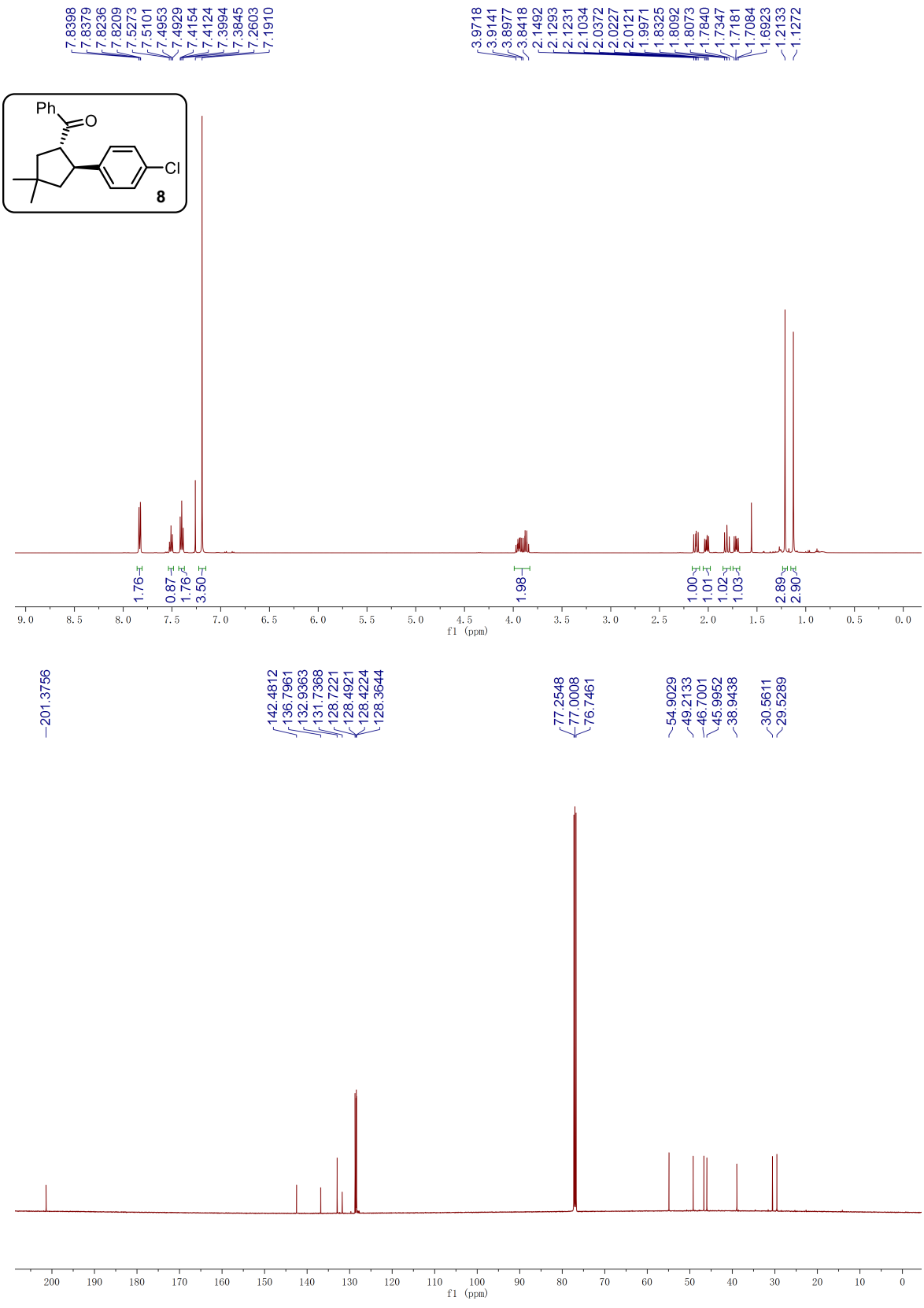
9. Sheldrick, G. M. *Acta Crystallogr.* **2015**, *A71*, 3–8.
10. Sheldrick, G.M. *Acta Crystallogr.* **2008**, *A64*, 112–122.
11. Müller, P. *Crystallogr. Rev.* **2009**, *15*, 57–83.

Section 7. Spectral data for products



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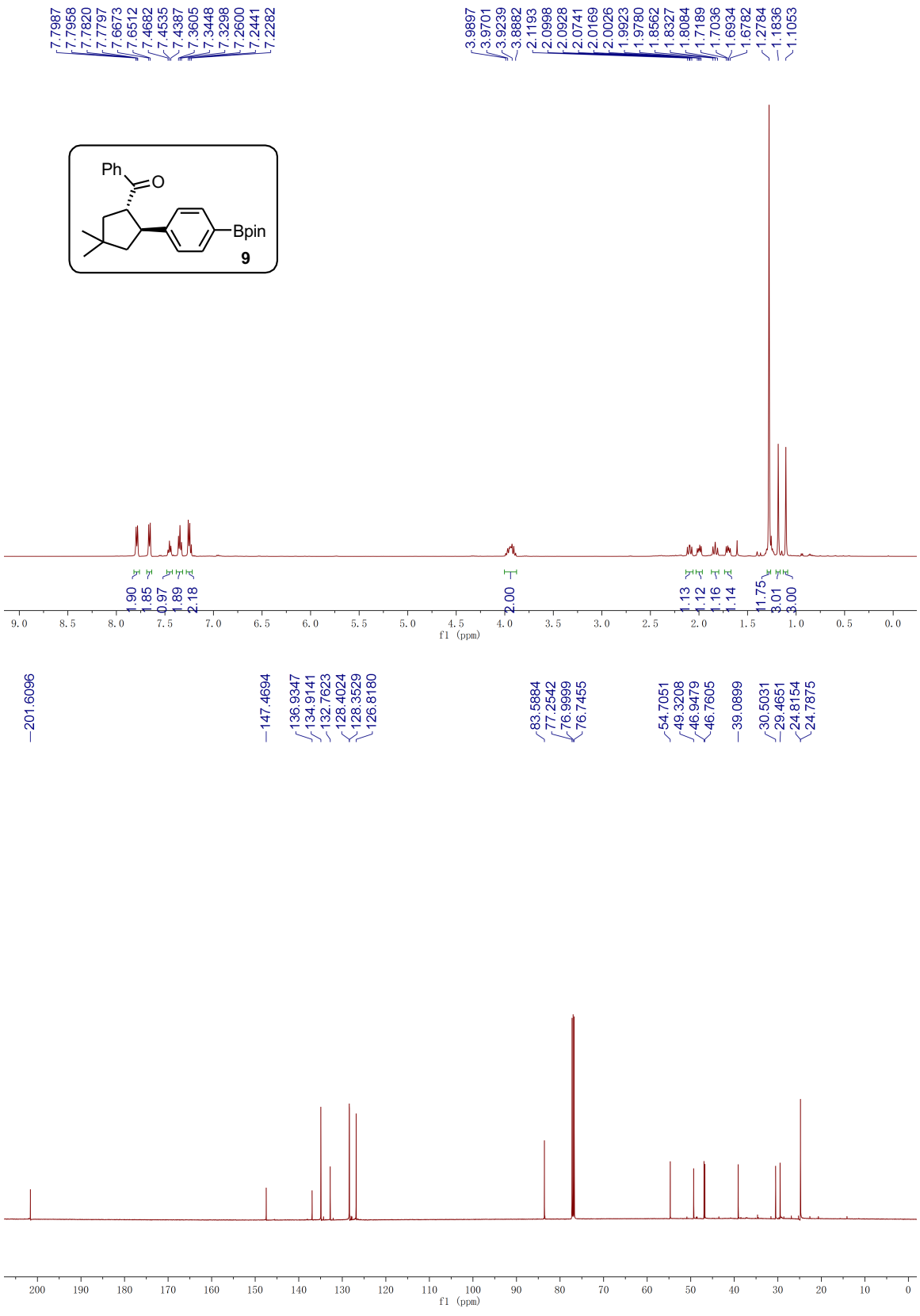
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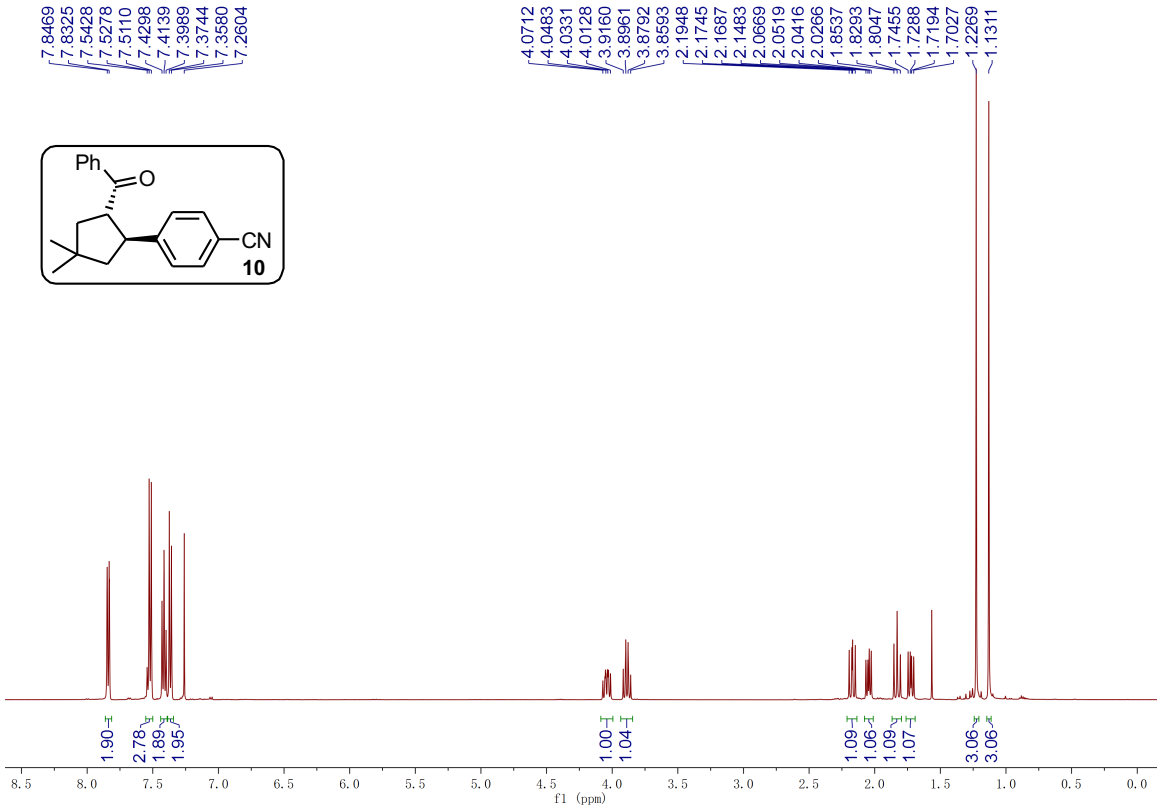
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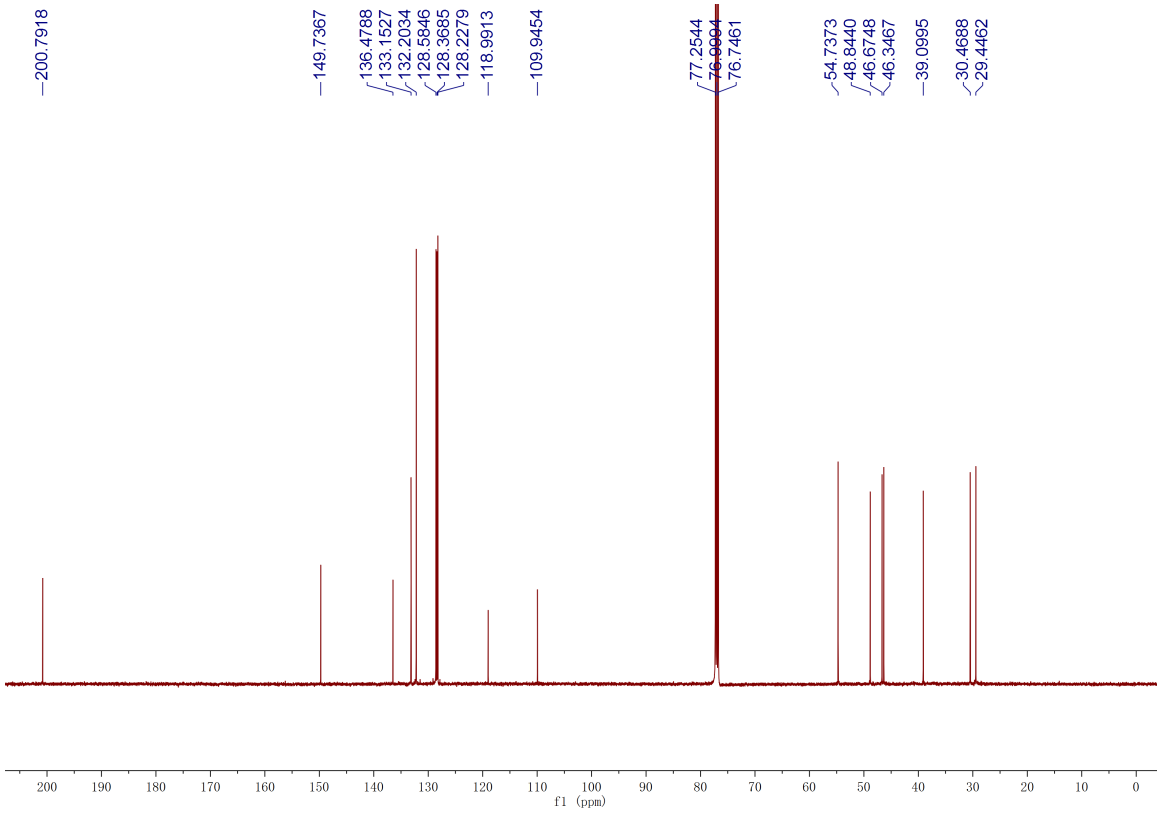
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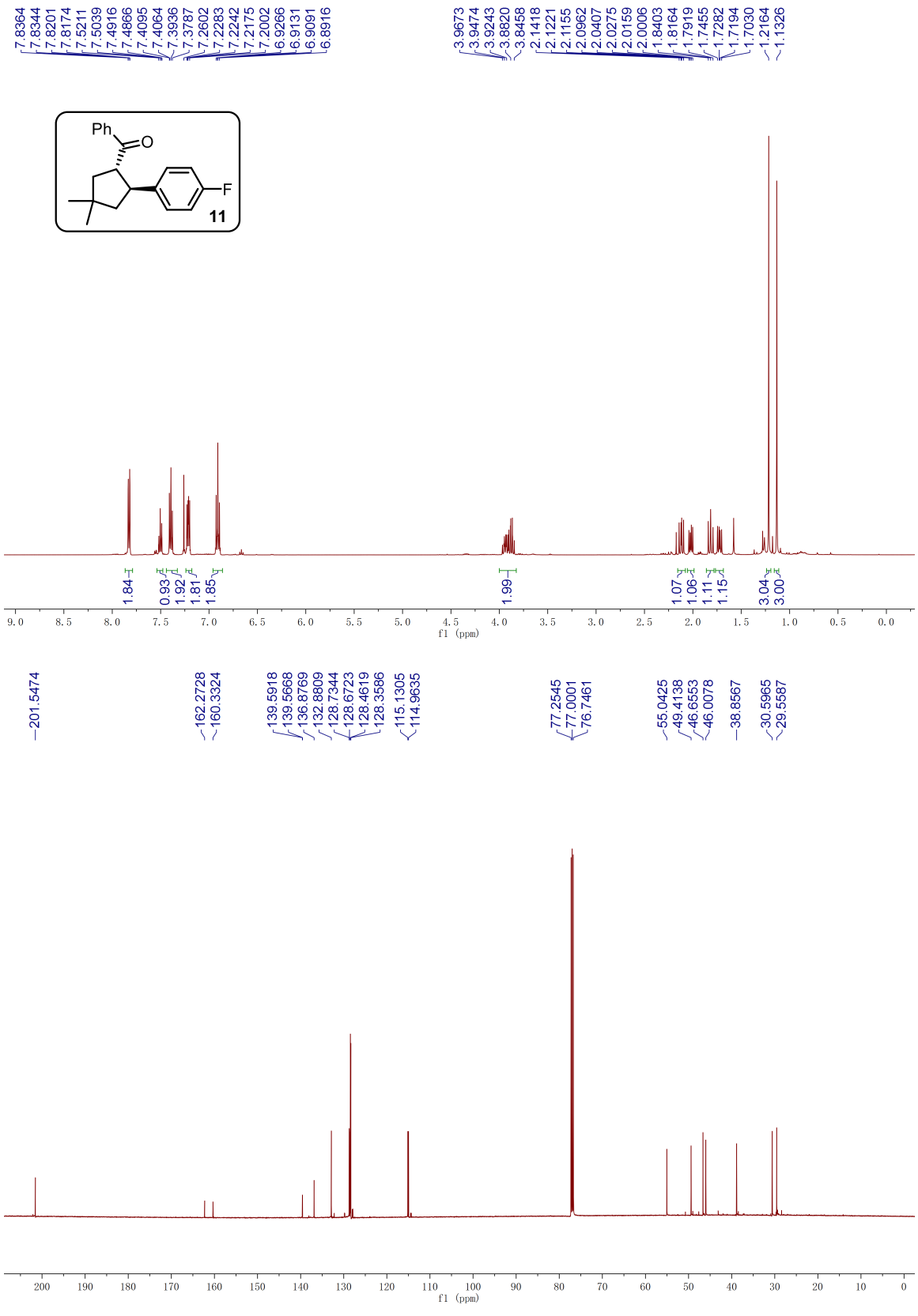
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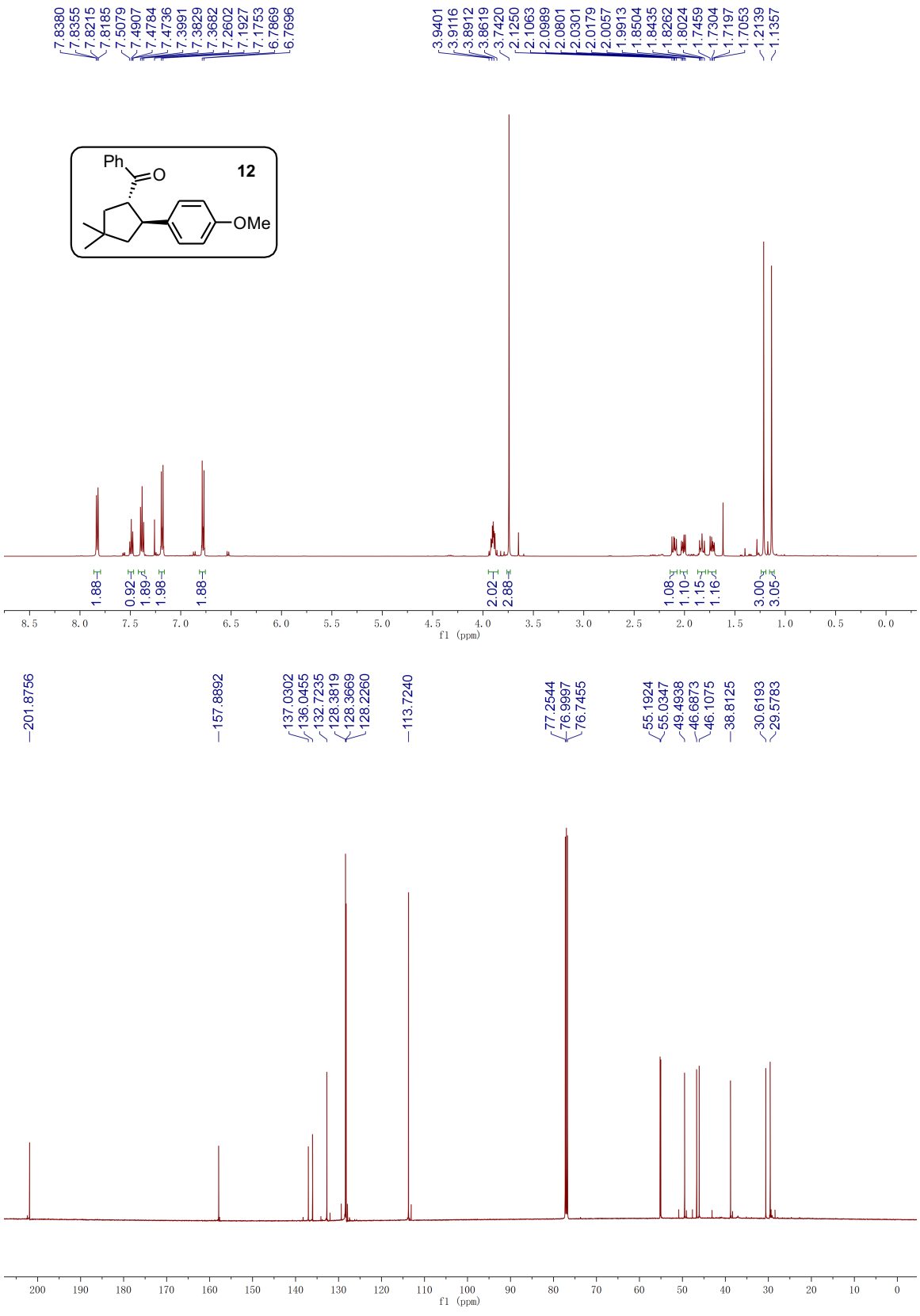
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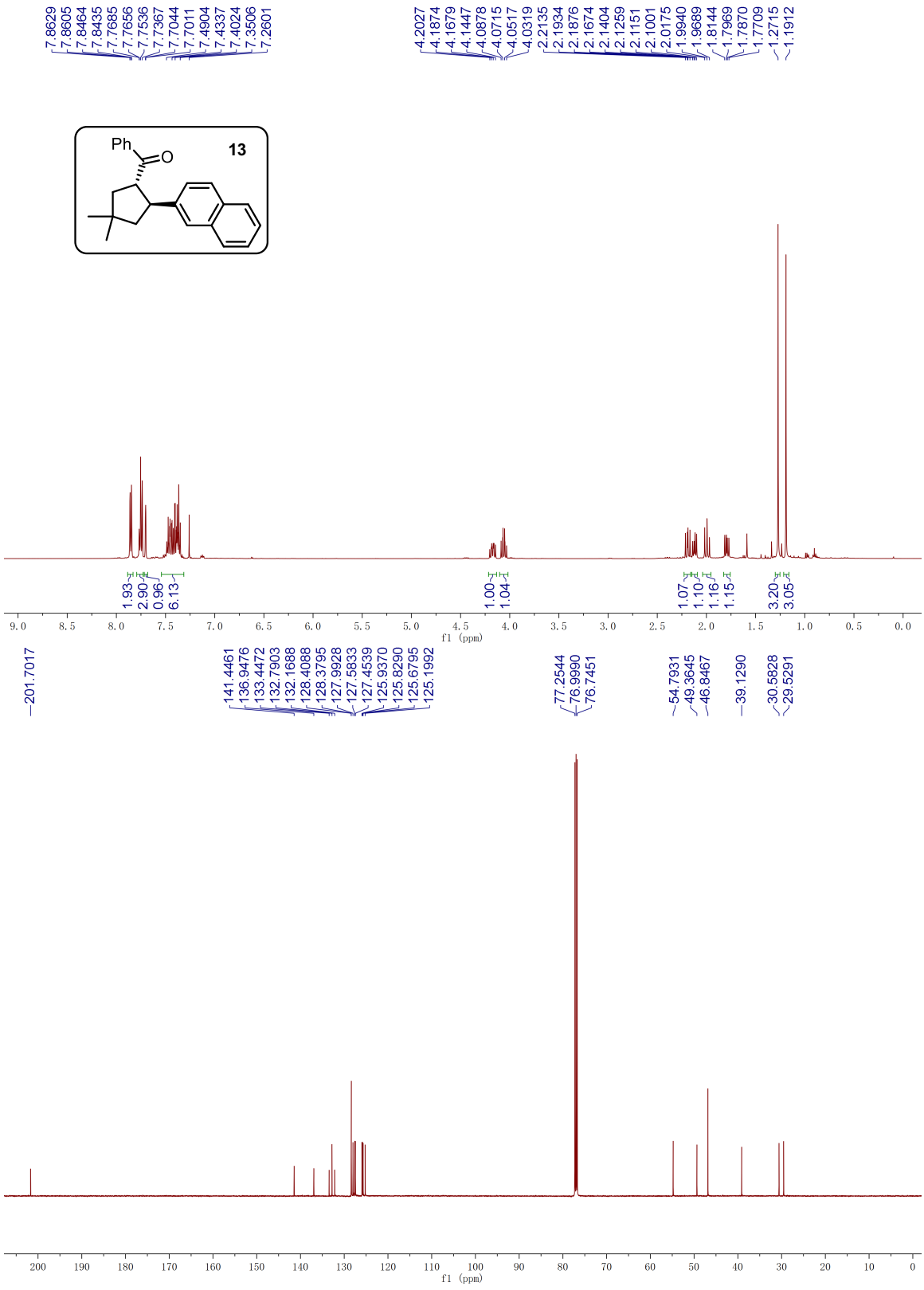
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f1 (ppm)
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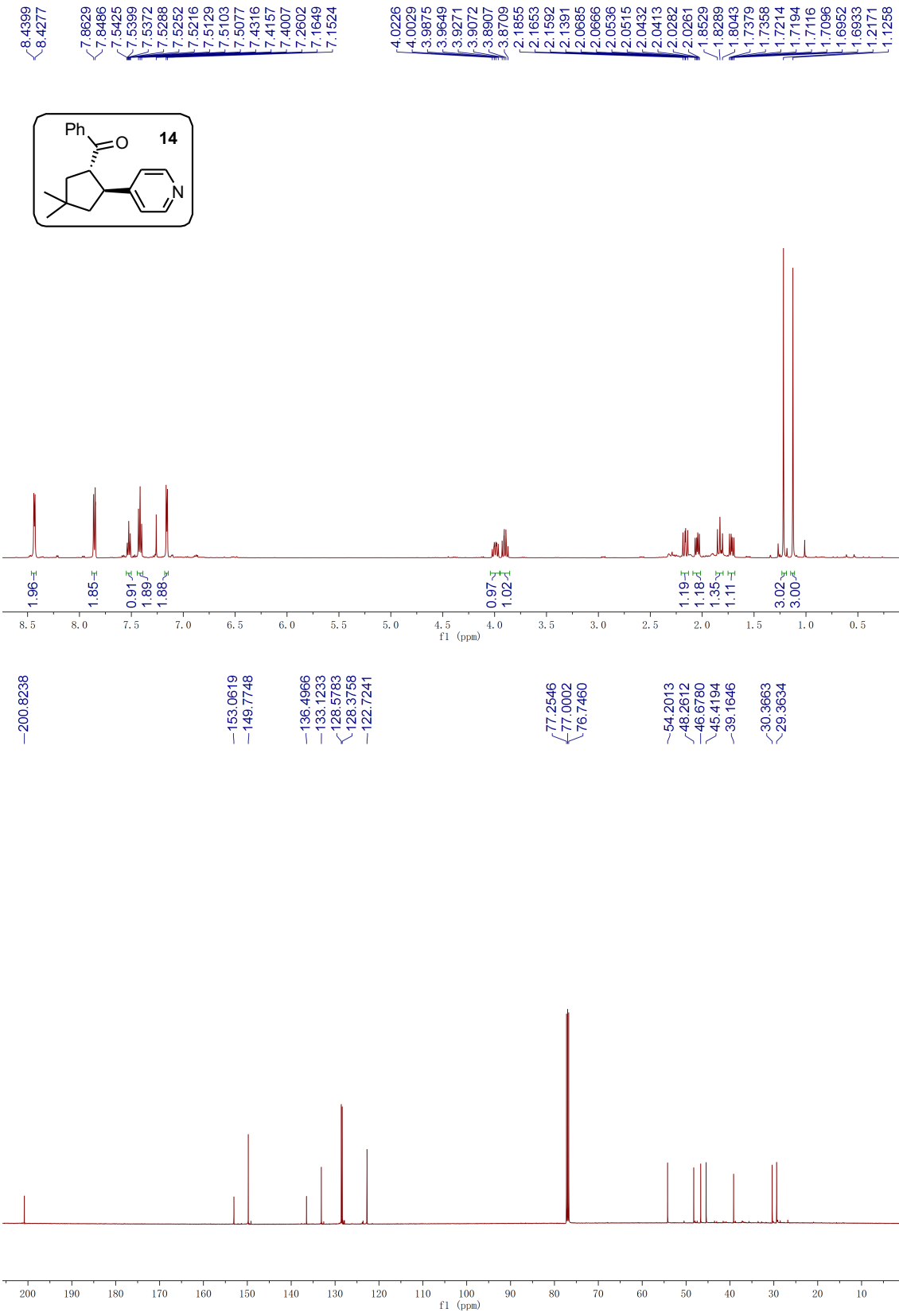
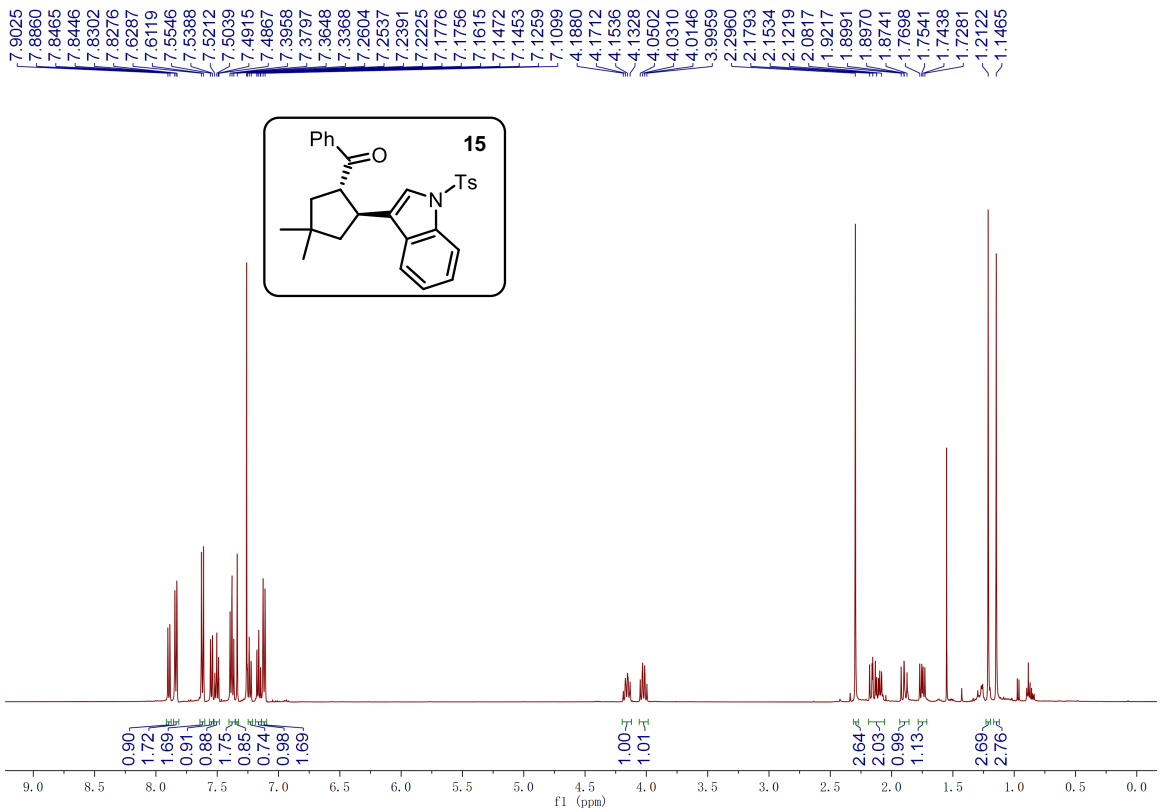
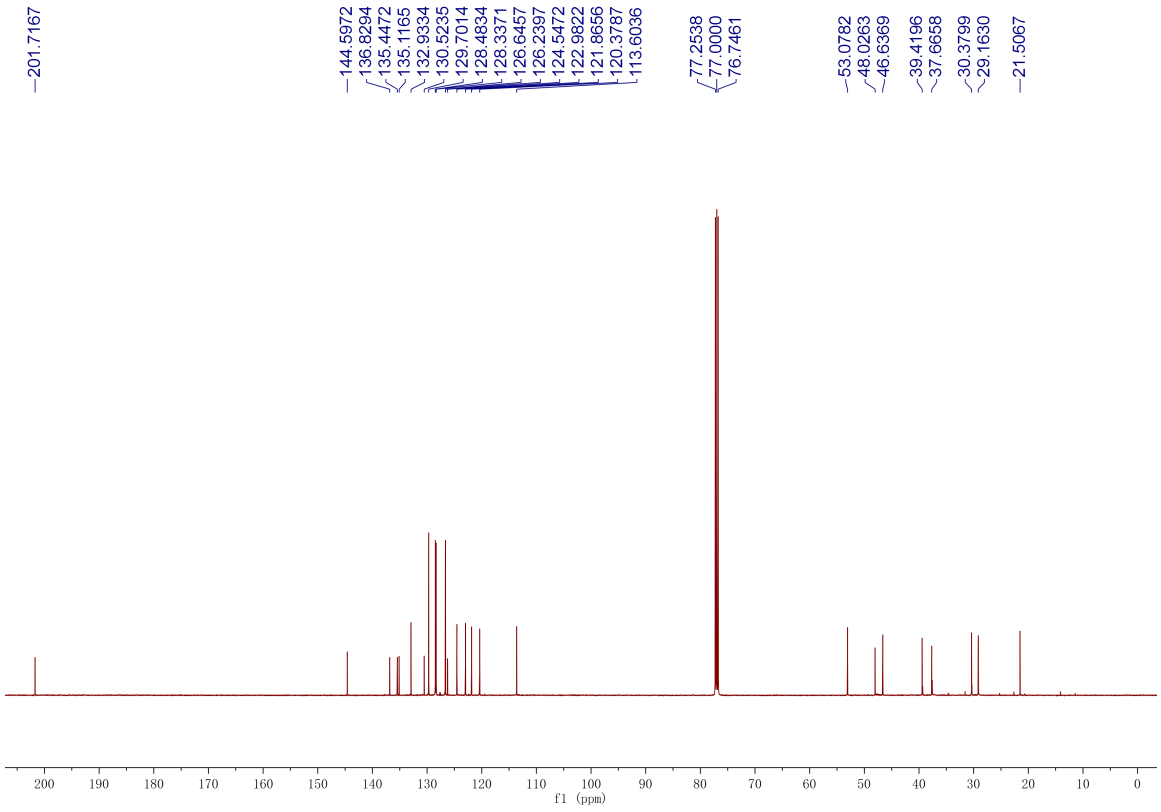
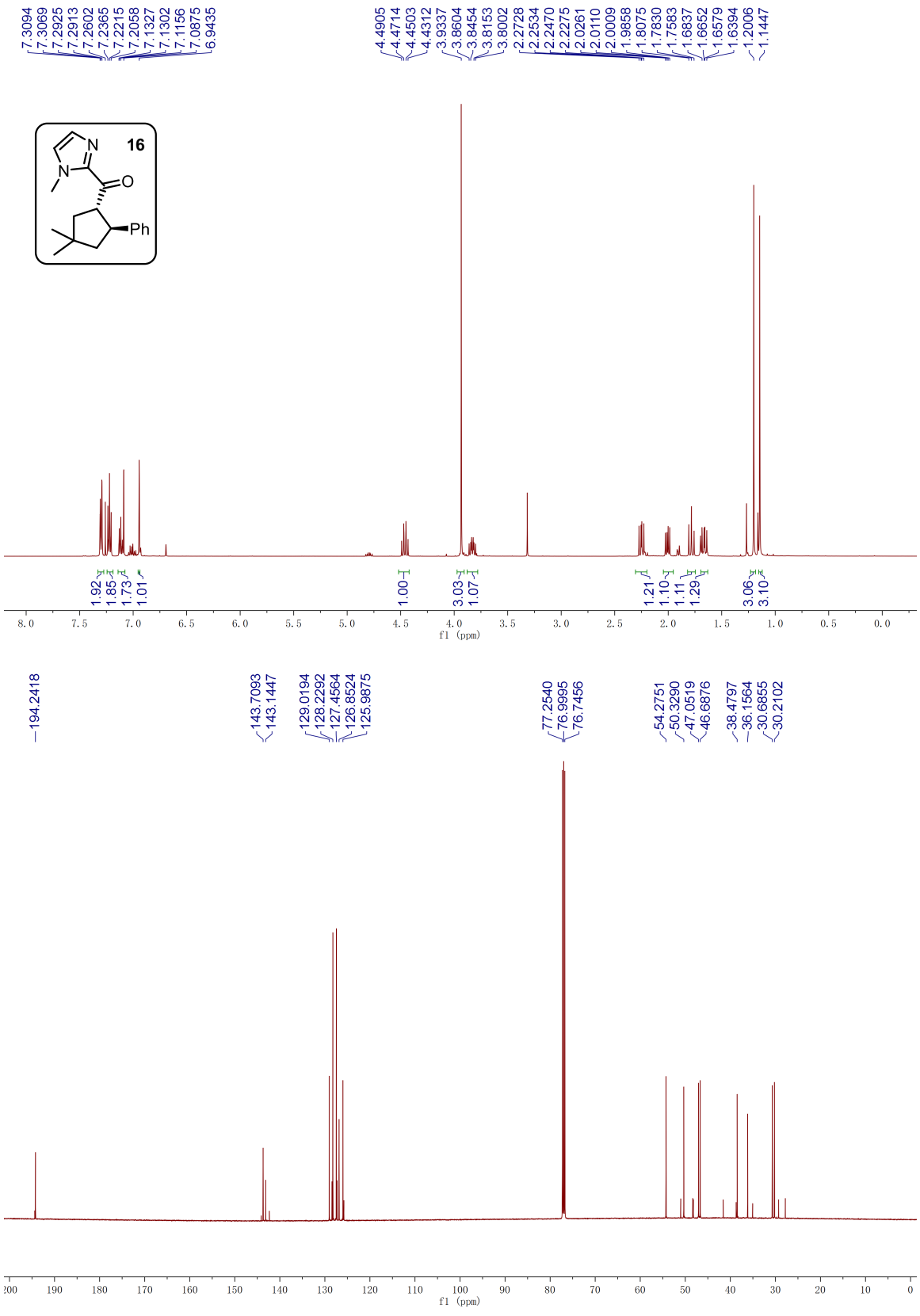
141.4461
136.9476
133.4472
132.7903
132.1688
128.4088
128.3795
127.9928
127.5833
127.4539
125.9370
125.8290
125.6795
125.1992
77.2544
76.9990
76.7451
54.7931
49.3645
46.8467
39.1290
30.5828
29.5291
f1 (ppm)

