Double axial chirality promoted asymmetric [2,3] Stevens rearrangement of *N*-cinnamyl L-alanine amide-derived ammonium ylides

Eiji Tayama, Noriko Naganuma, Hajime Iwamoto, and Eietsu Hasegawa*

Department of Chemistry, Faculty of Science, Niigata University 950-2181, Japan

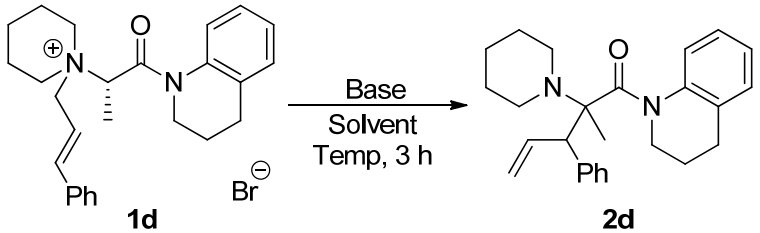
E-mail: tayama@chem.sc.niigata-u.ac.jp

Electronic Supplementary Information

Contents:

Effects of the base and solvent in the rearrangement of 1d

To investigate the effects of base and solvent on the asymmetric [2,3] Stevens rearrangement, we examined the reactions of **1d** under various conditions. When the reaction was performed with solid potassium *tert*-butoxide under the same conditions, nearly the same yield and selectivity were obtained (Entry 1). We tested analogous bases, such as sodium *tert*-butoxide in THF or potassium bis(trimethylsilyl)amide (KHMDS) in toluene, and did not observe remarkable improvements (Entries 2 and 3). The use of other solvents such as dichloromethane, *tert*-butyl methyl ether, acetonitrile, and DMF, resulted in lower yields or enantioselectivities (Entries 4–8). The rearrangement in DMSO at room temperature yielded a messy mixture (Entry 9). Alcoholic solvents, such as *tert*-butanol, resulted in a lower yield and selectivity (Entry 10).



1d **2d**

Entry	Solvent	Base	Temp (°C)	Yield of **2d** (%)[a,b]	Ee of **2d** (%)[c]
1	THF	^{t}BuOK solid	0	72	71
2	THF	^{t}BuONa in THF	0	48	71
3	THF	KHMDS in toluene	0	78	64
4	CH_2Cl_2	^{t}BuOK in THF	0	39	51
5	CH_2Cl_2	^{t}BuOK solid	0	54	54
6	^{t}BuOMe	^{t}BuOK solid	0	67	56
7	MeCN	^{t}BuOK in THF	0	27	50
8	DMF	^{t}BuOK in THF	0	34	53
9	DMSO	^{t}BuOK in THF	rt	messy	–
10	^{t}BuOH	^{t}BuOK in THF	rt	45	65

[a] Isolated yield.

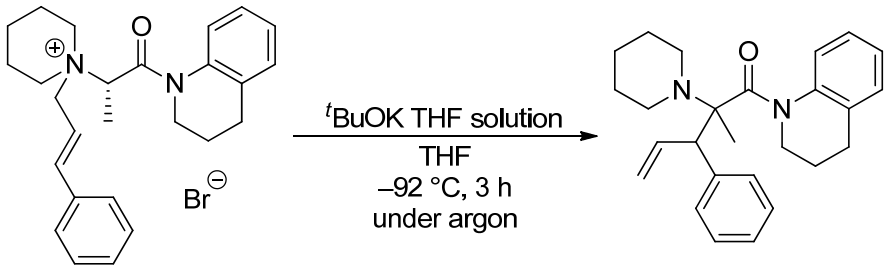
[b] Obtained as a single diastereomer.

[c] Determined by HPLC analysis using a chiral column.

Experimental details and products characterizations

General: Infrared spectra were recorded on a Perkin Elmer Spectrum GX FT-IR spectrometer. ^{1}H and ^{13}C NMR spectra were measured on a Varian 400 MHz spectrometer (^{1}H: 400 MHz, ^{13}C: 100 MHz) and a 700 MHz spectrometer (^{1}H: 700 MHz, ^{13}C: 175 MHz). The splitting patterns are denoted as follows: s, singlet; d, doublet; t, triplet; q, quartet; m, multiplet; and br, broad peak. Specific rotations (over 10% ee compounds) were recorded on a JASCO Polarimeter P–1010. High-resolution mass spectra were measured on a Thermo Fisher Scientific LC/FT-MS spectrometer. Elemental analyses were recorded on a J-Science Lab Micro Corder JM10. HPLC analyses were performed using a JASCO HPLC pump PU-2080 and a UV/VIS detector UV-2075. Reactions involving air- or moisture-sensitive compounds were conducted in appropriate round-bottomed flasks with a magnetic stirring bars under an argon atmosphere. Reactions under lower temperature were carried out using a Constant Temp. Bath with Magnetic Stirrer (PSL-1400 and PSL-1800, EYELA, Japan) and a Ultra-Cooling Reacter (UCR-150, Techno Sigma Co., Ltd., Japan). Tetrahydrofuran (THF) was purchased from KANTO Chemical Co., Inc., Japan as an anhydrous solvent. Aminomethylated polystyrene EHL (200–400 mesh), 2% DVB was purchased from Merck Millipore (Novabiochem). For thin layer chromatography (TLC) analysis throughout this work, Merck TLC plates (silica gel 60 F_{254}) were used. The products were purified by preparative column chromatography on silica gel (silica gel 60N, spherical neutral, KANTO Chemical Co., Inc., Japan).

Representative procedure for base-induced asymmetric [2,3] Stevens rearrangement of 1d via memory of chirality

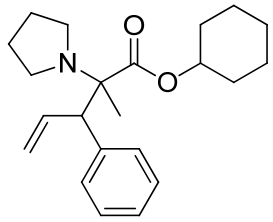


1d **2d**
62%, 91% ee

A 1.0 M THF solution of potassium *tert*-butoxide (0.29 mL, 0.29 mmol) was added to a suspension of **1d** (112 mg, 0.239 mmol) in THF (2.4 mL) at –92 °C under an argon atmosphere. After stirring for 3 h at the same temperature, the resulting mixture was poured into saturated aqueous ammonium chloride. The mixture was diluted with water and extracted with ethyl acetate. The combined extracts were washed with saturated aqueous sodium hydrogen carbonate and brine. The solution was dried over sodium sulfate and concentrated. Purification of the residue by chromatography on silica gel (hexane/ethyl acetate = 10/1 as the eluent) gave 1-(3,4-dihydroquinolin-1(2*H*)-yl)-2-methyl-3-phenyl-2-(piperidin-1-yl)pent-4-en-1-one (**2d**) (57.9 mg, 62% yield) as colorless crystals; $[\alpha]^{24}_{589}$ +159.0 (*c* 1.00, EtOH); 91% ee [determined by HPLC analysis: Daicel Chiralpak AD–H column, *n*-hexane/ethanol = 98.7/1.3 as the eluent (pre-eluted with *n*-hexane/2-propanol = 90/10), flow rate = 0.50 mL/min, t_R = 22.3 min for minor-**2d** and 60.4 min for major-**2d**]; IR (KBr) 3084, 3058,

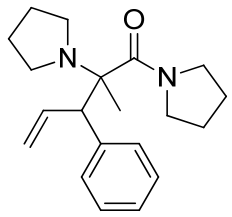
3014, 2985, 2937, 2850, 2808, 1631, 1598, 1489, 1455, 1440, 1389, 1368, 1276, 1256, 1235, 1206, 1158, 1104, 1064, 1035, 1001, 950, 915, 889, 861, 799, 758, 702 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.31 (2H, d, *J* = 7.4 Hz, ArH), 7.25-7.19 (2H, m, ArH), 7.13 (1H, tt, *J* = 7.4, 1.6 Hz, ArH), 7.00-6.96 (1H, m, ArH), 6.90 (1H, ddd, *J* = 7.4, 7.4, 1.6 Hz, ArH), 6.86 (1H, ddd, *J* = 7.4, 7.4, 1.6 Hz, ArH), 6.56 (1H, d, *J* = 7.4 Hz, ArH), 6.33 (1H, ddd, *J* = 17.0, 10.2, 9.0 Hz, CHC*H*=CH_2), 5.54 (1H, br, CH_2), 5.08-4.97 (2H, m, CHCH=CH_2), 4.08 (1H, d, *J* = 9.0 Hz, C*H*CH=CH_2), 3.20-2.70 (3H, br, CH_2), 2.70-2.56 (2H, br, CH_2), 2.46 (2H, br, CH_2), 2.10-1.96 (1H, m, CH_2), 1.94-1.82 (1H, m, CH_2), 1.65-1.39 (6H, m, CH_2), 1.53 (3H, s, CH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ (mixture of rotamers) 172.6, 172.1, 142.1, 141.6, 140.7, 140.13, 140.06, 139.2, 130.8, 130.2, 130.0, 129.1, 128.6, 128.3, 128.2, 128.1, 126.7, 126.4, 125.2, 125.1, 124.9, 124.8, 124.2, 124.1, 116.3, 115.8, 74.4, 73.4, 57.0, 56.9, 49.3, 48.6, 45.1, 44.1, 26.9, 26.8, 26.3, 25.9, 24.84, 24.79, 24.1, 15.3; HRMS–ESI (*m*/*z*): $[M+H]^+$ calcd for $C_{26}H_{33}N_2O$: 389.2587. Found: 389.2581. Anal. Calcd for $C_{26}H_{33}N_2O_{1.5}$ (as $0.5H_2O$): C, 78.55; H, 8.37; N, 7.05. Found: C, 78.48; H, 8.25; N, 6.75.

Cyclohexyl 2-methyl-3-phenyl-2-(pyrrolidin-1-yl)pent-4-enoate (2a): colorless oil; 0% ee (determined by



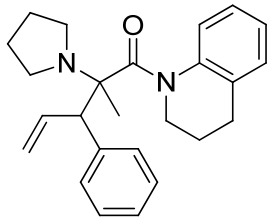
HPLC analysis: Daicel Chiralcel OD–H column, *n*-hexane as the eluent, flow rate = 0.50 mL/min, t_R = 19.2 min and 21.1 min); IR (film) 3062, 2936, 2858, 1713, 1636, 1601, 1495, 1453, 1413, 1380, 1358, 1332, 1287, 1230, 1194, 1143, 1106, 1079, 1036, 1013, 988, 968, 946, 912, 866, 842, 827, 789, 742, 704 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.27-7.12 (5H, m, Ph), 6.42 (1H, ddd, *J* = 17.2, 10.4, 8.2 Hz, CHC*H*=CH_2), 5.19 (1H, ddd, *J* = 10.4, 1.4, 1.4 Hz, CHCH=CH_2), 5.10 (1H, ddd, *J* = 17.2, 1.4, 1.4 Hz, CHCH=CH_2), 4.70 (1H, tt, *J* = 8.6, 3.6 Hz, OCH), 4.16 (1H, d, *J* = 8.2 Hz, C*H*CH=CH_2), 3.12-3.00 (2H, m, CH_2), 2.80-2.68 (2H, m, CH_2), 1.83-1.62 (6H, m, CH_2), 1.62-1.14 (8H, m, CH_2), 1.35 (3H, s, CH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ 171.7, 140.6, 137.7, 130.3, 127.7, 126.5, 116.9, 72.4, 68.2, 53.7, 46.8, 31.9, 31.7, 25.3, 24.0, 23.6, 23.5, 18.3; HRMS–ESI (*m*/*z*): $[M+H]^+$ calcd for $C_{22}H_{32}NO_2$: 342.2428. Found: 342.2414. Anal. Calcd for $C_{22}H_{31}NO_2$: C, 77.38; H, 9.15; N, 4.10. Found: C, 77.23; H, 9.07; N, 4.08.

2-Methyl-3-phenyl-1,2-di(pyrrolidin-1-yl)pent-4-en-1-one (2b): colorless crystals; < 7% ee [determined by



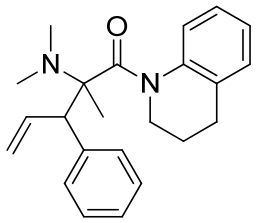
HPLC analysis: Daicel Chiralpak AS–H column, *n*-hexane/ethanol = 98.5/1.5 as the eluent, flow rate = 0.50 mL/min, t_R = 11.3 min and 12.7 min (not baseline separation)]; IR (KBr) 3026, 2968, 2944, 2871, 2814, 1614, 1490, 1453, 1424, 1371, 1336, 1294, 1248, 1216, 1192, 1160, 1147, 1109, 1073, 1031, 1003, 963, 940, 911, 891, 876, 855, 821, 760, 704 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.26-7.11 (5H, m, Ph), 6.36 (1H, ddd, *J* = 17.2, 10.0, 9.2 Hz, CHC*H*=CH_2), 5.05 (1H, d, *J* = 10.0 Hz, CHCH=CH_2), 5.00 (1H, d, *J* = 17.2 Hz, CHCH=CH_2), 3.94 (1H, d, *J* = 9.2 Hz, C*H*CH=CH_2), 3.47-3.18 (3H, m, CH_2), 3.11-2.96 (1H, m, CH_2), 2.95-2.83 (2H, m, CH_2), 2.62-2.50 (2H, m, CH_2), 1.77-1.63 (4H, m, CH_2), 1.63-1.47 (4H, m, CH_2), 1.41 (3H, s, CH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.3, 142.0, 139.9, 128.8, 127.9, 126.4, 116.0, 69.1, 56.8, 47.7, 47.1, 46.9, 27.0, 24.0, 22.8, 14.1; HRMS–ESI (*m*/*z*): $[M+H]^+$ calcd for $C_{20}H_{29}N_2O$: 313.2274. Found: 313.2268. Anal. Calcd for $C_{20}H_{28}N_2O$: C, 76.88; H, 9.03; N, 8.97. Found: C, 76.54; H, 9.10; N, 8.69.

1-(3,4-Dihydroquinolin-1(2*H*)-yl)-2-methyl-3-phenyl-2-(pyrrolidin-1-yl)pent-4-en-1-one (2c): colorless



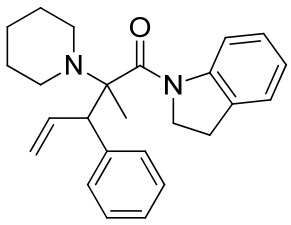
crystals; $[\alpha]^{23}_{589}$ +70.4 (*c* 1.00, EtOH); 42% ee (determined by HPLC analysis: Daicel Chiralcel OD–H column, *n*-hexane/isopropanol = 98/2 as the eluent, flow rate = 0.50 mL/min, t_R = 12.8 min for minor-**2c** and 16.9 min for major-**2c**); IR (KBr) 3058, 3018, 2945, 2871, 2809, 1636, 1599, 1490, 1454, 1436, 1387, 1340, 1300, 1281, 1256, 1228, 1200, 1172, 1142, 1129, 1121, 1085, 1065, 1032, 1000, 964, 947, 927, 907, 895, 840, 809, 757, 699 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.33-7.28 (2H, m, ArH), 7.28-7.21 (2H, m, ArH), 7.17 (1H, tt, *J* = 7.2, 1.4 Hz, ArH), 7.00 (1H, dd, *J* = 7.6, 1.2 Hz, ArH), 6.92 (1H, ddd, *J* = 7.6, 7.6, 1.2 Hz, ArH), 6.86 (1H, ddd, *J* = 7.6, 7.6, 1.2 Hz, ArH), 6.45 (1H, dd, *J* = 7.6, 1.2 Hz, ArH), 6.36 (1H, ddd, *J* = 17.0, 10.2, 8.4 Hz, CHC*H*=CH_2), 5.15-5.02 (3H, m, CHCH=CH_2 and CH_2), 4.21 (1H, d, *J* = 8.4 Hz, C*H*CH=CH_2), 3.18 (1H, ddd, *J* = 12.0, 9.2, 5.6 Hz, CH_2), 2.99-2.88 (2H, m, CH_2), 2.74-2.53 (4H, m, CH_2), 2.02-1.78 (2H, m, CH_2), 1.78-1.66 (4H, m, CH_2), 1.45 (3H, s, CH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.7, 141.7, 140.4, 139.7, 131.3, 129.0, 128.2, 128.1, 126.6, 125.0, 124.8, 124.3, 116.5, 70.3, 56.8, 46.9, 44.3, 25.7, 24.0, 23.7, 14.7; HRMS–ESI (*m*/*z*): $[M+H]^+$ calcd for $C_{25}H_{31}N_2O$: 375.2431. Found: 375.2425. Anal. Calcd for $C_{25}H_{30}N_2O$: C, 80.17; H, 8.07; N, 7.48. Found: C, 80.03; H, 8.09; N, 7.46.

1-(3,4-Dihydroquinolin-1(2*H*)-yl)-2-(dimethylamino)-2-methyl-3-phenylpent-4-en-1-one (2e): colorless



viscous oil; $[\alpha]^{24}_{589}$ +54.0 (*c* 1.00, EtOH); 30% ee (determined by HPLC analysis: Daicel Chiralpak AD–H column, *n*-hexane/2-propanol = 90/10 as the eluent, flow rate = 0.50 mL/min, t_R = 10.9 min for minor-**2e** and 12.8 min for major-**2e**); IR (KBr) 3082, 3058, 3003, 2947, 2868, 2830, 2788, 1634, 1598, 1490, 1452, 1391, 1368, 1340, 1299, 1282, 1259, 1228, 1202, 1159, 1122, 1095, 1046, 1002, 962, 950, 897, 811, 760, 701 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.32 (2H, dd, *J* = 7.6, 1.2 Hz, ArH), 7.24 (2H, dd, *J* = 7.6, 7.6 Hz, ArH), 7.16 (1H, tt, *J* = 7.6, 1.2 Hz, ArH), 6.99 (1H, dd, *J* = 7.6, 1.2 Hz, ArH), 6.92 (1H, ddd, *J* = 7.6, 7.6, 1.2 Hz, ArH), 6.85 (1H, ddd, *J* = 7.6, 7.6, 1.2 Hz, ArH), 6.39 (1H, d, *J* = 7.6 Hz, ArH), 6.33 (1H, ddd, *J* = 17.1, 10.1, 9.0 Hz, CHC*H*=CH_2), 5.21 (1H, br, CH_2), 5.14-5.02 (2H, m, CHCH=CH_2), 4.11 (1H, d, *J* = 9.0 Hz, C*H*CH=CH_2), 3.06 (1H, ddd, *J* = 12.0, 9.6, 5.2 Hz, CH_2), 2.71-2.54 (2H, m, CH_2), 2.38 (6H, s, $N(CH_3)_2$), 2.11-1.98 (1H, m, CH_2), 1.90-1.79 (1H, m, CH_2), 1.44 (3H, s, 2-CH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.2, 142.0, 140.4, 139.9, 131.3, 128.8, 128.3, 128.2, 126.6, 125.0, 124.8, 124.4, 116.4, 72.4, 56.7, 44.6, 40.2, 25.7, 23.8, 14.1; HRMS–ESI (*m*/*z*): $[M+H]^+$ calcd for $C_{23}H_{29}N_2O$: 349.2274. Found: 349.2271. Anal. Calcd for $C_{23}H_{29}N_2O_{1.5}$ (as $0.5H_2O$): C, 77.27; H, 8.18; N, 7.84. Found: C, 77.23; H, 8.17; N, 7.94.

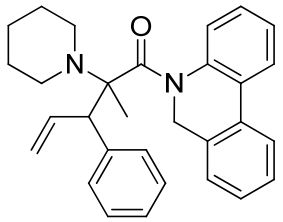
1-(Indolin-1-yl)-2-methyl-3-phenyl-2-(piperidin-1-yl)pent-4-en-1-one (2f): colorless crystals; 4% ee



(determined by HPLC analysis: Daicel Chiralpak AD–H column, *n*-hexane/ethanol = 90/10 as the eluent, flow rate = 0.50 mL/min, t_R = 9.5 min for major-**2f** and 12.0 min for minor-**2f**); IR (KBr) 3076, 3027, 2997, 2933, 2841, 1629, 1595, 1476, 1461, 1377, 1332, 1308, 1253, 1224, 1206, 1168, 1128, 1110, 1075, 1040, 998, 961, 946, 917, 877, 858, 829, 798, 759, 703 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.97 (1H, d, *J* = 7.6 Hz, ArH), 7.24 (2H, d, *J* = 7.6 Hz, ArH), 7.14 (2H, t, *J* = 7.6 Hz, ArH), 7.11-7.03 (3H, m, ArH), 6.93 (1H, ddd, *J* = 7.6, 7.6, 0.8 Hz, ArH), 6.32 (1H, ddd, *J* = 16.8, 9.6, 9.6 Hz, CHC*H*=CH_2), 5.04 (1H, dd, *J* = 9.6, 1.2 Hz, CHCH=CH_2), 4.99 (1H, d, *J* = 16.8 Hz, CHCH=CH_2), 4.79-4.63 (1H, m, CH_2), 4.01 (1H, br, CH_2),

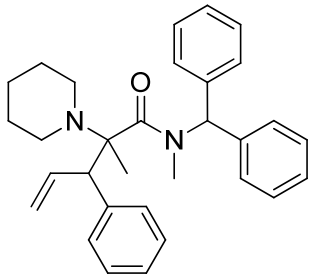
3.97 (1H, d, J = 9.6 Hz, C*H*CH=CH_2), 3.05-2.67 (2H, m, CH_2), 2.90 (2H, br, CH_2), 2.49-2.35 (2H, m, CH_2), 1.66-1.40 (6H, m, CH_2), 1.51 (3H, s, CH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ 171.9, 144.4, 141.8, 140.4, 131.7, 128.6, 128.1, 126.8, 126.5, 123.9, 123.4, 118.3, 115.9, 73.2, 56.1, 49.5, 48.7, 29.2, 26.8, 24.9, 14.8; HRMS–ESI (*m*/*z*): $[M+H]^+$ calcd for $C_{25}H_{31}N_2O$: 375.2431. Found: 375.2427. Anal. Calcd for $C_{25}H_{30}N_2O$: C, 80.17; H, 8.07; N, 7.48. Found: C, 79.78; H, 8.02; N, 7.37.

2-Methyl-1-(phenanthridin-5(6*H*)-yl)-3-phenyl-2-(piperidin-1-yl)pent-4-en-1-one (2g): colorless crystals;



$[\alpha]^{22}_{589}$ +209.6 (*c* 1.00, $CHCl_3$); 81% ee (determined by HPLC analysis: Daicel Chiralcel OD–H column, *n*-hexane/ethanol = 99/1 as the eluent, flow rate = 0.50 mL/min, t_R = 18.6 min for minor-**2g** and 24.8 min for major-**2g**); IR (KBr) 3068, 3023, 3002, 2940, 2855, 2806, 2764, 1642, 1599, 1486, 1441, 1385, 1351, 1313, 1282, 1263, 1225, 1162, 1103, 1029, 990, 947, 906, 764, 759, 735, 698 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.70 (1H, dd, J = 8.0, 1.2 Hz, ArH), 7.61 (1H, dd, J = 8.0, 1.2 Hz, ArH), 7.41-7.22 (7H, m, ArH), 7.16 (1H, tt, J = 7.4, 1.2 Hz, ArH), 7.09 (1H, ddd, J = 7.4, 7.4, 1.2 Hz, ArH), 7.01 (1H, ddd, J = 7.4, 7.4, 1.2 Hz, ArH), 6.79 (1H, br, CH_2), 6.65 (1H, br, ArH), 6.33 (1H, ddd, J = 17.0, 10.0, 8.6 Hz, CHC*H*=CH_2), 5.07 (1H, d, J = 10.0 Hz, CHCH=CH_2), 5.05 (1H, d, J = 17.0 Hz, CHCH=CH_2), 4.24 (1H, d, J = 12.0 Hz, CH_2), 4.14 (1H, d, J = 8.6 Hz, C*H*CH=CH_2), 2.86 (2H, br, CH_2), 2.27 (2H, br, CH_2), 1.58 (3H, s, CH_3), 1.42 (6H, br, CH_2); ^{13}C NMR (100 MHz, $CDCl_3$) δ 171.7, 142.0, 141.0, 137.9, 135.1, 132.2, 129.0, 128.5, 128.1, 127.9, 127.1, 126.79, 126.76, 126.1, 125.3, 125.1, 123.4, 123.1, 115.9, 73.3, 57.6, 48.4, 48.1, 26.41, 26.39, 24.5; HRMS–ESI (*m*/*z*): $[M+H]^+$ calcd for $C_{30}H_{33}N_2O$: 437.2587. Found: 437.2585. Anal. Calcd for $C_{30}H_{33}N_2O_{1.5}$ (as $0.5H_2O$): C, 80.86; H, 7.46; N, 6.29. Found: C, 80.80; H, 7.47; N, 6.02.

***N*-Benzhydryl-*N*,2-dimethyl-3-phenyl-2-(piperidin-1-yl)pent-4-enamide (2i):** colorless crystals; < 7% ee



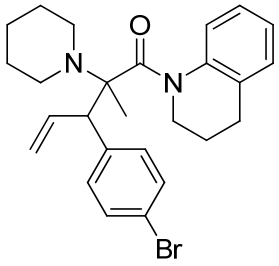
[determined by HPLC analysis: Daicel Chiralcel OD–H column, *n*-hexane/2-propanol = 99/1 as the eluent, flow rate = 0.50 mL/min, t_R = 16.3 min and 17.4 min (not baseline separation)]; IR (KBr) 3054, 3026, 3005, 2985, 2930, 2851, 2806, 1619, 1493, 1475, 1452, 1418, 1382, 1306, 1276, 1237, 1213, 1160, 1105, 1074, 1032, 998, 954, 924, 891, 867, 832, 798, 751, 735, 702 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.32-7.19 (8H, m, ArH), 7.15-7.09 (3H, m, ArH), 7.04 (2H, t, J = 7.4 Hz, ArH), 6.70 (1H, s, C*H*Ph_2), 6.30-6.06 (2H, m, ArH), 6.13 (1H, ddd, J = 17.0, 9.6, 8.8 Hz, CHC*H*=CH_2), 4.96 (1H, d, J = 9.6 Hz, CHCH=CH_2), 4.84 (1H, d, J = 17.0 Hz, CHCH=CH_2), 3.90 (1H, d, J = 8.8 Hz, C*H*CH=CH_2), 3.10 (3H, s, NCH_3), 2.81 (2H, br, CH_2), 2.33 (2H, br, CH_2), 1.65-1.35 (6H, m, CH_2), 1.54 (3H, s, 2-CH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.8, 141.8, 141.6, 139.9, 139.1, 129.1, 128.7, 128.6, 128.4, 128.1, 127.9, 127.0, 126.6, 126.5, 115.3, 71.9, 62.2, 57.2, 48.5, 33.3, 26.7, 24.9, 15.7; HRMS–ESI (*m*/*z*): $[M+H]^+$ calcd for $C_{31}H_{37}N_2O$: 453.2900. Found: 453.2901. Anal. Calcd for $C_{31}H_{36}N_2O$: C, 82.26; H, 8.02; N, 6.19. Found: C, 81.99; H, 8.02; N, 6.22.

***N*-Methoxy-*N*,2-dimethyl-3-phenyl-2-(piperidin-1-yl)pent-4-enamide (2j):** pale brown viscous oil; < 2% ee [determined by HPLC analysis: Daicel Chiralcel OD–H column, *n*-hexane/2-propanol = 99/1 as the eluent, flow rate = 0.50 mL/min, t_R = 14.4 min and 15.3 min (not baseline separation)]; IR (film) 3060, 2931, 2852, 2813, 1651, 1492, 1452, 1408, 1370, 1306, 1277, 1259, 1233, 1158, 1106, 1073, 1029, 1000, 950, 915, 885, 860, 829, 796, 781, 761, 737, 702 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.28-7.12 (5H, m, Ph), 6.27 (1H, ddd, *J* = 17.1, 10.2, 8.8 Hz, CHC*H*=CH_2), 5.06 (1H, ddd, *J* = 10.2, 1.0, 1.0 Hz, CHCH=CH_2), 4.97 (1H, ddd, *J* = 17.1, 1.0, 1.0 Hz, CHCH=CH_2), 4.03 (1H, br, C*H*CH=CH_2), 3.33 (3H, br, OCH_3), 3.03 (3H, br, NCH_3), 2.82 (2H, br, CH_2), 2.47-2.32 (2H, m, CH_2), 1.62-1.50 (4H, m, CH_2), 1.49-1.39 (2H, m, CH_2), 1.44 (3H, s, 2-CH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ 171.8, 141.9, 139.8, 129.1, 127.9, 126.4, 116.2, 71.3, 59.4, 55.3, 48.6, 35.4, 26.6, 24.9, 14.7; HRMS–ESI (*m*/*z*): $[M+H]^+$ calcd for $C_{19}H_{29}N_2O_2$: 317.2224. Found: 317.2218. Anal. Calcd for $C_{19}H_{28}N_2O_2$: C, 72.12; H, 8.92; N, 8.85. Found: C, 71.78; H, 8.82; N, 8.61.

***N*-(*tert*-Butoxy)-*N*,2-dimethyl-3-phenyl-2-(piperidin-1-yl)pent-4-enamide (2k):** pale brown oil; $[\alpha]^{23}_{589}$ – 37.1 (*c* 1.00, EtOH); 64% ee (determined by HPLC analysis: Daicel Chiralpak AD–H column, *n*-hexane/ethanol = 98/2 as the eluent, flow rate = 0.50 mL/min, t_R = 8.5 min for major-**2k** and 9.4 min for minor-**2k**); IR (film) 3059, 3026, 2976, 2931, 2851, 2814, 1678, 1473, 1452, 1413, 1386, 1364, 1315, 1302, 1264, 1235, 1189, 1167, 1112, 1065, 1035, 999, 949, 914, 888, 858, 824, 797, 736, 703 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.34 (2H, dd, *J* = 7.6, 1.2 Hz, Ph), 7.23 (2H, t, *J* = 7.6 Hz, Ph), 7.14 (1H, tt, *J* = 7.6, 1.2 Hz, Ph), 6.39 (1H, ddd, *J* = 16.8, 9.6, 9.6 Hz, CHC*H*=CH_2), 5.07-4.98 (2H, m, CHCH=CH_2), 4.04 (1H, br, C*H*CH=CH_2), 3.23 (3H, s, NCH_3), 2.84 (2H, br, CH_2), 2.53 (2H, br, CH_2), 1.57-1.38 (6H, m, CH_2), 1.44 (3H, s, 2-CH_3), 1.08 (9H, s, *t*-Bu); ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.8, 142.2, 139.9, 129.8, 128.0, 126.3, 116.1, 81.9, 71.8, 55.8, 48.4, 42.8, 27.6, 26.7, 25.0, 18.1; HRMS–ESI (*m*/*z*): $[M+H]^+$ calcd for $C_{22}H_{35}N_2O_2$: 359.2693. Found: 359.2683. Anal. Calcd for $C_{22}H_{34}N_2O_2$: C, 73.70; H, 9.56; N, 7.81. Found: C, 73.32; H, 9.85; N, 7.64.

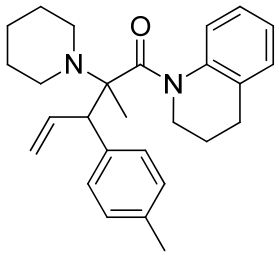
3-(4-Chlorophenyl)-1-(3,4-dihydroquinolin-1(2*H*)-yl)-2-methyl-2-(piperidin-1-yl)pent-4-en-1-one (2l): colorless crystals; $[\alpha]^{23}_{589}$ +96.9 (*c* 1.00, EtOH); 71% ee (determined by HPLC analysis: Daicel Chiralpak AD–H column, *n*-hexane/ethanol = 95/5 as the eluent, flow rate = 0.50 mL/min, t_R = 11.1 min for minor-**2l** and 17.8 min for major-**2l**); IR (KBr) 3003, 2935, 2850, 2811, 1638, 1600, 1490, 1453, 1442, 1385, 1368, 1342, 1282, 1261, 1231, 1206, 1160, 1092, 1068, 1040, 1013, 1000, 944, 913, 889, 828, 756, 709 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.28 (2H, d, *J* = 8.6 Hz, ArH), 7.19 (2H, d, *J* = 8.6 Hz, ArH), 7.04-6.98 (1H, m, ArH), 6.98-6.90 (2H, m, ArH), 6.70 (1H, br, ArH), 6.31 (1H, ddd, *J* = 16.8, 10.0, 8.8 Hz, CHC*H*=CH_2), 5.37 (1H, br, CH_2), 5.06 (1H, dd, *J* = 10.0, 0.8 Hz, CHCH=CH_2), 5.01 (1H, d, *J* = 16.8 Hz, CHCH=CH_2), 4.07 (1H, d, *J* = 8.8 Hz, C*H*CH=CH_2), 3.45-2.75 (3H, br, CH_2), 2.75-2.60 (2H, m, CH_2), 2.49 (2H, br, CH_2), 2.10-1.95 (1H, m, CH_2), 1.95-1.84 (1H, m, CH_2), 1.68-1.38 (6H, m, CH_2), 1.51 (3H, s, CH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.2, 140.8, 140.3, 140.0, 132.2, 130.7, 130.3, 128.5, 128.3, 125.1, 124.7, 124.4, 116.3, 73.3, 56.5, 48.6, 44.3, 27.0, 25.9, 24.8, 24.2, 17.0-14.0 (br); HRMS–ESI (*m*/*z*): $[M+H]^+$ calcd for $C_{26}H_{32}ClN_2O$: 423.2198. Found: 423.2197. Anal. Calcd for $C_{26}H_{31}ClN_2O$: C, 73.83; H, 7.39; N, 6.62. Found: C, 73.49; H, 7.43; N, 6.68.

3-(4-Bromophenyl)-1-(3,4-dihydroquinolin-1(2*H*)-yl)-2-methyl-2-(piperidin-1-yl)pent-4-en-1-one (2m):



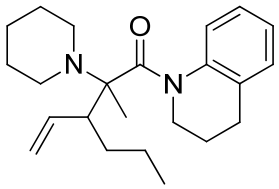
colorless crystals; $[\alpha]^{24}_{589}$ +109.9 (*c* 1.00, $CHCl_3$); 86% ee (determined by HPLC analysis: Daicel Chiralpak AD–H column, *n*-hexane/ethanol = 98/2 as the eluent, flow rate = 0.50 mL/min, t_R = 14.4 min for minor-**2m** and 22.6 min for major-**2m**); IR (KBr) 3059, 2998, 2934, 2848, 2809, 2765, 1636, 1600, 1488, 1455, 1442, 1385, 1369, 1342, 1308, 1281, 1260, 1233, 1205, 1158, 1104, 1069, 1040, 1008, 950, 919, 887, 863, 820, 794, 755, 719 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.35 (2H, d, *J* = 8.2 Hz, ArH), 7.22 (2H, d, *J* = 8.2 Hz, ArH), 7.04-6.98 (1H, m, ArH), 6.98-6.92 (2H, m, ArH), 6.68 (1H, br, ArH), 6.31 (1H, ddd, *J* = 16.8, 10.0, 9.2 Hz, CHC*H*=CH_2), 5.38 (1H, br, CH_2), 5.06 (1H, d, *J* = 10.0 Hz, CHCH=C*H*$_2$), 5.01 (1H, d, *J* = 16.8 Hz, CHCH=C*H*$_2$), 4.05 (1H, d, *J* = 9.2 Hz, C*H*CH=CH_2), 3.15 (1H, br, CH_2), 2.88 (2H, br, CH_2), 2.74-2.60 (2H, m, CH_2), 2.49 (2H, br, CH_2), 2.08-1.85 (2H, m, CH_2), 1.64-1.40 (6H, m, CH_2), 1.51 (3H, s, CH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.1, 141.4, 140.2, 140.0, 131.3, 130.7, 128.5, 125.1, 124.7, 124.4, 120.4, 116.4, 73.2, 56.5, 48.5, 44.3, 27.0, 25.9, 24.8, 24.2, 15.9; HRMS–ESI (*m*/*z*): $[M+H]^+$ calcd for $C_{26}H_{32}BrN_2O$: 467.1693. Found: 467.1678. Anal. Calcd for $C_{26}H_{31}BrN_2O$: C, 66.81; H, 6.68; N, 5.99. Found: C, 66.66; H, 6.72; N, 5.96.

1-(3,4-Dihydroquinolin-1(2*H*)-yl)-2-methyl-2-(piperidin-1-yl)-3-(*p*-tolyl)pent-4-en-1-one (2n):



colorless crystals; $[\alpha]^{23}_{589}$ +145.2 (*c* 1.00, EtOH); 85% ee (determined by HPLC analysis: Daicel Chiralpak AD–H column, *n*-hexane/ethanol = 98/2 as the eluent, flow rate = 0.50 mL/min, t_R = 13.2 min for minor-**2n** and 27.3 min for major-**2n**); IR (KBr) 3016, 2991, 2937, 2852, 2807, 1633, 1599, 1512, 1490, 1453, 1439, 1386, 1367, 1341, 1300, 1279, 1262, 1232, 1206, 1157, 1102, 1069, 1037, 999, 947, 915, 887, 858, 843, 816, 760, 718, 707 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.19 (2H, d, *J* = 8.0 Hz, ArH), 7.02 (2H, d, *J* = 8.0 Hz, ArH), 6.98 (1H, dd, *J* = 7.4, 1.2 Hz, ArH), 6.90 (1H, ddd, *J* = 7.4, 7.4, 1.2 Hz, ArH), 6.86 (1H, ddd, *J* = 7.4, 7.4, 1.2 Hz, ArH), 6.55 (1H, d, *J* = 7.4 Hz, ArH), 6.32 (1H, ddd, *J* = 16.0, 9.6, 9.6 Hz, CHC*H*=CH_2), 5.55 (1H, br, CH_2), 5.10-4.95 (2H, m, CHCH=C*H*$_2$), 4.03 (1H, d, *J* = 9.6 Hz, C*H*CH=CH_2), 3.20-2.75 (3H, br, CH_2), 2.71-2.57 (2H, m, CH_2), 2.45 (2H, br, CH_2), 2.24 (3H, s, $ArCH_3$), 2.10-1.95 (1H, m, CH_2), 1.94-1.82 (1H, m, CH_2), 1.70-1.38 (6H, m, CH_2), 1.52 (3H, s, 2-CH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.2, 140.9, 140.2, 139.2, 136.0, 130.8, 128.9, 128.4, 128.2, 124.85, 124.79, 124.1, 115.6, 73.5, 56.6, 48.6, 44.1, 26.9, 25.9, 24.8, 24.2, 20.8, 14.9; HRMS–ESI (*m*/*z*): $[M+H]^+$ calcd for $C_{27}H_{35}N_2O$: 403.2744. Found: 403.2739. Anal. Calcd for $C_{27}H_{34}N_2O$: C, 80.55; H, 8.51; N, 6.96. Found: C, 80.32; H, 8.43; N, 7.05.

