Supporting Information

Palladium-Catalyzed Intramolecular Transfer Hydrogenation & Cycloaddition of *p*-Quinamine-Tethered Alkylidenecyclopropanes to Synthesize Perhydroindole Scaffolds

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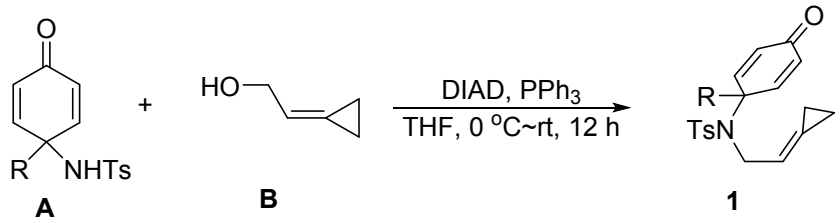
CONTENTS

1. General remarks.

Melting point (MP) was obtained with a Yanagimoto micro melting point apparatus and is uncorrected. Infrared spectra were measured on a spectrometer. ^{1}H NMR spectra were recorded on a Agilent DD2 400-MR spectrometer for solution in $CDCl_3$ with tetramethylsilane (TMS) as internal standard; *J*-values are in Hz. ^{13}C NMR spectra were recorded at 100 MHz. ^{19}F NMR spectra were recorded at 376 MHz. Data for ^{1}H, ^{13}C, ^{19}F NMR were recorded as follows: chemical shift (δ, ppm), multiplicity (s = singlet, d = doublet, t = triplet, m = multiplet, q = quartet, br = broad). Mass spectra were recorded with a HP-5989 instrument and HRMS was measured by a Finnigan MA+ mass spectrometer. Organic solvents used were dried by standard methods when necessary. Commercially available reagents were used without further purification. All reactions were monitored by TLC with Huanghai GF_{254} silica gel coated plates. Flash column chromatography was carried out using 300-400 mesh silica gel at increased pressure. All reactions were performed under argon using standard Schlenk techniques.

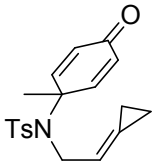
Compounds **A**[1] and **B**[2] were prepared according to the previous literature.

2. General procedure for synthesis of 1.



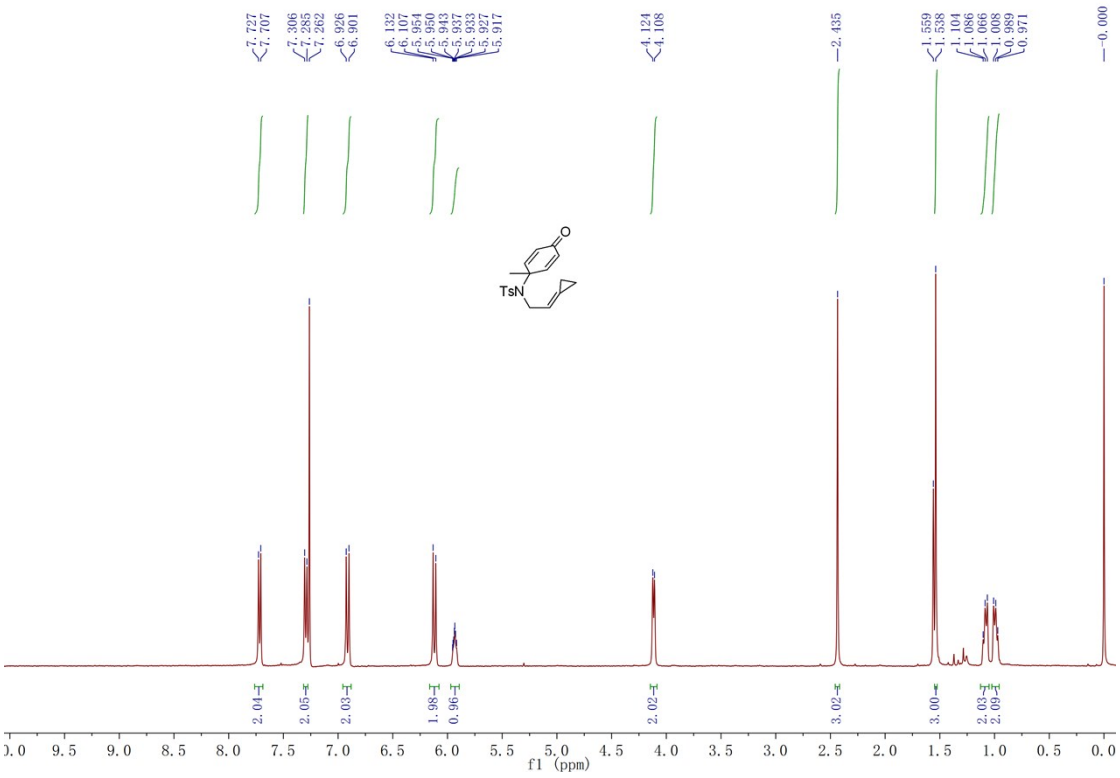
To a solution of **A** (2.0 mmol, 1.0 equiv), 2-cyclopropylideneethan-1-ol **B** (168.0 mg, 2.0 mmol, 1.0 equiv), and triphenylphosphine (628.8 mg, 2.4 mmol, 1.2 equiv) in THF (50 mL), (0.44 mL, 2.2 mmol, 1.1 equiv) was added DIAD dropwise at 0 °C. The resulting mixture was allowed to warm to room temperature and was stirred for 12 hours. Then, the resulting solution was concentrated in vacuum and the residue was purified by a silica gel flash chromatography (eluent: petroleum ether / ethyl acetate = 8 / 1) to give white solid **1**.

3. Characterization and spectra charts for 1.



Compound 1a:

2.0 mmol scale, a white solid, 80% yield (548.8 mg). M.p.: 113-115 °C. ^{1}H NMR ($CDCl_3$, TMS, 400 MHz) δ 0.97-1.01 (m, 2H), 1.06-1.11 (m, 2H), 1.54 (s, 3H), 2.44 (s, 3H), 4.12 (d, *J* = 6.4 Hz, 2H), 5.91-5.95 (m, 1H), 6.12 (d, *J* = 10.0 Hz, 2H), 6.91 (d, *J* = 10.0 Hz, 2H), 7.30 (d, *J* = 8.0 Hz, 2H), 7.72 (d, *J* = 8.0 Hz, 2H). ^{13}C NMR ($CDCl_3$, TMS, 100 MHz) 2.0, 2.3, 21.5, 26.1, 49.3, 59.8, 116.1, 126.2, 127.1, 127.4, 129.6, 139.3, 143.5, 151.7, 184.5. IR (neat) 3050, 2980, 2958, 2924, 2869, 1723, 1667, 1628, 1598, 1494, 1449, 1392, 1327, 1288, 1246, 1181, 1154, 1089, 1020, 960, 889, 862, 813, 718, 706, 676 cm^{-1}. HRMS (ESI) Calcd. for $C_{19}H_{25}N_2O_3S^{+1}(M+NH_4)^+$ requires 361.1580, Found: 361.1583.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5.933
5.927
5.917
4.124
4.108
2.435
1.559
1.538
1.104
1.086
1.066
1.008
0.989
0.971
0.000
TsN
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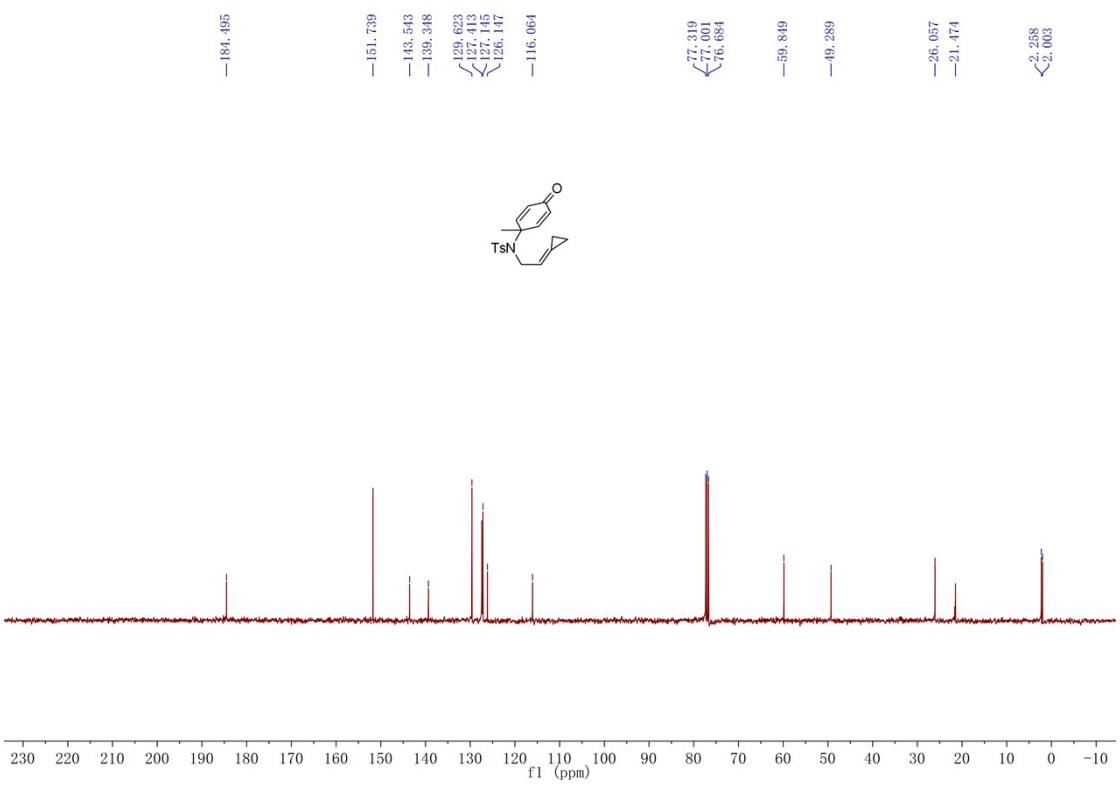
2.05
2.03
1.98
0.96
2.02
3.02
3.00
2.03
2.09
f1 (ppm)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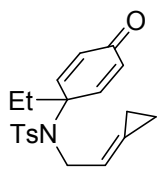
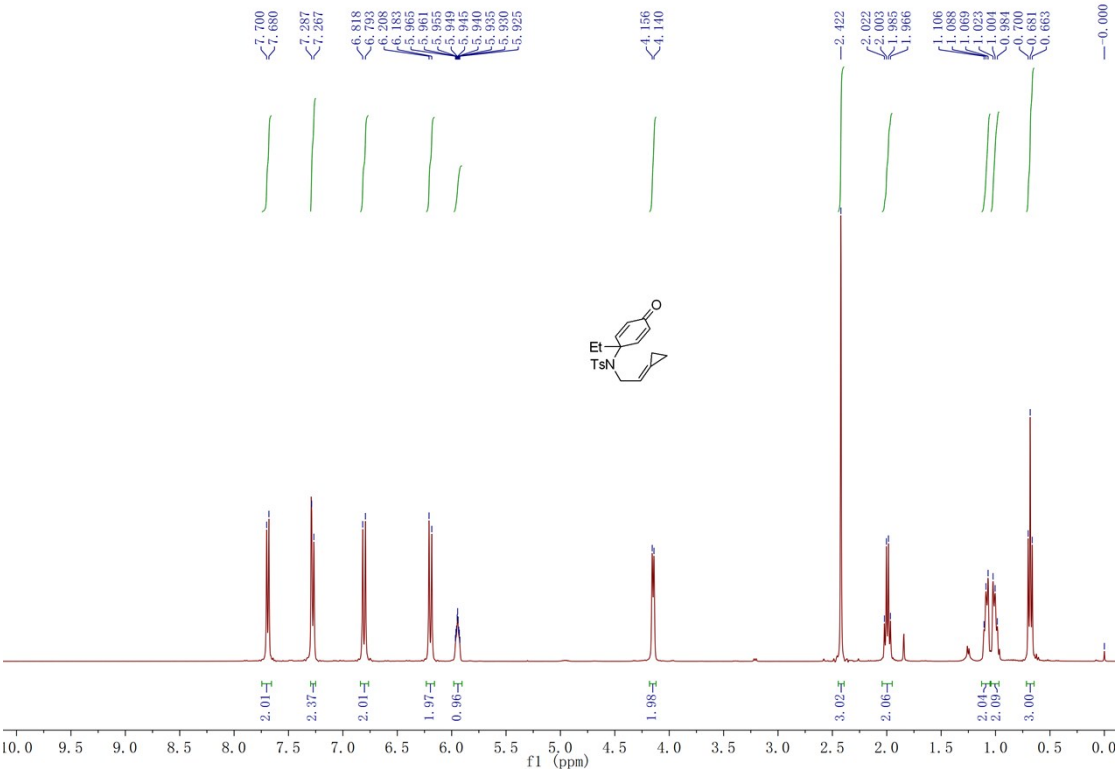
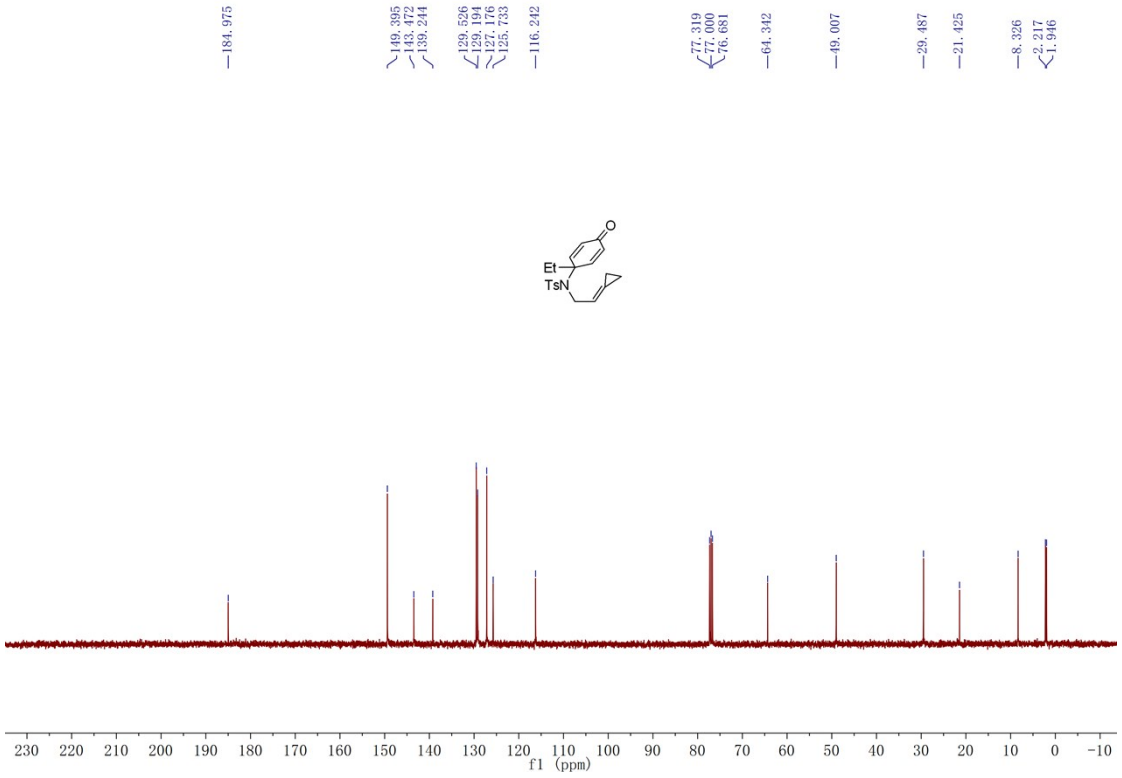
2.003
TsN
f1 (ppm)

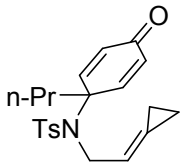

O
Et
TsN

Compound 1b:

2.0 mmol scale, a white solid, 49% yield (347.5 mg). M.p.: 67-68 °C. ^{1}H NMR ($CDCl_3$, TMS, 400 MHz) δ 0.68 (t, *J* = 7.6 Hz, 3H), 0.98-1.03 (m, 2H), 1.06-1.11 (m, 2H), 1.99 (q, *J* = 7.6 Hz, 2H), 2.42 (s, 3H), 4.15 (d, *J* = 6.4 Hz, 2H), 5.92-5.97 (m, 1H), 6.20 (d, *J* = 10.0 Hz, 2H), 6.81 (d, *J* = 10.0 Hz, 2H), 7.28 (d, *J* = 8.0 Hz, 2H), 7.69 (d, *J* = 8.0 Hz, 2H). ^{13}C NMR ($CDCl_3$, TMS, 100 MHz) 1.9, 2.2, 8.3, 21.4, 29.5, 49.0, 64.3, 116.2, 125.7, 127.2, 129.2, 129.5, 139.2, 143.5, 149.4, 185.0. IR (neat) 3052, 3023, 2984, 2972, 2940, 2916, 2877, 1744, 1670, 1628, 1493, 1442, 1385, 1373, 1340, 1324, 1303, 1287, 1263, 1180, 1146, 1102, 1088, 1068, 1041, 1004, 989, 968, 956, 935, 910, 888, 863, 828, 811, 790, 766, 749, 723, 705, 687 cm^{-1}. HRMS (ESI) Calcd. for $C_{20}H_{24}NO_3S^{+1}(M+H)^+$ requires 358.1471, Found: 358.1457.

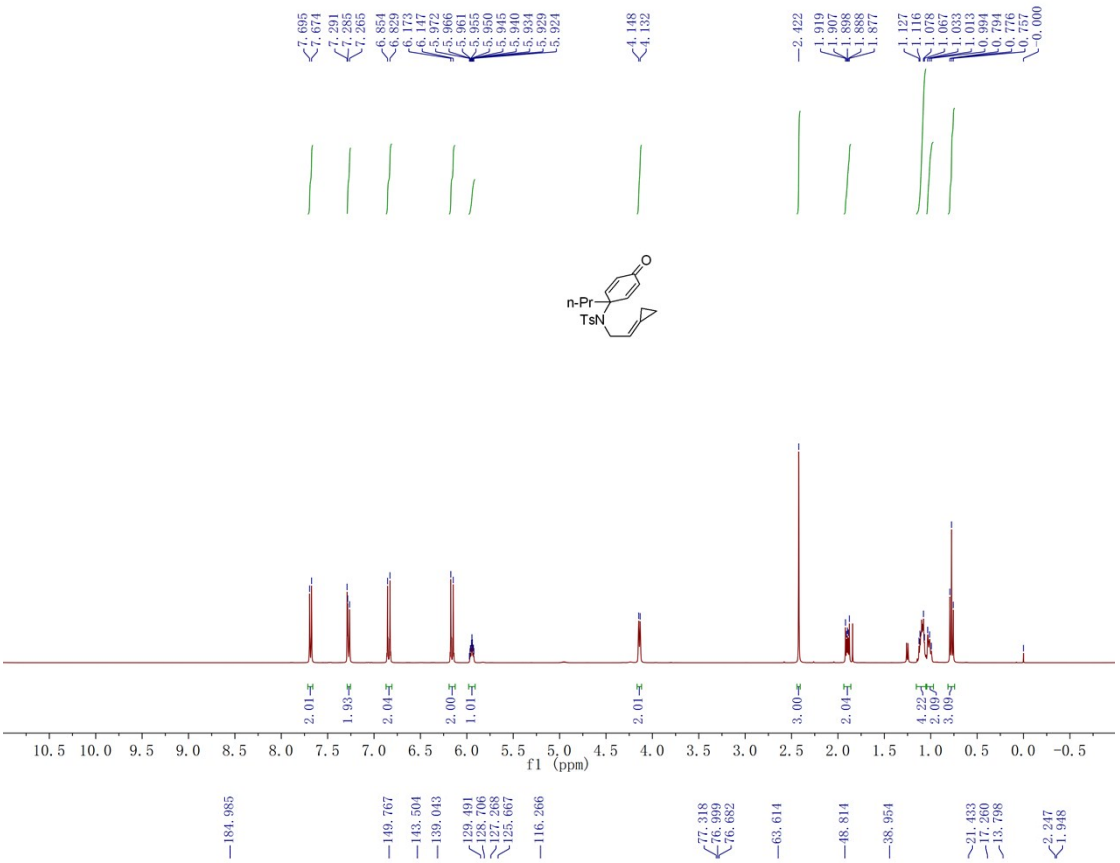






Compound 1c:

2.0 mmol scale, a white solid, 55% yield (409.6 mg). M.p.: 68-70 ^{o}C. ^{1}H NMR ($CDCl_3$, TMS, 400 MHz) δ 0.78 (t, *J* = 7.6 Hz, 3H), 0.99-1.04 (m, 2H), 1.06-1.13 (m, 4H), 1.87-1.92 (m, 2H), 2.42 (s, 3H), 4.14 (d, *J* = 6.4 Hz, 2H), 5.92-5.98 (m, 1H), 6.16 (d, *J* = 10.0 Hz, 2H), 6.84 (d, *J* = 10.0 Hz, 2H), 7.28 (d, *J* = 8.0 Hz, 2H), 7.68 (d, *J* = 8.0 Hz, 2H). ^{13}C NMR ($CDCl_3$, TMS, 100 MHz) 1.9, 2.2, 13.8, 17.3, 21.4, 39.0, 48.8, 63.6, 116.3, 125.7, 127.3, 128.7, 129.5, 139.0, 143.5, 149.8, 185.0. IR (neat) 3057, 3034, 2976, 2955, 2941, 2872, 1745, 1667, 1627, 1491, 1462, 1390, 1360, 1329, 1290, 1263, 1157, 1111, 1085, 1044, 994, 963, 943, 899, 865, 802, 767, 746, 703, 682 cm^{-1}. HRMS (ESI) Calcd. for $C_{21}H_{26}NO_3S^{+1}(M+H)^+$ requires 372.1628, Found: 372.1619.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1.919
1.907
1.898
1.888
1.877
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1.116
1.078
1.067
1.033
1.013
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0.794
0.776
0.757
0.000
n-Pr
TsN
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2.00
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2.01
3.00
2.04
4.22
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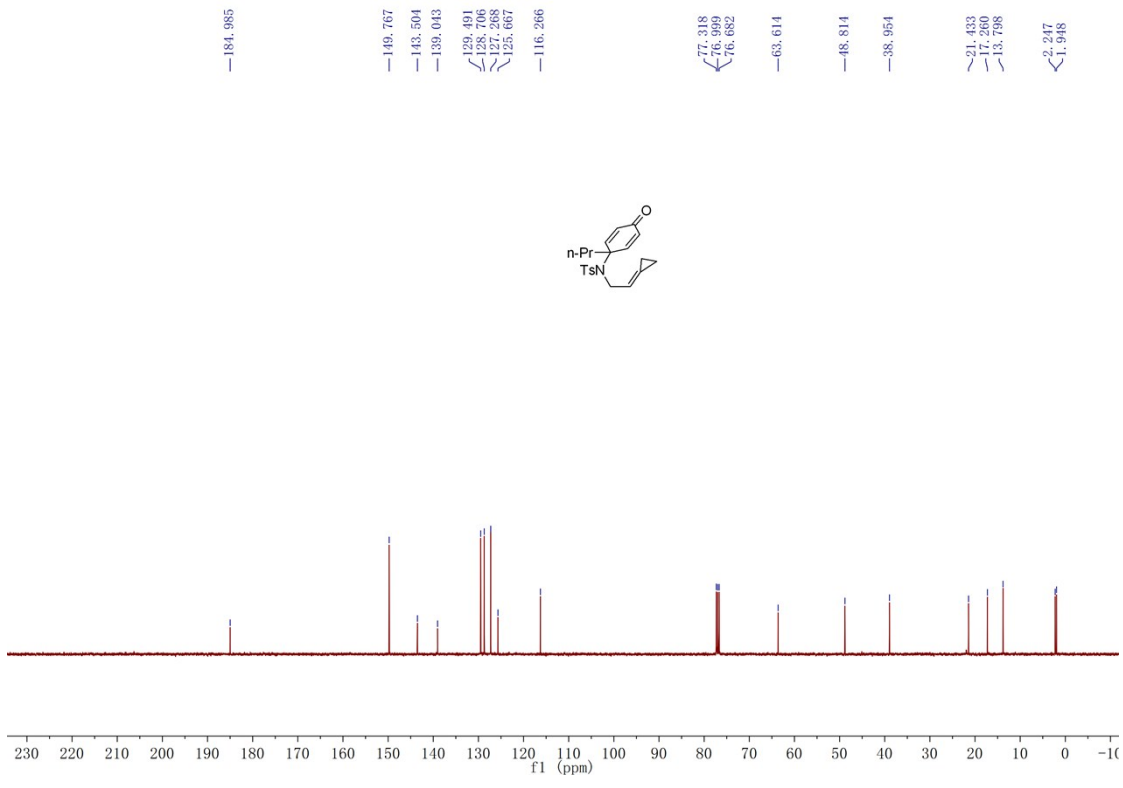
3.09
f1 (ppm)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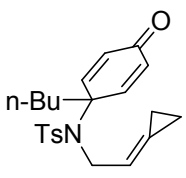
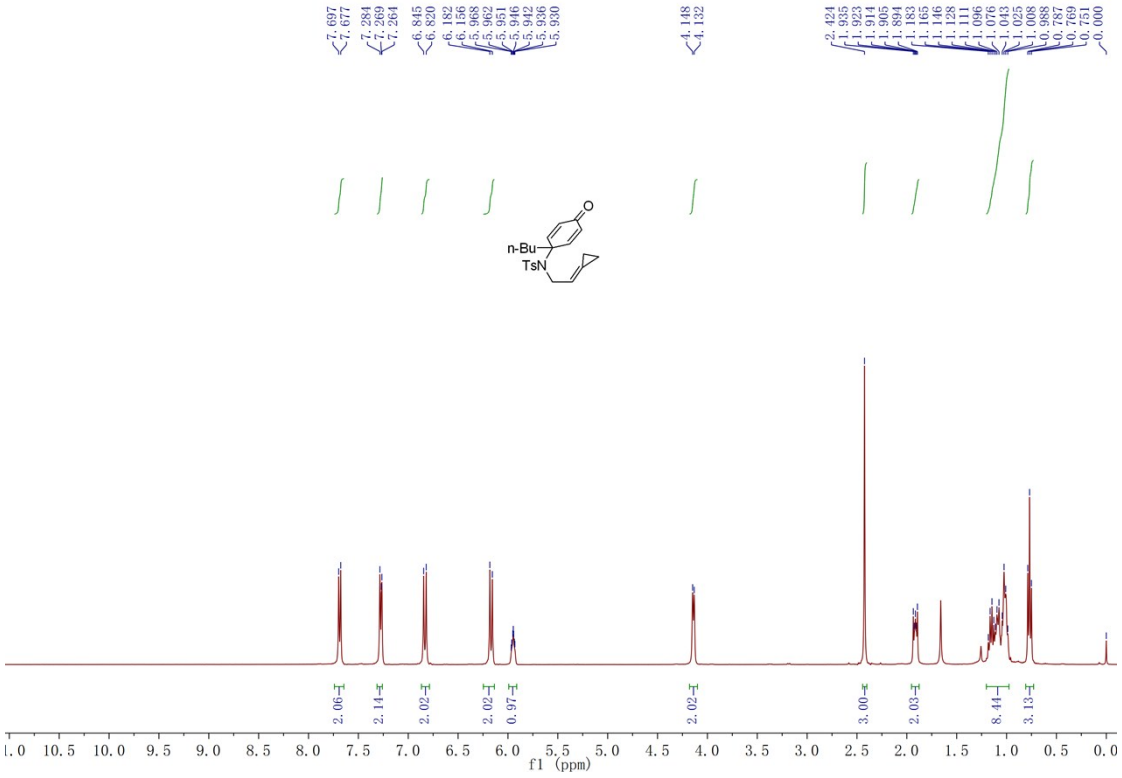
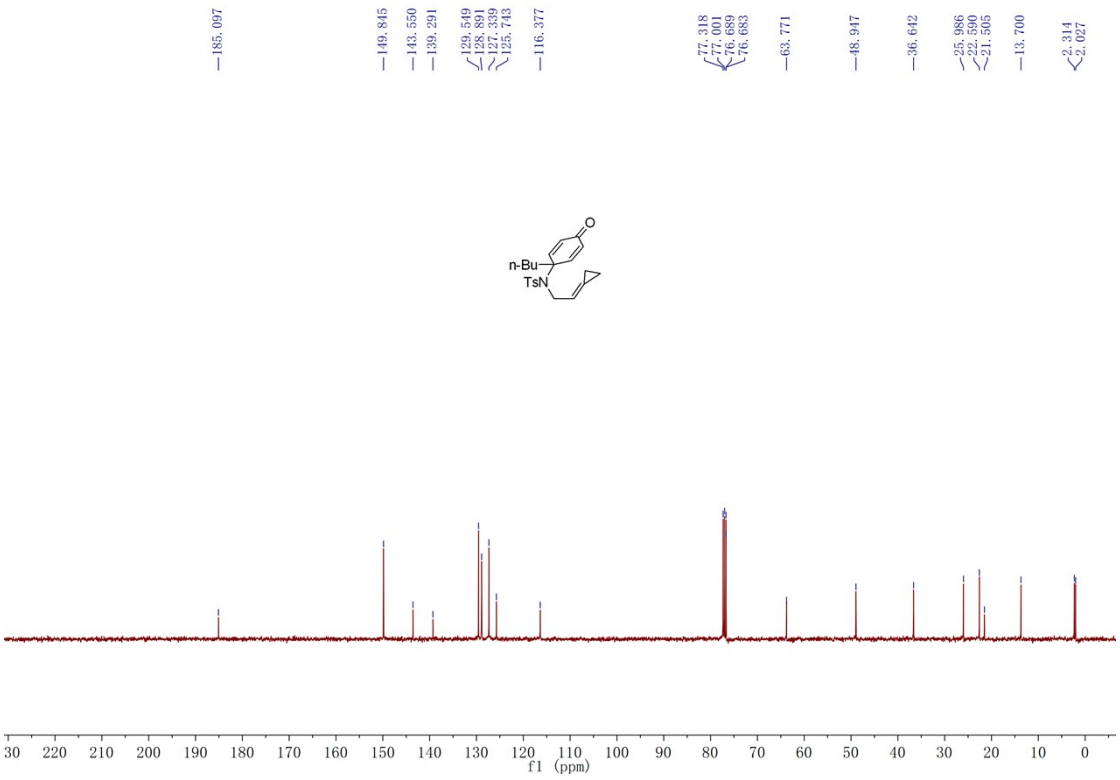
n-Pr
TsN
f1 (ppm)

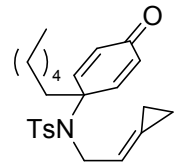

n-Bu
TsN

Compound 1d:

2.0 mmol scale, a light yellow solid, 64% yield (491.8 mg). M.p.: 57-60 ^{o}C. ^{1}H NMR ($CDCl_3$, TMS, 400 MHz) δ 0.77 (t, *J* = 7.2 Hz, 3H), 0.98-1.19 (m, 8H), 1.89-1.94 (m, 2H), 2.42 (s, 3H), 4.14 (d, *J* = 6.4 Hz, 2H), 5.93-5.97 (m, 1H), 6.17 (d, *J* = 10.0 Hz, 2H), 6.83 (d, *J* = 10.0 Hz, 2H), 7.27 (d, *J* = 8.0 Hz, 2H), 7.69 (d, *J* = 8.0 Hz, 2H). ^{13}C NMR ($CDCl_3$, TMS, 100 MHz) 2.0, 2.3, 13.7, 21.5, 22.6, 26.0, 36.6, 48.9, 63.8, 116.4, 125.7, 127.3, 128.9, 129.5, 139.3, 143.6, 149.8, 185.1. IR (neat) 2923, 2853, 1770, 1746, 1667, 1626, 1492, 1463, 1359, 1329, 1157, 1083, 1035, 1016, 998, 934, 910, 863, 804, 765, 744, 703, 676 cm^{-1}. HRMS (ESI) Calcd. for $C_{22}H_{28}NO_3S^{+1}(M+H)^+$ requires 386.1784, Found: 386.1784.