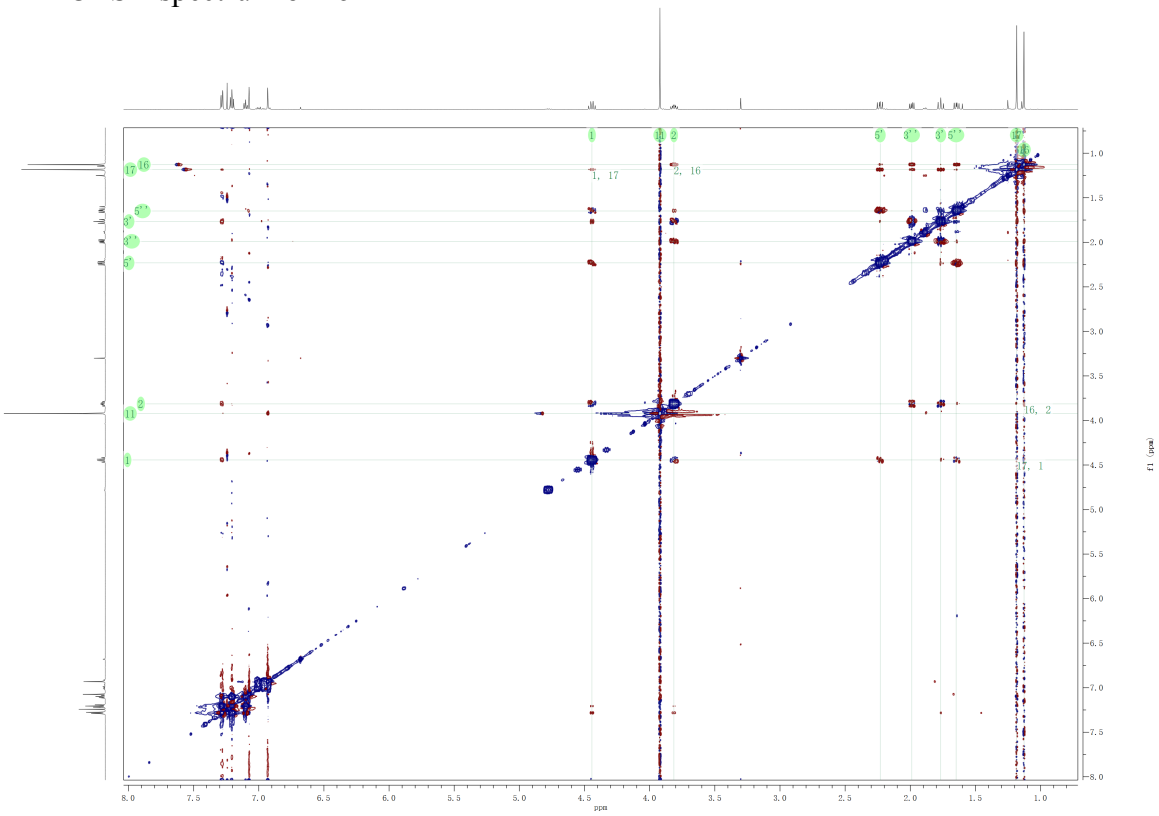

8.4399
8.4277
7.8629
7.8486
7.5425
7.5399
7.5372
7.5288
7.5252
7.5216
7.5129
7.5103
7.5077
7.4316
7.4157
7.4007
7.2602
7.1649
7.1524
4.0226
4.0029
3.9875
3.9649
3.9271
3.9072
3.8907
3.8709
2.1855
2.1653
2.1592
2.1391
2.0685
2.0666
2.0536
2.0515
2.0432
2.0413
2.0282
2.0261
1.8529
1.8289
1.8043
1.7379
1.7358
1.7214
1.7194
1.7116
1.7096
1.6952
1.6933
1.2171
1.1258
Ph
O
14
N
1.96
1.85
0.91
1.89
1.88
0.97
1.02
1.19
1.18
1.35
1.11
3.02
3.00
f1 (ppm)
200.8238
153.0619
149.7748
136.4966
133.1233
128.5783
128.3758
122.7241
77.2546
77.0002
76.7460
54.2013
48.2612
46.6780
45.4194
39.1646
30.3663
29.3634
f1 (ppm)


7.9025
7.8860
7.8465
7.8446
7.8302
7.8276
7.6287
7.6119
7.5546
7.5388
7.5212
7.5039
7.4915
7.4867
7.3958
7.3797
7.3648
7.3368
7.2604
7.2537
7.2391
7.2225
7.1776
7.1756
7.1615
7.1472
7.1453
7.1259
7.1099
4.1880
4.1712
4.1536
4.1328
4.0502
4.0310
4.0146
3.9959
2.2960
2.1793
2.1534
2.1219
2.0817
1.9217
1.8991
1.8970
1.8741
1.7698
1.7541
1.7438
1.7281
1.2122
1.1465
Ph
O
N
Ts
15
0.90
1.72
1.69
0.91
0.88
1.75
0.85
0.74
0.98
1.69
1.00
1.01
2.64
2.03
0.99
1.13
2.69
2.76
f1 (ppm)

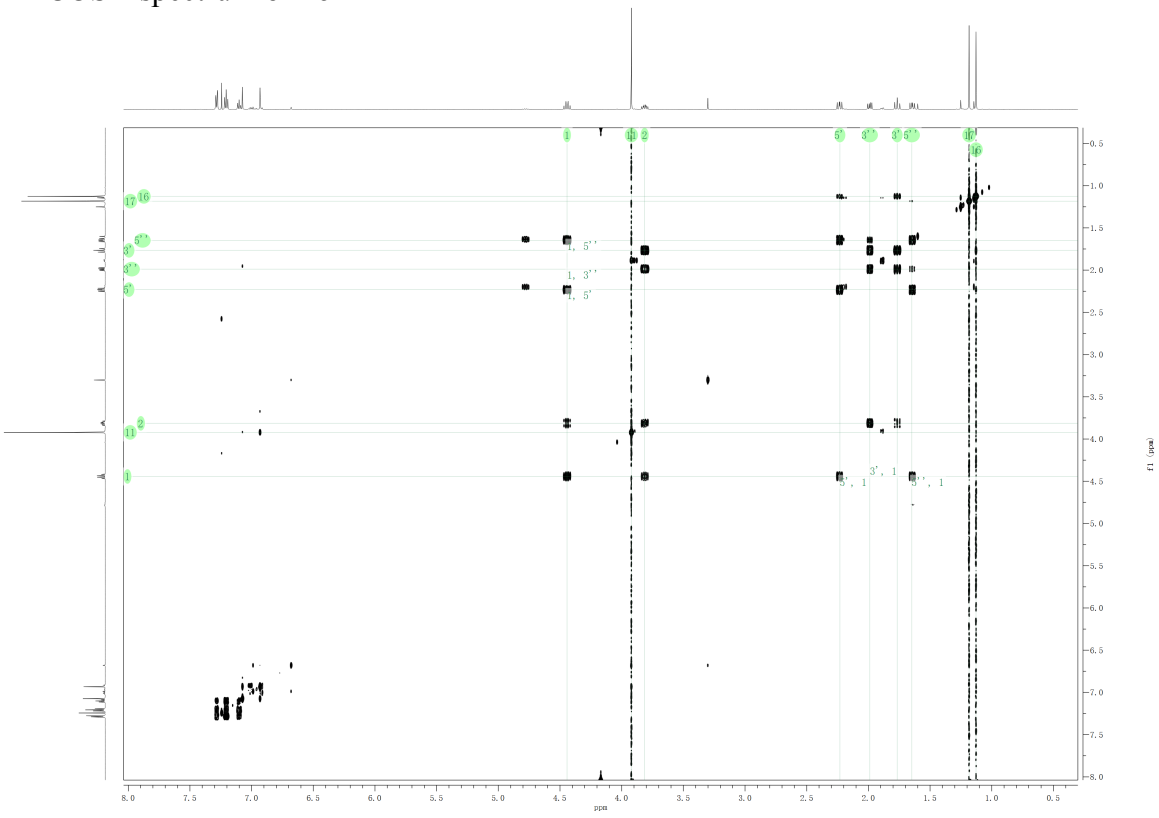

201.7167
144.5972
136.8294
135.4472
135.1165
132.9334
130.5235
129.7014
128.4834
128.3371
126.6457
126.2397
124.5472
122.9822
121.8656
120.3787
113.6036
77.2538
77.0000
76.7461
53.0782
48.0263
46.6369
39.4196
37.6658
30.3799
29.1630
21.5067
f1 (ppm)


7.3094
7.3069
7.2925
7.2913
7.2602
7.2365
7.2215
7.2058
7.1327
7.1302
7.1156
7.0875
6.9435
4.4905
4.4714
4.4503
4.4312
3.9337
3.8604
3.8454
3.8153
3.8002
2.2728
2.2534
2.2470
2.2275
2.0261
2.0110
2.0009
1.9858
1.8075
1.7830
1.7583
1.6837
1.6652
1.6579
1.6394
1.2006
1.1447
16
N
N
O
Ph
1.92
1.85
1.73
1.01
1.00
3.03
1.07
1.21
1.10
1.11
1.29
3.06
3.10
f1 (ppm)
194.2418
143.7093
143.1447
129.0194
128.2292
127.4564
126.8524
125.9875
77.2540
76.9995
76.7456
54.2751
50.3290
47.0519
46.6876
38.4797
36.1564
30.6855
30.2102
f1 (ppm)

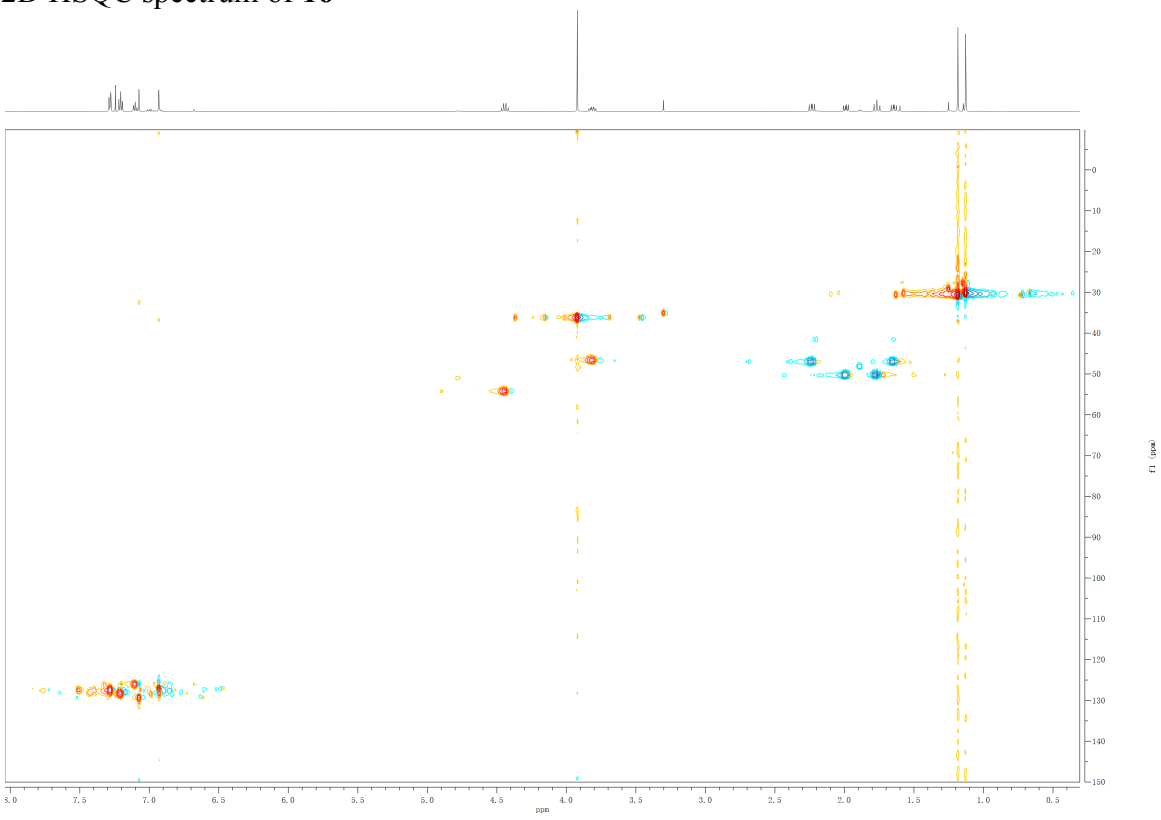
2D ROESY spectrum of **16**

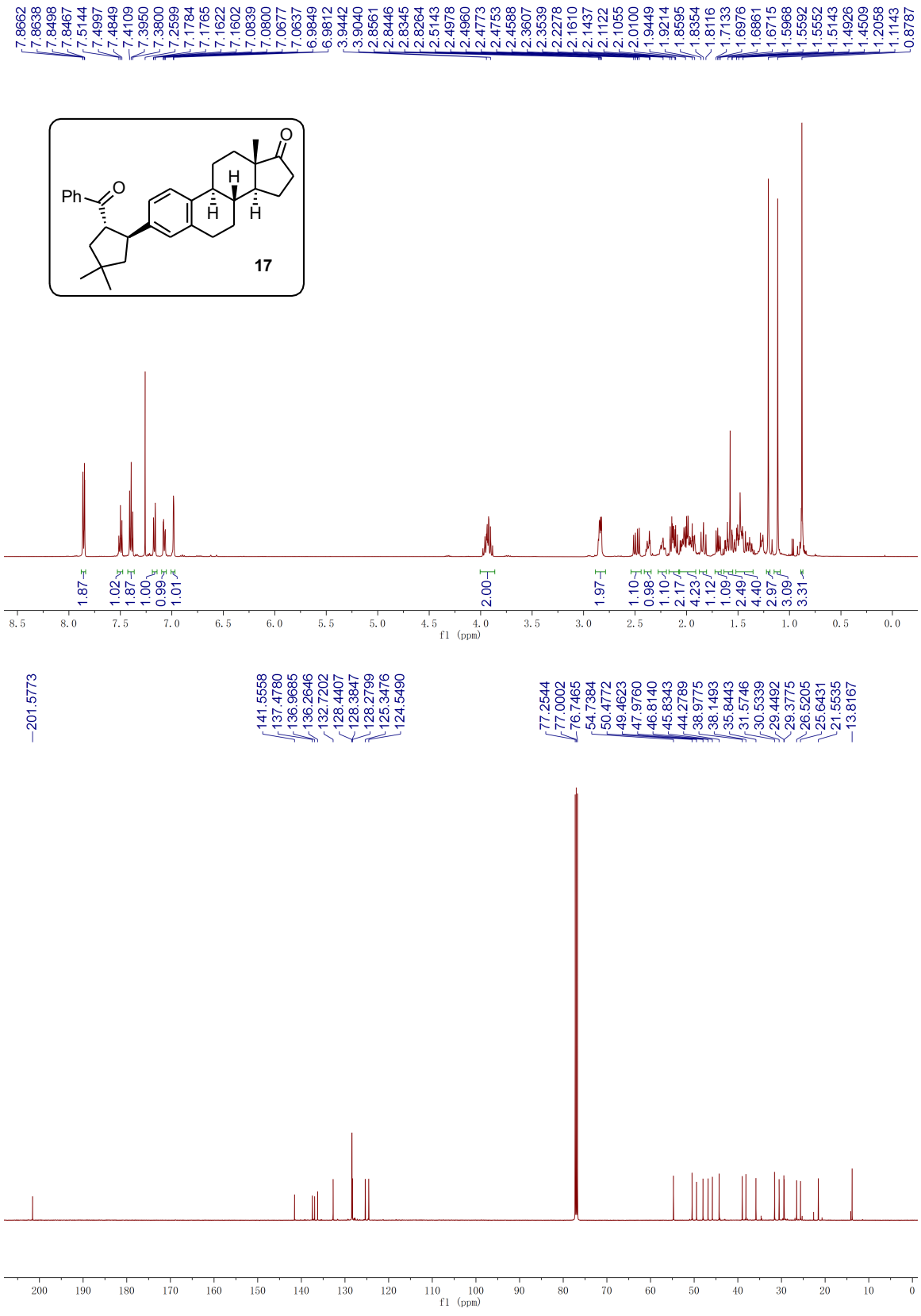


2D COSY spectrum of **16**

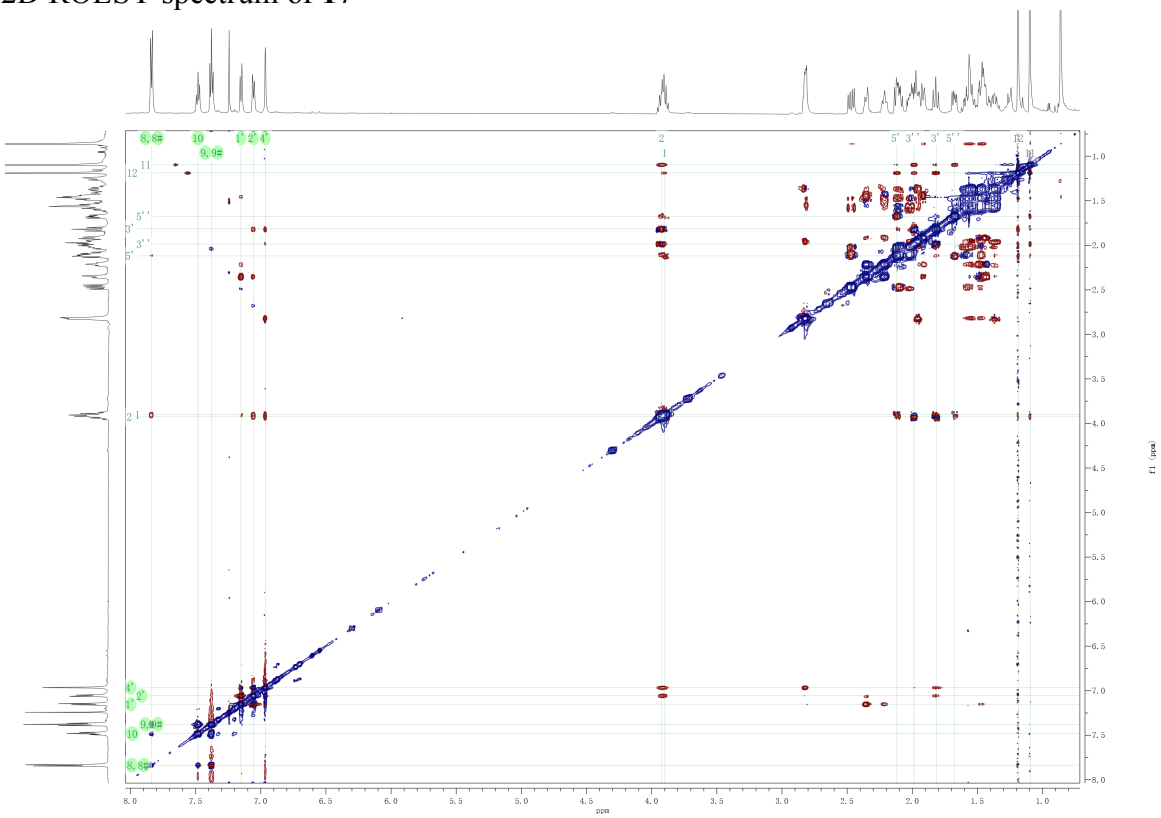


2D HSQC spectrum of **16**

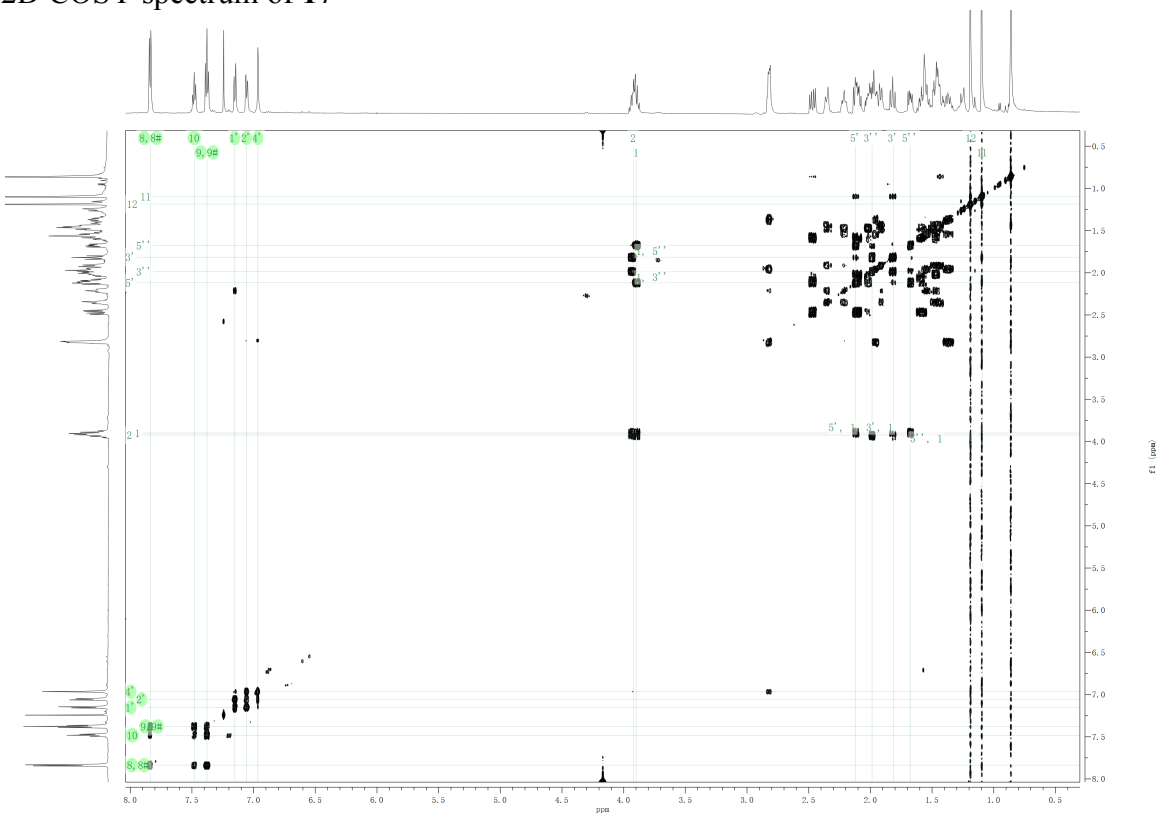



7.8662
7.8638
7.8498
7.8467
7.5144
7.4997
7.4849
7.4109
7.3950
7.3800
7.2599
7.1784
7.1765
7.1622
7.1602
7.0839
7.0800
7.0677
7.0637
6.9849
6.9812
3.9442
3.9040
2.8561
2.8446
2.8345
2.8264
2.5143
2.4978
2.4960
2.4773
2.4753
2.4588
2.3607
2.3539
2.2278
2.1610
2.1437
2.1122
2.1055
2.0100
1.9449
1.9214
1.8595
1.8354
1.8116
1.7133
1.6976
1.6861
1.6715
1.5968
1.5592
1.5552
1.5143
1.4926
1.4509
1.2058
1.1143
0.8787
Ph
O
O
H
H
H
17
1.87
1.02
1.87
1.00
0.99
1.01
2.00
1.97
1.10
0.98
1.10
2.17
4.23
1.12
1.09
2.49
4.40
2.97
3.09
3.31
f1 (ppm)
201.5773
141.5558
137.4780
136.9685
136.2646
132.7202
128.4407
128.3847
128.2799
125.3476
124.5490
77.2544
77.0002
76.7465
54.7384
50.4772
49.4623
47.9760
46.8140
45.8343
44.2789
38.9775
38.1493
35.8443
31.5746
30.5339
29.4492
29.3775
26.5205
25.6431
21.5535
13.8167
f1 (ppm)

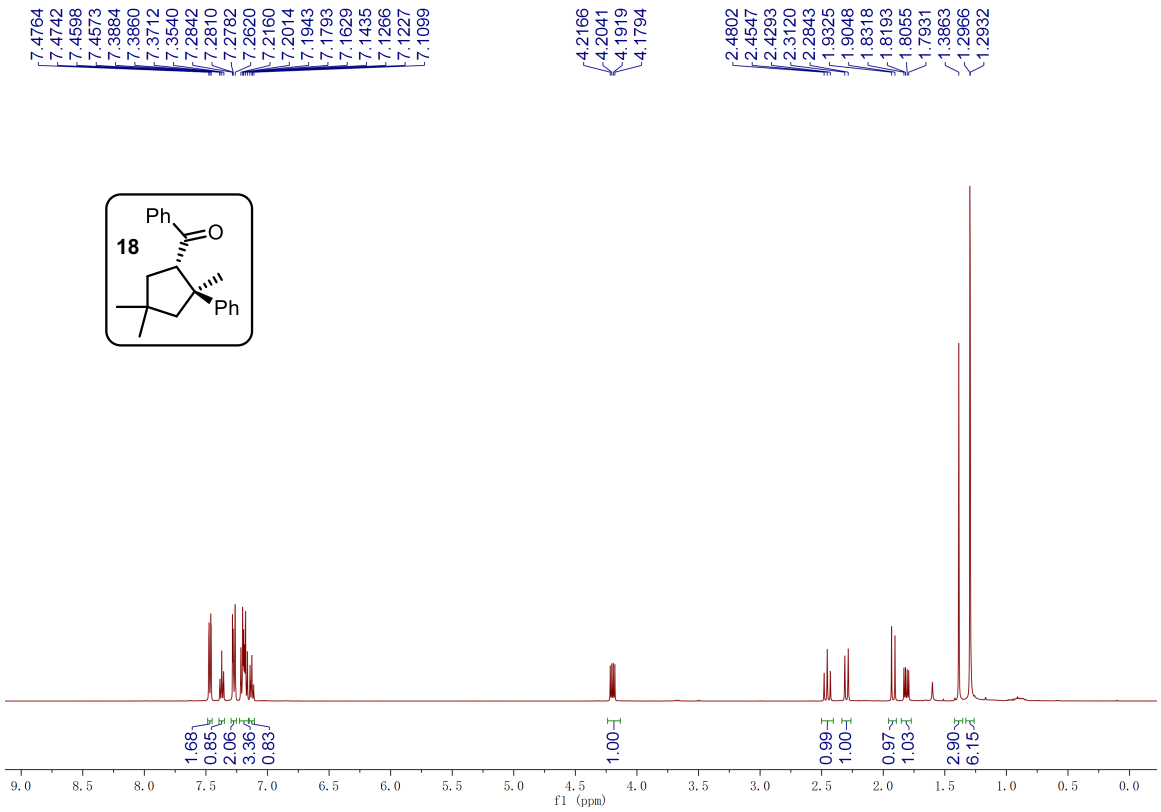
2D ROESY spectrum of **17**

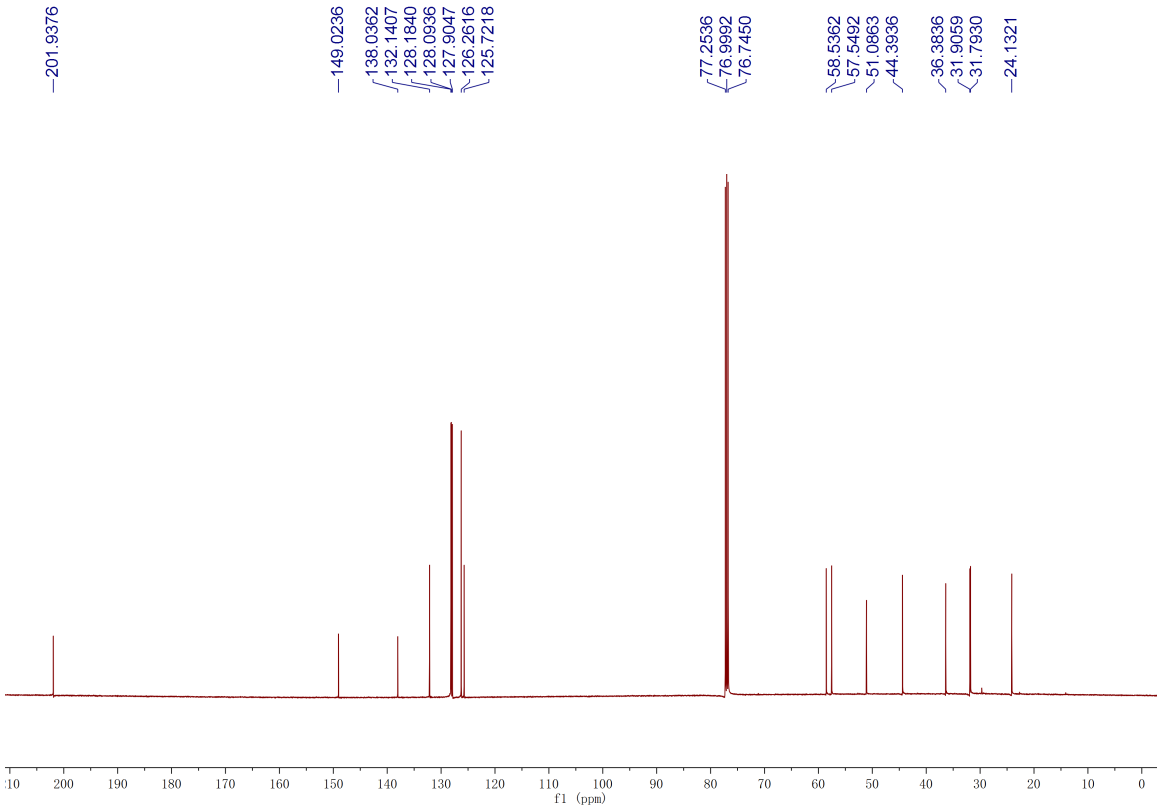


2D COSY spectrum of **17**

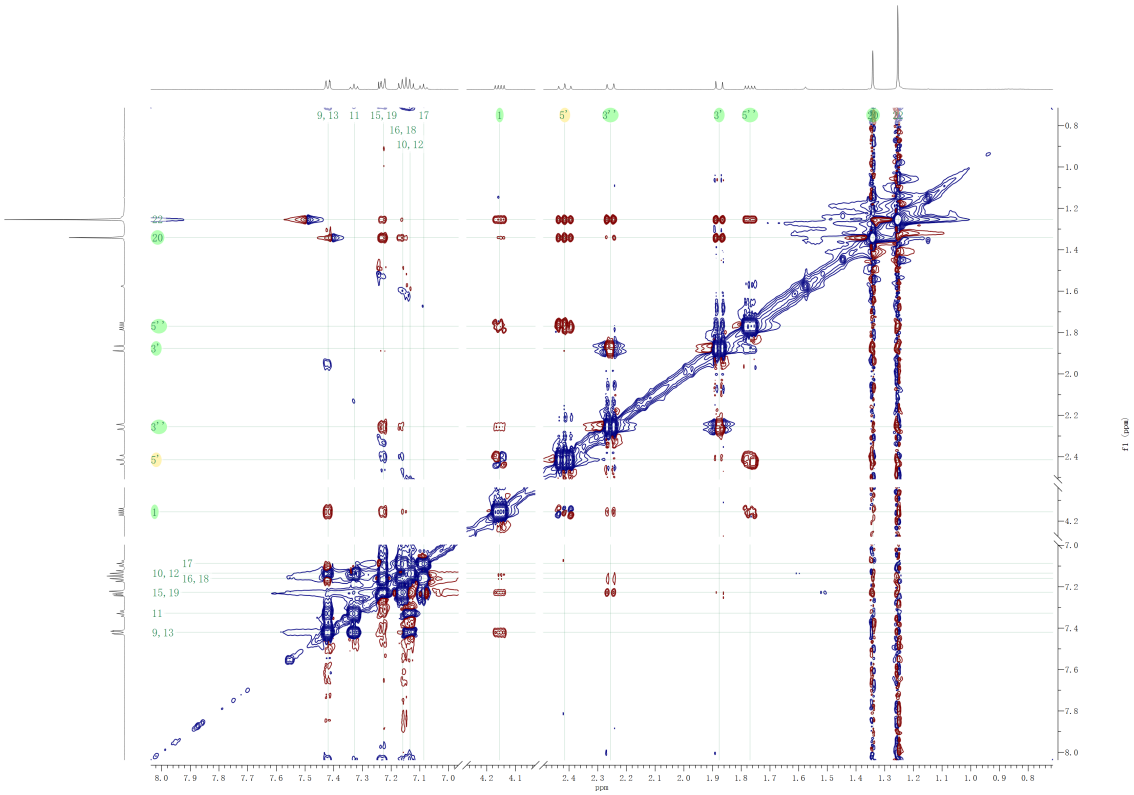


2D HSQC spectrum of **17**

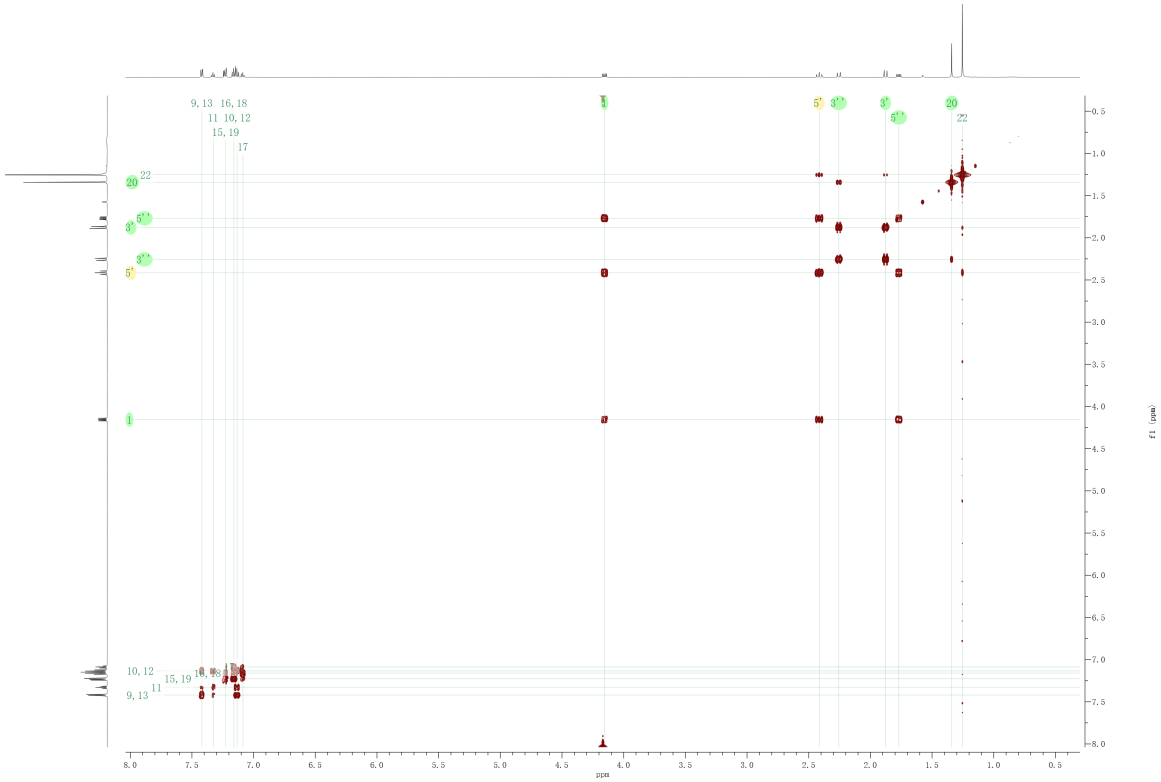

7.4764
7.4742
7.4598
7.4573
7.3884
7.3860
7.3712
7.3540
7.2842
7.2810
7.2782
7.2620
7.2160
7.2014
7.1943
7.1793
7.1629
7.1435
7.1266
7.1227
7.1099
4.2166
4.2041
4.1919
4.1794
2.4802
2.4547
2.4293
2.3120
2.2843
1.9325
1.9048
1.8318
1.8193
1.8055
1.7931
1.3863
1.2966
1.2932
18
Ph
O
Ph
1.68
0.85
2.06
3.36
0.83
1.00
0.99
1.00
0.97
1.03
2.90
6.15
f1 (ppm)


201.9376
149.0236
138.0362
132.1407
128.1840
128.0936
127.9047
126.2616
125.7218
77.2536
76.9992
76.7450
58.5362
57.5492
51.0863
44.3936
36.3836
31.9059
31.7930
24.1321
f1 (ppm)