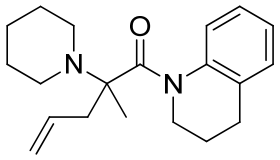
1-(3,4-Dihydroquinolin-1(2*H*)-yl)-2-methyl-2-(piperidin-1-yl)-3-vinylhexan-1-one (2p):



colorless crystals; 5% ee (determined by HPLC analysis: Daicel Chiralpak AD–H column, *n*-hexane/ethanol = 99/1 as the eluent, flow rate = 0.50 mL/min, t_R = 8.5 min for minor-**2p** and 19.0 min for major-**2p**); IR (KBr) 3072, 3032, 2929, 2855, 2805, 1641, 1602, 1489, 1452, 1371, 1350, 1303, 1287, 1247, 1222, 1204, 1169, 1131, 1118, 1096, 1065, 1042, 996, 961, 943, 915, 893, 876, 847, 809, 754, 711 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.61 (1H, d, *J* = 7.8 Hz, ArH), 7.11 (1H, t, *J* = 7.8 Hz, ArH), 7.10 (1H, d, *J* = 7.8 Hz, ArH), 7.01 (1H, t, *J* = 7.8 Hz, ArH), 5.71 (1H, ddd, *J* = 17.0, 9.8, 9.8 Hz, CHC*H*=CH_2), 5.26 (1H, br, CH_2), 5.13 (1H, d, *J* = 9.8 Hz, CHCH=C*H*$_2$), 5.06 (1H, d, *J* = 17.0 Hz, CHCH=C*H*$_2$), 3.85 (1H, br, C*H*CH=CH_2), 2.87-2.67 (2H, br, CH_2), 2.80 (2H, t, *J* =

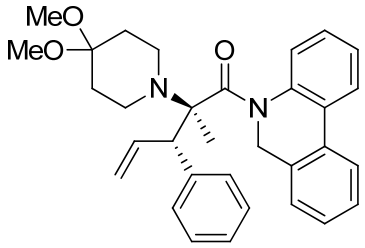
7.0 Hz, CH_2), 2.65-2.38 (3H, m, CH_2), 2.10-1.91 (2H, m, CH_2), 1.79-1.64 (1H, m, CH_2), 1.64-1.05 (9H, m, CH_2), 1.30 (3H, s, 2-CH_3), 0.87 (3H, t, J = 6.8 Hz, $CHCH_2CH_2CH_3$); ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.4, 140.6, 139.4, 130.2, 129.1, 125.2, 125.1, 124.2, 117.2, 72.9, 51.8, 48.5, 45.3, 31.9, 26.7, 26.2, 25.0, 24.4, 20.9, 14.6, 14.1; HRMS–ESI (*m*/*z*): $[M+H]^+$ calcd for $C_{23}H_{35}N_2O$: 355.2744. Found: 355.2731. Anal. Calcd for $C_{23}H_{34}N_2O$: C, 77.92; H, 9.67; N, 7.90. Found: C, 78.15; H, 9.86; N, 7.81.

1-(3,4-Dihydroquinolin-1(2*H*)-yl)-2-methyl-2-(piperidin-1-yl)pent-4-en-1-one (2q): colorless viscous oil;



3% ee (determined by HPLC analysis: Daicel Chiralcel OJ–H column, *n*-hexane/2-propanol = 60/40 as the eluent, flow rate = 0.50 mL/min, t_R = 12.5 min for minor-**2q** and 16.9 min for major-**2q**); IR (film) 3072, 2933, 2851, 2807, 2758, 2702, 1652, 1601, 1581, 1490, 1452, 1382, 1370, 1288, 1277, 1247, 1229, 1203, 1166, 1118, 1098, 1068, 1035, 992, 960, 916, 875, 798, 756, 710 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.64 (1H, d, J = 7.6 Hz, ArH), 7.14-7.07 (2H, m, ArH), 7.01 (1H, dd, J = 7.6, 7.6 Hz, ArH), 5.86 (1H, ddt, J = 17.2, 9.6, 7.2 Hz, CH_2CH=CH_2), 5.13-5.01 (2H, m, CH_2CH=CH_2), 4.94 (1H, br, CH_2), 4.14-3.98 (1H, m, CH_2), 2.80 (2H, t, J = 7.0 Hz, CH_2), 2.73 (1H, dd, J = 13.3, 7.2 Hz, CH_2CH=CH_2), 2.64 (2H, br, CH_2), 2.50 (2H, br, CH_2), 2.41 (1H, dd, J = 13.3, 7.2 Hz, CH_2CH=CH_2), 2.03 (1H, dd, J = 6.6, 6.6 Hz, CH_2), 2.00 (1H, dd, J = 6.6, 6.6 Hz, CH_2), 1.58 (4H, br, CH_2), 1.47 (2H, br, CH_2), 1.28 (3H, s, CH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.1, 140.3, 134.5, 130.4, 128.9, 125.2, 124.3, 117.8, 69.2, 47.7, 44.5, 40.6, 26.8, 26.0, 24.9, 24.2, 16.1; HRMS–ESI (*m*/*z*): $[M+H]^+$ calcd for $C_{20}H_{29}N_2O$: 313.2274. Found: 313.2267. Anal. Calcd for $C_{20}H_{29}N_2O_{1.5}$ (as $0.5H_2O$): C, 74.73; H, 9.09; N, 8.71. Found: C, 74.64; H, 8.97; N, 8.93.

2-(4,4-Dimethoxypiperidin-1-yl)-2-methyl-1-(phenanthridin-5(6*H*)-yl)-3-phenylpent-4-en-1-one (4):



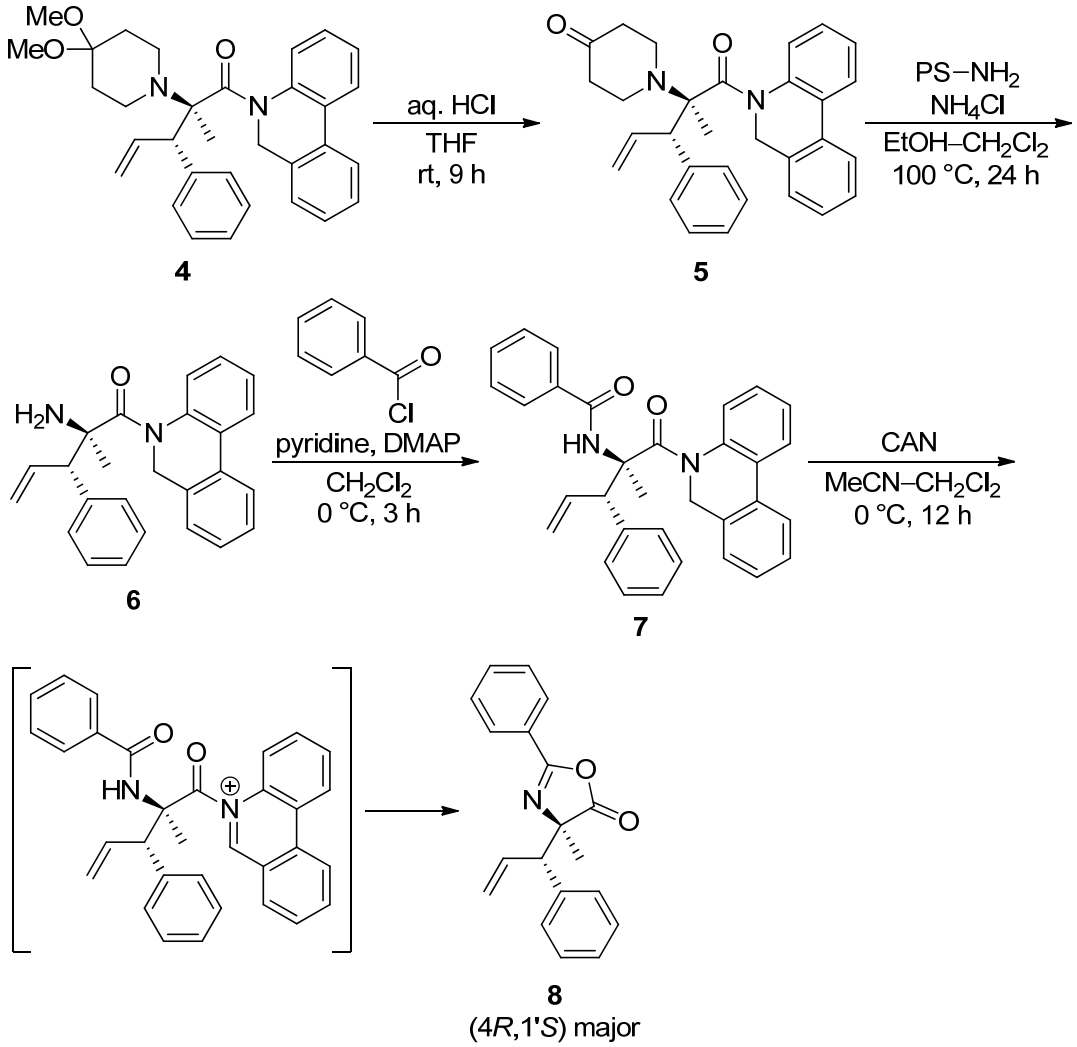
(2*R*,3*S*)-major

colorless crystals; $[\alpha]^{22}_{589}$ +157.3 (*c* 1.00, $CHCl_3$); 80% ee [(2*R*,3*S*)/(2*S*,3*R*): major diastereomer], 81% ee [(2*R*,3*R*)/(2*S*,3*S*): minor diastereomer], (2*S*,3*R*)/(2*R*,3*S*)/(2*R*,3*R*)/(2*S*,3*S*) = 8.8/78.1/11.8/1.3 [determined by HPLC analysis: Daicel Chiralpak IB column, *n*-hexane/ethanol = 97/3 as the eluent, flow rate = 0.50 mL/min, t_R = 14.0 min for (2*S*,3*R*)-**4**, 15.4 min for (2*R*,3*S*)-**4**, 17.6 min for (2*R*,3*R*)-**4**, and 19.4 min for (2*S*,3*S*)-**4**]; IR (KBr) 3074, 2944, 2895, 2852, 2827, 1634, 1599, 1486, 1440, 1388, 1354, 1314, 1252, 1228, 1181, 1151, 1127, 1092, 1052, 1000, 980, 950, 913, 891, 868, 804, 756, 736, 703 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ (9/1 mixture of diastereomers) 7.80-7.67 (1.1H, m, ArH), 7.61 (0.9H, J = 7.8, 1.2 Hz, ArH), 7.43-6.98 (7.3H, m, ArH), 7.18 (0.9H, tt, J = 7.6, 1.2 Hz, ArH), 7.10 (0.9H, ddd, J = 7.6, 7.6, 1.2 Hz, ArH), 7.02 (0.9H, dd, J = 7.6, 7.6 Hz, ArH), 6.65 (2H, br, ArH and CH_2), 6.40-6.20 (1H, m, $CHCH$=CH_2), 5.09 (0.9H, d, J = 10.0 Hz, $CHCH$=CH_2), 5.08 (1H, d, J = 17.2 Hz, $CHCH$=CH_2), 4.91 (0.1H, d, J = 9.6 Hz, $CHCH$=CH_2), 4.60 (0.1H, br, CH_2), 4.22 (0.9H, br, CH_2), 4.15 (1H, d, J = 8.8 Hz, $CHCH$=CH_2), 3.40-2.38 (2H, br, CH_2), 3.12 (5.4H, s, OCH_3), 3.10 (0.6H, s, OCH_3), 2.29 (2H, br, CH_2), 1.90-1.35 (7H, br, CH_2 and 2-CH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ (major diastereomer) 171.4, 141.7, 140.7, 137.8, 135.0, 132.1, 129.0, 128.5, 128.0, 127.2, 126.83, 126.81, 125.8, 125.4, 125.2, 123.5, 123.2, 116.1, 98.0, 72.9, 57.8, 48.2, 47.4, 44.3, 32.8, 14.0; HRMS–ESI (*m*/*z*): $[M+H]^+$ calcd for $C_{32}H_{37}N_2O_3$: 497.2799. Found: 497.2795. Anal. Calcd for $C_{32}H_{38}N_2O_4$ (as $1H_2O$): C, 74.68; H, 7.44; N, 5.44. Found: C, 74.83; H, 7.15; N, 5.47.

(*E*)-2-(2-Cinnamylpiperidin-1-yl)-*N*-methyl-*N*-phenylpropanamide (9): colorless gum; $[\alpha]^{23}_{589}$ –69.7 (*c* 1.00, EtOH); IR (KBr) 3058, 3025, 2931, 2850, 2797, 2751, 1656, 1594, 1494, 1451, 1418, 1383, 1302, 1260, 1210, 1154, 1111, 1029, 991, 971, 926, 861, 773, 744, 699 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.46-7.15 (10H, m, ArH), 6.43 (1H, d, *J* = 15.9 Hz, CH=C*H*Ph), 5.85 (1H, dd, *J* = 15.9, 10.2 Hz, C*H*=CHPh), 3.41-3.28 (1H, m, NCHCO), 3.32 (3H, s, NCH_3), 2.77-2.64 (1H, m, CH_2), 2.39-2.18 (4H, m, CH_2), 1.62-1.42 (4H, m, CH_2), 1.40-1.27 (2H, m, CH_2), 0.97 (3H, d, *J* = 6.4 Hz, CHCH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ 176.2, 144.5, 136.9, 134.2, 129.4, 128.4, 127.4, 127.3, 127.1, 126.3, 126.2, 71.6, 50.7, 38.7, 37.3, 26.7, 24.8, 16.1; HRMS–ESI (*m*/*z*): $[M+H]^+$ calcd for $C_{24}H_{31}N_2O$: 363.2431. Found: 363.2424. Anal. Calcd for $C_{24}H_{31}N_2O_{1.5}$: C, 77.59; H, 8.41; N, 7.54 (as $0.5H_2O$). Found: C, 77.98; H, 8.18; N, 7.58.

Determination of absolute configuration of 4 by conversion to the known compound 8

The absolute configuration of the major diastereomer of **8** was determined to be (4*R*,1'*S*) by comparison of the ^{1}H NMR spectrum, the value of the optical rotation, and HPLC retention time with that reported for **8**.[1] Therefore, the absolute configuration of major diastereomer of **4** was determined to be (2*R*,3*S*). The relative stereochemistry of major diastereomer of **4** was confirmed as the *rel*-(2*R*,3*S*) by a single crystal X-ray diffraction. CCDC-995320 contains the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data_request/cif.

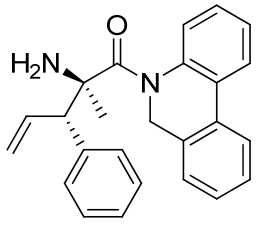


(Step 1) A solution of **4** (116 mg, 0.234 mmol) in THF (2.3 mL) was treated with 1 M hydrochloric acid (2.3 mL) at room temperature and the mixture was stirred for 9 h at room temperature. The resulting mixture was treated with saturated aqueous sodium hydrogen carbonate and extracted with dichloromethane. The combined extracts were washed with brine, dried over sodium sulfate, and concentrated to obtain 1-(-2-methyl-1-oxo-1-(phenanthridin-5(6*H*)-yl)-3-phenylpent-4-en-2-yl)piperidin-4-one (**5**) (108 mg, quant.) as a white

[1] (a) Chen, W.; Hartwig, J. F. *J. Am. Chem. Soc.* **2013**, *135*, 2068–2071. (b) Kawatsura, M.; Tsuji, H.; Uchida, K.; Itoh, T. *Tetrahedron* **2011**, *67*, 7686–7691.

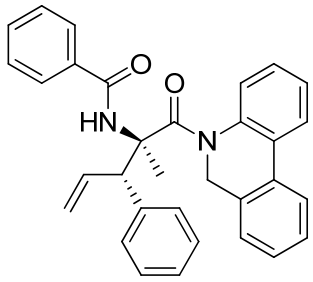
solid. The crude product was used without purification. (Step 2) A mixture of **5** (108 mg), ammonium chloride (15 mg, 0.28 mmol), aminomethylated polystyrene EHL (200–400 mesh), 2% DVB (substitution: 3.9 mmol/g, 90 mg), ethanol (2.3 mL), and dichloromethane (2.3 mL) was heated at 100 °C for 24 h in an Ace pressure tube (Aldrich). The resulting mixture was cooled to room temperature and filtered through a pad of Celite. The filtrate was treated with saturated aqueous sodium hydrogen carbonate and extracted with dichloromethane. The combined extracts were washed with brine, dried over sodium sulfate, and concentrated. Purification of the residue by chromatography on silica gel (dichloromethane/methanol = 50/1 as the eluent) gave 2-amino-2-methyl-1-(phenanthridin-5(6*H*)-yl)-3-phenylpent-4-en-1-one (**6**) (67.6 mg, 78%) as a white solid. (Step 3) A solution of **6** (67.2 mg, 0.182 mmol), pyridine (58 μL, 0.72 mmol), and 4,4-dimethylaminopyridine (2 mg, 0.02 mmol) in dichloromethane (1.8 mL) was treated with benzoyl chloride (64 μL, 0.55 mmol) at 0 °C and the mixture was stirred for 3 h at the same temperature. The resulting mixture was treated with 1 M hydrochloric acid and extracted with dichloromethane. The combined extracts were washed with saturated aqueous sodium hydrogen carbonate and brine. The dichloromethane solution was dried over sodium sulfate and concentrated. Purification of the residue by chromatography on silica gel (dichloromethane/ethyl acetate = 20/1 to 10/1 as the eluent) gave *N*-(2-methyl-1-oxo-1-(phenanthridin-5(6*H*)-yl)-3-phenylpent-4-en-2-yl)benzamide (**7**) (73.8 mg, 86%) as colorless crystals. (Step 4) Ammonium cerium(IV) nitrate (CAN) (0.26 g, 0.47 mmol) was added to a solution of **7** (73.8 mg, 0.156 mmol) in acetonitrile (1.6 mL) and dichloromethane (0.8 mL) at 0 °C. After stirring for 12 h at the same temperature, the resulting mixture was diluted with water and extracted with ethyl acetate. The combined extracts were washed with saturated aqueous sodium hydrogen carbonate and brine. The ethyl acetate solution was dried over sodium sulfate and concentrated. The residue was purified by chromatography on silica gel (*n*-hexane/ethyl acetate = 10/1 as the eluent) to obtain 4-methyl-2-phenyl-4-(1'-phenylallyl)oxazol-5(4*H*)-one (**8**) (36.0 mg, 79%) as a colorless oil.

2-Amino-2-methyl-1-(phenanthridin-5(6*H*)-yl)-3-phenylpent-4-en-1-one (6): white solid; $[\alpha]^{22}_{589}$ +81.3 (*c* 1.00, $CHCl_3$); IR (KBr) 3368, 3306, 3062, 3026, 2971, 2927, 2854, 1649, 1600, 1485, 1454, 1441, 1380, 1365, 1311, 1287, 1262, 1219, 1189, 1131, 1093, 991, 920, 871, 832, 764, 737, 701 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ (9/1 mixture of diastereomers) 7.80-7.70 (2H, m, ArH), 7.42-7.18 (11H, m, ArH), 6.39-6.15 (0.1H, m, CHC*H*=CH_2), 6.22 (0.9H, ddd, *J* = 17.1, 10.2, 8.6 Hz, CHC*H*=CH_2), 5.72 (0.9H, d, *J* = 14.8 Hz, $CONCH_2$), 5.42 (0.1H, d, *J* = 13.6 Hz, $CONCH_2$), 5.24-4.85 (0.3H, m, CHCH=CH_2 and $CONCH_2$) 5.10 (0.9H, dd, *J* = 10.2, 1.2 Hz, CHCH=CH_2), 5.04 (0.9H, dd, *J* = 17.1, 1.2 Hz, CHCH=CH_2), 4.95 (0.9H, s, *J* = 14.8 Hz, $CONCH_2$), 4.05 (0.1H, d, *J* = 9.6 Hz, C*H*CH=CH_2), 4.01 (0.9H, d, *J* = 8.6 Hz, C*H*CH=CH_2), 1.59 (2H, s, NH_2), 1.43 (0.3H, s, CH_3), 1.28 (2.7H, s, CH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ (major diastereomer) 175.0, 139.6, 139.1, 136.8, 134.9, 132.6, 129.7, 129.6, 128.2, 127.7, 127.4, 127.1, 126.1, 125.9, 125.6, 124.1, 123.5, 118.3, 63.0, 58.0, 49.4, 26.7; HRMS–ESI (*m*/*z*): $[M+H]^+$ calcd for $C_{25}H_{25}N_2O$: 369.1961. Found: 369.1951. Elemental analysis was not obtained, as a pure sample could not be isolated.



(2*R*,3*S*)-major

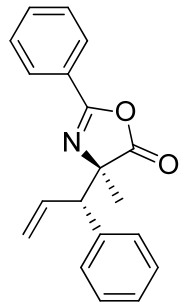
***N*-(2-Methyl-1-oxo-1-(phenanthridin-5(6*H*)-yl)-3-phenylpent-4-en-2-yl)benzamide (7):** colorless crystals;



(2*R*,3*S*)-major

$[\alpha]^{24}_{589}$ –58.6 (*c* 1.00, $CHCl_3$); IR (KBr) 3401, 3067, 3028, 2943, 2863, 1659, 1599, 1578, 1505, 1476, 1454, 1442, 1376, 1275, 1224, 1191, 1174, 1142, 1109, 1093, 1069, 1027, 1001, 941, 925, 803, 769, 737, 729, 719, 700 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ (9/1 mixture of diastereomers) 7.85-7.65 (5H, m, ArH), 7.53 (1H, t, *J* = 7.6 Hz, ArH), 7.45 (2H, dd, *J* = 7.6, 7.6 Hz, ArH), 7.38 (1H, t, *J* = 7.6 Hz, ArH), 7.35-7.04 (7H, m, ArH), 7.01 (0.9H, s, NH), 6.96-6.86 (2H, m, ArH), 6.63 (0.1H, s, NH), 6.53 (0.9H, ddd, *J* = 17.0, 10.0, 10.0 Hz, CHC*H*=CH_2), 6.24 (0.1H, ddd, *J* = 16.6, 10.0, 10.0 Hz, CHC*H*=CH_2), 5.54 (0.9H, d, *J* = 17.0 Hz, CHCH=CH_2), 5.53 (0.9H, d, *J* = 10.0 Hz, CHCH=CH_2), 5.26 (1H, d, *J* = 14.0 Hz, $CONCH_2$), 4.96 (0.1H, d, *J* = 10.0 Hz, CHCH=CH_2), 4.83 (1H, d, *J* = 14.0 Hz, $CONCH_2$), 4.54 (0.1H, d, *J* = 16.6 Hz, CHCH=CH_2), 4.16 (1H, d, *J* = 10.0 Hz, C*H*CH=CH_2), 1.74 (0.3H, s, CH_3), 1.65 (2.7H, s, CH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ (major diastereomer) 169.0, 165.5, 138.6, 137.0, 136.6, 134.0, 133.9, 132.6, 131.8, 129.3, 128.8, 128.6, 128.4, 128.2, 127.52, 127.48, 127.4, 126.8, 126.5, 125.6, 125.2, 123.8, 123.7, 120.5, 62.8, 56.3, 48.9, 20.3; HRMS–ESI (*m*/*z*): $[M+Na]^+$ calcd for $C_{32}H_{28}N_2O_2Na$: 495.2043. Found: 495.2038. Anal. Calcd for $C_{32}H_{28}N_2O_2$: C, 81.33; H, 5.97; N, 5.93. Found: C, 81.32; H, 6.01; N, 6.04.

4-Methyl-2-phenyl-4-(1'-phenylallyl)oxazol-5(4*H*)-one (8): colorless oil; $[\alpha]^{20}_{589}$ +50.1 (*c* 0.70, CH_2Cl_2);

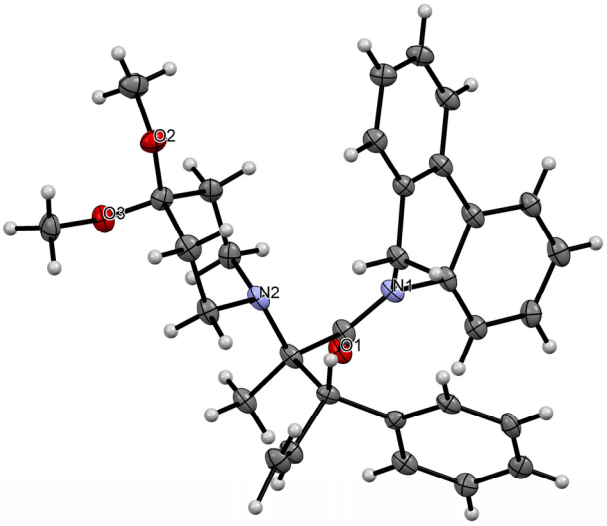


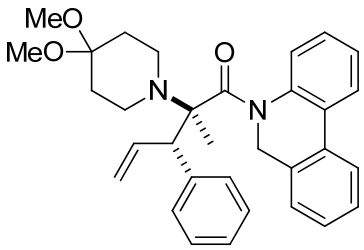
(4*R*,1'*S*)-major

(4*S*,1'*S*)/(4*R*,1'*R*)/(4*R*,1'S)/(4*S*,1'*R*) = 0.9/7.9/82.1/9.1 [determined by HPLC analysis: Daicel Chiralcel OJ–H column, *n*-hexane/2-propanol = 90/10 as the eluent, flow rate = 0.50 mL/min, t_R = 14.4 min for (4*S*,1'*S*)-**8**, 17.9 min for (4*R*,1'*R*)-**8**, 37.8 min for (4*R*,1'*S*)-**8**, and 45.3 min for (4*S*,1'*R*)-**8**]; IR (film) 3062, 3031, 2978, 2930, 2866, 1817, 1654, 1601, 1580, 1492, 1451, 1417, 1371, 1341, 1320, 1294, 1214, 1198, 1155, 1089, 1070, 1030, 1005, 927, 911, 876, 830, 817, 779, 756, 709 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ (9/1 mixture of diastereomers) 8.01 (1.8H, dd, *J* = 7.6, 1.2 Hz, ArH), 7.88 (0.2H, dd, *J* = 8.0, 1.2 Hz, ArH), 7.61-7.40 (4.8H, m, ArH), 7.33 (1.8H, dd, *J* = 7.6, 7.6 Hz, ArH), 7.26 (0.9H, t, *J* = 7.6 Hz, ArH), 7.20-7.09 (0.5H, m, ArH), 6.38 (0.1H, ddd, *J* = 17.0, 9.8, 9.8 Hz, CHC*H*=CH_2), 6.01 (0.9H, ddd, *J* = 16.8, 9.8, 9.8 Hz, CHC*H*=CH_2), 5.32 (0.1H, d, *J* = 9.8 Hz, CHCH=CH_2), 5.30 (0.1H, d, *J* = 17.0 Hz, CHCH=CH_2), 5.19 (0.9H, d, *J* = 16.8 Hz, CHCH=CH_2), 5.09 (0.9H, dd, *J* = 9.8, 1.2 Hz, CHCH=CH_2), 3.72 (0.1H, d, *J* = 9.8 Hz, C*H*CH=CH_2), 3.69 (0.9H, d, *J* = 9.8 Hz, C*H*CH=CH_2), 1.58 (0.3H, s, CH_3), 1.35 (2.7H, s, CH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ (major diastereomer) 180.6, 159.8, 138.3, 135.5, 132.6, 129.1, 128.7, 128.5, 127.9, 127.4, 125.8, 118.9, 73.5, 57.5, 22.4; HRMS–ESI (*m*/*z*): $[M+H]^+$ calcd for $C_{19}H_{18}NO_2$: 292.1332. Found: 292.1326.

Crystal data of *rel*-(2*R*,3*S*)-2-(4,4-dimethoxypiperidin-1-yl)-2-methyl-1-(phenanthridin-5(6*H*)-yl)-3-phenylpent-4-en-1-one (*rac*-4): Recrystallization of *rac*-**4** [*rel*-(2*R*,3*S*)/(2*R*,3*R*) = 9/1] from ethanol gave a single crystal suitable for X-ray crystallographic analysis as a diastereomerically pure form. CCDC-995320 contains the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data_request/cif.

Empirical Formula	$C_{32}H_{36}N_2O_3$
Formula Weight	496.65
Crystal System	triclinic
Lattice Parameters	a = 11.0902(3) Å
	b = 11.2800(3) Å
	c = 12.2160(3) Å
	α = 92.946(2)°
	β = 100.863(1)°
	γ = 117.888(2)°
	V = 1309.26(6) Å^3
Space Group	P-1 (#2)
Z value	2
Temperature	143 K
No. of Reflections Measured	Total: 10975
	Unique: 5557 (R_{int} = 0.0199)
Residuals: R_1 ($I > 2.00\sigma(I)$)	0.1041
Residuals: wR_2 (All reflections)	0.3840
Goodness of Fit Indicator	0.864





rel-(2*R*,3*S*)-**4**

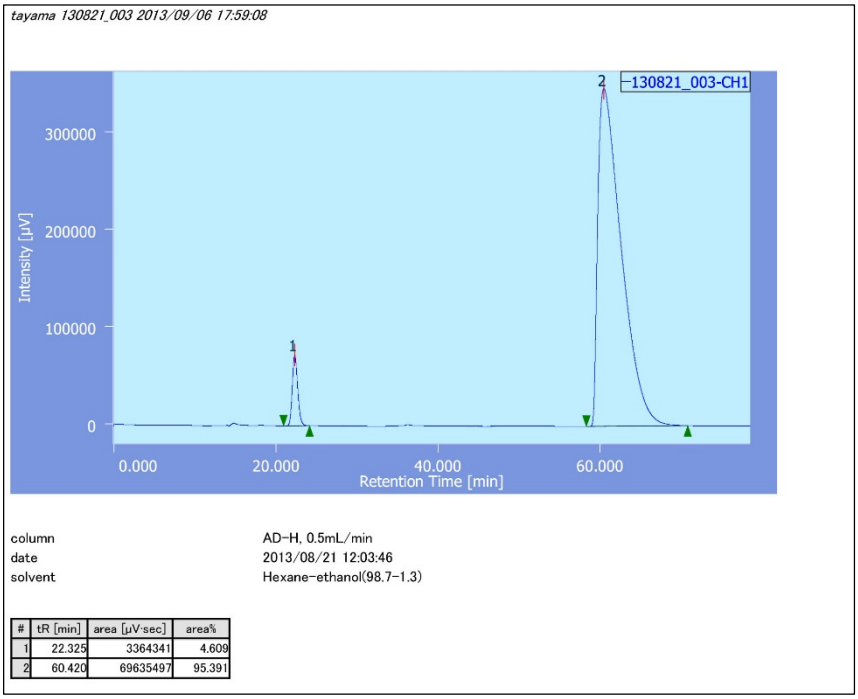
Molecular structure of *rac*-**4**

Determination of enantiomer excess (ee) of 2 and 4 by chiral HPLC analysis

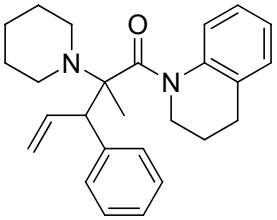
The ee of **2** and **4** were determined by HPLC analysis using chiral column (Daicel) in comparison with the corresponding chromatogram of racemic compounds. The racemic [2,3] Stevens rearrangement products (*rac*-**2** and *rac*-**4**) were obtained by the reaction of racemic substrates (*rac*-**1** and *rac*-**3**).

Representative HPLC data of [2,3] Stevens rearrangement product 2d, 2n, and 4

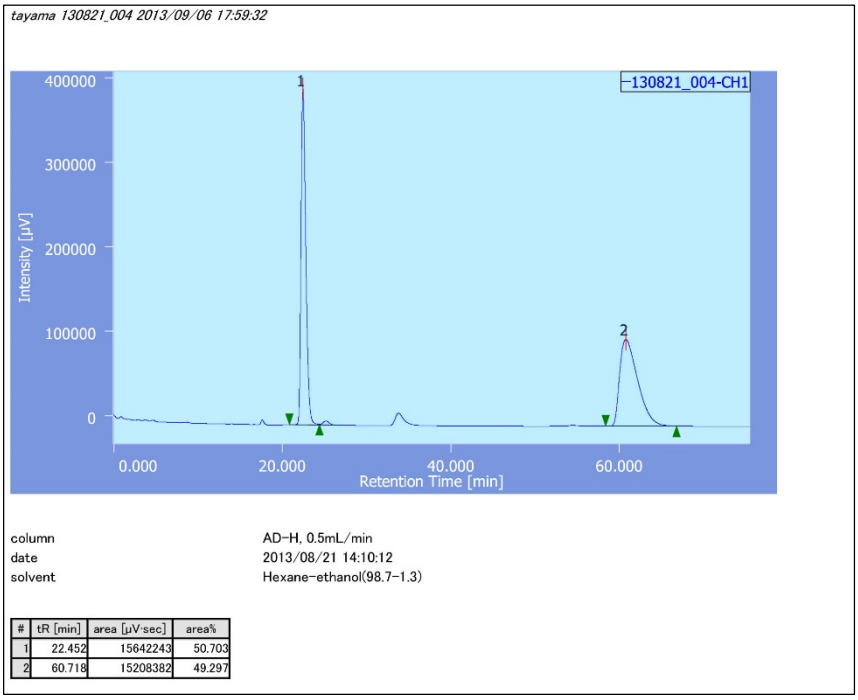
2d: 91% ee [Daicel Chiralpak AD–H column, *n*-hexane/ethanol = 98.7/1.3 as the eluent (pre-eluted with *n*-hexane/2-propanol = 90/10), flow rate = 0.50 mL/min, t_R = 22.3 min for minor-**2d** and 60.4 min for major-**2d**]



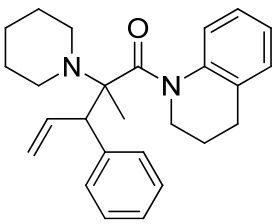
#	tR [min]	area [μV·sec]	area%
1	22.325	3364341	4.609
2	60.420	69635497	95.391



2d
91% ee
(Table 2, Entry 9)

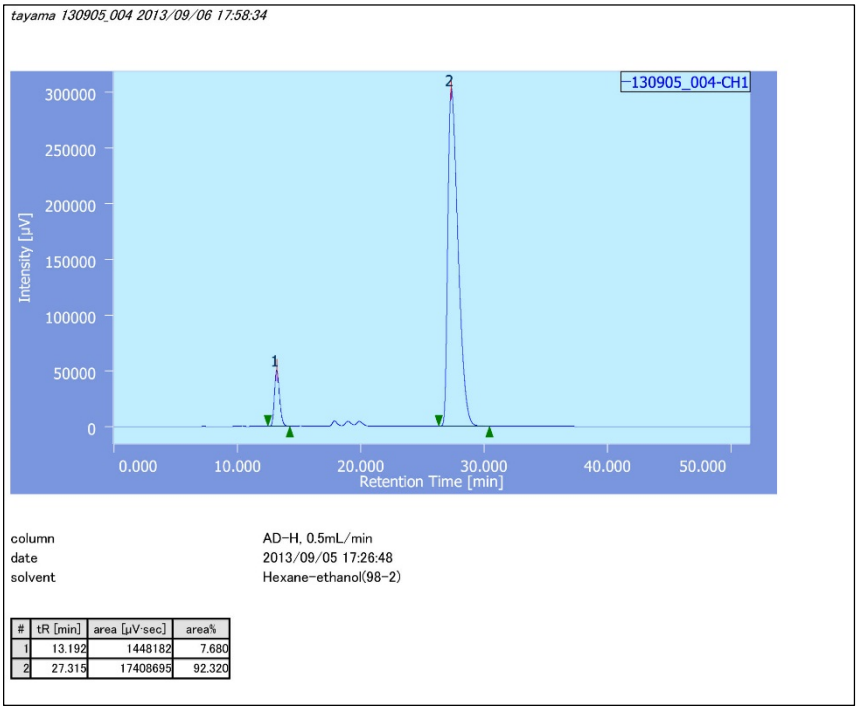


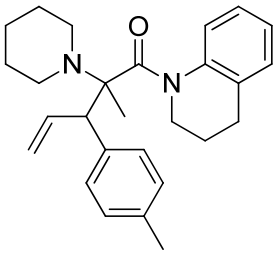
#	tR [min]	area [μV·sec]	area%
1	22.452	15642243	50.703
2	60.718	15208382	49.297



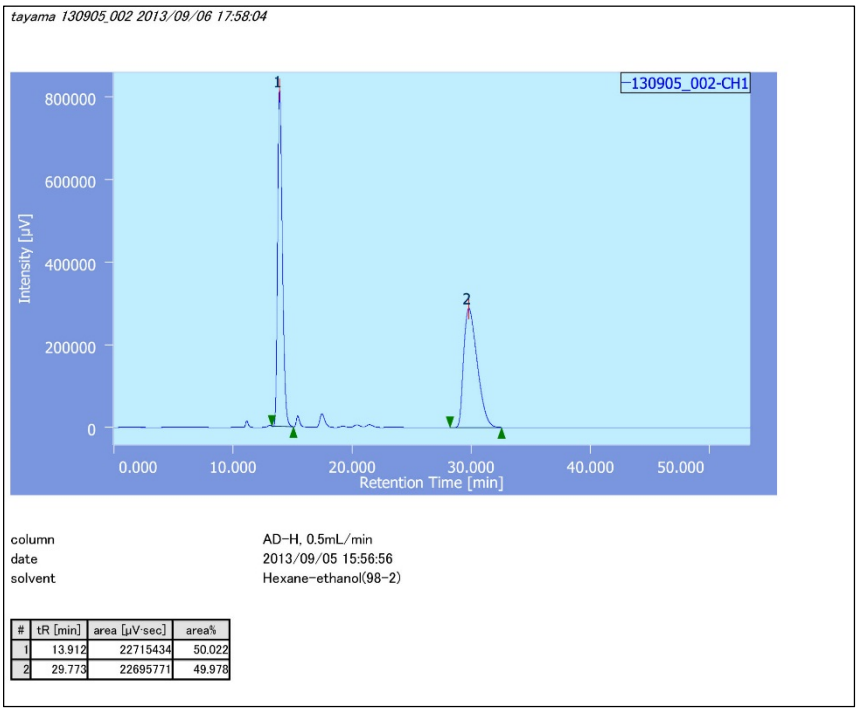
rac-**2d**

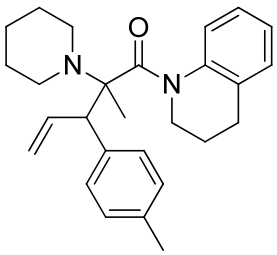
2n: 85% ee (Daicel Chiralpak AD–H column, *n*-hexane/ethanol = 98/2 as the eluent, flow rate = 0.50 mL/min, t_R = 13.2 min for minor-**2n** and 27.3 min for major-**2n**)