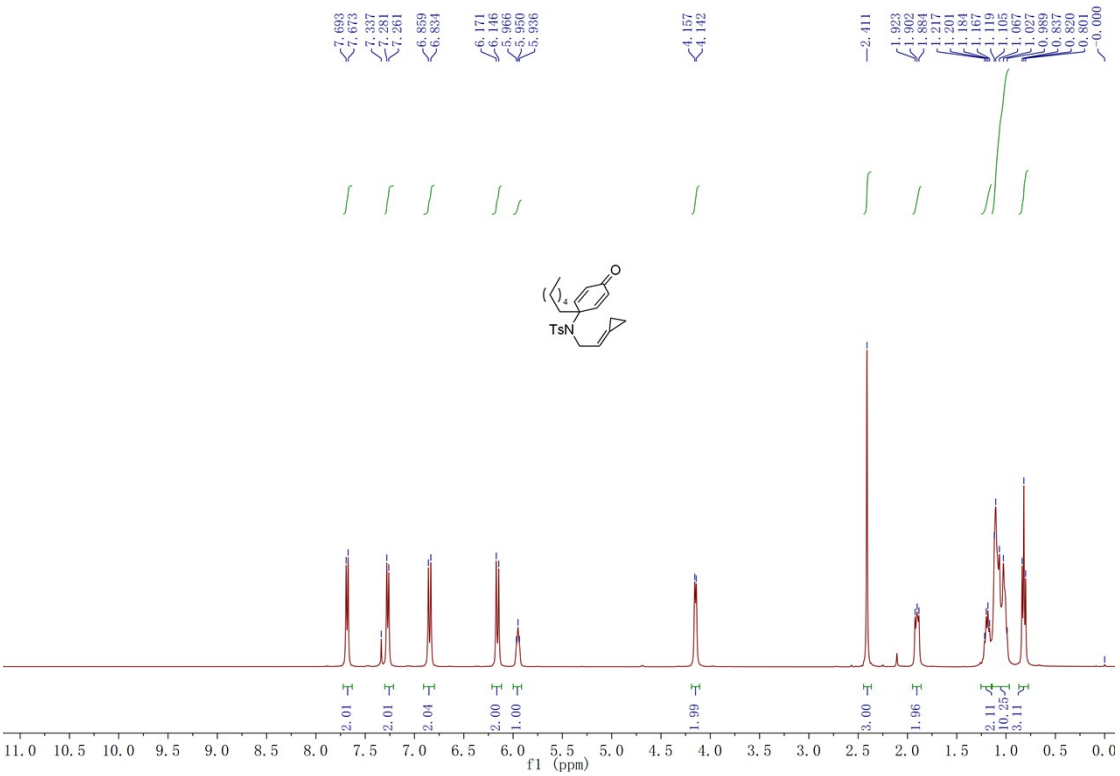






Compound 1e:

2.0 mmol scale, a white solid, 71% yield (587.6 mg). M.p.: 37-38 ^{o}C. ^{1}H NMR ($CDCl_3$, TMS, 400 MHz) δ 0.82 (t, *J* = 7.2 Hz, 3H), 0.98-1.12 (m, 10H), 1.16-1.22 (m, 2H), 1.88-1.93 (m, 2H), 2.41 (s, 3H), 4.15 (d, *J* = 6.0 Hz, 2H), 5.93-5.97 (m, 1H), 6.16 (d, *J* = 10.0 Hz, 2H), 6.85 (d, *J* = 10.0 Hz, 2H), 7.27 (d, *J* = 8.0 Hz, 2H), 7.68 (d, *J* = 8.0 Hz, 2H). ^{13}C NMR ($CDCl_3$, TMS, 100 MHz) 1.8, 2.1, 13.7, 21.2, 22.2, 23.6, 28.8, 31.1, 36.6, 48.7, 63.5, 116.2, 125.4, 127.1, 128.6, 129.3, 139.0, 143.3, 149.7, 184.8. IR (neat) 3050, 2981, 2953, 2928, 2872, 2857, 1745, 1667, 1627, 1594, 1493, 1456, 1330, 1154, 1085, 1017, 994, 959, 931, 909, 887, 870, 856, 811, 766, 746, 717, 705, 682 cm^{-1}. HRMS (ESI) Calcd. for $C_{24}H_{32}NO_3S^{+1}$(M+H)$^{+}$ requires 414.2097, Found: 414.2101.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1.902
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1.217
1.201
1.184
1.167
1.119
1.105
1.067
1.027
0.989
0.837
0.820
0.801
0.000
TsN
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2.00
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1.99
3.00
1.96
2.11
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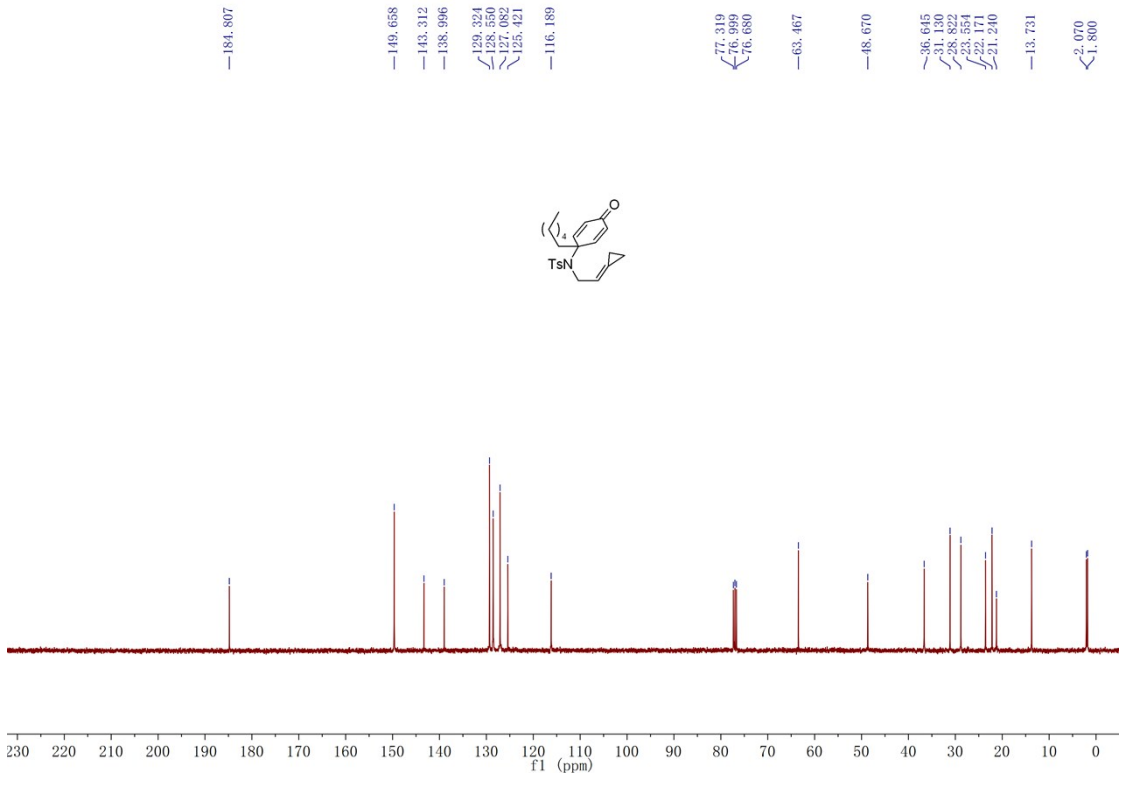
f1 (ppm)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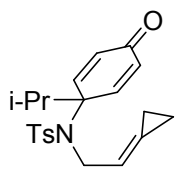
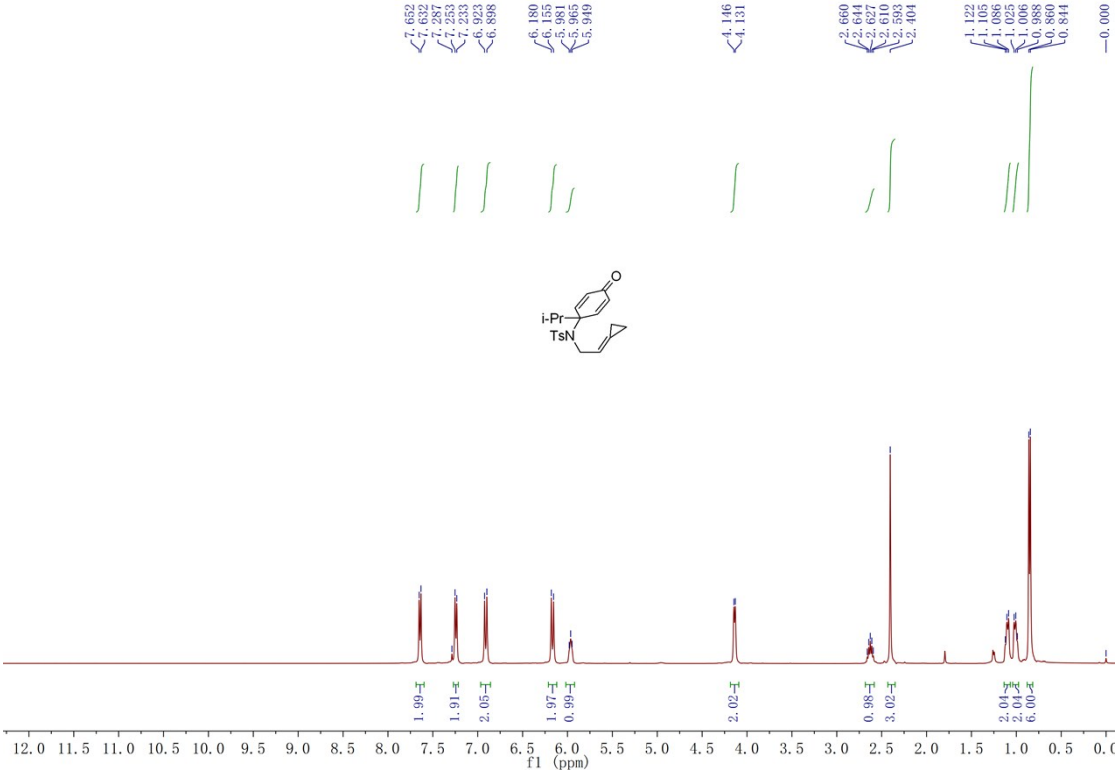
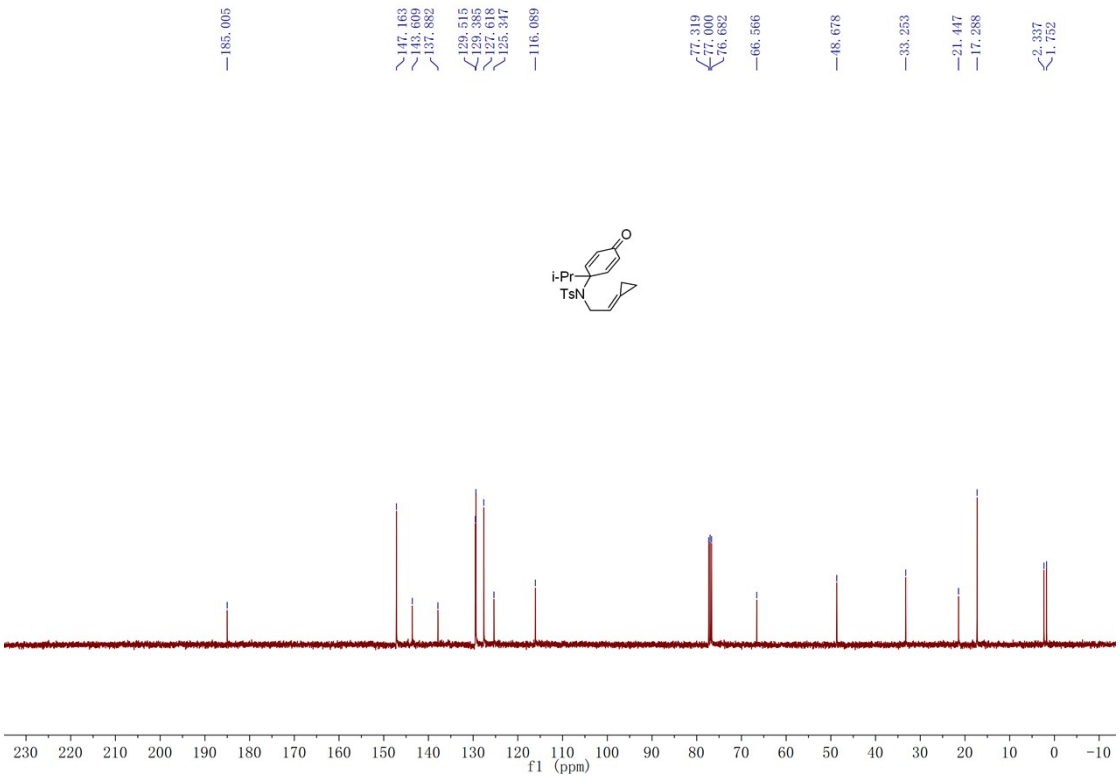
13.731
2.070
1.800
TsN
f1 (ppm)

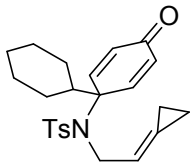

O
i-Pr
TsN

Compound 1f:

2.0 mmol scale, a light yellow solid, 34% yield (255.4 mg). M.p.: 123-126 °C. ^{1}H NMR ($CDCl_3$, TMS, 400 MHz) δ 0.84 (s, 3H), 0.86 (s, 3H), 0.98-1.03 (m, 2H), 1.08-1.13 (m, 2H), 2.40 (s, 3H), 2.59-2.66 (m, 1H), 4.14 (d, *J* = 6.0 Hz, 2H), 5.94-5.99 (m, 1H), 6.17 (d, *J* = 10.0 Hz, 2H), 6.91 (d, *J* = 10.0 Hz, 2H), 7.24 (d, *J* = 8.0 Hz, 2H), 7.64 (d, *J* = 8.0 Hz, 2H). ^{13}C NMR ($CDCl_3$, TMS, 100 MHz) 1.8, 2.3, 17.3, 21.4, 33.3, 48.7, 66.6, 116.1, 125.3, 127.6, 129.4, 129.5, 137.9, 143.6, 147.2, 185.0. IR (neat) 3052, 2974, 2934, 2869, 1745, 1666, 624, 1492, 1456, 1359, 1330, 1157, 1104, 1083, 1018, 994, 909, 887, 871, 809, 789, 767, 745, 704, 683, 660 cm^{-1}. HRMS (ESI) Calcd. for $C_{21}H_{26}NO_3S^{+1}(M+H)^+$ requires 372.1628, Found: 372.1628.

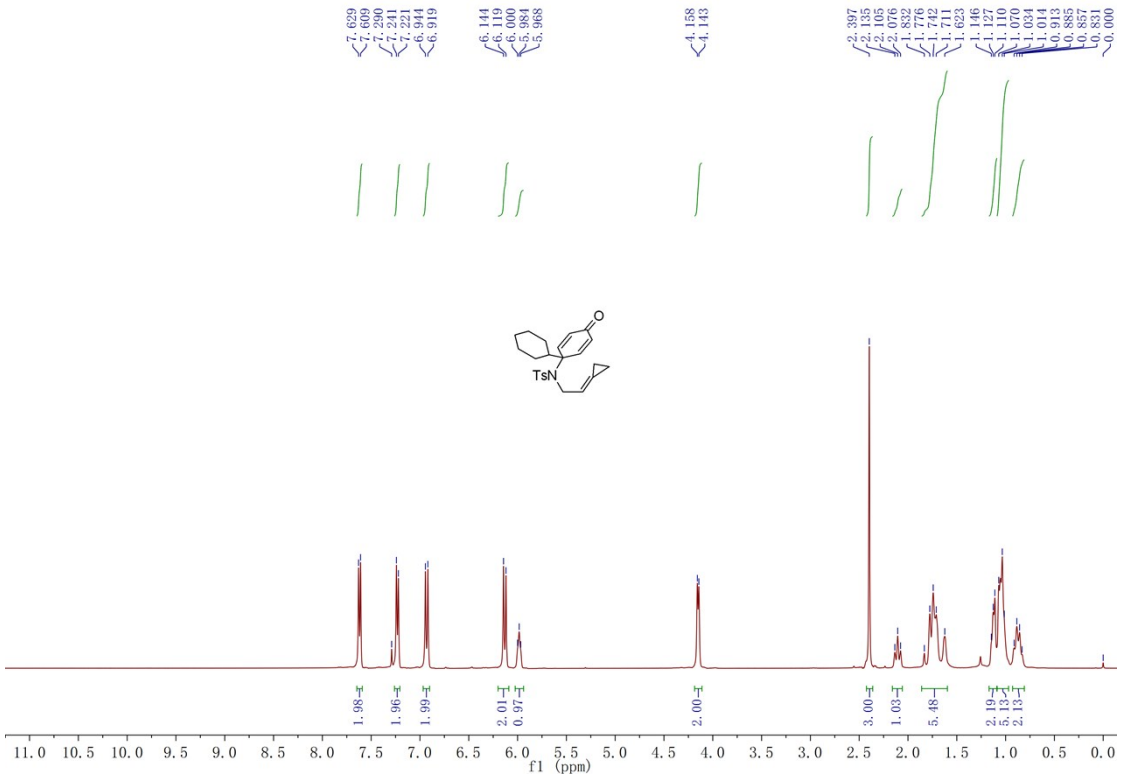






Compound 1g:

2.0 mmol scale, a yellow solid, 35% yield (288.8 mg). M.p.: 83-86 ^{o}C. ^{1}H NMR ($CDCl_3$, TMS, 400 MHz) δ 0.83-0.92 (m, 2H), 1.01-1.07 (m, 5H), 1.11-1.15 (m, 2H), 1.62-1.78 (m, 5H), 2.07-2.14 (m, 1H), 2.40 (s, 3H), 4.15 (d, J = 6.0 Hz, 2H), 5.96-6.00 (m, 1H), 6.13 (d, J = 10.0 Hz, 2H), 6.93 (d, J = 10.0 Hz, 2H), 7.23 (d, J = 8.0 Hz, 2H), 7.62 (d, J = 8.0 Hz, 2H). ^{13}C NMR ($CDCl_3$, TMS, 100 MHz) 1.8, 2.3, 21.4, 26.1, 26.4, 27.7, 43.7, 48.6, 66.1, 116.3, 124.9, 127.5, 129.1, 129.3, 137.8, 143.6, 147.6, 185.2. IR (neat) 2953, 2942, 2932, 2853, 1745, 1618, 1493, 1462, 1359, 1327, 1288, 1246, 1188, 1159, 1035, 1017, 984, 932, 851, 813, 765, 744, 728, 703, 660 cm^{-1}. HRMS (ESI) Calcd. for $C_{24}H_{30}NO_3S^{+1}(M+H)^+$ requires 412.1941, Found: 412.1943.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2.135
2.105
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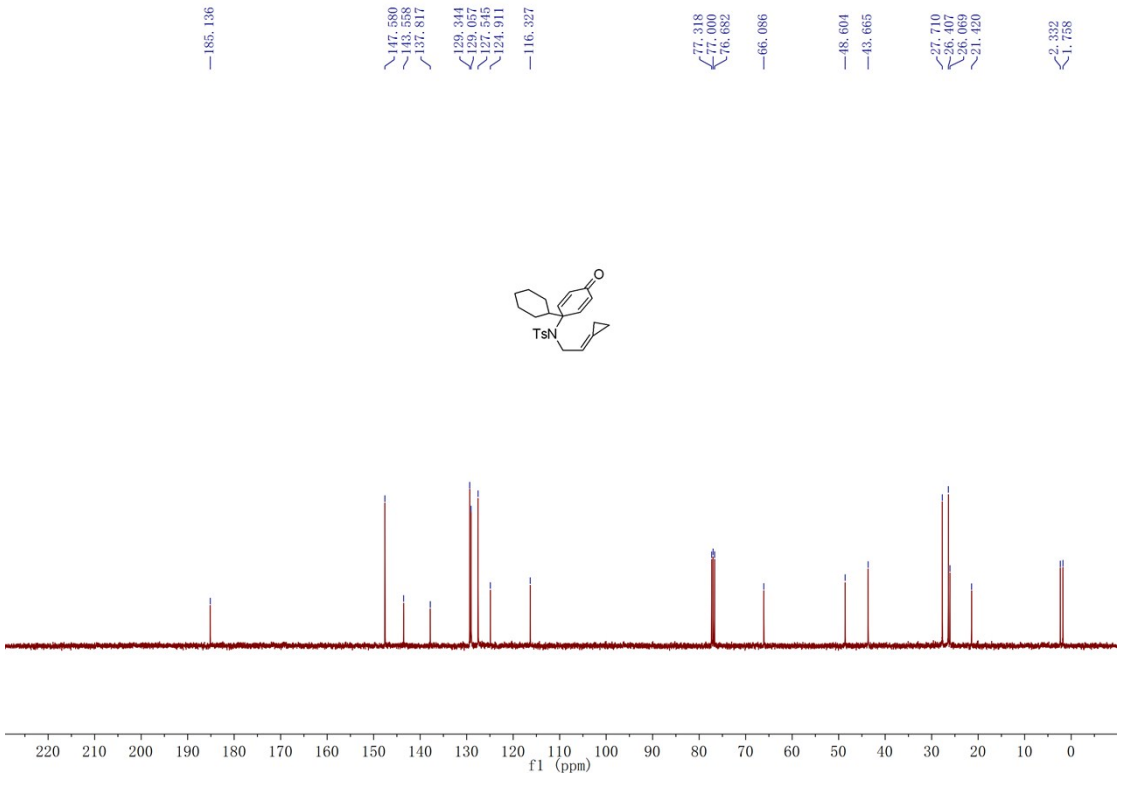
1.711
1.623
1.146
1.127
1.110
1.070
1.034
1.014
0.913
0.885
0.857
0.831
0.000
TsN
1.98
1.96
1.99
2.01
0.97
2.00
3.00
1.03
5.48
2.19
5.13
2.13
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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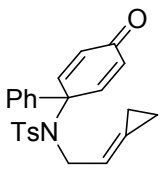
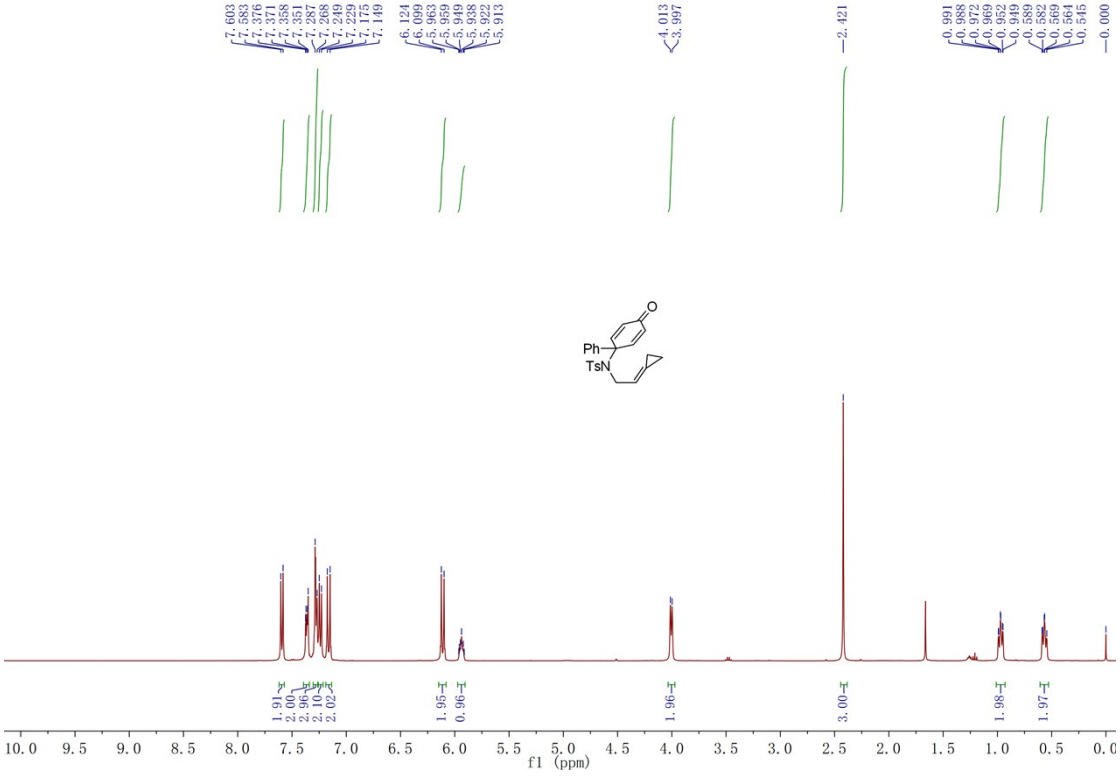
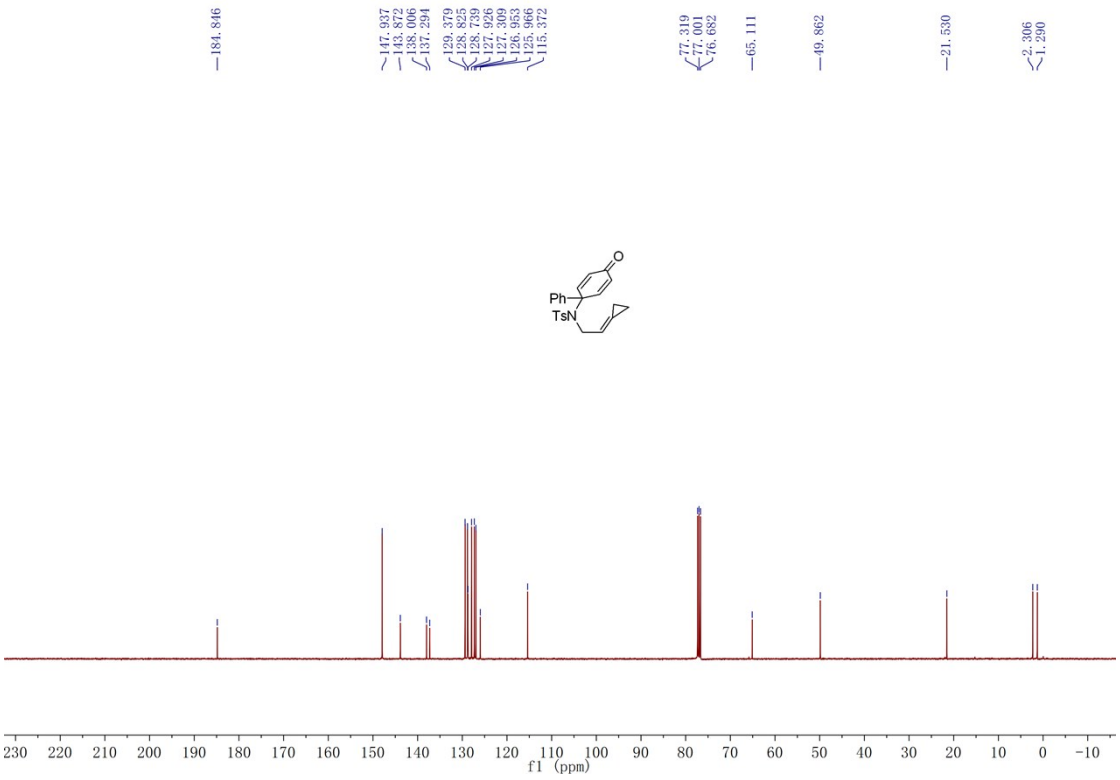
127.545
124.911
116.327
77.318
77.000
76.682
66.086
48.604
43.665
27.710
26.407
26.069
21.420
2.332
1.758
TsN
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

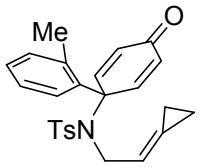

O
Ph
TsN

Compound 1h:

2.0 mmol scale, a white solid, 86% yield (700.2 mg). M.p.: 68-71 °C. ^{1}H NMR ($CDCl_3$, TMS, 400 MHz) δ 0.54-0.59 (m, 2H), 0.94-1.00 (m, 2H), 2.42 (s, 3H), 4.01 (d, *J* = 6.4 Hz, 2H), 5.91-5.97 (m, 1H), 6.11 (d, *J* = 10.0 Hz, 2H), 7.16 (d, *J* = 10.0 Hz, 2H), 7.24 (d, *J* = 8.0 Hz, 2H), 7.26-7.29 (m, 3H), 7.35-7.38 (m, 2H), 7.59 (d, *J* = 8.0 Hz, 2H). ^{13}C NMR ($CDCl_3$, TMS, 100 MHz) 1.3, 2.3, 21.5, 49.9, 65.1, 115.4, 126.0, 127.0, 127.3, 127.9, 128.7, 128.8, 129.4, 137.3, 138.0, 143.9, 147.9, 184.8. IR (neat) 3056, 3023, 2979, 2921, 2848, 1666, 1627, 1597, 1488, 1448, 1398, 1338, 1289, 1269, 1236, 1182, 1155, 1092, 1048, 1006, 957, 919, 908, 861, 811, 751, 735, 718, 699, 682 cm^{-1}. HRMS (ESI) Calcd. for $C_{24}H_{24}NO_3S^{+1}(M+H)^+$ requires 406.1471, Found: 406.1474.