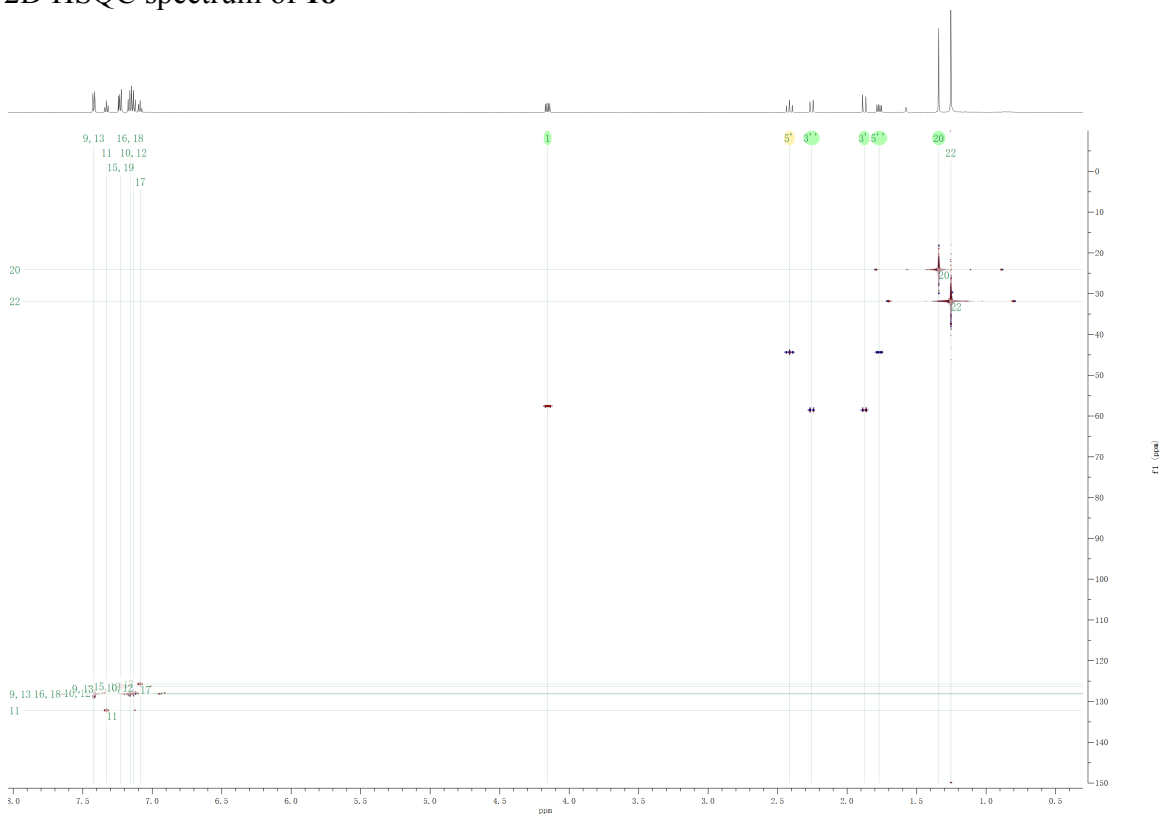
2D ROESY spectrum of **18**

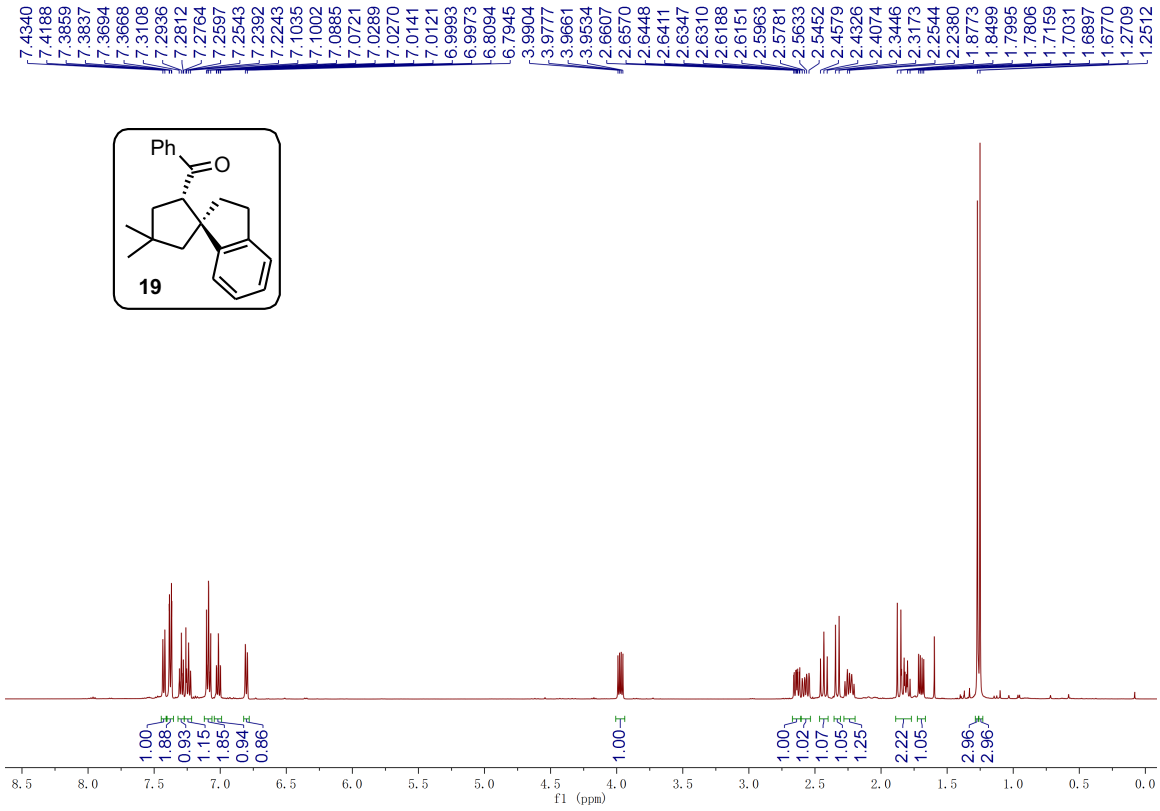


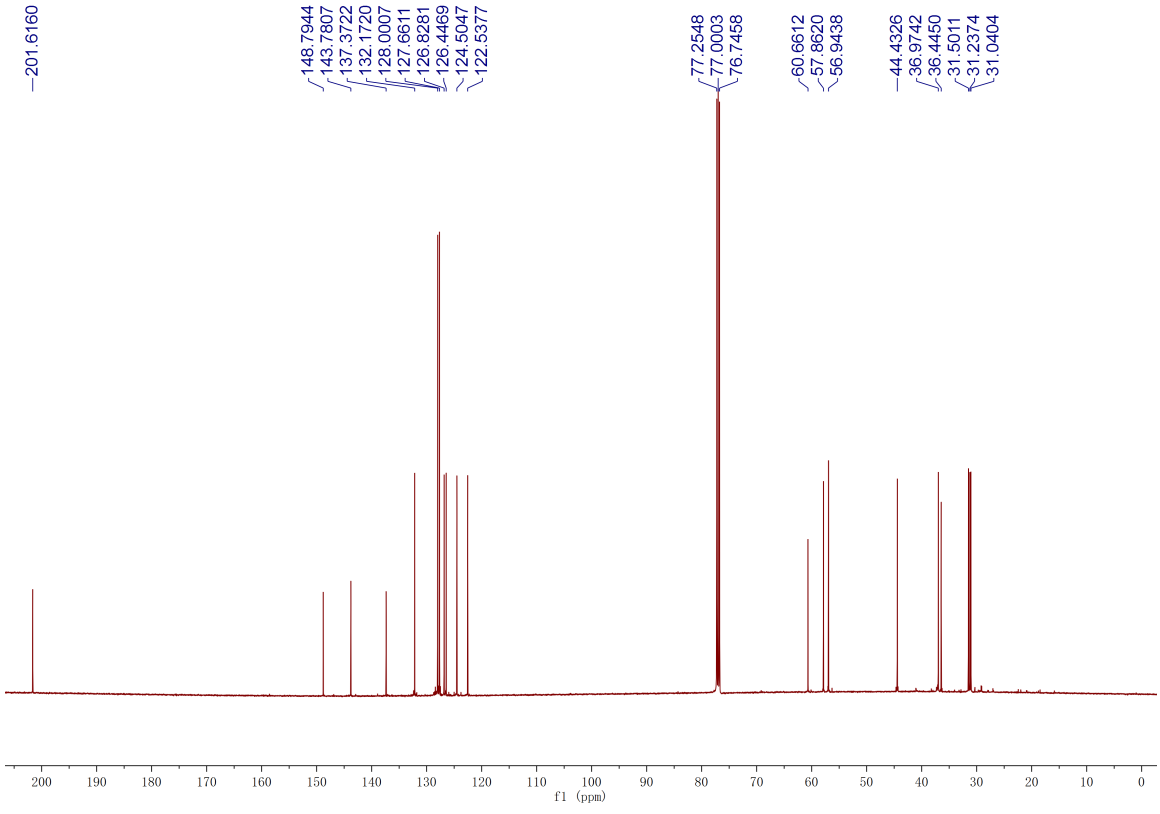
2D COSY spectrum of **18**



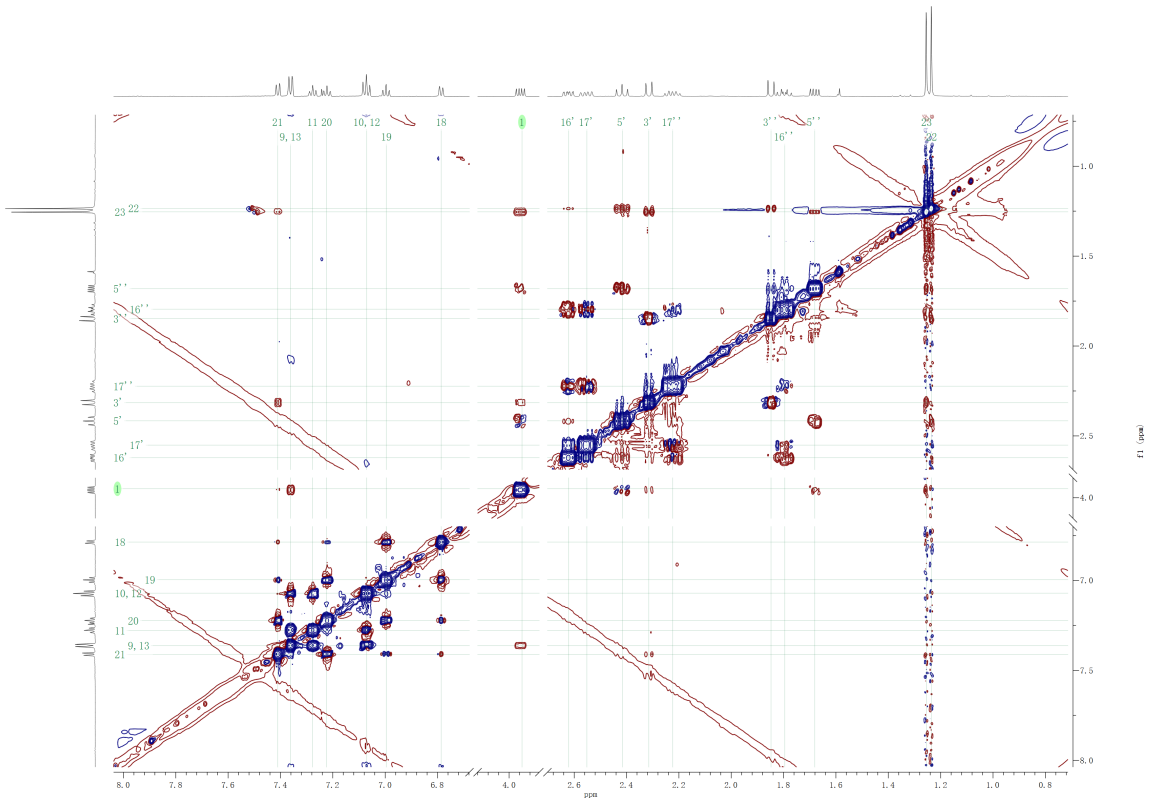
2D HSQC spectrum of **18**



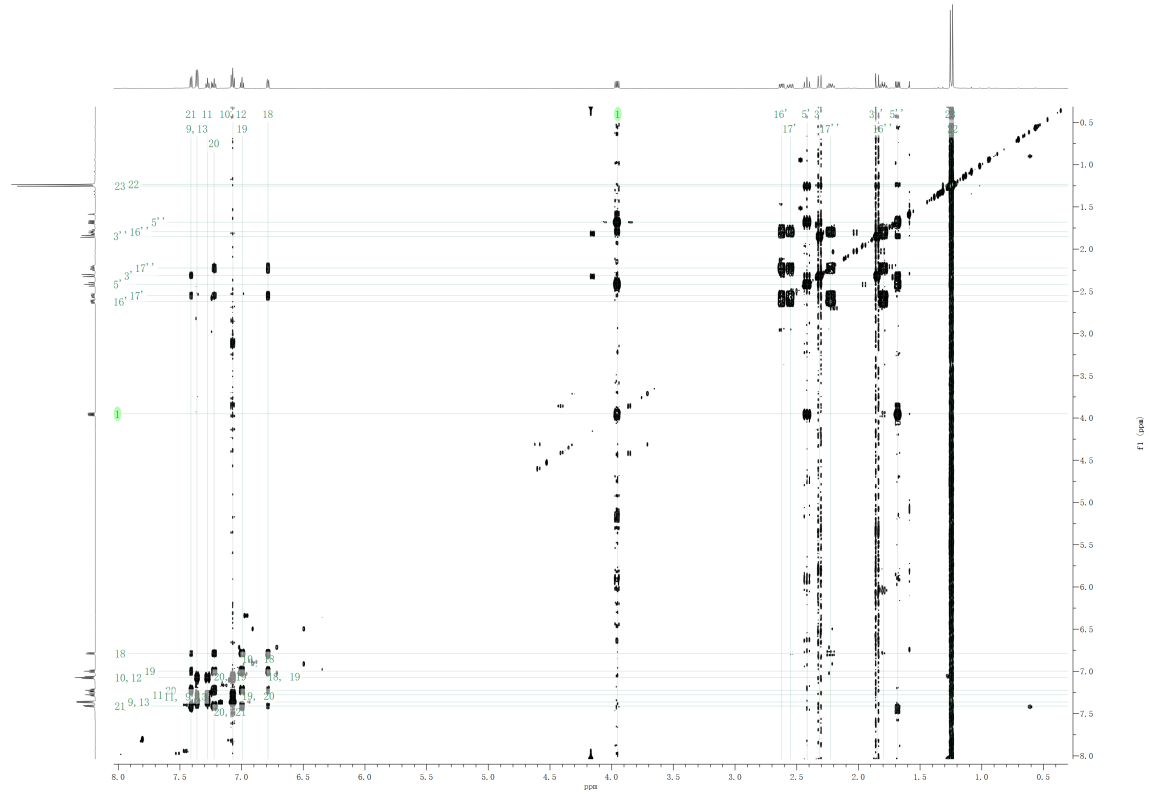

7.4340
7.4188
7.3859
7.3837
7.3694
7.3668
7.3108
7.2936
7.2812
7.2764
7.2597
7.2543
7.2392
7.2243
7.1035
7.1002
7.0885
7.0721
7.0289
7.0270
7.0141
7.0121
6.9993
6.9973
6.8094
6.7945
3.9904
3.9777
3.9661
3.9534
2.6607
2.6570
2.6448
2.6411
2.6347
2.6310
2.6188
2.6151
2.5963
2.5781
2.5633
2.5452
2.4579
2.4326
2.4074
2.3446
2.3173
2.2544
2.2380
1.8773
1.8499
1.7995
1.7806
1.7159
1.7031
1.6897
1.6770
1.2709
1.2512
Ph
O
19
1.00
1.88
0.93
1.15
1.85
0.94
0.86
1.00
1.00
1.02
1.07
1.05
1.25
2.22
1.05
2.96
2.96
f1 (ppm)


201.6160
148.7944
143.7807
137.3722
132.1720
128.0007
127.6611
126.8281
126.4469
124.5047
122.5377
77.2548
77.0003
76.7458
60.6612
57.8620
56.9438
44.4326
36.9742
36.4450
31.5011
31.2374
31.0404
f1 (ppm)

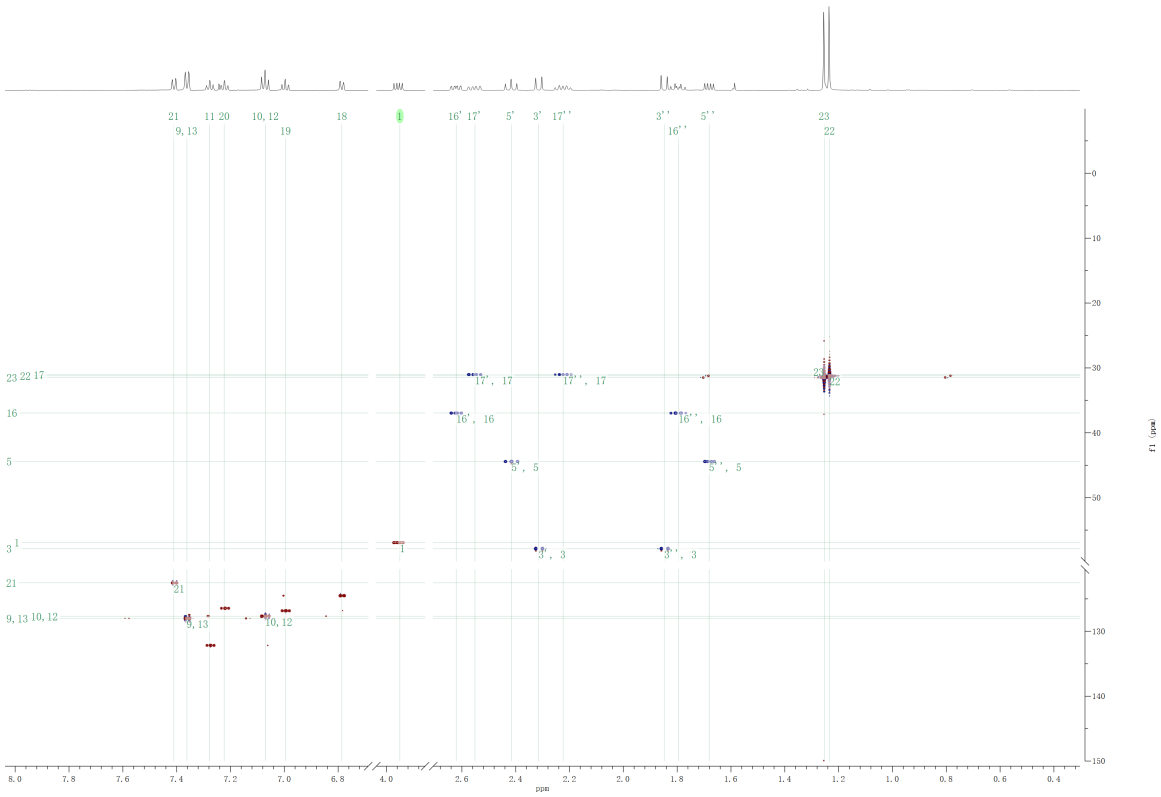
2D ROESY spectrum of **19**

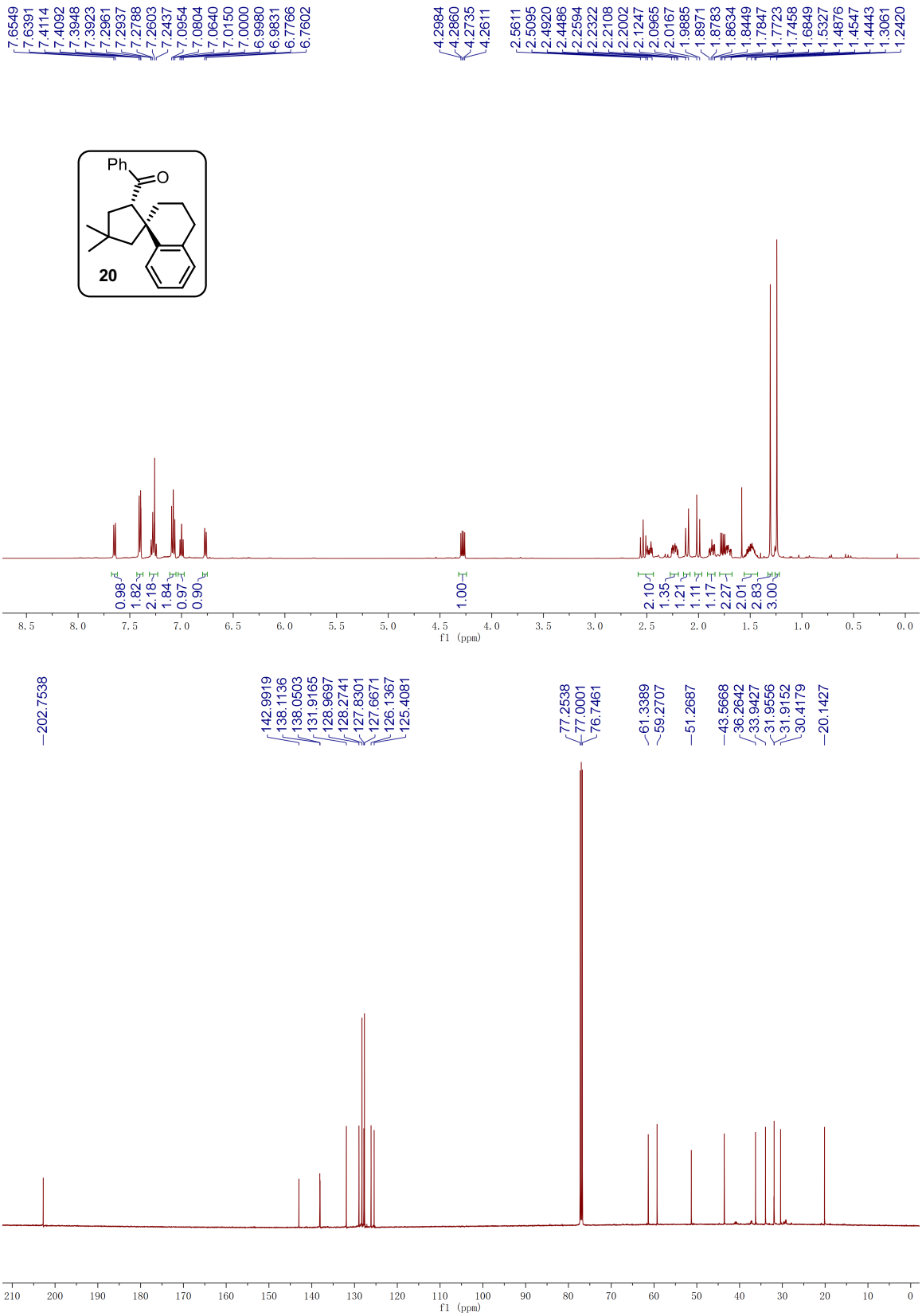


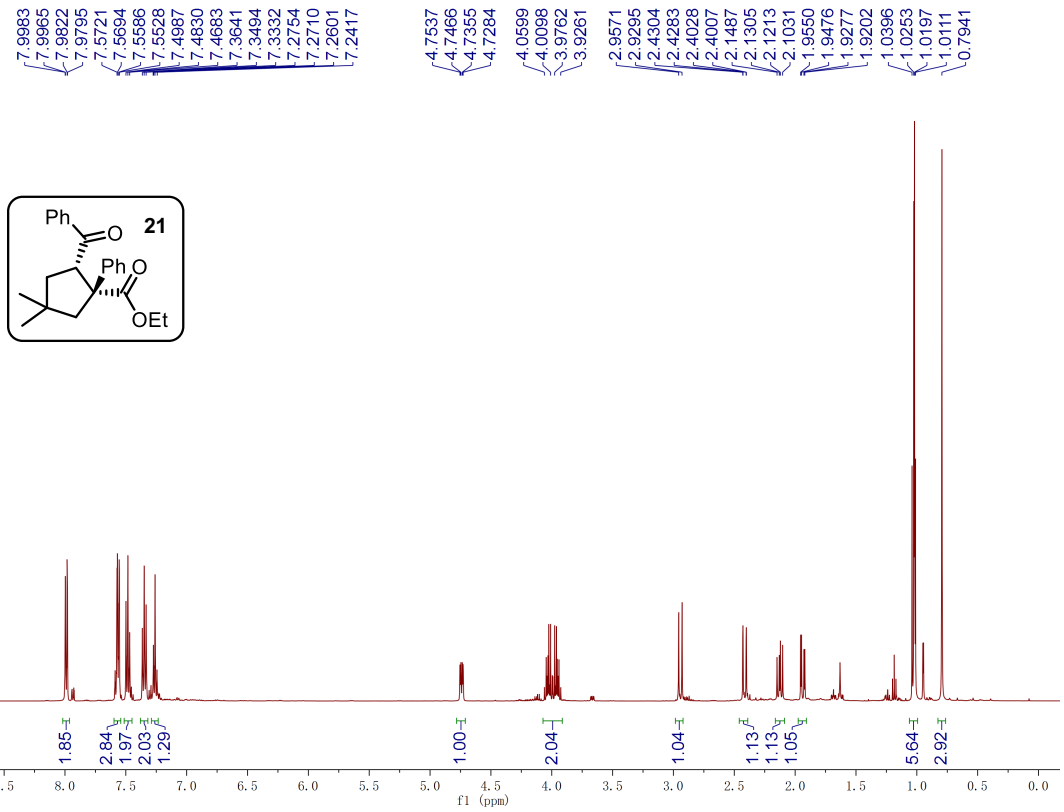
2D COSY spectrum of **19**

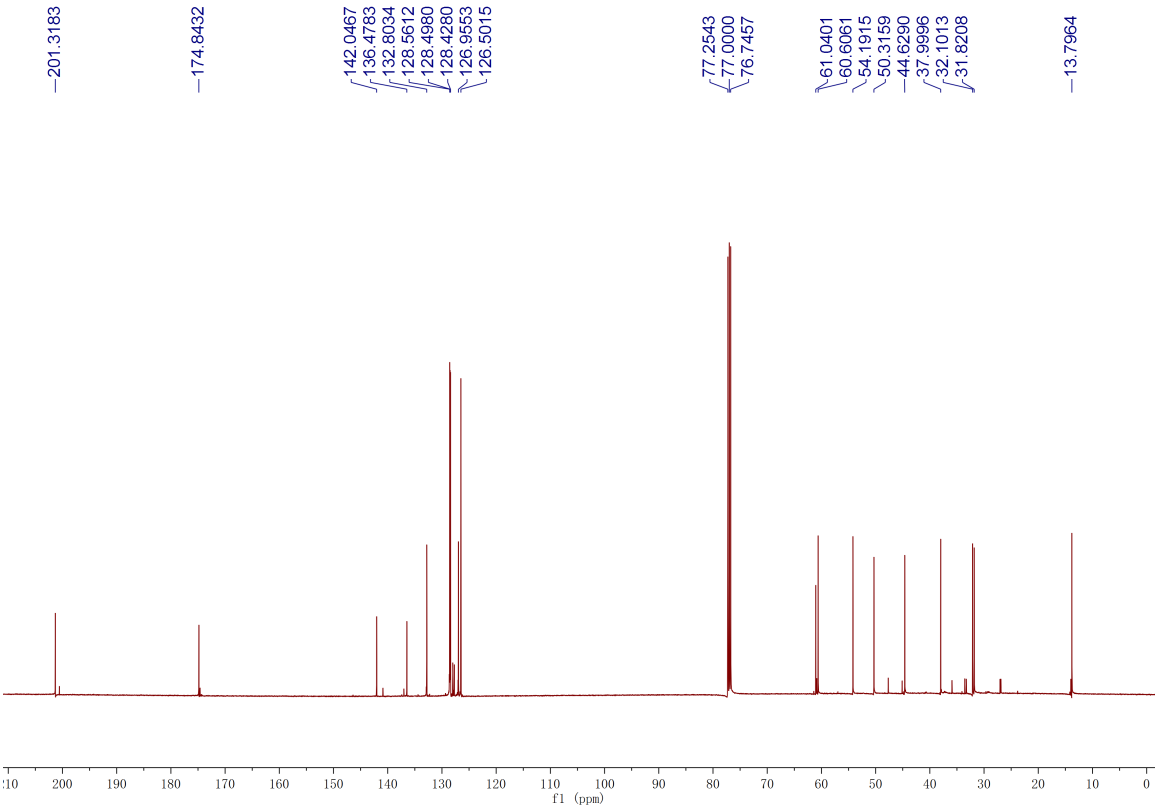


2D HSQC spectrum of **19**

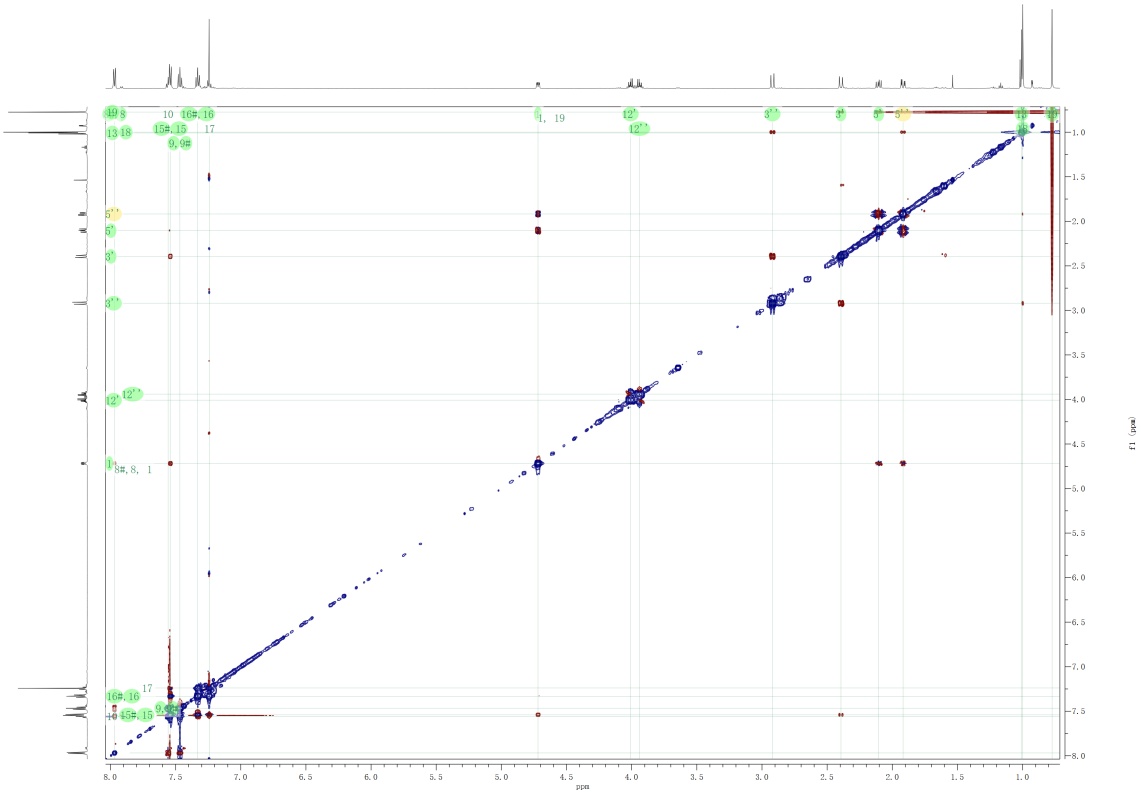



7.6549
7.6391
7.4114
7.4092
7.3948
7.3923
7.2961
7.2937
7.2788
7.2603
7.2437
7.0954
7.0804
7.0640
7.0150
7.0000
6.9980
6.9831
6.7766
6.7602
4.2984
4.2860
4.2735
4.2611
2.5611
2.5095
2.4920
2.4486
2.2594
2.2322
2.2108
2.2002
2.1247
2.0965
2.0167
1.9885
1.8971
1.8783
1.8634
1.8449
1.7847
1.7723
1.7458
1.6849
1.5327
1.4876
1.4547
1.4443
1.3061
1.2420
Ph
O
20
0.98
1.82
2.18
1.84
0.97
0.90
1.00
2.10
1.35
1.21
1.11
1.17
2.27
2.01
2.83
3.00
f1 (ppm)
202.7538
142.9919
138.1136
138.0503
131.9165
128.9697
128.2741
127.8301
127.6671
126.1367
125.4081
77.2538
77.0001
76.7461
61.3389
59.2707
51.2687
43.5668
36.2642
33.9427
31.9556
31.9152
30.4179
20.1427
f1 (ppm)

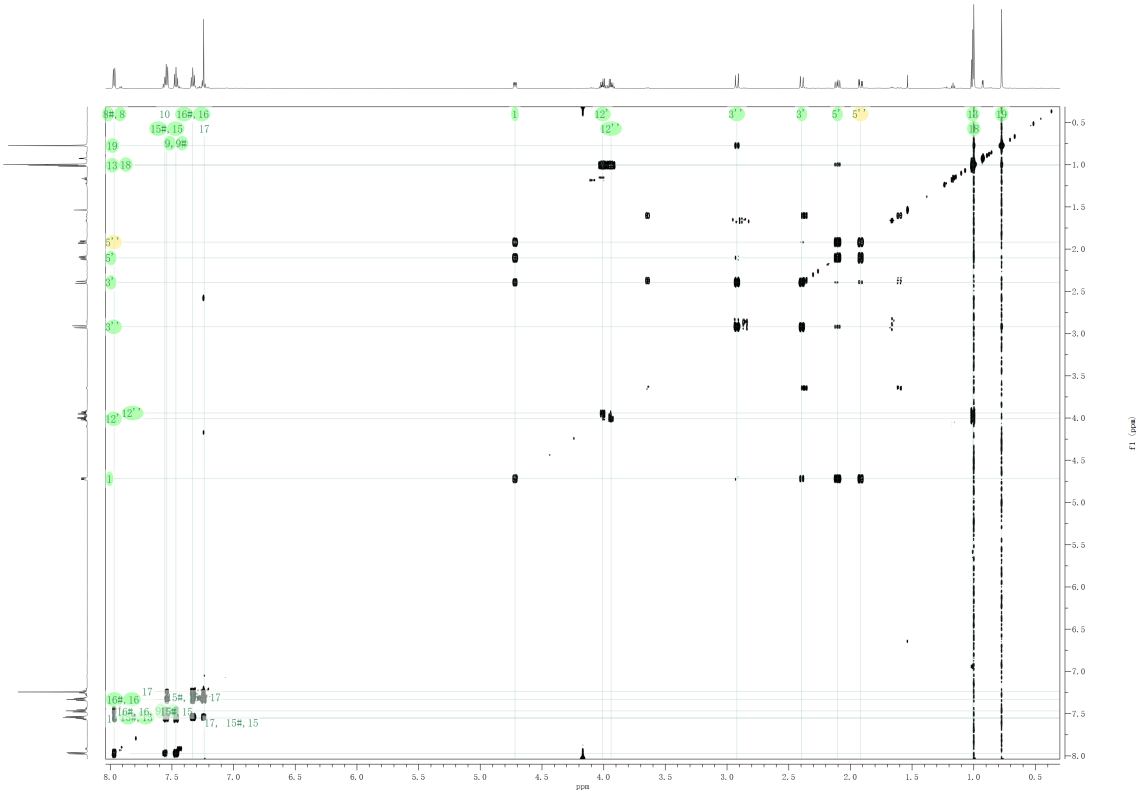

7.9983
7.9965
7.9822
7.9795
7.5721
7.5694
7.5586
7.5528
7.4987
7.4830
7.4683
7.3641
7.3494
7.3332
7.2754
7.2710
7.2601
7.2417
4.7537
4.7466
4.7355
4.7284
4.0599
4.0098
3.9762
3.9261
2.9571
2.9295
2.4304
2.4283
2.4028
2.4007
2.1487
2.1305
2.1213
2.1031
1.9550
1.9476
1.9277
1.9202
1.0396
1.0253
1.0197
1.0111
0.7941
Ph
O
21
Ph
O
OEt
1.85
2.84
1.97
2.03
1.29
1.00
2.04
1.04
1.13
1.13
1.05
5.64
2.92
f1 (ppm)


201.3183
174.8432
142.0467
136.4783
132.8034
128.5612
128.4980
128.4280
126.9553
126.5015
77.2543
77.0000
76.7457
61.0401
60.6061
54.1915
50.3159
44.6290
37.9996
32.1013
31.8208
13.7964
f1 (ppm)

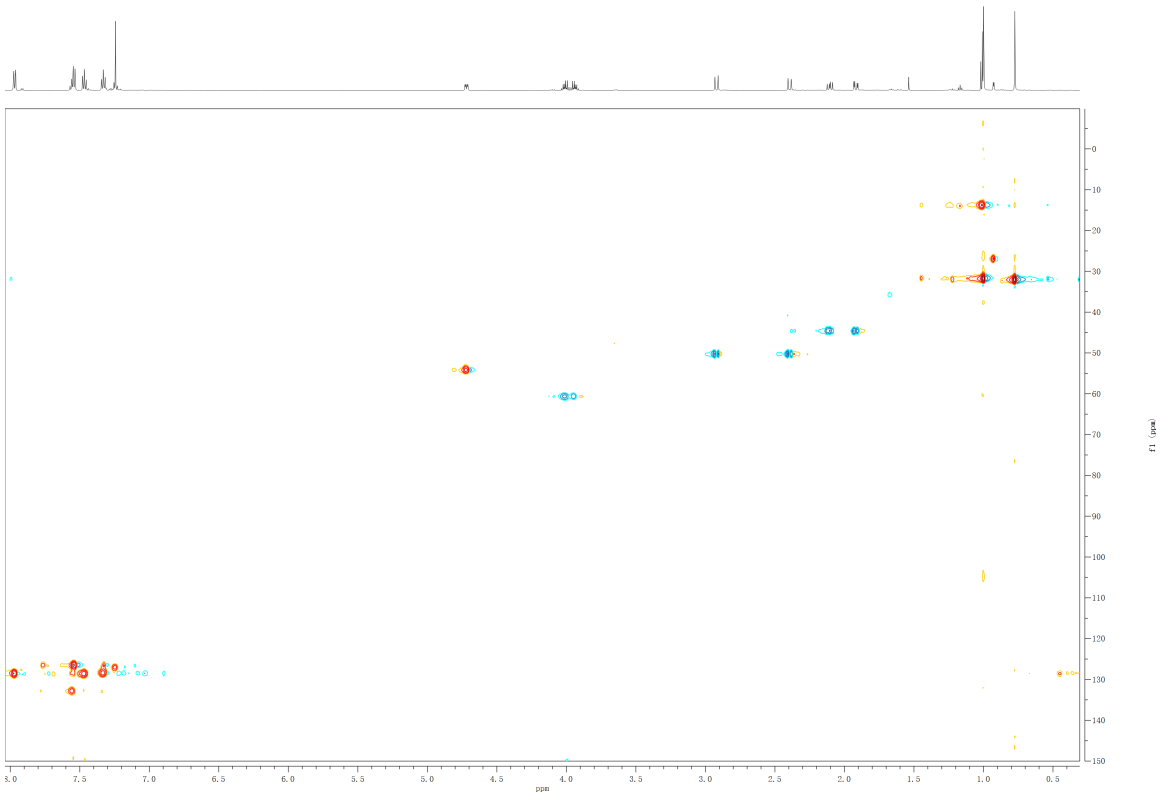
2D ROESY spectrum of **21**

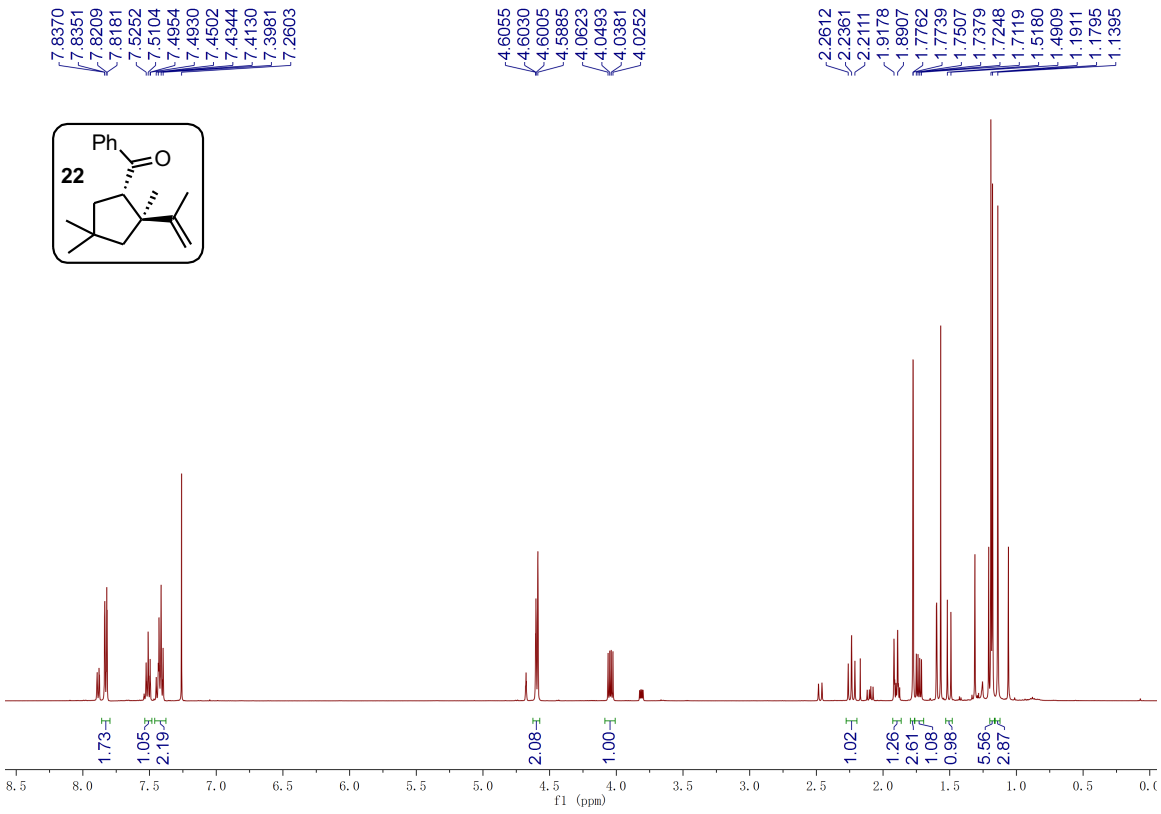


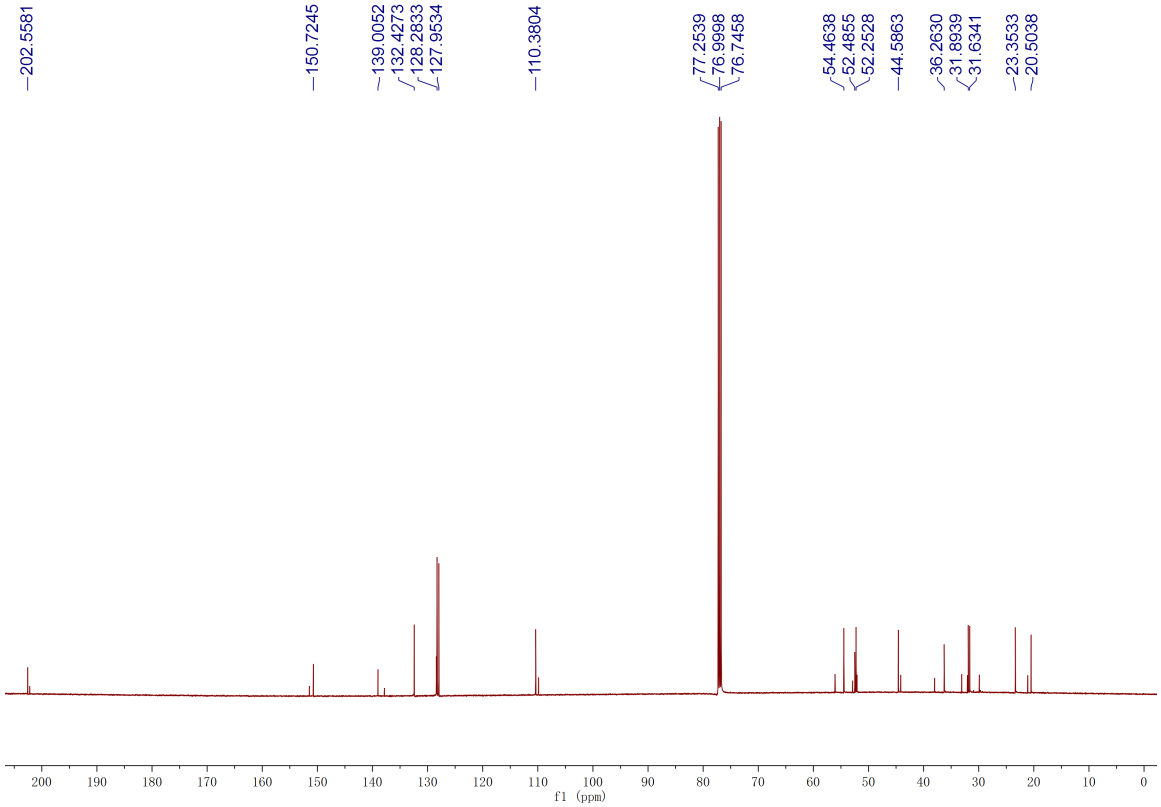
2D COSY spectrum of **21**



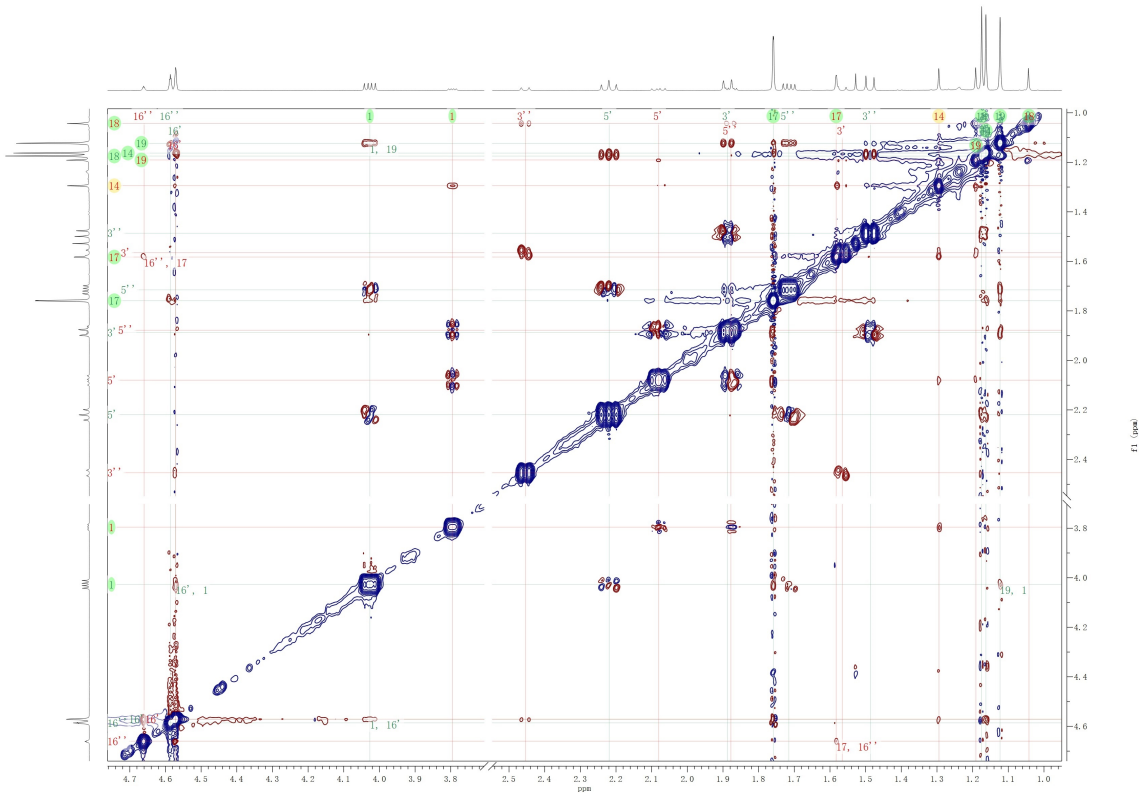
2D HSQC spectrum of **21**



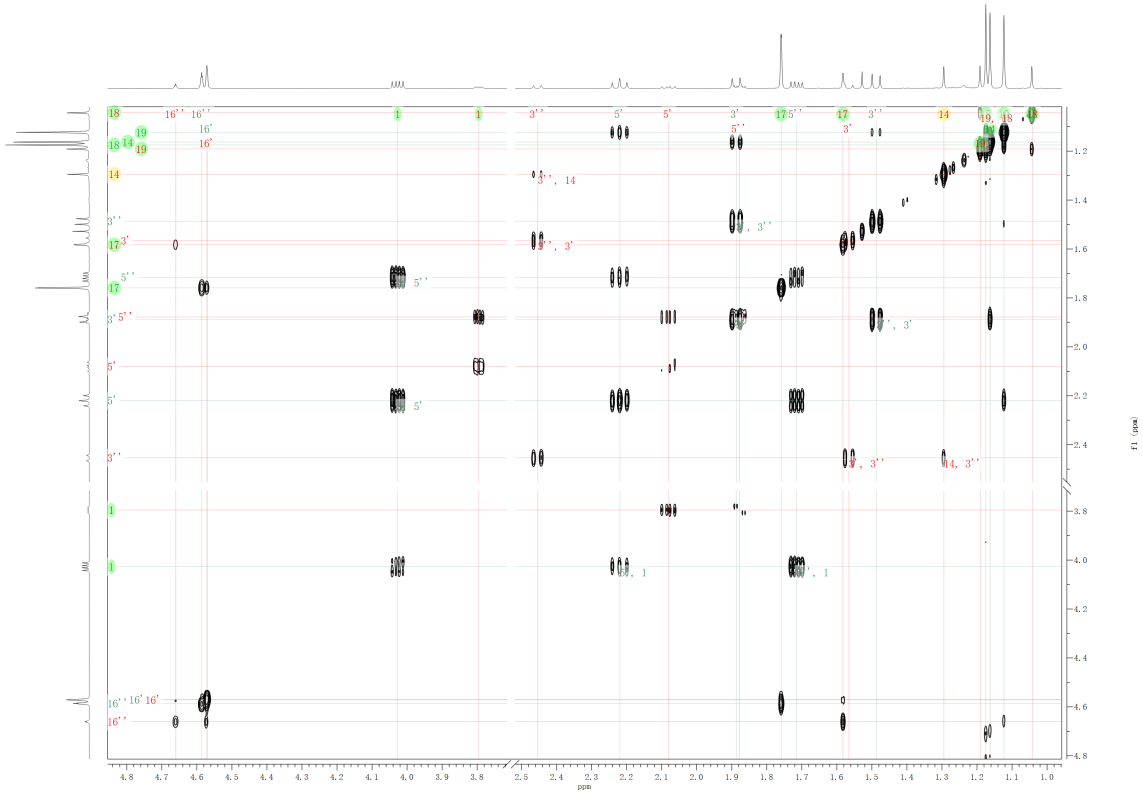

7.8370
7.8351
7.8209
7.8181
7.5252
7.5104
7.4954
7.4930
7.4502
7.4344
7.4130
7.3981
7.2603
4.6055
4.6030
4.6005
4.5885
4.0623
4.0493
4.0381
4.0252
2.2612
2.2361
2.2111
1.9178
1.8907
1.7762
1.7739
1.7507
1.7379
1.7248
1.7119
1.5180
1.4909
1.1911
1.1795
1.1395
Ph
O
22
1.73
1.05
2.19
2.08
1.00
1.02
1.26
2.61
1.08
0.98
5.56
2.87
f1 (ppm)