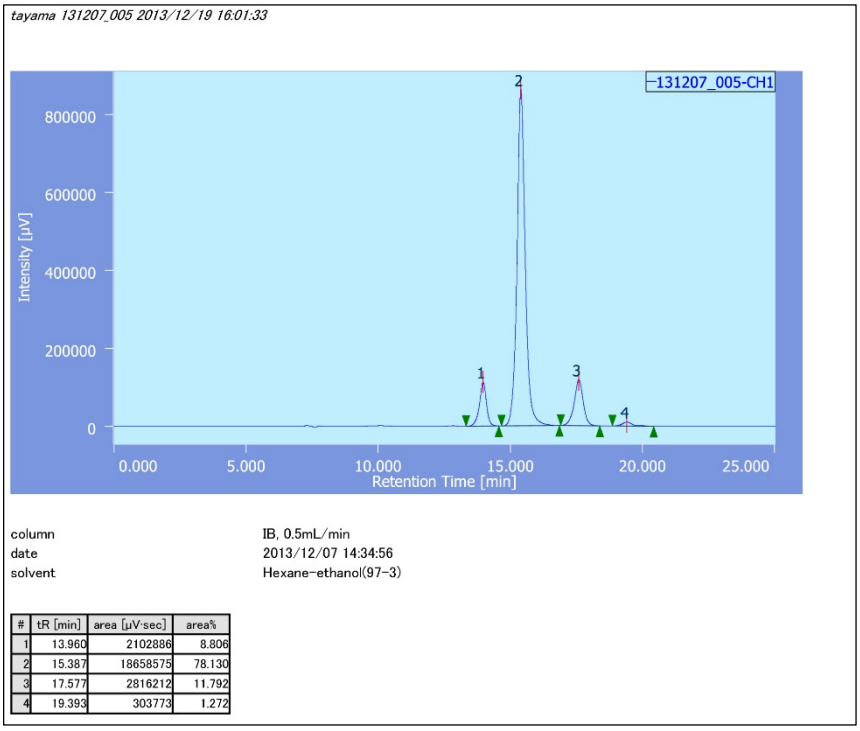
2n
85% ee
(Table 2, Entry 11)



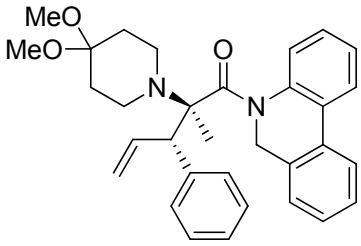


rac-**2n**

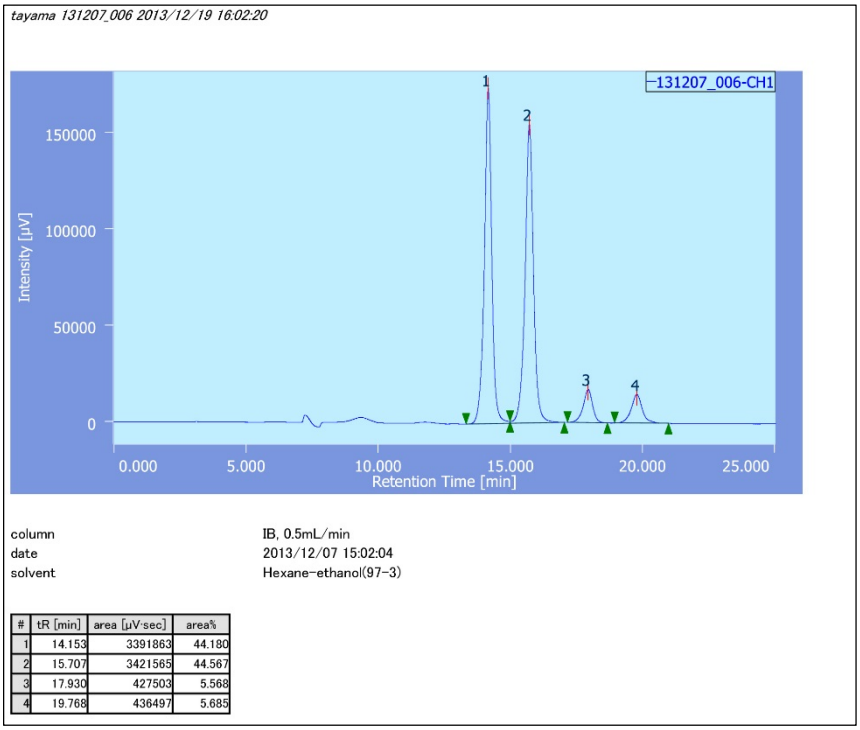
4: 80% ee [(2*R*,3*S*)/(2*S*,3*R*), major diastereomer], 81% ee [(2*R*,3*R*)/(2*S*,3*S*), minor diastereomer]; (2*S*,3*R*)/(2*R*,3*S*)/(2*R*,3*R*)/(2*S*,3*S*) = 8.8/78.1/11.8/1.3 [determined by HPLC analysis: Daicel Chiralpak IB column, *n*-hexane/ethanol = 97/3 as the eluent, flow rate = 0.50 mL/min, t_R = 14.0 min for (2*S*,3*R*)-**4**, 15.4 min for (2*R*,3*S*)-**4**, 17.6 min for (2*R*,3*R*)-**4**, and 19.4 min for (2*S*,3*S*)-**4**]



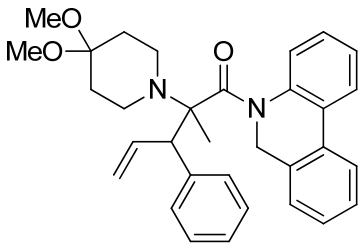
#	tR [min]	area [μV·sec]	area%
1	13.960	2102886	8.806
2	15.387	18658575	78.130
3	17.577	2816212	11.792
4	19.393	303773	1.272



4
80% ee
[(2*R*,3*S*)/(2*S*,3*R*), major]
81% ee
[(2*R*,3*R*)/(2*S*,3*S*), minor]



#	tR [min]	area [μV·sec]	area%
1	14.153	3391863	44.180
2	15.707	3421565	44.567
3	17.930	427503	5.568
4	19.768	436497	5.685

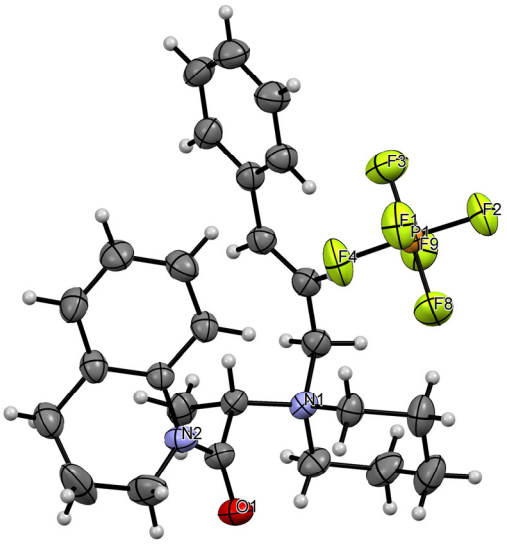


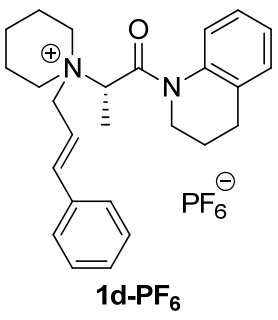
rac-**4**

Single crystal X-ray diffraction of 1d-PF_6

Crystal data of (*S*)-1-cinnamyl-1-(1-(3,4-dihydroquinolin-1(2*H*)-yl)-1-oxopropan-2-yl)piperidin-1-ium hexafluorophosphate (1d-PF_6): Recrystallization from ethanol gave a single crystal suitable for X-ray crystallographic analysis. CCDC-995319 contains the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data_request/cif.

Empirical Formula	$C_{26}H_{33}F_6N_2OP$
Formula Weight	534.52
Crystal System	orthorhombic
Lattice Parameters	a = 11.9319(4) Å
	b = 13.4450(4) Å
	c = 16.1494(6) Å
	V = 2590.8(2) $Å^3$
Space Group	$P2_12_12_1$ (#19)
Z value	4
Temperature	296 K
No. of Reflections Measured	Total: 22049
	Unique: 5605 (R_{int} = 0.0237)
	Friedel pairs: 2468
Residuals: R_1 ($I > 2.00\sigma(I)$)	0.0670
Residuals: wR_2 (All reflections)	0.2425
Goodness of Fit Indicator	1.031
Flack Parameter (Friedel pairs = 2468)	0.00(17)

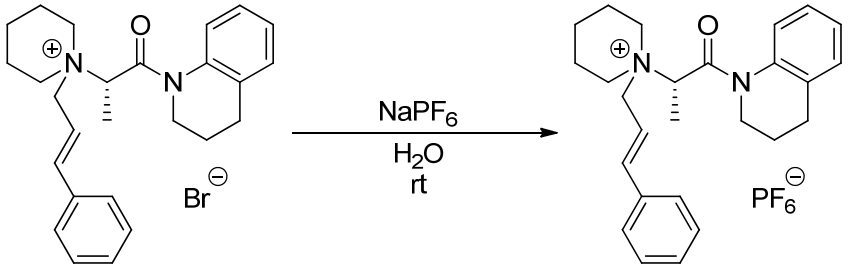




1d-PF_6

Molecular structure of **1d-PF_6**

Preparation of 1d-PF_6



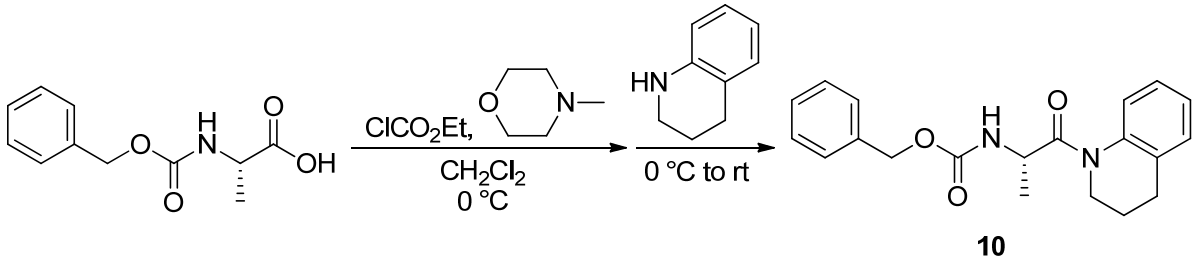
1d **1d-PF_6**

A suspension of **1d** (47 mg, 0.10 mmol) and sodium hexafluorophosphate (20 mg, 0.12 mmol) in water (2 mL) was stirred for 6 h at room temperature. The resulting mixture was diluted with water and extracted with dichloromethane. The dichloromethane solution was dried over sodium sulfate and concentrated to obtain **1d-PF_6** (49 mg, 92%) as colorless crystals. Recrystallization from ethanol gave a single crystal suitable for X-ray crystallographic analysis; mp 209–210 °C; IR (KBr) 3026, 2944, 2873, 1658, 1602, 1580, 1490, 1473, 1459, 1411, 1380, 1356, 1340, 1305, 1290, 1234, 1198, 1128, 1106, 1087, 1076, 990, 943, 924, 846, 761, 695 cm^{-1}; ^1H NMR (400 MHz, DMSO-d_6) δ (8/2 mixture of rotamers) 7.78 (0.2H, d, J = 7.2 Hz, ArH), 7.50 (0.4H, d, J = 7.2 Hz, ArH), 7.45-6.79 (9.4H, m, ArH and CH=C*H*Ph), 6.62-6.47 (0.2H, m, C*H*=CHPh), 6.10-5.90 (0.8H, m, C*H*=CHPh), 4.88-4.74 (0.8H, m, NCHCO), 4.74-4.63 (0.2H, m, NCHCO), 4.56 (0.8H, dd, J = 14.0, 6.0 Hz, CH_2), 4.47-4.33 (0.2H, m, CH_2), 4.24-3.70 (3H, m, CH_2), 3.67-3.37 (2.4H, m, CH_2), 3.32-3.12 (1.6H, m, CH_2), 2.77-2.43 (2H, m, CH_2), 2.25-1.32 (11H, m, CH_2 and CHC*H*$_3$); ^{13}C NMR (100 MHz, DMSO-d_6) δ (8/2 mixture of rotamers) 167.4, 166.2, 141.6, 140.1, 136.8, 135.2, 134.8, 131.9, 129.1, 128.8, 128.6, 127.2, 127.0, 126.9, 125.4, 125.2, 124.0, 116.1, 114.8, 64.4, 61.4, 57.1, 56.1, 55.7, 55.4, 55.1, 54.8, 45.1, 43.1, 25.8, 23.4, 20.6, 19.4, 19.1, 18.9, 12.3, 11.7; HRMS–ESI (*m*/*z*): $[M–Br]^+$ calcd for $C_{26}H_{33}N_2O$: 389.2587. Found: 389.2577. Anal. Calcd for $C_{26}H_{33}F_6N_2OP$: C, 58.42; H, 6.22; N, 5.24. Found: C, 58.20; H, 6.26; N, 4.93.

Preparation and characterization of chiral tertiary amine 1' (precursor of 1)

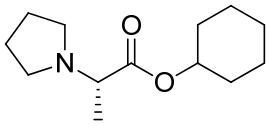
The ee of UV-active **1'** were determined by HPLC analysis using chiral column (Daicel) in comparison with the corresponding chromatogram of racemic compounds (*rac*-**1'**).

Representative procedure for preparation of (*S*)-1-(3,4-dihydroquinolin-1(2*H*)-yl)-2-(piperidin-1-yl)propan-1-one (1d')

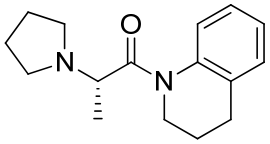


(Step 1) Ethyl chloroformate (0.76 mL, 8.0 mmol) was added to a solution of Cbz-L-alanine (1.79 g, 8.0 mmol) and *N*-methylmorpholine (0.88 mL, 8.0 mmol) in dichloromethane (40 mL) at 0 °C. After stirring for 20 min at the same temperature, 1,2,3,4-tetrahydroquinoline (1.0 mL, 8.0 mmol) was added to the mixture at 0 °C. The reactant was stirred for 30 min at 0 °C and for 7 h at room temperature. The resulting mixture was quenched with saturated aqueous ammonium chloride and extracted with dichloromethane. The combined extracts were washed with brine, dried over sodium sulfate, and concentrated. Purification of the residue by chromatography on silica gel (*n*-hexane/ethyl acetate = 3/1 to 1.5/1 as the eluent) afforded (*S*)-benzyl (1-(3,4-dihydroquinolin-1(2*H*)-yl)-1-oxopropan-2-yl)carbamate (**10**) (2.32 g, 86% yield) as a colorless viscous oil. (Step 2) A mixture of **10** (2.32 g, 6.86 mmol) and palladium on activated carbon (loading: 10 wt. %, 0.15 g) in methanol (34 mL) was stirred for 5 h at room temperature under a hydrogen atmosphere. The resulting mixture was filtered through a pad of Celite and the filtrate was concentrated. A mixture of the residual oil, 1,5-dibromopentane (934 μL, 6.86 mmol), and sodium hydrogen carbonate (2.88 g, 34.3 mmol) in acetonitrile (34 mL) was refluxed for 12 h. The resulting mixture was cooled to room temperature and filtered. The filtrate was concentrated and the residue was purified by chromatography on silica gel (dichloromethane/methanol = 20/1 to 10/1 as the eluent) to obtain **1d'** (1.37 g, 73% yield) as a pale yellow oil. $[\alpha]^{26}_{589}$ –48.3 (*c* 1.00, EtOH); >99% ee [determined by HPLC analysis: Daicel Chiralpak AD–H column, *n*-hexane/ethanol = 97/3 as the eluent, flow rate = 0.50 mL/min, t_R = 13.1 min for (*S*)-**1d'** and 14.8 min for (*R*)-**1d'**]; IR (film) 3036, 2932, 2850, 2802, 2752, 1655, 1603, 1580, 1492, 1454, 1397, 1380, 1292, 1238, 1201, 1166, 1118, 1065, 1036, 935, 861, 758 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.40-7.00 (4H, m, ArH), 4.20-3.40 (3H, br, NCHCO and $CONCH_2$), 2.70 (2H, br, CH_2), 2.41 (4H, br, CH_2), 2.10-1.80 (2H m, CH_2), 1.57-1.31 (6H, br, CH_2), 1.23 (3H, d, J = 6.8 Hz, CH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.5, 139.5, 133.9, 128.3, 126.0, 125.2, 124.3, 59.0, 49.8, 42.3, 26.7, 26.4, 24.5, 24.2, 12.5; HRMS–ESI (*m*/*z*): $[M+H]^+$ calcd for $C_{17}H_{25}N_2O$: 273.1961. Found: 273.1959.

(*S*)-Cyclohexyl 2-(pyrrolidin-1-yl)propanoate (1a'): prepared by the literature[2]; colorless oil; $[\alpha]^{24}_{589}$ –19.5 (*c* 1.00, EtOH); ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.82 (1H, tt, *J* = 9.2, 3.6 Hz, OCH), 3.14 (1H, q, *J* = 7.0 Hz, NCHCO), 2.71-2.58 (4H, m, CH_2), 1.91-1.68 (8H, m, CH_2 and *c*-Hex), 1.60-1.19 (6H, m, *c*-Hex), 1.36 (3H, d, *J* = 7.0 Hz, CH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.3, 72.7, 62.2, 50.9, 31.6, 31.5, 25.3, 23.8, 23.5, 17.5; IR (film) 2937, 2859, 2807, 1728, 1452, 1367, 1320, 1261, 1165, 1080, 1039, 1016, 984, 943, 925, 908, 871, 842, 799, 757 cm^{-1}; HRMS–ESI (*m*/*z*): $[M+H]^+$ calcd for $C_{13}H_{24}NO_2$: 226.1802. Found: 226.1797. Anal. Calcd for $C_{13}H_{23}NO_2$: C, 69.29; H, 10.29; N, 6.22. Found: C, 69.05; H, 10.47; N, 6.12.

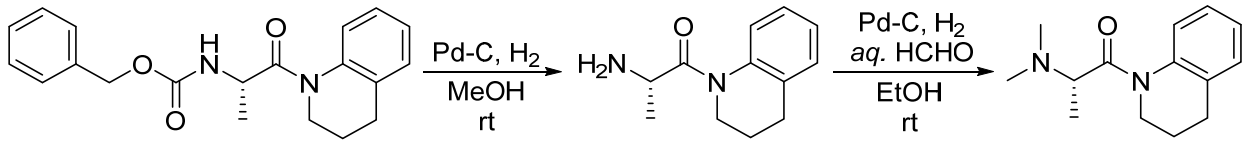


(*S*)-1,2-Di(pyrrolidin-1-yl)propan-1-one (1b'): prepared by the same procedure with **1d'** using pyrrolidine instead of 1,2,3,4-tetrahydroquinoline in step 1 and 1,4-dibromobutane instead of 1,5-dibromopentane in step 2 (78% overall yield); colorless oil; $[\alpha]^{26}_{589}$ –35.4 (*c* 1.00, EtOH); IR (film) 2969, 2875, 2807, 1634, 1432, 1370, 1339, 1252, 1227, 1192, 1165, 1083, 1038, 972, 938, 913, 868, 732 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.60 (1H, dt, *J* = 10.0, 6.8 Hz, $CONCH_2$), 3.55-3.44 (3H, m, $CONCH_2$), 3.28 (1H, q, *J* = 6.8 Hz, NCHCO), 2.69-2.52 (4H, m, CH_2), 2.03-1.89 (2H, m, CH_2), 1.89-1.81 (2H, m, CH_2), 1.81-1.71 (4H, m, CH_2), 1.30 (3H, d, *J* = 6.8 Hz, CH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.1, 60.8, 50.8, 46.4, 45.8, 26.2, 24.0, 23.4, 15.5; HRMS–ESI (*m*/*z*): $[M+H]^+$ calcd for $C_{11}H_{21}N_2O$: 197.1648. Found: 197.1645.



(*S*)-1-(3,4-Dihydroquinolin-1(2*H*)-yl)-2-(pyrrolidin-1-yl)propan-1-one (1c'): prepared by the same procedure with **1d'** using 1,4-dibromobutane instead of 1,5-dibromopentane in step 2 (84% overall yield); pale yellow oil; $[\alpha]^{23}_{589}$ –42.9 (*c* 1.00, EtOH); 98% ee [determined by HPLC analysis: Daicel Chiralpak AD–H column, *n*-hexane/ethanol = 90/10 as the eluent, flow rate = 0.50 mL/min, t_R = 11.7 min for (*R*)-**1c** and 12.7 min for (*S*)-**1c**]; IR (KBr) 2952, 2877, 2844, 2806, 1657, 1603, 1580, 1492, 1455, 1398, 1366, 1289, 1233, 1201, 1164, 1132, 1070, 946, 859, 761 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.27-7.03 (4H, br, ArH), 4.03 (1H, q, *J* = 6.7 Hz, NCHCO), 3.88 (1H, br, $CONCH_2$), 3.76 (1H, br, $CONCH_2$), 2.86 (2H, br, CH_2), 2.70 (4H, br, CH_2), 2.08-1.90 (2H, m, CH_2), 1.83 (4H, br, CH_2), 1.38 (3H, br, CH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ 171.9, 138.6, 134.4, 128.5, 126.4, 125.9, 124.5, 57.1, 50.2, 42.5, 26.5, 24.0, 23.4, 15.8; HRMS–ESI (*m*/*z*): $[M+H]^+$ calcd for $C_{16}H_{23}N_2O$: 259.1805. Found: 259.1803.

(*S*)-1-(3,4-Dihydroquinolin-1(2*H*)-yl)-2-(dimethylamino)propan-1-one (1e'):



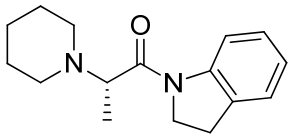
10 **11** (crude) **1e'**

(Step 1) A mixture of **10** (2.41 g, 7.1 mmol) and palladium on activated carbon (loading: 10 wt. %, 0.15 g) in methanol (36 mL) was stirred for 42 h at room temperature under a hydrogen atmosphere. The resulting mixture was filtered through a pad of Celite and the filtrate was concentrated to obtain crude (*S*)-2-amino-1-(3,4-dihydroquinolin-1(2*H*)-yl)propan-1-one (**11**) (1.34 g, 92% yield) as a pale yellow oil. (Step 2) A mixture

[2] Tayama, E.; Igarashi, T.; Iwamoto, H.; Hasegawa, E. *Org. Biomol. Chem.* **2012**, *10*, 339–345.

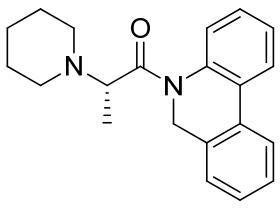
of **11** (409 mg, 2.0 mmol), palladium on activated carbon (loading: 10 wt. %, 42 mg), and formaldehyde solution (37 wt.% in water, 1.6 mL, 20 mmol) in ethanol (10 mL) was stirred for 10 h under a hydrogen atmosphere. The resulting mixture was filtered through a pad of Celite and the filtrate was diluted with water. The mixture was extracted with ethyl acetate and the combined extracts were washed with brine. The ethyl acetate solution was dried over sodium sulfate and concentrated. The residue was purified by chromatography on silica gel (dichloromethane/methanol = 20/1 to 10/1 as the eluent) to obtain **1e'** (336 mg, 72% yield) as a colorless oil. $[\alpha]^{25}_{589}$ –79.4 (*c* 1.00, EtOH); 99% ee [determined by HPLC analysis: Daicel Chiralpak AD–H column, *n*-hexane/2-propanol = 95/5 as the eluent, flow rate = 0.50 mL/min, t_R = 15.7 min for (*S*)-**1e'** and 20.1 min for (*R*)-**1e'**]; IR (film) 3036, 2937, 2866, 2825, 2783, 1655, 1604, 1579, 1492, 1458, 1390, 1288, 1236, 1199, 1171, 1089, 1058, 1047, 966, 942, 804, 759 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.39-7.04 (4H, m, ArH), 4.00-3.60 (3H, br, NCHCO and $CONCH_2$), 2.70 (2H, br, CH_2), 2.26 (6H, s, $N(CH_3)_2$), 2.10-1.85 (2H, m, CH_2), 1.23 (3H, d, *J* = 6.8 Hz, $CHCH_3$); ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.4, 139.2, 133.9, 128.3, 126.1, 125.2, 124.4, 58.2, 42.3, 41.0, 26.7, 24.1, 13.5; HRMS–ESI (*m*/*z*): $[M+H]^+$ calcd for $C_{14}H_{21}N_2O$: 233.1648. Found: 233.1647.

(*S*)-1-(Indolin-1-yl)-2-(piperidin-1-yl)propan-1-one (1f'): prepared by the same procedure with **1d'** using



indoline instead of 1,2,3,4-tetrahydroquinoline in step 2 (56% overall yield); pale yellow crystals; $[\alpha]^{28}_{589}$ –20.8 (*c* 1.00, EtOH); >99% ee [determined by HPLC analysis: Daicel Chiralpak AD–H column, *n*-hexane/ethanol = 90/10 as the eluent, flow rate = 0.50 mL/min, t_R = 11.7 min for (*S*)-**1f'** and 14.1 min for (*R*)-**1f'**]; IR (KBr) 3024, 2981, 2934, 2851, 2786, 2747, 1652, 1596, 1482, 1460, 1441, 1406, 1383, 1337, 1302, 1281, 1211, 1172, 1154, 1123, 1112, 1088, 1068, 1036, 955, 933, 886, 860, 784, 762, 756 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 8.27 (1H, d, *J* = 7.6 Hz, ArH), 7.23-7.15 (2H, m, ArH), 7.01 (1H, ddd, *J* = 7.6, 7.6, 1.0 Hz, ArH), 4.63 (1H, ddd, *J* = 10.0, 10.0, 7.6 Hz, $CONCH_2$), 4.02 (1H, ddd, *J* = 10.0, 10.0, 7.6 Hz, $CONCH_2$), 3.50 (1H, q, *J* = 6.8 Hz, NCHCO), 3.24-3.08 (2H, m, CH_2), 2.68-2.54 (2H, m, CH_2), 2.54-2.42 (2H, m, CH_2), 1.62-1.47 (4H, m, CH_2), 1.47-1.36 (2H, m, CH_2), 1.23 (3H, d, *J* = 6.8 Hz, CH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ 171.1, 143.5, 131.4, 127.3, 124.4, 123.5, 117.2, 63.2, 49.9, 47.6, 28.3, 26.4, 24.4, 9.0; HRMS–ESI (*m*/*z*): $[M+H]^+$ calcd for $C_{16}H_{23}N_2O$: 259.1805. Found: 259.1800.

(*S*)-1-(Phenanthridin-5(6*H*)-yl)-2-(piperidin-1-yl)propan-1-one (1g'): prepared by the same procedure



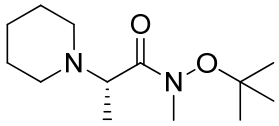
with **1d'** using 5,6-dihydrophenanthridine instead of 1,2,3,4-tetrahydroquinoline in step 2 (58% overall yield); colorless gum; $[\alpha]^{24}_{589}$ –80.6 (*c* 1.00, EtOH); 99% ee [determined by HPLC analysis: Daicel Chiralcel OD–H column, *n*-hexane/ethanol = 95/5 as eluent, flow rate = 0.50 mL/min, t_R = 15.1 min for (*R*)-**1g'** and 22.4 min for (*S*)-**1g'**]; IR (film) 3069, 3035, 2934, 2852, 2805, 2755, 1659, 1603, 1488, 1443, 1398, 1382, 1306, 1265, 1227, 1190, 1165, 1123, 1097, 1036, 996, 946, 909, 762, 736 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.82-7.72 (2H, m, ArH), 7.56 (1H, br, ArH), 7.41-7.23 (5H, m, ArH), 5.50-4.40 (2H, br, NCHCO and $CONCH_2$), 3.81 (1H, br, $CONCH_2$), 2.70-2.00 (4H, br, CH_2), 1.70-1.00 (9H, br, CH_2 and CH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.2, 138.4, 135.3, 132.0, 129.7, 127.9, 127.5, 126.0, 124.3, 123.1, 58.4, 49.4, 45.2, 26.2, 24.3, 11.1; HRMS–ESI (*m*/*z*): $[M+H]^+$ calcd for $C_{21}H_{25}N_2O$: 321.1961. Found: 321.1956.

(*S*)-*N*-Methyl-*N*-phenyl-2-(piperidin-1-yl)propanamide (1h'): prepared by the same procedure with **1d'** using *N*-methylaniline instead of 1,2,3,4-tetrahydroquinoline in step 2 (60% overall yield); pale yellow oil; $[\alpha]^{25}_{589}$ –22.6 (*c* 1.00, EtOH); >99% ee [determined by HPLC analysis: Daicel Chiralcel OD–H column, *n*-hexane/ethanol = 99/1 as the eluent, flow rate = 0.50 mL/min, t_R = 16.0 min for (*S*)-**1h'** and 19.7 min for (*R*)-**1h'**]; IR (film) 3060, 2933, 2852, 2801, 2751, 1659, 1595, 1496, 1452, 1382, 1307, 1267, 1219, 1168, 1117, 1073, 1033, 1000, 946, 894, 862, 772, 734, 701 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.40 (2H, dd, *J* = 7.6, 7.6 Hz, Ph), 7.32 (1H, tt, *J* = 7.6, 1.4 Hz, Ph), 7.22 (2H, dd, *J* = 7.6, 1.4 Hz, Ph), 3.27 (3H, s, NCH_3), 3.21 (1H, q, *J* = 6.8 Hz, NCHCO), 2.52-2.42 (2H, m, CH_2), 2.37-2.27 (2H, m, CH_2), 1.56-1.32 (6H, m, CH_2), 1.14 (3H, d, *J* = 6.8 Hz, CHC*H*$_3$); ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.2, 144.0, 129.4, 127.5, 127.4, 59.2, 50.2, 37.3, 26.3, 24.5, 13.1; HRMS–ESI (*m*/*z*): $[M+H]^+$ calcd for $C_{15}H_{23}N_2O$: 247.1805. Found: 247.1800.

(*S*)-*N*-Benzhydryl-*N*-methyl-2-(piperidin-1-yl)propanamide (1i'): prepared by the same procedure with **1d'** using *N*-(diphenylmethyl)methylamine instead of 1,2,3,4-tetrahydroquinoline in step 2 (42% overall yield); colorless viscous oil; $[\alpha]^{24}_{589}$ –36.5 (*c* 1.00, EtOH); 97% ee [determined by HPLC analysis: Daicel Chiralpak AD–H column, *n*-hexane/2-propanol = 90/10 as the eluent, flow rate = 0.50 mL/min, t_R = 17.0 min for (*S*)-**1i'** and 22.4 min for (*R*)-**1i'**]; IR (film) 3059, 3028, 2933, 2851, 2805, 2755, 1647, 1602, 1494, 1469, 1450, 1398, 1384, 1338, 1279, 1211, 1165, 1121, 1105, 1066, 1033, 1009, 962, 935, 867, 785, 756, 734, 701 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ (5/5 mixture of rotamers) 7.40-7.15 (10.5H, m, Ph and C*H*Ph_2), 7.10 (0.5H, s, C*H*Ph_2), 3.58 (0.5H, q, *J* = 6.8 Hz, NCHCO), 3.53 (0.5H, q, *J* = 6.8 Hz, NCHCO), 2.94 (1.5H, s, NCH_3), 2.72 (1.5H, s, NCH_3), 2.65-2.53 (2H, m, CH_2), 2.51-2.39 (2H, m, CH_2), 1.65-1.48 (4H, m, CH_2), 1.48-1.35 (2H, m, CH_2), 1.19 (1.5H, d, *J* = 6.8 Hz, CHC*H*$_3$), 1.13 (1.5H, d, *J* = 6.8 Hz, CHC*H*$_3$); ^{13}C NMR (100 MHz, $CDCl_3$) δ (5/5 mixture of rotamers) 173.1, 172.9, 140.0, 139.4, 129.3, 129.2, 128.6, 128.3, 128.23, 128.19, 128.0, 127.5, 127.4, 127.30, 127.27, 126.9, 62.7, 61.2, 60.9, 60.2, 49.8, 31.7, 31.0, 26.4, 24.4, 24.3, 8.8, 8.3; HRMS–ESI (*m*/*z*): $[M+H]^+$ calcd for $C_{22}H_{29}N_2O$: 337.2274. Found: 337.2266.

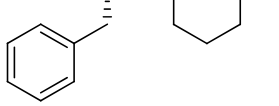
(*S*)-*N*-Methoxy-*N*-methyl-2-(piperidin-1-yl)propanamide (1j'): prepared by the same procedure with **1d'** using and *N*,*O*-dimethylhydroxylamine hydrochloride instead of 1,2,3,4-tetrahydroquinoline in the presence of 2 equivalents of *N*-methylmorpholine in step 2 (51% overall yield); pale red oil; $[\alpha]^{23}_{589}$ –23.4 (*c* 1.00, EtOH); IR (film) 2933, 2853, 2805, 2754, 1663, 1443, 1418, 1383, 1325, 1301, 1271, 1217, 1167, 1119, 1072, 1051, 1036, 1023, 992, 947, 901, 862, 785, 764, 726, 701 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 3.83-3.68 (1H, m, NCHCO), 3.75 (3H, s, OCH_3), 3.20 (3H, s, NCH_3), 2.73-2.57 (2H, m, CH_2), 2.57-2.45 (2H, m, CH_2), 1.64-1.50 (4H, m, CH_2), 1.47-1.38 (2H, m, CH_2), 1.22 (3H, d, *J* = 6.8 Hz, CHC*H*$_3$); ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.6, 61.3, 58.4, 50.4, 31.9, 26.1, 24.4, 12.7; HRMS–ESI (*m*/*z*): $[M+H]^+$ calcd for $C_{10}H_{21}N_2O_2$: 201.1598. Found: 201.1595.

(*S*)-*N*-(*tert*-Butoxy)-*N*-methyl-2-(piperidin-1-yl)propanamide (1k'): prepared by the same procedure with



1d' using and *O*-(*tert*-butyl)-*N*-methylhydroxylamine hydrochloride[3] instead of 1,2,3,4-tetrahydroquinoline and 2 equivalents of *N*-methylmorpholine in step 2 (76% overall yield); pale yellow oil; $[\alpha]^{23}_{589}$ +0.5 (*c* 1.00, EtOH); IR (film) 2977, 2933, 2852, 2805, 2755, 1662, 1467, 1453, 1443, 1407, 1365, 1306, 1271, 1238, 1160, 1117, 1065, 1047, 1035, 1024, 965, 928, 915, 852, 791, 746, 727 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 3.93 (1H, br, NCHCO), 3.28 (3H, s, NCH_3), 2.62 (2H, br, CH_2), 2.52 (2H, br, CH_2), 1.65-1.48 (4H, m, CH_2), 1.48-1.38 (2H, m, CH_2), 1.31 (9H, s, *t*-Bu), 1.23 (3H, d, *J* = 6.8 Hz, $CHCH_3$); ^{13}C NMR (100 MHz, $CDCl_3$) δ 177.3, 82.5, 57.7, 50.4, 38.8, 27.6, 26.4, 24.6, 14.0; HRMS–ESI (*m*/*z*): $[M+H]^+$ calcd for $C_{13}H_{27}N_2O_2$: 243.2067. Found: 243.2061.