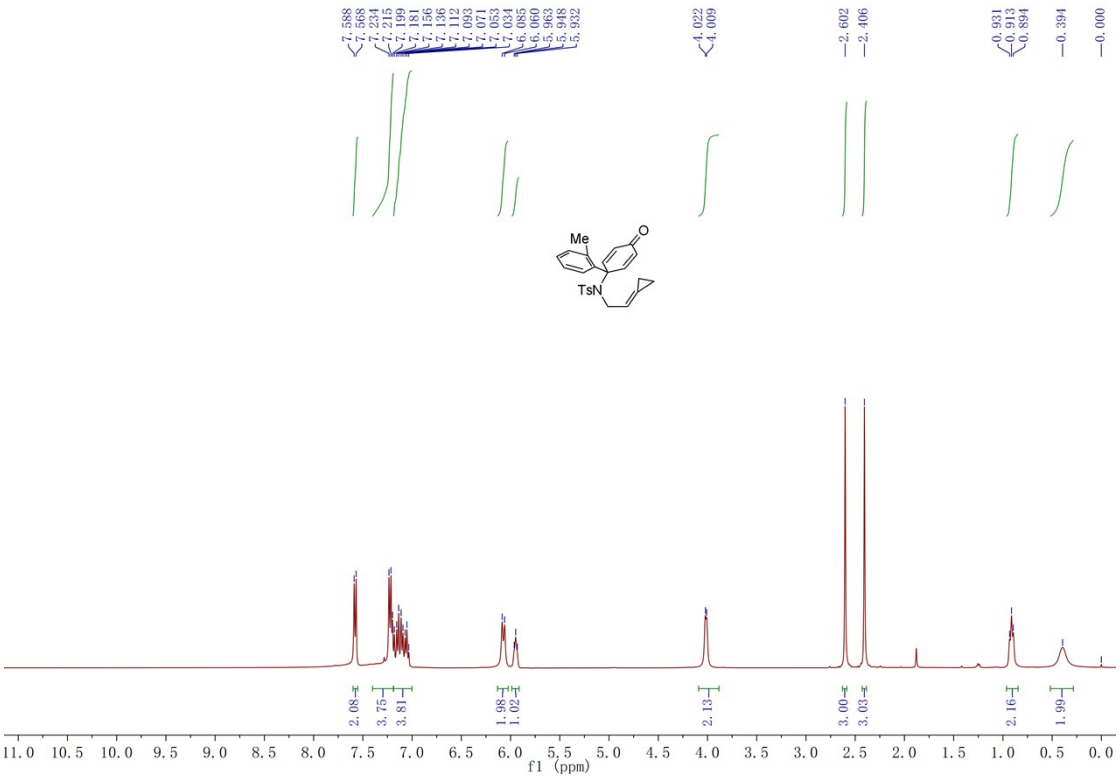






Compound 1i:

2.0 mmol scale, a white solid, 74% yield (622.6 mg). M.p.: 152-154 ^{o}C. ^{1}H NMR ($CDCl_3$, TMS, 400 MHz) δ 0.39 (br, 2H), 0.89-0.93 (m, 2H), 2.41 (s, 3H), 2.60 (s, 3H), 4.02 (d, J = 5.2 Hz, 2H), 5.93-5.97 (m, 1H), 6.07 (d, J = 10.0 Hz, 2H), 7.03-7.19 (m, 4H), 7.19-7.24 (m, 4H), 7.58 (d, J = 8.0 Hz, 2H). ^{13}C NMR ($CDCl_3$, TMS, 100 MHz) 0.9, 2.3, 21.2, 21.4, 49.6, 65.3, 114.7, 126.3, 126.4, 126.5, 127.9, 129.0, 129.2, 133.2, 135.3, 136.9, 138.0, 143.8, 184.6. IR (neat) 3094, 3057, 3033, 3013, 2981, 2925, 2848, 1669, 1628, 1597, 1485, 1432, 1402, 1377, 1336, 1313, 1281, 1243, 1189, 1156, 1116, 1097, 1083, 1038, 1016, 1001, 970, 955, 939, 912, 867, 842, 823, 809, 792, 758, 718, 705, 686 cm^{-1}. HRMS (ESI) Calcd. for $C_{25}H_{26}NO_3S^{+1}(M+H)^+$ requires 420.1628, Found: 420.1633.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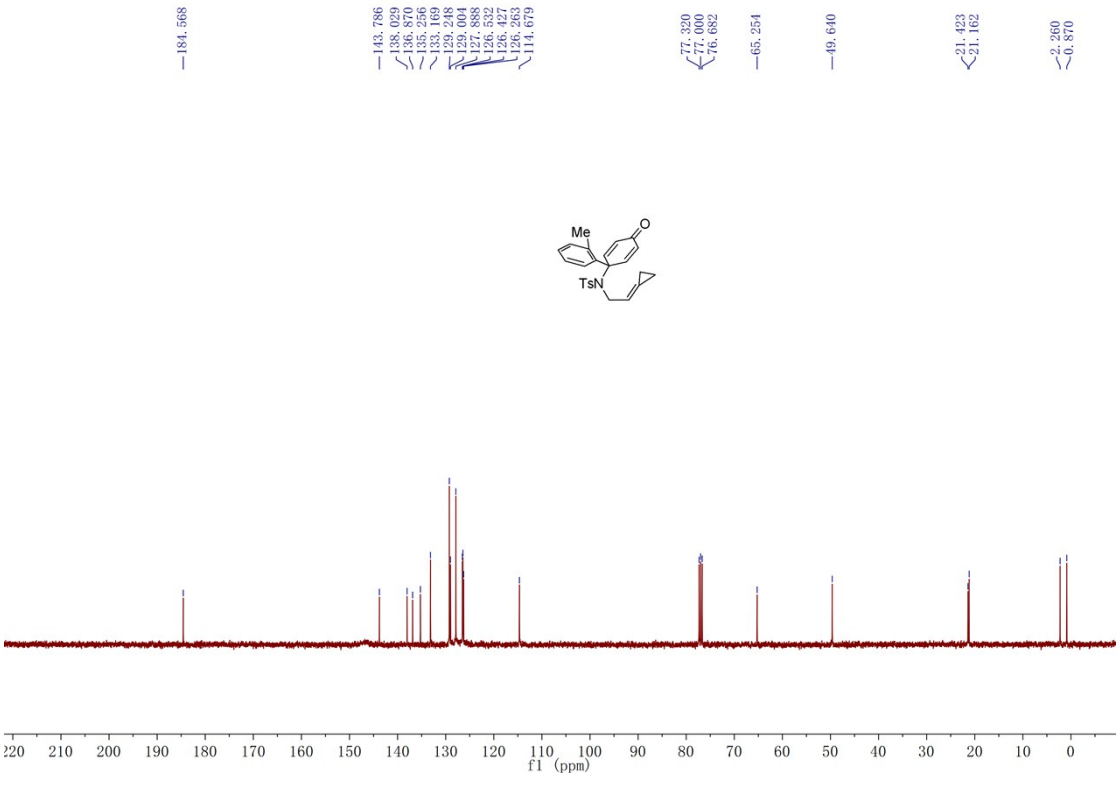
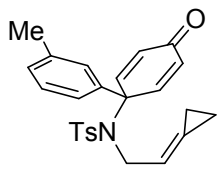
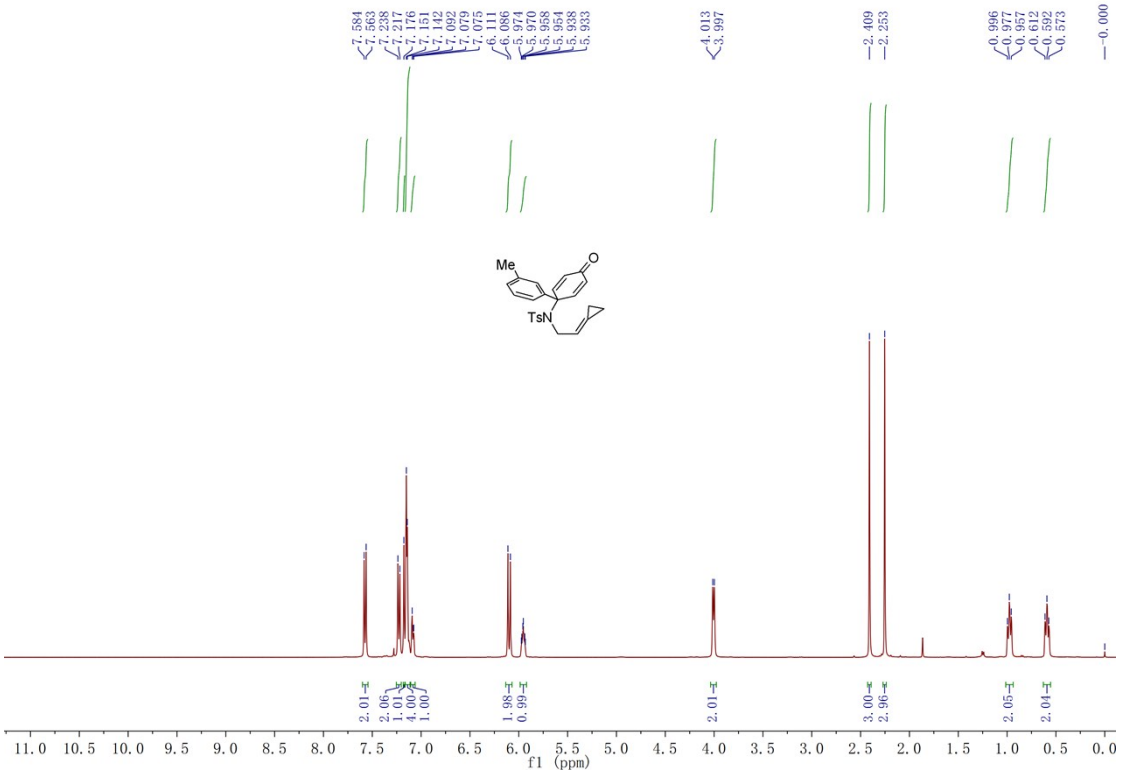
7.568
7.234
7.215
7.199
7.181
7.156
7.136
7.112
7.093
7.071
7.053
7.034
6.085
6.060
5.963
5.948
5.932
4.022
4.009
2.602
2.406
0.931
0.913
0.894
0.394
0.000
Me
O
TsN
2.08
3.75
3.81
1.98
1.02
2.13
3.00
3.03
2.16
1.99
f1 (ppm)

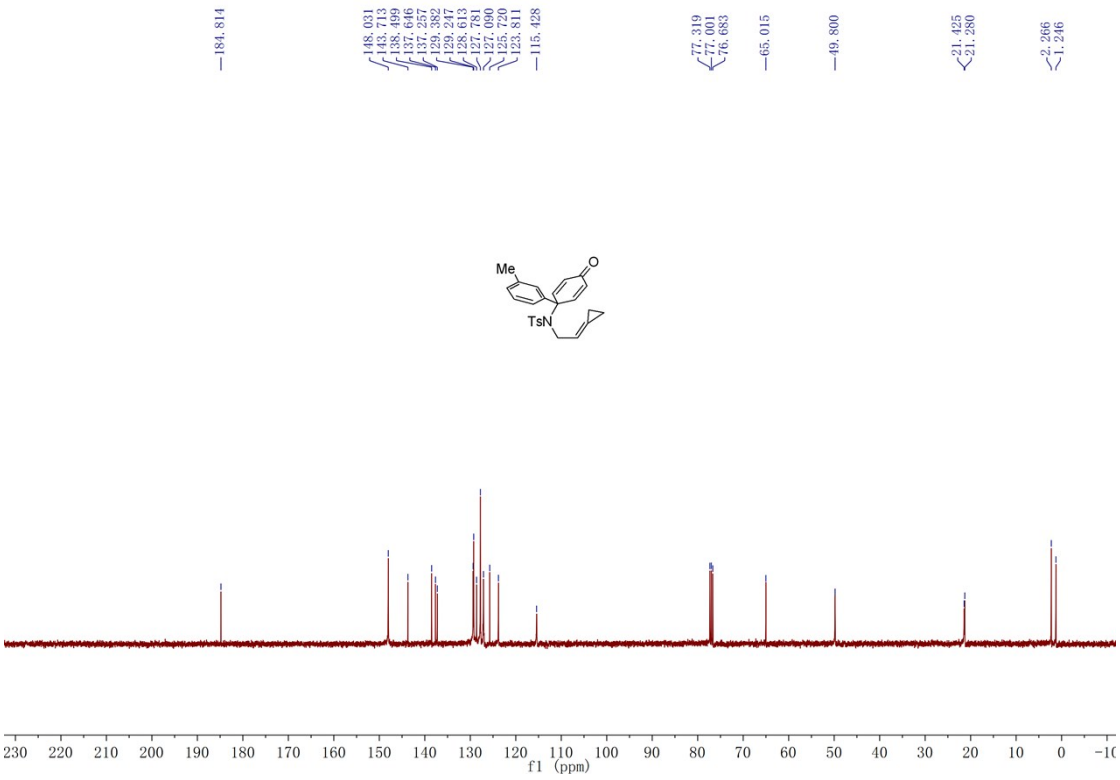

184.568
143.786
138.029
136.870
135.256
133.169
129.248
129.004
127.888
126.532
126.427
126.263
114.679
77.320
77.000
76.682
65.254
49.640
21.423
21.162
2.260
0.870
Me
O
TsN
f1 (ppm)

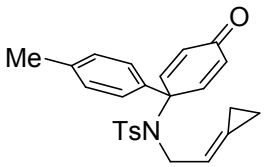

Me
O
TsN

Compound 1j:

2.0 mmol scale, a white solid, 62% yield (522.1 mg). M.p.: 134-137 °C. ^{1}H NMR ($CDCl_3$, TMS, 400 MHz) δ 0.57-0.62 (m, 2H), 0.95-1.00 (m, 2H), 2.25 (s, 3H), 2.41 (s, 3H), 4.01 (d, *J* = 6.4 Hz, 2H), 5.93-5.98 (m, 1H), 6.10 (d, *J* = 10.0 Hz, 2H), 7.07-7.10 (m, 1H), 7.14-7.16 (m, 4H), 7.18 (s, 1H), 7.23 (d, *J* = 8.4 Hz, 2H), 7.57 (d, *J* = 8.4 Hz, 2H). ^{13}C NMR ($CDCl_3$, TMS, 100 MHz) 1.2, 2.3, 21.3, 21.4, 49.8, 65.0, 115.4, 123.8, 125.7, 127.1, 127.8, 128.6, 129.2, 129.4, 137.3, 137.6, 138.5, 143.7, 148.0, 184.8. IR (neat) 3029, 2976, 2926, 2887, 2858, 1745, 1623, 1492, 1462, 1361, 1332, 1290, 1245, 1187, 1157, 1096, 1081, 1036, 1017, 994, 959, 911, 887, 865, 804, 765, 744, 703, 682, 659 cm^{-1}. HRMS (ESI) Calcd. for $C_{25}H_{26}NO_3S^{+1}(M+H)^+$ requires 420.1628, Found: 420.1629.

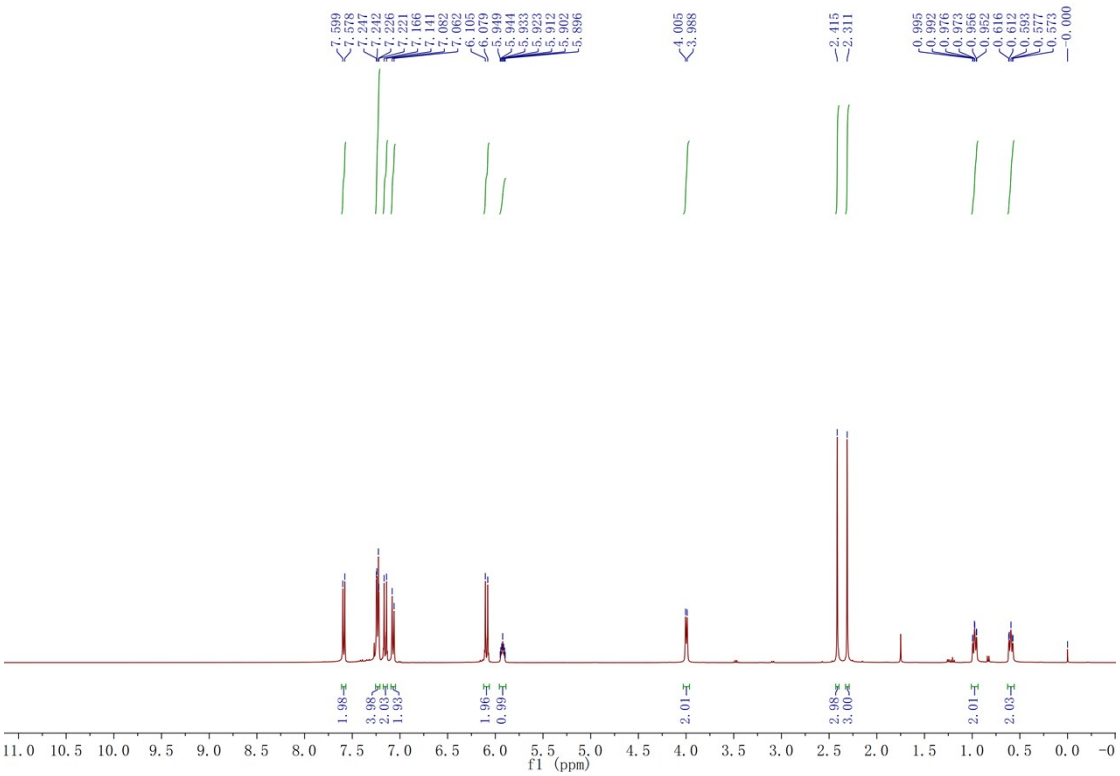


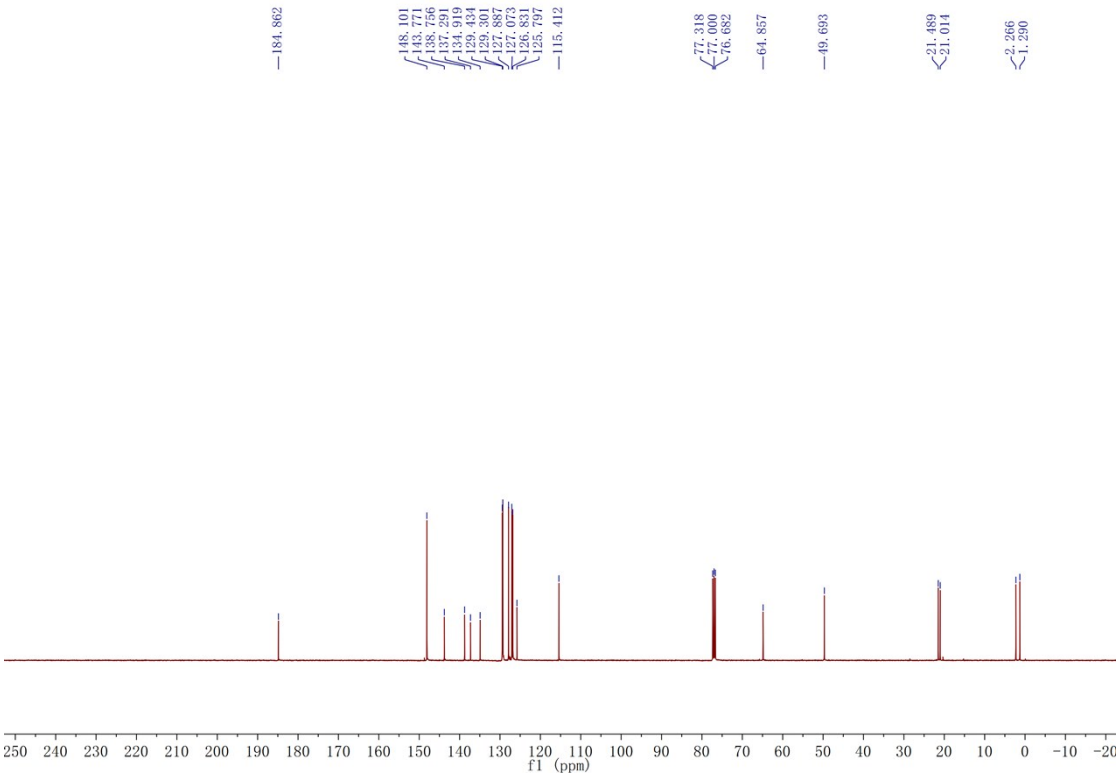




Compound 1k:

2.0 mmol scale, a white solid, 76% yield (641.8 mg). M.p.: 93-95 ^{o}C. ^{1}H NMR ($CDCl_3$, TMS, 400 MHz) δ 0.57-0.62 (m, 2H), 0.96-1.00 (m, 2H), 2.31 (s, 3H), 2.42 (s, 3H), 4.00 (d, *J* = 6.8 Hz, 2H), 5.89-5.95 (m, 1H), 6.09 (d, *J* = 10.0 Hz, 2H), 7.07 (d, *J* = 8.0 Hz, 2H), 7.15 (d, *J* = 10.0 Hz, 2H), 7.23 (d, *J* = 8.4 Hz, 2H), 7.24 (d, *J* = 8.4 Hz, 2H), 7.59 (d, *J* = 8.4 Hz, 2H). ^{13}C NMR ($CDCl_3$, TMS, 100 MHz) 1.3, 2.3, 21.0, 21.5, 49.7, 64.9, 115.4, 125.8, 126.8, 127.1, 127.9, 129.3, 129.4, 134.9, 137.3, 138.8, 143.8, 148.1, 184.9. IR (neat) 3053, 3023, 2979, 2921, 2864, 1666, 1626, 1598, 1506, 1494, 1435, 1396, 1338, 1289, 1268, 1236, 1181, 1156, 1091, 1048, 1006, 957, 910, 861, 828, 812, 788, 734, 714, 705, 682 cm^{-1}. HRMS (ESI) Calcd. for $C_{25}H_{26}NO_3S^{+1}(M+H)^+$ requires 420.1628, Found: 420.1629.


7.599
7.578
7.247
7.242
7.226
7.221
7.166
7.141
7.082
7.062
6.105
6.079
5.949
5.944
5.933
5.923
5.912
5.902
5.896
4.005
3.988
2.415
2.311
0.995
0.992
0.976
0.973
0.956
0.952
0.616
0.612
0.593
0.577
0.573
0.000
1.98
3.98
2.03
1.93
1.96
0.99
2.01
2.98
3.00
2.01
2.03
f1 (ppm)


184.862
148.101
143.771
138.756
137.291
134.919
129.434
129.301
127.887
127.073
126.831
125.797
115.412
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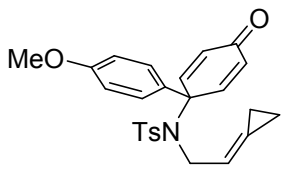
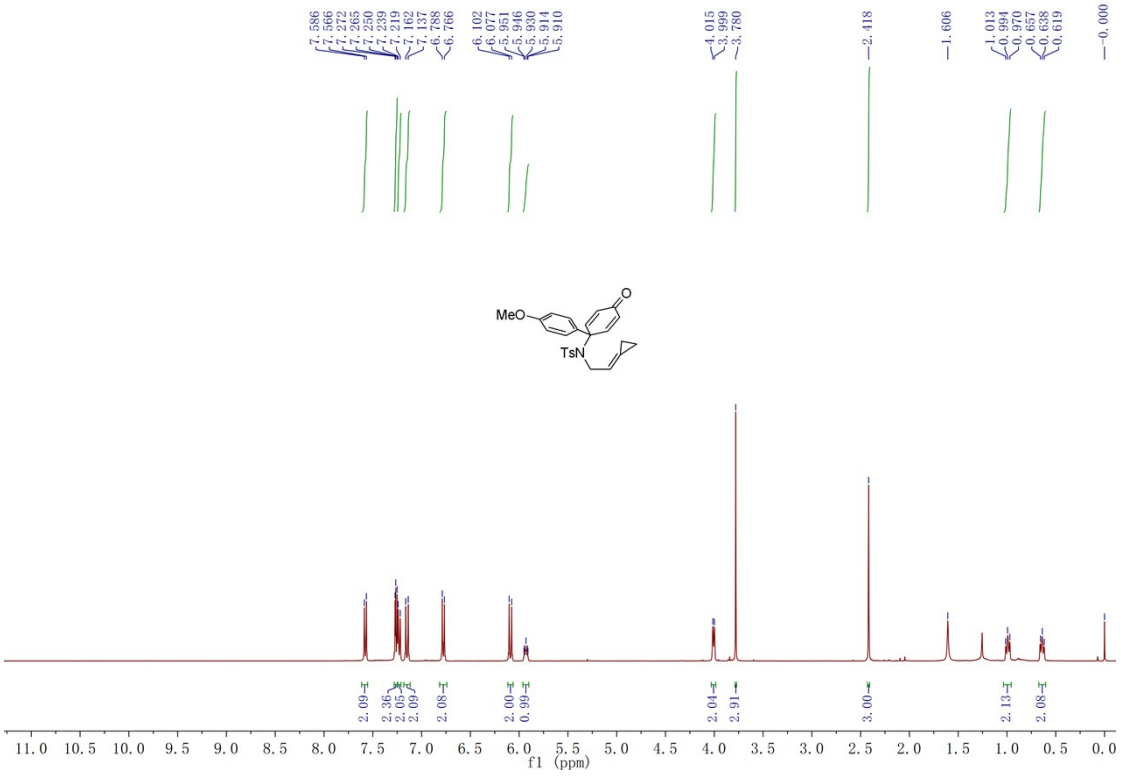
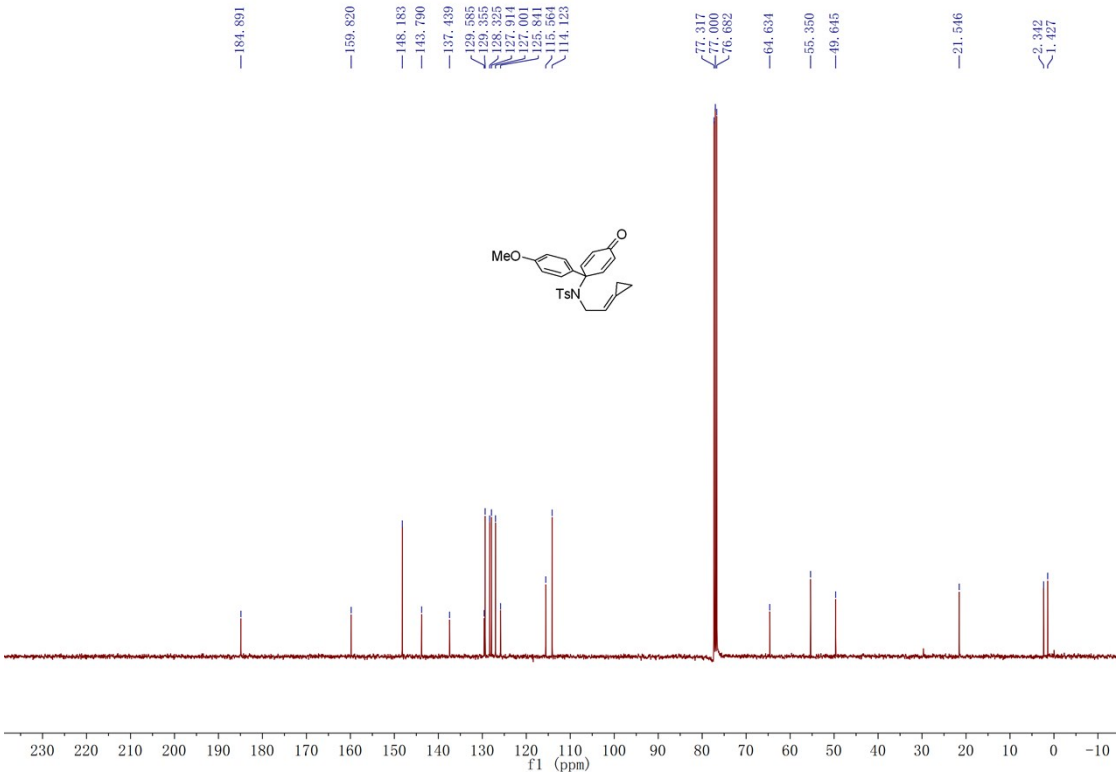
77.000
76.682
64.857
49.693
21.489
21.014
2.266
1.290
f1 (ppm)

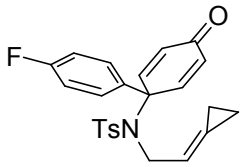

MeO
O
TsN

Compound 1l:

2.0 mmol scale, a white solid, 20% yield (174.1 mg). M.p.: 182-183 °C. ^{1}H NMR ($CDCl_3$, TMS, 400 MHz) δ 0.62-0.66 (m, 2H), 0.97-1.02 (m, 2H), 2.42 (s, 3H), 3.78 (s, 3H), 4.01 (d, *J* = 6.4 Hz, 2H), 5.91-5.96 (m, 1H), 6.09 (d, *J* = 10.0 Hz, 2H), 6.78 (d, *J* = 8.8 Hz, 2H), 7.15 (d, *J* = 10.0 Hz, 2H), 7.23 (d, *J* = 8.0 Hz, 2H), 7.26 (d, *J* = 8.8 Hz, 2H), 7.58 (d, *J* = 8.0 Hz, 2H). ^{13}C NMR ($CDCl_3$, TMS, 100 MHz) 1.4, 2.3, 21.5, 49.6, 55.4, 64.6, 114.1, 115.6, 125.8, 127.0, 127.9, 128.3, 129.4, 129.6, 137.4, 143.8, 148.2, 159.8, 184.9. IR (neat) 3050, 2955, 2924, 2851, 1764, 1746, 1622, 1492, 1462, 1360, 1330, 1246, 1188, 1158, 1082, 1035, 1018, 993, 910, 887, 870, 810, 766, 744, 705, 659 cm^{-1}. HRMS (ESI) Calcd. for $C_{25}H_{26}NO_4S^{+1}(M+H)^+$ requires 436.1577, Found: 436.1580.

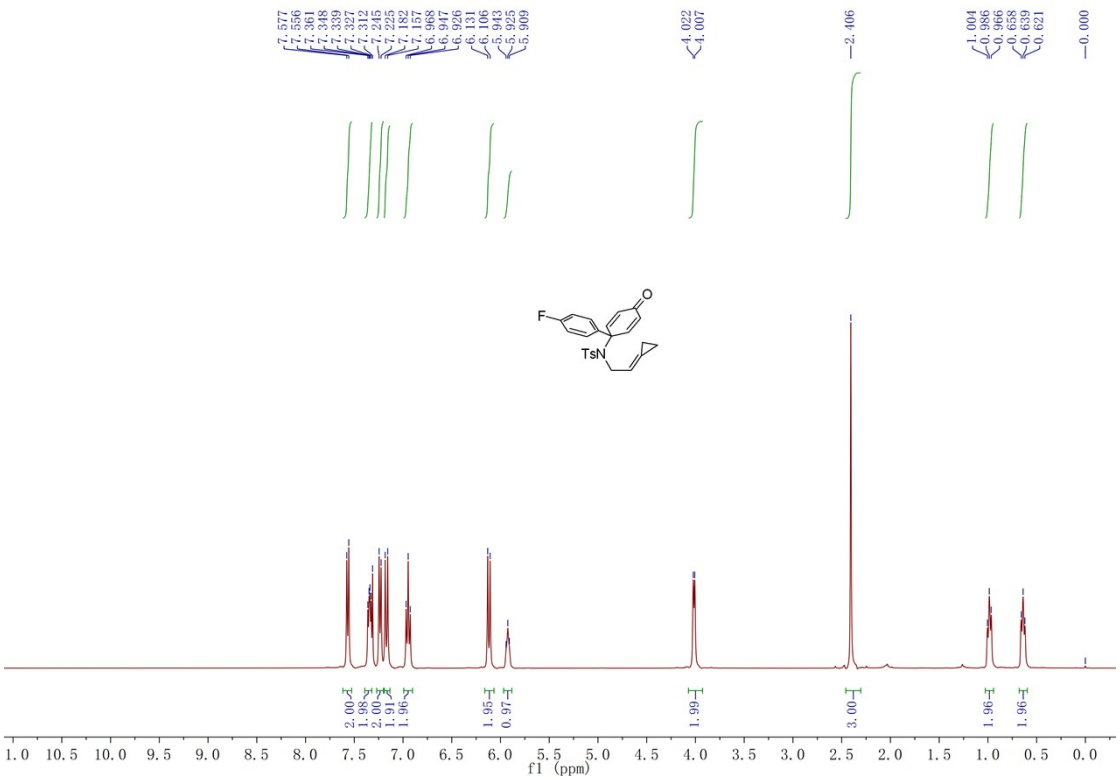






Compound 1m:

2.0 mmol scale, a light yellow solid, 77% yield (649.7 mg). M.p.: 104-106 ^{o}C. ^{1}H NMR ($CDCl_3$, TMS, 400 MHz) δ 0.62-0.66 (m, 2H), 0.96-1.01 (m, 2H), 2.41 (s, 3H), 4.01 (d, *J* = 6.0 Hz, 2H), 5.90-5.95 (m, 1H), 6.12 (d, *J* = 10.0 Hz, 2H), 6.92-6.97 (m, 2H), 7.17 (d, *J* = 10.0 Hz, 2H), 7.23 (d, *J* = 8.0 Hz, 2H), 7.32-7.37 (m, 2H), 7.56 (d, *J* = 8.0 Hz, 2H). ^{13}C NMR ($CDCl_3$, TMS, 100 MHz) δ 1.3, 2.2, 21.3, 49.6, 64.3, 115.2, 115.5 (d, *J* = 21.7 Hz), 125.9, 127.2, 127.6, 128.7 (d, *J* = 8.2 Hz), 129.2, 133.8 (d, *J* = 3.2 Hz), 137.1, 143.8, 147.6, 162.3 (d, *J* = 247.9 Hz), 184.4. ^{19}F NMR ($CDCl_3$, $CFCl_3$, 376 MHz) δ -112.24- -112.17 (m). IR (neat) 2974, 2921, 2887, 2853, 1767, 1745, 1665, 1623, 1594, 1493, 1462, 1360, 1330, 1236, 1188, 1158, 1082, 1042, 1016, 993, 931, 909, 887, 870, 809, 766, 745, 704, 681, 659 cm^{-1}. HRMS (ESI) Calcd. for $C_{24}H_{23}FNO_3S^{+1}(M+H)^+$ requires 424.1377, Found: 424.1377.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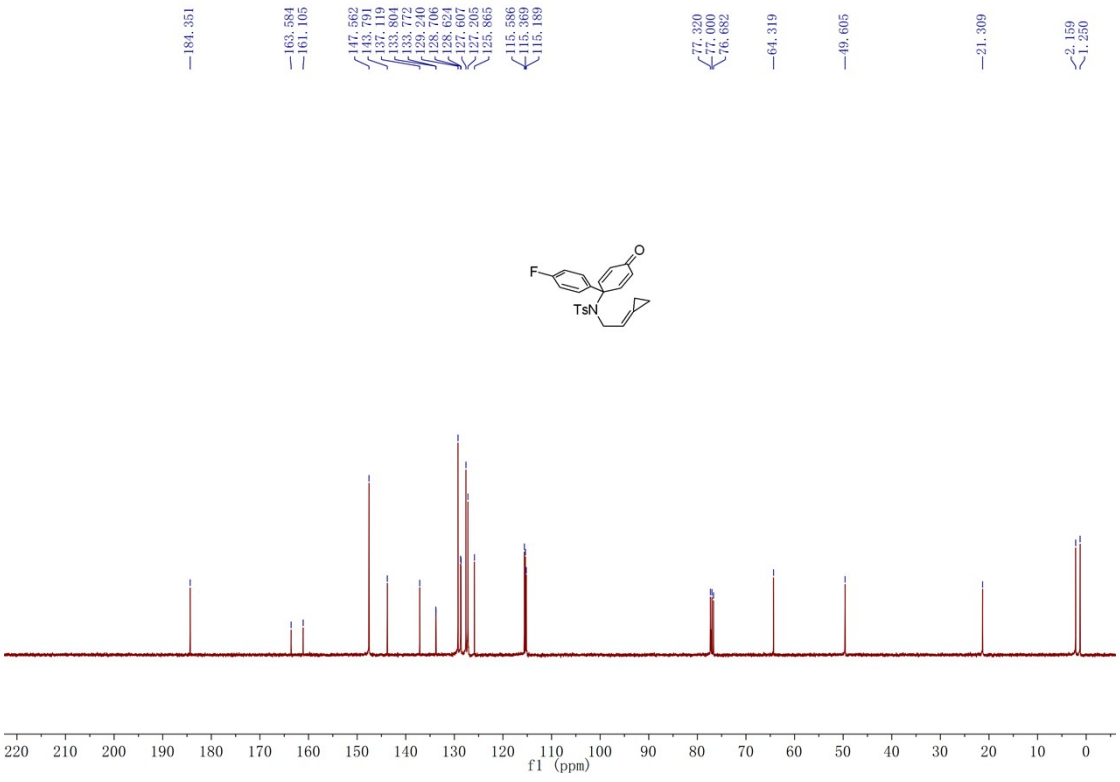
7.327
7.312
7.245
7.225
7.182
7.157
6.968
6.947
6.926
6.131
6.106
5.943
5.925
5.909
4.022
4.007
2.406
1.004
0.986
0.966
0.658
0.639
0.621
0.000
F
O
TsN
2.00
1.98
2.00
1.91
1.96
1.95
0.97
1.99
3.00
1.96
1.96
f1 (ppm)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129.096
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127.205
125.865
115.586
115.369
115.189
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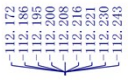
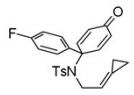
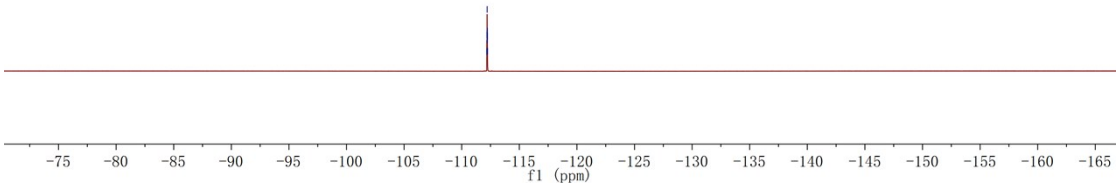
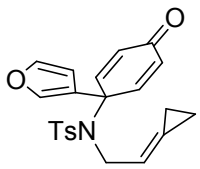
76.682
64.319
49.605
21.309
2.159
1.250
F
O
TsN
f1 (ppm)