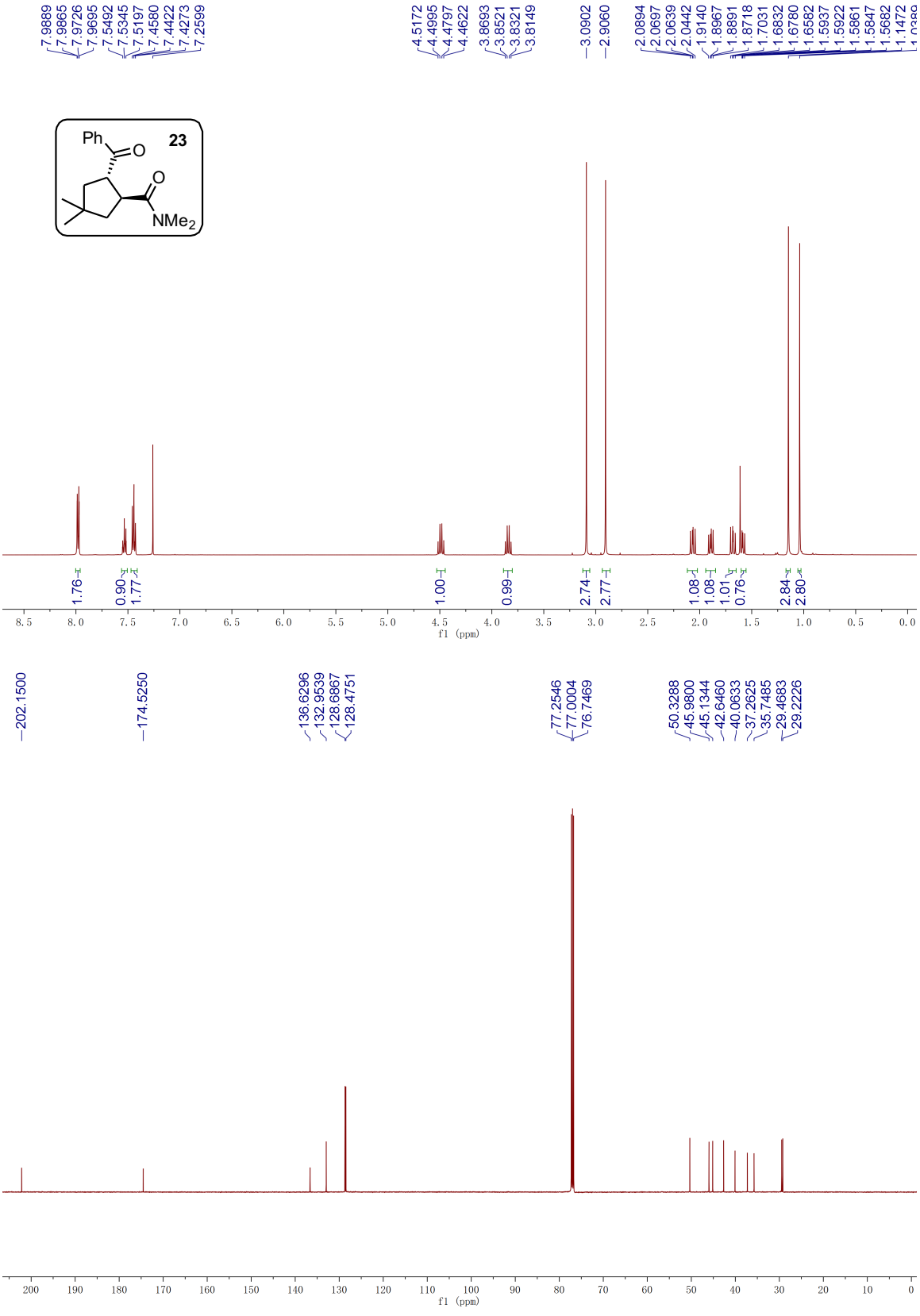

202.5581
150.7245
139.0052
132.4273
128.2833
127.9534
110.3804
77.2539
76.9998
76.7458
54.4638
52.4855
52.2528
44.5863
36.2630
31.8939
31.6341
23.3533
20.5038
f1 (ppm)

2D ROESY spectrum of **22**

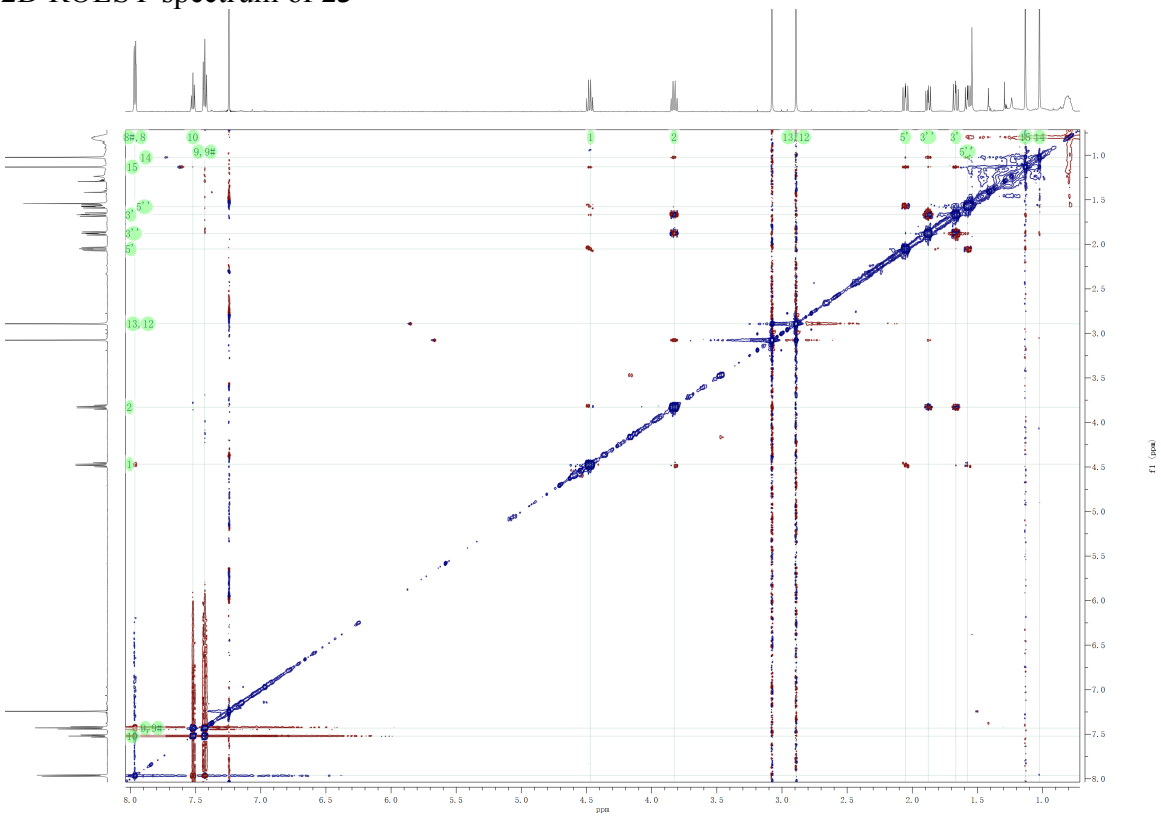


2D COSY spectrum of **22**

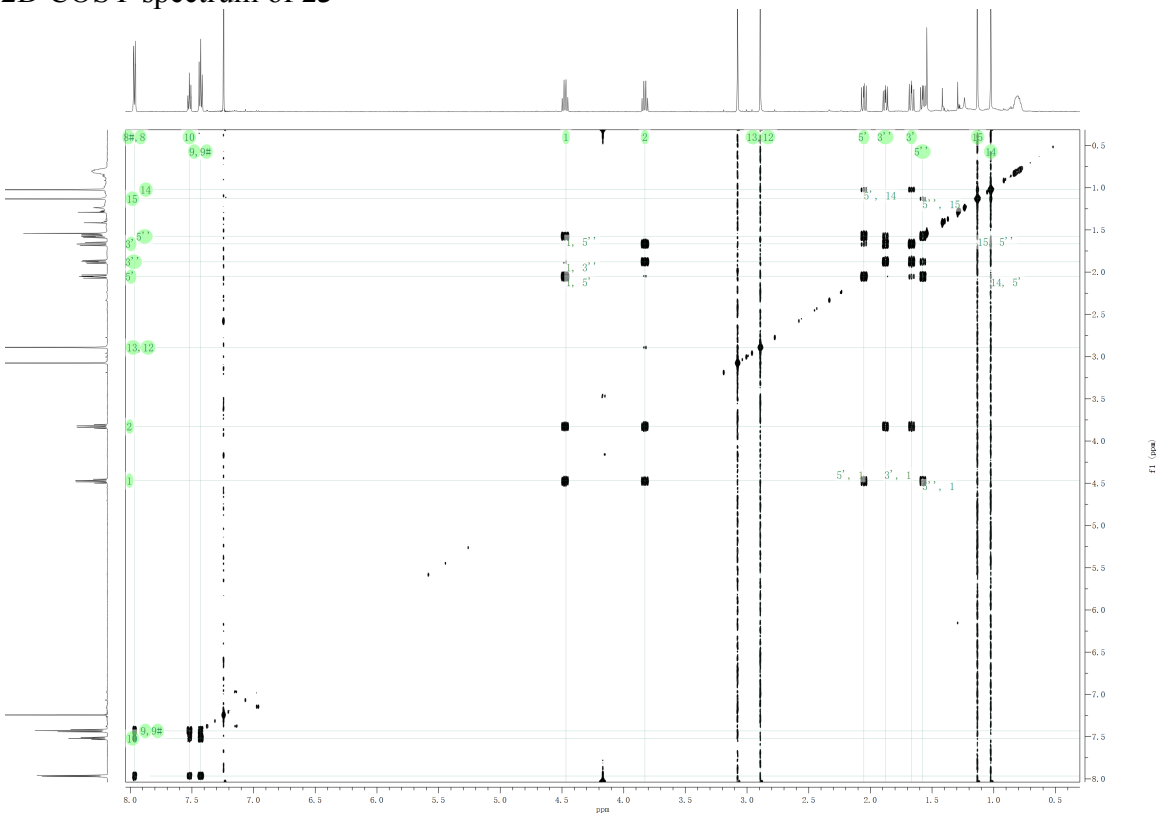



7.9889
7.9865
7.9726
7.9695
7.5492
7.5345
7.5197
7.4580
7.4422
7.4273
7.2599
4.5172
4.4995
4.4797
4.4622
3.8693
3.8521
3.8321
3.8149
3.0902
2.9060
2.0894
2.0697
2.0639
2.0442
1.9140
1.8967
1.8891
1.8718
1.7031
1.6832
1.6780
1.6582
1.5937
1.5922
1.5861
1.5847
1.5682
1.1472
Ph
O
O
NMe2
23
1.76
0.90
1.77
1.00
0.99
2.74
2.77
1.08
1.08
1.01
0.76
2.84
2.80
f1 (ppm)
202.1500
174.5250
136.6296
132.9539
128.6867
128.4751
77.2546
77.0004
76.7469
50.3288
45.9800
45.1344
42.6460
40.0633
37.2625
35.7485
29.4683
29.2226
f1 (ppm)

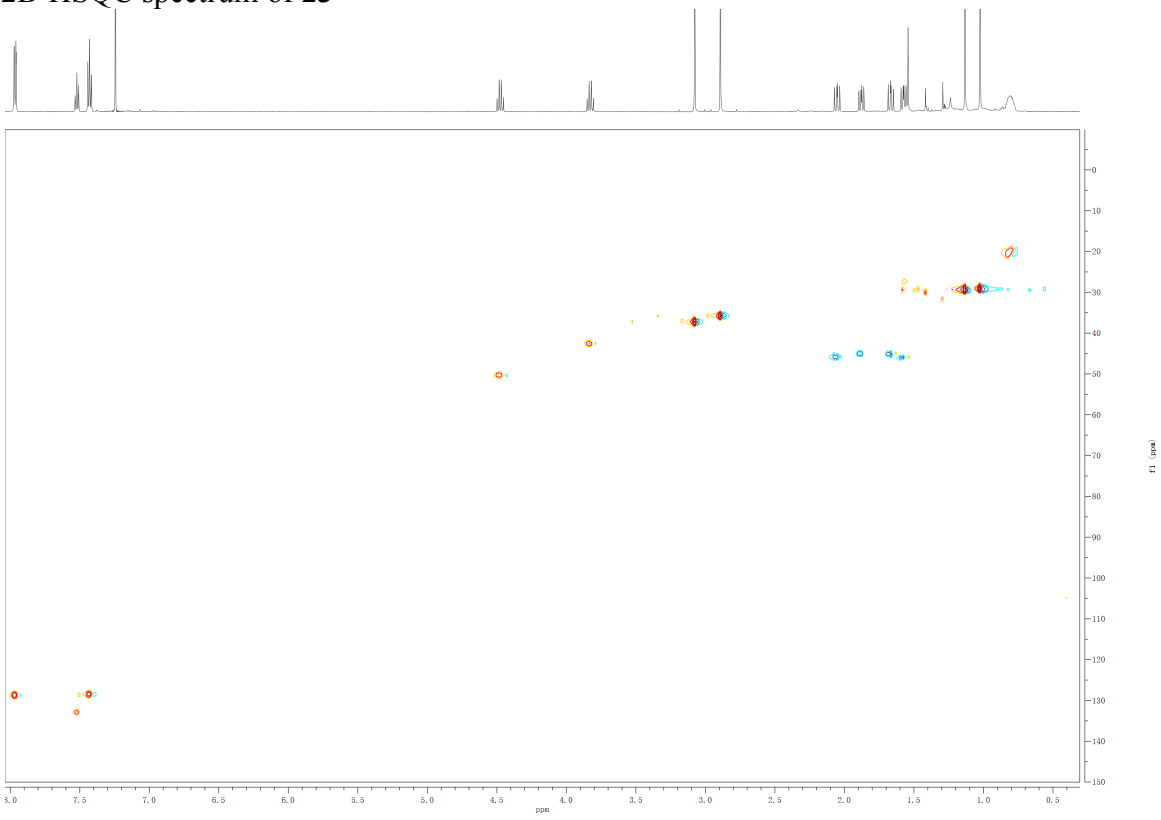
2D ROESY spectrum of **23**

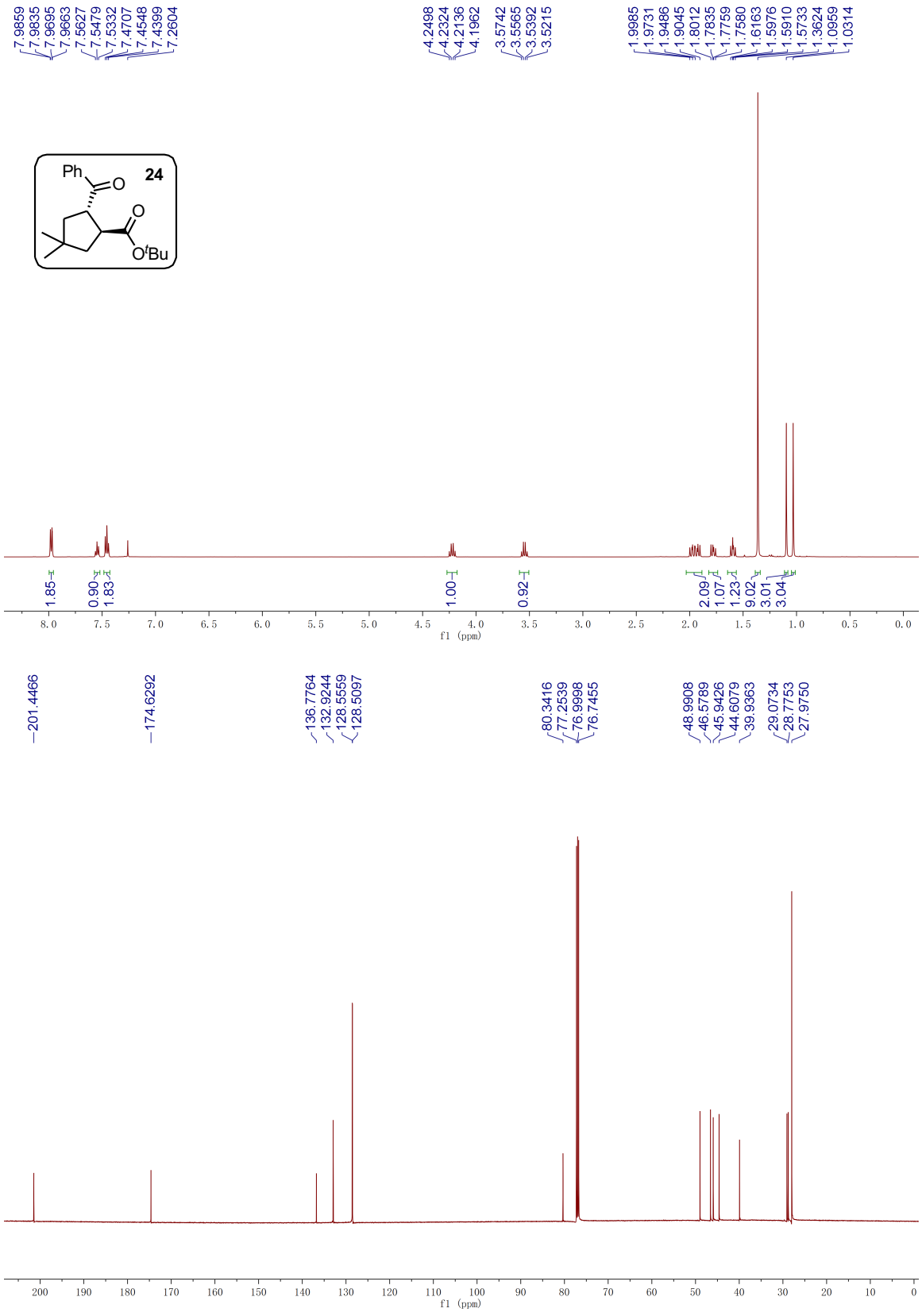


2D COSY spectrum of **23**

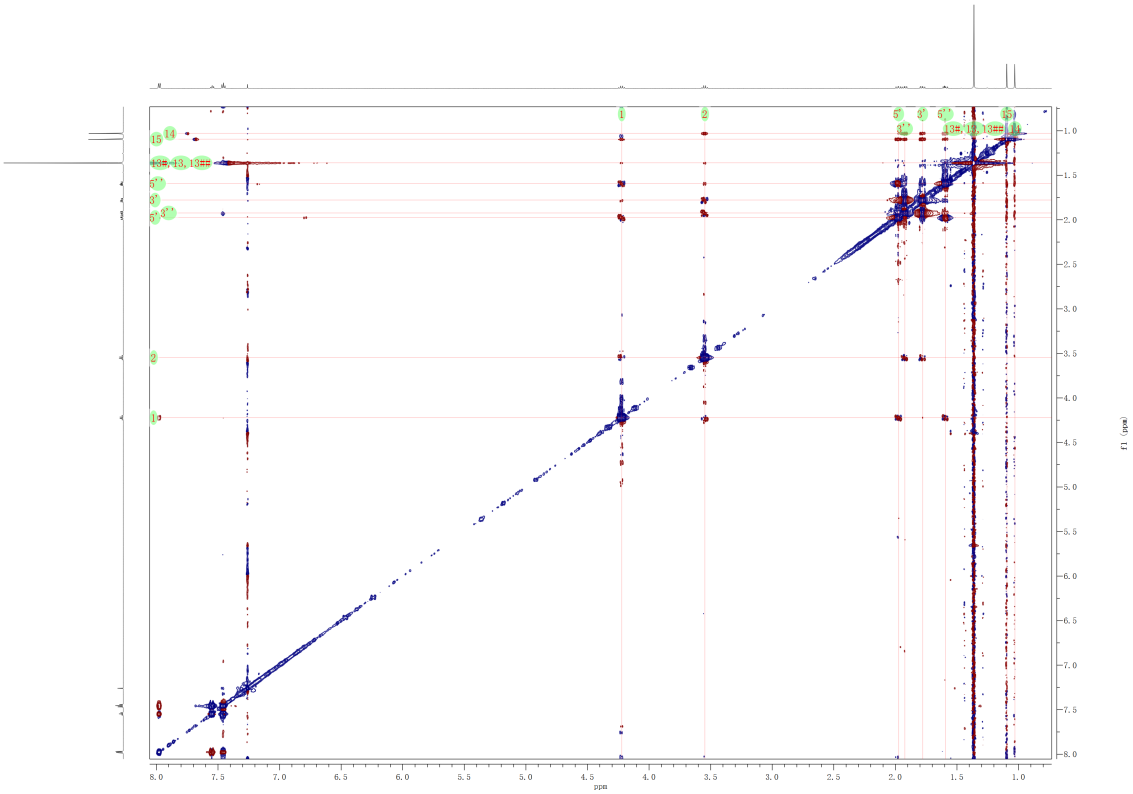


2D HSQC spectrum of **23**

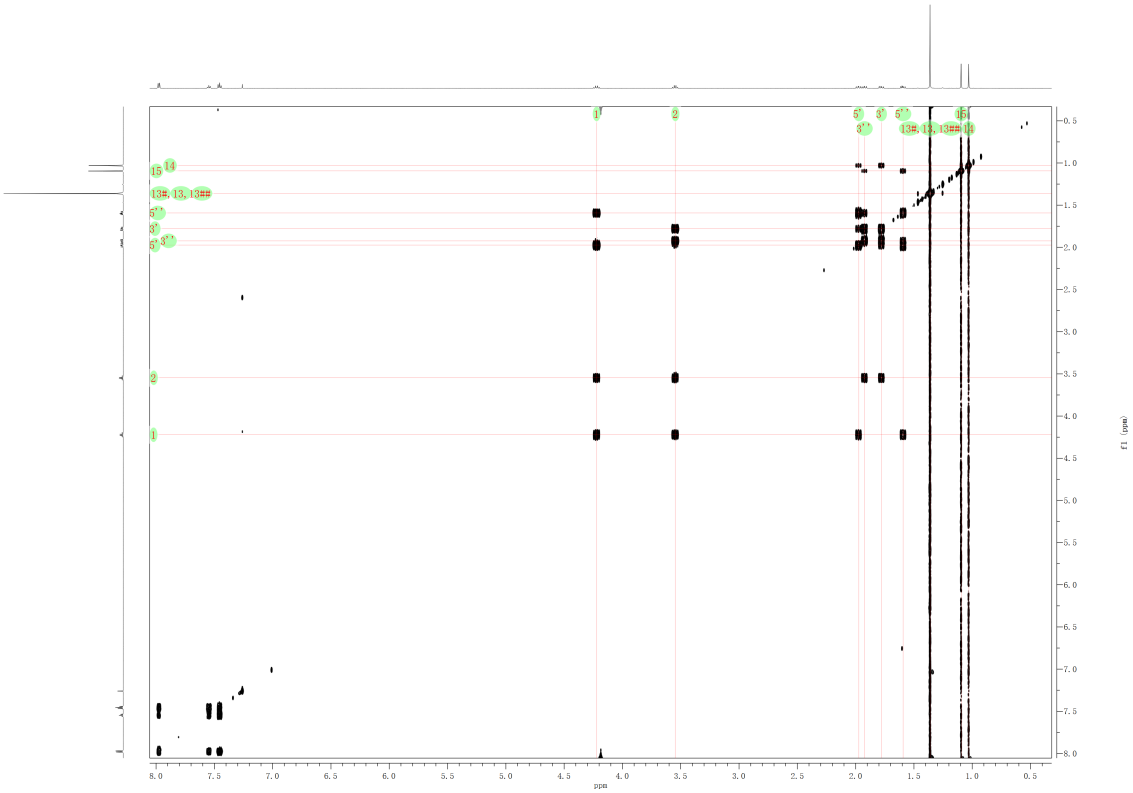



7.9859
7.9835
7.9695
7.9663
7.5627
7.5479
7.5332
7.4707
7.4548
7.4399
7.2604
4.2498
4.2324
4.2136
4.1962
3.5742
3.5565
3.5392
3.5215
1.9985
1.9731
1.9486
1.9045
1.8012
1.7835
1.7759
1.7580
1.6163
1.5976
1.5910
1.5733
1.3624
1.0959
1.0314
Ph
O
24
O
O'Bu
1.85
0.90
1.83
1.00
0.92
2.09
1.07
1.23
9.02
3.01
3.04
f1 (ppm)
201.4466
174.6292
136.7764
132.9244
128.5559
128.5097
80.3416
77.2539
76.9998
76.7455
48.9908
46.5789
45.9426
44.6079
39.9363
29.0734
28.7753
27.9750
f1 (ppm)

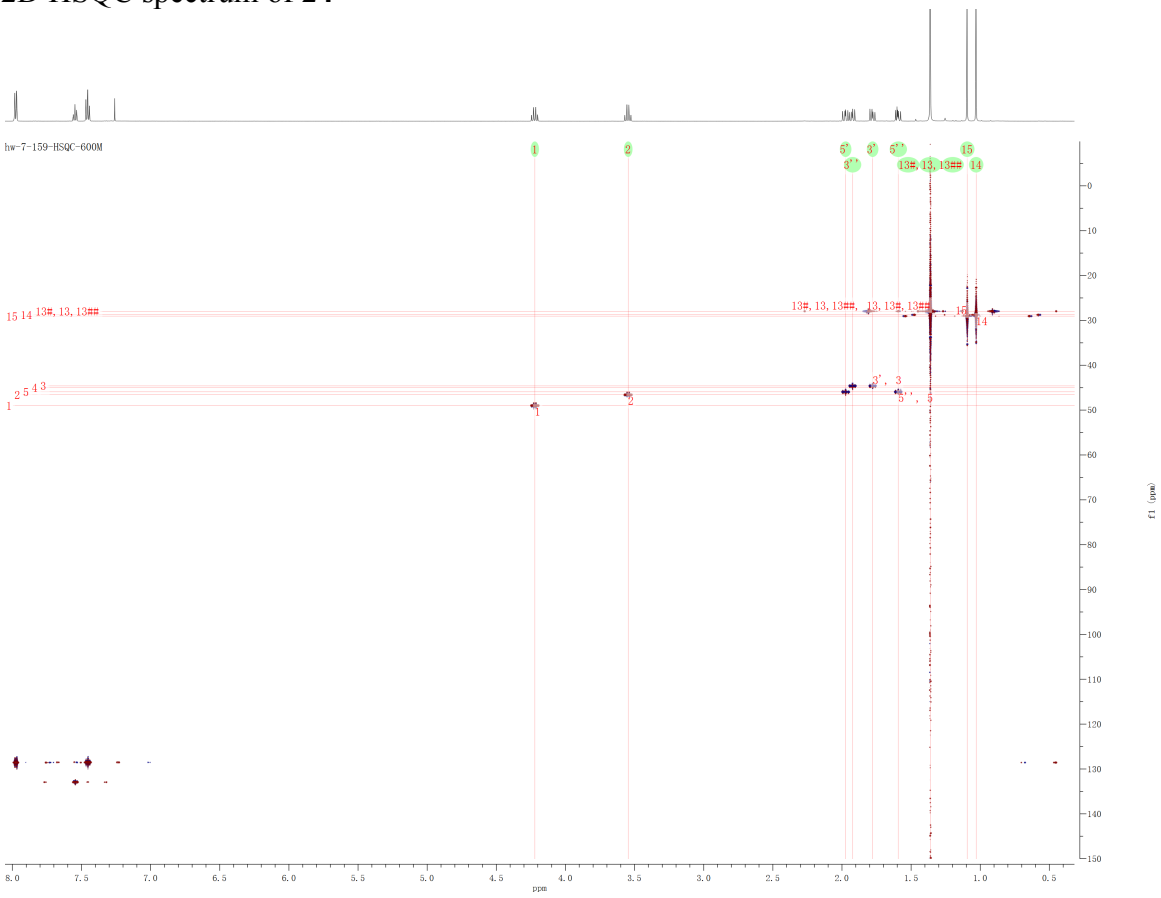
2D ROESY spectrum of **24**

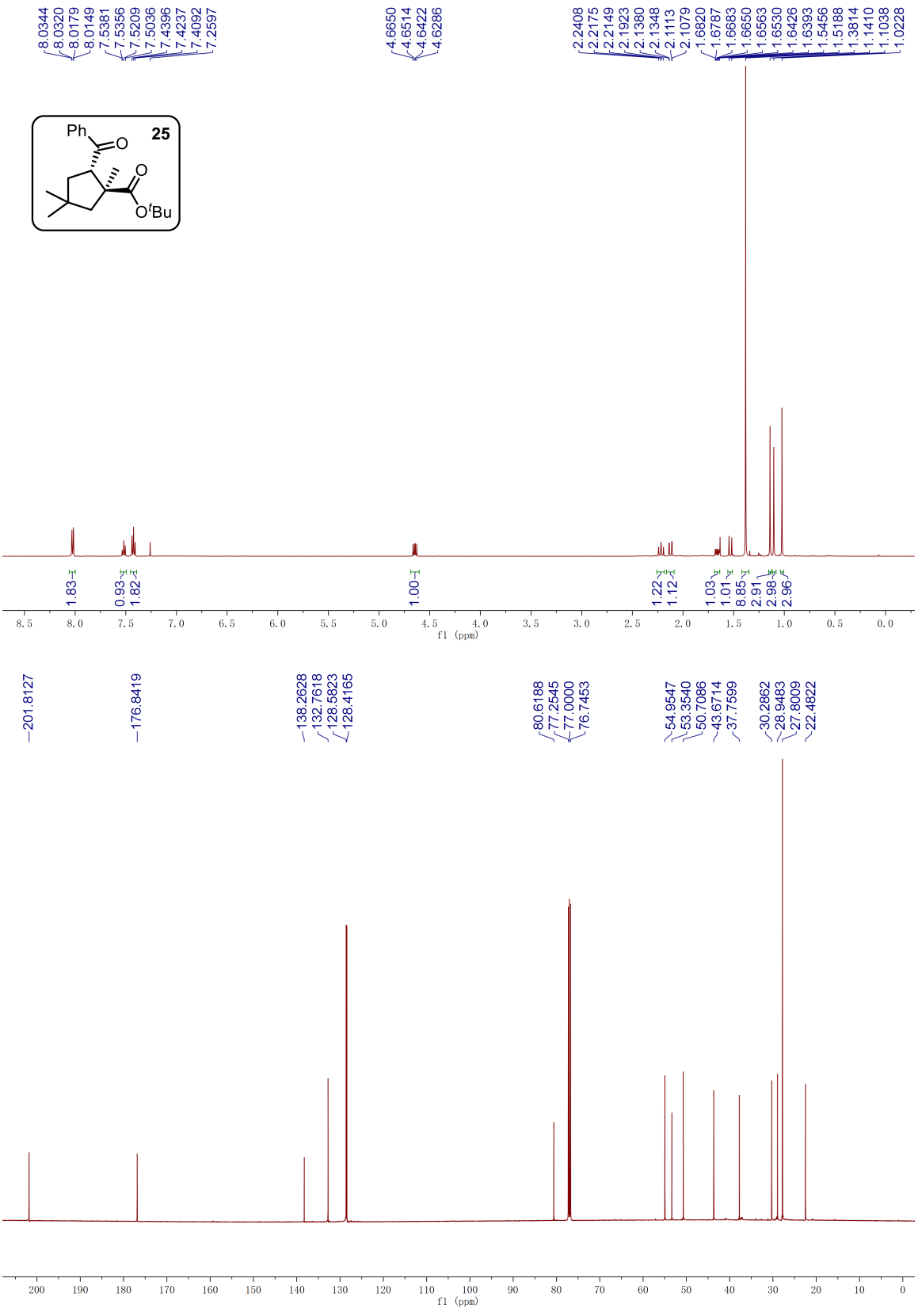


2D COSY spectrum of **24**

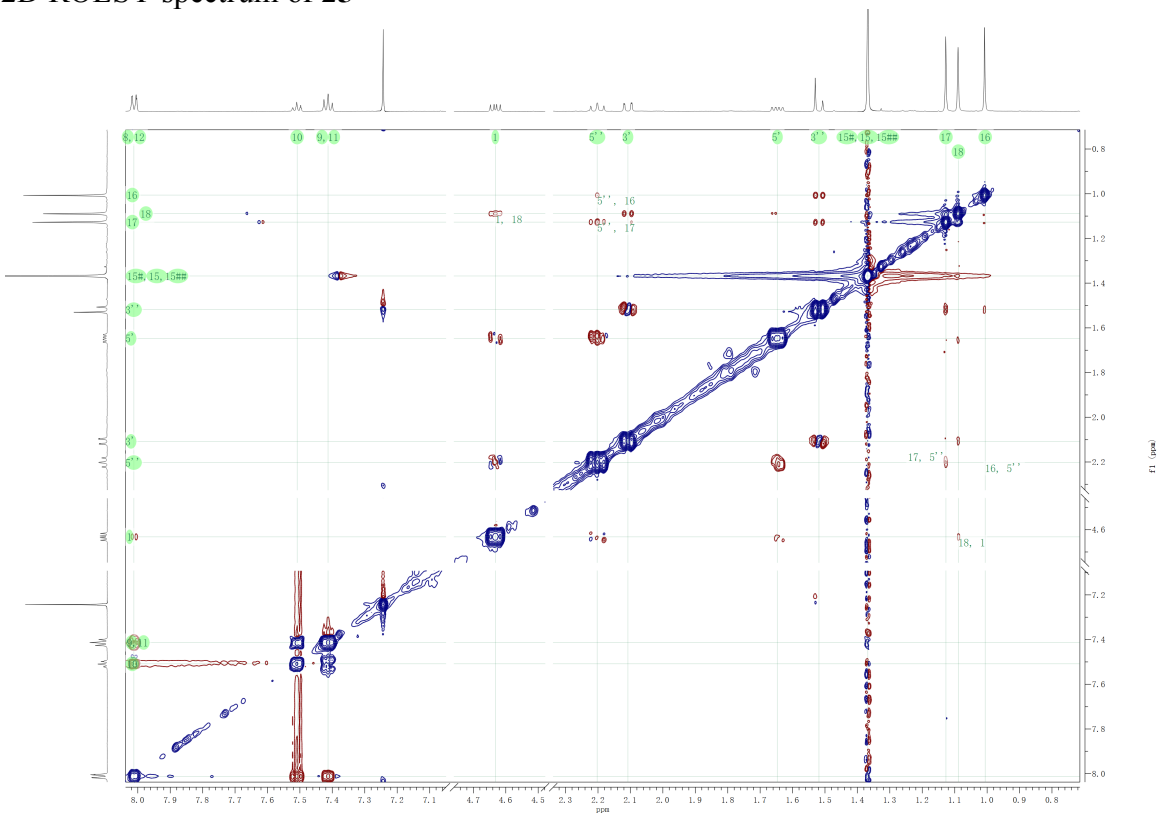


2D HSQC spectrum of **24**

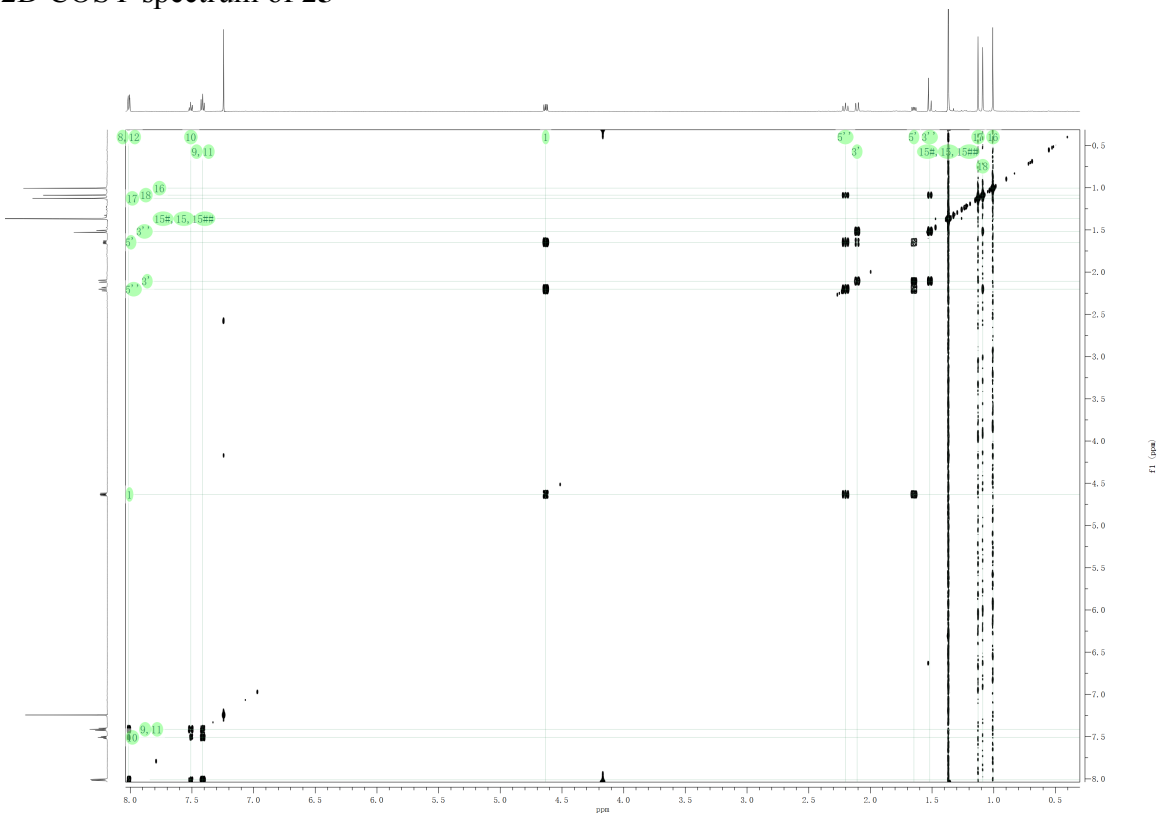



8.0344
8.0320
8.0179
8.0149
7.5381
7.5356
7.5209
7.5036
7.4396
7.4237
7.4092
7.2597
4.6650
4.6514
4.6422
4.6286
2.2408
2.2175
2.2149
2.1923
2.1380
2.1348
2.1113
2.1079
1.6820
1.6787
1.6683
1.6650
1.6563
1.6530
1.6426
1.6393
1.5456
1.5188
1.3814
1.1410
1.1038
1.0228
Ph
O
O
O
tBu
25
1.83
0.93
1.82
1.00
1.22
1.12
1.03
1.01
8.85
2.91
2.98
2.96
f1 (ppm)
201.8127
176.8419
138.2628
132.7618
128.5823
128.4165
80.6188
77.2545
77.0000
76.7453
54.9547
53.3540
50.7086
43.6714
37.7599
30.2862
28.9483
27.8009
22.4822
f1 (ppm)