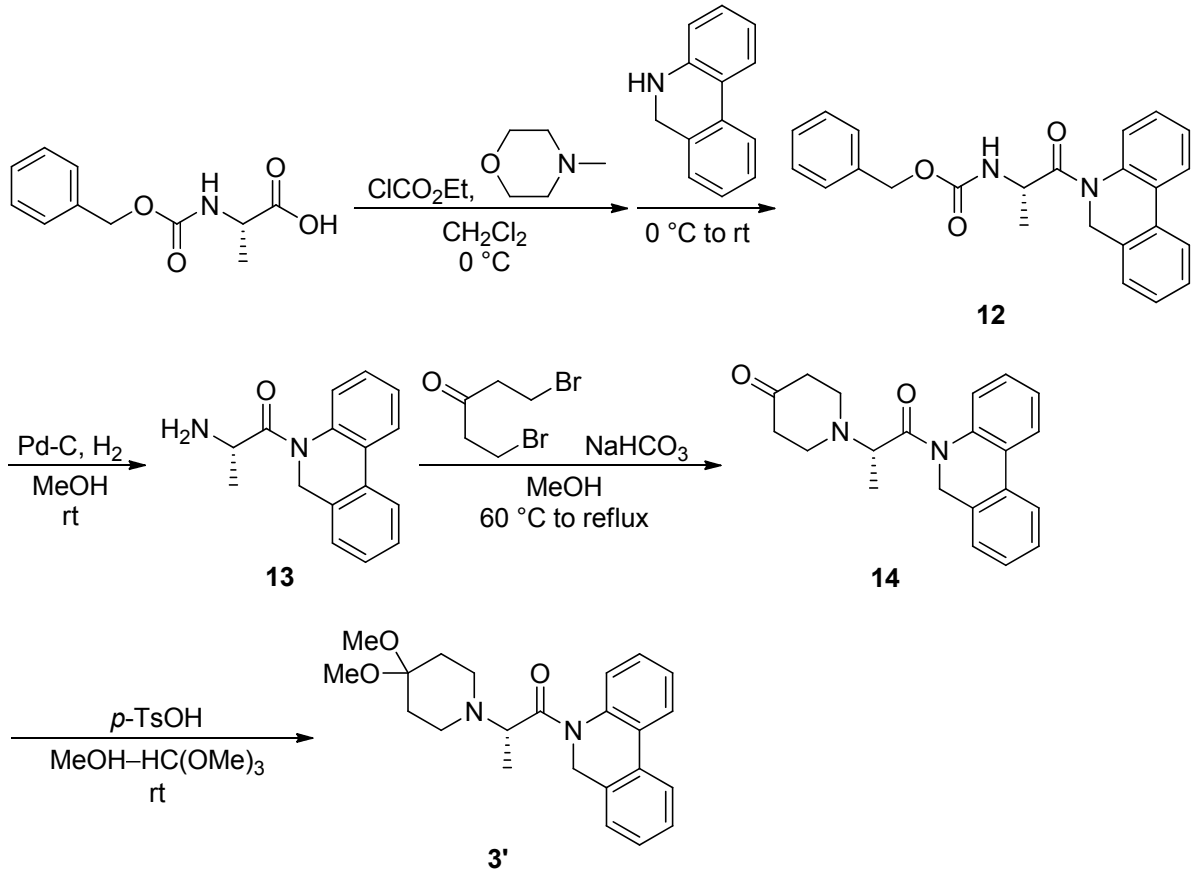
(*S*)-1-(3,4-Dihydroquinolin-1(2*H*)-yl)-3-phenyl-2-(piperidin-1-yl)propan-1-one (1r'): prepared by the same procedure with **1d'** using Cbz-L-phenylalanine instead of Cbz-L-alanine in step 1 (55% overall yield); colorless oil; $[\alpha]^{23}_{589}$ +23.1 (*c* 1.00, EtOH); >99% ee [determined by HPLC analysis: Daicel Chiralpak AD–H column, *n*-hexane/2-propanol = 90/10 as the eluent, flow rate = 0.50 mL/min, t_R = 11.8 min for (*S*)-**1r'** and 16.6 min for (*R*)-**1r'**]; IR (film) 3060, 3026, 2932, 2851, 2804, 2746, 1648, 1603, 1580, 1492, 1453, 1440, 1405, 1380, 1304, 1238, 1201, 1170, 1157, 1115, 1101, 1073, 1046, 1036, 1003, 973, 929, 909, 879, 863, 750, 701 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.27-6.97 (8H, m, ArH), 6.82 (1H, br, ArH), 3.88 (1H, d, *J* = 8.8 Hz, NCHCO or CH_2), 3.79-3.48 (2H, br, NCHCO and/or CH_2), 3.25 (1H, t, *J* = 11.4 Hz, CH_2), 2.81 (1H, d, *J* = 11.4 Hz, CH_2), 2.67 (2H, br, CH_2), 2.49 (3H, br, CH_2), 2.18 (1H, br, CH_2), 1.85-1.71 (1H, m, CH_2), 1.67-1.36 (7H, m, CH_2); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.5, 139.3, 139.2, 133.8, 129.4, 128.2, 127.9, 125.9, 125.8, 125.1, 124.5, 66.2, 50.1, 42.1, 32.5, 26.6, 26.4, 24.6, 24.0; HRMS–ESI (*m*/*z*): $[M+H]^+$ calcd for $C_{23}H_{29}N_2O$: 349.2274. Found: 349.2260.



(*S*)-1-(3,4-Dihydroquinolin-1(2*H*)-yl)-4-methyl-2-(piperidin-1-yl)pentan-1-one (1s'): prepared by the same procedure with **1d'** using Cbz-L-leucine instead of Cbz-L-alanine in step 1 (40% overall yield); colorless oil; $[\alpha]^{23}_{589}$ +43.6 (*c* 1.00, EtOH); 98% ee [determined by HPLC analysis: Daicel Chiralpak AD–H column, *n*-hexane/2-propanol = 95/5 as the eluent, flow rate = 0.50 mL/min, t_R = 10.0 min for (*S*)-**1s'** and 12.2 min for (*R*)-**1s'**]; IR (film) 3035, 2931, 2866, 2850, 2802, 2744, 1655, 1604, 1580, 1492, 1455, 1398, 1379, 1346, 1332, 1292, 1242, 1221, 1199, 1167, 1112, 1070, 1036, 996, 944, 915, 861, 799, 759, 708 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.36 (1H, br, ArH), 7.21-7.05 (3H, m, ArH), 4.00-3.55 (3H, br, NCHCO and CH_2), 2.69 (2H, br, CH_2), 2.52 (2H, br, CH_2), 2.40 (2H, br, CH_2), 2.05-1.87 (2H, m, CH_2), 1.71 (1H, br, CH_2), 1.58-1.32 (8H, m, CH_2 and $CH(CH_3)_2$), 0.85 (3H, br, $CH(CH_3)_2$), 0.75 (3H, br, $CH(CH_3)_2$); ^{13}C NMR (100 MHz, $CDCl_3$) δ 171.9, 139.6, 133.9, 128.1, 125.9, 125.2, 124.6, 61.7, 49.8, 42.2, 34.5, 26.8, 26.7, 25.0, 24.7, 24.3, 22.9, 22.3; HRMS–ESI (*m*/*z*): $[M+H]^+$ calcd for $C_{20}H_{31}N_2O$: 315.2431. Found: 315.2417.

[3] Labeeuw, O.; Phansavath, P.; Genêt, J.-P. *Tetrahedron Lett.* **2004**, *45*, 7107–7110.

(*S*)-1-(3,4-Dihydroquinolin-1(2*H*)-yl)-2-(4,4-dimethoxypiperidin-1-yl)propan-1-one (3')



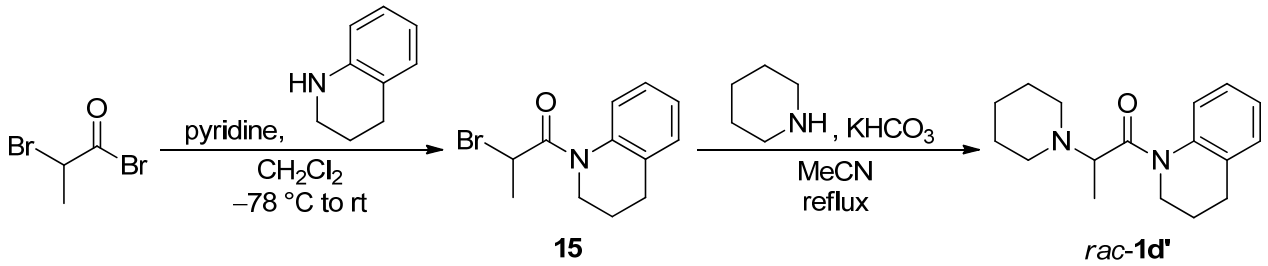
(Step 1) Ethyl chloroformate (0.57 mL, 6.0 mmol) was added to a solution of Cbz-L-alanine (1.34 g, 6.0 mmol) and *N*-methylmorpholine (0.66 mL, 6.0 mmol) in dichloromethane (30 mL) at 0 °C. After stirring for 30 min at the same temperature, a solution of 5,6-dihydrophenanthridine (1.09 g, 6.0 mmol) in dichloromethane (6 mL) was added at 0 °C and the mixture was stirred for 7 h at room temperature. The resulting mixture was quenched with saturated aqueous ammonium chloride and extracted with dichloromethane. The combined extracts were washed with brine, dried over sodium sulfate, and concentrated. Purification of the residue by chromatography on silica gel (dichloromethane/ethyl acetate = 100/0 to 10/1 as the eluent) gave (*S*)-benzyl (1-oxo-1-(phenanthridin-5(6*H*)-yl)propan-2-yl)carbamate (**12**) (1.88 g, 81% yield) as a white solid. (Step 2) A mixture of **12** (1.09 g, 2.82 mmol) and palladium on activated carbon (loading: 10 wt. %, 59 mg) in methanol (14 mL) was stirred for 6 h at room temperature under a hydrogen atmosphere. The resulting mixture was filtered through a pad of Celite and the filtrate was concentrated. The residual was purified by chromatography on silica gel (dichloromethane/methanol = 20/1 to 10/1 as the eluent) to afford (*S*)-2-amino-1-(phenanthridin-5(6*H*)-yl)propan-1-one (**13**) (0.60 g, 84% yield) as a colorless gum. (Step 3) 1,5-Dibromopentan-3-one[4] (0.28 mL, 2.1 mmol) was added to a mixture of **13** (0.54 g, 2.1 mmol) and sodium hydrogen carbonate (0.92 g, 11 mmol) in methanol (11 mL) at 60 °C and the mixture was refluxed for 30 min. The resulting mixture was diluted with water and extracted with ethyl acetate. The combined extracts were

[4] (a) Schumacher, R. A.; Tehim, A.; Xie, W. WO2010024980. (b) Rickerby, J.; Vallet, M.; Bernardinelli, G.; Viton, F.; Kündig, E. P. *Chem. Eur. J.* **2007**, *13*, 3354–3368.

washed with brine, dried over sodium sulfate, and concentrated. Purification of the residue by chromatography on silica gel (*n*-hexane/ethyl acetate = 2/1 to 1/1 as the eluent) afforded (*S*)-1-(1-oxo-1-(phenanthridin-5(6*H*)-yl)propan-2-yl)piperidin-4-one (**14**) (0.53 g, 75% yield) as pale yellow crystals. (Step 4) *p*-Toluenesulfonic acid monohydrate (48 mg, 0.25 mmol) was added to a solution of **14** (71 mg, 0.21 mmol) in methanol (0.5 mL) and trimethyl orthoformate (0.5 mL) at 0 °C. After stirring for 8 h at room temperature, the reactant was treated with saturated aqueous sodium hydrogen carbonate. The mixture was extracted with ethyl acetate and the combined extracts were washed with brine. The ethyl acetate solution was dried over sodium sulfate and concentrated. The residue was purified by chromatography on silica gel (*n*-hexane/ethyl acetate = 2/1 to 1/1 as the eluent) to obtain **3'** (79 mg, 99% yield) as a pale yellow solid. $[\alpha]^{23}_{589}$ –73.0 (*c* 1.00, EtOH); >99% ee [determined by HPLC analysis: Daicel Chiralpak AD–H column, *n*-hexane/ethanol = 80/20 as the eluent, flow rate = 0.50 mL/min, t_R = 12.0 min for (*S*)-**3'** and 18.2 min for (*R*)-**3'**]; IR (film) 3067, 3032, 2941, 2898, 2829, 1659, 1603, 1567, 1488, 1443, 1384, 1310, 1265, 1222, 1189, 1132, 1097, 1053, 1000, 945, 912, 764, 736 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.85-7.20 (8H, m, ArH), 5.60-4.30 (2H, br, $CONCH_2$), 3.84 (1H, br, NCHCO), 3.06 (6H, br, OCH_3), 2.70-2.00 (4H, br, CH_2), 1.95-0.95 (7H, br, CH_2 and $CHCH_3$); ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.1, 138.5, 135.3, 132.0, 129.7, 127.9, 127.8, 127.5, 126.16, 126.05, 124.3, 124.0, 123.1, 98.2, 57.8, 47.3, 45.4, 45.2, 32.5, 10.8; HRMS–ESI (*m*/*z*): $[M+H]^+$ calcd for $C_{23}H_{29}N_2O_3$: 381.2173. Found: 381.2168.

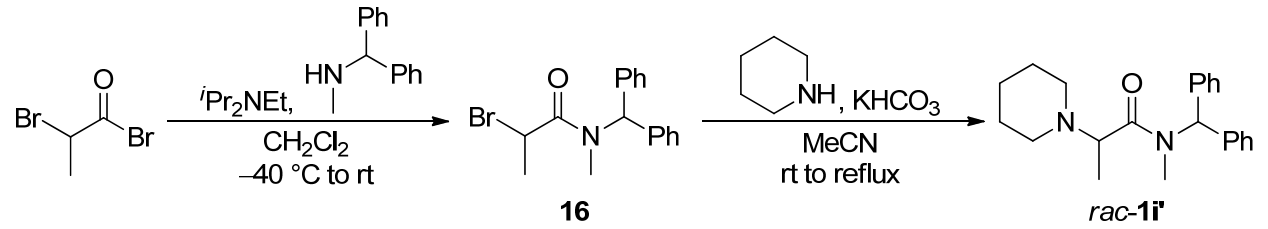
Preparation and characterization of "racemic" tertiary amine *rac*-1' (precursor of *rac*-1)

Representative procedure for preparation of 1-(3,4-dihydroquinolin-1(2*H*)-yl)-2-(piperidin-1-yl)propan-1-one (*rac*-1d')



(Step 1) A solution of 1,2,3,4-tetrahydroquinoline (0.63 mL, 5.0 mmol) and pyridine (0.40 mL, 5.0 mmol) in dichloromethane (25 mL) was treated with 2-bromopropionyl bromide (0.58 mL, 5.5 mmol) at –78 °C and stirred for 15 min. The mixture was allowed to warm at room temperature and stirred for 1.5 h. The resulting mixture was diluted with water and extracted with dichloromethane. The combined extracts were washed with water, dried over sodium sulfate, and concentrated. Purification of the residue by chromatography on silica gel (hexane/ethyl acetate = 6/1 to 4/1 as the eluent) gave 2-bromo-1-(3,4-dihydroquinolin-1(2*H*)-yl)propan-1-one (**15**) (1.34 g, quant.) as a colorless oil. (Step 2) A mixture of **15** (0.50 g, 1.9 mmol), piperidine (0.19 mL, 1.9 mmol), and potassium hydrogen carbonate (0.56 g, 5.6 mmol) in acetonitrile (9 mL) was refluxed for 6 h. The resulting mixture was cooled to room temperature and filtered. The filtrate was concentrated and the residue was purified by chromatography on silica gel (dichloromethane/methanol = 20/1 to 10/1 as the eluent) to obtain *rac*-**1d'** (0.52 g, quant.) as a pale yellow oil.

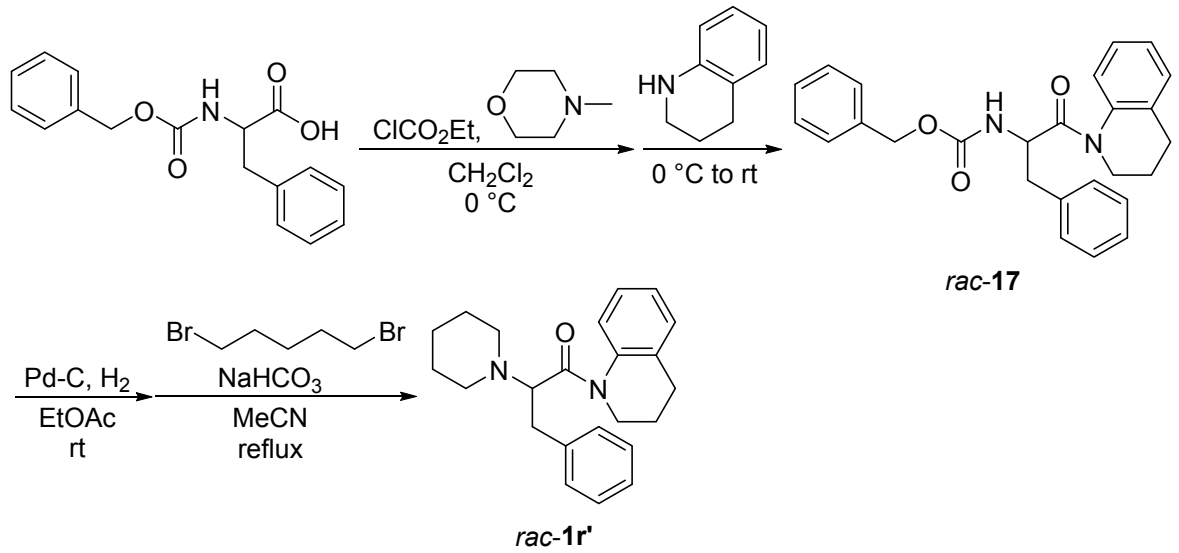
Representative procedure for preparation of *N*-benzhydryl-*N*-methyl-2-(piperidin-1-yl)propanamide (*rac*-1i')



(Step 1) A solution of *N*-(diphenylmethyl)methylamine (0.39 g, 2.0 mmol) and *N*,*N*-diisopropylethylamine (0.35 mL, 2.0 mmol) in dichloromethane (8 mL) was treated with 2-bromopropionyl bromide (0.23 mL, 2.2 mmol) at –40 °C and stirred for 1 h. The mixture was allowed to warm at room temperature and stirred for 3 h. The resulting mixture was diluted with water and extracted with dichloromethane. The combined extracts were washed with water, dried over sodium sulfate, and concentrated. Purification of the residue by chromatography on silica gel (hexane/ethyl acetate = 5/1 as the eluent) gave *N*-benzhydryl-2-bromo-*N*-methylpropanamide (**16**) (0.58 g, 87% yield) as a colorless oil. (Step 2) A mixture of **16** (0.57 g, 1.7 mmol), piperidine (0.21 mL, 2.1 mmol), and potassium hydrogen carbonate (0.53 g, 5.3 mmol) in acetonitrile (5.8 mL) was stirred for 15 h at room temperature and refluxed for 3 h. The resulting mixture was cooled to room temperature and filtered. The filtrate was concentrated and the residue was purified by chromatography on

silica gel (hexane/ethyl acetate = 7/1 to 2/1 as the eluent) to give *rac*-**1i'** (0.56 g, 98% yield) as a colorless viscous oil.

Representative procedure for the preparation of 1-(3,4-dihydroquinolin-1(2*H*)-yl)-3-phenyl-2-(piperidin-1-yl)propan-1-one (*rac*-1r')



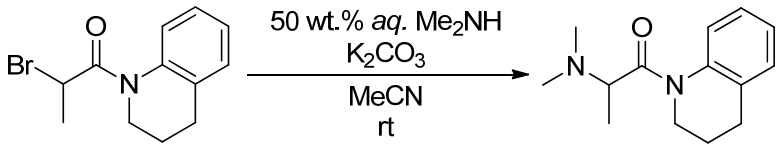
(Step 1) Ethyl chloroformate (0.44 mL, 4.6 mmol) was added to a solution of Cbz-DL-phenylalanine (1.39 g, 4.6 mmol) and *N*-methylmorpholine (0.51 mL, 4.6 mmol) in dichloromethane (9.2 mL) at 0 °C. After stirring for 1 h at the same temperature, 1,2,3,4-tetrahydroquinoline (0.58 mL, 4.6 mmol) was added to the mixture at 0 °C. The reactant was stirred for 30 min at 0 °C and for 14 h at room temperature. The resulting mixture was quenched with saturated aqueous ammonium chloride and extracted with dichloromethane. The combined extracts were washed with brine, dried over sodium sulfate, and concentrated. Purification of the residue by chromatography on silica gel (*n*-hexane/ethyl acetate = 5/1 to 3/1 as the eluent) afforded benzyl (1-(3,4-dihydroquinolin-1(2*H*)-yl)-1-oxo-3-phenylpropan-2-yl)carbamate (*rac*-**17**) (1.24 g, 65% yield) as a colorless viscous oil. (Step 2) A mixture of *rac*-**17** (1.23 g, 3.0 mmol) and palladium on activated carbon (loading: 10 wt.%, 67 mg) in methanol (6 mL) was stirred for 12 h at room temperature under a hydrogen atmosphere. The resulting mixture was filtered through a pad of Celite and the filtrate was concentrated. A mixture of the residual oil, 1,5-dibromopentane (0.45 mL, 3.3 mmol), and sodium hydrogen carbonate (0.75 g, 8.9 mmol) in acetonitrile (8.5 mL) was refluxed for 17 h. The resulting mixture was cooled to room temperature and filtered. The filtrate was concentrated and the residue was purified by chromatography on silica gel (dichloromethane/methanol = 4/1 as the eluent) to obtain *rac*-**1r'** (1.20 g, quant.) as a colorless viscous oil.

Cyclohexyl 2-(pyrrolidin-1-yl)propanoate (*rac*-1a'): prepared from Cbz-DL-alanine by the literature.[2]

1,2-Di(pyrrolidin-1-yl)propan-1-one (*rac*-1b'): prepared by the same procedure with *rac*-**1d'** using pyrrolidine instead of 1,2,3,4-tetrahydroquinoline and piperidine (95% overall yield).

1-(3,4-Dihydroquinolin-1(2*H*)-yl)-2-(pyrrolidin-1-yl)propan-1-one (*rac*-1c'): prepared by the same procedure with *rac*-**1d'** using pyrrolidine instead of piperidine in step 2 (96% overall yield).

1-(3,4-Dihydroquinolin-1(2*H*)-yl)-2-(dimethylamino)propan-1-one (*rac*-1e')



15 *rac*-**1e'**

A mixture of **15** (277 mg, 1.03 mmol) and potassium carbonate (428 mg, 3.1 mmol) in acetonitrile (3.1 mL) was treated with dimethylamine solution (50 wt.% in water, 0.33 mL, 3.1 mmol) at room temperature. After stirring for 18 h at the same temperature, the resulting mixture was filtered and concentrated. The residue was purified by chromatography on silica gel (dichloromethane/methanol = 20/1 to 10/1 as the eluent) to obtain *rac*-**1e'** (218 mg, 91%) as a colorless oil.

1-(Indolin-1-yl)-2-(piperidin-1-yl)propan-1-one (*rac*-1f'): prepared by the same procedure with *rac*-**1d'** using indoline instead of 1,2,3,4-tetrahydroquinoline in step 2 (94% overall yield).

1-(Phenanthridin-5(6*H*)-yl)-2-(piperidin-1-yl)propan-1-one (*rac*-1g'): prepared by the same procedure with *rac*-**1d'** using 5,6-dihydrophenanthridine instead of 1,2,3,4-tetrahydroquinoline in step 1 (98% overall yield).

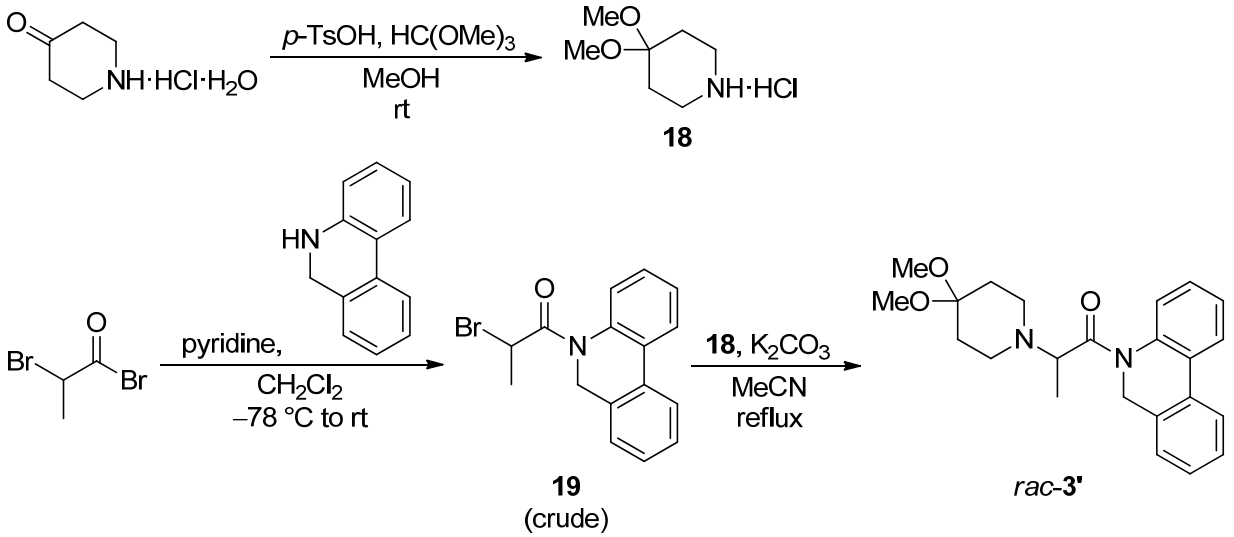
***N*-Methyl-*N*-phenyl-2-(piperidin-1-yl)propanamide (*rac*-1h'):** prepared by the same procedure with *rac*-**1d'** using *N*-methylaniline instead of 1,2,3,4-tetrahydroquinoline in step 1 (98% overall yield).

***N*-Methoxy-*N*-methyl-2-(piperidin-1-yl)propanamide (*rac*-1j'):** prepared by the same procedure with *rac*-**1i'** using *N*,*O*-dimethylhydroxylamine hydrochloride instead of *N*-(diphenylmethyl)methylamine in the presence of 2 equivalents of *N*,*N*-diisopropylethylamine in step 1 (60% overall yield).

***N*-(*tert*-Butoxy)-*N*-methyl-2-(piperidin-1-yl)propanamide (*rac*-1k'):** prepared by the same procedure with *rac*-**1i'** using *O*-(*tert*-butyl)-*N*-methylhydroxylamine hydrochloride[3] instead of *N*-(diphenylmethyl)methylamine in the presence of 2 equivalents of *N*,*N*-diisopropylethylamine in step 1 (69% overall yield).

1-(3,4-Dihydroquinolin-1(2*H*)-yl)-4-methyl-2-(piperidin-1-yl)pentan-1-one (*rac*-1s'): prepared by the same procedure with *rac*-**1r'** using Cbz-DL-leucine instead of Cbz-DL-phenylalanine in step 1 (60% overall yield).

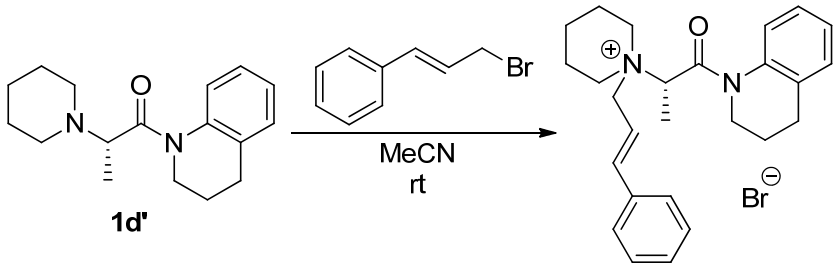
2-(4,4-Dimethoxypiperidin-1-yl)-1-(phenanthridin-5(6*H*)-yl)propan-1-one (*rac*-3')



(Step 1) A mixture of 4-piperidone hydrate hydrochloride (384 mg, 2.50 mmol), *p*-toluenesulfonic acid monohydrate (19 mg, 0.10 mmol), and trimethyl orthoformate (1.4 mL) in methanol (12 mL) was stirred for 22 h at room temperature. The resulting mixture was concentrated to obtain 4,4-dimethoxypiperidine hydrochloride (**18**) (467 mg, quant.) as a white solid. (Step 2) A solution of 5,6-dihydrophenanthridine (725 mg, 4.0 mmol) and pyridine (324 μL, 4.0 mmol) in dichloromethane (20 mL) was treated with 2-bromopropionyl bromide (461 μL, 4.4 mmol) at –78 °C. The mixture was allowed to warm at room temperature and stirred for 1.5 h. The resulting mixture was diluted with water and extracted with dichloromethane. The combined extracts were washed with water, dried over sodium sulfate, and concentrated to obtain **19** as a colorless gum. The product was used without purification. (Step 3) A mixture of **19**, **18** (0.73 g, 4.0 mmol), and potassium carbonate (2.76 g, 20 mmol) in acetonitrile (20 mL) was refluxed for 12 h. The resulting mixture was cooled to room temperature and filtered. The filtrate was concentrated and the residue was purified by chromatography on silica gel (hexane/ethyl acetate = 1.5/1 to 1/1.5 as the eluent) to obtain *rac*-**3'** (1.29 g, 85% yield) as a white solid.

Preparation and characterization of ammonium salt 1

Representative procedure for preparation of (*S*)-1-cinnamyl-1-(1-(3,4-dihydroquinolin-1(2*H*)-yl)-1-oxopropan-2-yl)piperidin-1-ium bromide (1d):



1d' **1d**

A solution of **1d'** (0.771 mg, 2.83 mmol) and cinnamyl bromide (0.51 mL, 3.4 mmol) in acetonitrile (14 mL) was stirred for 60 h at room temperature. Evaporation of the solvent and purification of the residue by chromatography on silica gel (dichloromethane/methanol = 15/1 to 7/1 as the eluent) gave **1d** (1.36 g, quant.) as a pale brown solid. $[\alpha]^{23}_{589}$ –94.1 (*c* 1.00, EtOH); IR (KBr) 3026, 3001, 2945, 2878, 1649, 1579, 1491, 1457, 1416, 1381, 1361, 1288, 1235, 1198, 1072, 992, 924, 865, 755, 696 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ (7/3 mixture of rotamers) 7.70 (0.3H, d, *J* = 8.4 Hz, ArH), 7.56 (0.6H, d, *J* = 6.8 Hz, ArH), 7.42-6.67 (9.4H, m, ArH and C*H*=C*H*Ph), 6.05 (0.7H, dt, *J* = 15.6, 7.6 Hz, C*H*=CHPh), 5.66 (0.3H, q, *J* = 6.8 Hz, NCHCO), 4.91 (0.7H, q, *J* = 6.8 Hz, NCHCO), 4.85-4.74 (0.3H, m, CH_2), 4.64 (1.4H, d, *J* = 7.6 Hz, CH_2), 4.52-4.32 (0.7H, m, CH_2), 4.21-3.39 (5.6H, m, CH_2), 2.77-2.49 (1.7H, m, CH_2), 2.42-2.28 (0.3H, m, CH_2), 2.24-1.43 (8H, m, CH_2), 1.86 (3H, d, *J* = 6.8 Hz, CHC*H*$_3$); ^{13}C NMR (100 MHz, $CDCl_3$) δ (7/3 mixture of rotamers) 167.9, 166.6, 143.6, 141.1, 136.6, 134.6, 134.5, 134.4, 131.9, 129.2, 129.1, 129.0, 128.8, 128.6, 128.4, 127.33, 127.27, 125.4, 124.3, 123.4, 114.8, 113.2, 66.0, 61.6, 57.9, 57.1, 56.2, 55.5, 46.4, 43.0, 26.2, 25.9, 23.6, 23.4, 20.6, 20.2, 19.8, 19.6, 13.7, 13.3; HRMS–ESI (*m*/*z*): $[M–Br]^+$ calcd for $C_{26}H_{33}N_2O$: 389.2587. Found: 389.2582.

(*S*)-1-Cinnamyl-1-(1-(cyclohexyloxy)-1-oxopropan-2-yl)pyrrolidin-1-ium bromide (1a): prepared by the same procedure with **1d** using **1a'** as a substrate (quant.); white solid; $[\alpha]^{24}_{589}$ –38.4 (*c* 1.00, EtOH); IR (KBr) 3029, 2992, 2943, 2857, 1730, 1628, 1484, 1452, 1404, 1388, 1334, 1305, 1278, 1256, 1243, 1209, 1177, 1131, 1091, 1040, 1011, 974, 960, 945, 929, 892, 841, 807, 756, 727, 694 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.54-7.47 (2H, m, Ph), 7.38-7.29 (3H, m, Ph), 7.07 (1H, d, *J* = 15.6 Hz, CH=C*H*Ph), 6.44 (1H, ddd, *J* = 15.6, 7.6, 7.6 Hz, C*H*=CHPh), 4.82 (1H, tt, *J* = 9.0, 4.0 Hz, OCH), 4.76 (1H, q, *J* = 7.2 Hz, NCHCO), 4.65 (1H, dd, *J* = 13.3, 7.6 Hz, C*H*$_2$CH=CH), 4.50 (1H, dd, *J* = 13.3, 7.6 Hz, C*H*$_2$CH=CH), 4.18-3.91 (4H, m, CH_2), 2.43-2.19 (4H, m, CH_2), 1.88-1.76 (2H, m, CH_2), 1.82 (3H, d, *J* = 7.2 Hz, CH_3), 1.75-1.65 (2H, m, CH_2), 1.58-1.18 (6H, m, CH_2); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.5, 142.7, 134.5, 129.2, 128.6, 127.1, 115.0, 75.8, 67.4, 64.3, 62.1, 61.6, 31.1, 30.9, 24.7, 23.9, 23.7, 23.29, 23.28, 14.5; HRMS–ESI (*m*/*z*): $[M–Br]^+$ calcd for $C_{22}H_{32}NO_2$: 342.2428. Found: 342.2418.

(*S*)-1-Cinnamyl-1-(1-oxo-1-(pyrrolidin-1-yl)propan-2-yl)pyrrolidin-1-ium bromide (1b): prepared by the same procedure with **1d** using **1b'** as a substrate (62% yield); white solid; $[\alpha]^{25}_{589}$ –80.9 (*c* 1.00, EtOH); IR (KBr) 3031, 2979, 2956, 2884, 1618, 1481, 1446, 1396, 1381, 1352, 1322, 1310, 1299, 1264, 1235, 1217, 1184, 1166, 1136, 1101, 1083, 1052, 1031, 1012, 982, 921, 897, 837, 764, 728, 697 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.56 (2H, d, *J* = 7.2 Hz, Ph), 7.35 (2H, t, *J* = 7.2 Hz, Ph), 7.31 (1H, t, *J* = 7.2 Hz, Ph), 6.89 (1H, d, *J* = 15.5 Hz, CH=C*H*Ph), 6.61 (1H, ddd, *J* = 15.5, 8.8, 6.4 Hz, C*H*=CHPh), 5.45 (1H, q, *J* = 6.8 Hz, NCHCO), 4.64 (1H, dd, *J* = 12.7, 8.8 Hz, CH_2CH=CH), 4.49 (1H, dd, *J* = 12.7, 6.4 Hz, CH_2CH=CH), 4.26-4.11 (3H, m, CH_2), 4.05-3.95 (1H, m, CH_2), 3.88-3.77 (1H, m, CH_2), 3.46-3.33 (1H, m, CH_2), 3.41 (2H, t, *J* = 6.6 Hz, CH_2), 2.28-2.05 (4H, m, CH_2), 1.92-1.61 (4H, m, CH_2), 1.67 (3H, d, *J* = 6.8 Hz, CHCH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.3, 141.6, 134.5, 129.1, 128.6, 127.0, 115.7, 66.4, 65.6, 62.2, 60.2, 47.3, 46.3, 25.6, 24.5, 23.6, 23.5, 13.6; HRMS–ESI (*m*/*z*): $[M–Br]^+$ calcd for $C_{20}H_{29}N_2O$: 313.2274. Found: 313.2261.

(*S*)-1-Cinnamyl-1-(1-(3,4-dihydroquinolin-1(2*H*)-yl)-1-oxopropan-2-yl)pyrrolidin-1-ium bromide (1c): prepared by the same procedure with **1d** using **1c'** as a substrate (75% yield); white solid; $[\alpha]^{23}_{589}$ –55.1 (*c* 1.00, $CHCl_3$); IR (KBr) 3027, 2953, 1654, 1602, 1579, 1491, 1450, 1376, 1290, 1235, 1204, 1137, 1071, 1027, 980, 923, 885, 840, 760, 694 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ (5/5 mixture of rotamers) 7.68 (0.5H, d, *J* = 8.0 Hz, ArH), 7.51 (1H, d, *J* = 6.0 Hz, ArH), 7.39-7.25 (3.5H, m, ArH), 7.25-6.95 (4.5H, m, ArH and CH=C*H*Ph), 6.89 (0.5H, d, *J* = 15.2 Hz, CH=C*H*Ph), 6.70-6.52 (0.5H, m), 6.23-6.01 (1H, m), 5.12-4.98 (0.5H, m, NCHCO), 4.77-4.40 (2H, m, CH_2), 4.37-3.55 (6H, m, CH_2), 2.75-2.05 (6H, m, CH_2), 2.05-1.83 (2H, m, CH_2), 1.79 (1.5H, d, *J* = 6.0 Hz, CHCH_3), 1.68 (1.5H, d, *J* = 6.0 Hz, CHCH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ (5/5 mixture of rotamers) 167.9, 166.8, 143.2, 141.8, 136.7, 136.5, 134.5, 134.4, 134.3, 131.7, 129.1, 129.0, 128.6, 128.5, 127.6, 127.3, 127.2, 125.5, 125.4, 124.3, 123.7, 115.8, 114.6, 66.3, 65.9, 64.3, 62.8, 62.0, 60.8, 60.7, 46.1, 43.0, 26.1, 26.0, 24.7, 24.1, 24.0, 23.8, 23.4, 22.8, 14.2, 14.0; HRMS–ESI (*m*/*z*): $[M–Br]^+$ calcd for $C_{25}H_{31}N_2O$: 375.2431. Found: 375.2426.

(*S*,*E*)-*N*-(1-(3,4-Dihydroquinolin-1(2*H*)-yl)-1-oxopropan-2-yl)-*N*,*N*-dimethyl-3-phenylprop-2-en-1-aminium bromide (1e): prepared by the same procedure with **1d** using **1e'** as a substrate (97% yield); white solid; $[\alpha]^{25}_{589}$ –69.7 (*c* 1.00, $CHCl_3$); IR (KBr) 3025, 2951, 1653, 1581, 1490, 1451, 1372, 1291, 1237, 1205, 1161, 1071, 990, 903, 879, 820, 760, 695 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ (6/4 mixture of rotamers) 7.64 (0.4H, d, *J* = 8.0 Hz, ArH), 7.53-7.44 (1H, m, ArH), 7.38-6.91 (9.2H, m, ArH and C*H*=C*H*Ph), 6.46 (0.4H, dt, *J* = 15.6, 7.6 Hz, C*H*=CHPh), 6.00-5.87 (1H, m, NCHCO), 4.91-4.61 (2.4H, m, CH_2), 4.42-4.30 (0.4H, m, CH_2), 3.99-3.65 (1.2H, m, CH_2), 3.59 (1.2H, s, NCH_3), 3.55 (1.8H, s, NCH_3), 3.49 (1.2H, s, NCH_3), 3.36 (1.8H, s, NCH_3), 2.78-2.55 (2H, m, CH_2), 2.17-1.86 (2H, m, CH_2), 1.82 (1.2H, d, *J* = 6.8 Hz, CHCH_3), 1.71 (1.8H, d, *J* = 6.8 Hz, CHCH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ (6/4 mixture of rotamers) 167.5, 166.3, 144.2, 143.5, 136.7, 136.5, 134.5, 134.2, 131.9, 129.3, 129.1, 129.0, 128.6, 128.4, 127.4, 127.23, 127.17, 125.6, 125.4, 124.5, 123.7, 114.3, 113.4, 65.84, 65.75, 62.2, 49.4, 48.65, 48.56, 47.7, 46.4, 43.1, 26.1, 24.1, 23.4, 13.6, 13.2; HRMS–ESI (*m*/*z*): $[M–Br]^+$ calcd for $C_{23}H_{29}N_2O$: 349.2274. Found: 349.2268.