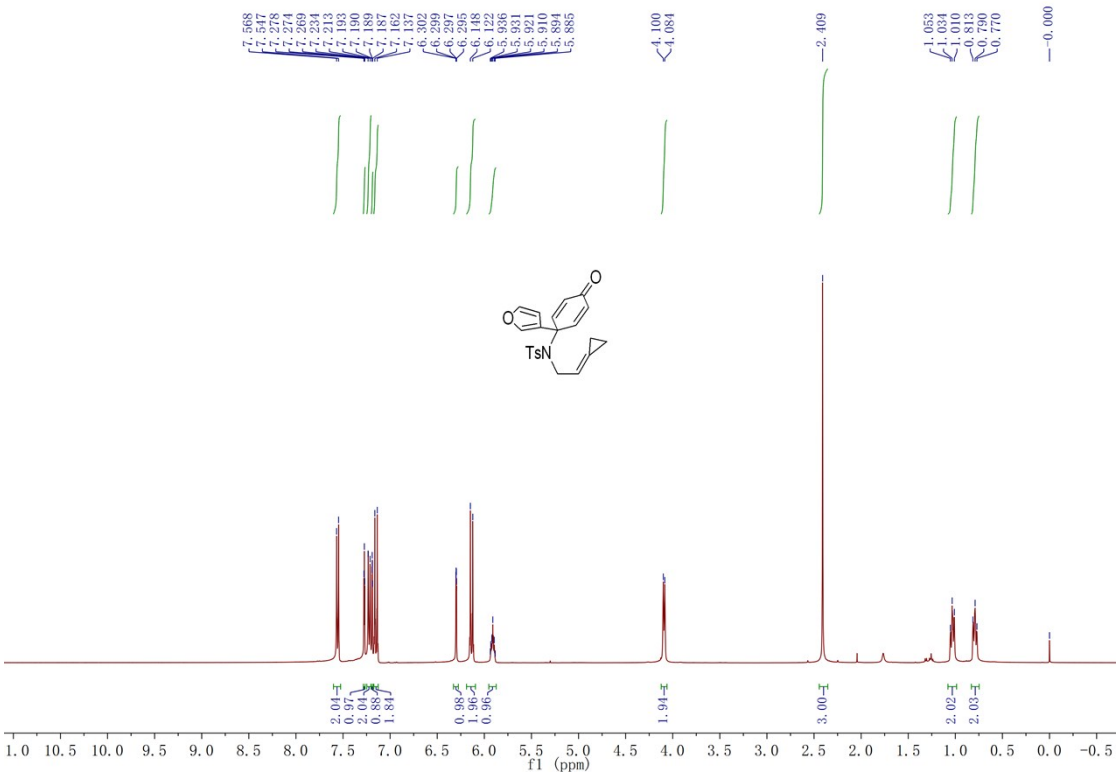






Compound 1n:

2.0 mmol scale, a white solid, 50% yield (392.6 mg). M.p.: 80-82 ^{o}C. ^{1}H NMR ($CDCl_3$, TMS, 400 MHz) δ 0.77-0.82 (m, 2H), 1.01-1.06 (m, 2H), 2.41 (s, 3H), 4.09 (d, *J* = 6.4 Hz, 2H), 5.88-5.94 (m, 1H), 6.14 (d, *J* = 10.0 Hz, 2H), 6.30 (dd, *J* = 0.8 Hz, 1.6 Hz, 1H), 7.15 (d, *J* = 10.0 Hz, 2H), 7.19 (dd, *J* = 0.8 Hz, 1.6 Hz, 1H), 7.22 (d, *J* = 8.4 Hz, 2H), 7.27 (dd, *J* = 1.6 Hz, 1.6 Hz, 1H), 7.56 (d, *J* = 8.4 Hz, 2H). ^{13}C NMR ($CDCl_3$, TMS, 100 MHz) 1.5, 2.3, 21.5, 49.0, 59.1, 109.7, 115.6, 123.5, 125.9, 127.5, 127.6, 129.3, 137.8, 140.5, 143.1, 143.6, 147.5, 184.3. IR (neat) 3036, 2953, 2936, 2851, 2845, 1745, 1618, 1492, 1462, 1360, 1331, 1269, 1246, 1188, 1157, 1101, 1082, 1037, 1018, 993, 909, 887, 870, 809, 790, 766, 744, 706, 683, 659 cm^{-1}. HRMS (ESI) Calcd. for $C_{22}H_{22}NO_4S^{+1}(M+H)^+$ requires 396.1264, Found: 396.1258.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7.234
7.213
7.193
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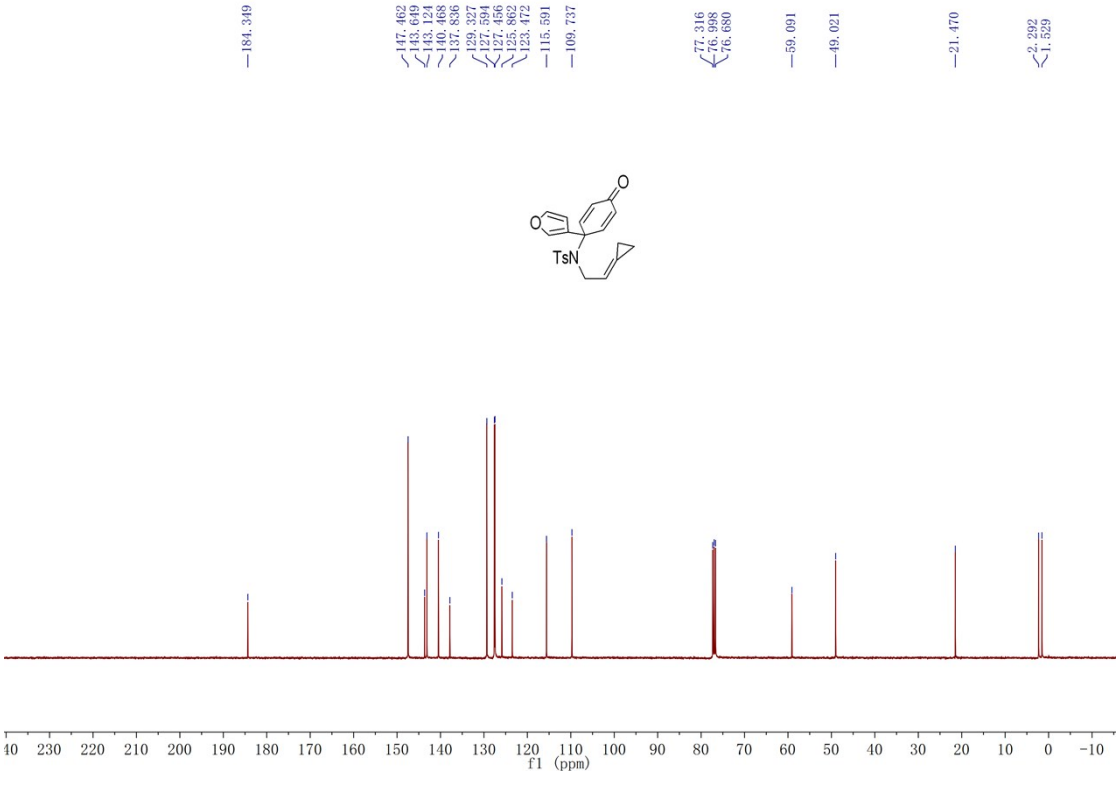
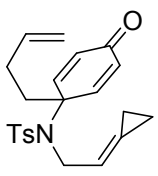
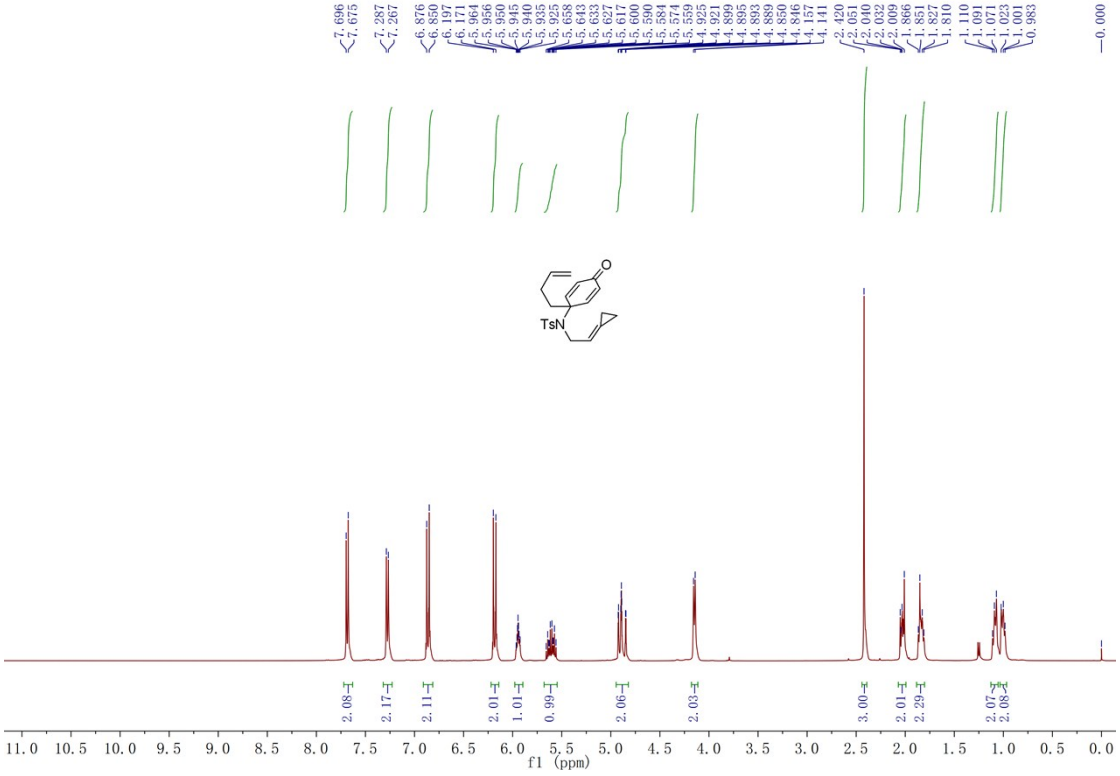
6.302
6.299
6.297
6.295
6.148
6.122
5.936
5.931
5.921
5.910
5.894
5.885
4.100
4.084
2.409
1.053
1.034
1.010
0.813
0.790
0.770
-0.000
TsN
2.04
0.97
2.04
0.88
1.84
0.98
1.96
0.96
1.94
3.00
2.02
2.03
f1 (ppm)

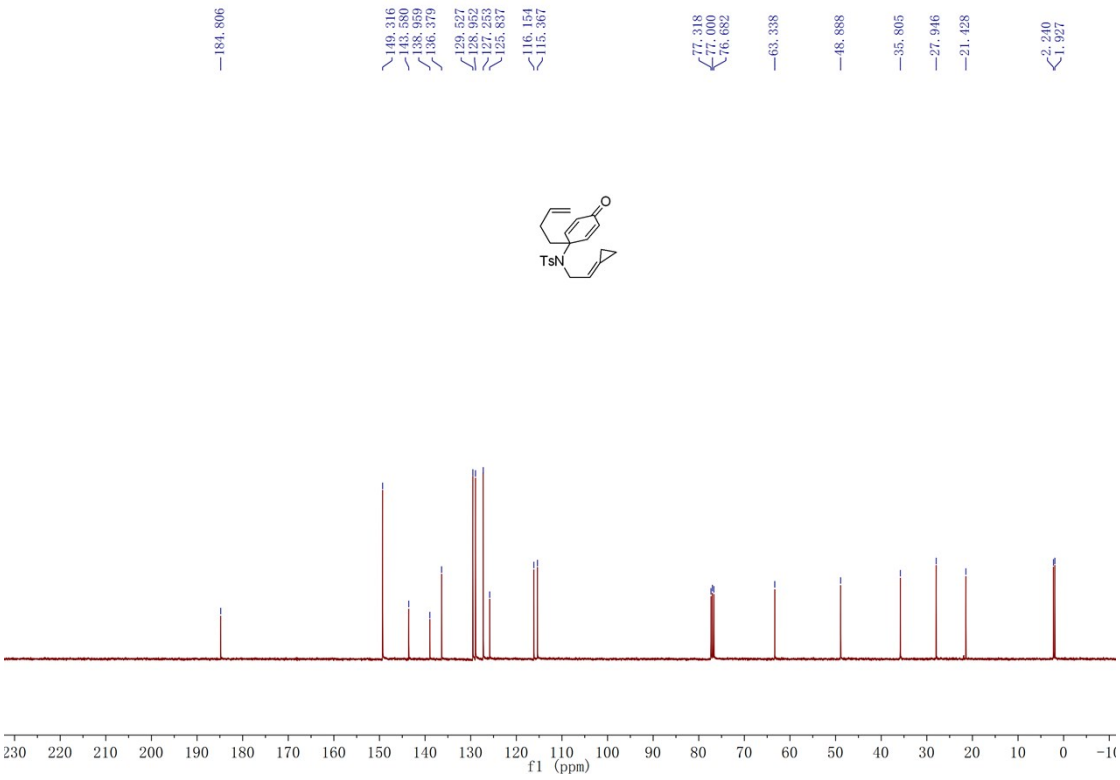

184.349
147.462
143.649
143.124
140.468
137.836
129.327
127.594
127.456
125.862
123.472
115.591
109.737
77.316
76.998
76.680
59.091
49.021
21.470
2.292
1.529
TsN
f1 (ppm)


O
TsN

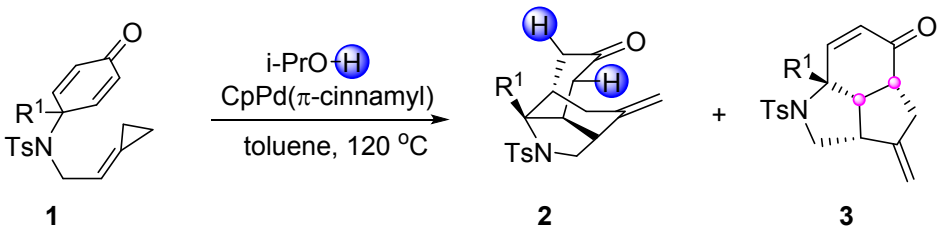
Compound 1o:

2.0 mmol scale, a white solid, 46% yield (354.3 mg). M.p.: 65-67 °C. ^{1}H NMR ($CDCl_3$, TMS, 400 MHz) δ 0.98-1.03 (m, 2H), 1.07-1.12 (m, 2H), 1.81-1.87 (m, 2H), 2.00-2.06 (m, 2H), 2.42 (s, 3H), 4.15 (d, J = 6.4 Hz, 2H), 4.84-4.93 (m, 2H), 5.55-5.66 (m, 1H), 5.92-5.97 (m, 1H), 6.18 (d, J = 10.4 Hz, 2H), 6.86 (d, J = 10.0 Hz, 2H), 7.28 (d, J = 8.0 Hz, 2H), 7.69 (d, J = 8.0 Hz, 2H). ^{13}C NMR ($CDCl_3$, TMS, 100 MHz) 1.9, 2.2, 21.4, 27.9, 35.8, 48.9, 63.3, 115.4, 116.2, 125.8, 127.3, 129.0, 129.5, 136.4, 139.0, 143.6, 149.3, 184.8. IR (neat) 3063, 3039, 2976, 2937, 2921, 2874, 2858, 1745, 1667, 1626, 1493, 1445, 1330, 1157, 1083, 1040, 993, 922, 902, 865, 804, 766, 744, 704, 679 cm^{-1}. HRMS (ESI) Calcd. for $C_{22}H_{26}NO_3S^{+1}(M+H)^+$ requires 384.1628, Found: 384.1630.




184.806
149.316
143.580
138.959
136.379
129.527
128.952
127.253
125.837
116.154
115.367
77.318
77.000
76.682
63.338
48.888
35.805
27.946
21.428
2.240
1.927
TsN
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

4. General procedure for the palladium-catalyzed intramolecular trasfer hydrogenation and cycloaddition.

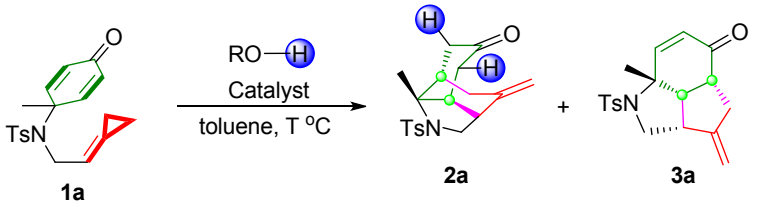


1 **2** **3**

A solution of **1** (0.15 mmol, 1.0 equiv), CpPd (π-cinnamyl) (0.015 mmol, 10 mol %) and i-PrOH (0.60 mmol, 4.0 equiv) in toluene (0.20 mL) was stirred at 120 °C under argon atmosphere for 12 hours. After the reaction completed, the mixture was concentrated in vacuo to yield the crude product, which was purified by a flash chromatography on silica gel (eluent: PE/EtOAc = 10/1 ~ 8/1) to furnish the desired product **2** and the by-product **3**.

5. Screening of conditions for the intramolecular transfer hydrogenation and cyclization of 1a

Table S1. Screening of Catalysts for the Intramolecular Transfer Hydrogenation and Cyclization of **1a**.

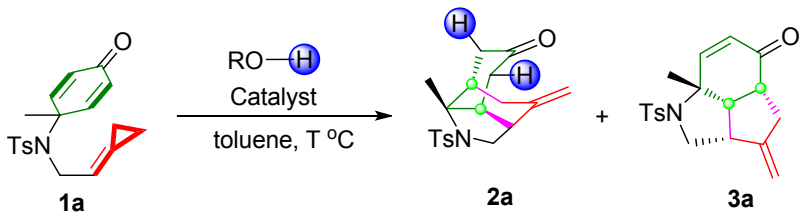


1a **2a** **3a**

Entry[a]	Solvent	Catalyst	R-OH	T (°C)	Yield (%)[b]		
					1a	**2a**	**3a**
1	toluene	$Pd_2(dba)_3$	-	100	-	37	4
2	toluene	$Pd(PPh_3)_4$	-	100	24	12	33
3	toluene	$Pd(PPh_3)_2Cl_2$	-	100	72	-	-
4	toluene	$Pd(OAc)_2$	-	100	-	-	-
5	toluene	$Pd(dba)_2$	-	100	-	34	14
6	toluene	Pd(dppe)	-	100	46	14	12
7	toluene	$Pd_2(dba)_3$	PhCOOH	100	-	-	-
8	toluene	$Pd_2(dba)_3$	Hantzsch Ester	100	-	58	trace
9	toluene	$Pd_2(dba)_3$	4Å	100	15	32	10
10	toluene	$Pd_2(dba)_3$	MeOH	100	-	54	10
11	toluene	$Pd_2(dba)_3$	EtOH	100	-	55	12
12	toluene	$Pd_2(dba)_3$	i-PrOH	100	-	59	10
13	toluene	$Pd_2(dba)_3$	Phenol	100	-	-	30
14	Tol/i-PrOH	$Pd_2(dba)_3$	-	100	-	28	24
15	xylene	$Pd_2(dba)_3$	i-PrOH	120	-	50	10
16	PhCl	$Pd_2(dba)_3$	i-PrOH	120	-	44	12
17	toluene	$Pd(PPh_3)_4$	4Å + K_2CO_3	120	54	8	6
18	MeCN	$Pd(PPh_3)_4$	Phenol	120	97	-	-
19	toluene	Pd/C	i-PrOH	120	90	-	-
20	toluene	$Pd_2(dba)_3$	Et_3N	120	-	47	14
21	toluene	$Pd_2(dba)_3$	AcOH	120	-	-	-
22	toluene	$Pd_2(dba)_3$	Phenol + LiCl	120	-	-	34

[a] Reactions were performed with **1a** (0.15 mmol), catalyst (10 mol%) and additive (0.6 mmol) in toluene (2.0 mL) at 100 or 120 °C. [b] Yields are determined by ^{1}H NMR using 1,3,5-trimethoxybenzene as an internal standard.

Table S2. Screening of Ligands for the Intramolecular Transfer Hydrogenation and Cyclization of **1a**.

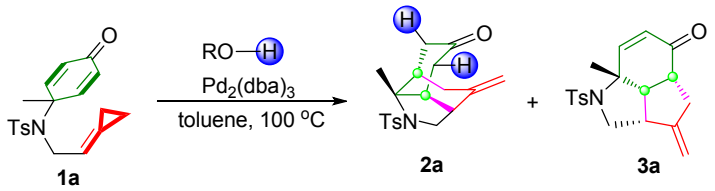


1a **2a** **3a**

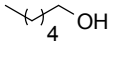
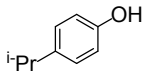
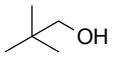
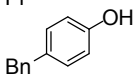
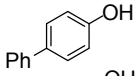
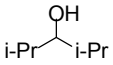
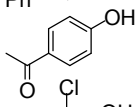
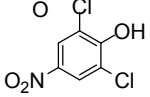
Entry[a]	Solvent	Catalyst	R-OH	T (°C)	Yield (%)[b]		
					1a	**2a**	**3a**
1	i-PrOH	$Pd(PPh_3)_4$	-	PPh_3	8	-	22
2	toluene	$Pd_2(dba)_3$	-	*R*-MONOPhos	-	20	8
3	toluene	$Pd_2(dba)_3$	-	*R*-BINAP	-	-	16
4	toluene	$Pd_2(dba)_3$	-	*S*-**L1**	-	18	6
5	toluene	$Pd_2(dba)_3$	i-PrOH	$P(Oi\text{-}Pr)_3$	-	40	10
6	toluene	$Pd_2(dba)_3$	i-PrOH	$P(OPh)_3$	-	16	-
7	toluene	$Pd_2(dba)_3$	i-PrOH	$P(O\text{-}2\text{-}toyl)_3$	-	30	36
8	toluene	$Pd_2(dba)_3$	i-PrOH	$P(O\text{-}2,4\text{-}^{t}Bu_2C_6H_3)_3$	-	24	12
9	toluene	$Pd_2(dba)_3$	*S*-BINOL	-	-	27	28
10	toluene	$Pd_2(dba)_3$	-	$P(i\text{-}Pr)_3$	-	36	10
11	toluene	$Pd_2(dba)_3$	-	$P(Cy)_3$	40	16	10
12	toluene	$Pd_2(dba)_3$	i-PrOH	$P(i\text{-}Pr)_3$	-	60	8
13	toluene	$Pd_2(dba)_3$	i-PrOH	$P(Cy)_3$	-	-	-

[a] Reactions were performed with **1a** (0.15 mmol), catalyst (10 mol%), ligands (20 mol%) and additive (0.6 mmol) in toluene (2.0 mL) at 120 °C. [b] Yields are determined by ^1H NMR using 1,3,5-trimethoxybenzene as an internal standard.

Table S3. Screening of Hydrogen Source for the Intramolecular Transfer Hydrogenation and Cyclization of **1a**.

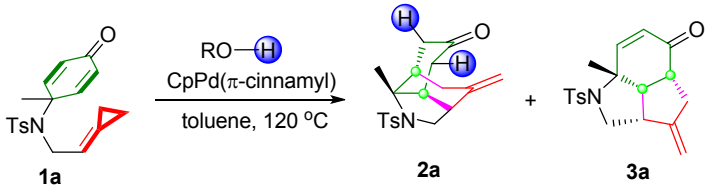


1a **2a** **3a**

Entry[a]	R-OH	Yield (%)[b]			Entry[a]	R-OH	Yield (%)[b]		
		1a	**2a**	**3a**			**1a**	**2a**	**3a**
1		-	53	18	7		-	-	16
2		-	64	11	8		-	-	32
3		-	48	32	9		-	-	32
4		-	70	14	10		-	36	20
5		-	37	20	11		-	-	10
6		-	56	22					

[a] Reactions were performed with **1a** (0.15 mmol), $Pd_2(dba)_3$ (10 mol%) and ROH (0.60 mol) in solvent (2.0 mL) at 100 °C. [b] Yields are determined by ^1H NMR using 1,3,5-trimethoxybenzene as an internal standard.

Table S4. Optimization of Conditions for the CpPd(π-cinnamyl)-Catalyzed Intramolecular Transfer Hydrogenation and Cyclization of **1a**.

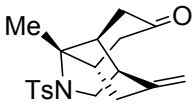


1a **2a** **3a**

Entry[a]	Solvent	R-OH	Ligand	Yield (%)[b]		
				1a	**2a**	**3a**
1	toluene	-	-	-	49	12
2	toluene	-	$PMePh_2$	-	-	-
3	toluene	$(i\text{-}Pr)_2CHOH$	-	-	68	10
4	toluene	i-PrOH	-	-	71(68)[c]	8
5	toluene	MeOH	-	-	44	14
6	toluene	Cinnamyl alcohol	-	-	29	6
7	toluene	$[NH_4]^+[HCOO]^-$	-	-	-	-

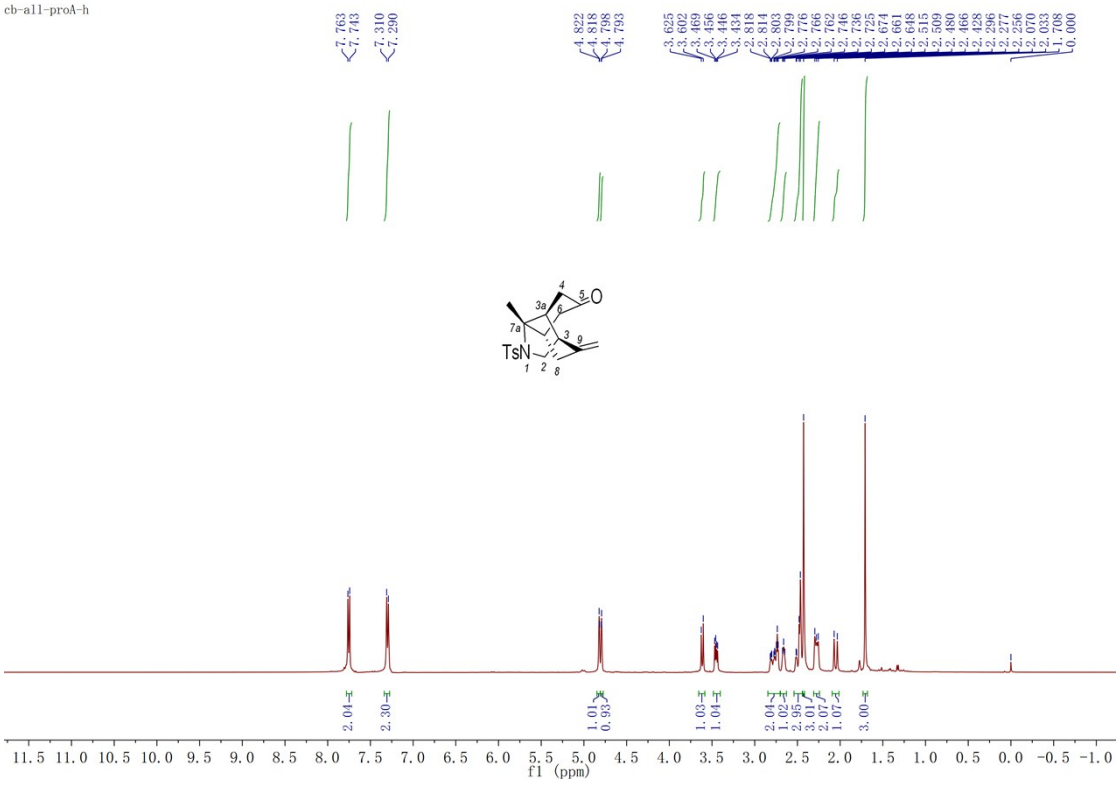
[a] Reactions were performed with **1a** (0.15 mmol), CpPd(π-cinnamyl) (10 mol%) and ROH (0.6 mol) in solvent (2.0 mL) at 120 °C. [b] Yields are determined by ^1H NMR using 1,3,5-trimethoxybenzene as an internal standard. [c] Yields of isolated product.