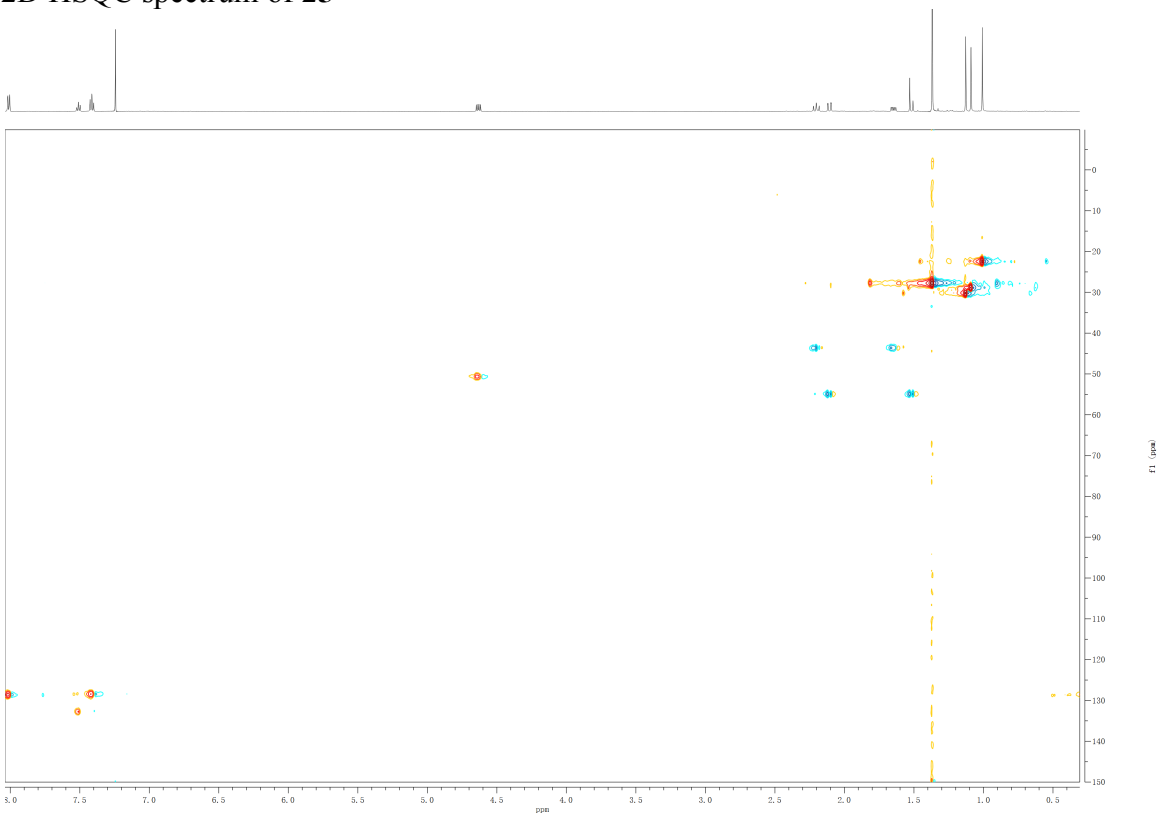
2D ROESY spectrum of **25**

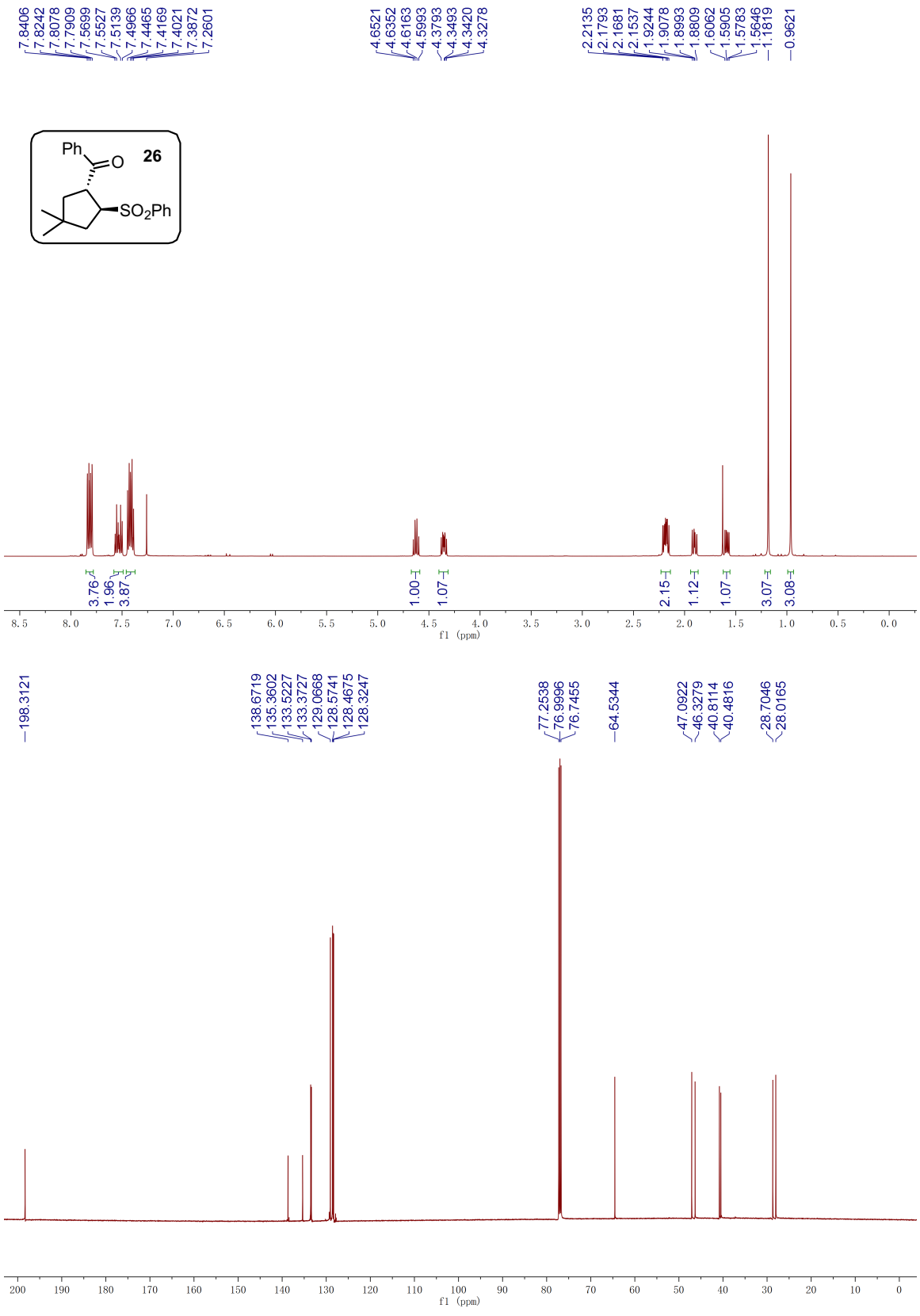


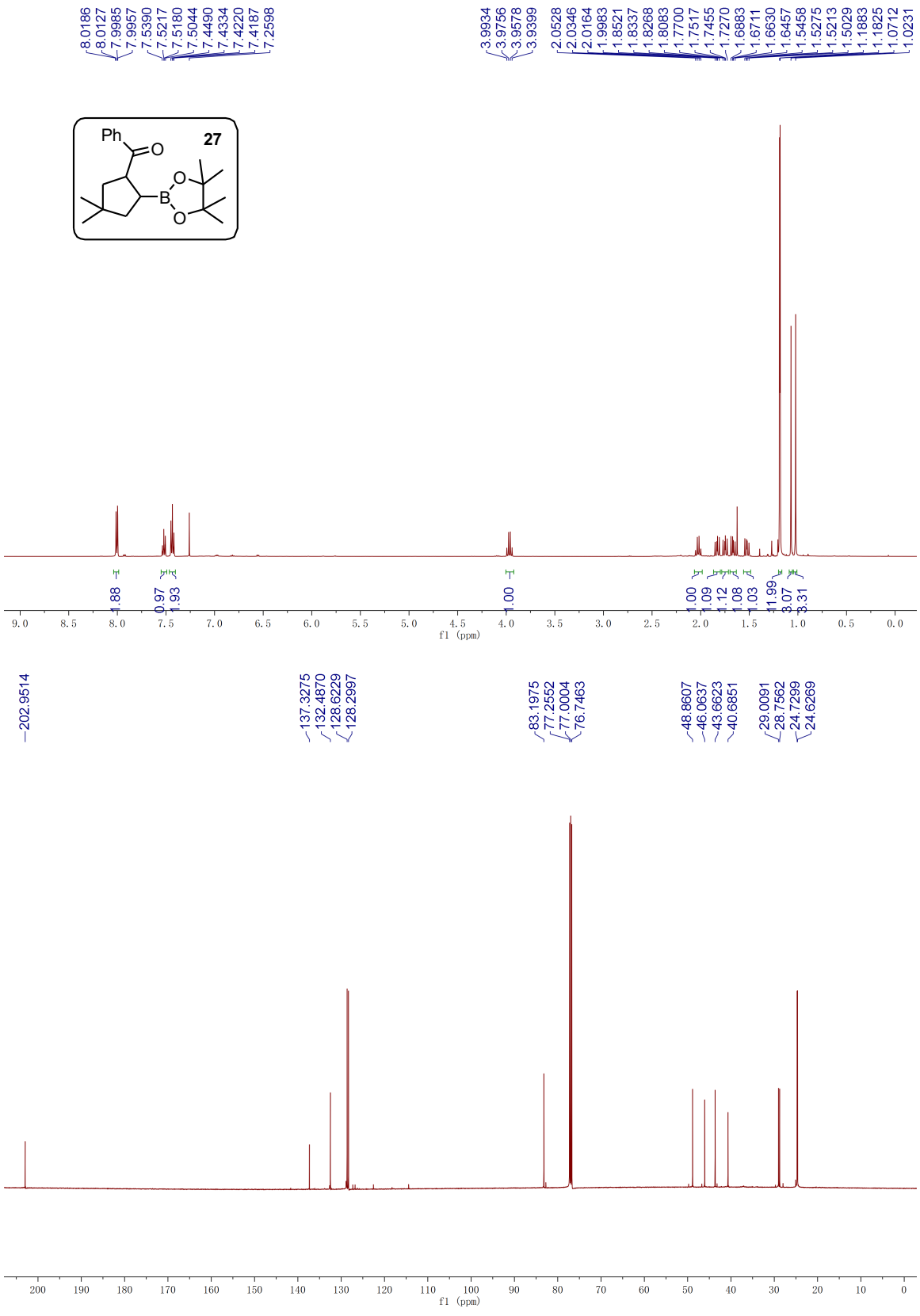
2D COSY spectrum of **25**



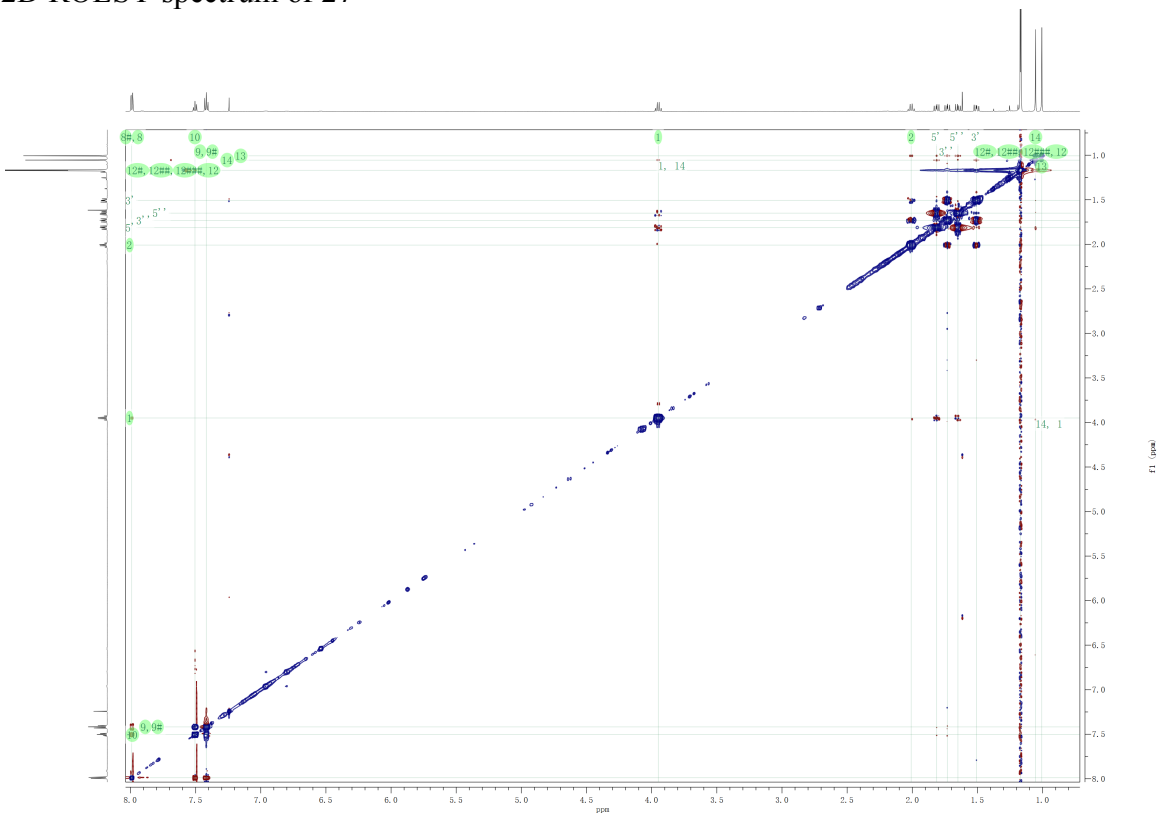
2D HSQC spectrum of **25**



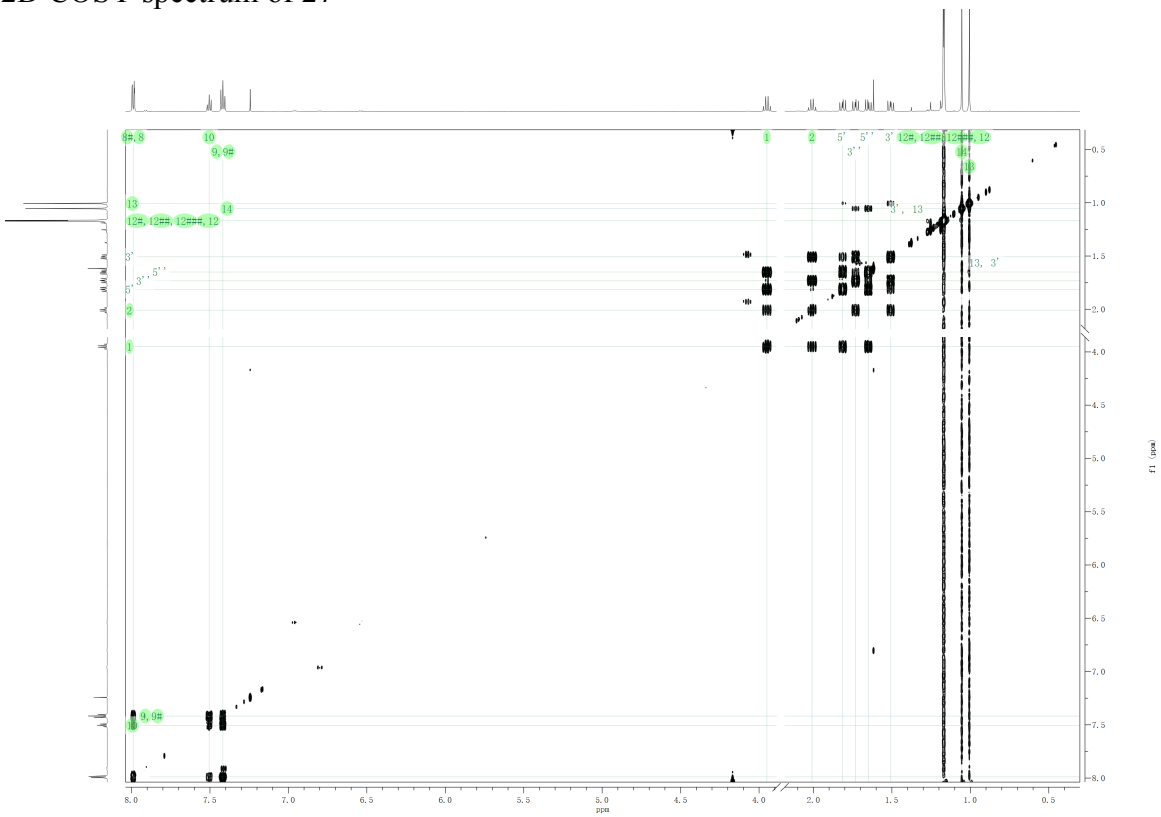

7.8406
7.8242
7.8078
7.7909
7.5699
7.5527
7.5139
7.4966
7.4465
7.4169
7.4021
7.3872
7.2601
4.6521
4.6352
4.6163
4.5993
4.3793
4.3493
4.3420
4.3278
2.2135
2.1793
2.1681
2.1537
1.9244
1.9078
1.8993
1.8809
1.6062
1.5905
1.5783
1.5646
1.1819
0.9621
Ph
O
26
SO2Ph
3.76
1.96
3.87
1.00
1.07
2.15
1.12
1.07
3.07
3.08
f1 (ppm)
198.3121
138.6719
135.3602
133.5227
133.3727
129.0668
128.5741
128.4675
128.3247
77.2538
76.9996
76.7455
64.5344
47.0922
46.3279
40.8114
40.4816
28.7046
28.0165
f1 (ppm)


8.0186
8.0127
7.9985
7.9957
7.5390
7.5217
7.5180
7.5044
7.4490
7.4334
7.4220
7.4187
7.2598
3.9934
3.9756
3.9578
3.9399
2.0528
2.0346
2.0164
1.9983
1.8521
1.8337
1.8268
1.8083
1.7700
1.7517
1.7455
1.7270
1.6883
1.6711
1.6630
1.6457
1.5458
1.5275
1.5213
1.5029
1.1883
1.1825
1.0712
1.0231
Ph
O
27
B
O
O
1.88
0.97
1.93
1.00
1.00
1.09
1.12
1.08
1.03
11.99
3.07
3.31
f1 (ppm)
202.9514
137.3275
132.4870
128.6229
128.2997
83.1975
77.2552
77.0004
76.7463
48.8607
46.0637
43.6623
40.6851
29.0091
28.7562
24.7299
24.6269
f1 (ppm)

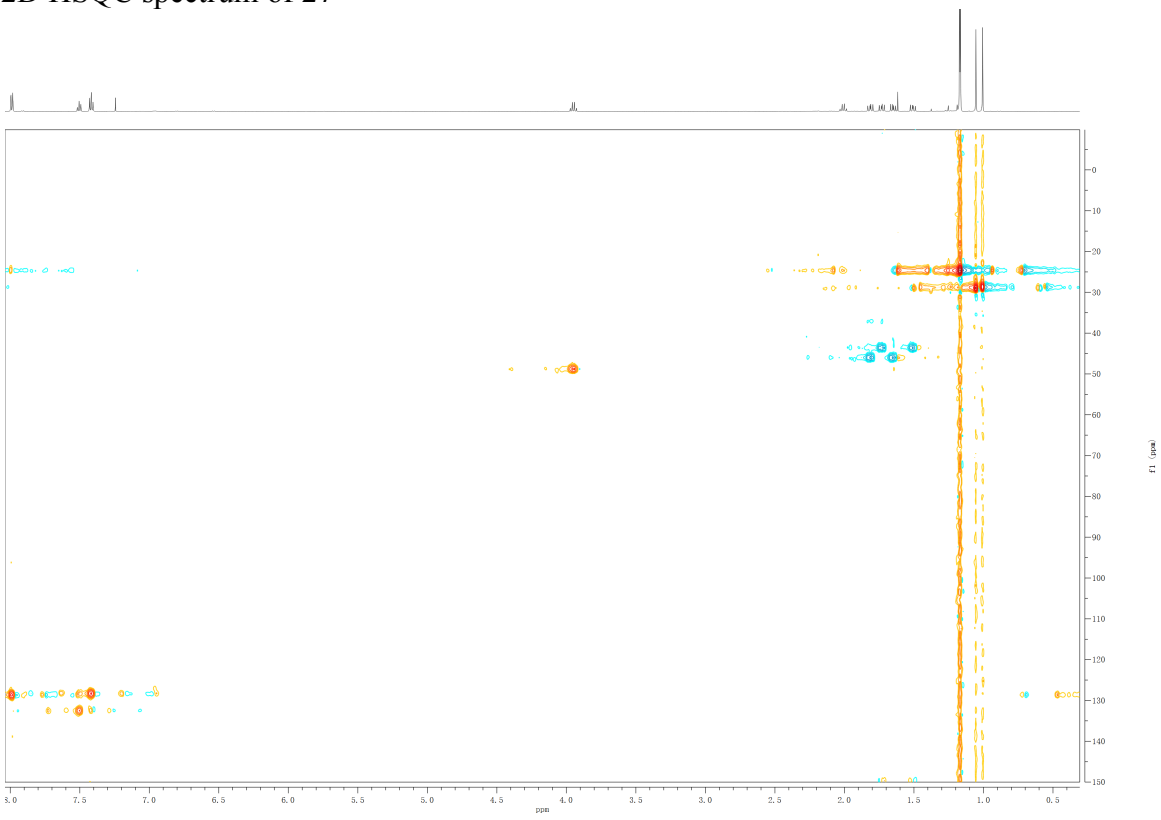
2D ROESY spectrum of **27**

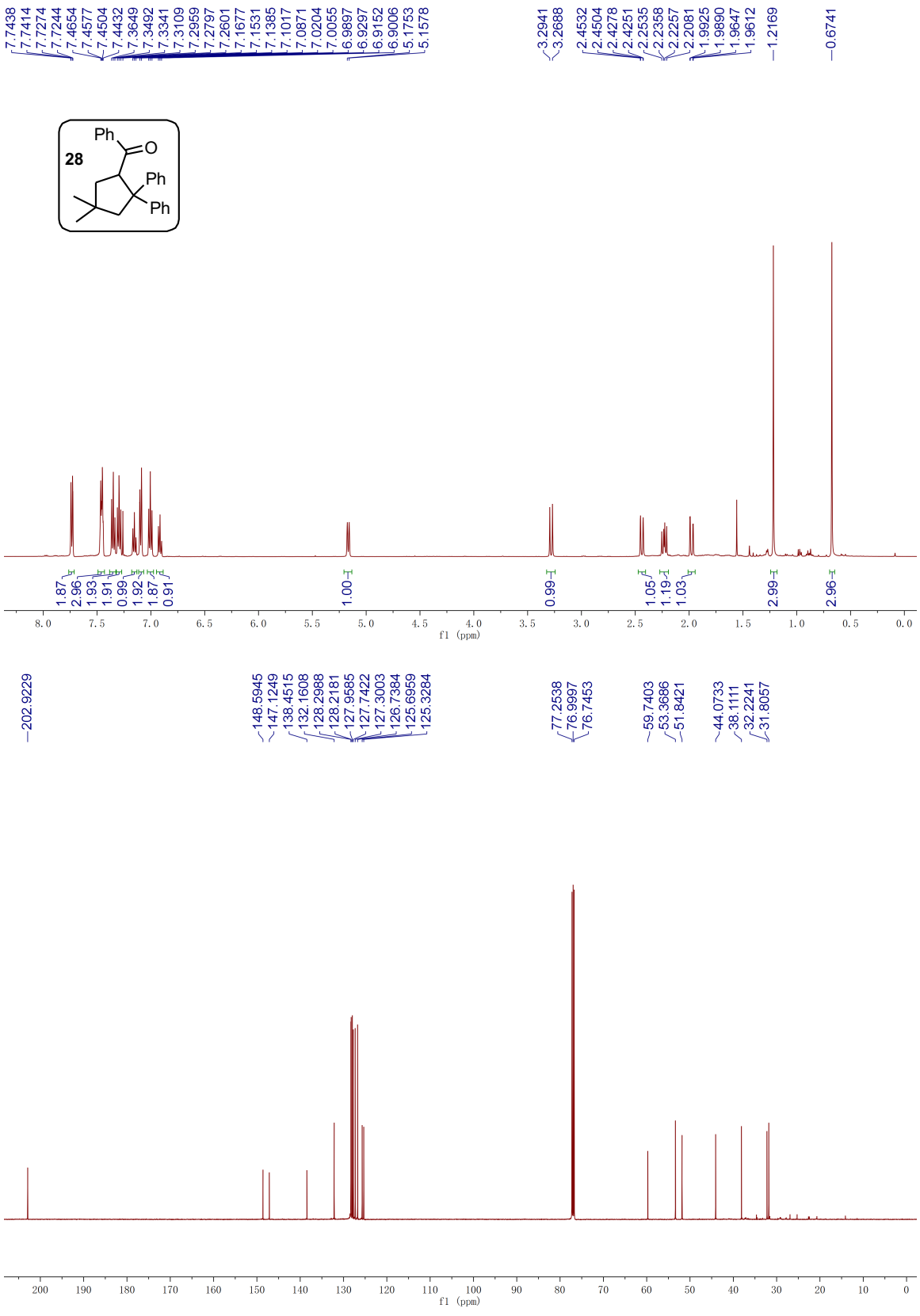


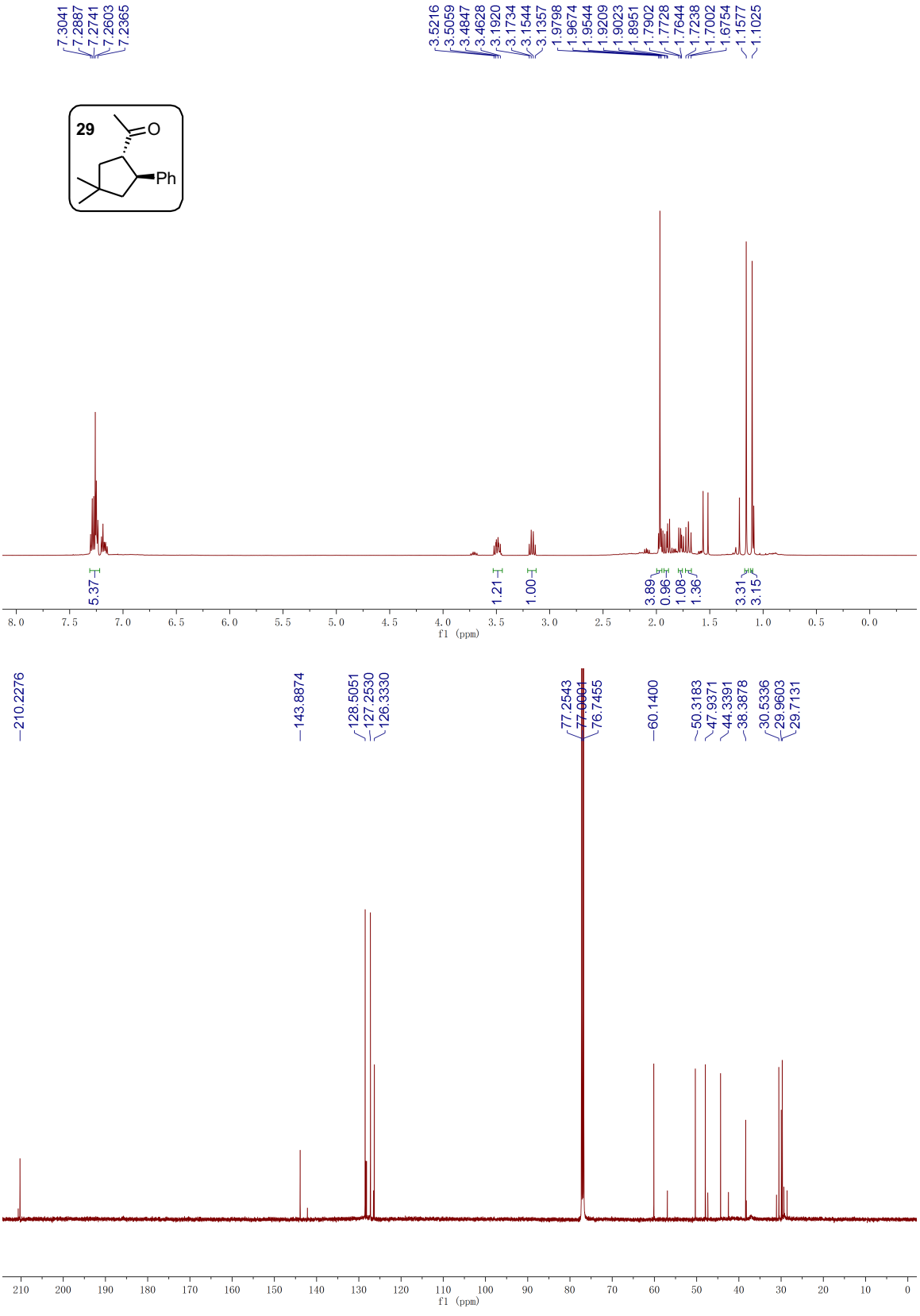
2D COSY spectrum of **27**

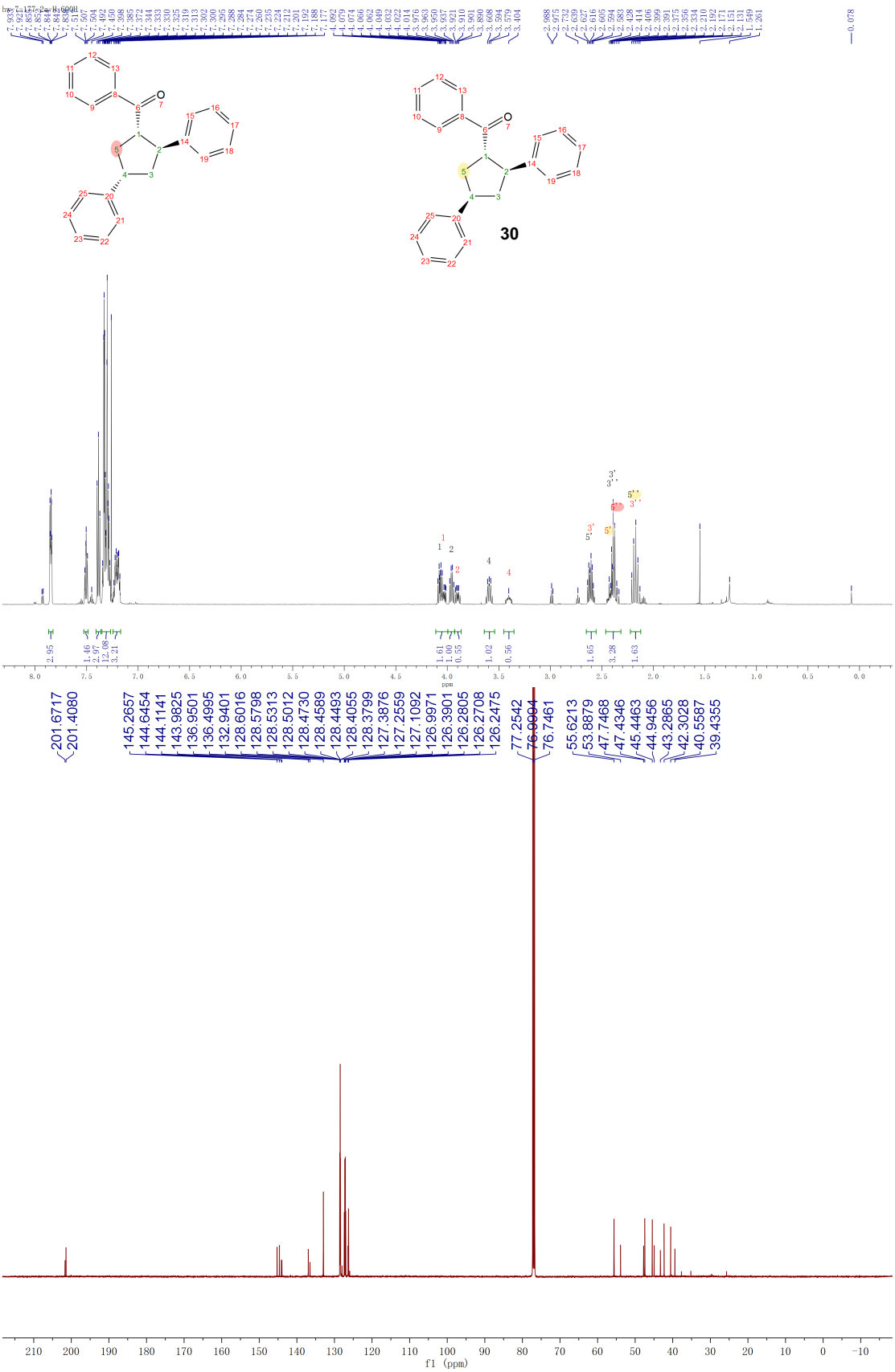


2D HSQC spectrum of **27**

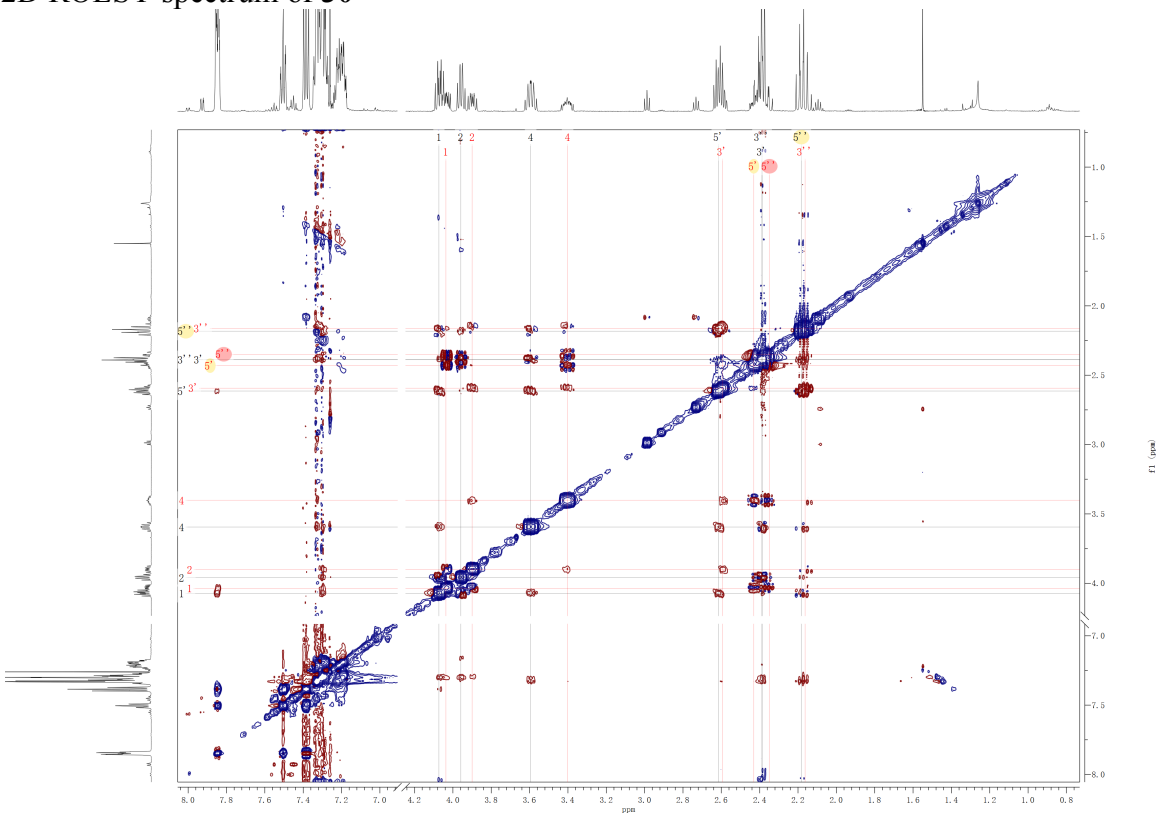



7.7438
7.7414
7.7274
7.7244
7.4654
7.4577
7.4504
7.4432
7.3649
7.3492
7.3341
7.3109
7.2959
7.2797
7.2601
7.1677
7.1531
7.1385
7.1017
7.0871
7.0204
7.0055
6.9897
6.9297
6.9152
6.9006
5.1753
5.1578
3.2941
3.2688
2.4532
2.4504
2.4278
2.4251
2.2535
2.2358
2.2257
2.2081
1.9925
1.9890
1.9647
1.9612
1.2169
0.6741
28
Ph
O
Ph
Ph
1.87
2.96
1.93
1.91
0.99
1.92
1.87
0.91
1.00
0.99
1.05
1.19
1.03
2.99
2.96
f1 (ppm)
202.9229
148.5945
147.1249
138.4515
132.1608
128.2988
128.2181
127.9585
127.7422
127.3003
126.7384
125.6959
125.3284
77.2538
76.9997
76.7453
59.7403
53.3686
51.8421
44.0733
38.1111
32.2241
31.8057
f1 (ppm)