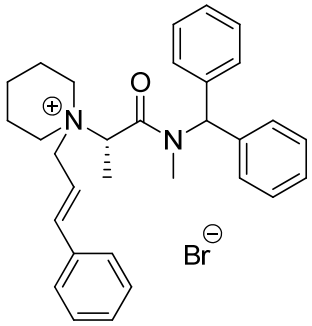
(*S*)-1-Cinnamyl-1-(1-(indolin-1-yl)-1-oxopropan-2-yl)piperidin-1-ium bromide (1f): prepared by the same procedure with **1d** using **1f'** as a substrate (89% yield); white solid; $[\alpha]^{24}_{589}$ –149.3 (*c* 1.00, EtOH); IR (KBr) 2976, 2941, 2873, 1651, 1599, 1484, 1438, 1397, 1357, 1321, 1287, 1170, 1129, 1079, 1050, 1026, 992, 926, 868, 822, 767, 752, 729, 698 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$+CD_3OD) δ 8.19 (1H, d, *J* = 8.0 Hz, ArH), 7.31-7.19 (6H, m, ArH), 7.14-7.05 (2H, m, ArH), 6.69-6.57 (2H, m, C*H*=C*H*Ph), 4.80 (1H, q, *J* = 6.8 Hz, NCHCO), 4.76-4.67 (1H, m, CH_2), 4.50 (1H, d, *J* = 12.4 Hz, CH_2), 4.39-4.27 (1H, m, CH_2), 4.18 (1H, d, *J* = 12.4 Hz, CH_2), 4.13 (1H, ddd, *J* = 10.8, 10.8, 6.2 Hz, CH_2), 3.92 (1H, ddd, *J* = 10.8, 10.8, 6.2 Hz, CH_2), 3.74 (1H, ddd, *J* = 12.6, 12.6, 3.6 Hz, CH_2), 3.56 (1H, ddd, *J* = 12.6, 12.6, 3.6 Hz, CH_2), 2.95 (1H, ddd, *J* = 16.2, 10.2, 6.2 Hz, CH_2), 2.43 (1H, ddd, *J* = 16.2, 10.2, 6.2 Hz, CH_2), 2.23-1.90 (5H, m, CH_2), 1.79 (3H, d, *J* = 6.8 Hz, CHC*H*$_3$), 1.75-1.60 (1H, m, CH_2); ^{13}C NMR (100 MHz, $CDCl_3$+CD_3OD) δ 166.4, 142.5, 141.6, 133.9, 132.2, 129.3, 128.6, 127.1, 125.1, 124.8, 117.1, 113.2, 104.9, 67.2, 58.2, 56.8, 56.5, 48.6, 27.4, 20.8, 20.1, 19.7, 12.7; HRMS–ESI (*m*/*z*): $[M–Br]^+$ calcd for $C_{25}H_{31}N_2O$: 375.2431. Found: 375.2423.

(*S*)-1-Cinnamyl-1-(1-(3,4-dihydroquinolin-1(2*H*)-yl)-1-oxopropan-2-yl)piperidin-1-ium bromide (1g): prepared by the same procedure with **1d** using **1g'** as a substrate (98% yield); pale yellow solid; $[\alpha]^{24}_{589}$ –139.5 (*c* 1.00, EtOH); IR (KBr) 3025, 2946, 1657, 1486, 1441, 1413, 1383, 1354, 1311, 1288, 1263, 1223, 1191, 1129, 1097, 980, 927, 866, 744, 695 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ (5/5 mixture of rotamers) 7.88 (0.5H, d, *J* = 7.6 Hz, ArH), 7.80-7.66 (2H, m, ArH), 7.63 (0.5H, d, *J* = 7.6 Hz, ArH), 7.48-6.93 (11H, m, ArH and C*H*=C*H*Ph), 6.77 (0.5H, d, *J* = 15.5 Hz, CH=C*H*Ph), 6.56 (0.5H, ddd, *J* = 15.5, 9.2, 6.0 Hz, C*H*=CHPh), 6.12 (0.5H, q, *J* = 6.8 Hz, NCHCO), 5.73 (1H, br, CH_2), 5.35-5.25 (0.5H, m, CH_2), 4.95 (0.5H, d, *J* = 16.4 Hz, CH_2), 4.90 (0.5H, q, *J* = 6.8 Hz, NCHCO), 4.70 (0.5H, dd, *J* = 13.7, 5.2 Hz, CH_2), 4.54 (1H, br, CH_2), 4.44 (0.5H, dd, *J* = 13.7, 9.4 Hz, CH_2), 4.36 (1H, br, CH_2), 4.13 (1H, br, CH_2), 3.91-3.78 (0.5H, m, CH_2), 3.78-3.43 (1.5H, m, CH_2), 2.77 (1H, br, CH_2), 2.30-1.05 (5H, m, CH_2), 1.76 (3H, d, *J* = 6.8 Hz, CHC*H*$_3$); ^{13}C NMR (100 MHz, $CDCl_3$) δ (5/5 mixture of rotamers) 167.5, 143.5, 141.4, 135.7, 135.2, 134.5, 134.4, 133.7, 132.9, 130.9, 130.8, 130.3, 129.8, 129.3, 129.0, 128.9, 128.7, 128.6, 128.5, 128.4, 128.2, 127.4, 127.3, 127.1, 126.75, 126.69, 126.2, 125.1, 124.9, 124.2, 123.4, 122.7, 114.4, 65.7, 57.9, 57.6, 57.2, 55.7, 55.4, 48.2, 46.0, 20.7, 20.6, 20.1, 20.0, 19.8, 19.4; HRMS–ESI (*m*/*z*): $[M–Br]^+$ calcd for $C_{30}H_{33}N_2O$: 437.2587. Found: 437.2577.

(*S*)-1-Cinnamyl-1-(1-(methyl(phenyl)amino)-1-oxopropan-2-yl)piperidin-1-ium bromide (1h): prepared by the same procedure with **1d** using **1h'** as a substrate (75% yield); pale brown solid; $[\alpha]^{23}_{589}$ –41.1 (*c* 1.00, EtOH); IR (KBr) 3023, 2946, 1657, 1593, 1494, 1467, 1452, 1403, 1380, 1349, 1309, 1271, 1199, 1116, 1090, 1031, 998, 928, 899, 865, 822, 753, 703 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.40-7.25 (5H, m, ArH), 7.22-7.10 (4H, m, ArH), 6.89-6.81 (1H, m, ArH), 6.78 (1H, d, *J* = 15.9 Hz, CH=C*H*Ph), 5.92 (1H, ddd, *J* = 15.9, 9.2, 6.2 Hz, C*H*=CHPh), 4.54 (1H, dd, *J* = 14.1, 6.2 Hz, C*H*$_2$CH=CH), 4.41 (1H, dd, *J* = 14.1, 9.2 Hz, C*H*$_2$CH=CH), 4.34 (1H, ddd, *J* = 12.9, 12.9, 3.8 Hz, CH_2), 4.09 (1H, q, *J* = 6.8 Hz, NCHCO), 3.64 (1H, d, *J* = 12.4 Hz, CH_2), 3.54-3.36 (2H, m, CH_2), 3.28 (3H, s, NCH_3),

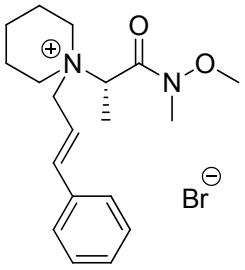
2.16-1.91 (3H, m, CH_2), 1.91-1.67 (2H, m, CH_2), 1.72 (3H, d, J = 6.8 Hz, CHCH_3), 1.58-1.40 (1H, m, CH_2); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.7, 143.2, 140.8, 134.1, 130.4, 129.2, 129.0, 128.3, 127.4, 126.3, 112.8, 61.7, 56.7, 55.7, 54.7, 37.7, 20.7, 20.2, 19.7, 12.7; HRMS–ESI (*m*/*z*): $[M–Br]^+$ calcd for $C_{24}H_{31}N_2O$: 363.2431. Found: 363.2415.

(*S*)-1-(1-(Benzhydryl(methyl)amino)-1-oxopropan-2-yl)-1-cinnamylpiperidin-1-ium bromide (1i):



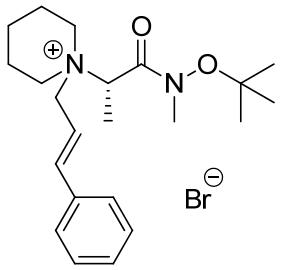
prepared by the same procedure with **1d** using **1i'** as a substrate (98% yield); white solid; $[\alpha]^{24}_{589}$ –92.7 (*c* 1.00, EtOH); IR (KBr) 3054, 3027, 2997, 2942, 2868, 1643, 1494, 1475, 1450, 1380, 1343, 1309, 1277, 1195, 1170,1134, 1074, 1049, 1029, 1000, 974, 925, 868, 827, 740, 700 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ (8/2 mixture of rotamers) 7.54 (0.4H, d, J = 7.2 Hz, ArH), 7.48 (1.6H, d, J = 7.2 Hz, ArH), 7.37-6.89 (14.2H, m, ArH, CH=C*H*Ph, and C*H*Ph_2), 6.73 (0.8H, d, J = 15.6 Hz, CH=C*H*Ph), 6.61-6.49 (1H, m, C*H*=CHPh), 5.45 (0.8H, q, J = 6.8 Hz, NCHCO), 5.34 (0.2H, q, J = 6.8 Hz, NCHCO), 4.81-4.60 (0.4H, m, CH_2), 4.75 (0.8H, dd, J = 14.1, 5.4 Hz, CH_2), 4.43 (0.8H, dd, J = 14.1, 8.8 Hz, CH_2), 4.33 (1H, d, J = 12.8 Hz, CH_2), 4.15 (0.8H, d, J = 12.8 Hz, CH_2), 3.95 (0.8H, ddd, J = 12.4, 12.4, 2.8 Hz, CH_2), 3.80 (0.2H, d, J = 12.0 Hz, CH_2), 3.71 (0.8H, ddd, J = 12.4, 12.4, 2.8 Hz, CH_2), 3.55 (0.2H, dd, J = 12.0, 12.0 Hz, CH_2), 3.40 (0.2H, d, J = 12.0 Hz, CH_2), 3.02 (2.4H, s, NCH_3), 2.80 (0.6H, s, NCH_3), 2.15-1.50 (6H, m, CH_2), 1.82 (2.4H, d, J = 6.8 Hz,, CHCH_3), 1.70 (0.6H, d, J = 6.8 Hz, CHCH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ (8/2 mixture of rotamers) 169.2, 169.1, 141.8, 141.1, 138.4, 138.3, 137.9, 137.5, 134.8, 134.6, 129.1, 128.64, 128.59, 128.57, 128.45, 128.37, 127.94, 127.91, 127.88, 127.8, 127.7, 127.5, 127.4, 115.0, 114.9, 65.5, 64.5, 64.1, 61.2, 57.6, 57.4, 56.8, 56.0, 55.9, 55.5, 33.7, 32.7, 20.7, 20.5, 20.1, 20.0, 19.9, 14.5, 13.4; HRMS–ESI (*m*/*z*): $[M–Br]^+$ calcd for $C_{31}H_{37}N_2O$: 453.2900. Found: 453.2894.

(*S*)-1-Cinnamyl-1-(1-(methoxy(methyl)amino)-1-oxopropan-2-yl)piperidin-1-ium bromide (1j):



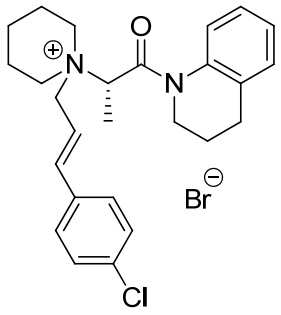
prepared by the same procedure with **1d** using **1j'** as a substrate (91% yield); white solid; $[\alpha]^{23}_{589}$ –24.0 (*c* 1.00, EtOH); IR (KBr) 2997, 2938, 2873, 1661, 1477, 1442, 1381, 1338, 1323, 1197, 1174, 1155, 1108, 1075, 1054, 1026, 988, 947, 928, 909, 870, 823, 760, 729, 698 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.58 (2H, d, J = 7.4 Hz, Ph), 7.39-7.28 (3H, m, Ph), 7.02 (1H, d, J = 15.6 Hz, CH=C*H*Ph), 6.57 (1H, ddd, J = 15.6, 7.8, 6.8 Hz, C*H*=CHPh), 4.97 (1H, q, J = 7.0 Hz, NCHCO), 4.72 (1H, dd, J = 13.9, 6.8 Hz, CH_2CH=CH), 4.60 (1H, dd, J = 13.9, 7.8 Hz, CH_2CH=CH), 4.05-3.88 (3H, m, CH_2), 3.71 (3H, s, OCH_3), 3.63 (1H, ddd, J = 12.2, 12.2, 3.2 Hz, CH_2), 3.19 (3H, s, NCH_3), 2.23-2.05 (2H, m, CH_2), 2.02-1.64 (4H, m, CH_2), 1.82 (3H, d, J = 7.0 Hz, CHCH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.7, 142.5, 134.6, 129.1, 128.7, 127.2, 114.4, 62.7, 62.54, 62.50, 58.2, 56.5, 56.0, 32.1, 20.5, 19.9, 13.0; HRMS–ESI (*m*/*z*): $[M–Br]^+$ calcd for $C_{19}H_{29}N_2O_2$: 317.2224. Found: 317.2220.

(*S*)-1-(1-(*tert*-Butoxy(methyl)amino)-1-oxopropan-2-yl)-1-cinnamylpiperidin-1-ium bromide (1k):



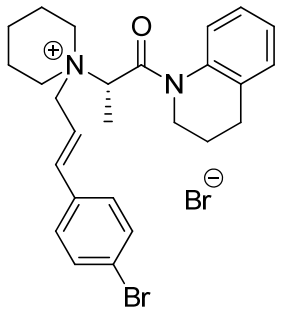
prepared by the same procedure with **1d** using **1k'** as a substrate (96% yield); white solid; $[\alpha]^{23}_{589}$ –16.7 (*c* 1.00, EtOH); IR (KBr) 3023, 2979, 2937, 1661, 1469, 1415, 1387, 1367, 1308, 1286, 1261, 1240, 1196, 1151, 1111, 1068, 1009, 942, 920, 899, 867, 837, 819, 786, 760, 732, 696 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.59 (2H, d, *J* = 6.8 Hz, Ph), 7.39-7.26 (4H, m, Ph and CH=C*H*Ph), 6.43 (1H, dt, *J* = 15.6, 7.8 Hz, C*H*=CHPh), 4.85 (1H, q, *J* = 6.8 Hz, NCHCO), 4.74 (2H, d, *J* = 7.8 Hz, CH_2CH=CH), 4.08 (1H, t, *J* = 12.0 Hz, CH_2), 3.77 (1H, d, *J* = 12.0 Hz, CH_2), 3.58 (1H, d, *J* = 12.0 Hz, CH_2), 3.28 (3H, s, NCH_3), 3.20 (1H, t, *J* = 12.0 Hz, CH_2), 2.35-2.08 (2H, m, CH_2), 1.96-1.75 (3H, m, CH_2), 1.82 (3H, d, *J* = 6.8 Hz, CHCH_3), 1.56-1.40 (1H, m, CH_2), 1.13 (9H, s, *t*-Bu); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.4, 143.5, 134.4, 129.3, 128.6, 127.2, 113.8, 84.6, 61.0, 57.1, 55.4, 55.1, 39.2, 27.3, 20.7, 20.2, 19.5, 11.8; HRMS–ESI (*m*/*z*): $[M–Br]^+$ calcd for $C_{22}H_{35}N_2O_2$: 359.2693. Found: 359.2677.

(*S*,*E*)-1-(3-(4-Chlorophenyl)allyl)-1-(1-(3,4-dihydroquinolin-1(2*H*)-yl)-1-oxopropan-2-yl)piperidin-1-ium bromide (1l):



prepared by the same procedure with **1d** using **1l'** as a substrate (91% yield); white solid; $[\alpha]^{23}_{589}$ –91.2 (*c* 1.00, EtOH); IR (KBr) 3012, 2947, 2873, 1650, 1491, 1460, 1412, 1381, 1351, 1308, 1235, 1197, 1126, 1089, 1011, 990, 943, 925, 868, 829, 804, 763 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ (7/3 mixture of rotamers) 7.69 (0.3H, d, *J* = 8.0 Hz, ArH), 7.55 (0.6H, d, *J* = 8.0 Hz, ArH), 7.41-6.69 (8.4H, m, ArH and C*H*=C*H*Ar), 6.16 (0.7H, ddd, *J* = 15.2, 8.6, 6.6 Hz, C*H*=CHAr), 5.66 (0.3H, q, *J* = 6.4 Hz, NCHCO), 4.90 (0.7H, q, *J* = 6.4 Hz, NCHCO), 4.81-4.64 (0.3H, m, CH_2), 4.69 (0.7H, dd, *J* = 13.6, 6.6 Hz, CH_2CH=CH), 4.60 (0.7H, dd, *J* = 13.6, 8.6 Hz, CH_2CH=CH), 4.53-4.30 (1H, m, CH_2), 4.18-3.78 (2H, m, CH_2), 3.75-3.57 (2H, m, CH_2), 3.57-3.39 (1.3H, m, CH_2), 2.75-2.51 (1.7H, m, CH_2), 2.45-1.40 (8.3H, m, CH_2), 1.84 (3H, d, *J* = 6.4 Hz, CHCH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ (7/3 mixture of rotamers) 168.0, 166.6, 142.1, 139.6, 137.7, 136.7, 134.9, 134.7, 133.1, 131.8, 129.1, 129.0, 128.8, 128.7, 128.6, 128.0, 127.4, 125.5, 125.1, 124.3, 123.6, 115.8, 114.4, 66.1, 61.6, 58.0, 57.8, 57.0, 56.3, 55.8, 46.4, 43.1, 26.2, 26.0, 23.6, 23.4, 21.3, 20.7, 20.2, 19.8, 19.6, 13.5, 13.3; HRMS–ESI (*m*/*z*): $[M–Br]^+$ calcd for $C_{26}H_{32}ClN_2O$: 423.2198. Found: 423.2187.

(*S*,*E*)-1-(3-(4-Bromophenyl)allyl)-1-(1-(3,4-dihydroquinolin-1(2*H*)-yl)-1-oxopropan-2-yl)piperidin-1-ium bromide (1m):



prepared by the same procedure with **1d** using **1m'** as a substrate (91% yield); white solid; $[\alpha]^{23}_{589}$ –88.1 (*c* 1.00, EtOH); IR (KBr) 3007, 2946, 2873, 1650, 1583, 1488, 1458, 1414, 1381, 1351, 1307, 1234, 1197, 1126, 1114, 1090, 1071, 1007, 940, 926, 867, 828, 801, 762 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ (7/3 mixture of rotamers) 7.69 (0.3H, d, *J* = 8.4 Hz, ArH), 7.49 (0.6H, d, *J* = 8.4 Hz, ArH), 7.44 (2H, d, *J* = 8.4 Hz, ArH), 7.29 (1.4H, d, *J* = 8.4 Hz, ArH), 7.22-6.80 (4.7H, m, ArH and C*H*=C*H*Ar), 6.72 (0.3H, d, *J* = 15.2 Hz, CH=C*H*Ar), 6.18 (0.7H, ddd, *J* = 15.2, 8.6, 6.6 Hz, C*H*=CHAr), 5.69 (0.3H, q, *J* = 6.8 Hz, NCHCO), 4.90 (0.7H, q, *J* = 6.8 Hz, NCHCO), 4.81-4.65 (0.3H, m, CH_2), 4.69 (0.7H, dd, *J* = 13.8, 6.6 Hz, CH_2CH=CH), 4.60 (0.7H, dd, *J* = 13.8, 8.6 Hz, CH_2CH=CH), 4.54-4.37 (0.7H, m, CH_2), 4.18-3.40 (5.6H, m, CH_2), 2.75-2.52 (1.7H, m, CH_2), 2.43-1.40 (8.3H, m, CH_2), 1.84 (3H, d, *J* = 6.8 Hz, CHCH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ (7/3 mixture of rotamers) 168.0,

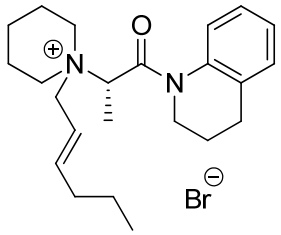
166.6, 142.2, 139.7, 136.7, 134.7, 133.6, 131.9, 131.8, 131.6, 129.2, 129.1, 129.0, 127.4, 125.5, 124.3, 123.6, 123.2, 116.0, 114.6, 66.1, 61.6, 58.0, 57.9, 57.0, 56.3, 55.8, 46.4, 43.1, 26.3, 26.1, 23.6, 23.5, 20.7, 20.3, 19.9, 19.7, 13.6, 13.3; HRMS–ESI (*m*/*z*): $[M–Br]^+$ calcd for $C_{26}H_{32}BrN_2O$: 467.1693. Found: 467.1684.

(*S*,*E*)-1-(1-(3,4-Dihydroquinolin-1(2*H*)-yl)-1-oxopropan-2-yl)-1-(3-(*p*-tolyl)allyl)piperidin-1-ium bromide (1n): prepared by the same procedure with **1d** using **1n'** as a substrate (86% yield); pale brown solid; $[\alpha]^{23}_{589}$ –92.8 (*c* 1.00, EtOH); IR (KBr) 3007, 2946, 2868, 1649, 1580, 1513, 1490, 1456, 1415, 1381, 1351, 1308, 1286, 1253, 1234, 1197, 1127, 1091, 1070, 1015, 989, 940, 925, 900, 867, 828, 799, 762 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ (7/3 mixture of rotamers) 7.70 (0.3H, d, *J* = 8.0 Hz, ArH), 7.42 (0.6H, d, *J* = 7.2 Hz, ArH), 7.29-6.88 (7.8H, m, ArH and CH=C*H*Ar), 6.77 (0.3H, d, *J* = 15.6 Hz, CH=C*H*Ar), 6.69-6.56 (0.3H, m, C*H*=CHAr), 5.94 (0.7H, ddd, *J* = 15.6, 6.8, 6.8 Hz, C*H*=CHAr), 5.67 (0.3H, q, *J* = 6.4 Hz, NCHCO), 4.91 (0.7H, q, *J* = 6.4 Hz, NCHCO), 4.83-4.71 (0.3H, m, CH_2), 4.71-4.53 (1.4H, m, CH_2), 4.52-4.26 (0.7H, m, CH_2), 4.22-3.37 (5.6H, m, CH_2), 2.77-2.50 (2H, m, CH_2), 2.45-1.46 (8H, m, CH_2), 2.36 (2.1H, s, $ArCH_3$), 2.32 (0.9H, s, $ArCH_3$), 1.86 (3H, d, *J* = 6.4 Hz, $CHCH_3$); ^{13}C NMR (100 MHz, $CDCl_3$) δ (7/3 mixture of rotamers) 168.0, 166.7, 143.7, 141.2, 139.4, 139.2, 136.7, 134.7, 132.0, 131.8, 131.7, 129.3, 129.1, 128.9, 127.4, 127.2, 125.4, 124.3, 123.4, 113.5, 111.9, 66.1, 61.7, 58.0, 57.1, 56.1, 55.5, 46.5, 43.1, 26.2, 26.0, 23.6, 23.4, 21.2, 20.6, 20.2, 19.9, 19.7, 13.7, 13.4; HRMS–ESI (*m*/*z*): $[M–Br]^+$ calcd for $C_{27}H_{35}N_2O$: 403.2744. Found: 403.2727.

(*S*,*Z*)-1-(1-(3,4-Dihydroquinolin-1(2*H*)-yl)-1-oxopropan-2-yl)-1-(3-phenylallyl)piperidin-1-ium bromide (1o): prepared by the same procedure with **1d** using (*Z*)-(3-bromoprop-1-en-1-yl)benzene[5] (*Z*/*E* = 9:1) as a substrate (87% yield); pale red solid; $[\alpha]^{22}_{589}$ –67.6 (*c* 1.00, EtOH); IR (KBr) 3023, 2948, 2873, 1650, 1602, 1581, 1490, 1454, 1415, 1383, 1354, 1305, 1286, 1256, 1234, 1197, 1170, 1124, 1089, 1028, 929, 865, 809, 769, 701 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ [*Z*/*E* = 8/2, 7/3 mixture of rotamers (ca. 55/30/10/5 mixtures)] 7.71 (0.05H, d, *J* = 8.4 Hz, *E*-ArH), 7.58-7.45 (0.65H, m, *Z*-ArH), 7.43-6.67 (9.35H, m, ArH and C*H*=C*H*Ph), 6.40 (0.30H, dt, *J* = 10.8, 6.6 Hz, *Z*-C*H*=CHPh), 6.05 (0.10H, dt, *J* = 15.2, 7.2 Hz, *E*-C*H*=CHPh), 5.88-5.64 (0.90H, m, *Z*-C*H*=CHPh and NCHCO), 4.98-3.40 (8.65H, m, NCHCO and CH_2), 2.87-2.51, 2.45-1.46, and 1.35-1.22 (13H, m, CH_2 and $CHCH_3$); ^{13}C NMR (100 MHz, $CDCl_3$) δ [*Z*/*E* = 8/2, 7/3 mixture of rotamers (ca. 55/30/10/5 mixtures), assigned only *Z*-isomer] 167.2, 166.4, 141.5, 138.5, 136.9, 136.6, 135.0, 134.3, 134.0, 131.5, 129.2, 128.7, 128.6, 128.4, 128.2, 127.8, 127.6, 127.4, 125.4, 125.2, 124.7, 124.2, 117.2, 116.5, 65.9, 62.6, 56.8, 56.1, 55.7, 55.6, 51.7, 51.4, 46.6, 43.0, 26.3, 26.1, 23.9, 23.4, 20.6, 20.5, 20.0, 19.8, 13.5, 12.7; HRMS–ESI (*m*/*z*): $[M–Br]^+$ calcd for $C_{26}H_{33}N_2O$: 389.2587. Found: 389.2579.

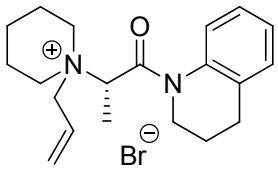
[5] (a) Fan, S.; Chen, F.; Zhang, X. *Angew. Chem. Int. Ed.* **2011**, *50*, 5918–5923. (b) Pavlakos, E.; Georgiou, T.; Tofi, M.; Montagnon, T.; Vassilikogiannakis, G. *Org. Lett.* **2009**, *11*, 4556–4559.

(*S*,*E*)-1-(1-(3,4-Dihydroquinolin-1(2*H*)-yl)-1-oxopropan-2-yl)-1-(hex-2-en-1-yl)piperidin-1-ium bromide



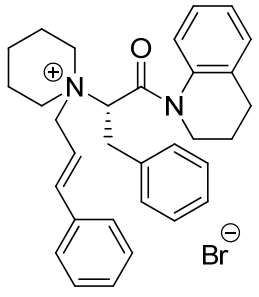
(1p): prepared by the same procedure with **1d** using (*E*)-1-bromohex-2-ene instead of cinnamyl bromide (82% yield); pale brown solid; $[\alpha]^{24}_{589}$ –96.2 (*c* 1.00, EtOH); IR (KBr) 2956, 2868, 1648, 1580, 1490, 1457, 1418, 1381, 1307, 1289, 1235, 1199, 1126, 1092, 986, 923, 863, 827, 766 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ (8/2 mixture of rotamers) 7.67 (0.2H, d, *J* = 7.6 Hz, ArH), 7.39-7.04 (2.8H, m, ArH), 7.08 (1H, d, *J* = 7.6 Hz, ArH), 6.18 (1H, dt, *J* = 14.8, 6.8 Hz, C*H*=CH$(CH_2)_2CH_3$), 5.92-5.77 (0.2H, m, CH=C*H*$(CH_2)_2CH_3$), 5.50-5.38 (0.2H, m, NCHCO), 5.21 (0.8H, dt, *J* = 14.8, 6.8 Hz, CH=C*H*$(CH_2)_2CH_3$), 4.80 (0.8H, q, *J* = 6.8 Hz, NCHCO), 4.71-4.56 (0.2H, m, CH_2), 4.49-4.29 (1.8H, m, CH_2), 4.27-3.32 (6H, m, CH_2), 2.78 (1H, dt, *J* = 15.8, 6.2 Hz, CH_2), 2.67 (1H, dt, *J* = 15.8, 7.0 Hz, CH_2), 2.24-1.50 (10H, m, CH_2), 1.85 (3H, d, *J* = 6.8 Hz, CH*C*H_3), 1.50-1.18 (2H, m, CH_2), 0.84 (3H, t, *J* = 7.2 Hz, CH_2*C*H_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ (8/2 mixture of rotamers) 166.9, 165.8, 146.3, 144.2, 136.2, 134.3, 130.9, 128.6, 128.3, 126.8, 126.5, 124.9, 124.8, 123.9, 122.9, 115.8, 114.0, 64.7, 60.9, 56.8, 56.0, 55.1, 54.7, 54.6, 45.8, 42.5, 33.7, 25.6, 23.3, 22.8, 20.8, 20.5, 19.9, 19.3, 18.9, 13.1, 12.8, 12.7; HRMS–ESI (*m*/*z*): $[M–Br]^+$ calcd for $C_{23}H_{35}N_2O$: 355.2744. Found: 355.2738.

(*S*)-1-Allyl-1-(1-(3,4-dihydroquinolin-1(2*H*)-yl)-1-oxopropan-2-yl)piperidin-1-ium bromide (1q):



prepared by the same procedure with **1d** using 2 equivalents of allyl bromide instead of cinnamyl bromide (43% yield); pale brown solid; $[\alpha]^{24}_{589}$ –90.6 (*c* 1.00, EtOH); IR (KBr) 2946, 2873, 1650, 1491, 1460, 1421, 1383, 1341, 1287, 1235, 1201, 1168, 1121, 1088, 1052, 1014, 945, 864, 826, 769 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ (7/3 mixture of rotamers) 7.65 (0.3H, d, *J* = 7.6 Hz, ArH), 7.40-7.03 (3.7H, m, ArH), 6.43-6.27 (0.3H, m, C*H*=CH_2), 5.88-5.50 (3H, m, C*H*=CH_2 and NCHCO), 4.87 (0.7H, q, *J* = 6.8 Hz, NCHCO), 4.74-4.61 (0.3H, m, CH_2), 4.61-4.44 (1.3H, m, CH_2), 4.44-4.26 (0.7H, m, CH_2), 4.22-3.40 (5.7H, m, CH_2), 2.85-2.58 (2H, m, CH_2), 2.42-1.49 (8H, m, CH_2), 1.85 (3H, d, *J* = 6.8 Hz, CH*C*H_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ (7/3 mixture of rotamers) 167.6, 166.4, 136.7, 134.8, 131.8, 129.9, 129.3, 128.9, 127.6, 127.4, 125.6, 125.4, 125.1, 124.5, 123.6, 123.5, 66.2, 61.6, 58.4, 57.5, 57.1, 56.0, 55.8, 46.5, 43.2, 26.2, 23.9, 23.4, 20.55, 20.46, 20.1, 20.0, 19.8, 19.6, 13.7, 13.4; HRMS–ESI (*m*/*z*): $[M–Br]^+$ calcd for $C_{20}H_{29}N_2O$: 313.2274. Found: 313.2265.

(*S*)-1-Cinnamyl-1-(1-(3,4-dihydroquinolin-1(2*H*)-yl)-1-oxo-3-phenylpropan-2-yl)piperidin-1-ium bromide (1r):



prepared by the same procedure with **1d** using **1r'** as a substrate (60% yield); red solid; $[\alpha]^{24}_{589}$ –66.3 (*c* 1.00, EtOH); IR (KBr) 3023, 2947, 2873, 1645, 1490, 1453, 1409, 1290, 1234, 1194, 1111, 1073, 1028, 995, 942, 861, 822, 753, 699 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ (7/3 mixture of rotamers) 7.64-7.56 (1H, m, ArH), 7.47-7.10 (11.3H, m ArH and CH=C*H*Ph), 7.07 (0.3H, t, *J* = 7.4 Hz, ArH), 7.02 (0.3H, d, *J* = 7.4 Hz, ArH), 6.90 (0.7H, d, *J* = 7.4 Hz, ArH), 6.78 (0.3H, dt, *J* = 15.6, 7.6 Hz, C*H*=CHPh), 6.71 (0.7H, dd, *J* = 7.6, 7.6 Hz, ArH), 6.37 (0.7H, dd, *J* = 7.6, 7.6 Hz, ArH), 6.05 (0.7H, br, C*H*=CHPh), 5.69 (0.3H, br, CH_2), 5.63 (0.3H, dd, *J* = 11.8, 3.0 Hz, NCHCO), 5.12-4.94 (1.7H, m, NCHCO and CH_2), 4.78-4.66 (1H, m, CH_2), 4.38 (0.3H, ddd, *J* = 13.0, 13.0, 3.2 Hz, CH_2), 4.30-4.10 (1H, m, CH_2), 4.10-3.89 (2.4H, m, CH_2), 3.87-3.73 (0.6H, m, CH_2), 3.56-3.10 (3.4H, m, CH_2), 2.42 (0.3H, dt, *J* = 16.0, 7.4 Hz, CH_2), 2.33-1.76 (7H, m, CH_2), 1.76-1.52 (1.7H, m, CH_2), 1.52-1.35 (0.7H, m, CH_2), 0.99 (0.3H, dtt, *J* = 13.6, 6.8, 6.8 Hz, CH_2); ^{13}C NMR (100 MHz, $CDCl_3$) δ (7/3 mixture of rotamers) 165.9, 165.2, 143.7, 141.6,

136.5, 136.2, 134.8, 134.5, 133.2, 132.6, 132.4, 130.3, 129.7, 129.3, 129.1, 129.0, 128.9, 128.7, 128.5, 127.9, 127.4, 127.3, 126.9, 126.7, 125.7, 125.4, 124.3, 124.1, 115.8, 113.5, 70.5, 65.9, 58.0, 57.7, 56.7, 56.1, 55.9, 46.6, 43.6, 34.2, 32.9, 26.0, 25.9, 23.1, 20.7, 20.5, 20.3, 19.8; HRMS–ESI (*m*/*z*): $[M–Br]^+$ calcd for $C_{32}H_{37}N_2O$: 465.2900. Found: 465.2891.

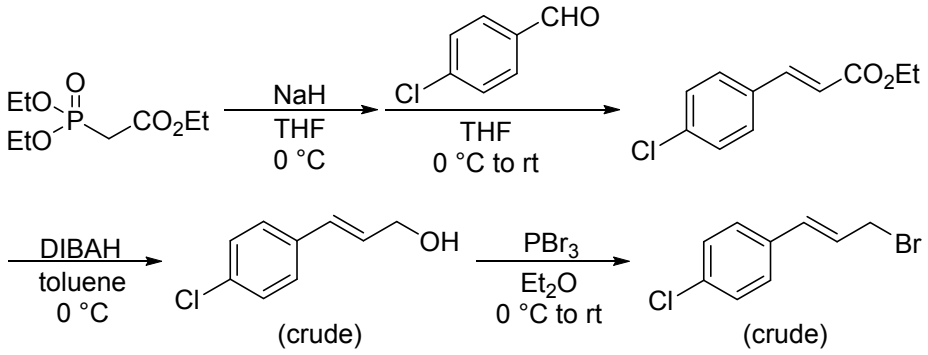
(*S*)-1-Cinnamyl-1-(1-(3,4-dihydroquinolin-1(2*H*)-yl)-4-methyl-1-oxopentan-2-yl)piperidin-1-ium bromide (1s): prepared by the same procedure with **1d** using **1s'** as a substrate (71% yield); red solid; $[\alpha]^{24}_{589}$ +105.7 (*c* 1.00, EtOH); IR (KBr) 2954, 2899, 2875, 1644, 1620, 1580, 1488, 1462, 1407, 1356, 1284, 1243, 1224, 1193, 1165, 1118, 1071, 1052, 1026, 999, 943, 928, 877, 823, 755, 693 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ (8/2 mixture of rotamers) 7.67 (0.2H, d, *J* = 8.0 Hz, ArH), 7.61-7.56 (0.4H, m, ArH), 7.54-7.47 (1.6H, m, ArH), 7.42-7.29 (3H, m, ArH), 7.22-7.06 (2.4H, m, ArH and CH=C*H*Ph), 6.98 (0.8H, d, *J* = 15.6 Hz, CH=C*H*Ph), 6.87 (0.8H, ddd, *J* = 7.6, 7.6, 0.8 Hz, ArH), 6.72 (0.2H, dt, *J* = 15.6, 7.6 Hz, C*H*=CHPh), 6.56 (0.8H, ddd, *J* = 7.6, 7.6, 0.8 Hz, ArH), 6.42 (0.8H, ddd, *J* = 15.6, 9.6, 5.8 Hz, C*H*=CHPh), 5.27 (0.2H, dd, *J* = 11.2, 2.0 Hz, NCHCO), 4.95 (0.8H, dd, *J* = 8.2, 5.8 Hz, NCHCO), 4.86-4.72 (0.4H, m, CH_2), 4.79 (0.8H, dd, *J* = 14.0, 5.8 Hz, CH_2), 4.60-4.16 (2.2H, m, CH_2), 4.48 (0.8H, dd, *J* = 14.0, 9.8 Hz, CH_2), 3.93-3.64 (2.2H, m, CH_2), 3.53-3.40 (0.8H, m, CH_2), 3.35 (0.8H, t, *J* = 11.4 Hz, CH_2), 2.77 (0.4H, t, *J* = 7.0 Hz, CH_2), 2.68 (0.8H, dt, *J* = 16.2, 6.8 Hz, CH_2), 2.59 (0.8H, dt, *J* = 16.2, 6.8 Hz, CH_2), 2.36-1.69 (9.2H, m, CH_2), 1.67-1.54 (0.2H, m, C*H*$(CH_3)_2$), 1.52-1.37 (0.8H, m, CH_2), 1.25 (0.8H, sept, *J* = 6.4 Hz, C*H*$(CH_3)_2$), 1.10 (0.6H, d, *J* = 6.4 Hz, CH(C*H*$_3)_2$), 1.00 (0.6H, d, *J* = 6.4 Hz, CH(C*H*$_3)_2$), 0.97 (2.4H, d, *J* = 6.4 Hz, CH(C*H*$_3)_2$), 0.34 (2.4H, d, *J* = 6.4 Hz, CH(C*H*$_3)_2$); ^{13}C NMR (100 MHz, $CDCl_3$) δ (8/2 mixture of rotamers) 167.0, 166.8, 143.9, 141.8, 136.8, 136.7, 134.81, 134.75, 134.5, 132.0, 129.4, 129.2, 128.8, 128.6, 127.5, 127.3, 127.2, 126.0, 125.6, 124.5, 124.3, 115.8, 113.6, 69.0, 64.8, 58.2, 57.8, 56.95, 56.86, 56.4, 55.5, 47.1, 43.8, 37.5, 37.4, 36.4, 36.2, 26.2, 25.3, 24.9, 24.3, 24.1, 23.9, 23.2, 22.1, 20.9, 20.82, 20.76, 20.5, 20.3, 20.1; HRMS–ESI (*m*/*z*): $[M–Br]^+$ calcd for $C_{29}H_{39}N_2O$: 431.3057. Found: 431.3049.