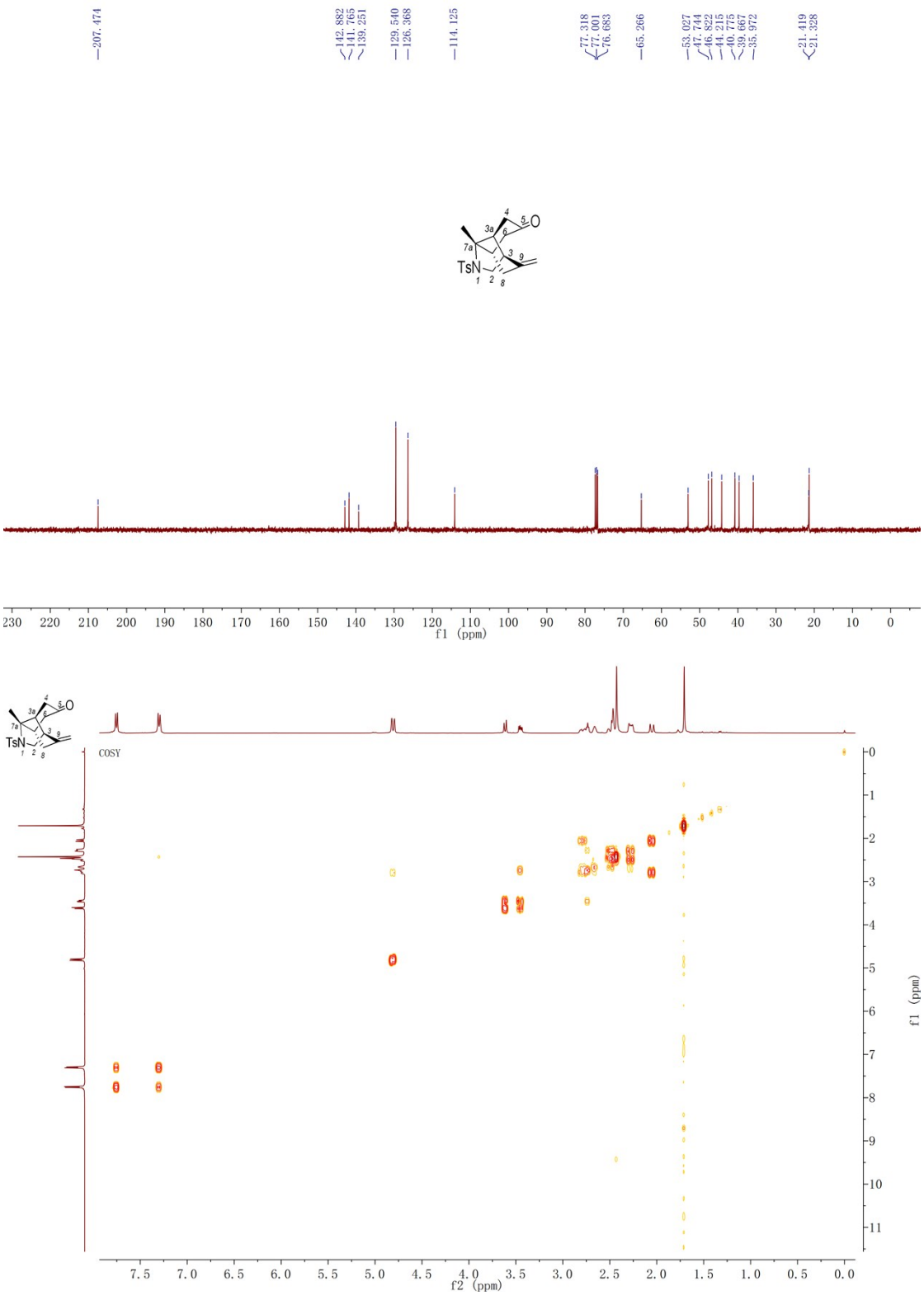
6. Characterization and spectra charts for 2

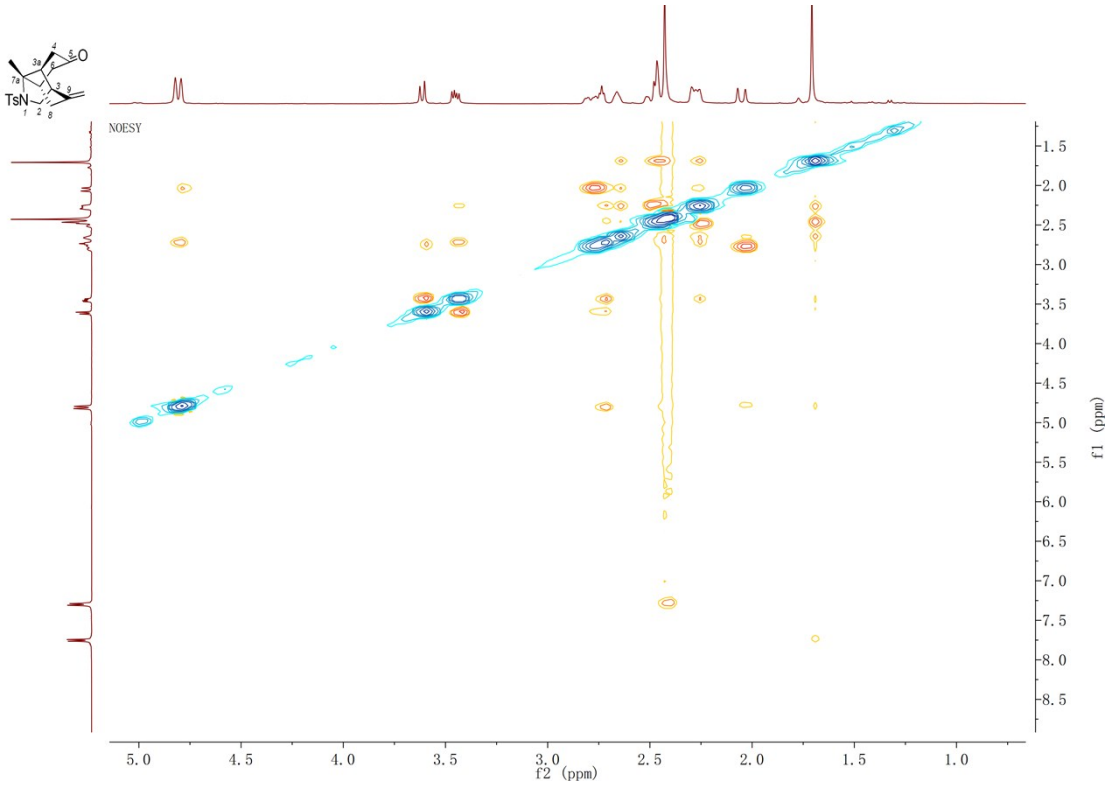


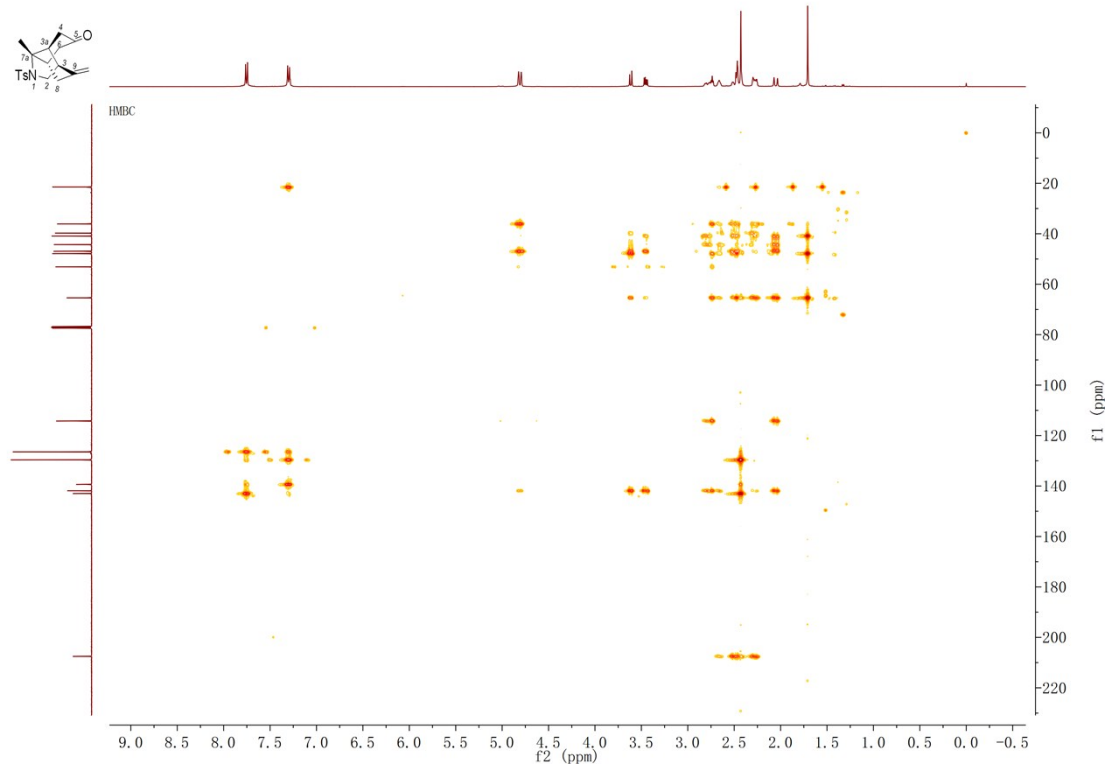
Compound 2a:

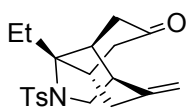
0.15 mmol scale, a light yellow solid, 68% yield (35.2 mg). M.p.: 130-133 °C. ^{1}H NMR ($CDCl_3$, TMS, 400 MHz) δ 1.71 (s, 3H), 2.05 (d, *J* = 14.8 Hz, 1H), 2.26-2.31 (m, 2H), 2.43 (s, 3H), 2.46-2.53 (m, 3H), 2.64-2.68 (m, 1H), 2.74 (t, *J* = 4.4 Hz, 1H), 2.76-2.82 (m, 1H), 3.45 (dd, *J* = 4.4 Hz, 9.2 Hz, 1H), 3.61 (d, *J* = 9.2 Hz, 1H), 4.80 (d, *J* = 2.0 Hz, 1H), 4.82 (d, *J* = 2.0 Hz, 1H), 7.30 (d, *J* = 8.0 Hz, 2H), 7.75 (d, *J* = 8.0 Hz, 2H). ^{13}C NMR ($CDCl_3$, TMS, 100 MHz) δ 21.3, 21.4, 36.0, 39.7, 40.8, 44.2, 46.8, 47.7, 53.0, 65.3, 114.1, 126.4, 129.5, 139.3, 141.8, 142.9, 207.5. IR (neat) 3068, 2979, 2942, 2882, 1712, 1652, 1598, 1494, 1445, 1405, 1319, 1287, 1228, 1197, 1151, 1130, 1095, 1079, 1039, 1008, 902, 814, 734, 707, 672, 653 cm^{-1}. HRMS (ESI) Calcd. for $C_{19}H_{24}NO_3S^{+1}(M+H)^+$ requires: 346.1471, found: 346.1472.




207.474
142.882
141.765
139.251
129.540
126.368
114.125
77.318
77.001
76.683
65.266
53.027
47.744
46.822
44.215
40.775
39.667
35.972
21.419
21.328
TsN
f1 (ppm)
COSY
f2 (ppm)



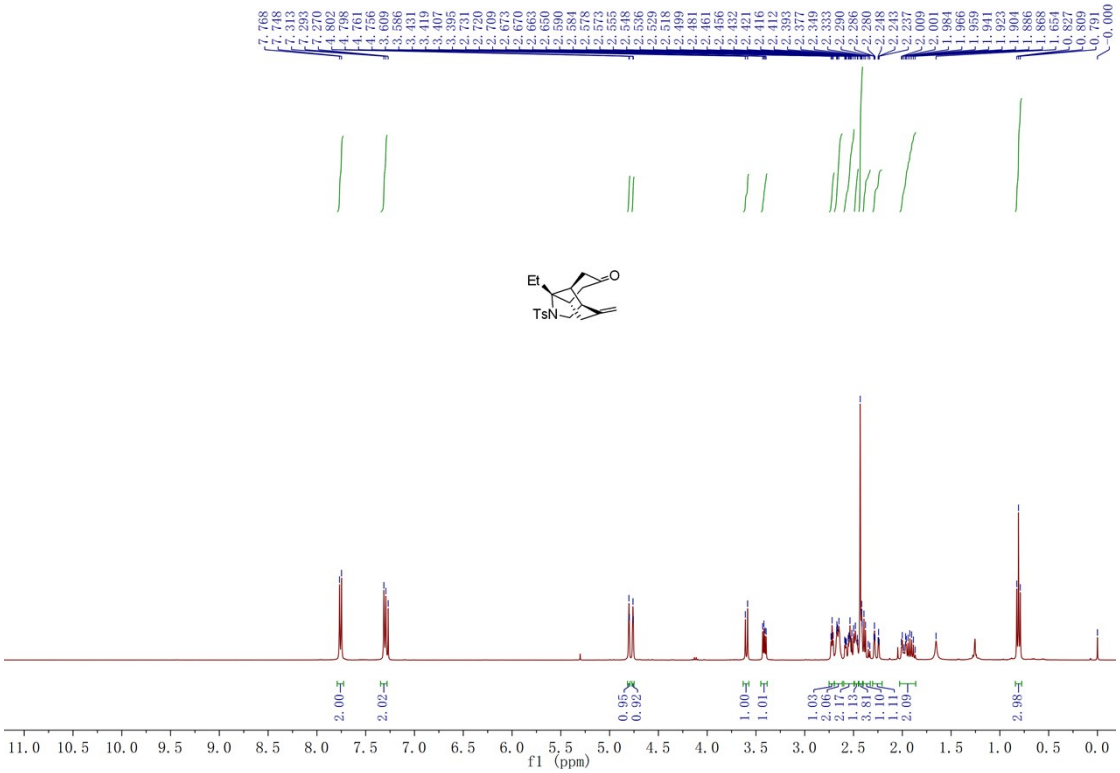


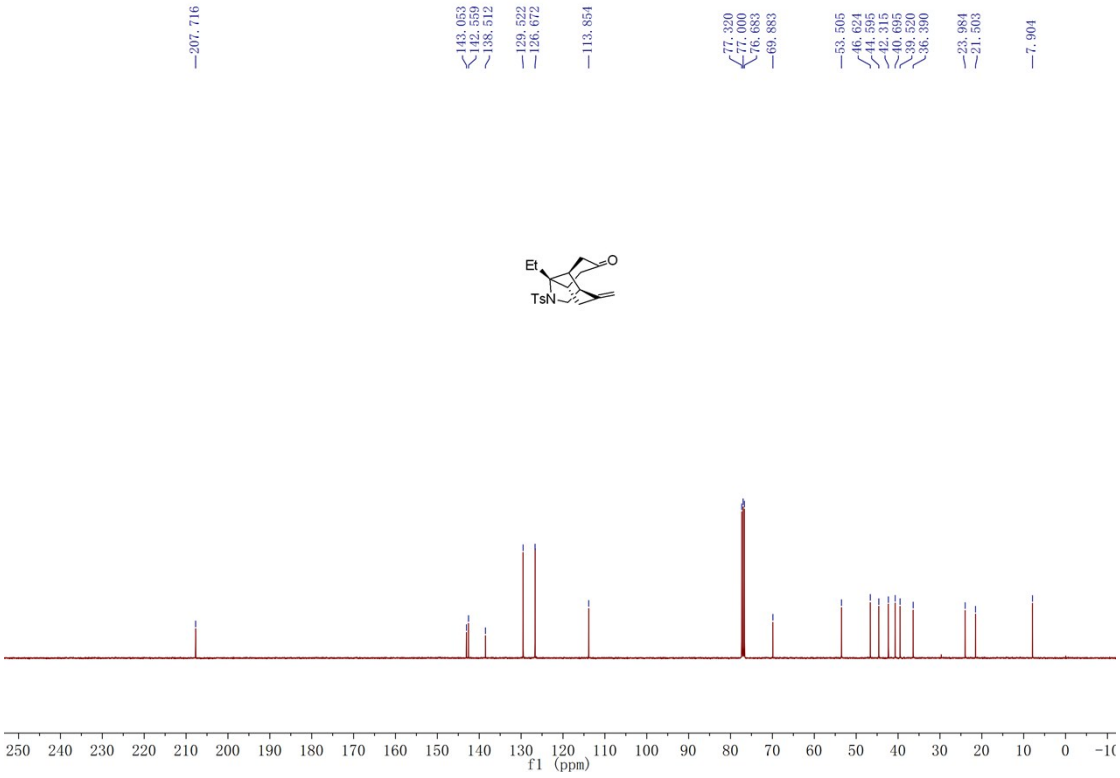


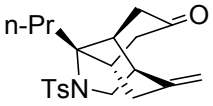
Compound 2b:

0.15 mmol scale, a white solid, 53% yield (28.6 mg). M.p.: 189-190 ^{o}C. ^{1}H NMR ($CDCl_3$, TMS,

400 MHz) δ 0.81 (t, *J* = 7.2 Hz, 3H), 1.86-2.01 (m, 2H), 2.23-2.29 (m, 1H), 2.33-2.40 (m, 1H), 2.41-2.44 (m, 4H), 2.45-2.49 (m, 1H), 2.49-2.59 (m, 2H), 2.65-2.68 (m, 2H), 2.72 (t, *J* = 4.4 Hz, 1H), 3.41 (dd, *J* = 4.8 Hz, 9.6 Hz, 1H), 3.60 (d, *J* = 9.6 Hz, 1H), 4.76 (d, *J* = 2.0 Hz, 1H), 4.80 (d, *J* = 2.0 Hz, 1H), 7.29 (d, *J* = 8.0 Hz, 2H), 7.76 (d, *J* = 8.0 Hz, 2H). ^{13}C NMR ($CDCl_3$, TMS, 100 MHz) δ 7.9, 21.5, 24.0, 36.4, 39.5, 40.7, 42.3, 44.6, 46.6, 53.5, 69.9, 113.9, 126.7, 129.5, 138.5, 142.6, 143.1, 207.7. IR (neat) 3065, 3050, 3023, 2979, 2923, 2882, 2845, 1711, 1647, 1598, 1493, 1452, 1403, 1320, 1286, 1227, 1197, 1153, 1124, 1094, 1072, 1030, 1008, 955, 901, 845, 815, 792, 734, 707, 698, 669 cm^{-1}. HRMS (ESI) Calcd. for $C_{20}H_{26}NO_3S^{+1}(M+H)^+$ requires: 360.1628, found: 360.1635.

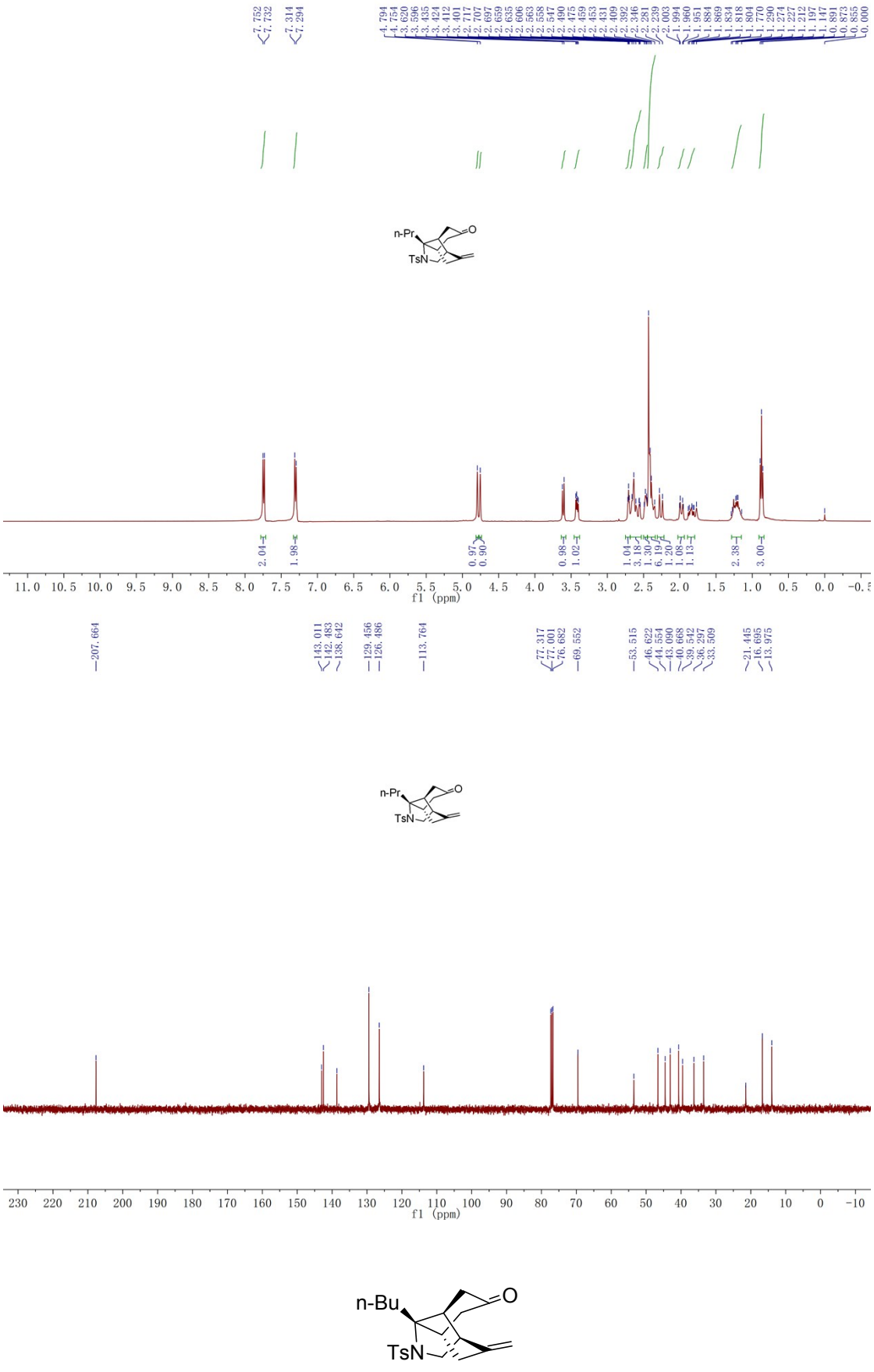






Compound 2c:

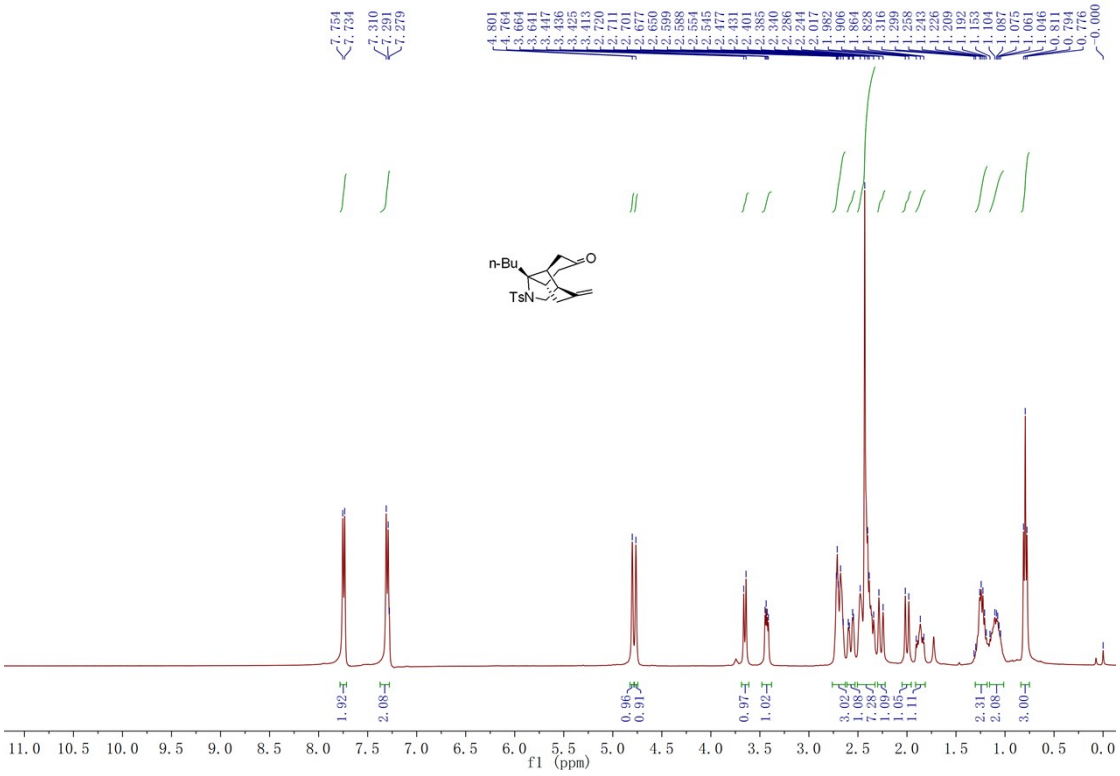
0.15 mmol scale, a light yellow solid, 62% yield (34.7 mg). M.p.: 122-125 ^{o}C. ^{1}H NMR ($CDCl_3$, TMS, 400 MHz) δ 0.87 (t, *J* = 7.2 Hz, 3H), 1.14-1.29 (m, 2H), 1.80-1.89 (m, 1H), 1.98 (dd, *J* = 3.6 Hz, 17.2 Hz, 1H), 2.26 (d, *J* = 17.2 Hz, 1H), 2.34-2.44 (m, 6H), 2.45-2.50 (m, 1H), 2.54-2.66 (m, 3H), 2.71 (t, *J* = 4.0 Hz, 1H), 3.42 (dd, *J* = 4.4 Hz, 9.2 Hz, 1H), 3.61 (d, *J* = 9.6 Hz, 1H), 4.75 (s, 1H), 4.79 (s, 1H), 7.30 (d, *J* = 8.0 Hz, 2H), 7.74 (d, *J* = 8.0 Hz, 2H). ^{13}C NMR ($CDCl_3$, TMS, 100 MHz) δ 14.0, 16.7, 21.4, 33.5, 36.3, 39.5, 40.7, 43.1, 44.6, 46.6, 53.5, 69.6, 113.8, 126.5, 129.5, 138.6, 142.5, 143.0, 207.7. IR (neat) 3068, 2955, 2932, 2873, 1712, 1598, 1494, 1448, 1403, 1321, 1303, 1261, 1226, 1197, 1154, 1095, 1079, 1040, 1011, 967, 899, 815, 734, 708, 699, 666 cm^{-1}. HRMS (ESI) Calcd. for $C_{21}H_{28}NO_3S^{+1}$(M+H)$^{+}$ requires: 374.1784, found: 374.1783.

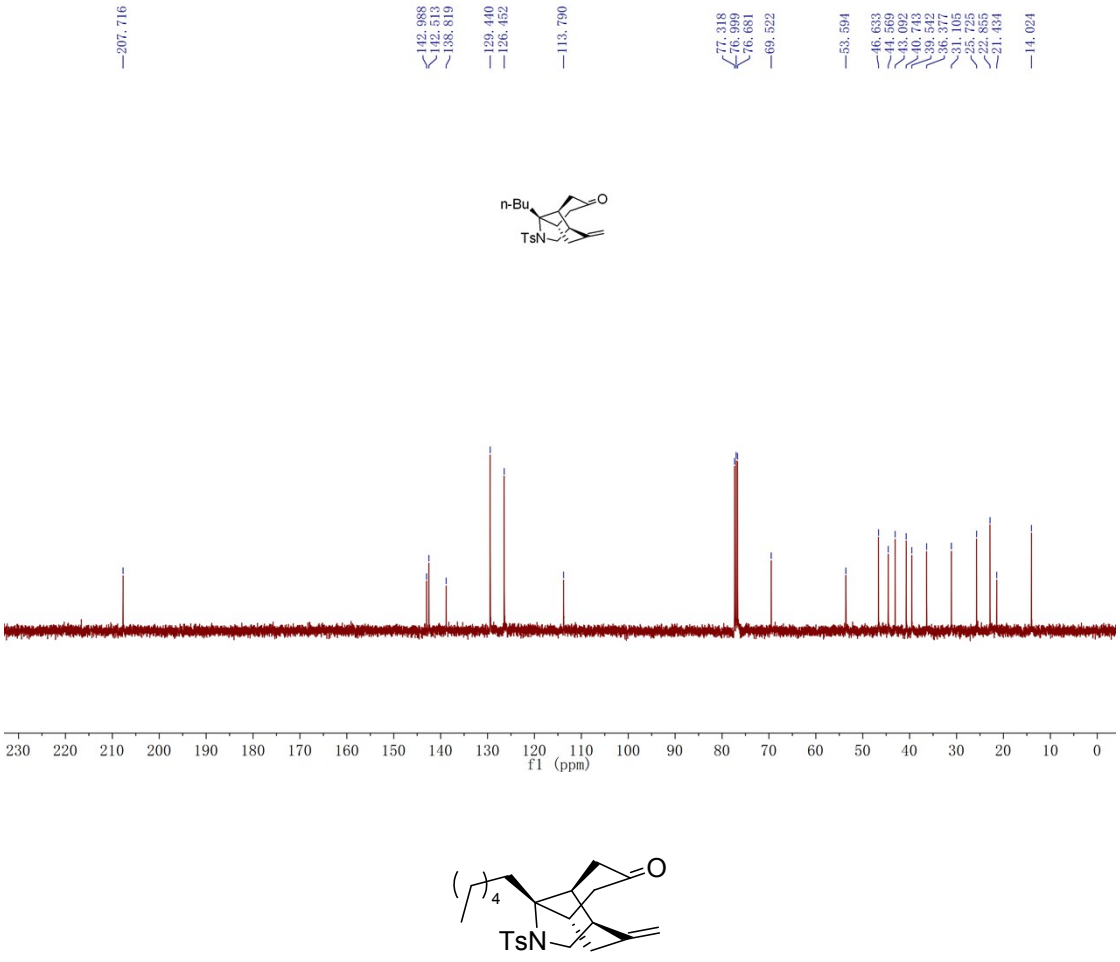


Compound 2d:

0.15 mmol scale, a light yellow solid, 57% yield (33.1 mg). M.p.: 146-148 °C. ^{1}H NMR ($CDCl_3$,

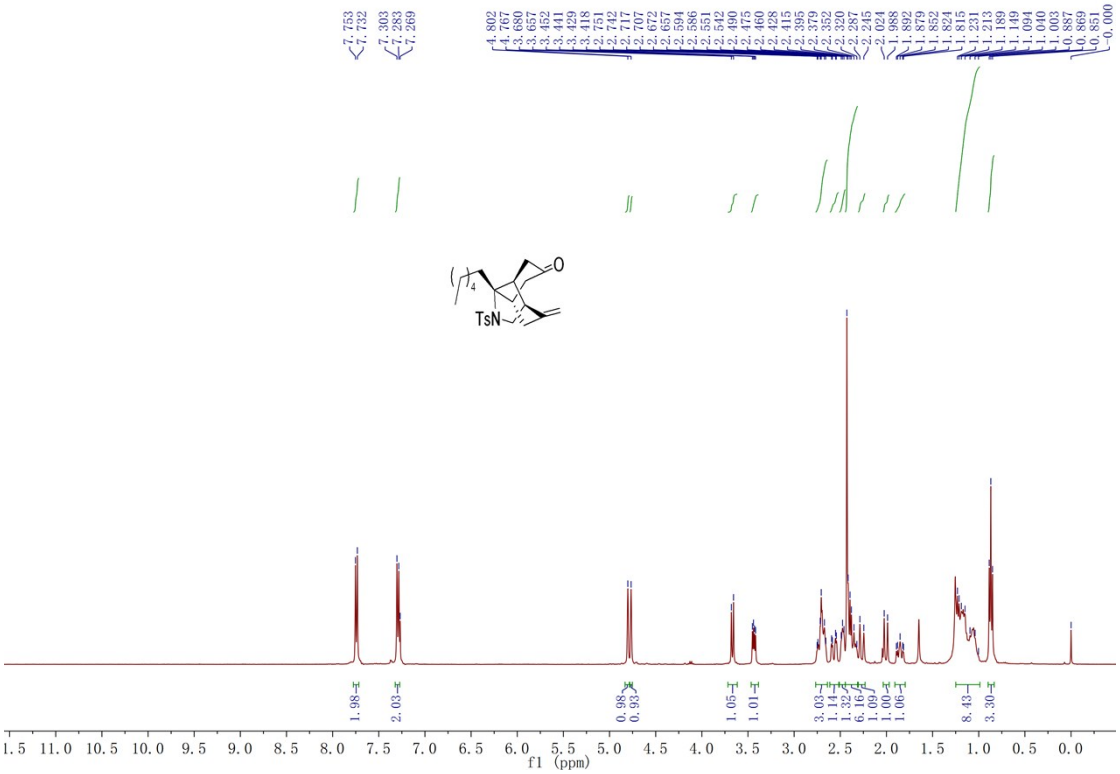
TMS, 400 MHz) δ 0.79 (t, *J* = 7.2 Hz, 3H), 1.04-1.16 (m, 2H), 1.19-1.32 (m, 2H), 1.82-1.91 (m, 1H), 2.00 (d, *J* = 14.0 Hz, 1H), 2.27 (d, *J* = 16.8 Hz, 1H), 2.34-2.48 (m, 7H), 2.54-2.60 (m, 1H), 2.65-2.72 (m, 3H), 3.43 (dd, *J* = 4.8 Hz, 9.2 Hz, 1H), 3.65 (d, *J* = 9.2 Hz, 1H), 4.76 (s, 1H), 4.80 (s, 1H), 7.30 (d, *J* = 8.0 Hz, 2H), 7.74 (d, *J* = 8.0 Hz, 2H). ^{13}C NMR ($CDCl_3$, TMS, 100 MHz) δ 14.0, 21.4, 22.9, 25.7, 31.1, 36.4, 39.5, 40.7, 43.1, 44.6, 46.6, 53.6, 69.5, 113.8, 126.5, 129.4, 138.8, 142.5, 143.0, 207.7. IR (neat) 3073, 2951, 2924, 2870, 1712, 1647, 1594, 1447, 1404, 1322, 1303, 1226, 1196, 1154, 1095, 1073, 1037, 1014, 966, 898, 814, 795, 734, 708, 699, 665 cm^{-1}. HRMS (ESI) Calcd. for $C_{22}H_{30}NO_3S^{+1}(M+H)^+$ requires: 388.1941, found: 388.1943.

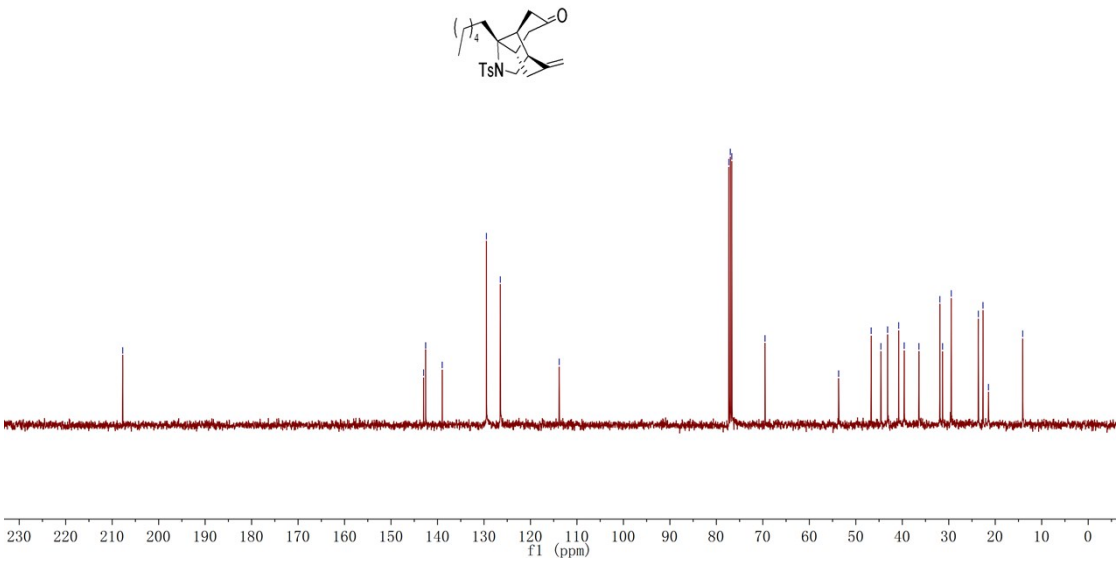


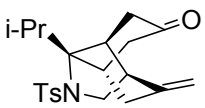


Compound 2e:

0.15 mmol scale, a light yellow solid, 43% yield (26.8 mg). M.p.: 140-143 ^{o}C. ^{1}H NMR ($CDCl_3$, TMS, 400 MHz) δ 0.87 (t, *J* = 7.2 Hz, 3H), 1.00-1.24 (m, 8H), 1.81-1.90 (m, 1H), 2.01 (d, *J* = 14.4 Hz, 1H), 2.26 (d, *J* = 16.8 Hz, 1H), 2.32-2.43 (m, 6H), 2.46-2.49 (m, 1H), 2.54-2.60 (m, 1H), 2.65-2.76 (m, 3H), 3.43 (dd, *J* = 4.4 Hz, 9.2 Hz, 1H), 3.67 (d, *J* = 9.2 Hz, 1H), 4.77 (s, 1H), 4.80 (s, 1H), 7.29 (d, *J* = 8.0 Hz, 2H), 7.74 (d, *J* = 8.0 Hz, 2H). ^{13}C NMR ($CDCl_3$, TMS, 100 MHz) δ 14.1, 21.4, 22.6, 23.6, 29.5, 31.3, 31.9, 36.4, 39.6, 40.8, 43.2, 44.6, 46.7, 53.7, 69.5, 113.8, 126.5, 129.5, 139.0, 142.6, 143.0, 207.7. IR (neat) 3073, 2950, 2923, 2869, 2852, 1715, 1598, 1494, 1449, 1403, 1322, 1303, 1226, 1195, 1154, 1096, 1073, 1024, 997, 963, 900, 813, 797, 735, 708, 699, 684, 666 cm^{-1}. HRMS (ESI) Calcd. for $C_{24}H_{34}NO_3S^{+1}(M+H)^+$ requires: 416.2254, found: 416.2255.