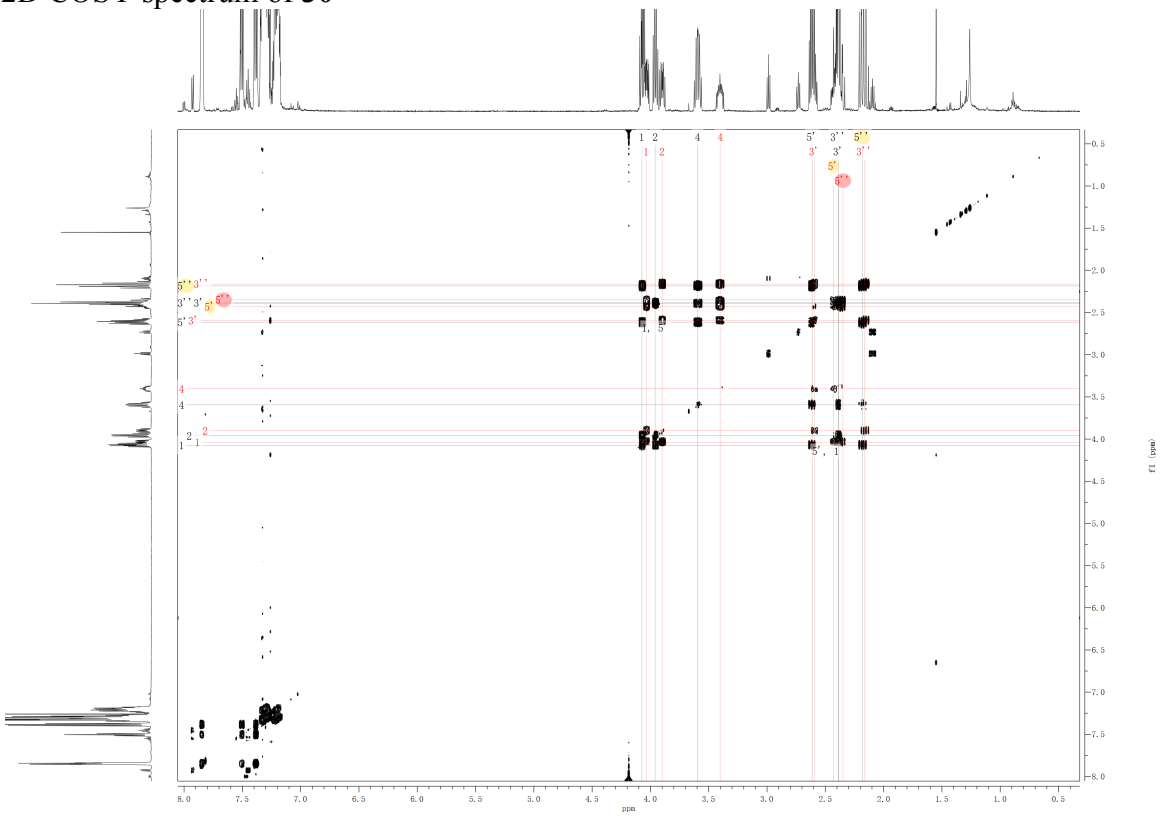

7.3041
7.2887
7.2741
7.2603
7.2365
3.5216
3.5059
3.4847
3.4628
3.1920
3.1734
3.1544
3.1357
1.9798
1.9674
1.9544
1.9209
1.9023
1.8951
1.7902
1.7728
1.7644
1.7238
1.7002
1.6754
1.1577
1.1025
29
O
Ph
5.37
1.21
1.00
3.89
0.96
1.08
1.36
3.31
3.15
f1 (ppm)
210.2276
143.8874
128.5051
127.2530
126.3330
77.2543
77.0001
76.7455
60.1400
50.3183
47.9371
44.3391
38.3878
30.5336
29.9603
29.7131
f1 (ppm)


30

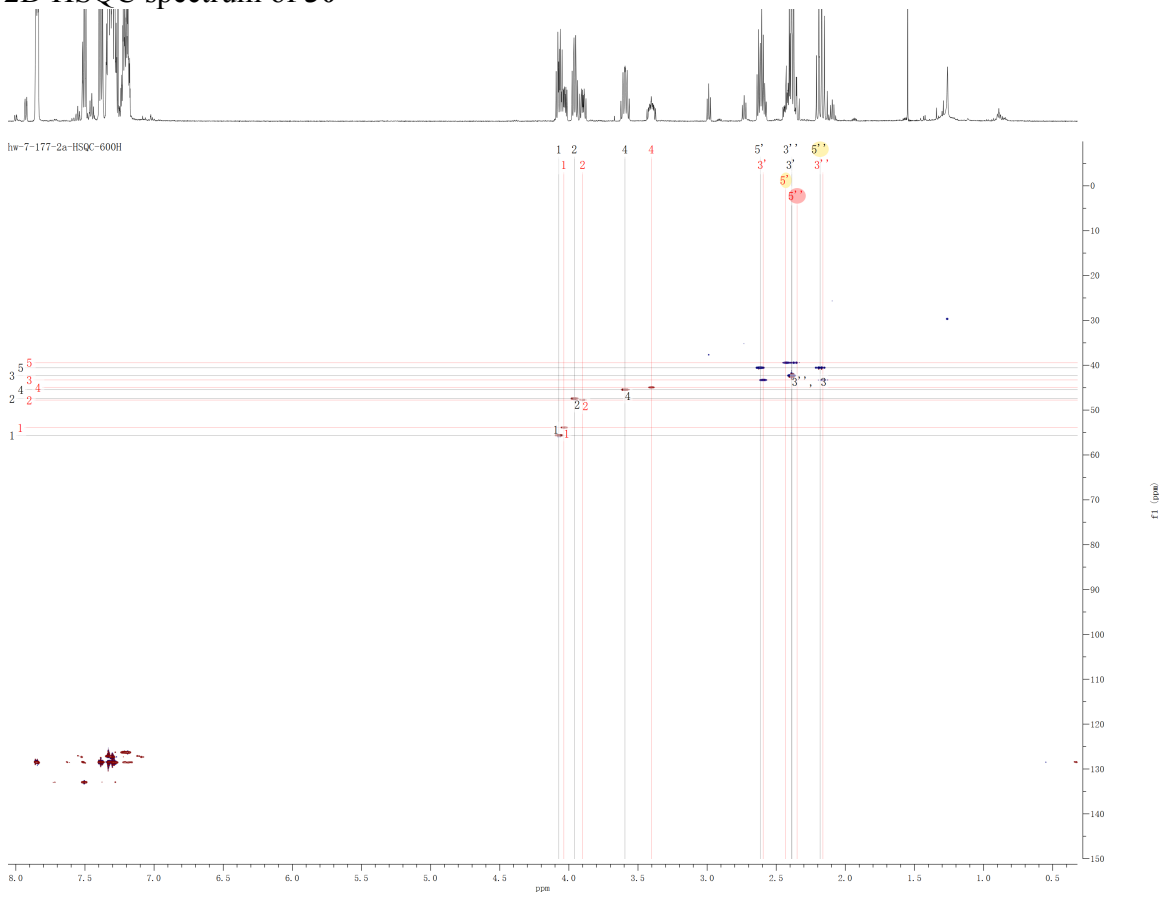
2D ROESY spectrum of **30**

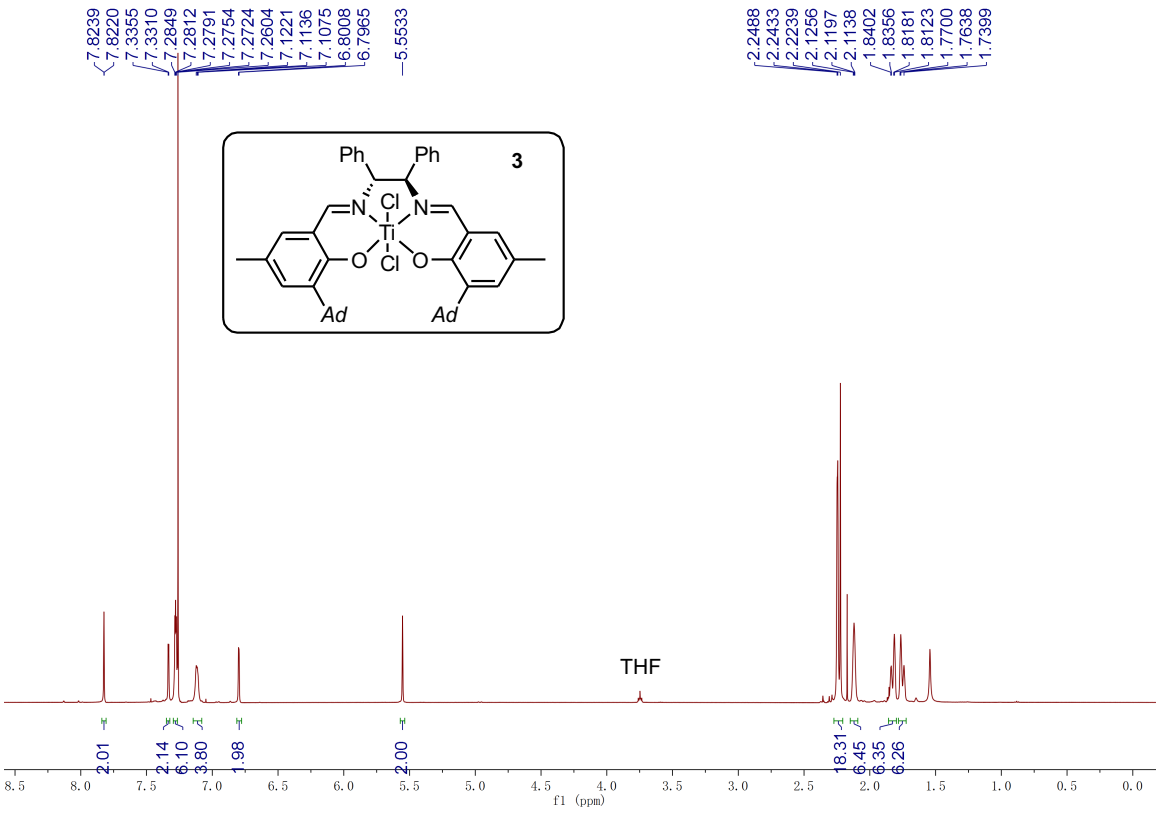


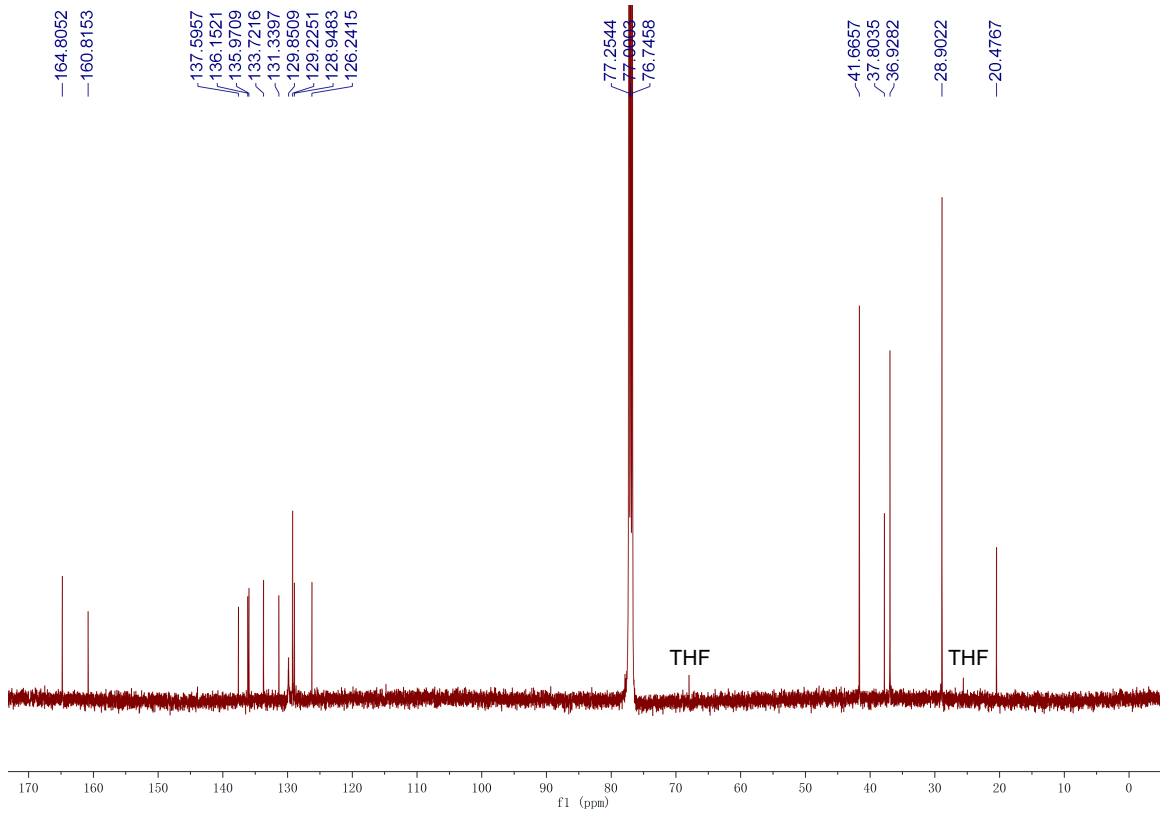
2D COSY spectrum of **30**



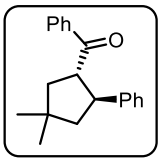
2D HSQC spectrum of **30**




7.8239
7.8220
7.3355
7.3310
7.2849
7.2812
7.2791
7.2754
7.2724
7.2604
7.1221
7.1136
7.1075
6.8008
6.7965
5.5533
2.2488
2.2433
2.2239
2.1256
2.1197
2.1138
1.8402
1.8356
1.8181
1.8123
1.7700
1.7638
1.7399
Ph
Ph
3
N
Cl
N
Ti
O
Cl
O
Ad
Ad
THF
2.01
2.14
6.10
3.80
1.98
2.00
18.31
6.45
6.35
6.26
f1 (ppm)


164.8052
160.8153
137.5957
136.1521
135.9709
133.7216
131.3397
129.8509
129.2251
128.9483
126.2415
77.2544
77.0003
76.7458
41.6657
37.8035
36.9282
28.9022
20.4767
THF
THF
f1 (ppm)

HPLC traces

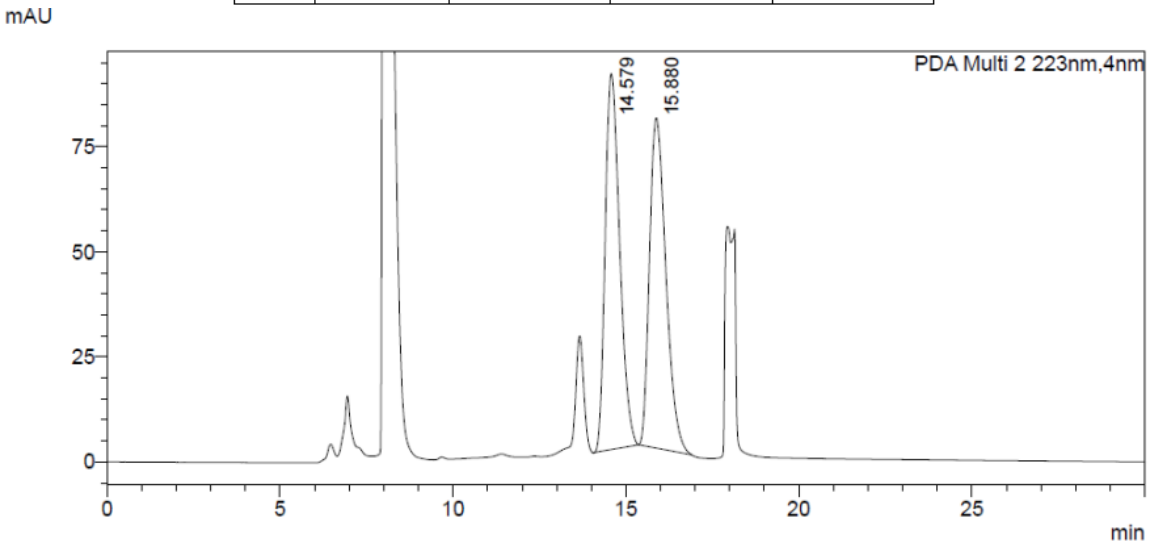


2

Racemic: hw-6-160-trans-AS-0%-0.5

PDA Ch2 223nm

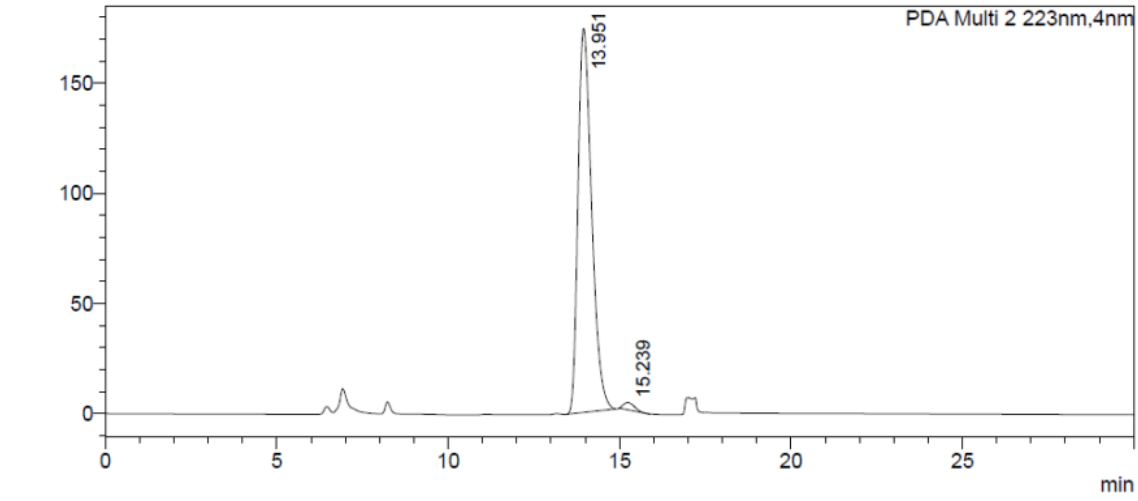
Peak#	Ret. Time	Area	Height	Area%
1	14.579	2600733	89457	50.095
2	15.880	2590915	78619	49.905
Total		5191649	168076	100.000

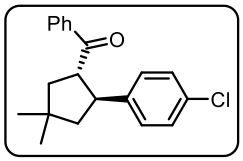


Scalemic: hw-6-148-2-AS-0%-0.5

PDA Ch2 223nm

Peak#	Ret. Time	Area	Height	Area%
1	13.951	4830518	174363	98.502
2	15.239	73443	3289	1.498
Total		4903961	177652	100.000



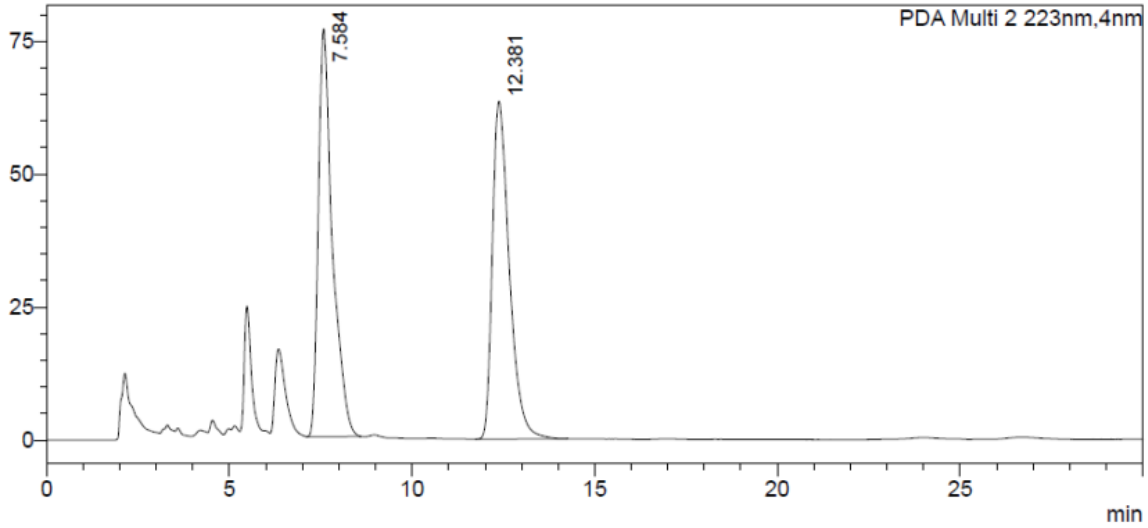


8

Racemic: hw-6-192a-AD-0.5%-1.0

PDA Ch2 223nm

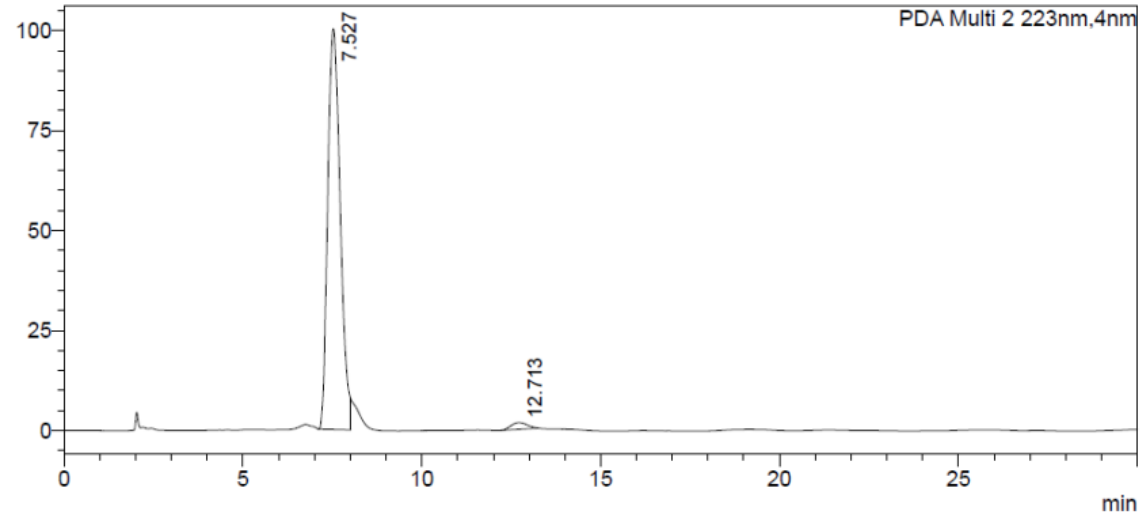
Peak#	Ret. Time	Area	Height	Area%
1	7.584	2062884	76680	50.094
2	12.381	2055129	63516	49.906
Total		4118013	140196	100.000

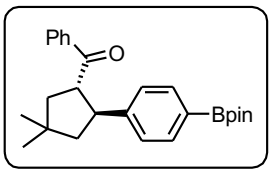


Scalemic: hw-6-172a-AD-0.5%-1.0

PDA Ch2 223nm

Peak#	Ret. Time	Area	Height	Area%
1	7.527	2434731	100165	97.891
2	12.713	52455	1662	2.109
Total		2487185	101828	100.000



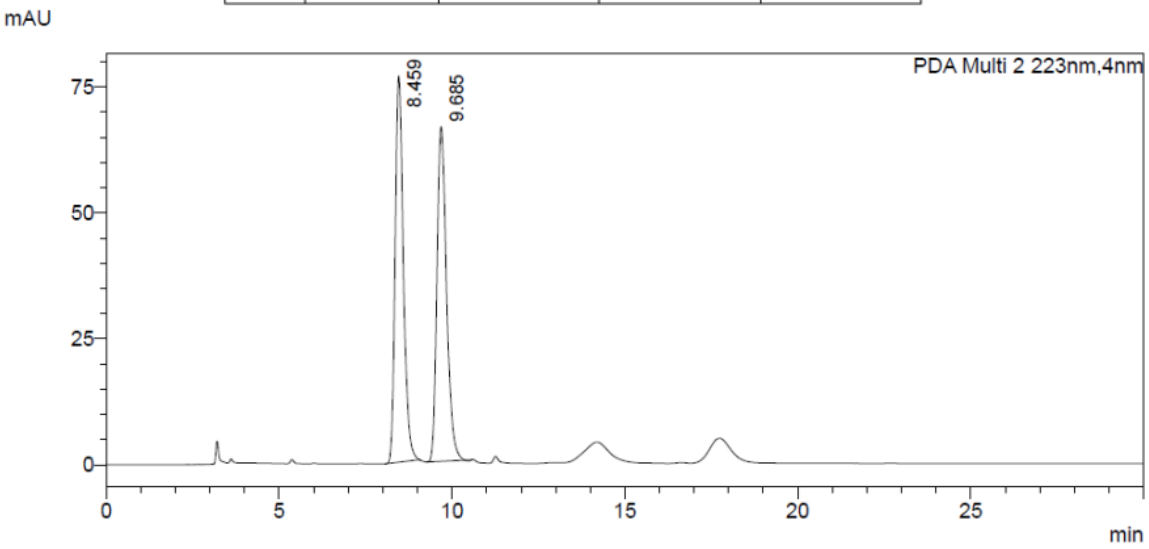


9

Racemic: hw-7-12a-OD-0.5%-1.0

PDA Ch2 223nm

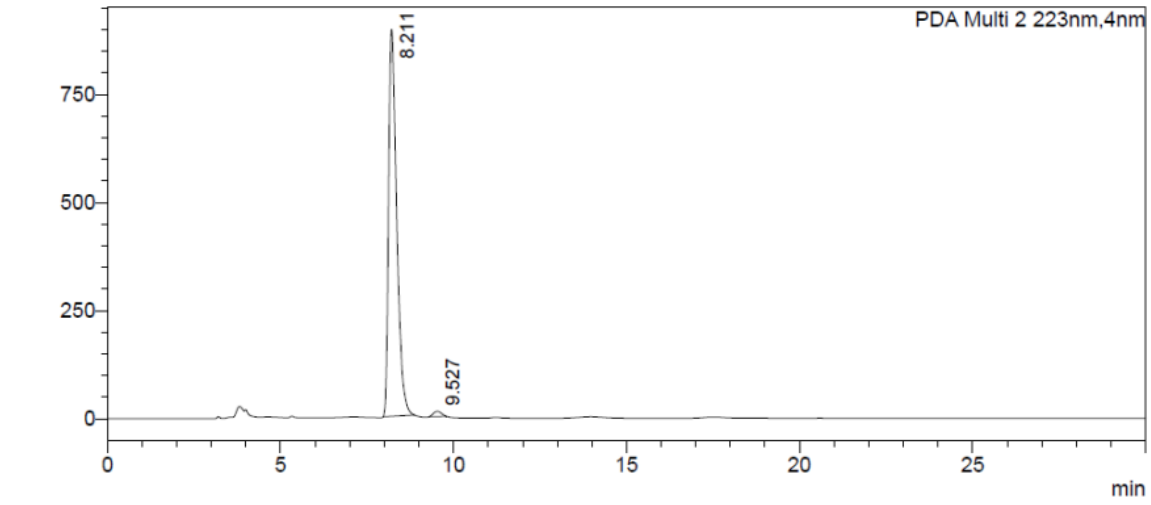
Peak#	Ret. Time	Area	Height	Area%
1	8.459	1267238	76697	49.901
2	9.685	1272285	66395	50.099
Total		2539523	143091	100.000

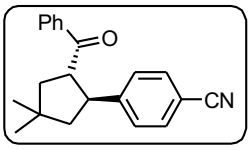


Scalemic: hw-7-67-OD-0.5%-1.0

PDA Ch2 223nm

Peak#	Ret. Time	Area	Height	Area%
1	8.211	14561337	894754	98.650
2	9.527	199279	12459	1.350
Total		14760616	907213	100.000



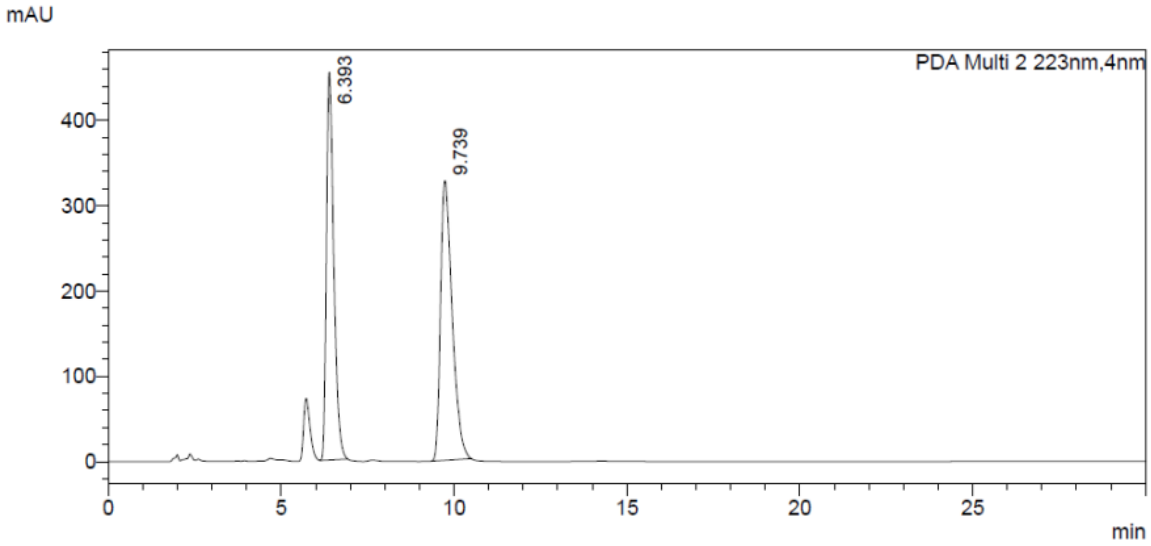


10

Racemic: hw-6-192c-tlc-AD-5.0%-1.0

PDA Ch2 223nm

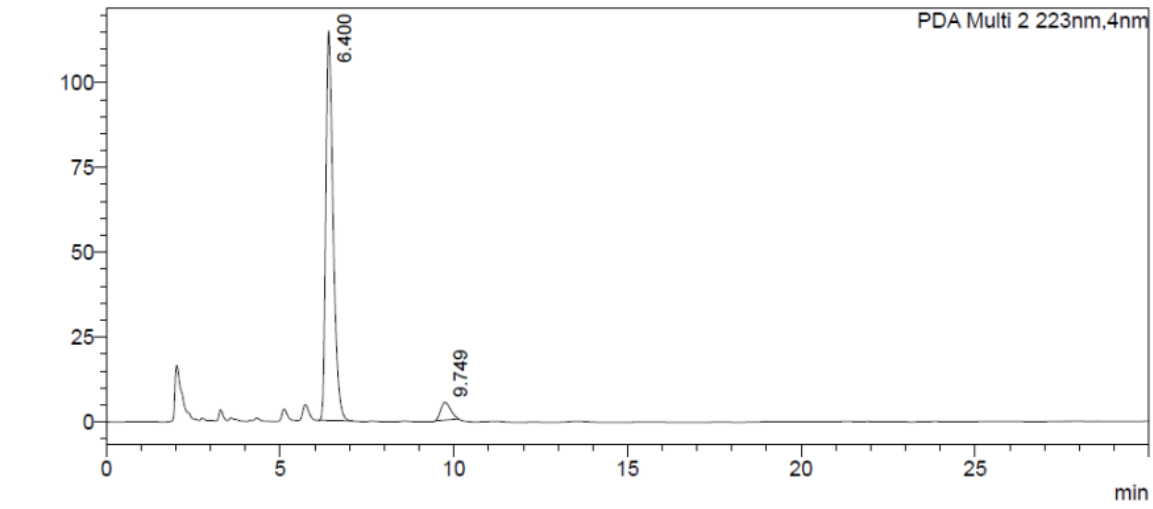
Peak#	Ret. Time	Area	Height	Area%
1	6.393	6731948	454317	46.839
2	9.739	7640540	327922	53.161
Total		14372488	782238	100.000

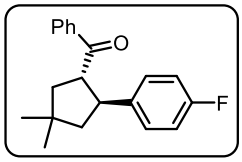


Scalemic: hw-7-87b-AD-5%-1.0

PDA Ch2 223nm

Peak#	Ret. Time	Area	Height	Area%
1	6.400	1690800	114905	94.254
2	9.749	103078	5187	5.746
Total		1793878	120092	100.000



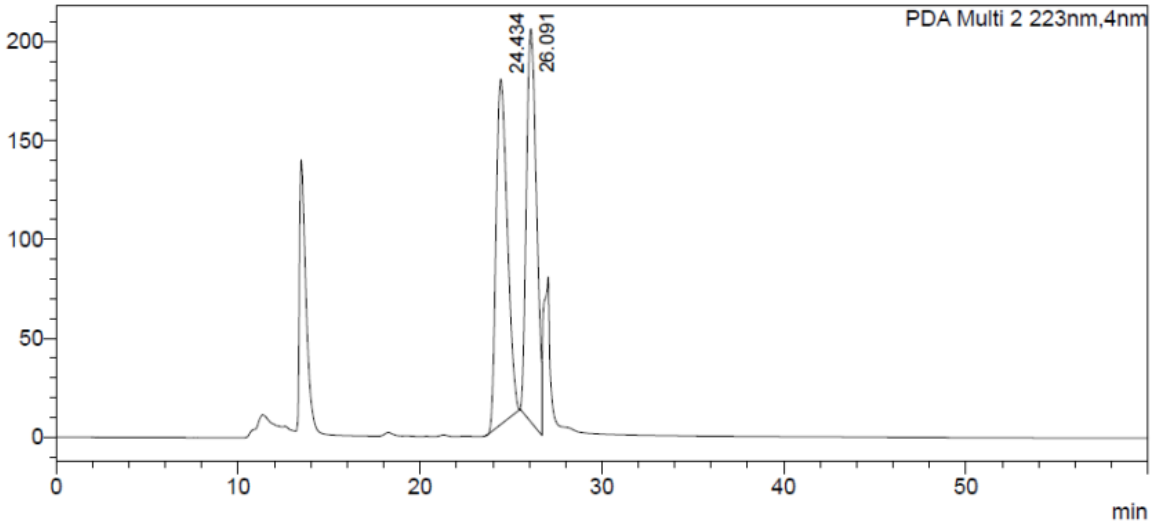


11

Racemic: hw-6-192b-AS-0%-0.3-60 min

PDA Ch2 223nm

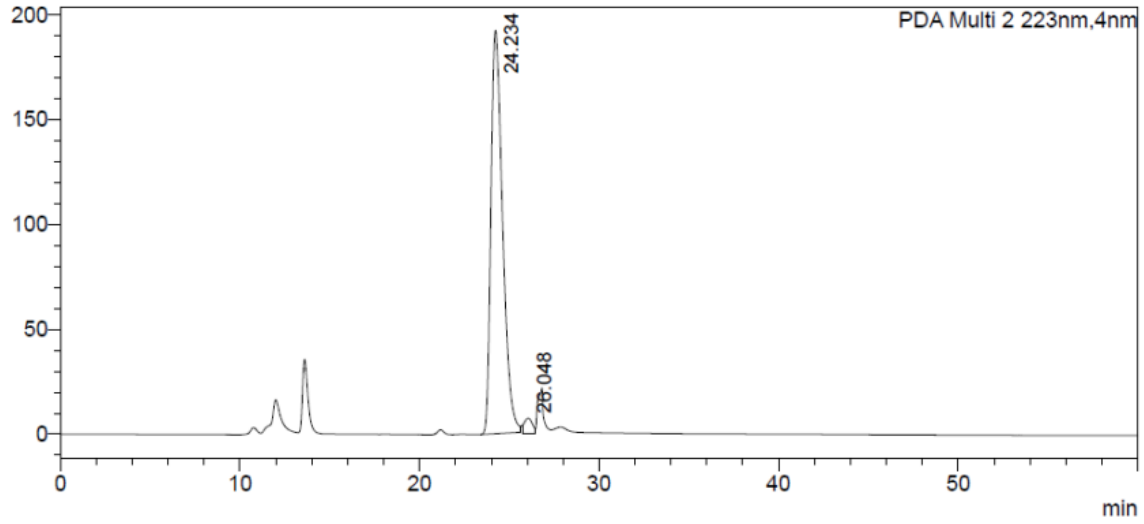
Peak#	Ret. Time	Area	Height	Area%
1	24.434	7506414	174575	49.531
2	26.091	7648644	198619	50.469
Total		15155059	373194	100.000

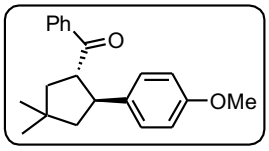


Scalemic: hw-6-179-re-AS-0%-0.3

PDA Ch2 223nm

Peak#	Ret. Time	Area	Height	Area%
1	24.234	8638950	192210	97.223
2	26.048	246783	7686	2.777
Total		8885733	199896	100.000



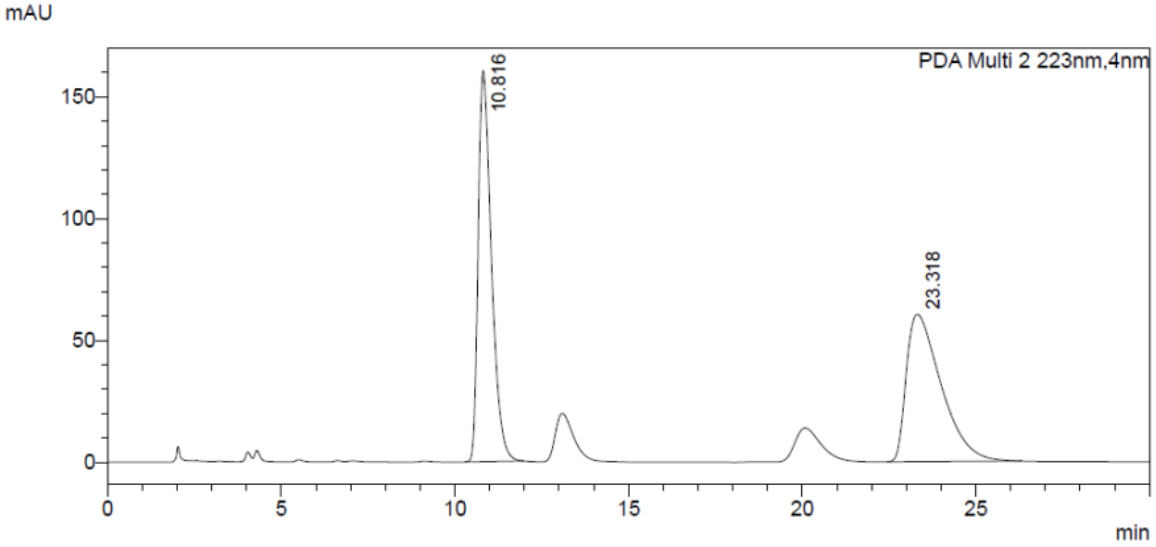


12

Racemic: hw-6-205b-AD-0.5%-1.0

PDA Ch2 223nm

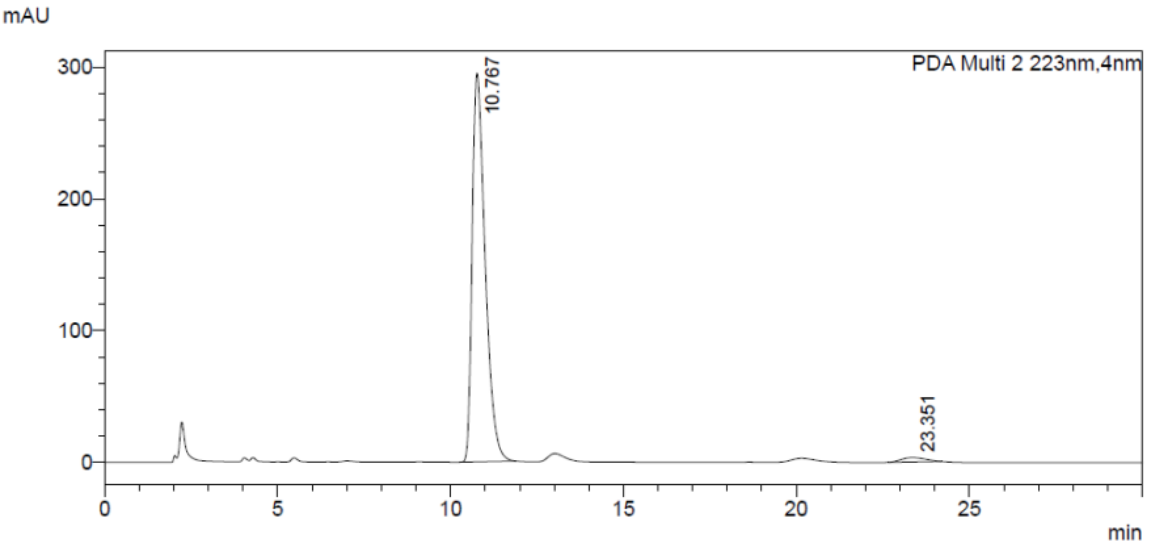
Peak#	Ret. Time	Area	Height	Area%
1	10.816	4256596	160496	50.214
2	23.318	4220331	60477	49.786
Total		8476927	220974	100.000

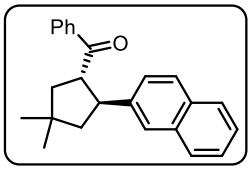


Scalemic: hw-6-203-AD-0.5%-1.0

PDA Ch2 223nm

Peak#	Ret. Time	Area	Height	Area%
1	10.767	7688800	295138	97.952
2	23.351	160786	3342	2.048
Total		7849586	298480	100.000