(*S*)-1-Cinnamyl-4,4-dimethoxy-1-(1-oxo-1-(phenanthridin-5(6*H*)-yl)propan-2-yl)piperidin-1-ium bromide (3): prepared by the same procedure with **1d** using **3'** as a substrate (70% yield); white solid; $[\alpha]^{23}_{589}$ –160.1 (*c* 1.00, EtOH); IR (KBr) 2959, 2834, 1659, 1485, 1442, 1411, 1382, 1348, 1312, 1264, 1223, 1192, 1161, 1119, 1053, 1002, 979, 943, 871, 843, 750, 695 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ (5/5 mixture of rotamers) 7.90 (0.5H, d, *J* = 7.6 Hz, ArH), 7.83-7.66 (2H, m, ArH), 7.60 (0.5H, d, *J* = 7.6 Hz, ArH), 7.55-6.85 (11H, m, ArH and C*H*=C*H*Ph), 6.68 (0.5H, d, *J* = 15.2 Hz, CH=C*H*Ph), 6.64-6.51 (0.5H, m, C*H*=CHPh), 6.39 (0.5H, q, *J* = 6.8 Hz, NCHCO), 5.71 (1H, br, CH_2), 5.31 (0.5H, d, *J* = 15.6 Hz, CH_2), 5.03-4.86 (1H, m, NCHCO and CH_2), 4.86-4.65 (1H, m, CH_2), 4.65-4.49 (1H, m, CH_2), 4.49-3.43 (2H, m, CH_2), 4.40 (0.5H, dd, *J* = 13.8, 9.4 Hz, CH_2), 3.68 (0.5H, dd, *J* = 13.0, 13.0 Hz, CH_2), 3.56 (0.5H, ddd, *J* = 13.0, 13.0, 3.2 Hz, CH_2), 3.23 (1.5H, s, OCH_3), 3.21 (1.5H, s, OCH_3), 3.06 (1.5H, br, OCH_3), 2.74 (1.5H, br, OCH_3), 2.49 (0.5H, br, CH_2), 2.38-1.00 (5.5H, m, CH_2 and CHC*H*$_3$), 1.72 (1.5H, d, *J* = 6.8 Hz, CHC*H*$_3$); ^{13}C NMR (100 MHz, $CDCl_3$) δ (5/5 mixture of rotamers) 167.4, 143.9, 141.8, 135.6, 135.3, 134.3, 134.2, 133.9, 132.8, 131.0, 130.7, 130.2, 130.0, 129.5, 129.3, 129.0, 128.7, 128.60, 128.57, 128.4, 128.3, 127.5, 127.1, 127.0, 126.8, 126.4,

125.1, 124.7, 124.3, 123.5, 122.6, 113.6, 94.9, 65.3, 57.8, 54.1, 52.3, 48.15, 48.08, 48.0, 47.9, 47.3, 46.1, 27.6, 27.5, 27.3, 13.5; HRMS–ESI (*m*/*z*): $[M–Br]^+$ calcd for $C_{32}H_{37}N_2O_3$: 497.2799. Found: 497.2785.

Preparation of other compounds

(*E*)-1-(3-Bromoprop-1-en-1-yl)-4-chlorobenzene

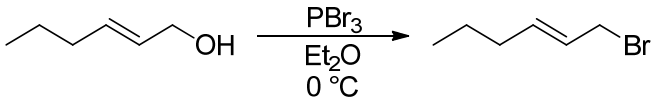


(Step 1) Triethyl phosphonoacetate (2.0 mL, 10 mmol) was added to a suspension of sodium hydride (60 wt.% in oil, 0.44 g, 11 mmol) in THF (30 mL) at 0 °C and the mixture was stirred for 15 min. To the resulting mixture, 4-chlorobenzaldehyde (1.41 g, 10 mmol) was added in one portion at the same temperature. The resulting mixture was stirred for 12 h at room temperature and quenched with saturated aqueous ammonium chloride at 0 °C. Extractive workup and purification of the residue by chromatography on silica gel (*n*-hexane/ethyl acetate = 20/1 to 15/1 as the eluent) afforded (*E*)-ethyl 3-(4-chlorophenyl)acrylate (1.91 g, 91% yield) as a colorless oil. (Step 2) A 1 M solution of DIBAH solution in *n*-hexane (1.2 mL, 1.2 mmol) was added to a solution of (*E*)-ethyl 3-(4-chlorophenyl)acrylate (105 mg, 0.50 mmol) in toluene (1.2 mL) at 0 °C. The mixture was stirred for 30 min and quenched with water at the same temperature. The mixture was treated with 1 M hydrochloric acid and extracted with ethyl acetate. The combined extracts were washed with saturated aqueous sodium hydrogen carbonate and brine. The organic solution was dried over sodium sulfate and concentrated to obtain (*E*)-3-(4-chlorophenyl)prop-2-en-1-ol (85 mg, quant.) as colorless crystals. The crude product was used without purification. (Step 3) Phosphorus tribromide (0.23 mL, 2.4 mmol) was added to a solution of (*E*)-3-(4-chlorophenyl)prop-2-en-1-ol (0.22 g, 1.3 mmol) in diethyl ether (4.3 mL) at 0 °C. The mixture was stirred for 30 min at 0 °C and 2 h at room temperature. The resulting mixture was treated with water and extracted with ethyl acetate. The combined extracts were washed with saturated aqueous sodium hydrogen carbonate and aqueous saturated sodium bromide. The solution was dried over sodium sulfate and concentrated to obtain (*E*)-1-(3-bromoprop-1-en-1-yl)-4-chlorobenzene (0.27 g, 90% yield) as a colorless oil. The crude product was used without purification.

(*E*)-1-Bromo-4-(3-bromoprop-1-en-1-yl)benzene: prepared by the same procedures with (*E*)-1-(3-bromoprop-1-en-1-yl)-4-chlorobenzene using 4-bromobenzaldehyde instead of 4-chlorobenzaldehyde in step 1 (62% overall yield).

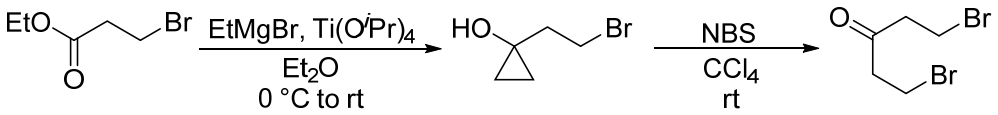
(*E*)-1-(3-Bromoprop-1-en-1-yl)-4-methylbenzene: prepared by the same procedures with (*E*)-1-(3-bromoprop-1-en-1-yl)-4-chlorobenzene using 4-methylbenzaldehyde instead of 4-chlorobenzaldehyde in step 1 (82% overall yield).

(*E*)-1-Bromohex-2-ene



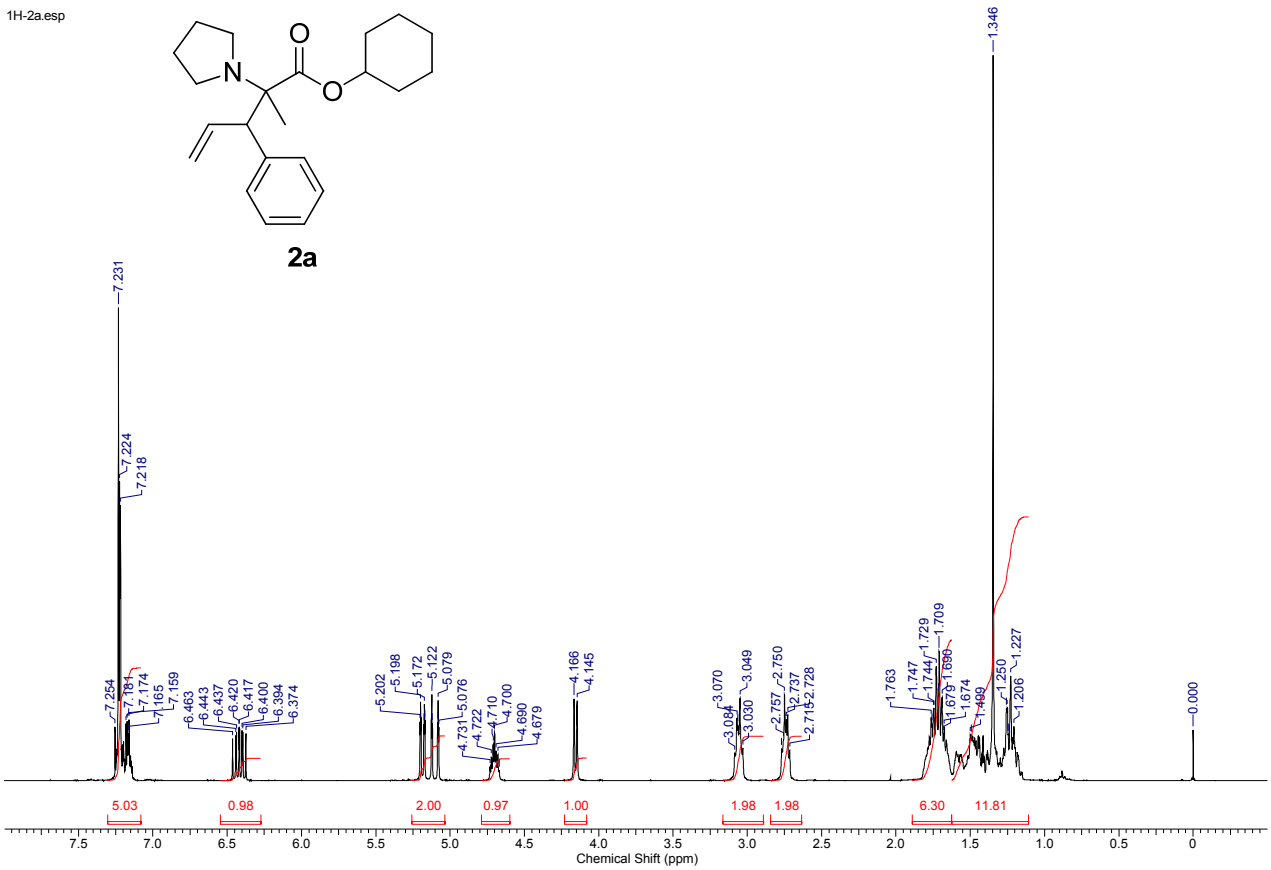
Phosphorus tribromide (1.55 mL, 16.5 mmol) was added to a solution of (*E*)-hex-2-en-1-ol (1.77 mL, 15.0 mmol) in diethyl ether (30 mL) at 0 °C and the mixture was stirred for 1 h at the same temperature. The resulting mixture was treated with water and extracted with diethyl ether. The combined extracts were washed with saturated aqueous sodium hydrogen carbonate and aqueous saturated sodium bromide. The diethyl ether solution was dried over sodium sulfate and concentrated to obtain (*E*)-1-bromohex-2-ene (1.90 g, 78% yield) as a colorless oil. The crude product was used without purification.

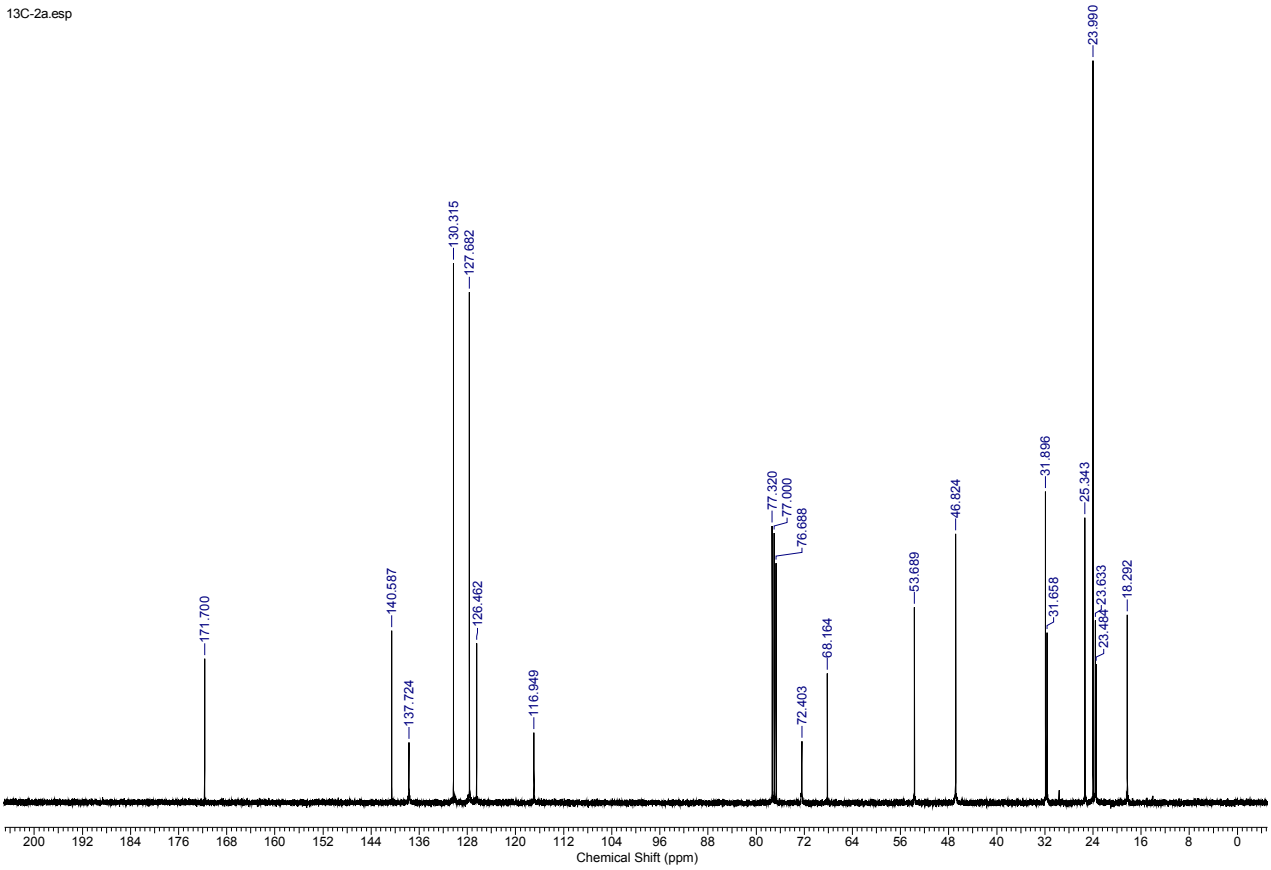
1,5-Dibromopentan-3-one[4]

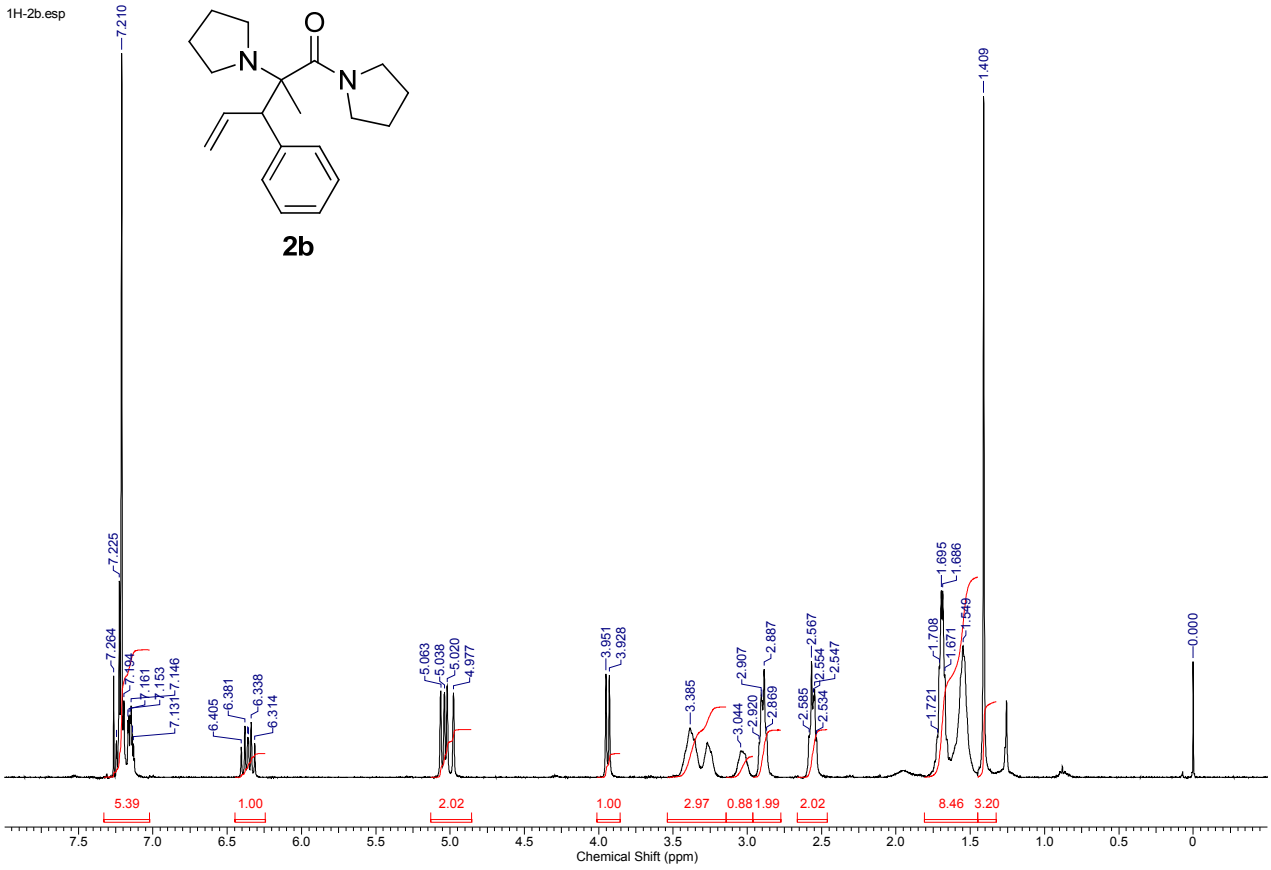


(Step 1) A solution of ethylmagenesium bromide in diethyl ether [prepared from magnesium turnings (0.65 g, 27 mmol) and ethyl bromide (2.0 mL, 27 mmol) in diethyl ether (13 mL)] was added to a solution of ethyl 3-bromopropionate (1.54 mL, 12.0 mmol) and titanium tetraisopropoxide (0.36 mL, 1.2 mmol) in diethyl ether (12 mL) at 0 °C. The mixture was stirred for 16 h at room temperature and quenched with water. The mixture was treated with 5% (v/v) sulfonic acid and extracted with ethyl acetate. The combined extracts were washed with saturated aqueous sodium hydrogen carbonate and aqueous saturated sodium bromide. Evaporation of the solvent and purification of the residue by chromatography on silica gel (*n*-hexane/ethyl acetate = 8/1 to 4/1 as the eluent) gave 1-(2-bromoethyl)cyclopropanol (1.71 g, 86% yield) as a pale brown oil. (Step 2) *N*-Bromosuccinimide (1.85 g, 10.4 mmol) was added to a solution of 1-(2-bromoethyl)cyclopropanol (1.71 g, 10.4 mmol) in carbon tetrachloride (21 mL) at room temperature and the mixture was stirred for 2 h at the same temperature. The resulting mixture was filtered and the filtrate was concentrated. Purification of the residue by chromatography on silica gel (*n*-hexane/ethyl acetate = 15/1 to 8/1 as the eluent) afforded 1,5-dibromopentan-3-one (2.05 g, 81% yield) as a pale brown oil.

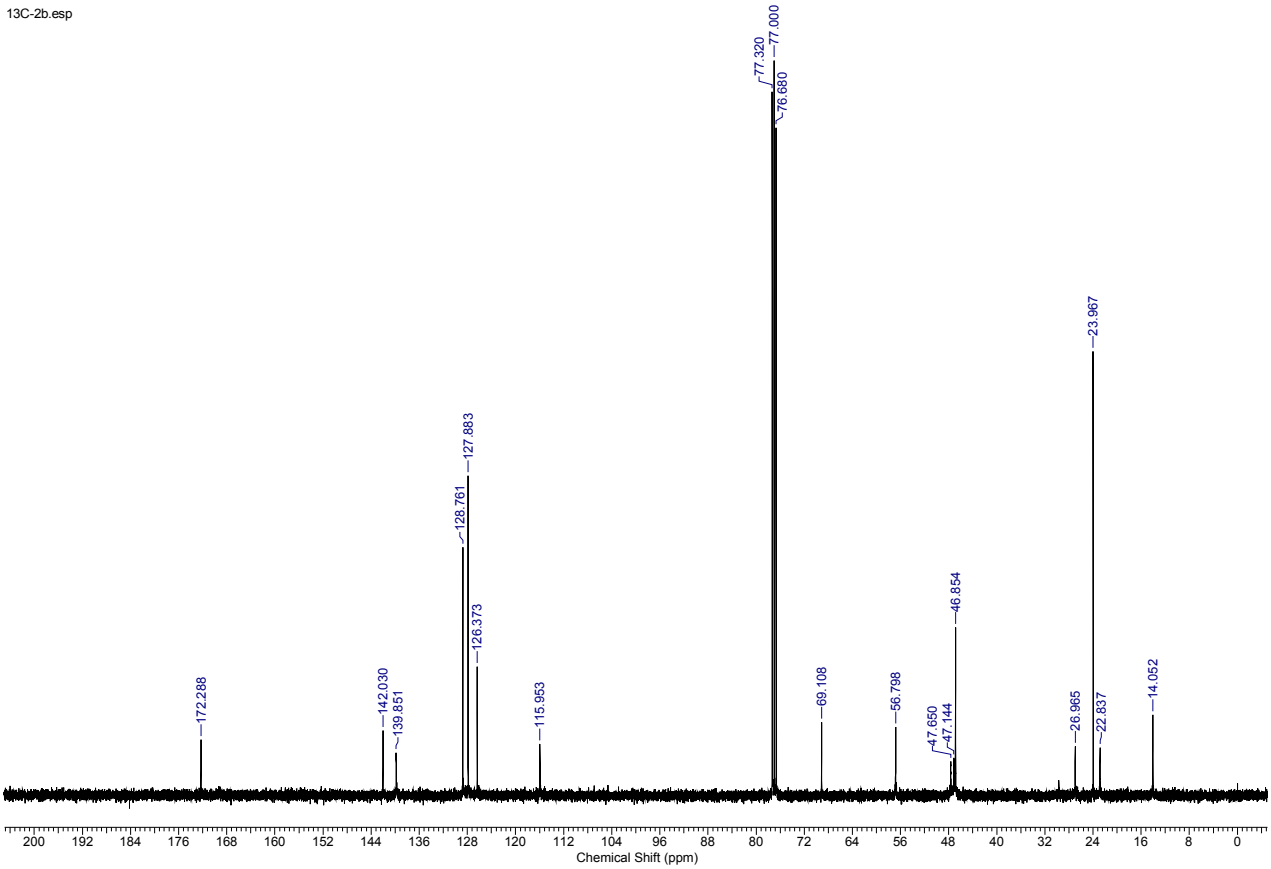
Copies of NMR spectra of 2, 4, 6–8

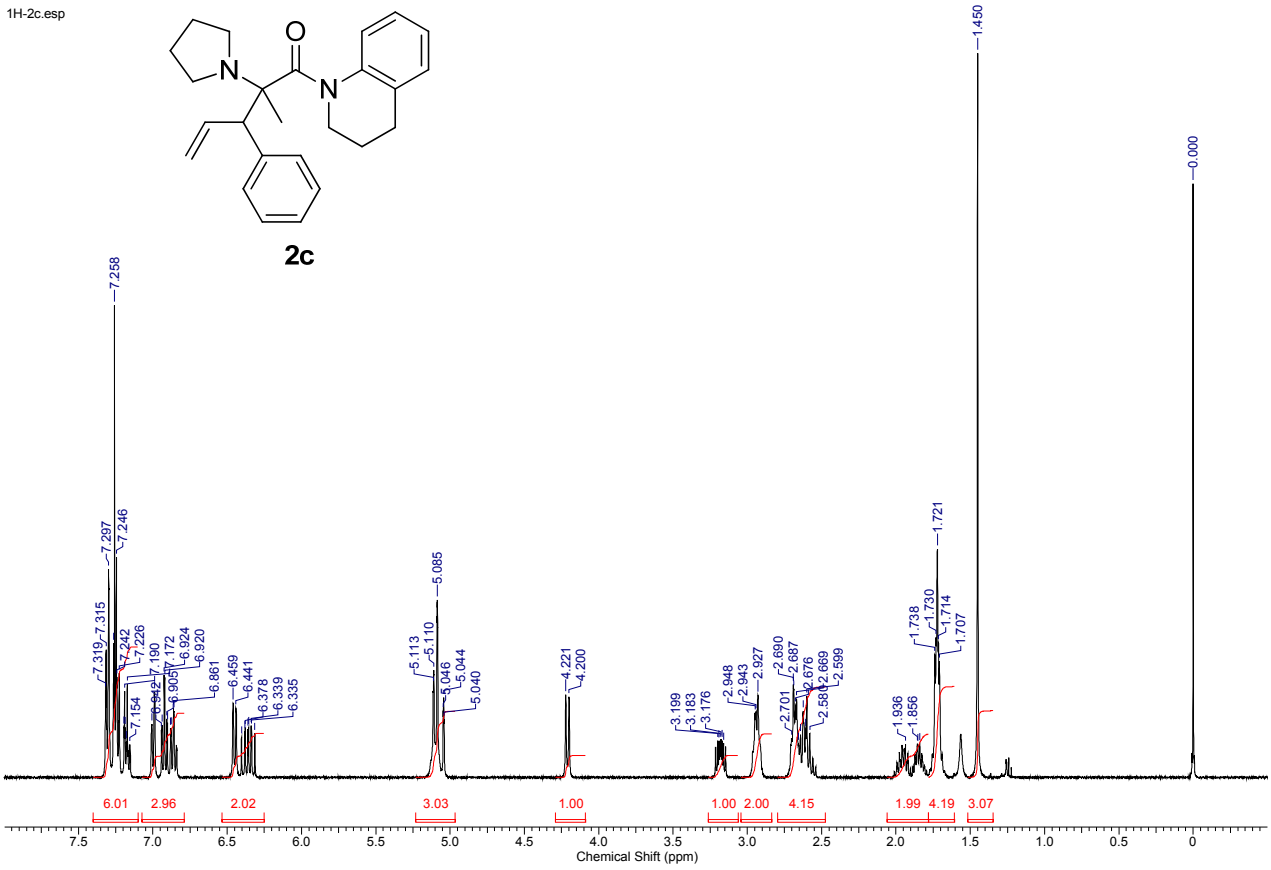


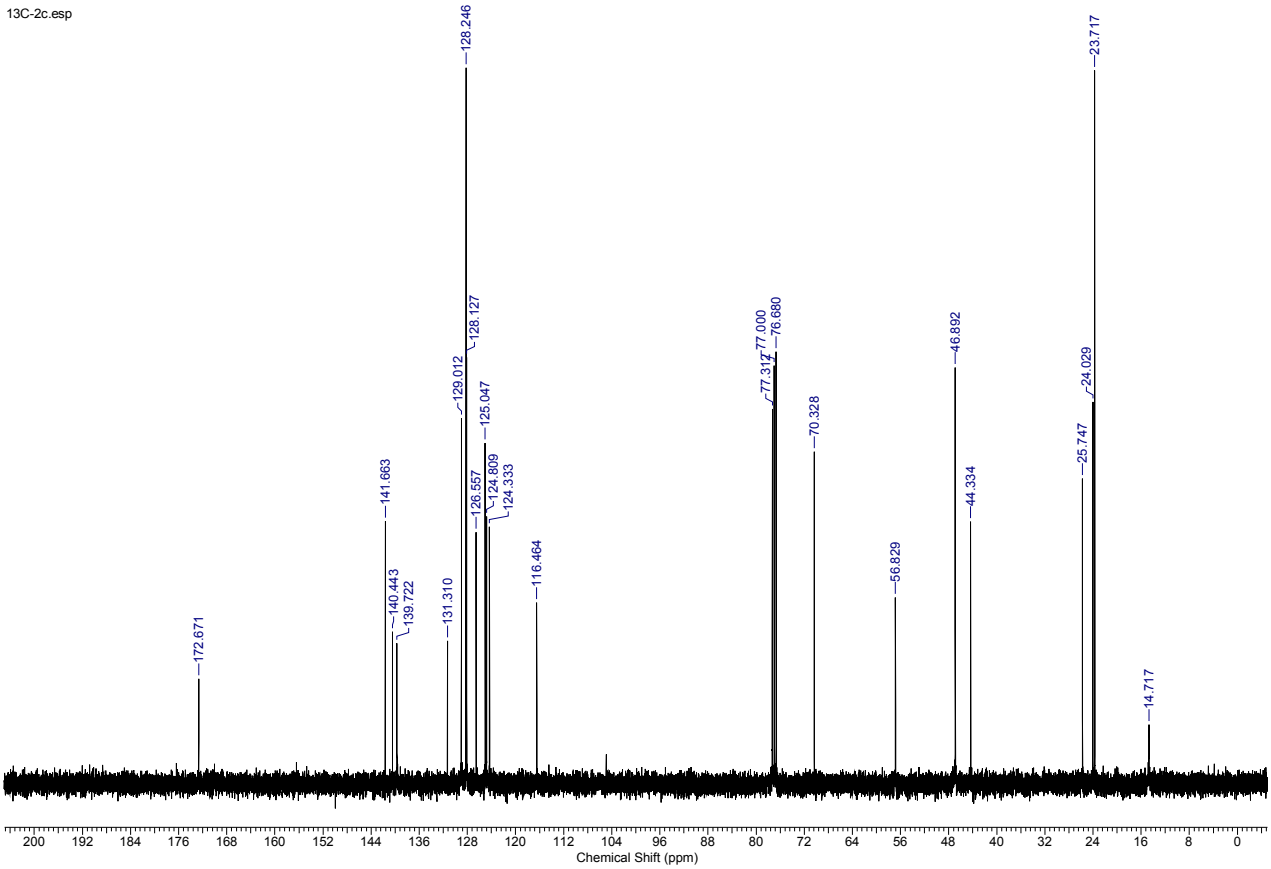


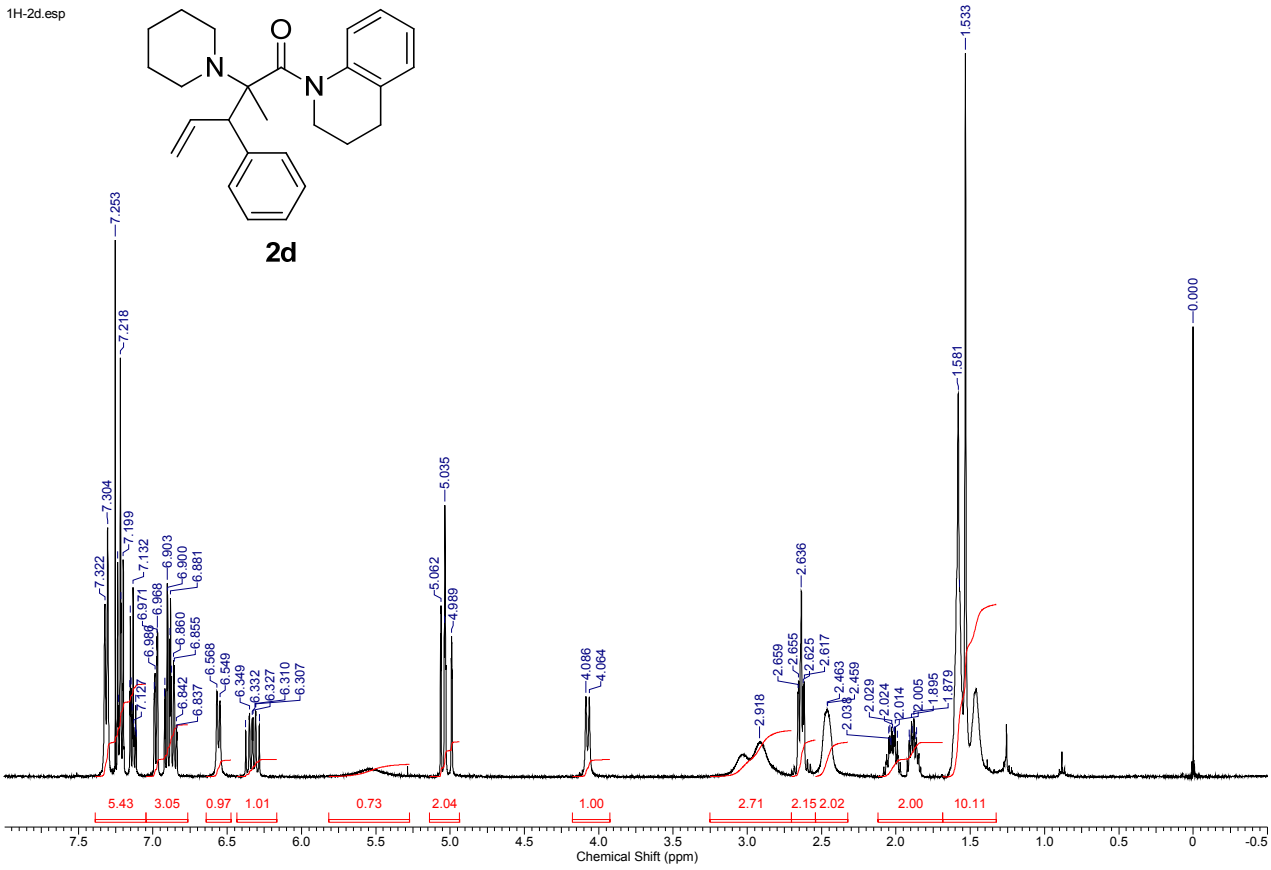

1H-2b.esp
7.210
7.225
7.264
7.194
7.161
7.153
7.146
7.131
6.405
6.381
6.338
6.314
5.063
5.038
5.020
4.977
3.951
3.928
3.385
3.044
2.920
2.907
2.887
2.869
2.585
2.567
2.554
2.534
2.547
1.721
1.708
1.695
1.686
1.671
1.549
1.409
0.000
5.39
1.00
2.02
1.00
2.97
0.88
1.99
2.02
8.46
3.20
Chemical Shift (ppm)

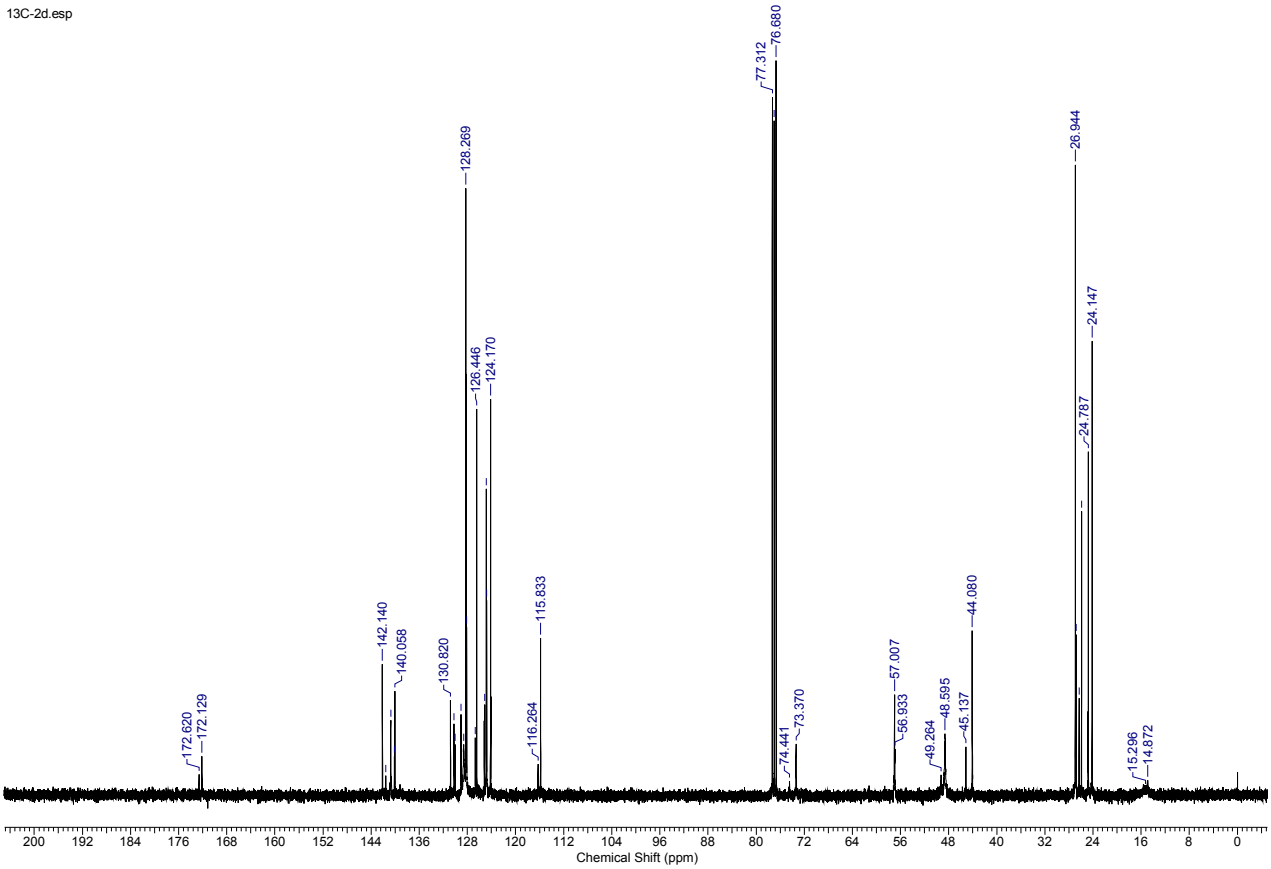
2b


13C-2b.esp
172.288
142.030
139.851
128.761
127.883
126.373
115.953
77.320
77.000
76.680
69.108
56.798
47.650
47.144
46.854
26.965
23.967
22.837
14.052
Chemical Shift (ppm)