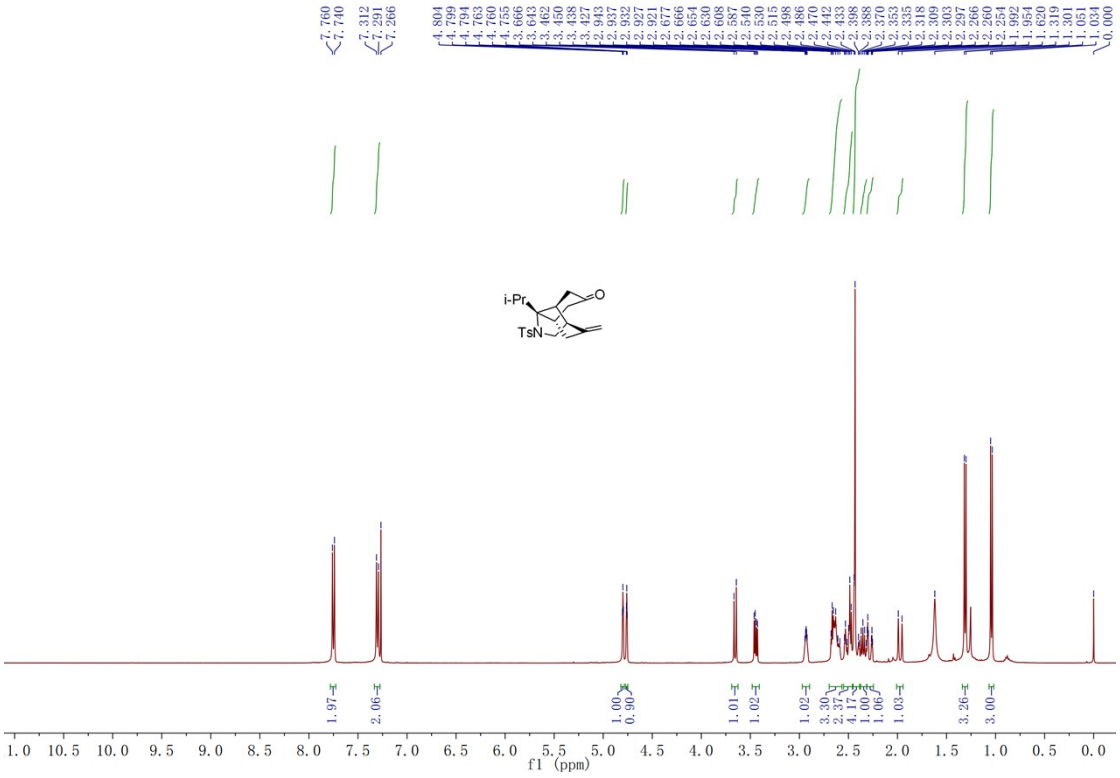


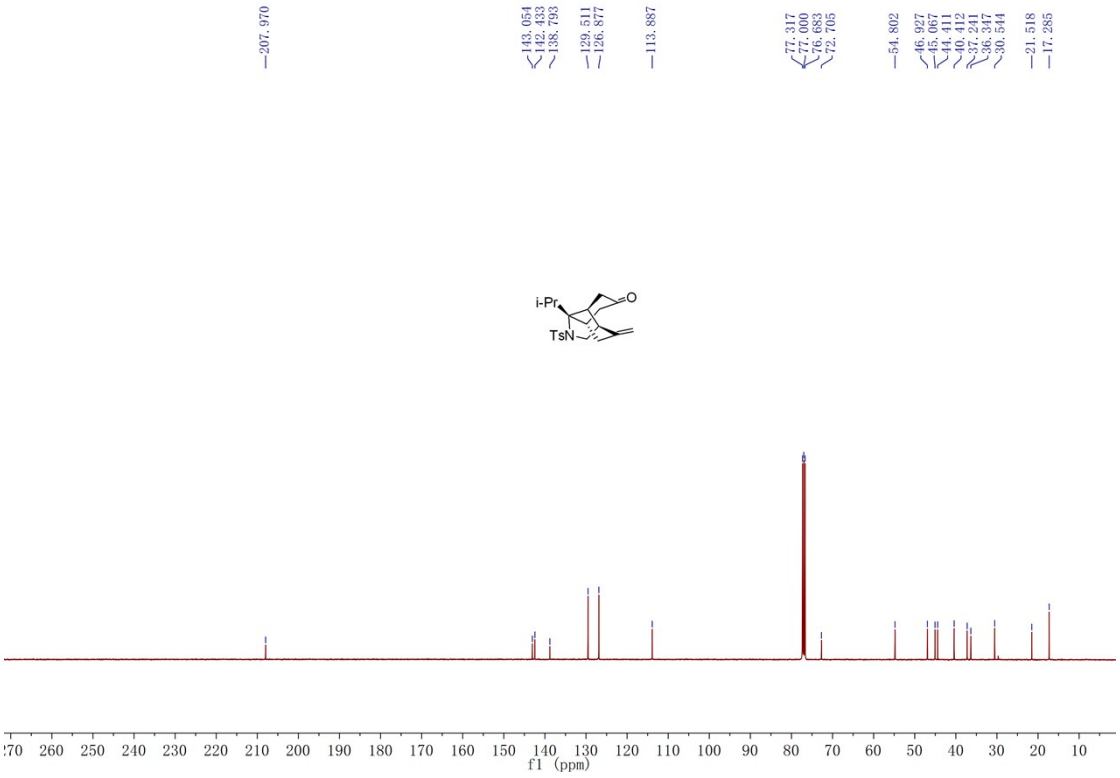


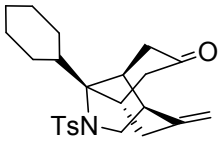
Compound 2f:

0.15 mmol scale, a white solid, 30% yield (16.7 mg). M.p.: 186-187 ^{o}C. ^{1}H NMR ($CDCl_3$, TMS,

400 MHz) δ 1.04 (d, J = 6.8 Hz, 3H), 1.31 (d, J = 6.8 Hz, 3H), 1.97 (d, J = 15.2 Hz, 1H), 2.25-2.31 (m, 1H), 2.31-2.37 (m, 1H), 2.38-2.45 (m, 4H), 2.47-2.54 (m, 2H), 2.58-2.68 (m, 3H), 2.92-2.95 (m, 1H), 3.44 (dd, J = 4.4 Hz, 9.2 Hz, 1H), 3.65 (d, J = 9.2 Hz, 1H), 4.75-4.77 (m, 1H), 4.79-4.81 (m, 1H), 7.30 (d, J = 8.0 Hz, 2H), 7.75 (d, J = 8.0 Hz, 2H). ^{13}C NMR ($CDCl_3$, TMS, 100 MHz) δ 17.3, 21.5, 30.5, 36.3, 37.2, 40.4, 44.4, 45.1, 46.9, 54.8, 72.7, 113.9, 126.9, 129.5, 138.8, 142.4, 143.1, 208.0. IR (neat) 3068, 2963, 2937, 2882, 1714, 1649, 1597, 1451, 1408, 1338, 1327, 1226, 1189, 1157, 1104, 1090, 1076, 1050, 1004, 926, 900, 815, 790, 708, 669 cm^{-1}. HRMS (ESI) Calcd. for $C_{21}H_{28}NO_3S^{+1}(M+H)^+$ requires: 374.1784, found: 374.1784.

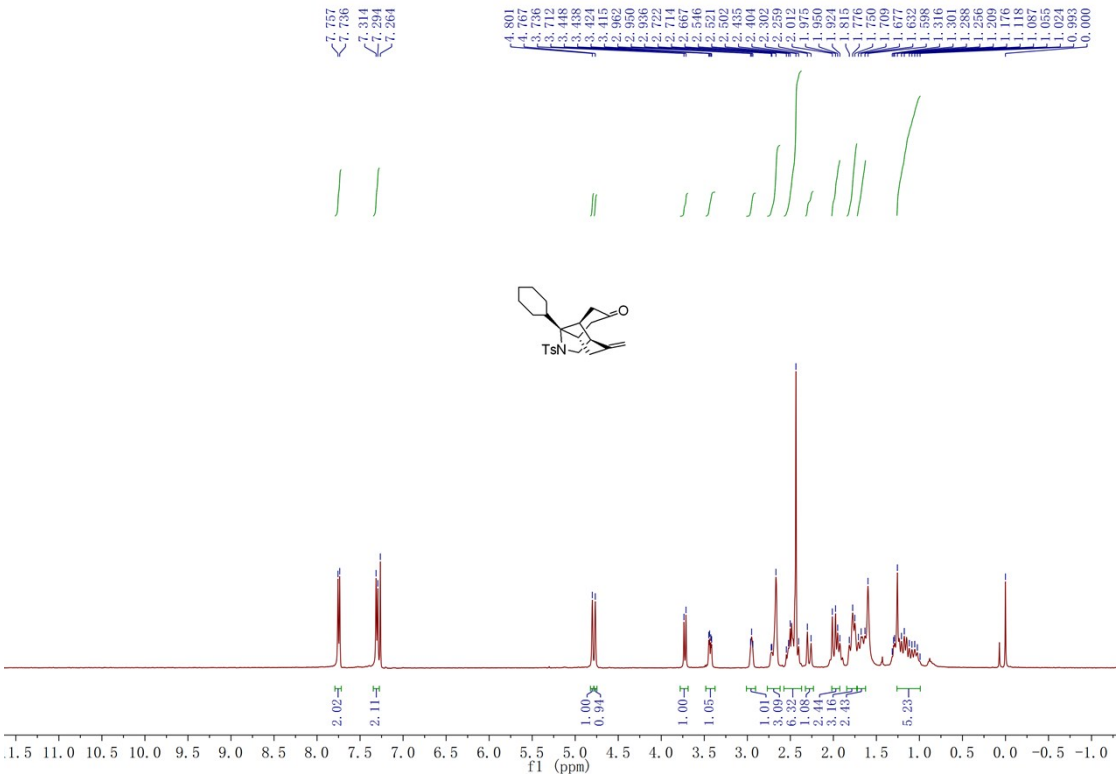


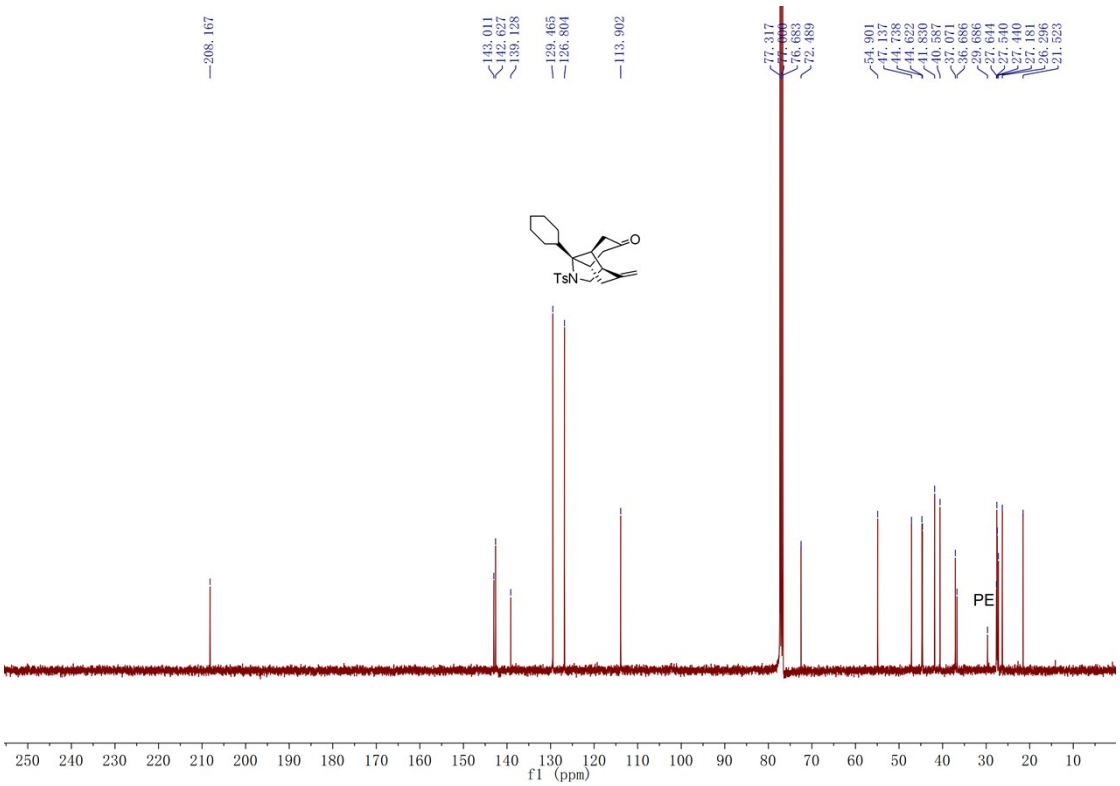


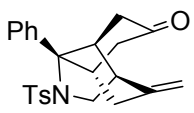


Compound 2g:

0.15 mmol scale, a light yellow solid, 25% yield (15.5 mg). M.p.: 198-200 °C. ^{1}H NMR ($CDCl_3$, TMS, 400 MHz) δ 0.99-1.32 (m, 5H), 1.63-1.71 (m, 2H), 1.75-1.82 (m, 3H), 1.92-2.02 (m, 2H), 2.25-2.31 (m, 1H), 2.40-2.55 (m, 6H), 2.66-2.73 (m, 3H), 2.93-2.97 (m, 1H), 3.43 (dd, J = 4.4 Hz, 9.6 Hz, 1H), 3.72 (d, J = 9.6 Hz, 1H), 4.77 (s, 1H), 4.80 (s, 1H), 7.30 (d, J = 8.0 Hz, 2H), 7.75 (d, J = 8.0 Hz, 2H). ^{13}C NMR ($CDCl_3$, TMS, 100 MHz) δ 21.5, 26.3, 27.2, 27.4, 27.5, 27.6, 36.7, 37.1, 40.6, 41.8, 44.6, 44.7, 47.1, 54.9, 72.5, 113.9, 126.8, 129.5, 139.1, 142.6, 143.0, 208.2. IR (neat) 2923, 2852, 1714, 1647, 1594, 1448, 1406, 1328, 1222, 1200, 1155, 1129, 1094, 1069, 1038, 1008, 964, 902, 812, 787, 735, 710, 668 cm^{-1}. HRMS (ESI) Calcd. for $C_{24}H_{32}NO_3S^{+1}(M+H)^+$ requires: 414.2097, found: 414.2096.



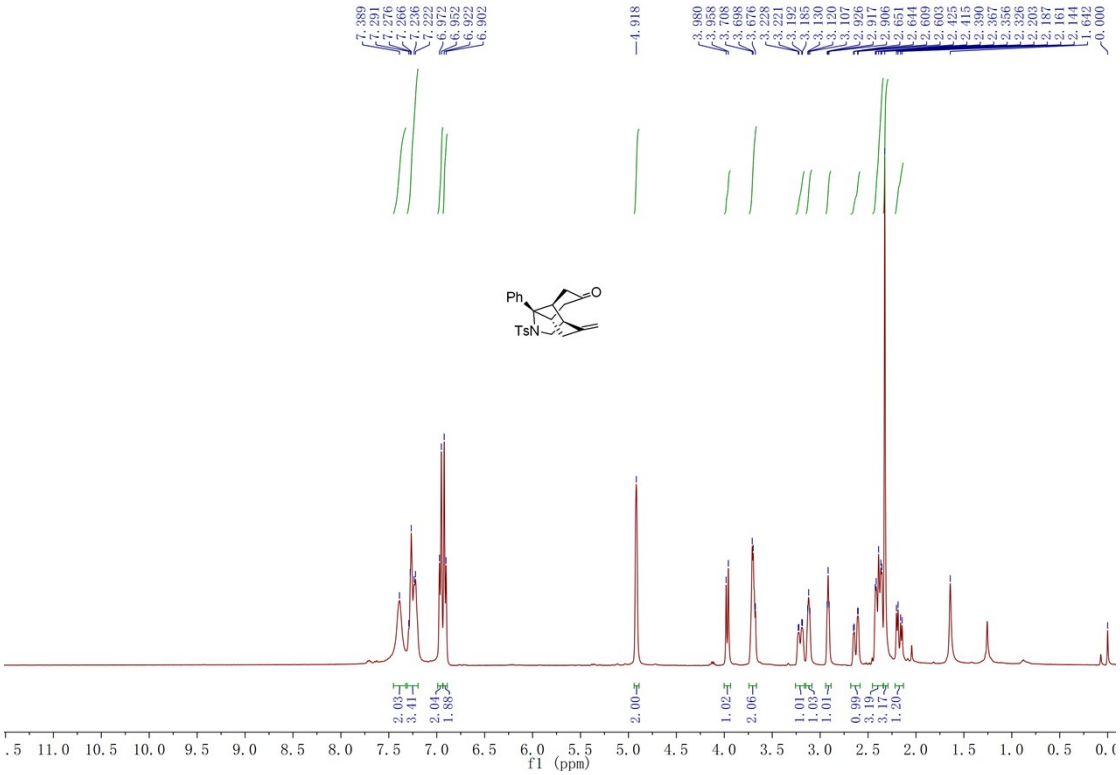


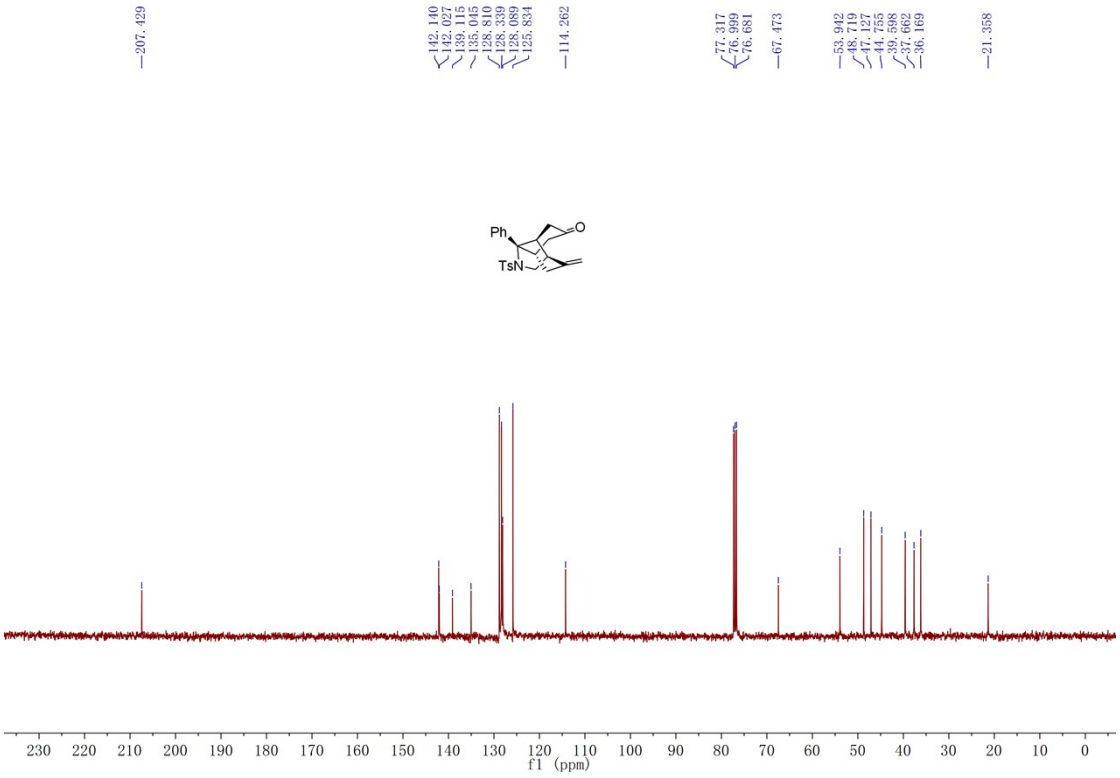


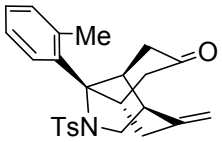
Compound 2h:

0.15 mmol scale, a light yellow solid, 30% yield (18.3 mg). M.p.: 232-235 ^{o}C. ^{1}H NMR ($CDCl_3$,

TMS, 400 MHz) δ 2.17 (dd, *J* = 6.4 Hz, 17.2 Hz, 1H), 2.33 (s, 3H), 2.35-2.43 (m, 3H), 2.63 (dd, *J* = 2.8 Hz, 16.4 Hz, 1H), 2.92 (t, *J* = 4.4 Hz, 1H), 3.10-3.13 (m, 1H), 3.21 (dd, *J* = 2.8 Hz, 14.4 Hz, 1H), 3.67-3.71 (m, 2H), 3.97 (d, *J* = 8.8 Hz, 1H), 4.92 (s, 2H), 6.91 (d, *J* = 8.0 Hz, 2H), 6.96 (d, *J* = 8.0 Hz, 2H), 7.22-7.30 (m, 3H), 7.39 (br, 2H). ^{13}C NMR ($CDCl_3$, TMS, 100 MHz) δ 21.4, 36.2, 37.7, 39.6, 44.8, 47.1, 48.7, 53.9, 67.5, 114.3, 125.8, 128.1, 128.3, 128.8, 135.0, 139.1, 142.0, 142.1, 207.4. IR (neat) 3063, 3029, 2979, 2946, 2921, 2874, 2845, 1712, 1652, 1597, 1496, 1447, 1401, 1330, 1234, 1183, 1153, 1109, 1093, 1063, 1026, 1015, 977, 945, 928, 901, 853, 813, 796, 753, 734, 695, 678, 665 cm^{-1}. HRMS (ESI) Calcd. for $C_{24}H_{29}N_2O_3S^{+1}(M+NH_4)^+$ requires: 425.1893, found: 425.1893.

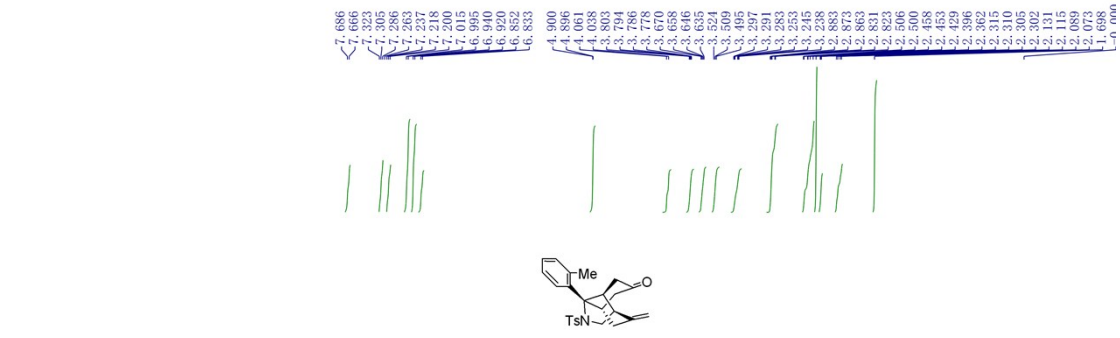


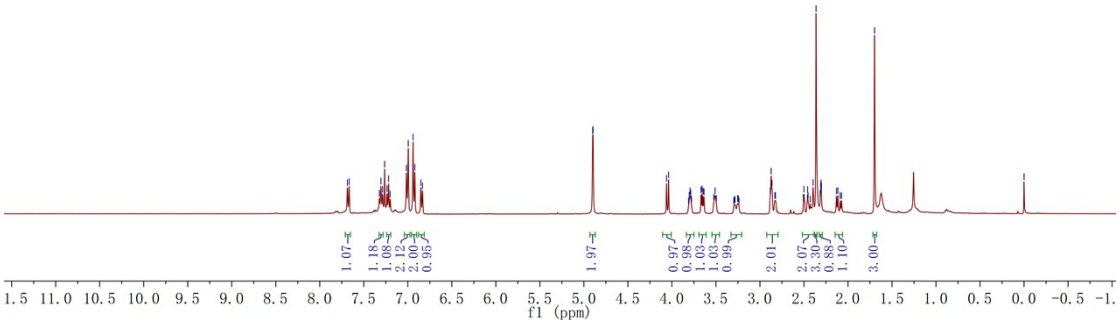


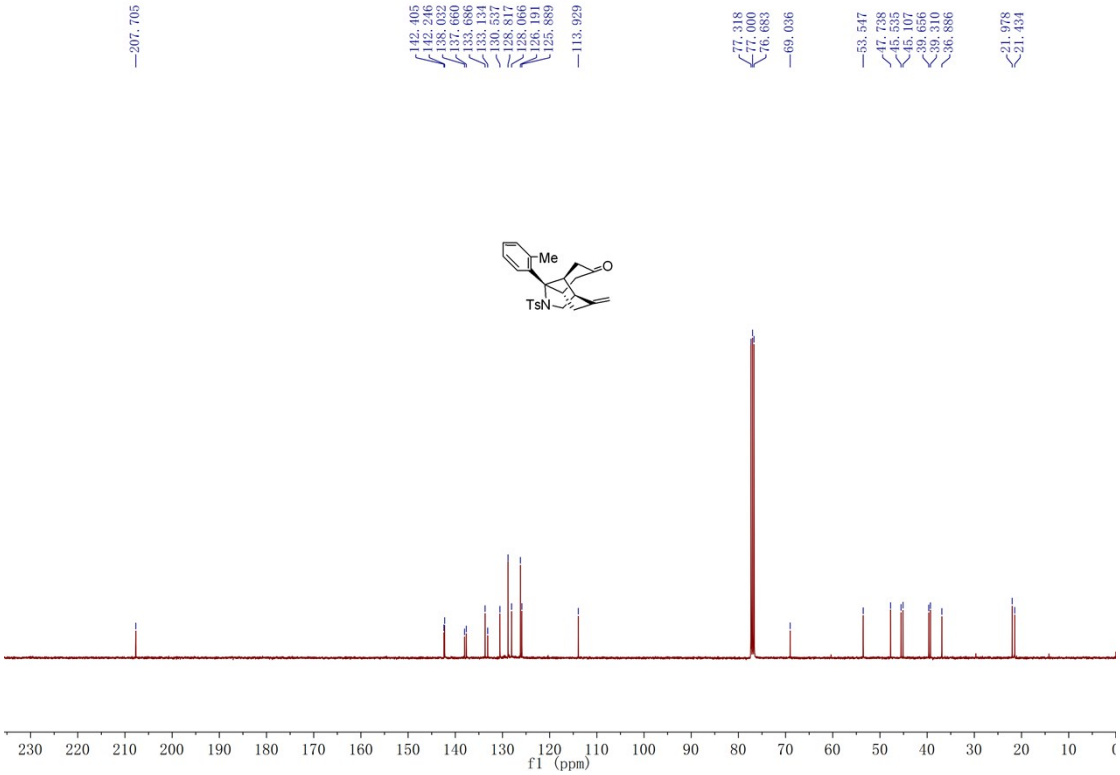


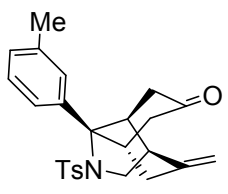
Compound 2i:

0.15 mmol scale, a light yellow solid, 41% yield (25.9 mg). M.p.: 210-212 ^{o}C. ^{1}H NMR ($CDCl_3$, TMS, 400 MHz) δ 1.70 (s, 3H), 2.10 (dd, *J* = 6.4 Hz, 17.2 Hz, 1H), 2.30-2.32 (m, 1H), 2.36 (s, 3H), 2.39-2.51 (m, 2H), 2.82-2.89 (m, 2H), 3.23-3.30 (m, 1H), 3.49-3.53 (m, 1H), 3.65 (dd, *J* = 4.4 Hz, 9.2 Hz, 1H), 3.77-3.82 (m, 1H), 4.05 (d, *J* = 9.2 Hz, 1H), 4.90 (d, *J* = 2.0 Hz, 2H), 6.84 (d, *J* = 7.6 Hz, 1H), 6.93 (d, *J* = 8.0 Hz, 2H), 7.01 (d, *J* = 8.0 Hz, 2H), 7.22 (dd, *J* = 7.6 Hz, 7.6 Hz, 1H), 7.31 (dd, *J* = 7.6 Hz, 7.6 Hz, 1H), 7.67 (d, *J* = 7.6 Hz, 1H). ^{13}C NMR ($CDCl_3$, TMS, 100 MHz) δ 21.4, 22.0, 36.9, 39.3, 39.7, 45.1, 45.5, 47.7, 53.5, 69.0, 113.9, 125.9, 126.2, 128.1, 128.8, 130.5, 133.1, 133.7, 137.7, 138.0, 142.2, 142.4, 207.7. IR (neat) 3057, 3026, 2989, 2950, 2922, 2866, 2845, 1715, 1597, 1483, 1453, 1401, 1375, 1330, 1305, 1266, 1230, 1211154, 1124, 1103, 1056, 1024, 1016, 975, 942, 904, 852, 813, 800, 783, 753, 733, 706, 673, 657 cm^{-1}. HRMS (ESI) Calcd. for $C_{25}H_{31}N_2O_3S^{+1}(M+NH_4)^+$ requires: 439.2050, found: 439.2050.