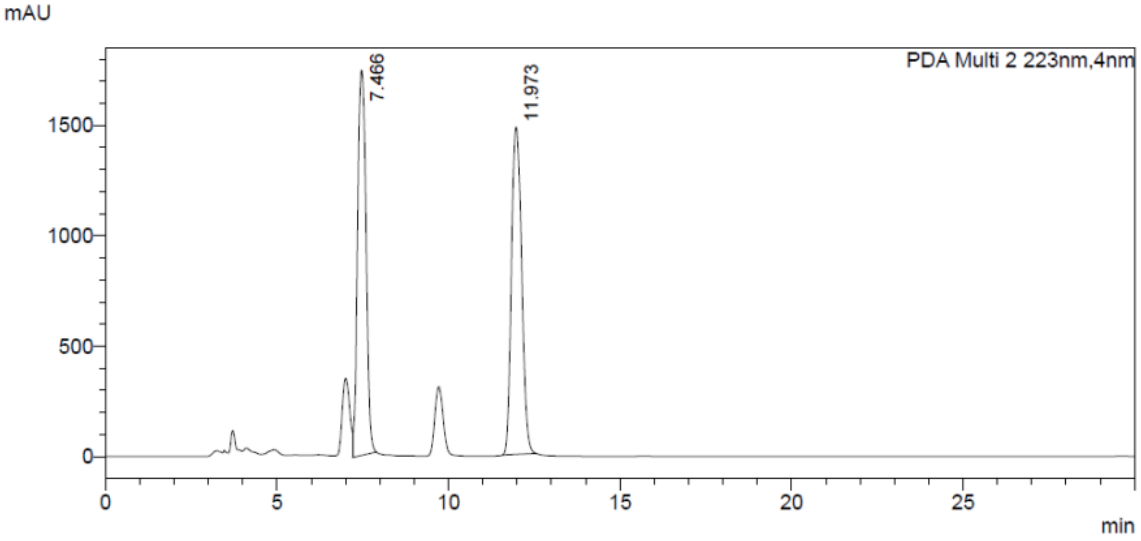


13

Racemic: hw-6-200-IA-2%-1.0-30 min

PDA Ch2 223nm

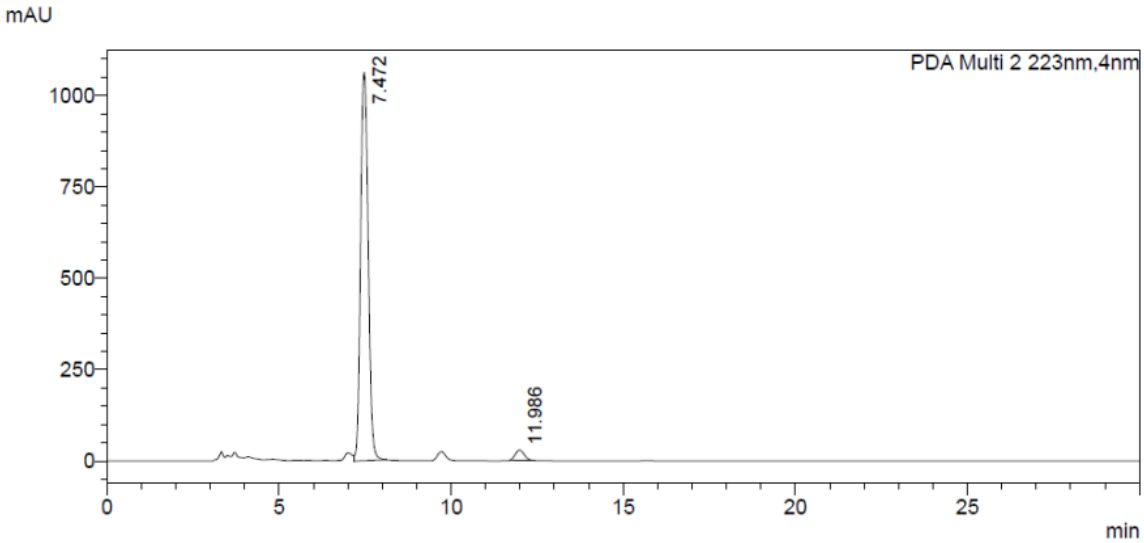
Peak#	Ret. Time	Area	Height	Area%
1	7.466	29790874	1745317	49.285
2	11.973	30654868	1482779	50.715
Total		60445743	3228096	100.000

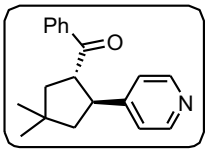


Scalemic: hw-6-193-re-IA-2%-1.0

PDA Ch2 223nm

Peak#	Ret. Time	Area	Height	Area%
1	7.472	16356772	1061854	97.008
2	11.986	504549	27988	2.992
Total		16861320	1089841	100.000



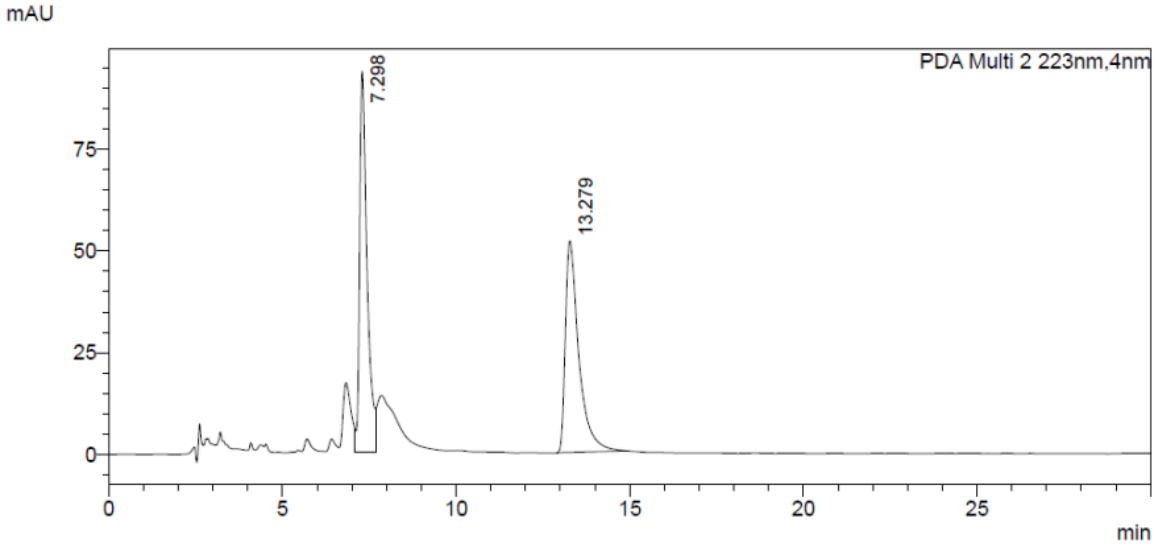


14

Racemic: hw-7-25a-IA-12%-1.2

PDA Ch2 223nm

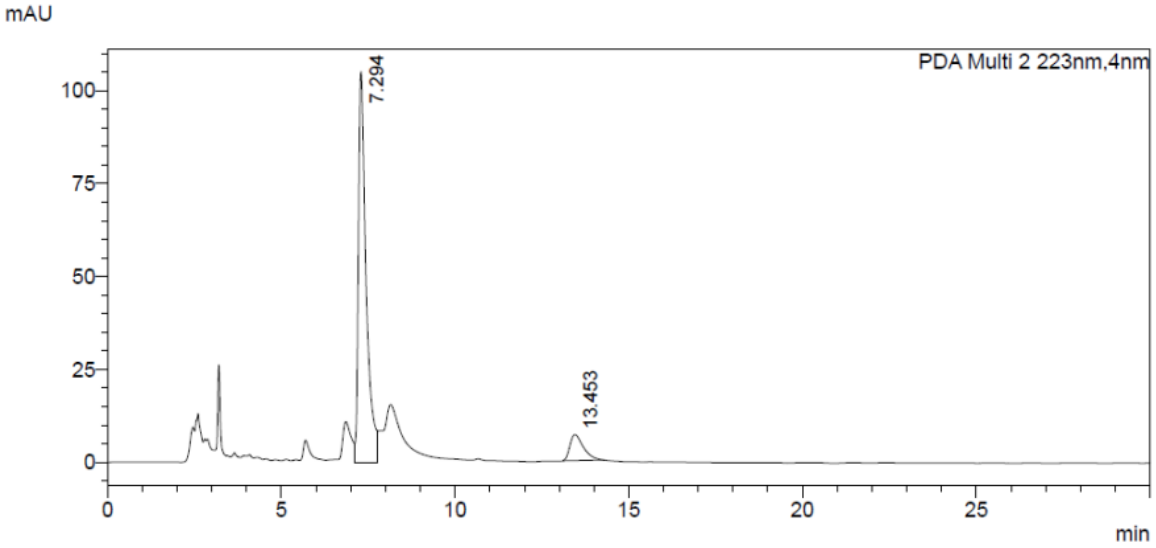
Peak#	Ret. Time	Area	Height	Area%
1	7.298	1390235	93651	49.888
2	13.279	1396484	51991	50.112
Total		2786719	145641	100.000

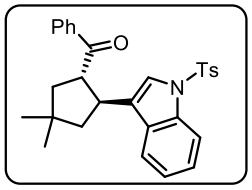


Scalemic: hw-7-23-IA-12%-1.2

PDA Ch2 223nm

Peak#	Ret. Time	Area	Height	Area%
1	7.294	1624668	105271	89.553
2	13.453	189534	7005	10.447
Total		1814202	112277	100.000



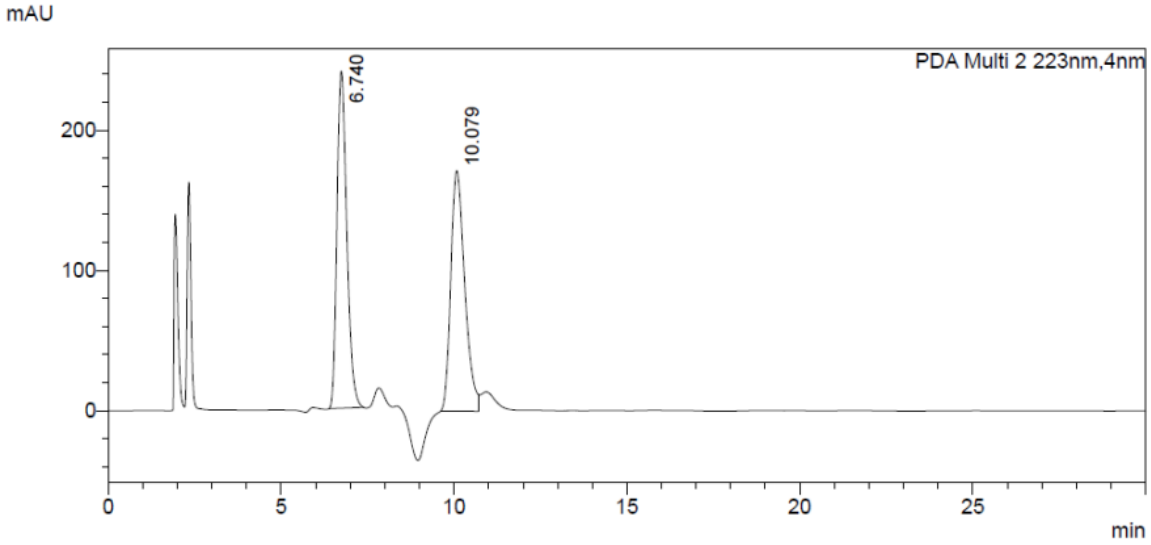


15

Racemic: hw-6-201-AD-6%-1.0

PDA Ch2 223nm

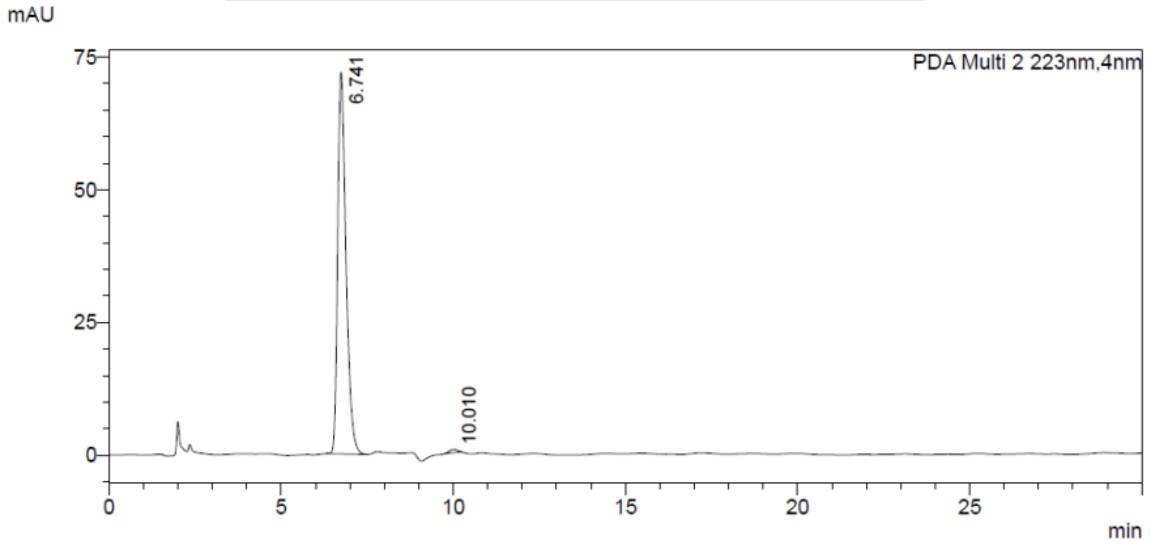
Peak#	Ret. Time	Area	Height	Area%
1	6.740	4754081	240392	49.729
2	10.079	4805871	171629	50.271
Total		9559952	412021	100.000

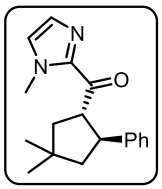


Scalemic: hw-6-199-AD-6%-1.0

PDA Ch2 223nm

Peak#	Ret. Time	Area	Height	Area%
1	6.741	1204034	71914	99.176
2	10.010	10008	612	0.824
Total		1214043	72525	100.000



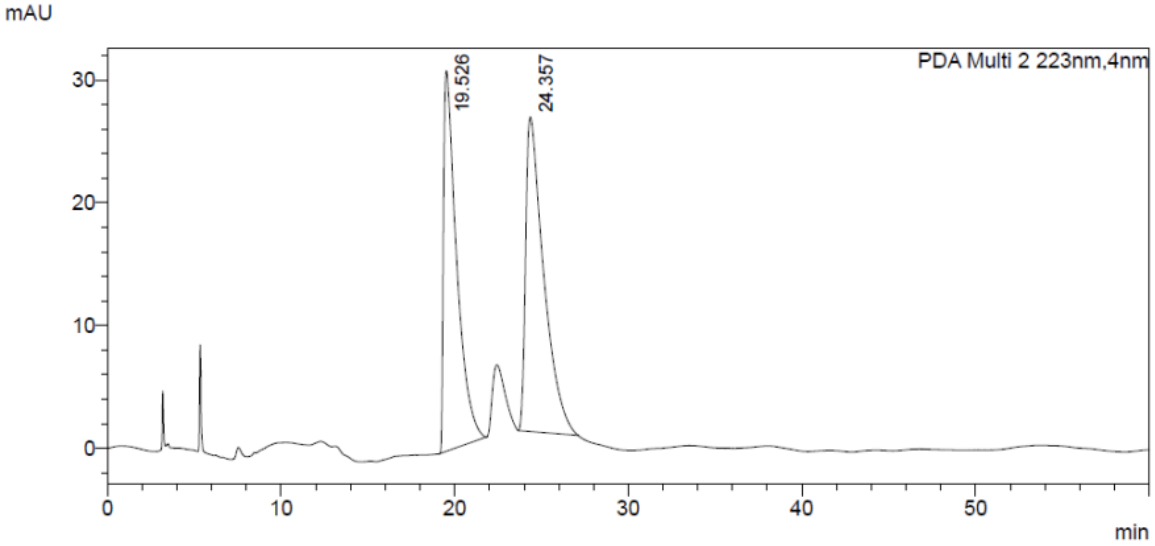


16

Racemic: hw-7-13-IA-0.5%-1.0

PDA Ch2 223nm

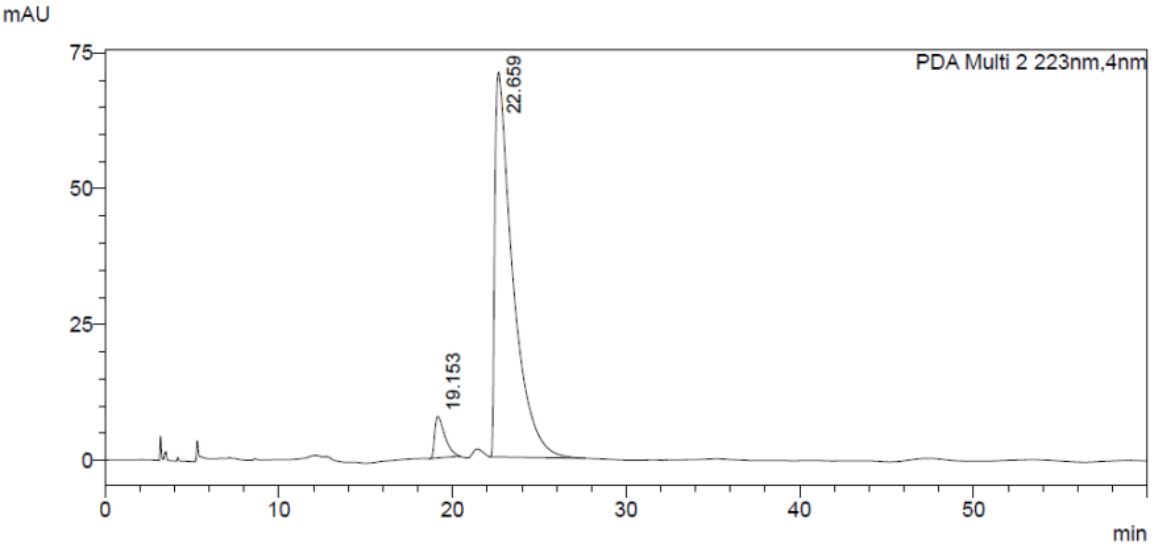
Peak#	Ret. Time	Area	Height	Area%
1	19.526	1630493	30997	46.799
2	24.357	1853552	25618	53.201
Total		3484046	56615	100.000

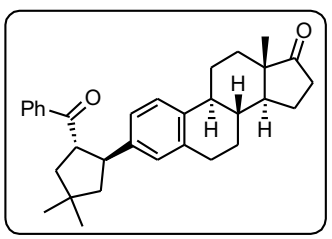


Scalemic: hw-7-3-IA-0.5%-1.0

PDA Ch2 223nm

Peak#	Ret. Time	Area	Height	Area%
1	19.153	310251	7674	5.757
2	22.659	5079095	70909	94.243
Total		5389346	78583	100.000



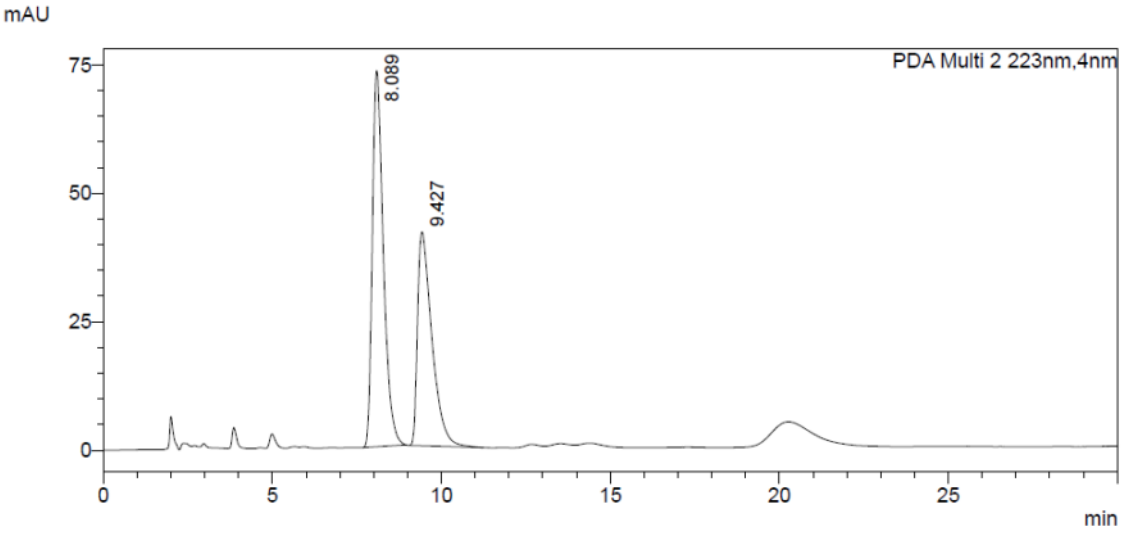


17

Racemic: hw-7-25b-AD-3%-1.0

PDA Ch2 223nm

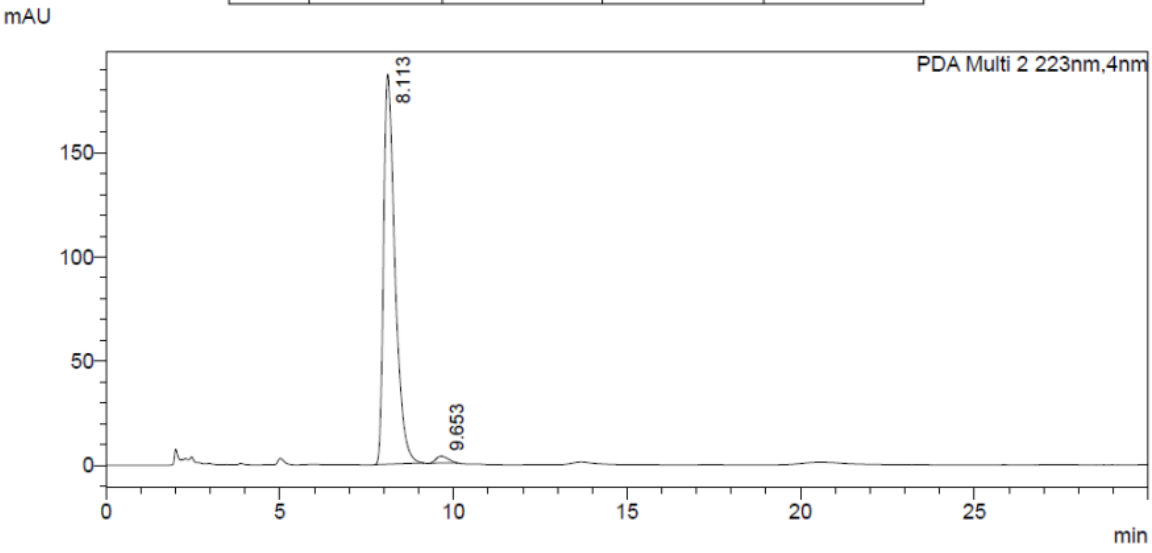
Peak#	Ret. Time	Area	Height	Area%
1	8.089	1661435	73179	57.446
2	9.427	1230721	41594	42.554
Total		2892157	114772	100.000

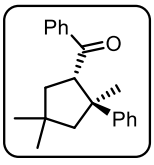


Scalemic: hw-7-22-AD-3%-1.0

PDA Ch2 223nm

Peak#	Ret. Time	Area	Height	Area%
1	8.113	4260899	187205	98.207
2	9.653	77782	3261	1.793
Total		4338680	190466	100.000



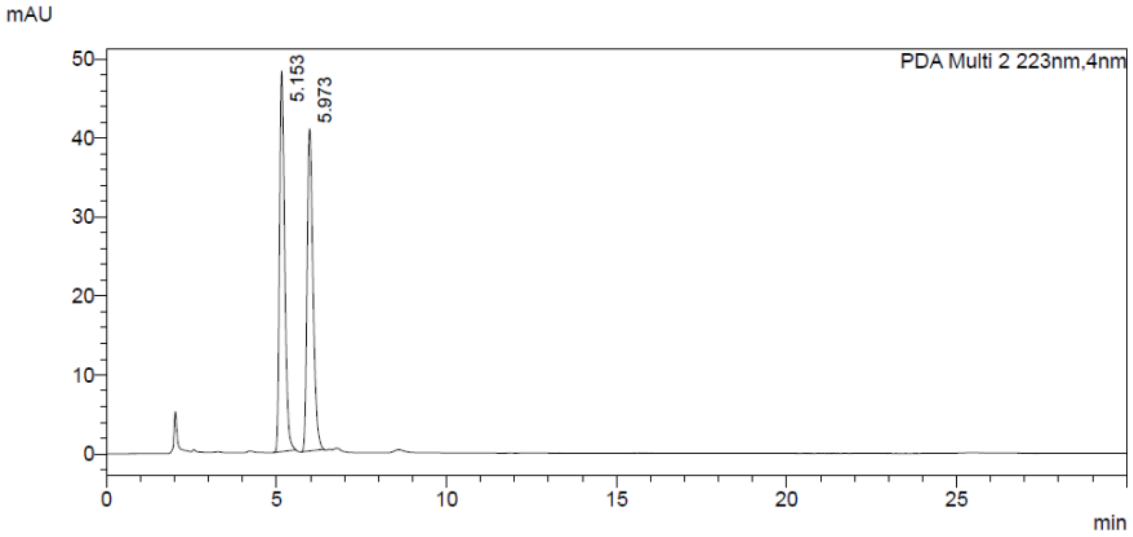


18

Racemic: hw-6-196b-tlc-AD-0.5%-1.0

PDA Ch2 223nm

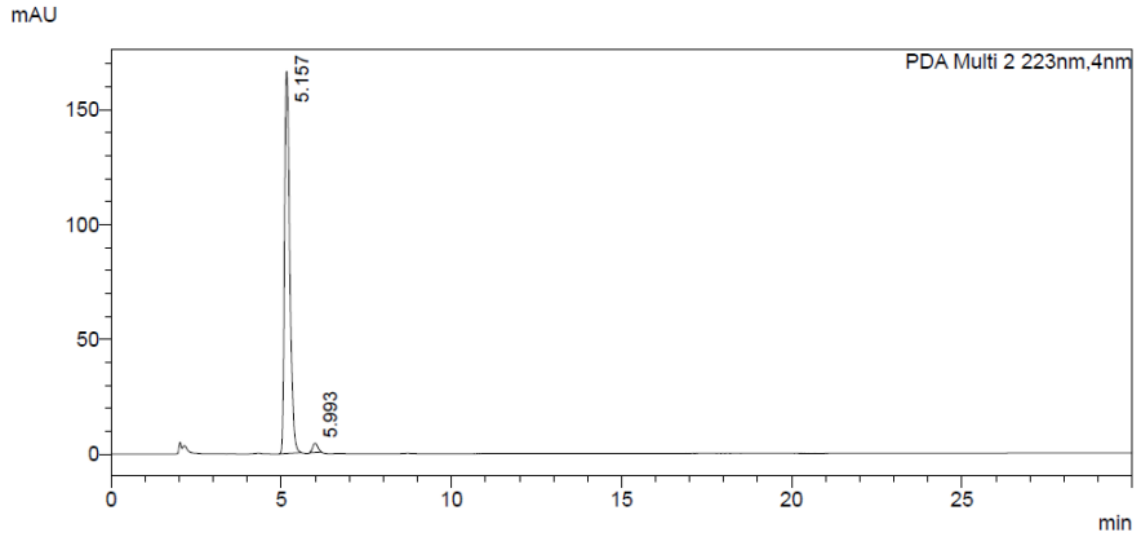
Peak#	Ret. Time	Area	Height	Area%
1	5.153	505350	48199	50.549
2	5.973	494371	40777	49.451
Total		999721	88976	100.000

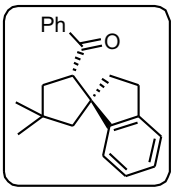


Scalemic: hw-6-186-re-AD-0.5%-1.0

PDA Ch2 223nm

Peak#	Ret. Time	Area	Height	Area%
1	5.157	1787600	166507	97.758
2	5.993	40989	4033	2.242
Total		1828589	170540	100.000



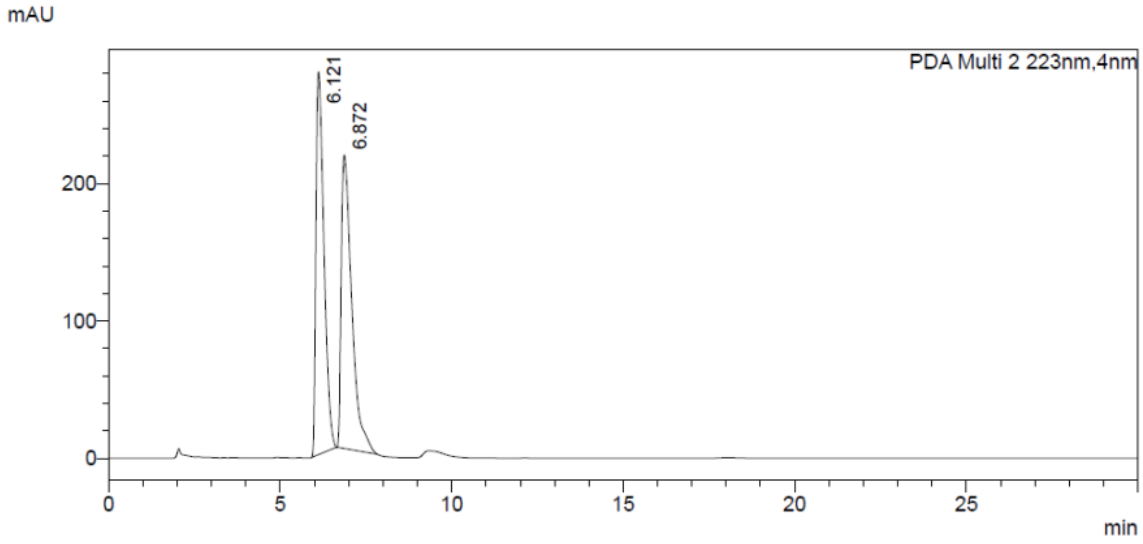


19

Racemic: hw-7-7-AD-0.2%-1.0

PDA Ch2 223nm

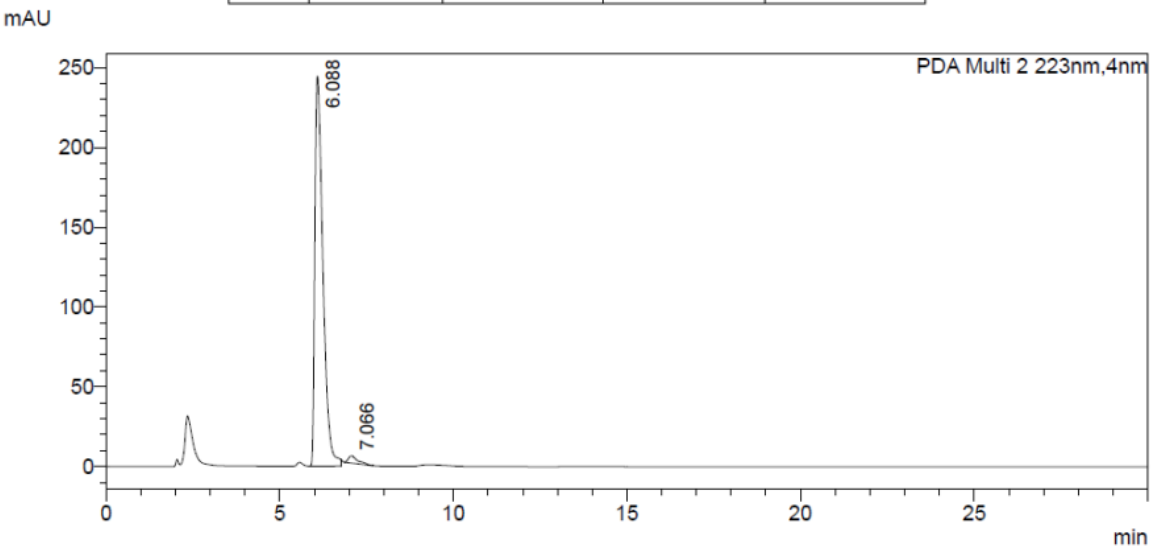
Peak#	Ret. Time	Area	Height	Area%
1	6.121	4532634	278692	49.732
2	6.872	4581552	213664	50.268
Total		9114187	492356	100.000

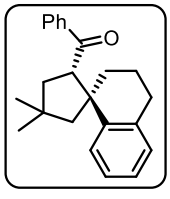


Scalemic: hw-7-6-AD-0.2%-1.0

PDA Ch2 223nm

Peak#	Ret. Time	Area	Height	Area%
1	6.088	3960254	244445	97.868
2	7.066	86282	4575	2.132
Total		4046535	249020	100.000



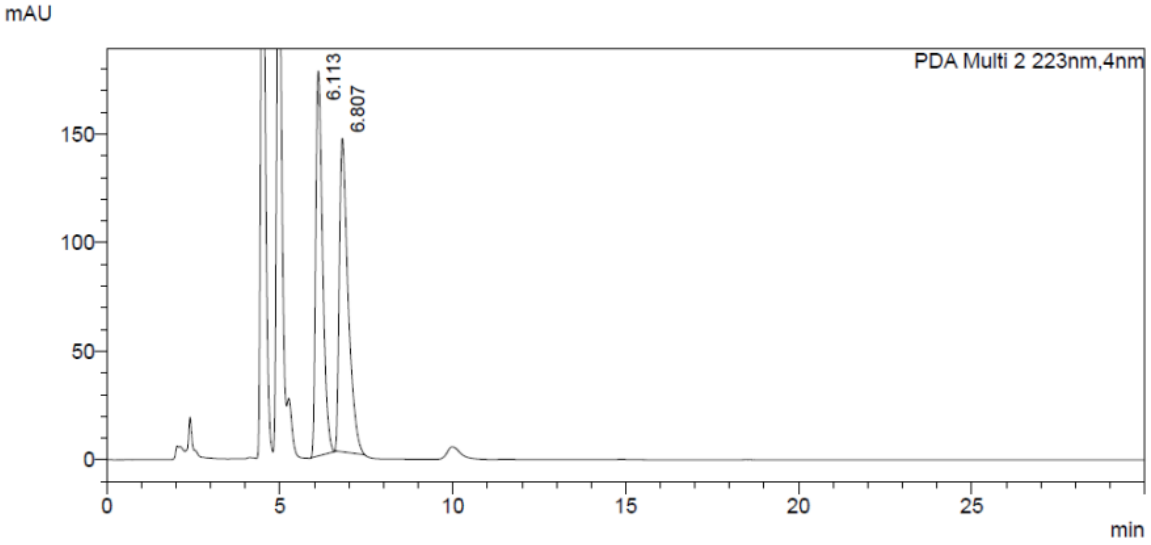


20

Racemic: hw-6-208-AD-0.5%-1.0

PDA Ch2 223nm

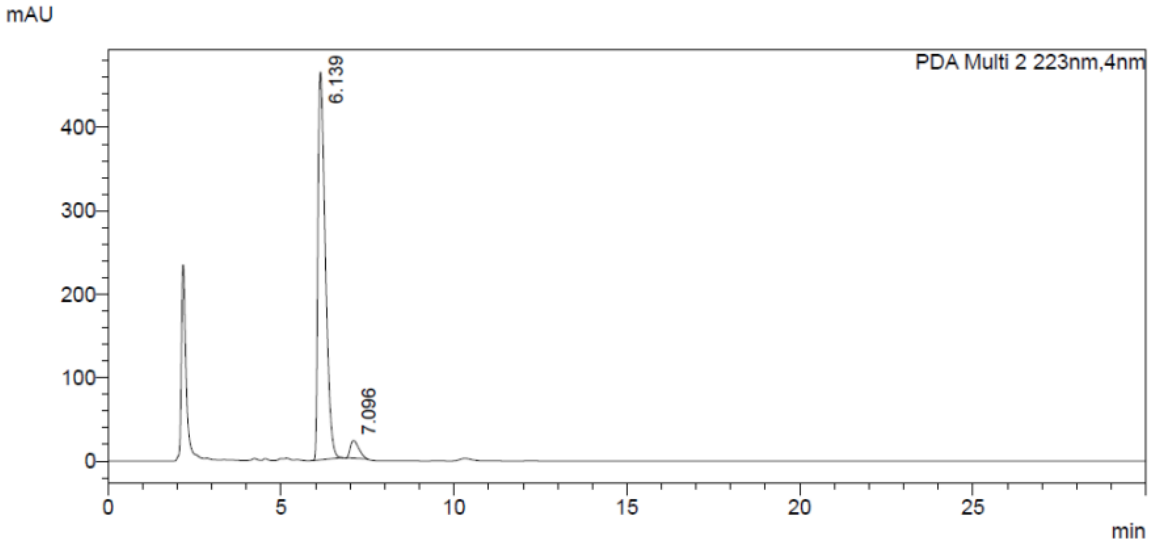
Peak#	Ret. Time	Area	Height	Area%
1	6.113	2457839	177291	49.032
2	6.807	2554892	144492	50.968
Total		5012731	321783	100.000

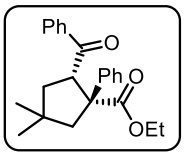


Scalemic: hw-7-36-AD-0.5%-1.0

PDA Ch2 223nm

Peak#	Ret. Time	Area	Height	Area%
1	6.139	6893107	464760	95.047
2	7.096	359204	21149	4.953
Total		7252311	485909	100.000



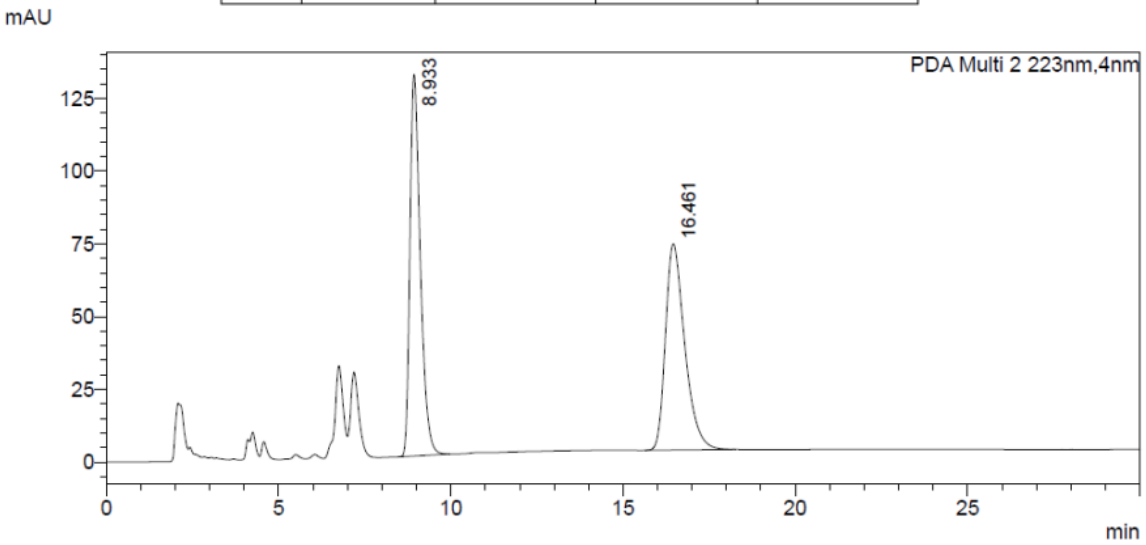


21

Racemic: hw-7-37-AD-2%-1.0

PDA Ch2 223nm

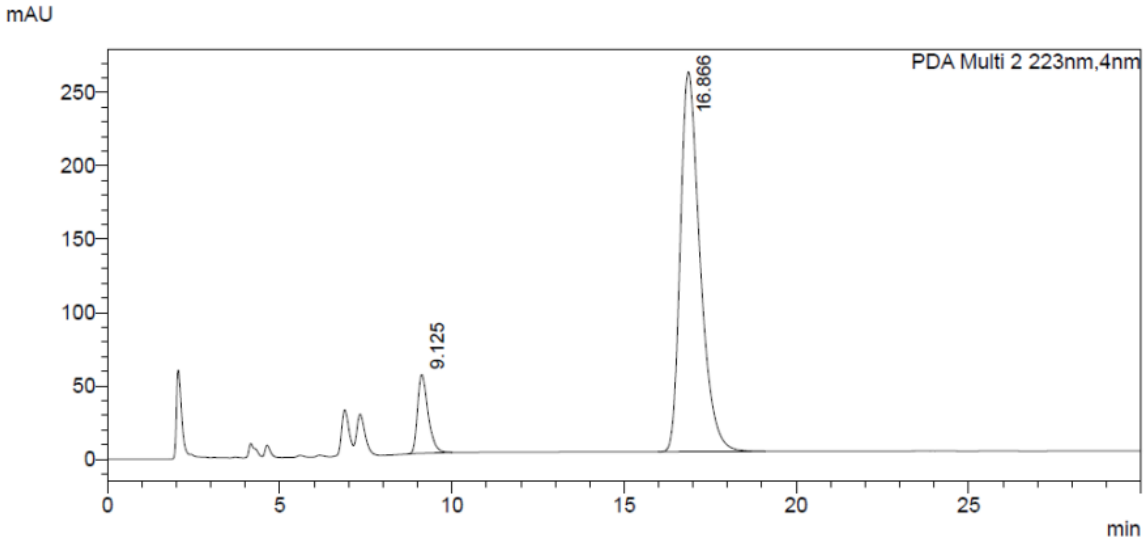
Peak#	Ret. Time	Area	Height	Area%
1	8.933	2746578	131089	49.896
2	16.461	2758013	70861	50.104
Total		5504591	201950	100.000