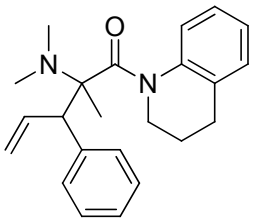

1H-2c.esp
2c
Chemical Shift (ppm)


13C-2c.esp
Chemical Shift (ppm)


1H-2d.esp
2d
Chemical Shift (ppm)

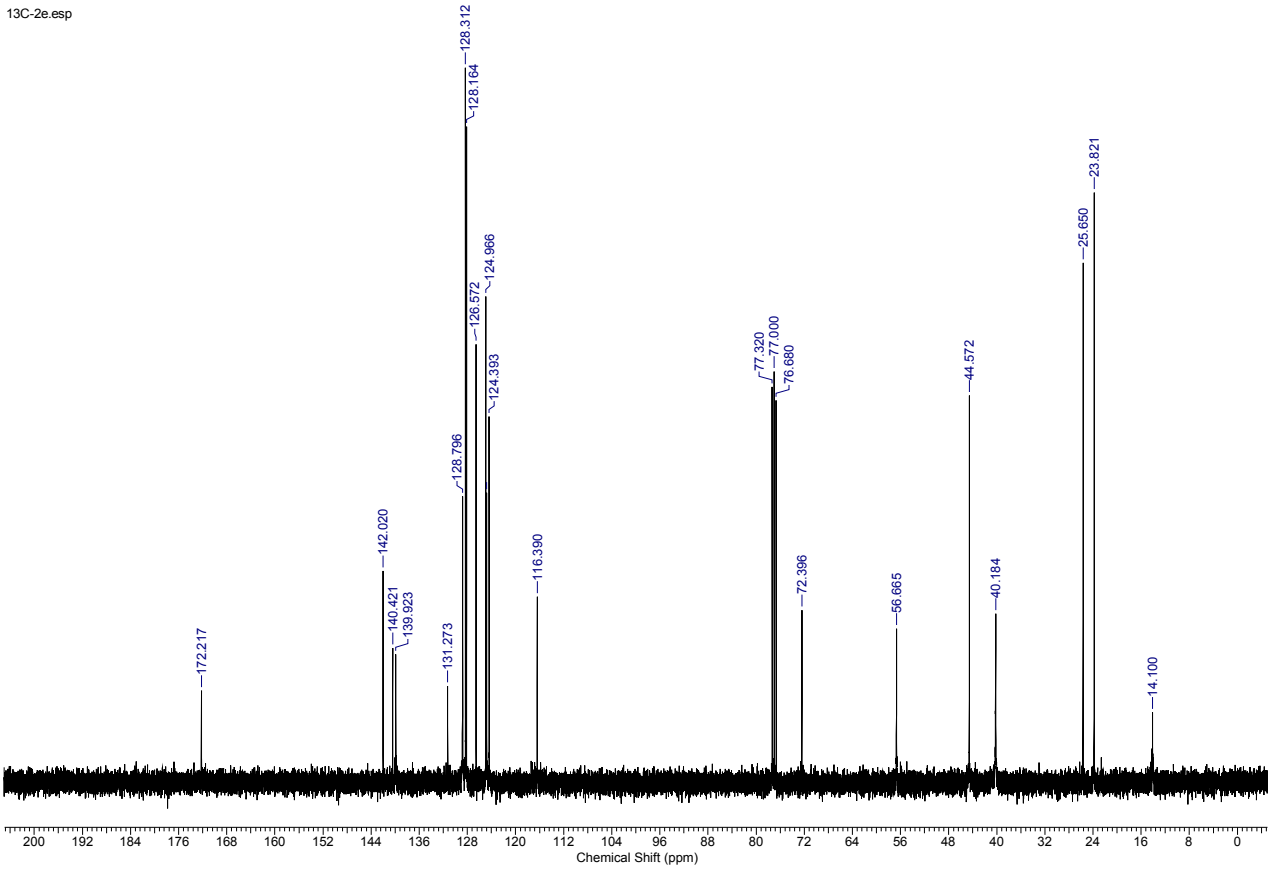

13C-2d.esp
Chemical Shift (ppm)

1H-2e.esp

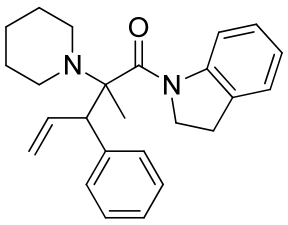


2e

13C-2e.esp

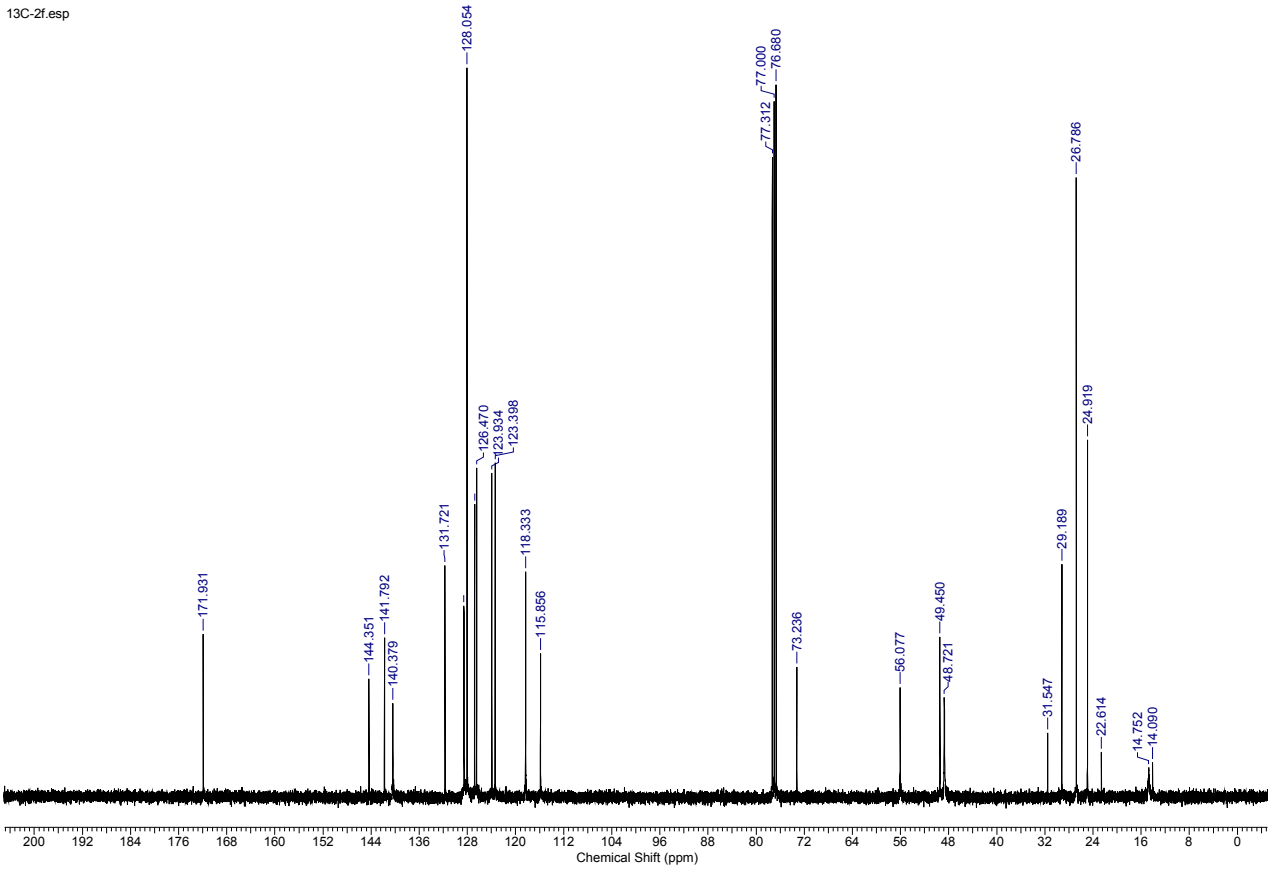


1H-2f.esp

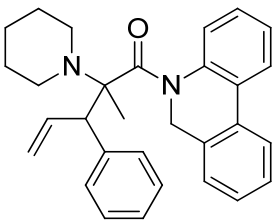


2f

13C-2f.esp

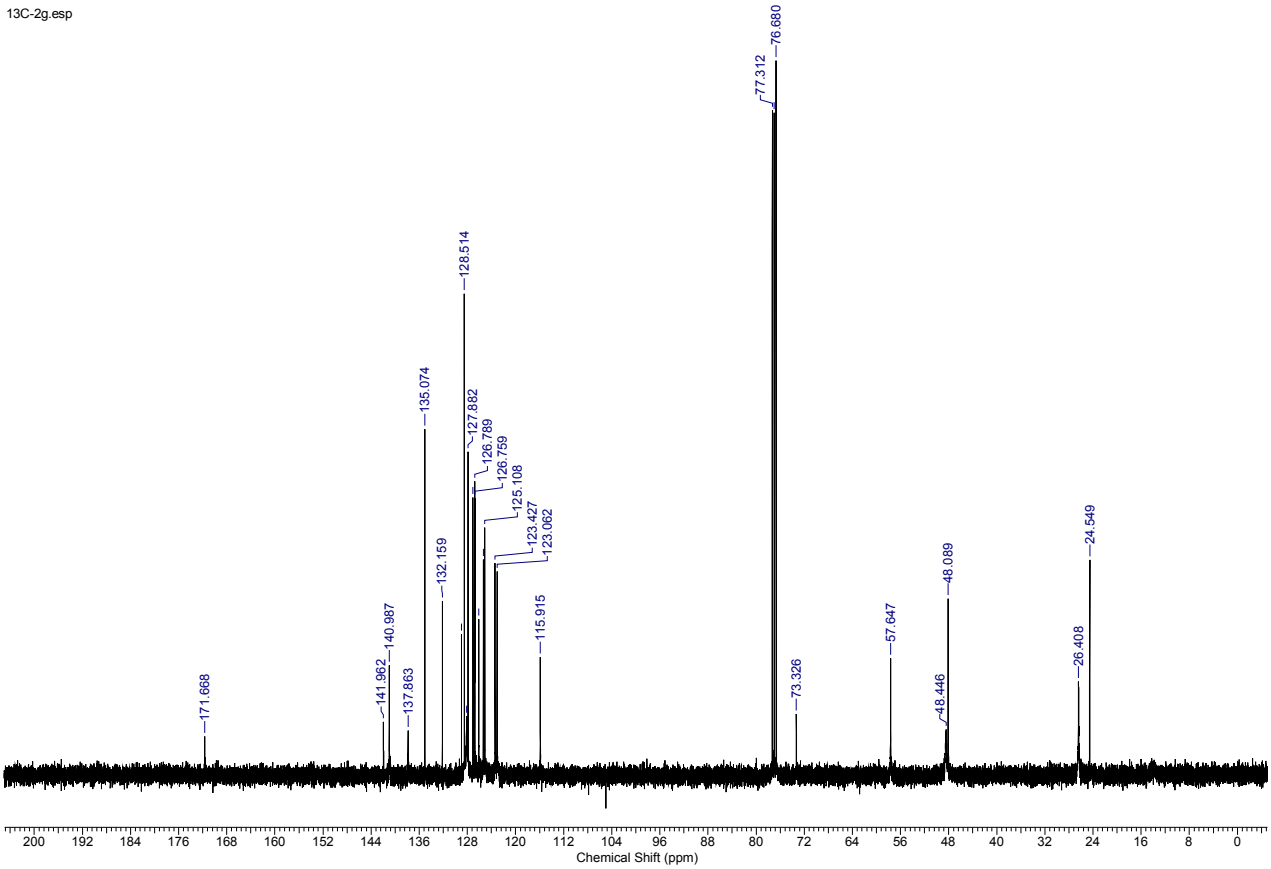


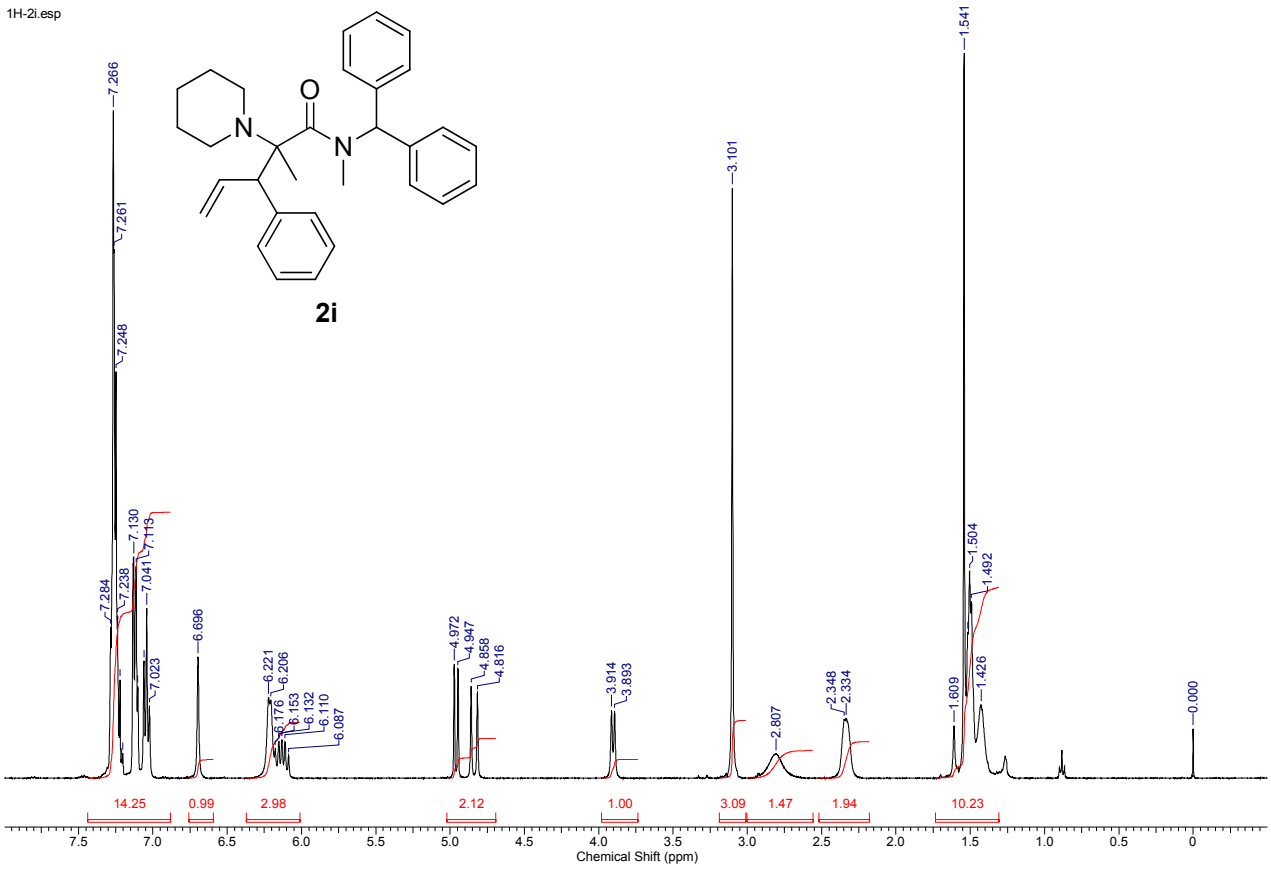
1H-2g.esp

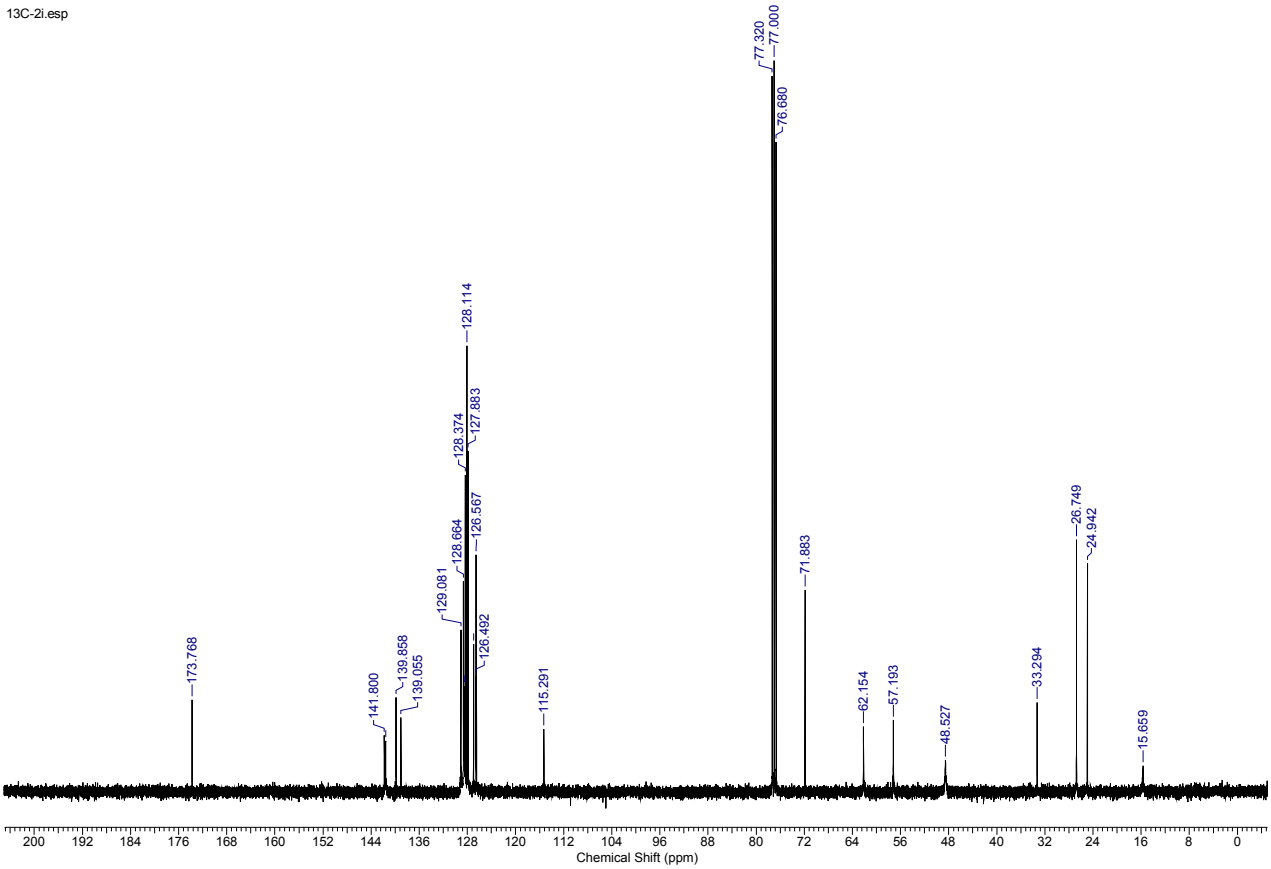


2g

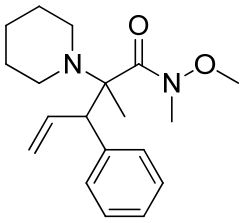
13C-2g.esp




1H-2i.esp
2i
7.266
7.261
7.248
7.284
7.238
7.130
7.113
7.041
7.023
6.696
6.221
6.206
6.176
6.153
6.132
6.110
6.087
4.972
4.947
4.858
4.816
3.914
3.893
3.101
2.807
2.348
2.334
1.609
1.541
1.504
1.492
1.426
0.000
14.25
0.99
2.98
2.12
1.00
3.09
1.47
1.94
10.23
Chemical Shift (ppm)

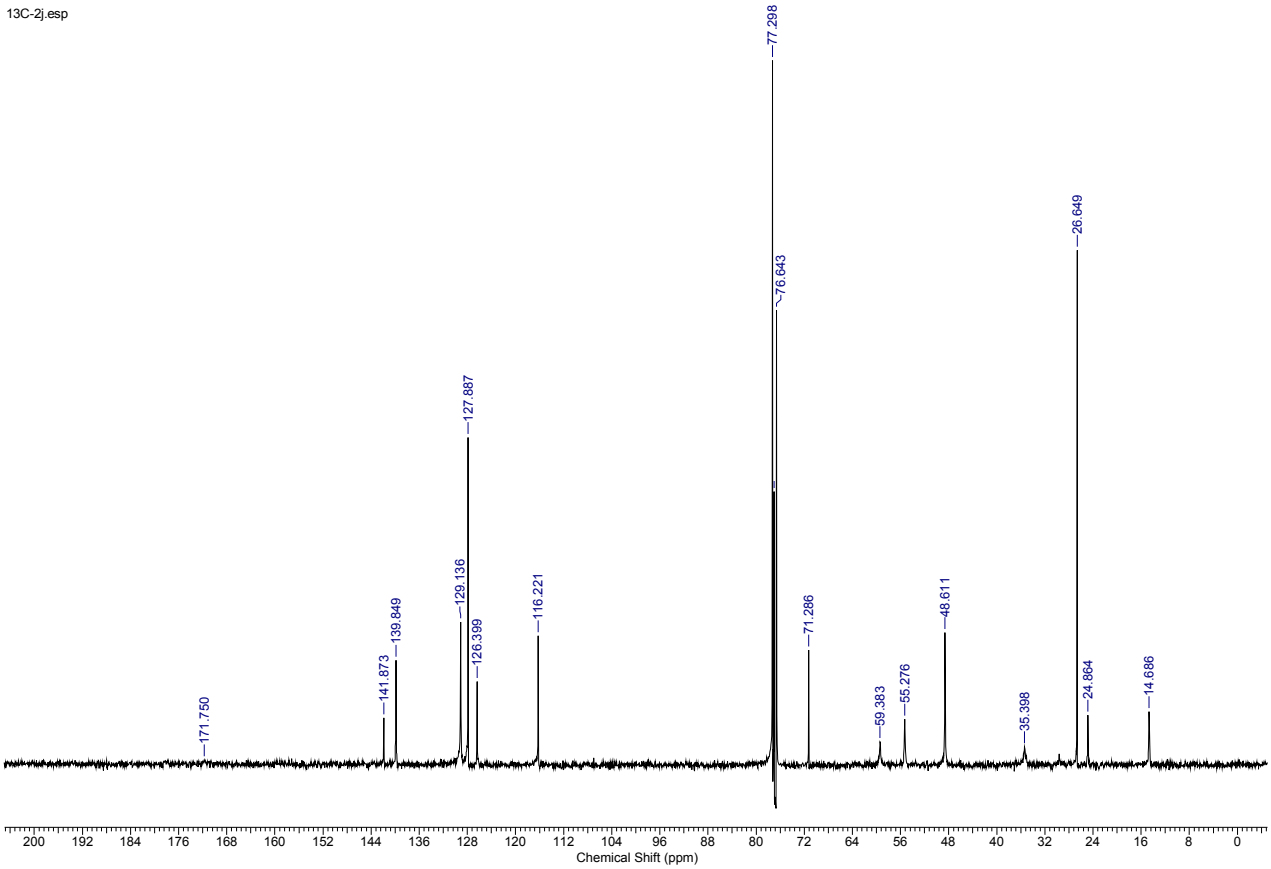

13C-2i.esp
77.320
77.000
76.680
128.114
128.374
127.883
126.567
129.081
128.664
126.492
173.768
141.800
139.858
139.055
115.291
71.883
62.154
57.193
48.527
33.294
26.749
24.942
15.659
Chemical Shift (ppm)