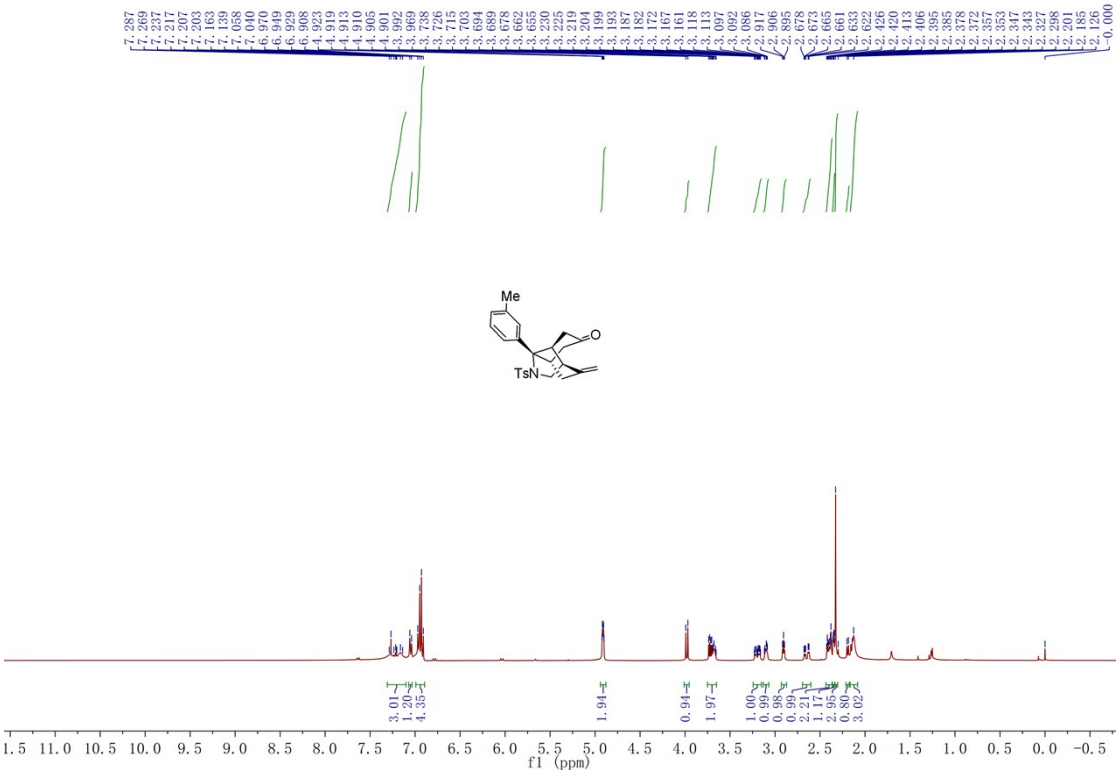


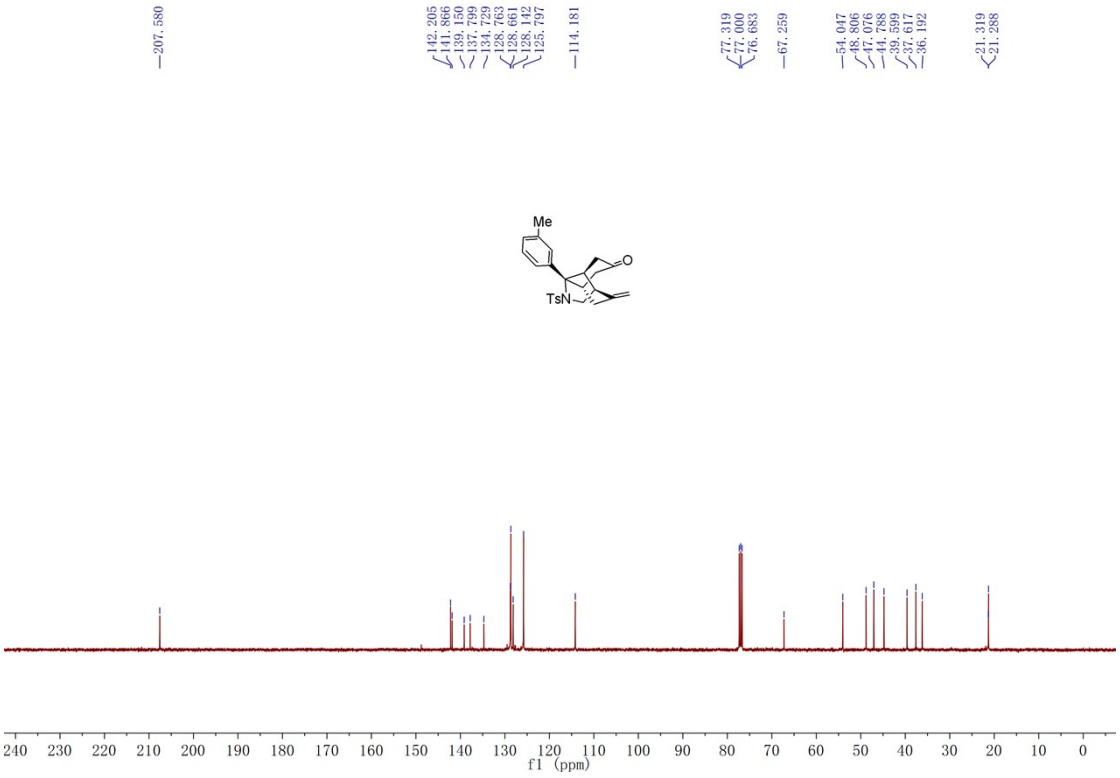


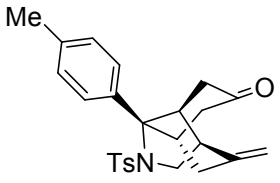


Compound 2j:

0.15 mmol scale, a light yellow solid, 49% yield (31.0 mg). M.p.: 250-253 °C. ^{1}H NMR ($CDCl_3$, TMS, 400 MHz) δ 2.13 (br, 3H), 2.19 (d, *J* = 6.4 Hz, 1H), 2.33 (s, 3H), 2.34-2.36 (m, 1H), 2.37-2.43 (m, 2H), 2.62-2.68 (m, 1H), 2.91 (t, *J* = 4.4 Hz, 1H), 3.08-3.12 (m, 1H), 3.16-3.23 (m, 1H), 3.65-3.70 (m, 1H), 3.72 (dd, *J* = 4.4 Hz, 9.2 Hz, 1H), 3.98 (d, *J* = 9.2 Hz, 1H), 4.90-4.93 (m, 2H), 6.90-6.97 (m, 4H), 7.05 (d, *J* = 7.2 Hz, 1H), 7.13-7.29 (m, 3H). ^{13}C NMR ($CDCl_3$, TMS, 100 MHz) δ 21.29, 21.32, 36.2, 37.6, 39.6, 44.8, 47.1, 48.8, 54.0, 67.3, 114.2, 125.8, 128.1, 128.7, 128.8, 134.7, 137.8, 139.2, 141.9, 142.2, 207.6. IR (neat) 3065, 3026, 2979, 2945, 2921, 2874, 1714, 1598, 1494, 1445, 1402, 1340, 1330, 1200, 1154, 1112, 1066, 1017, 979, 958, 929, 902, 854, 813, 779, 734, 706, 694, 677, 666 cm^{-1}. HRMS (ESI) Calcd. for $C_{25}H_{31}N_2O_3S^{+1}(M+NH_4)^+$ requires: 439.2050, found: 439.2047.

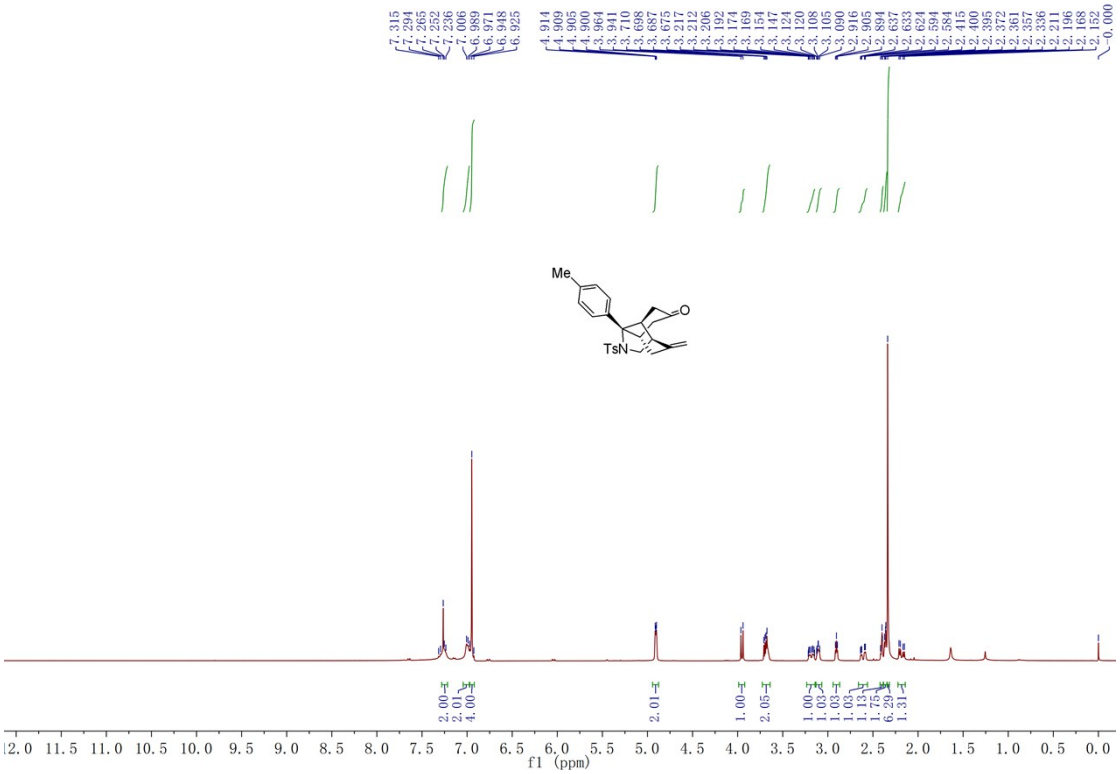


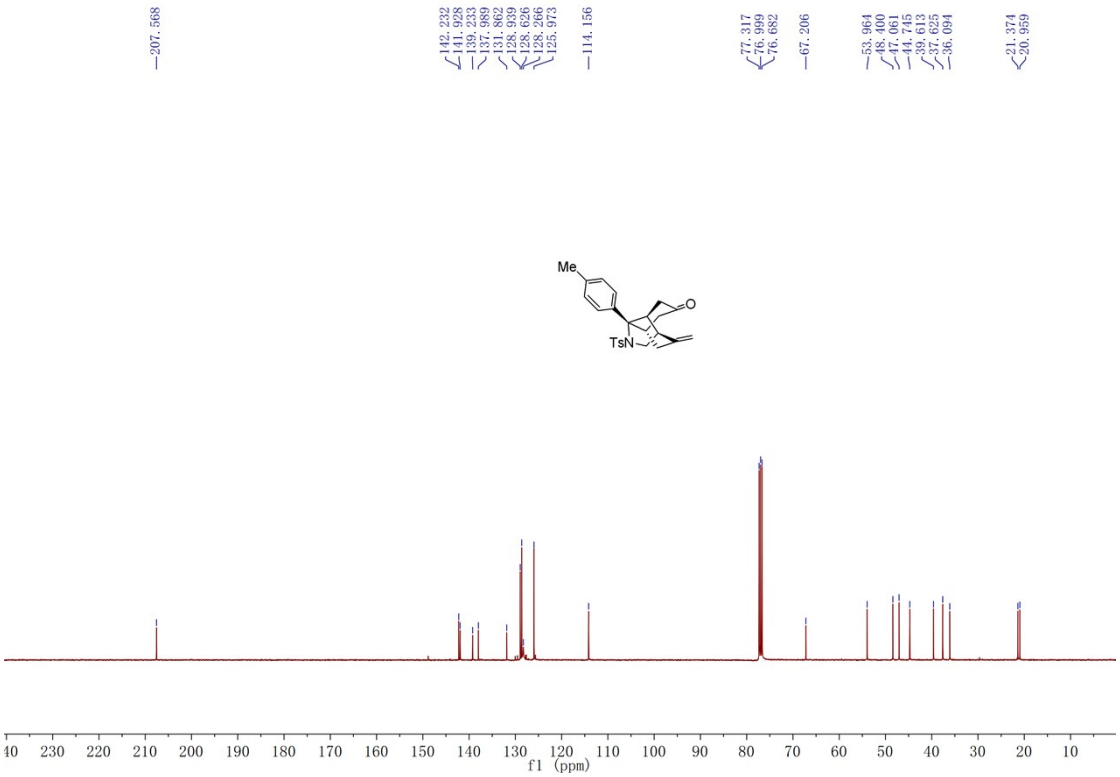


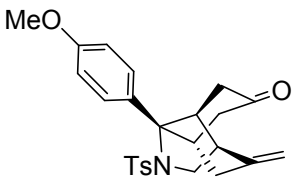


Compound 2k:

0.15 mmol scale, a white solid, 50% yield (31.6 mg). M.p.: 216-218 ^{o}C. ^{1}H NMR ($CDCl_3$, TMS, 400 MHz) δ 2.18 (dd, *J* = 6.4 Hz, 17.6 Hz, 1H), 2.34 (s, 6H), 2.35-2.38 (m, 2H), 2.39-2.42 (m, 1H), 2.58-2.64 (m, 1H), 2.91 (t, *J* = 4.4 Hz, 1H), 3.09-3.13 (m, 1H), 3.14-3.22 (m, 1H), 3.67-3.71 (m, 2H), 3.95 (d, *J* = 9.2 Hz, 1H), 4.90 (d, *J* = 2.0 Hz, 1H), 4.91 (d, *J* = 2.0 Hz, 1H), 6.92-6.98 (m, 4H), 7.00 (d, *J* = 6.8 Hz, 2H), 7.23-7.32 (m, 2H). ^{13}C NMR ($CDCl_3$, TMS, 100 MHz) δ 21.0, 21.4, 36.1, 37.6, 39.6, 44.7, 47.1, 48.4, 54.0, 67.2, 114.2, 126.0, 128.3 (br), 128.6, 128.9, 131.9, 138.0, 139.2, 141.9, 142.2, 207.6. IR (neat) 3065, 3026, 2979, 2944, 2921, 2874, 1712, 1597, 1515, 1494, 1445, 1405, 1328, 1234, 1183, 1154, 1110, 1092, 1065, 1016, 977, 946, 901, 881, 857, 811, 734, 705, 672 cm^{-1}. HRMS (ESI) Calcd. for $C_{25}H_{31}N_2O_3S^{+1}(M+NH_4)^+$ requires: 439.2050, found: 439.2051.

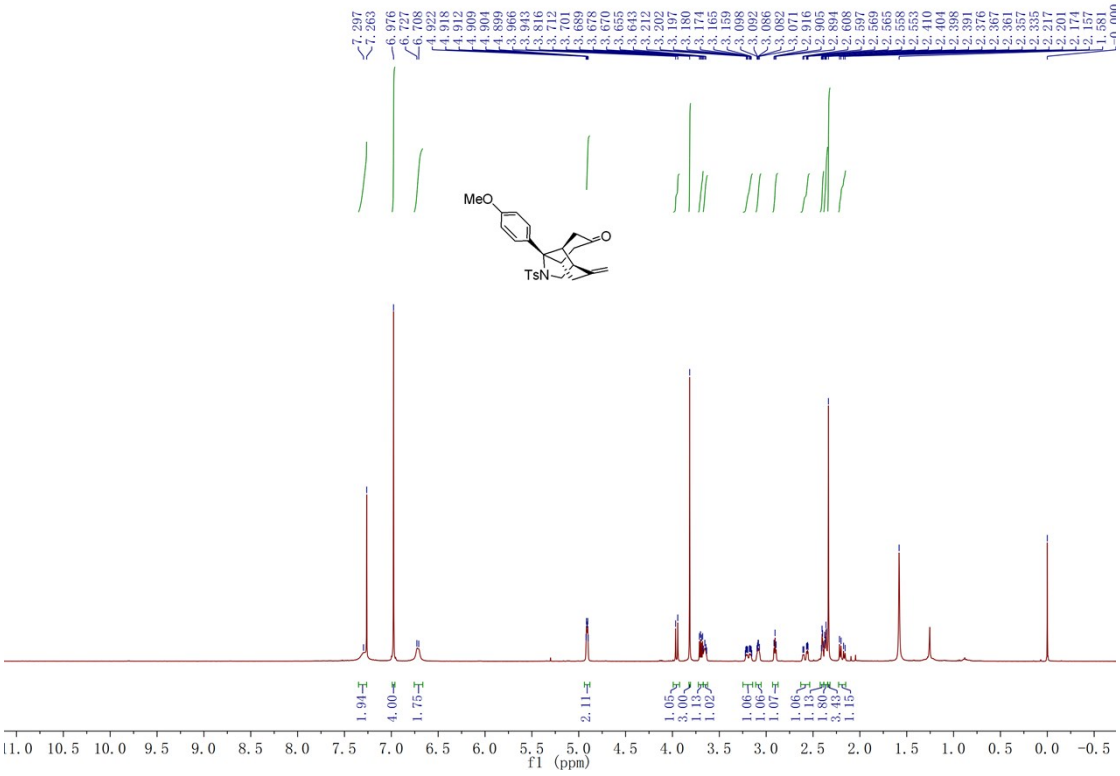


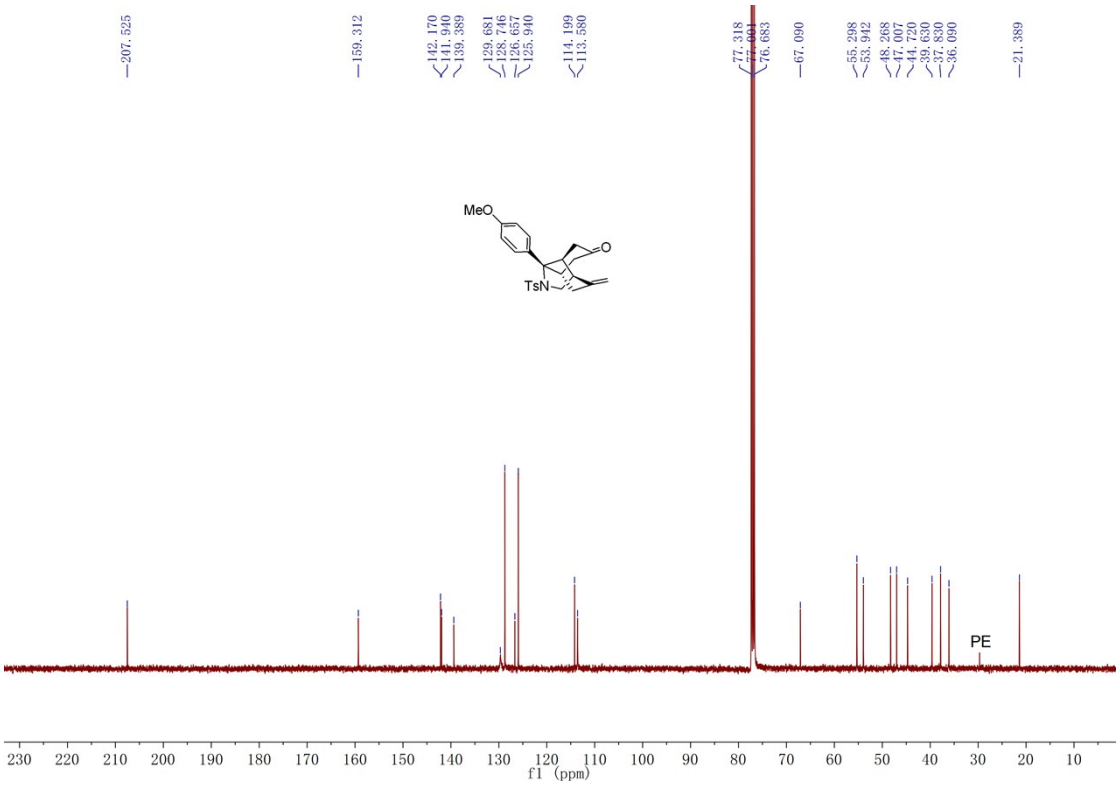


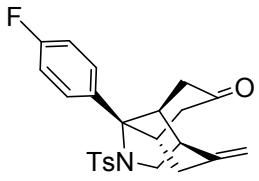


Compound 2l:

0.15 mmol scale, a white solid, 27% yield (17.7 mg). M.p.: 250-252 °C. ^{1}H NMR ($CDCl_3$, TMS, 400 MHz) δ 2.19 (dd, *J* = 6.4 Hz, 17.2 Hz, 1H), 2.34 (s, 3H), 2.35-2.38 (m, 2H), 2.39-2.41 (m, 1H), 2.55-2.61 (m, 1H), 2.91 (t, *J* = 4.4 Hz, 1H), 3.07-3.10 (m, 1H), 3.15-3.23 (m, 1H), 3.63-3.67 (m, 1H), 3.70 (dd, *J* = 4.4 Hz, 9.2 Hz, 1H), 3.82 (s, 3H), 3.95 (d, *J* = 9.2 Hz, 1H), 4.89-4.93 (m, 2H), 6.72 (d, *J* = 7.6 Hz, 2H), 7.00 (s, 4H), 7.30 (br, 2H). ^{13}C NMR ($CDCl_3$, TMS, 100 MHz) δ 21.4, 36.1, 37.8, 39.6, 44.7, 47.0, 48.3, 53.9, 55.3, 67.1, 113.6, 114.2, 125.9, 126.7, 128.7, 129.7 (br), 139.4, 141.9, 142.2, 159.3, 207.5. IR (neat) 3065, 3039, 2981, 2925, 2872, 2851, 1711, 1609, 1514, 1444, 1402, 1327, 1304, 1257, 1236, 1182, 1153, 1112, 1091, 1066, 1029, 1015, 977, 946, 909, 880, 858, 814, 801, 734, 705, 674 cm^{-1}. HRMS (ESI) Calcd. for $C_{25}H_{31}N_2O_4S^{+1}(M+NH_4)^+$ requires: 455.1999, found: 455.2002.

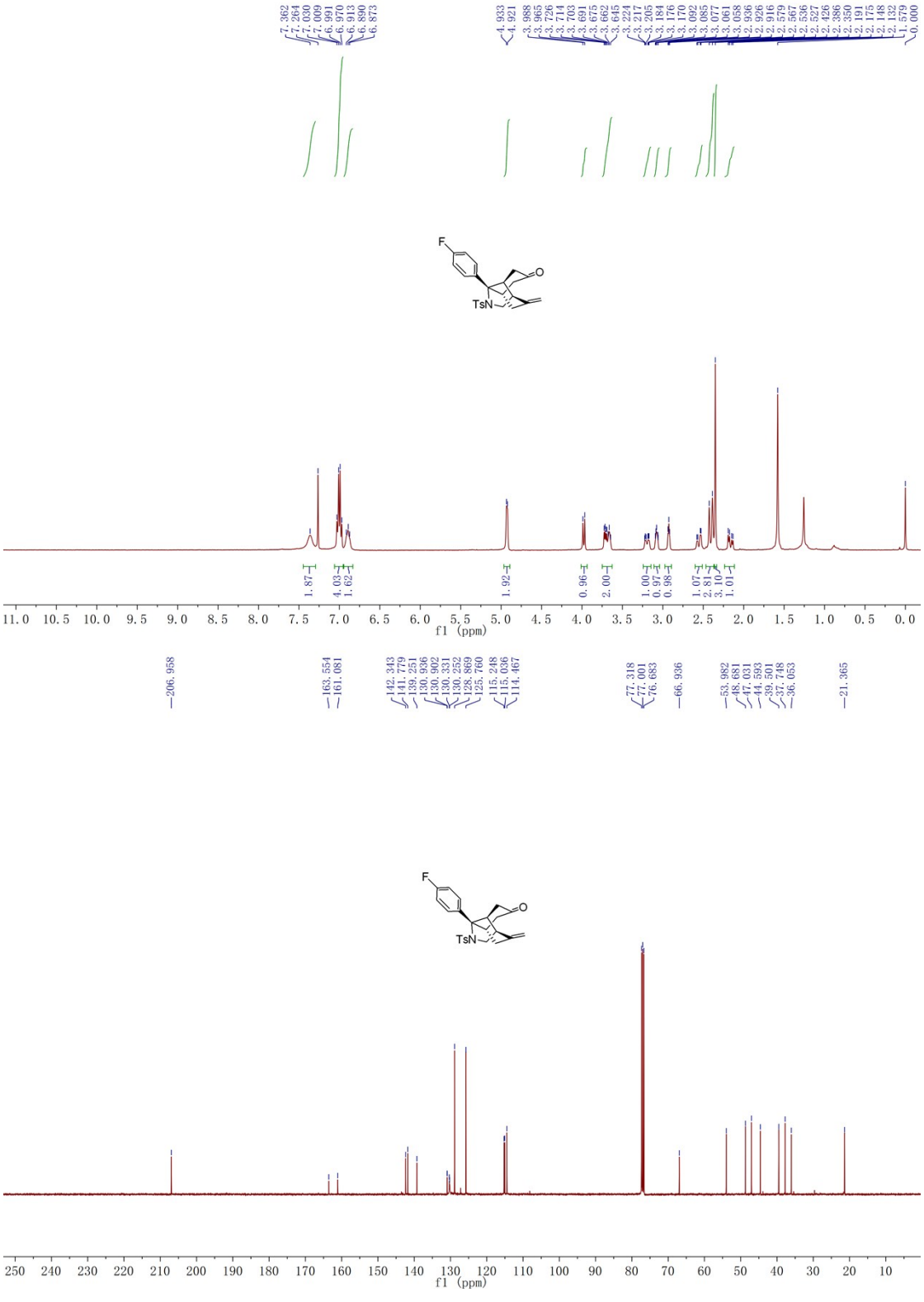


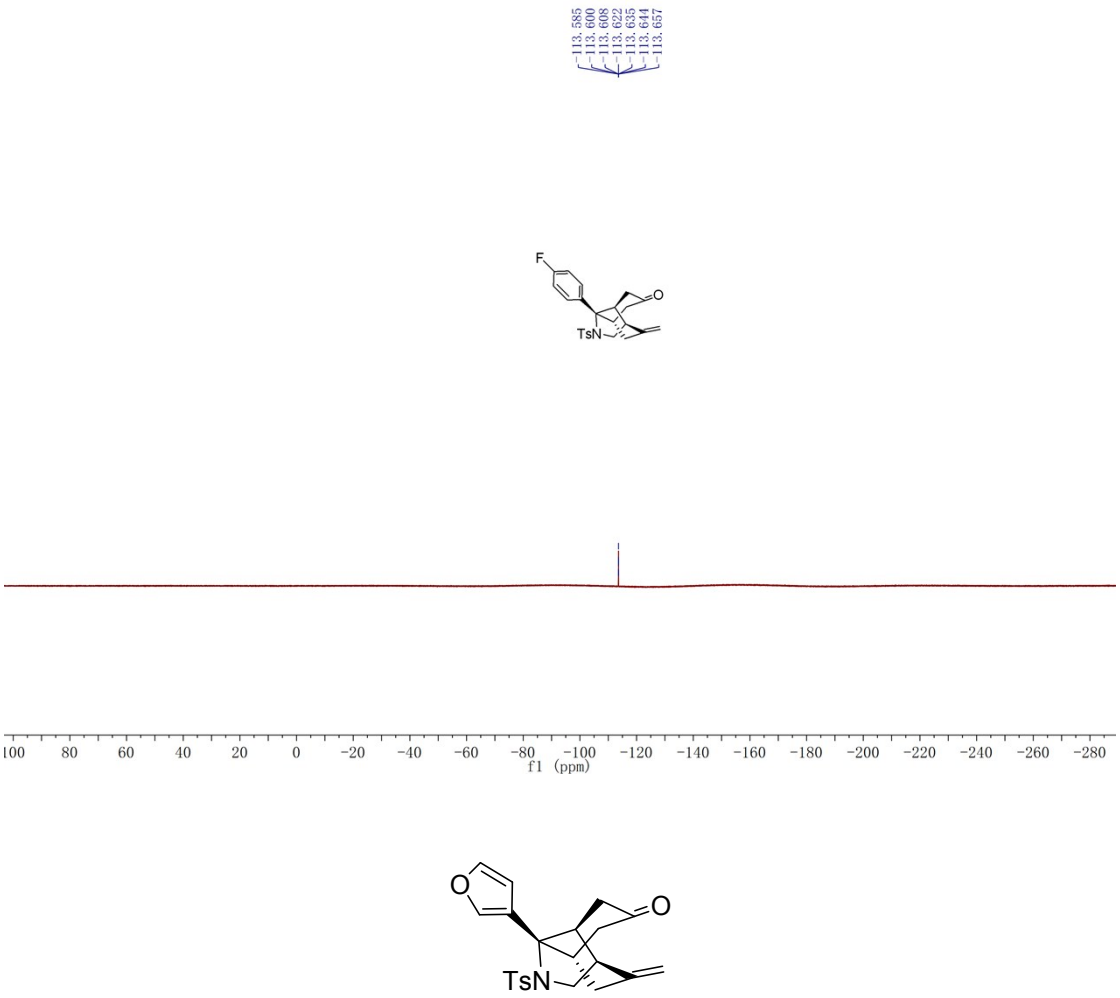




Compound 2m:

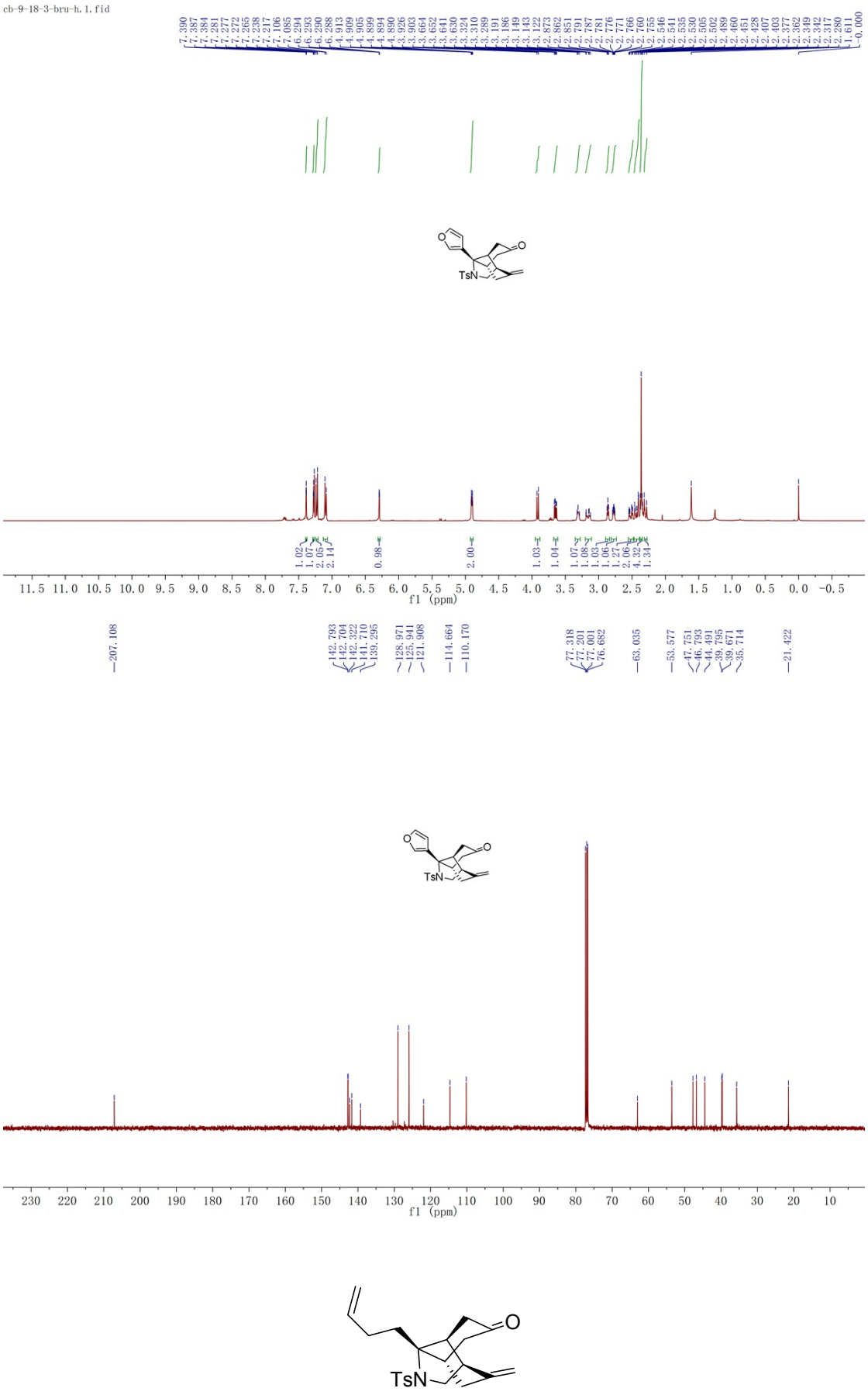
0.15 mmol scale, a light yellow solid, 39% yield (24.9 mg). M.p.: 203-205 °C. ^{1}H NMR ($CDCl_3$, TMS, 400 MHz) δ 2.16 (dd, *J* = 6.4 Hz, 17.2 Hz, 1H), 2.35 (s, 3H), 2.38-2.43 (m, 3H), 2.52-2.58 (m, 1H), 2.93 (t, *J* = 4.0 Hz, 1H), 3.05-3.10 (m, 1H), 3.17-3.23 (m, 1H), 3.64-3.73 (m, 2H), 3.98 (d, *J* = 9.2 Hz, 1H), 4.93 (d, *J* = 4.8 Hz, 2H), 6.87-6.92 (m, 2H), 6.98 (d, *J* = 8.4 Hz, 2H), 7.02 (d, *J* = 8.4 Hz, 2H), 7.36 (br, 2H). ^{13}C NMR ($CDCl_3$, TMS, 100 MHz) δ 21.4, 36.1, 37.7, 39.5, 44.6, 47.0, 48.7, 54.0, 66.9, 114.5, 115.1 (d, *J* = 21.2 Hz), 125.8, 128.9, 130.3 (d, *J* = 7.9 Hz), 130.9 (d, *J* = 3.4 Hz), 139.3, 141.8, 142.3, 162.3 (d, *J* = 247.3 Hz), 207.0. ^{19}F NMR ($CDCl_3$, $CFCl_3$, 376 MHz) δ -113.66--113.59 (m). IR (neat) 3052, 2953, 2927, 2887, 2848, 1716, 1601, 1511, 1495, 1482, 1445, 1409, 1377, 1339, 1317, 1305, 1263, 1234, 1209, 1183, 1163, 1149, 1112, 1091, 1064, 1030, 1015, 1006, 981, 947, 905, 881, 860, 809, 736, 720, 705, 677 cm^{-1}. HRMS (ESI) Calcd. for $C_{24}H_{25}NO_3SF^{+1}(M+NH_4)^+$ requires: 426.1534, found: 426.1533.