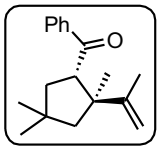


Scalemic: hw-7-27-AD-2%-1.0

PDA Ch2 223nm

Peak#	Ret. Time	Area	Height	Area%
1	9.125	1137252	53625	9.944
2	16.866	10299583	258958	90.056
Total		11436835	312583	100.000



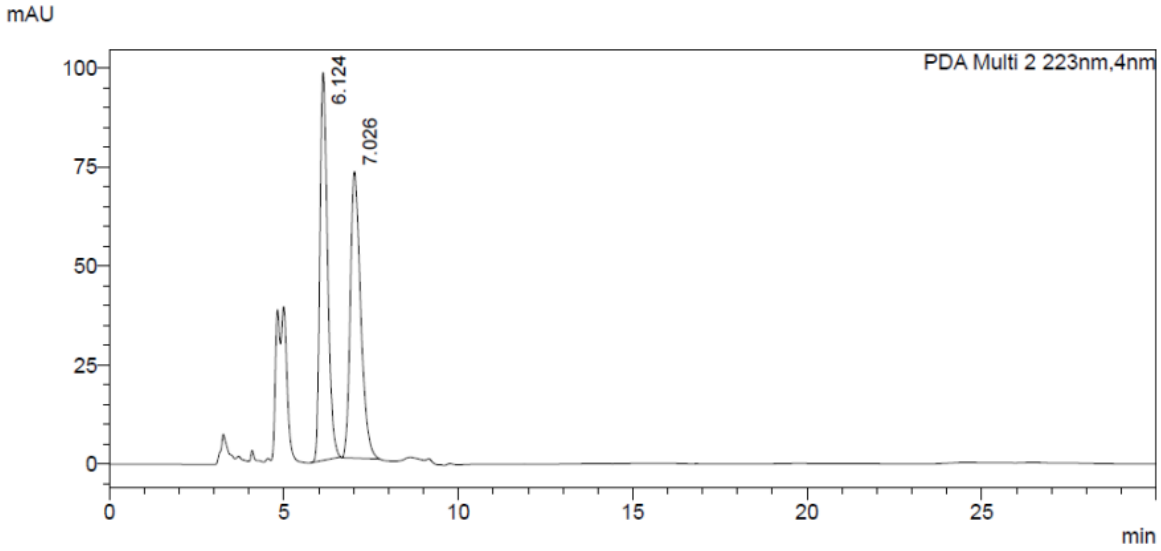


22

Racemic: hw-6-205c-tlc-AS-0.1%-1.0

PDA Ch2 223nm

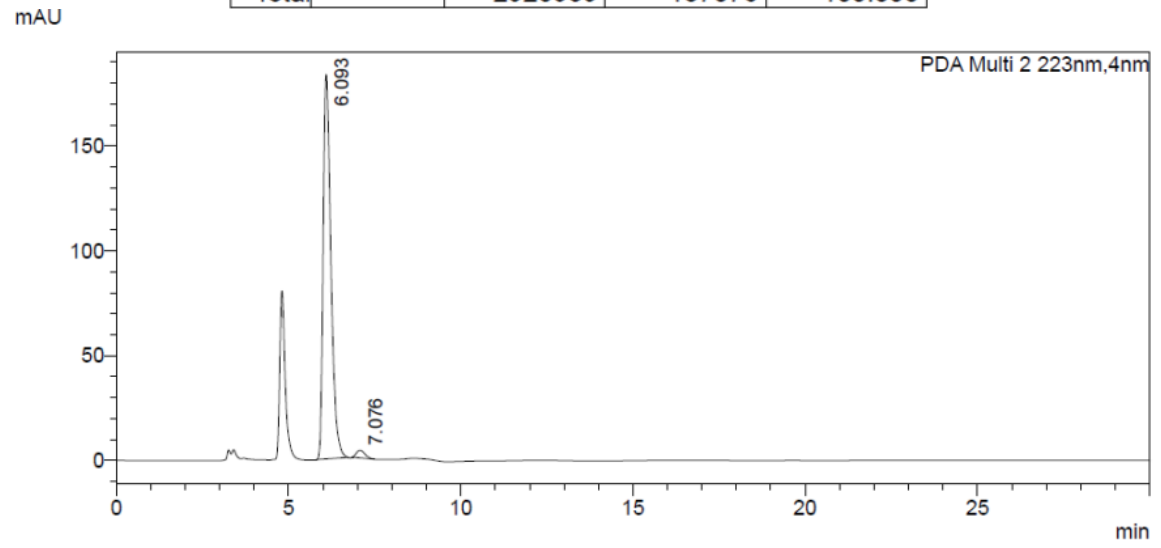
Peak#	Ret. Time	Area	Height	Area%
1	6.124	1500656	97902	50.134
2	7.026	1492615	72290	49.866
Total		2993270	170191	100.000

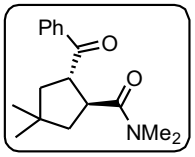


Scalemic: hw-6-204-AS-0.1%-1.0

PDA Ch2 223nm

Peak#	Ret. Time	Area	Height	Area%
1	6.093	2858284	183399	97.853
2	7.076	62705	3676	2.147
Total		2920989	187076	100.000



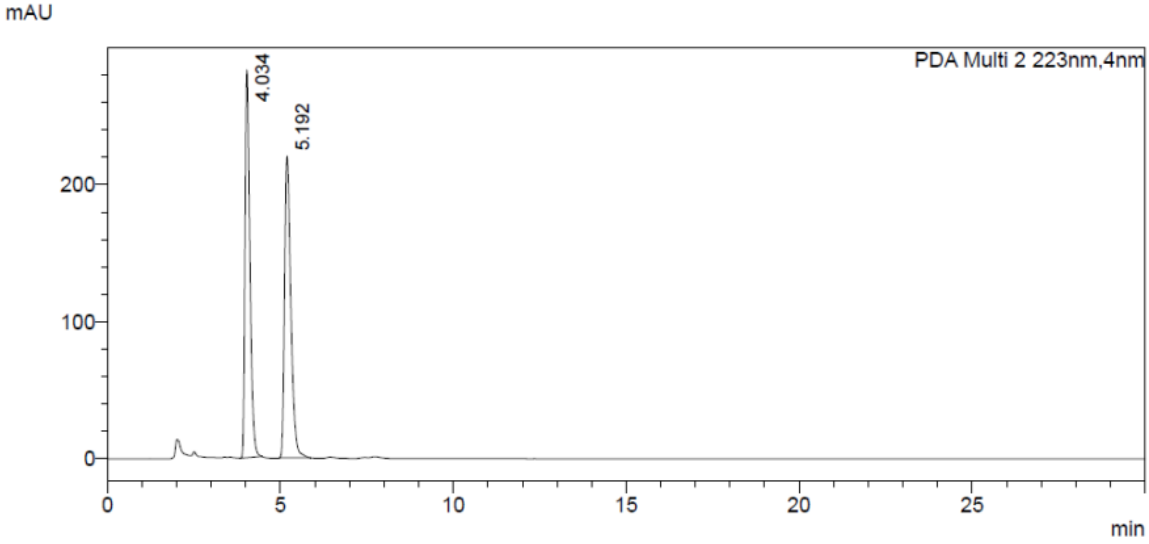


23

Racemic: hw-7-81-AD-12%-1.0

PDA Ch2 223nm

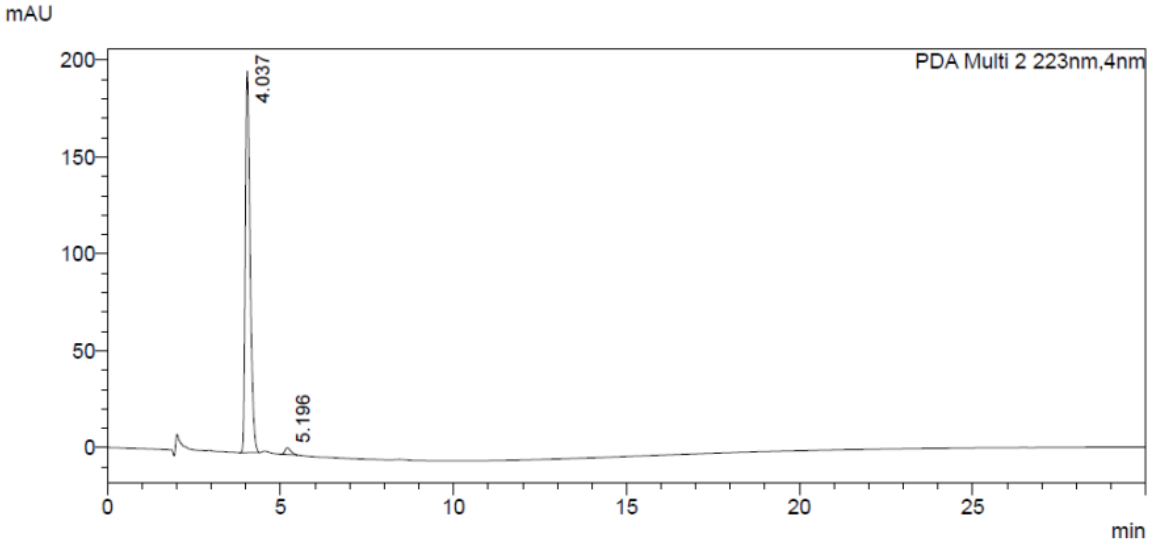
Peak#	Ret. Time	Area	Height	Area%
1	4.034	2752773	282731	49.766
2	5.192	2778664	219906	50.234
Total		5531437	502637	100.000

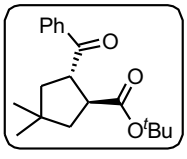


Scalemic: hw-7-79-AD-12%-1.0

PDA Ch2 223nm

Peak#	Ret. Time	Area	Height	Area%
1	4.037	1903961	196839	97.935
2	5.196	40138	3402	2.065
Total		1944099	200241	100.000



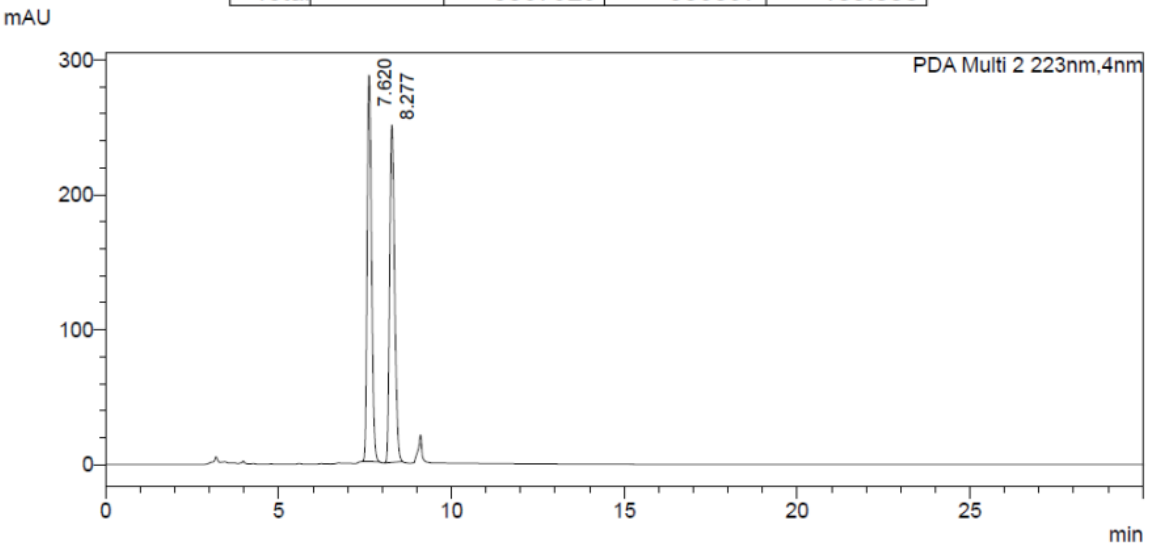


24

Racemic: hw-6-36a-tlc-1-IA-0.5%-1.0

PDA Ch2 223nm

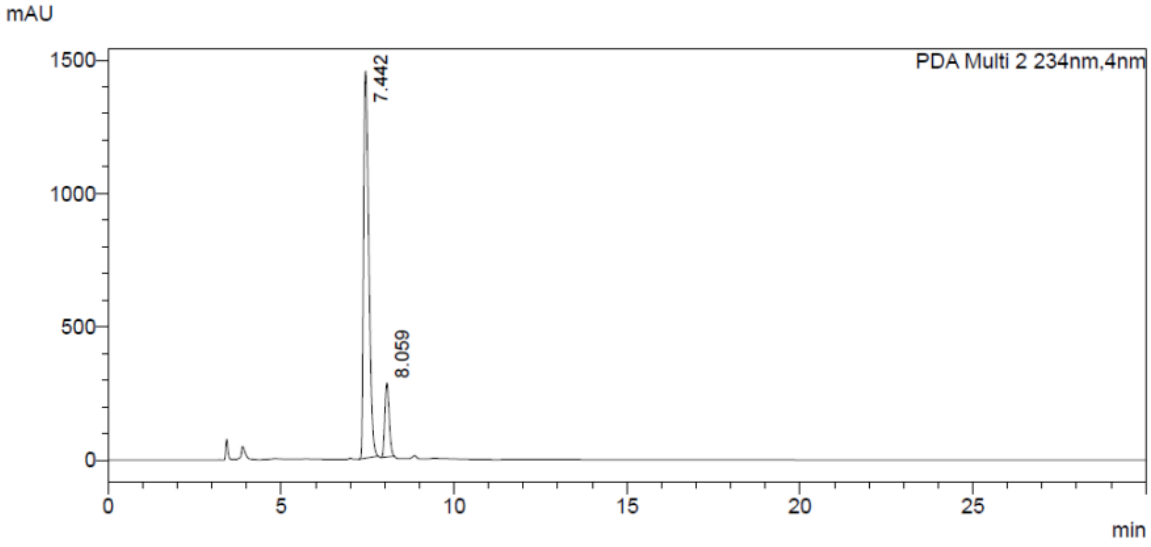
Peak#	Ret. Time	Area	Height	Area%
1	7.620	2543220	286463	50.183
2	8.277	2524709	249934	49.817
Total		5067929	536397	100.000

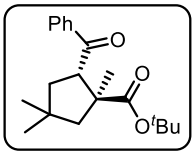


Scalemic: hw-6-157a-IA-0.5%-1.0

PDA Ch2 234nm

Peak#	Ret. Time	Area	Height	Area%
1	7.442	15252295	1451194	86.394
2	8.059	2402046	277662	13.606
Total		17654341	1728857	100.000



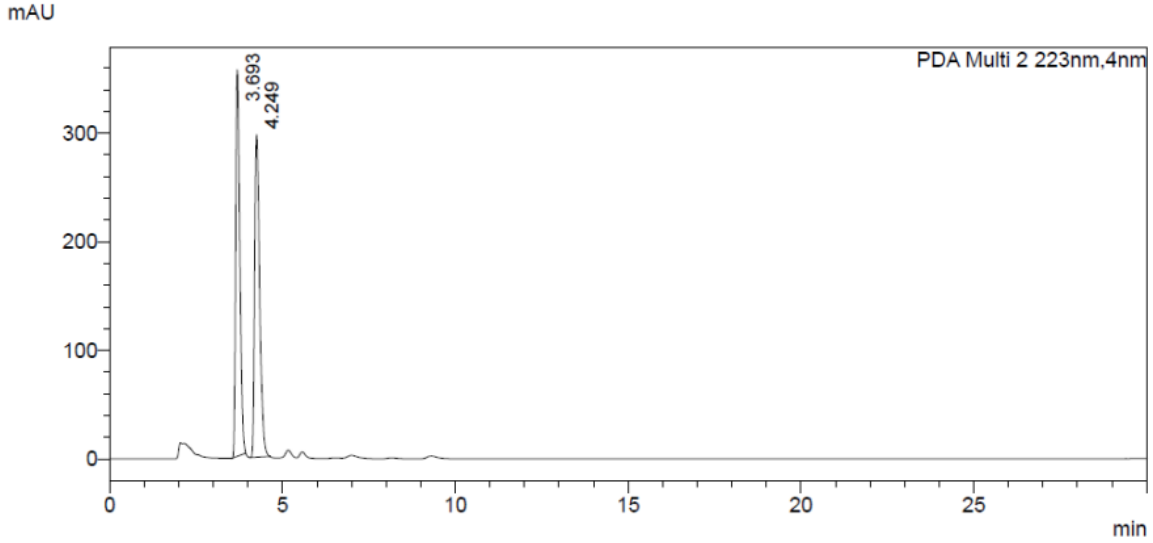


25

Racemic: hw-7-35b-AD-0.5%-1.0

PDA Ch2 223nm

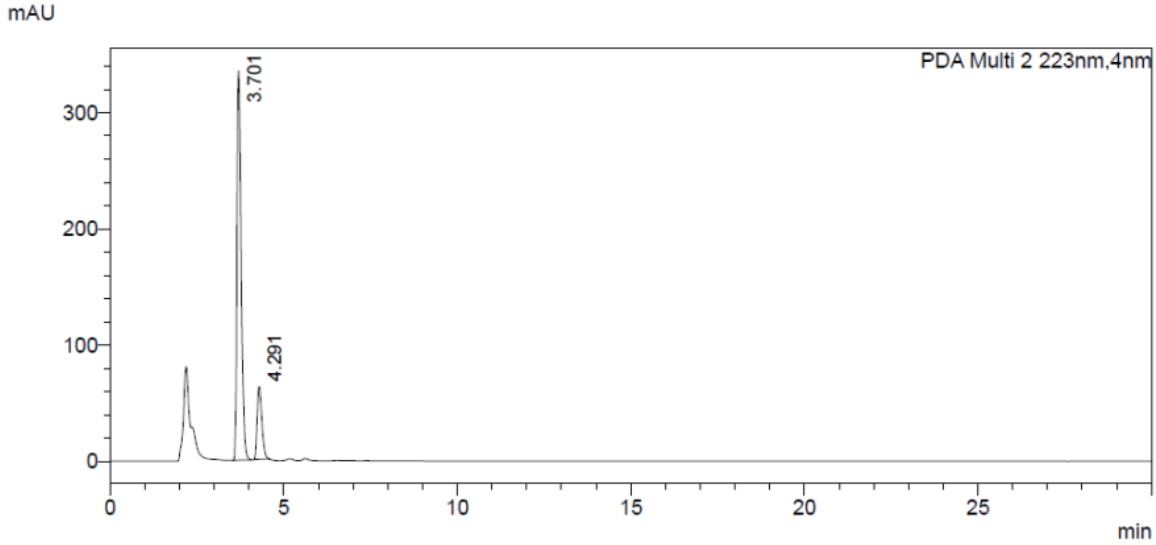
Peak#	Ret. Time	Area	Height	Area%
1	3.693	2960193	355948	49.589
2	4.249	3009206	297130	50.411
Total		5969399	653079	100.000

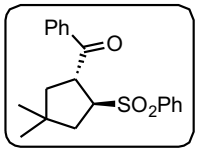


Scalemic: hw-7-30-AD-0.5%-1.0

PDA Ch2 223nm

Peak#	Ret. Time	Area	Height	Area%
1	3.701	2815939	335156	82.569
2	4.291	594483	62593	17.431
Total		3410422	397749	100.000



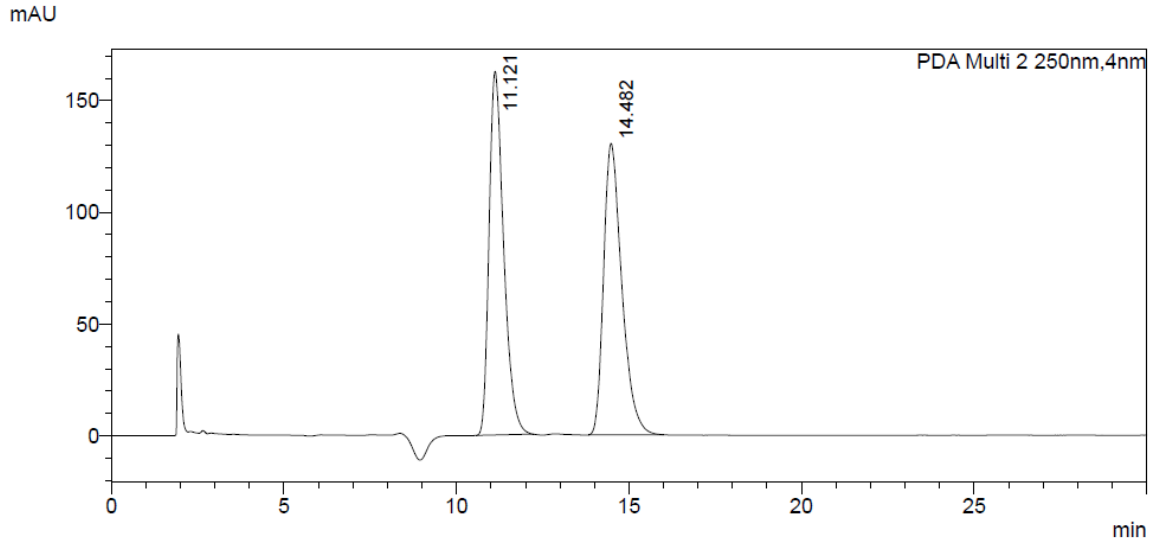


26

Racemic: hw-6-205a-AD-6%-1.0

PDA Ch2 250nm

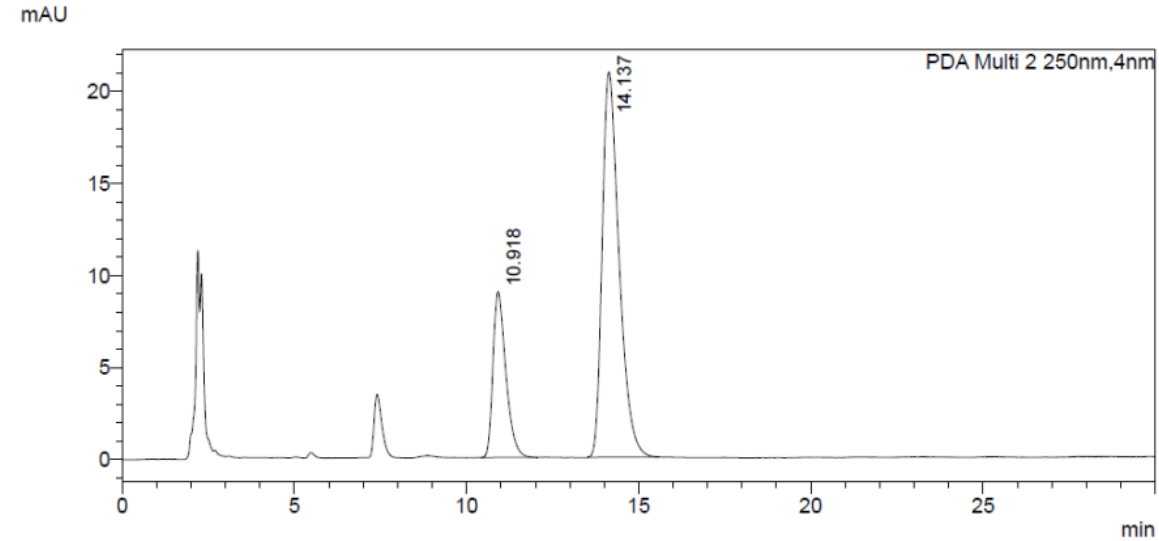
Peak#	Ret. Time	Area	Height	Area%
1	11.121	4780492	162666	49.952
2	14.482	4789646	130416	50.048
Total		9570138	293082	100.000

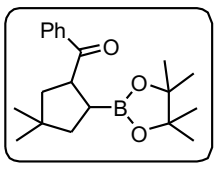


Scalemic: hw-7-167b-AD-6%-1.0

PDA Ch2 250nm

Peak#	Ret. Time	Area	Height	Area%
1	10.918	234425	9008	24.755
2	14.137	712547	20929	75.245
Total		946972	29937	100.000



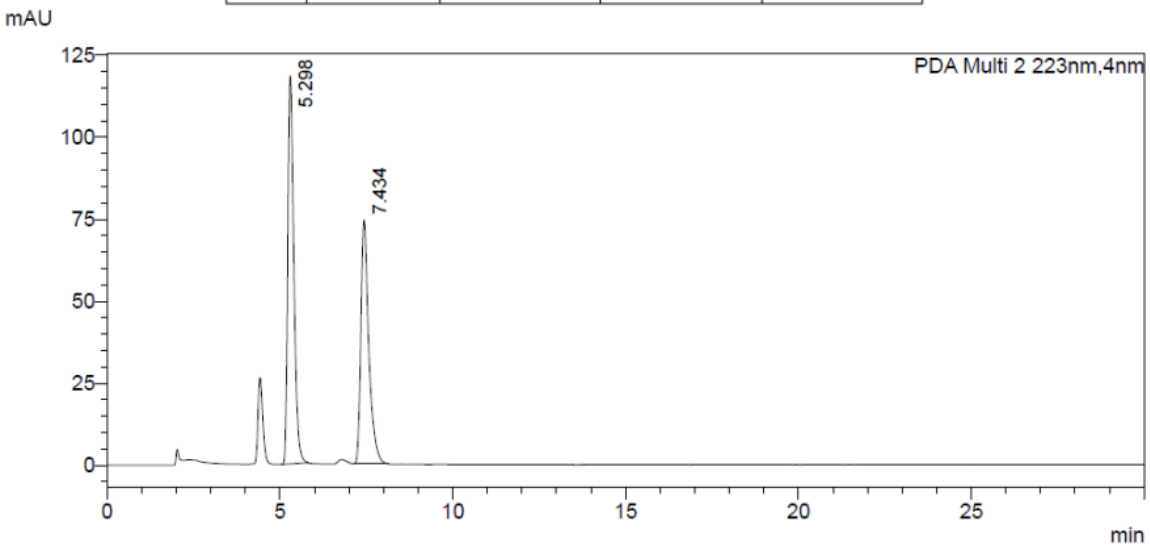


27

Racemic: hw-7-35a-AD-0.5%-1.0

PDA Ch2 223nm

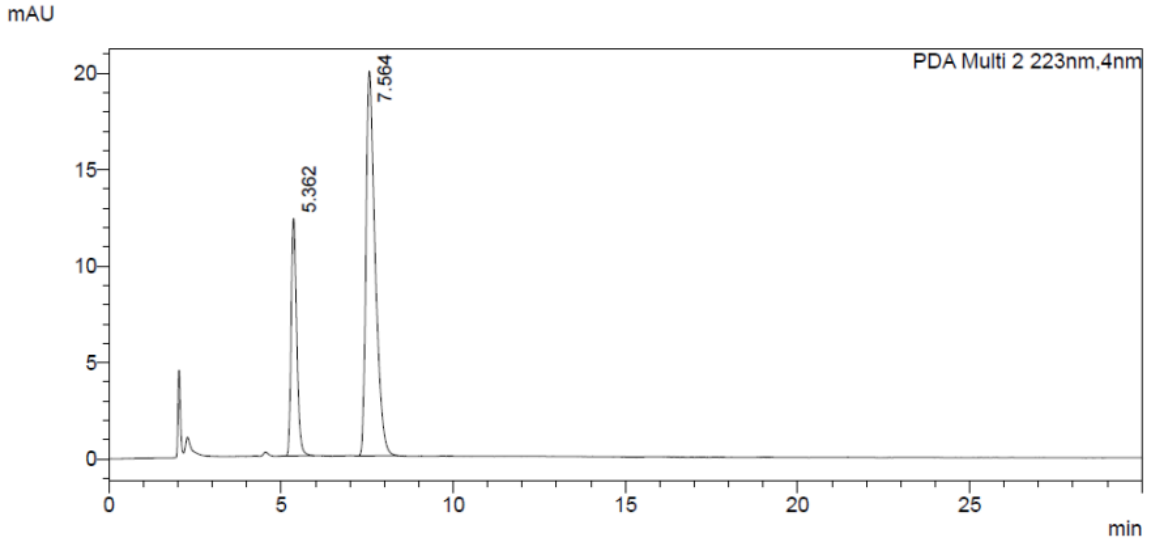
Peak#	Ret. Time	Area	Height	Area%
1	5.298	1426500	118271	54.759
2	7.434	1178573	74357	45.241
Total		2605073	192628	100.000

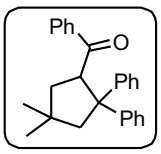


Scalemic: hw-7-161-AD-0.5%-1.0

PDA Ch2 223nm

Peak#	Ret. Time	Area	Height	Area%
1	5.362	138086	12311	27.129
2	7.564	370912	19944	72.871
Total		508998	32255	100.000



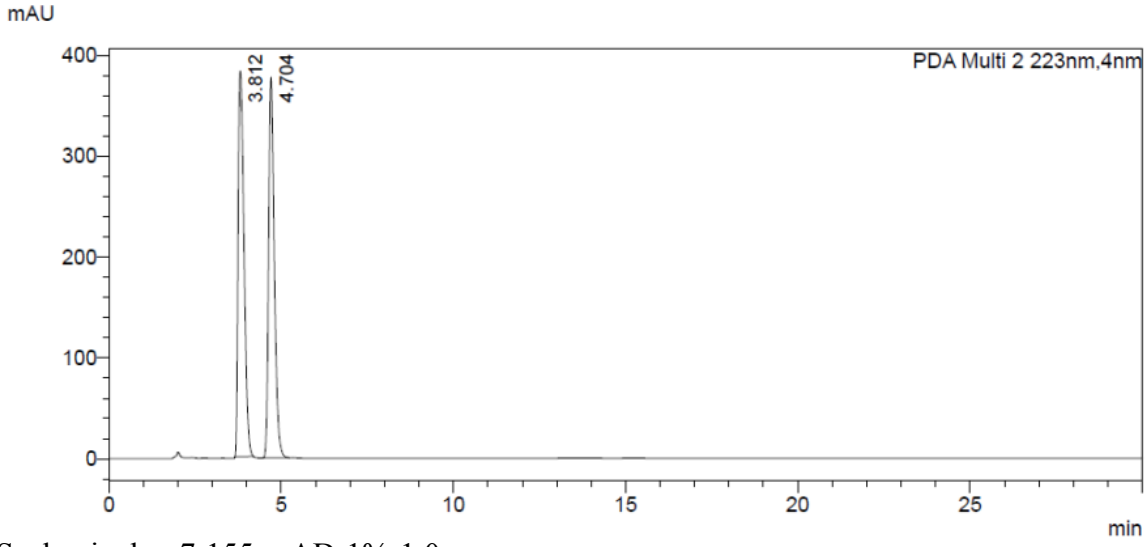


28

Racemic: hw-7-12b-tlc-AD-1%-1.0

PDA Ch2 223nm

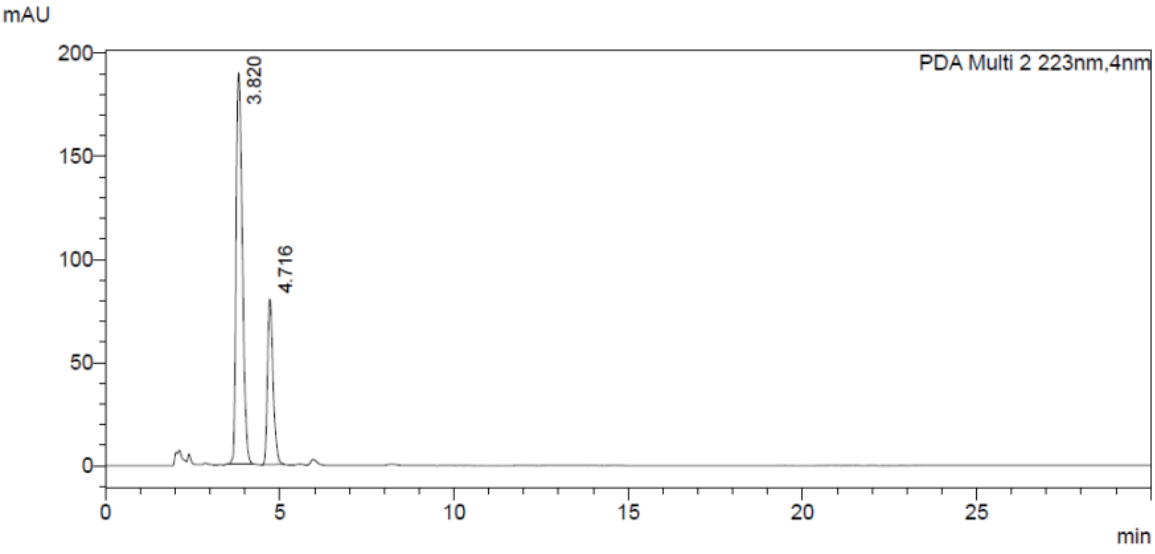
Peak#	Ret. Time	Area	Height	Area%
1	3.812	4593506	382348	51.461
2	4.704	4332672	377255	48.539
Total		8926178	759603	100.000

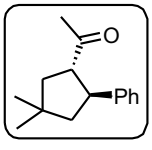


Scalemic: hw-7-155re-AD-1%-1.0

PDA Ch2 223nm

Peak#	Ret. Time	Area	Height	Area%
1	3.820	2340503	189498	72.400
2	4.716	892242	80246	27.600
Total		3232744	269744	100.000



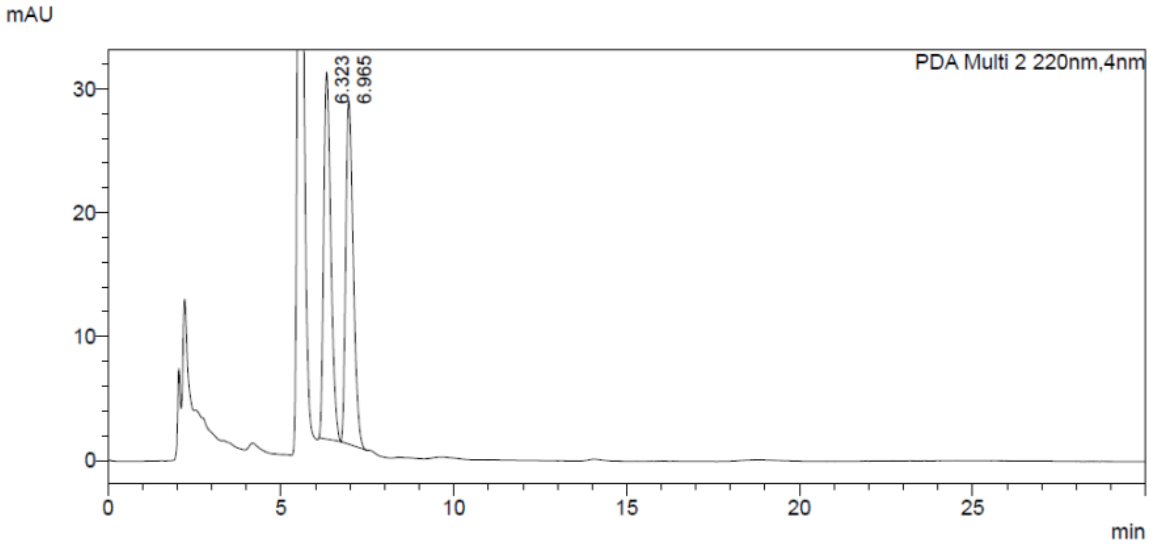


29

Racemic: hw-7-148-AD-0.3%-1.0

PDA Ch2 220nm

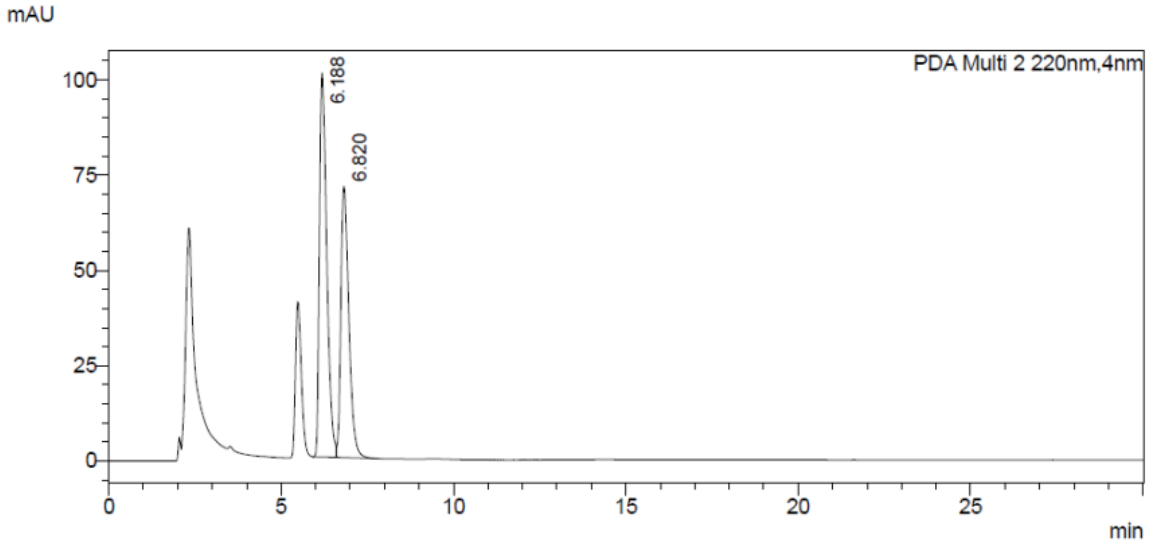
Peak#	Ret. Time	Area	Height	Area%
1	6.323	425444	29619	50.414
2	6.965	418455	27706	49.586
Total		843899	57325	100.000

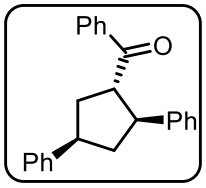


Scalemic: hw-7-147-AD-0.3%-1.0

PDA Ch2 220nm

Peak#	Ret. Time	Area	Height	Area%
1	6.188	1480824	100830	56.417
2	6.820	1143955	71174	43.583
Total		2624779	172004	100.000



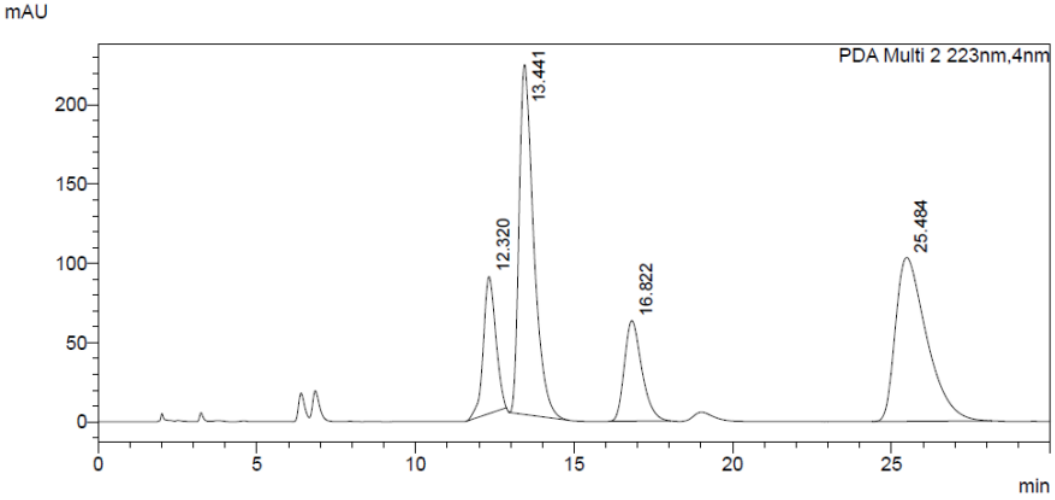


30

Racemic: hw-7-62-AD-1.0%-1.0

PDA Ch2 223nm

Peak#	Ret. Time	Area	Height	Area%
1	12.320	2358065	86400	12.466
2	13.441	7066400	220741	37.355
3	16.822	2425492	63380	12.822
4	25.484	7066751	103450	37.357
Total		18916708	473971	100.000



Scalemic: hw-7-177-2a-AD-1%-1.0

PDA Ch2 223nm

Peak#	Ret. Time	Area	Height	Area%
1	12.486	760984	27225	32.196
2	13.542	1411562	45079	59.721
3	17.044	28858	783	1.221
4	24.866	162187	2816	6.862
Total		2363592	75902	100.000