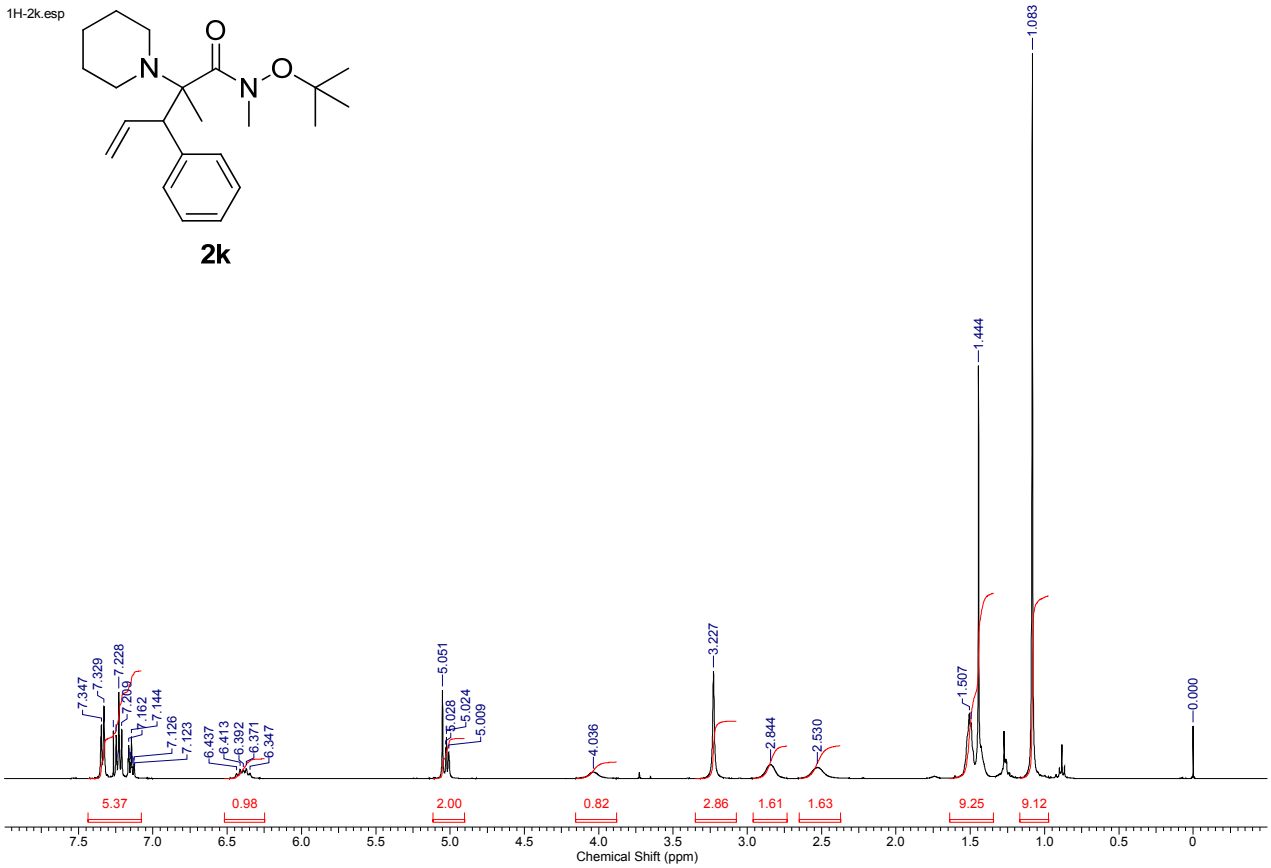
1H-2j.esp

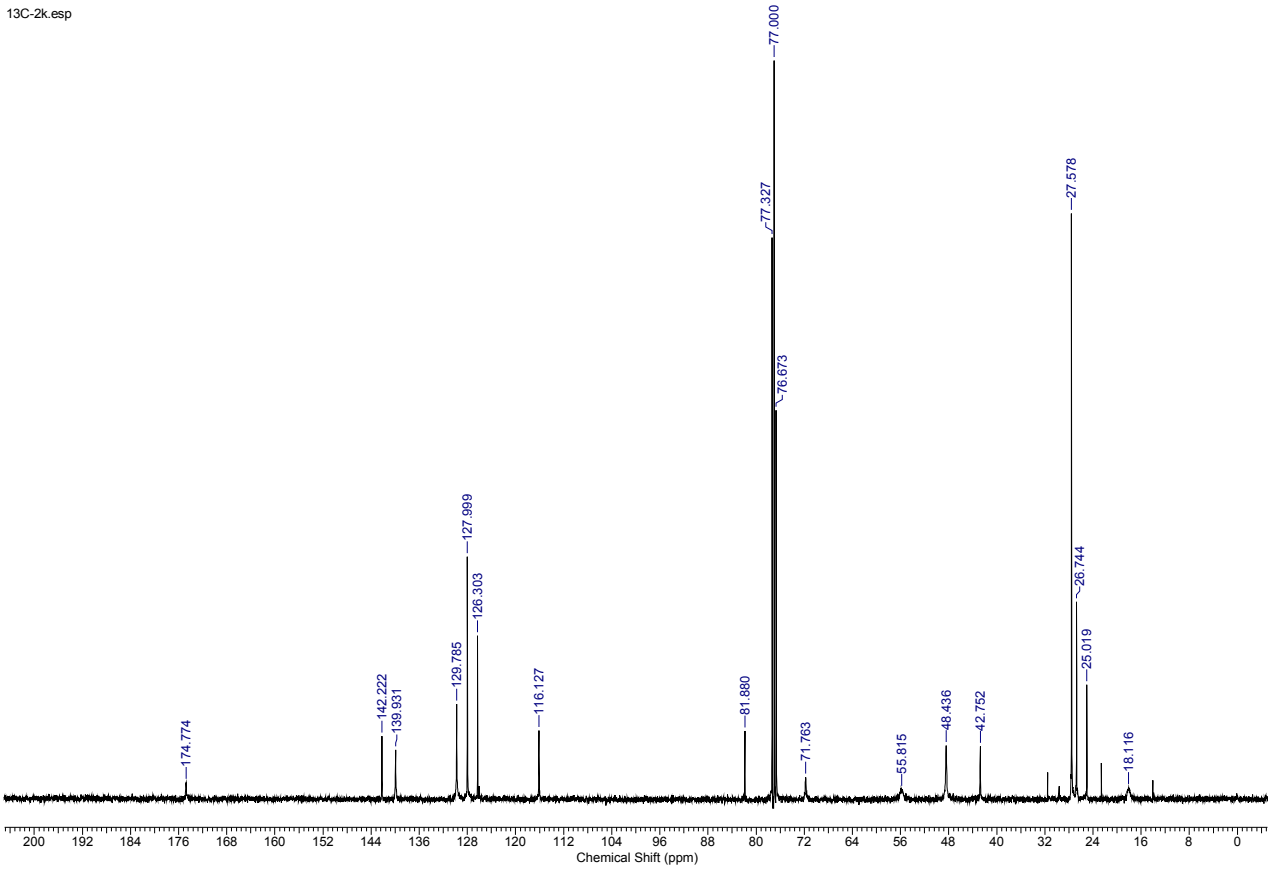


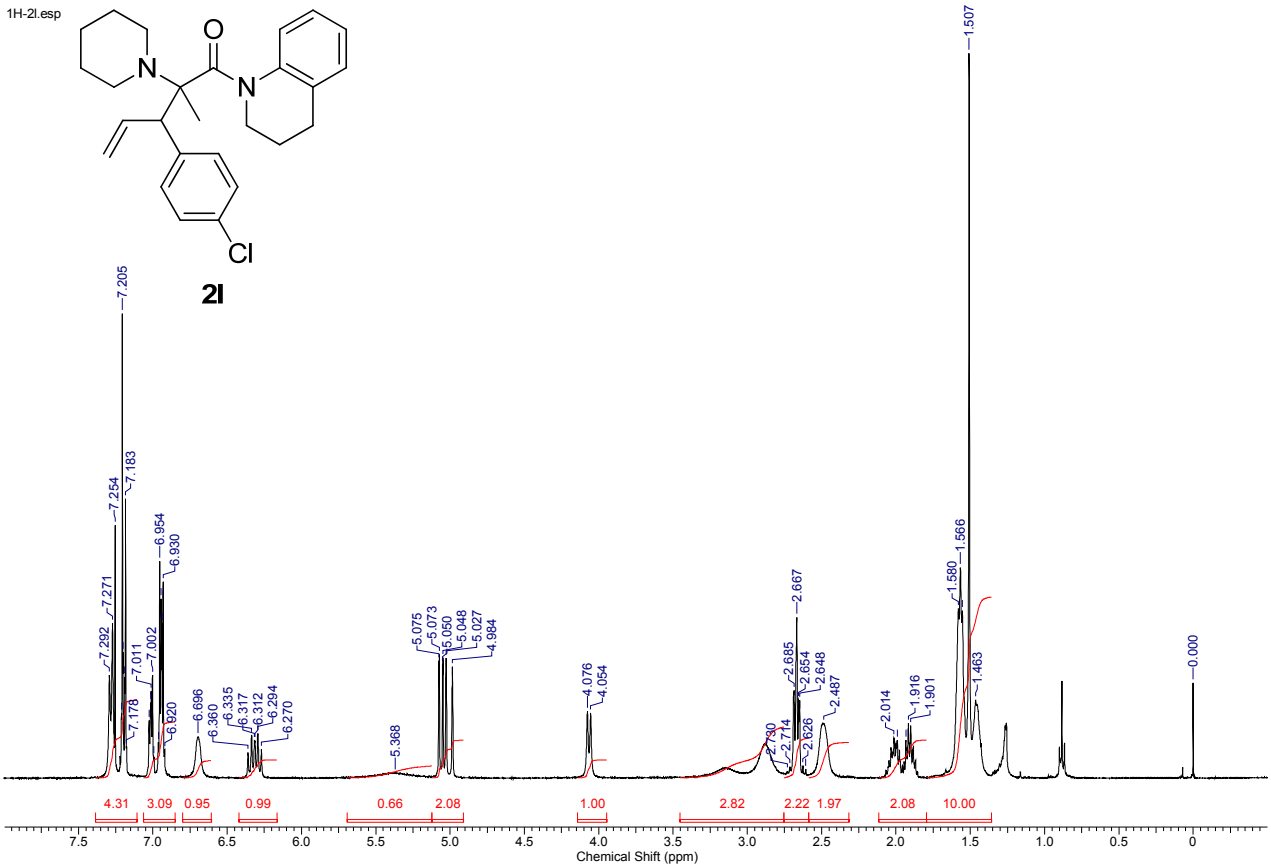
2j

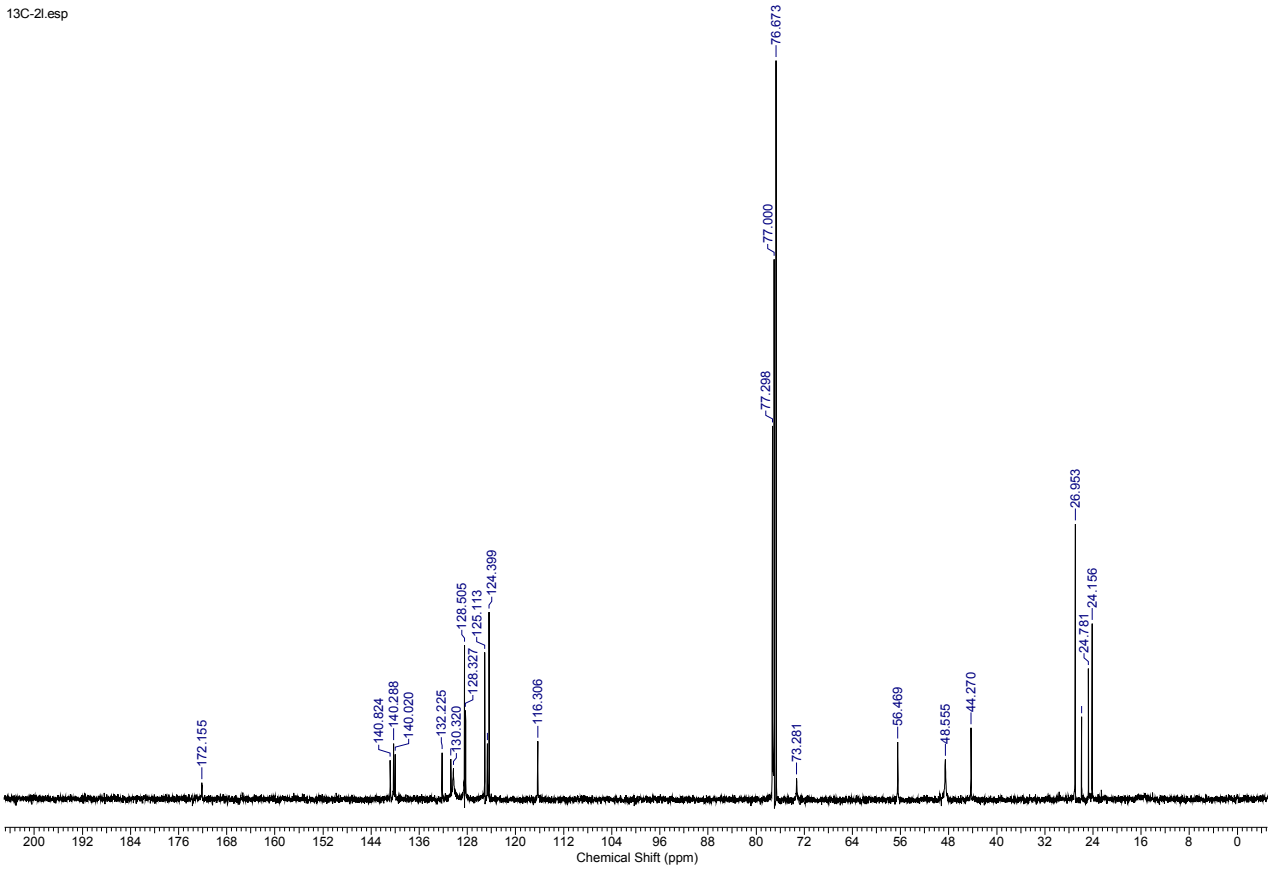
13C-2j.esp

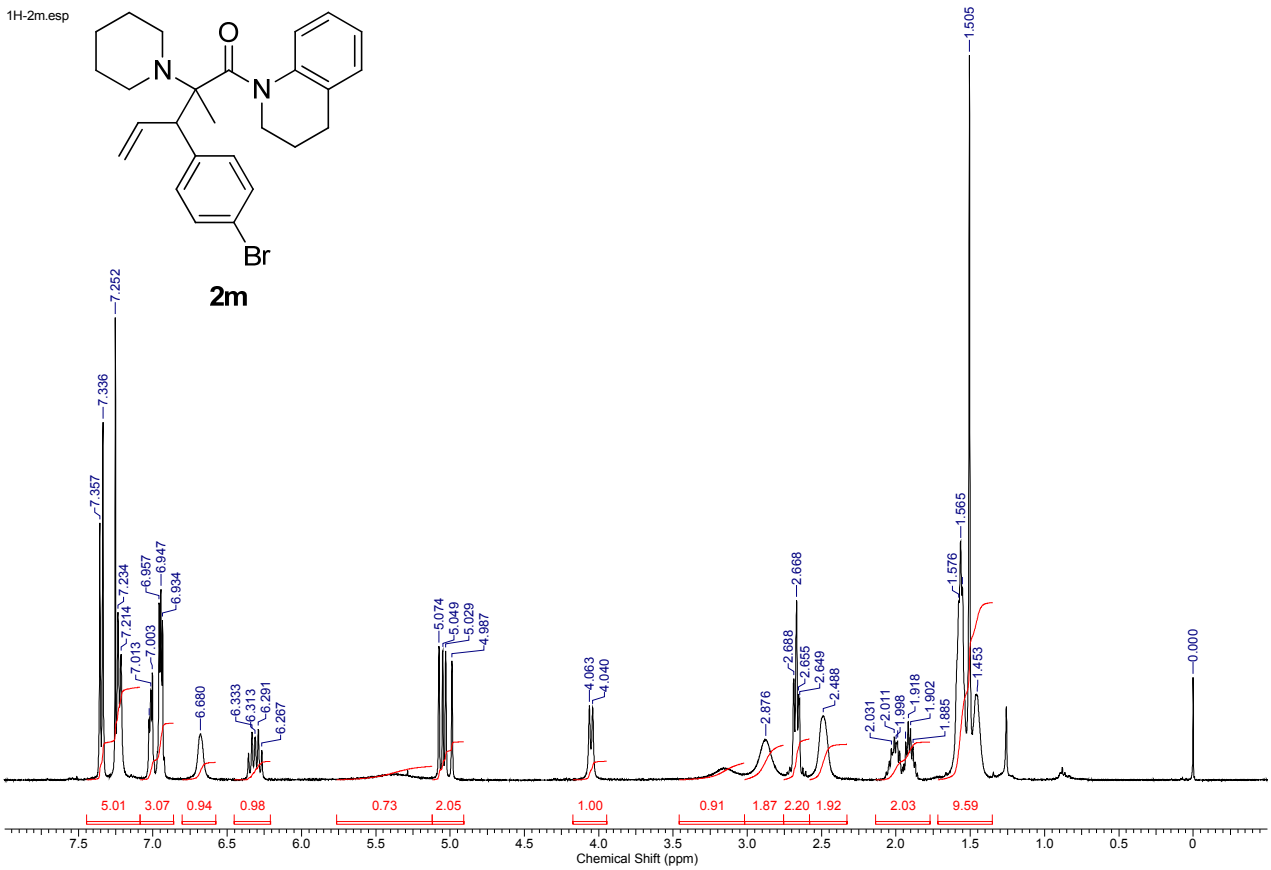


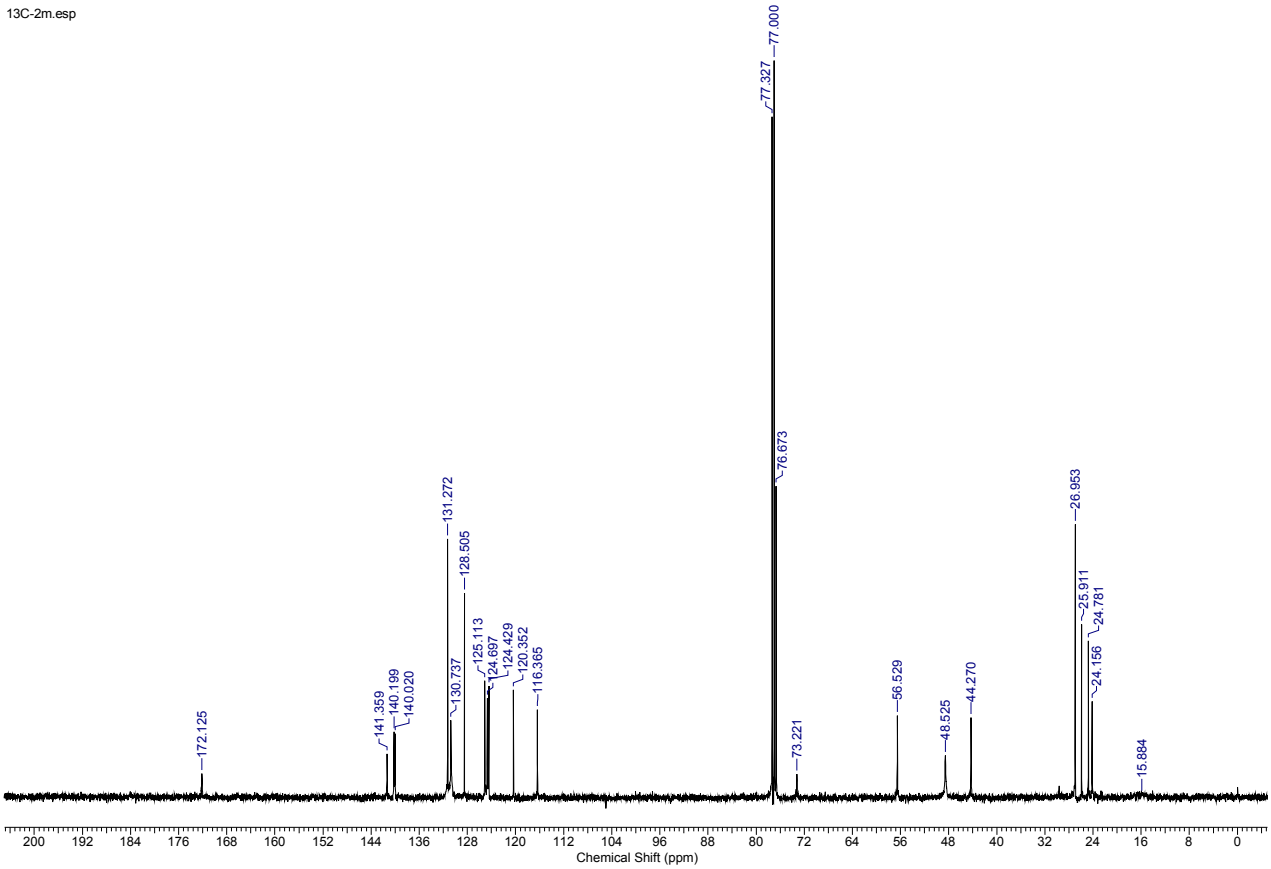

1H-2k.esp
2k
7.347
7.329
7.228
7.209
7.162
7.144
7.126
7.123
6.437
6.413
6.392
6.371
6.347
5.051
5.028
5.024
5.009
4.036
3.227
2.844
2.530
1.507
1.444
1.083
0.000
5.37
0.98
2.00
0.82
2.86
1.61
1.63
9.25
9.12
Chemical Shift (ppm)

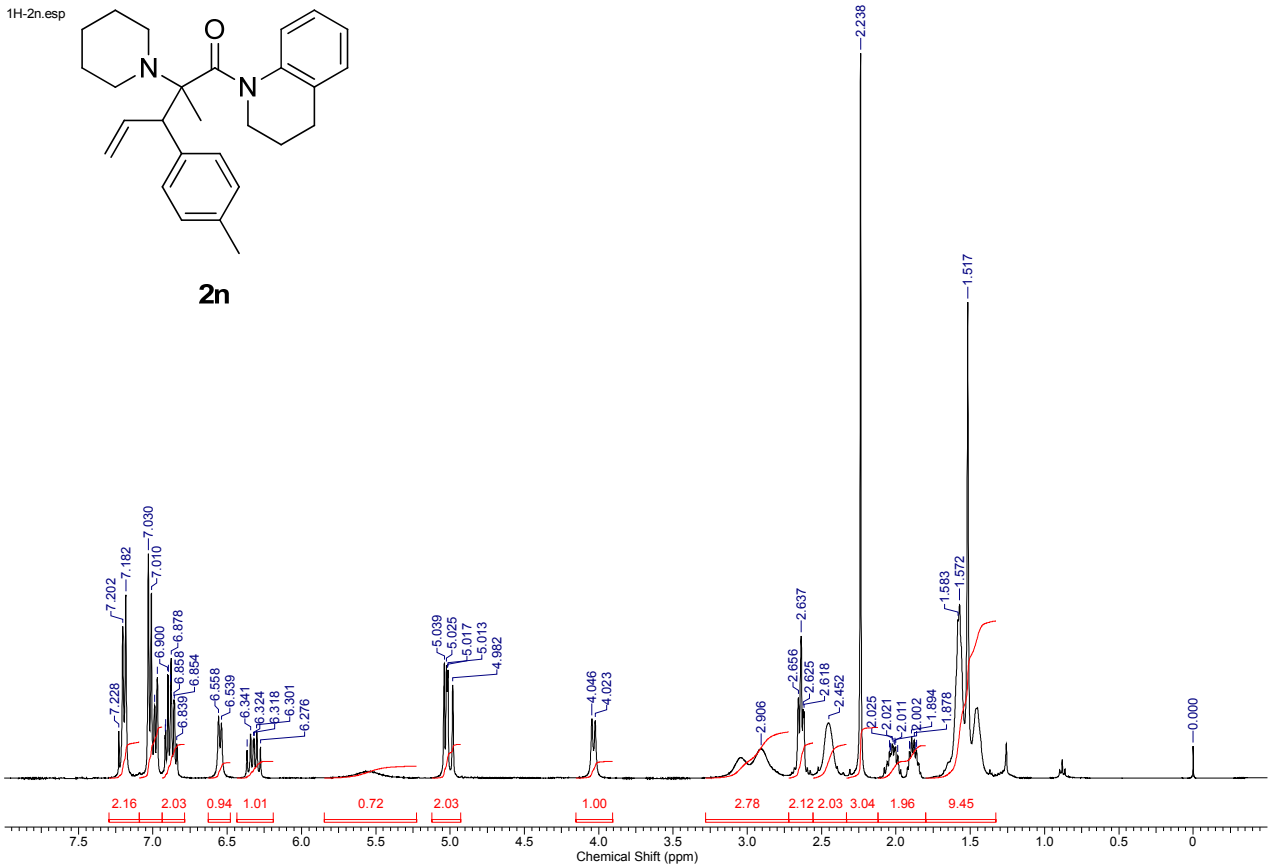

13C-2k.esp
174.774
142.222
139.931
129.785
127.999
126.303
116.127
81.880
77.000
77.327
76.673
71.763
55.815
48.436
42.752
27.578
26.744
25.019
18.116
Chemical Shift (ppm)

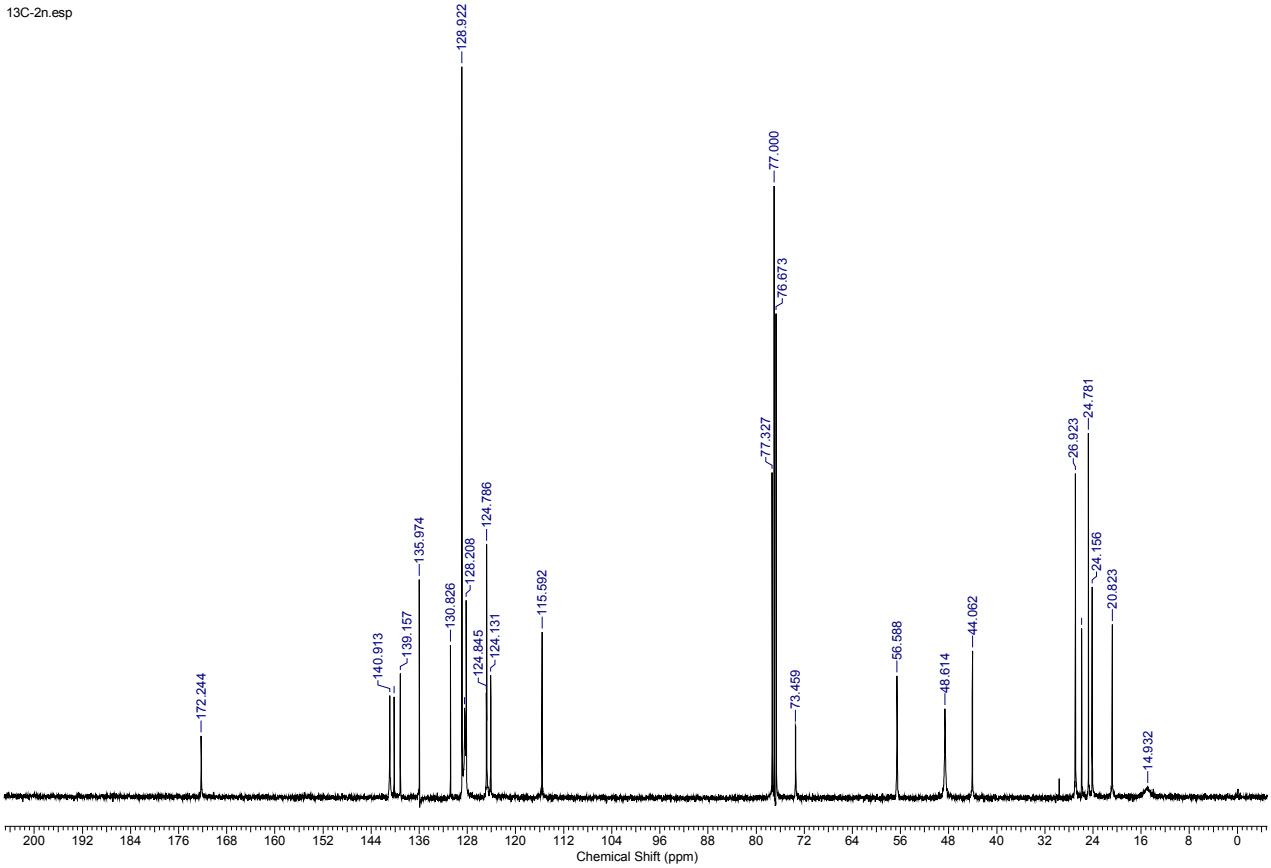

1H-2l.esp
O
N
N
Cl
2l
7.205
7.254
7.183
6.954
6.930
7.271
7.292
7.011
7.002
7.178
6.920
6.696
6.360
6.335
6.317
6.312
6.294
6.270
5.368
5.075
5.073
5.060
5.048
5.027
4.984
4.076
4.054
2.730
2.714
2.685
2.667
2.654
2.648
2.626
2.487
2.014
1.916
1.901
1.580
1.566
1.507
1.463
0.000
4.31
3.09
0.95
0.99
0.66
2.08
1.00
2.82
2.22
1.97
2.08
10.00
Chemical Shift (ppm)


13C-2l.esp
172.155
140.824
140.288
140.020
132.225
130.320
128.505
128.327
125.113
124.399
116.306
77.298
77.000
76.673
73.281
56.469
48.555
44.270
26.953
24.781
24.156
Chemical Shift (ppm)

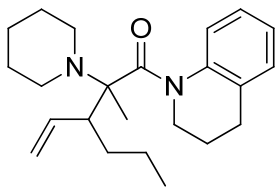

1H-2m.esp
O
N
N
Br
2m
7.252
7.336
7.357
7.234
6.957
6.947
6.934
7.214
7.013
7.003
6.680
6.333
6.313
6.291
6.267
5.074
5.049
5.029
4.987
4.063
4.040
2.876
2.688
2.668
2.655
2.649
2.488
2.031
2.011
1.998
1.918
1.902
1.885
1.576
1.565
1.505
1.453
0.000
5.01
3.07
0.94
0.98
0.73
2.05
1.00
0.91
1.87
2.20
1.92
2.03
9.59
Chemical Shift (ppm)


13C-2m.esp
77.327
77.000
76.673
172.125
141.359
140.199
140.020
131.272
130.737
128.505
125.113
124.697
124.429
120.352
116.365
73.221
66.529
48.525
44.270
26.953
25.911
24.781
24.156
15.884
Chemical Shift (ppm)


1H-2n.esp
2n
Chemical Shift (ppm)

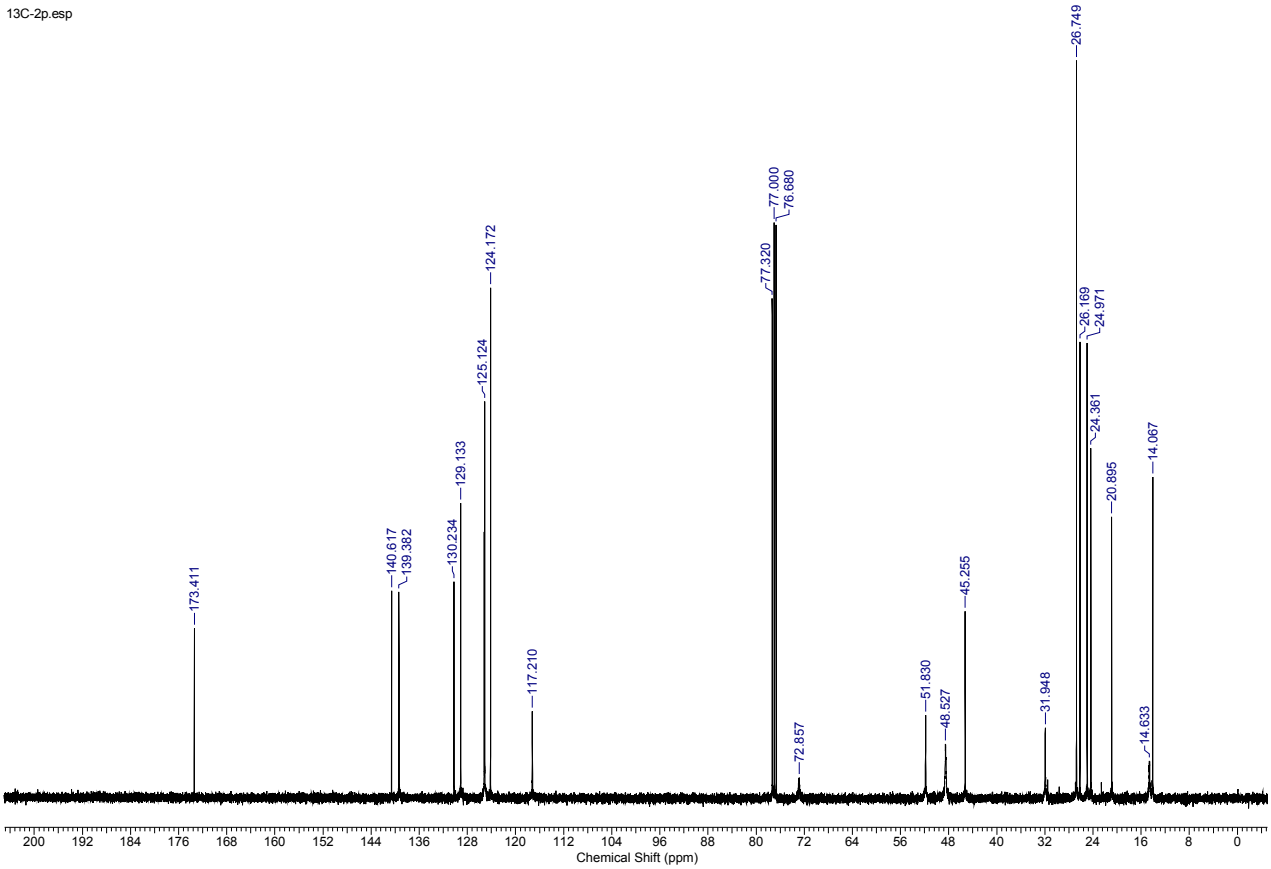

13C-2n.esp
Chemical Shift (ppm)

1H-2p.esp

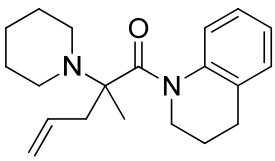


2p

13C-2p.esp

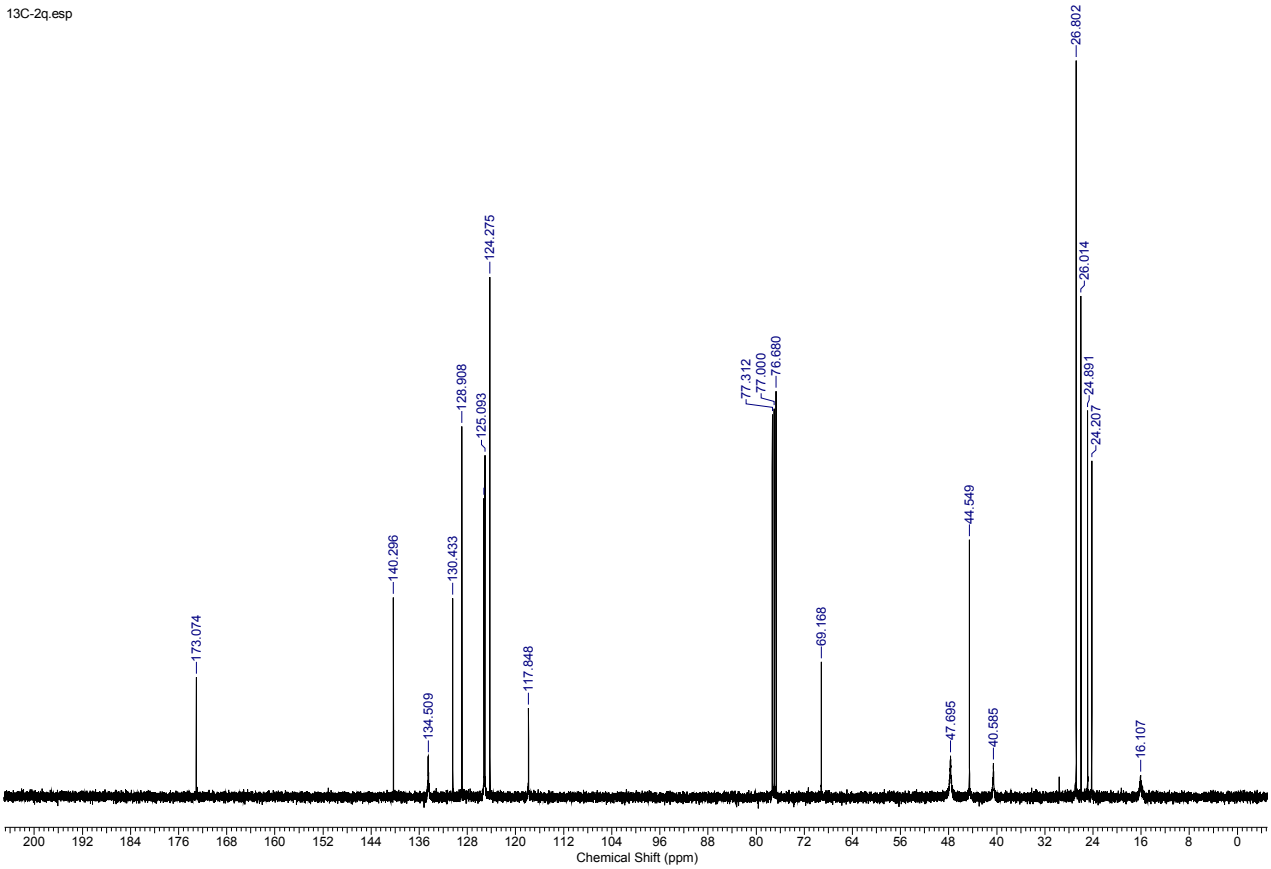


1H-2q.esp

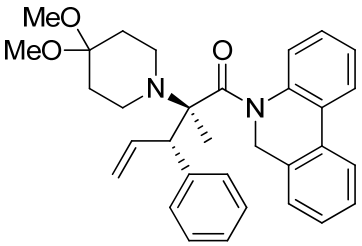


2q

13C-2q.esp

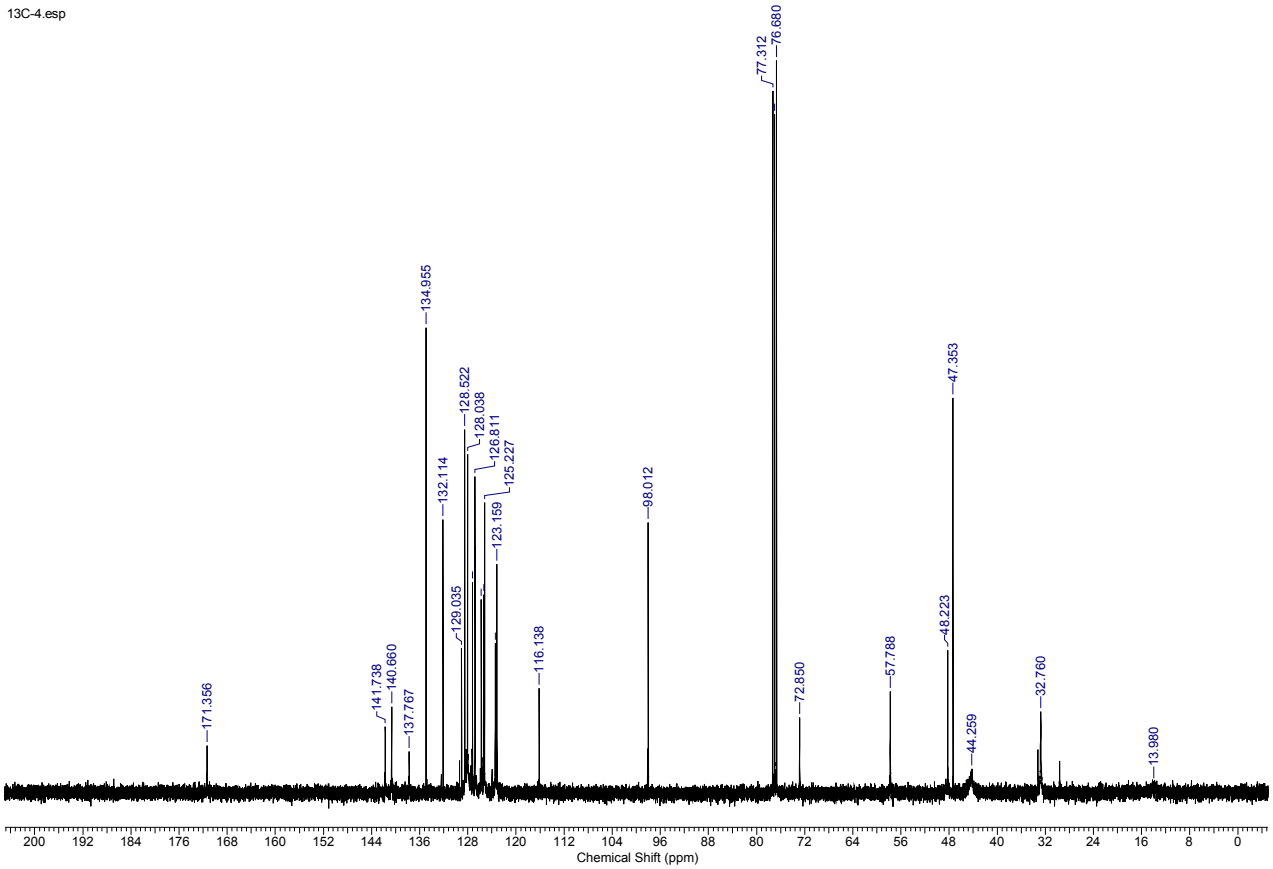


1H-4.esp

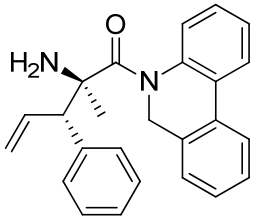


4
(2*R*,3*S*)-major

13C-4.esp



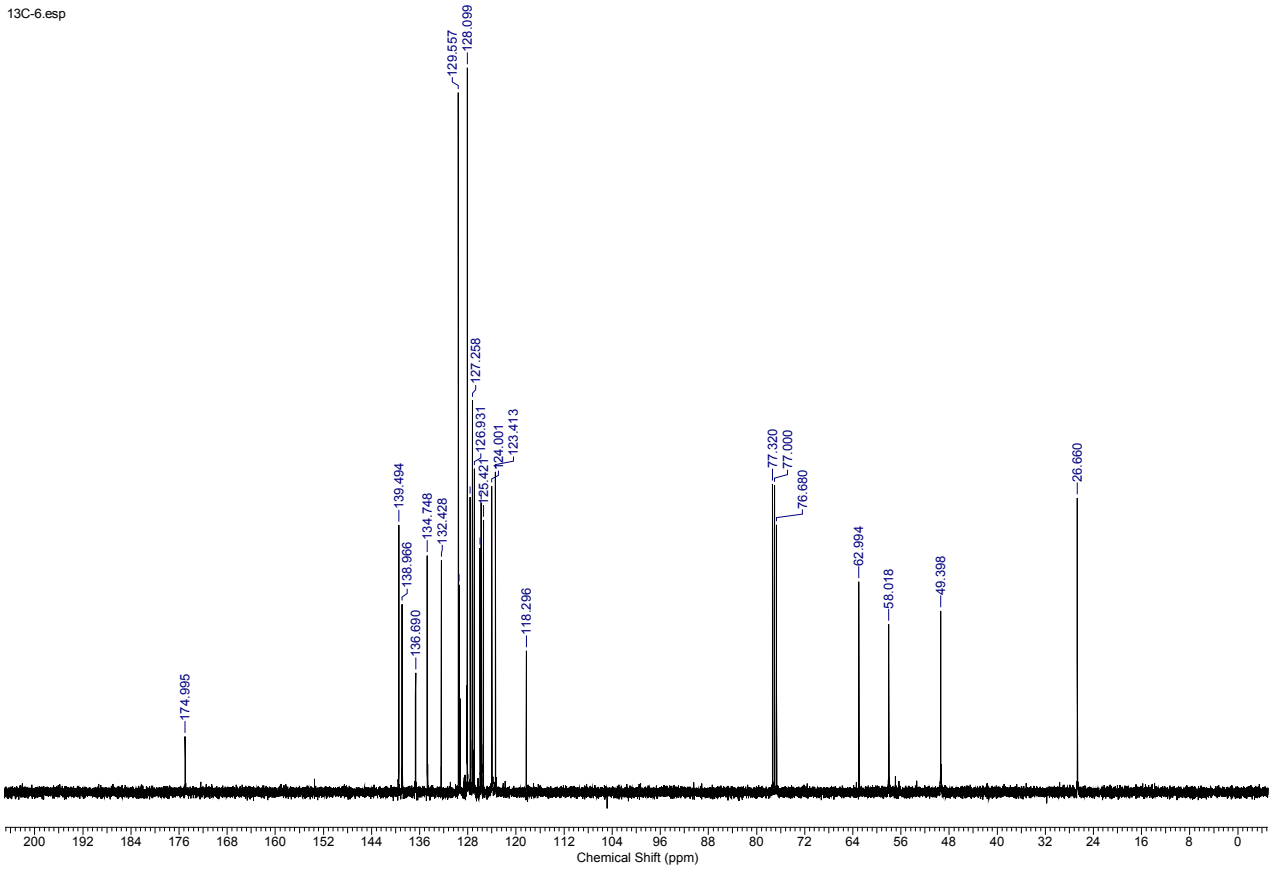
1H-6.esp



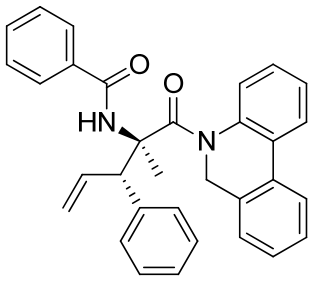
6

(2*R*,3*S*)-major

13C-6.esp



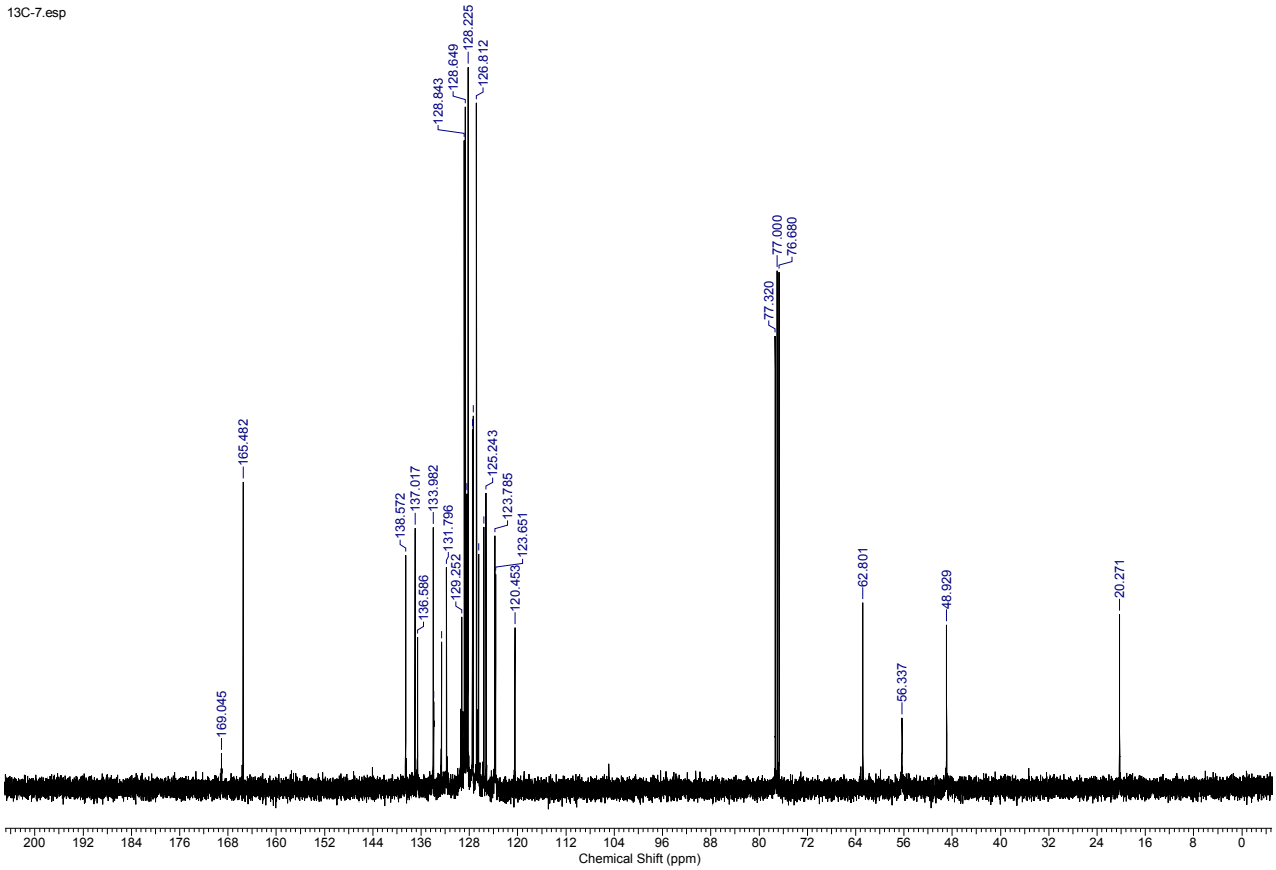
1H-7.esp



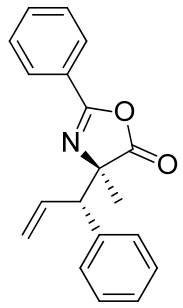
7

(2*R*,3*S*)-major

13C-7.esp

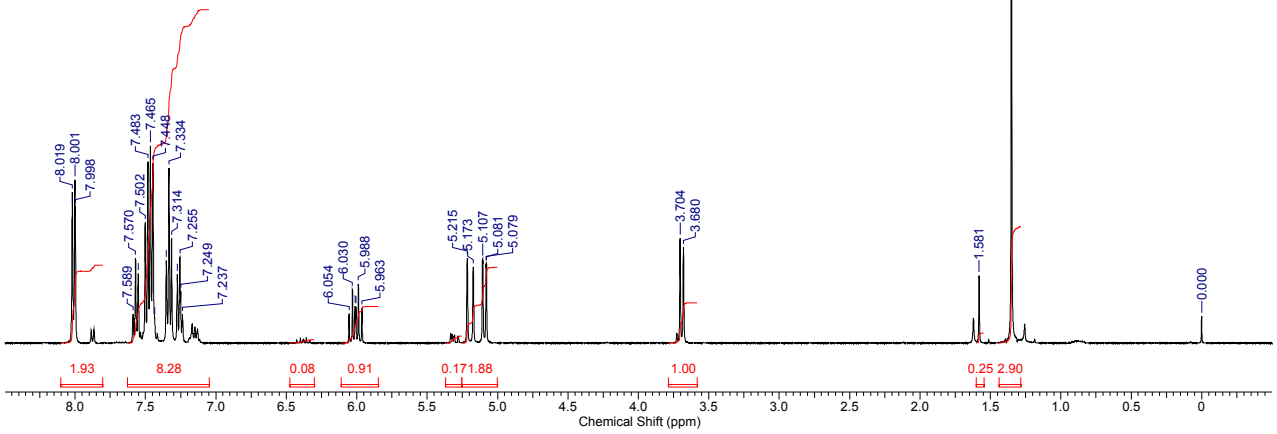


1H-8.esp



8

(4*R*,1'*S*)-major



13C-8.esp