7.362
7.264
7.030
7.009
6.991
6.970
6.913
6.890
6.873
4.933
4.921
3.988
3.965
3.726
3.714
3.703
3.691
3.675
3.662
3.645
3.224
3.217
3.205
3.184
3.176
3.170
3.092
3.085
3.077
3.061
3.058
2.936
2.926
2.916
2.579
2.567
2.536
2.527
2.426
2.386
2.350
2.191
2.175
2.148
2.132
1.579
0.000
F
O
TsN
1.87
4.03
1.62
1.92
0.96
2.00
1.00
0.97
0.98
1.07
2.81
3.10
1.01
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)
206.958
163.554
161.081
142.343
141.779
139.251
130.936
130.902
130.331
130.252
128.869
125.760
115.248
115.036
114.467
77.318
77.001
76.683
66.936
53.982
48.681
47.031
44.593
39.501
37.748
36.053
21.365
F
O
TsN
250 240 230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)



Compound 2n:

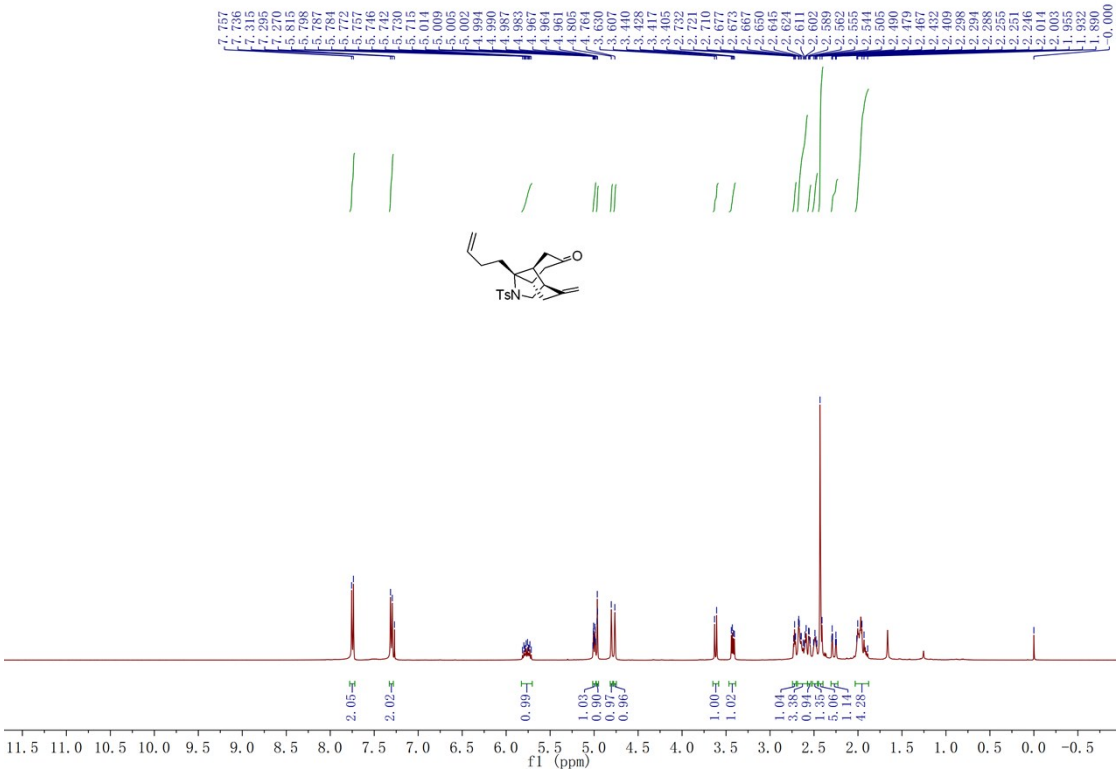
0.15 mmol scale, a yellow solid, 31% yield (18.5 mg). M.p.: 150-152 ^{o}C. ^{1}H NMR ($CDCl_3$, TMS, 400 MHz) δ 2.28-2.32 (m, 1H), 2.34-2.38 (m, 4H), 2.40-2.46 (m, 2H), 2.48-2.55 (m, 1H), 2.75-2.80 (m, 1H), 2.86 (t, *J* = 4.4 Hz, 1H), 3.12-3.20 (m, 1H), 3.28-3.33 (m, 1H), 3.65 (dd, *J* = 4.4 Hz, 9.2 Hz, 1H), 3.91 (d, *J* = 9.2 Hz, 1H), 4.89-4.92 (m, 2H), 6.29 (dd, *J* = 1.2 Hz, 2.0 Hz, 1H), 7.10 (d, *J* = 8.4 Hz, 2H), 7.23 (d, *J* = 8.4 Hz, 2H), 7.28 (dd, *J* = 2.0 Hz, 2.0 Hz, 1H), 7.39 (dd, *J* = 1.2 Hz, 1.2 Hz, 1H). ^{13}C NMR ($CDCl_3$, TMS, 100 MHz) δ 21.4, 35.7, 39.7, 39.8, 44.5, 46.8, 47.8, 53.6, 63.0, 110.2, 114.7, 121.9, 125.9, 129.0, 139.3, 141.7, 142.3, 142.7, 142.8, 207.1. IR (neat) 3141, 3068, 2981, 2945, 2924, 2877, 2851, 1712, 1597, 1505, 1445, 1402, 1328, 1288, 1190, 1154, 1122, 1094, 1067, 1031, 1015, 991, 969, 906, 874, 866, 813, 795, 734, 706, 672 cm^{-1}. HRMS (ESI) Calcd. for $C_{22}H_{24}NO_4S^{+1}(M+H)^+$ requires: 398.1421, found: 398.1420.

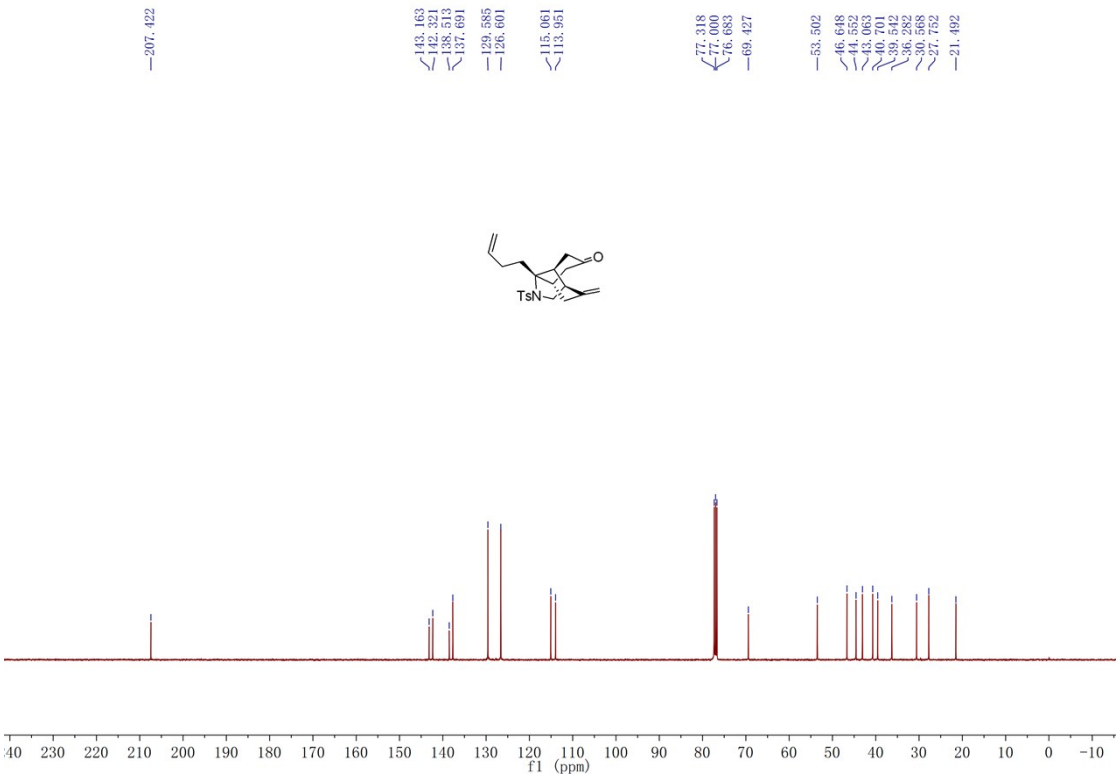


Compound 2o:

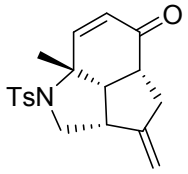
0.15 mmol scale, a light yellow solid, 53%

yield (30.5 mg). M.p.: 150-152 °C. ^{1}H NMR ($CDCl_3$, TMS, 400 MHz) δ 1.89-2.02 (m, 4H), 2.24-2.30 (m, 1H), 2.40-2.44 (m, 5H), 2.47-2.51 (m, 1H), 2.54-2.57 (m, 1H), 2.58-2.68 (m, 3H), 2.72 (d, *J* = 4.4 Hz, 1H), 3.42 (dd, *J* = 4.4 Hz, 9.2 Hz, 1H), 3.62 (d, *J* = 9.2 Hz, 1H), 4.76 (s, 1H), 4.81 (s, 1H), 4.96-4.97 (m, 1H), 4.98-5.02 (m, 1H), 5.71-5.82 (m, 1H), 7.31 (d, *J* = 8.0 Hz, 2H), 7.75 (d, *J* = 8.0 Hz, 2H). ^{13}C NMR ($CDCl_3$, TMS, 100 MHz) δ 21.5, 27.8, 30.6, 36.3, 39.5, 40.7, 43.1, 44.6, 46.6, 53.5, 69.4, 114.0, 115.1, 126.6, 129.6, 137.7, 138.5, 142.3, 143.2, 207.4. IR (neat) 3073, 3026, 2976, 2938, 2877, 2848, 1712, 1640, 1597, 1493, 1449, 1404, 1321, 1303, 1196, 1154, 1095, 1071, 997, 982, 904, 815, 795, 735, 709, 668 cm^{-1}. HRMS (ESI) Calcd. for $C_{22}H_{28}NO_3S^{+1}(M+H)^+$ requires: 386.1784, found: 386.1784.



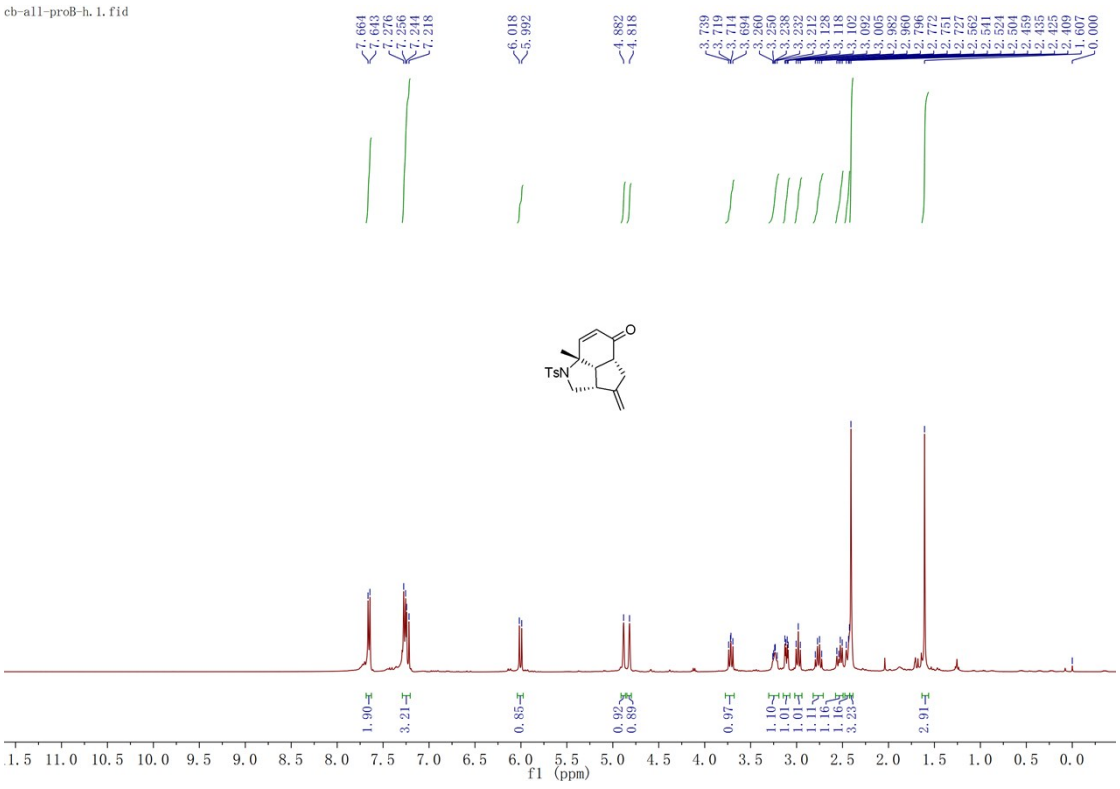

207.422
143.163
142.321
138.513
137.691
129.585
126.601
115.061
113.951
77.318
77.000
76.683
69.427
53.502
46.648
44.552
43.063
40.701
39.542
36.282
30.568
27.752
21.492
O
TsN
f1 (ppm)

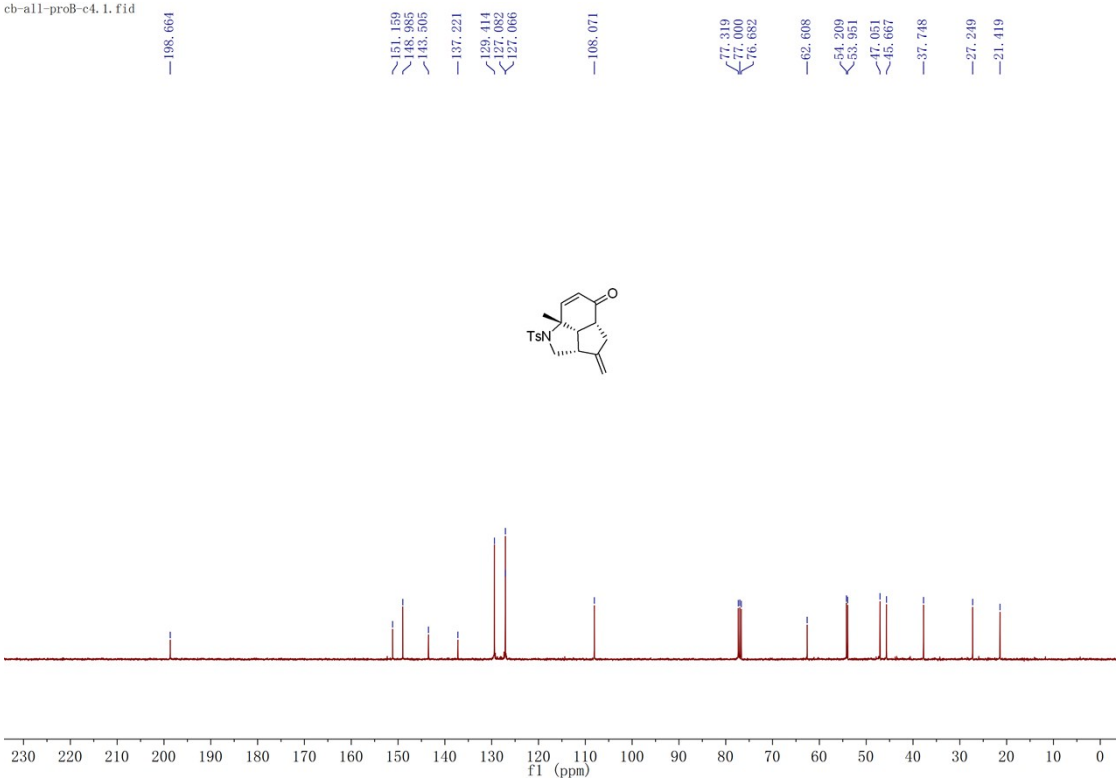
7. Characterization and spectra charts for 3a.

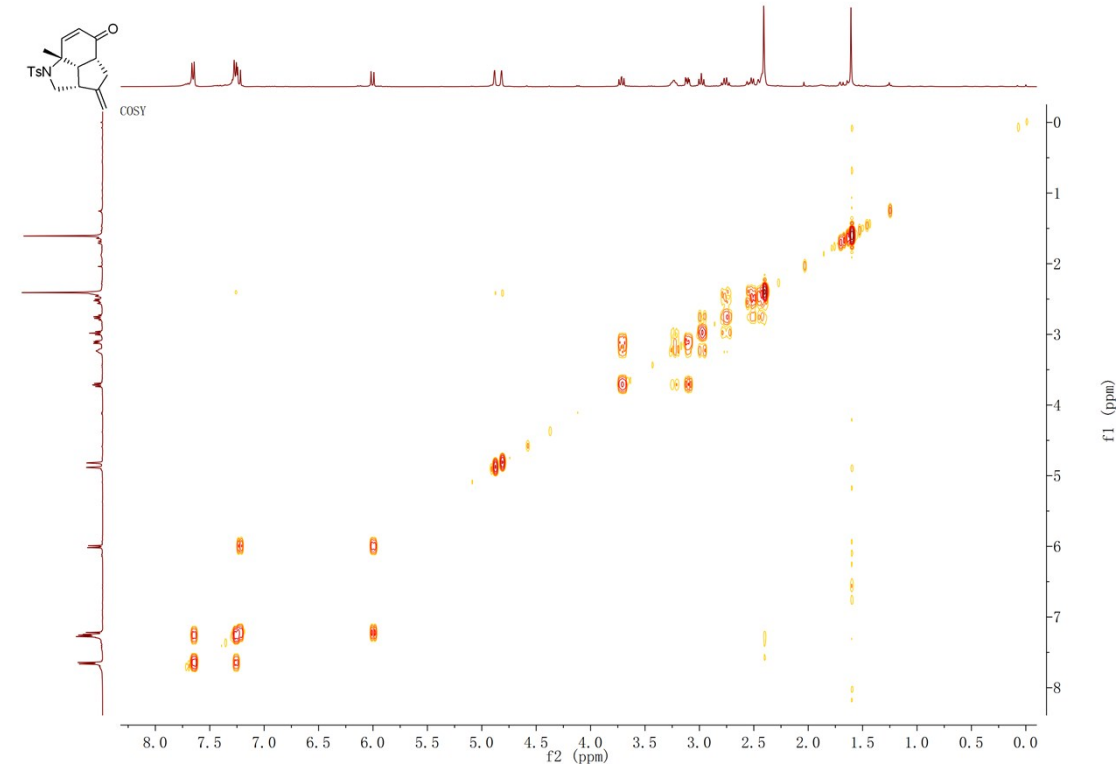


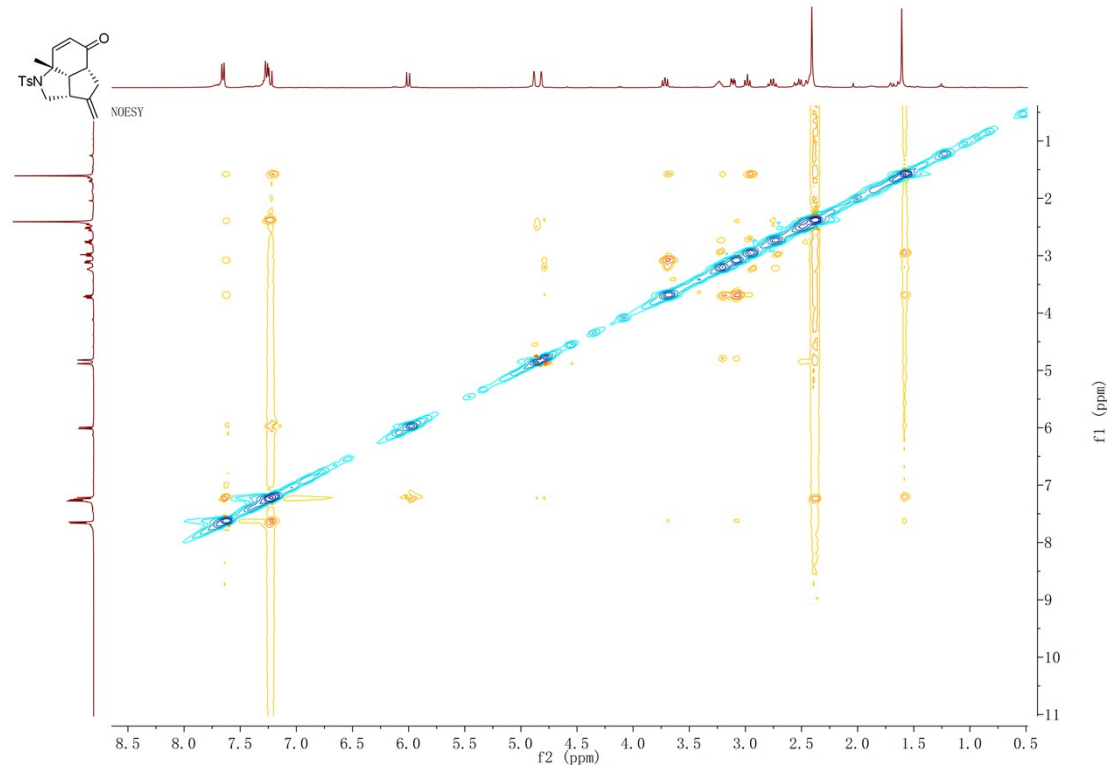
Compound 3a:

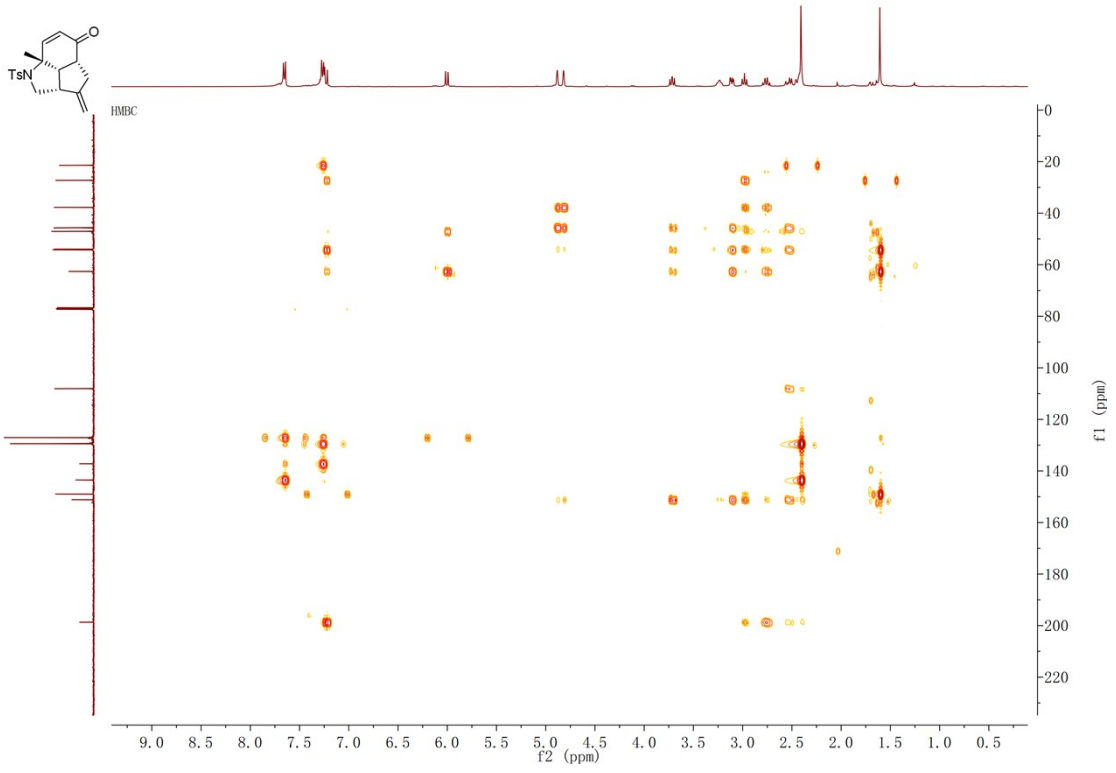
0.15 mmol scale, a light yellow solid, 10% yield (5.2 g). M.p.: 46-49 °C. ^{1}H NMR ($CDCl_3$, TMS, 400 MHz) δ 1.61 (s, 3H), 2.40-2.46 (m, 4H), 2.50-2.57 (m, 1H), 2.76 (dd, *J* = 9.6 Hz, 18.0 Hz, 1H), 2.98 (t, *J* = 9.2 Hz, 1H), 3.11 (dd, *J* = 4.0 Hz, 10.4 Hz, 1H), 3.21-3.26 (m, 1H), 3.72 (dd, *J* = 8.0 Hz, 10.0 Hz, 1H), 4.82 (s, 1H), 4.88 (s, 1H), 6.01 (d, *J* = 10.4 Hz, 1H), 7.23 (d, *J* = 10.4 Hz, 1H), 7.27 (d, *J* = 8.0 Hz, 2H), 7.65 (d, *J* = 8.0 Hz, 2H). ^{13}C NMR ($CDCl_3$, TMS, 100 MHz) δ 21.4, 27.2, 37.7, 45.7, 47.1, 54.0, 54.2, 62.6, 108.1, 127.07, 127.08, 129.4, 137.2, 143.5, 149.0, 151.2, 198.7. IR (neat) 3068, 3042, 2966, 2924, 2869, 1673, 1597, 1494, 1447, 1393, 1375, 1335, 1303, 1198, 1153, 1090, 1035, 988, 953, 895, 814, 734, 707, 673 cm^{-1}. HRMS (ESI) Calcd. for $C_{19}H_{25}N_2O_3S^{+1}(M+NH_4)^+$ requires: 361.1580, found: 361.1574.



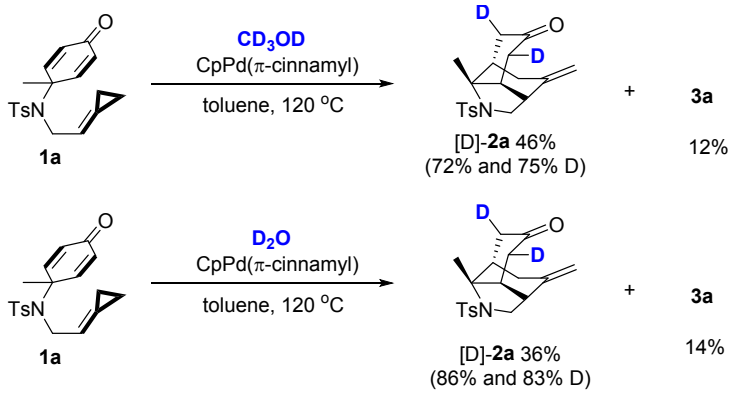

cb-all-proB-c4.1.fid
198.664
151.159
148.985
143.505
137.221
129.414
127.082
127.066
108.071
77.319
77.000
76.682
62.608
54.209
53.951
47.051
45.667
37.748
27.249
21.419
TsN
O
f1 (ppm)


TsN
O
COSY
f2 (ppm)
f1 (ppm)

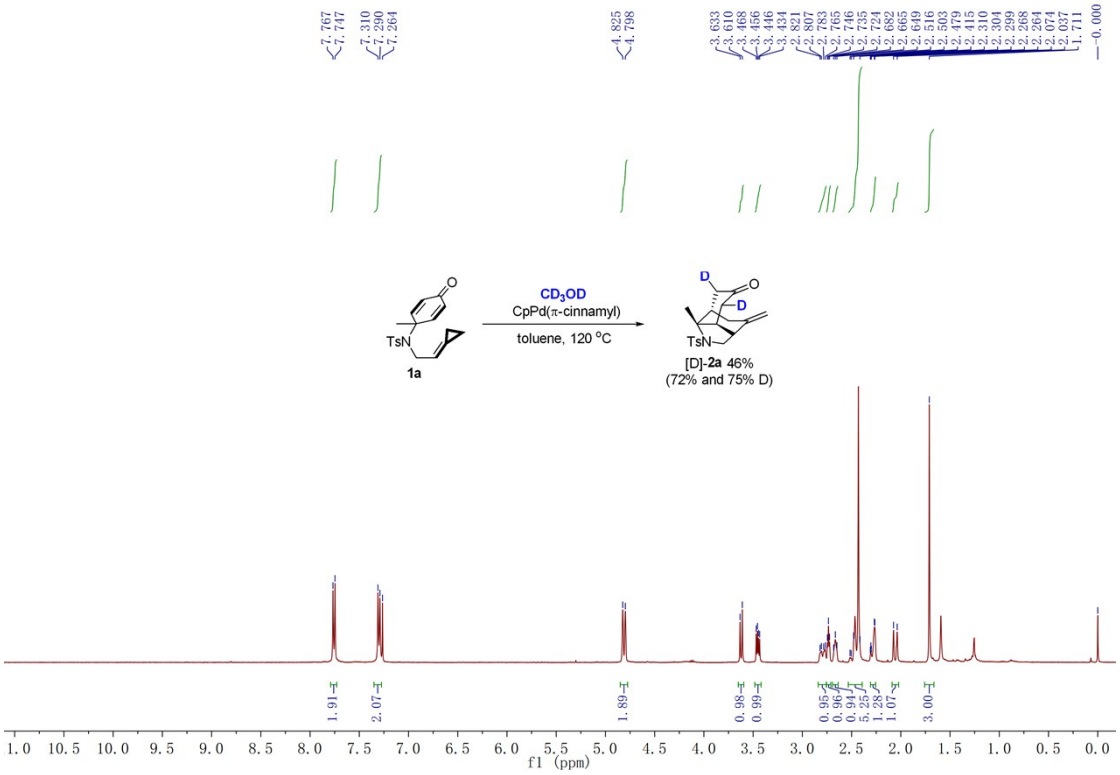

TsN
O
NOESY
f2 (ppm)
f1 (ppm)

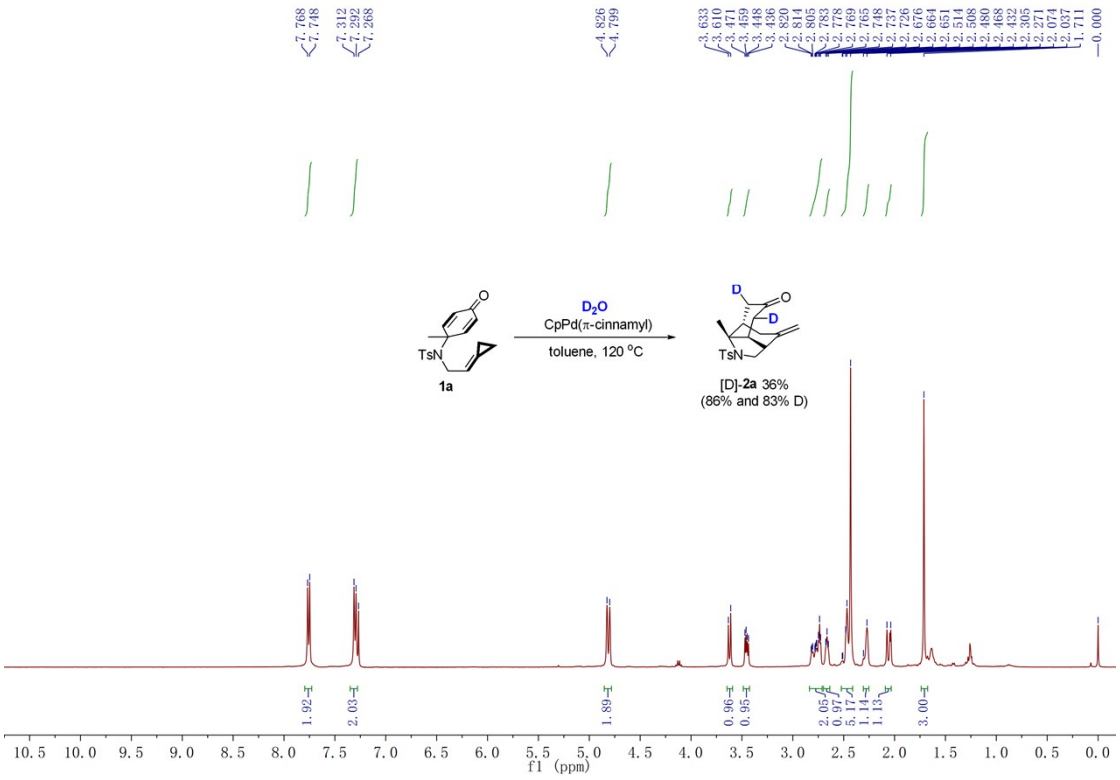

TsN
O
HMBC
f2 (ppm)
f1 (ppm)

8. General procedure for synthesis of [D]-2a and its spectra chart.



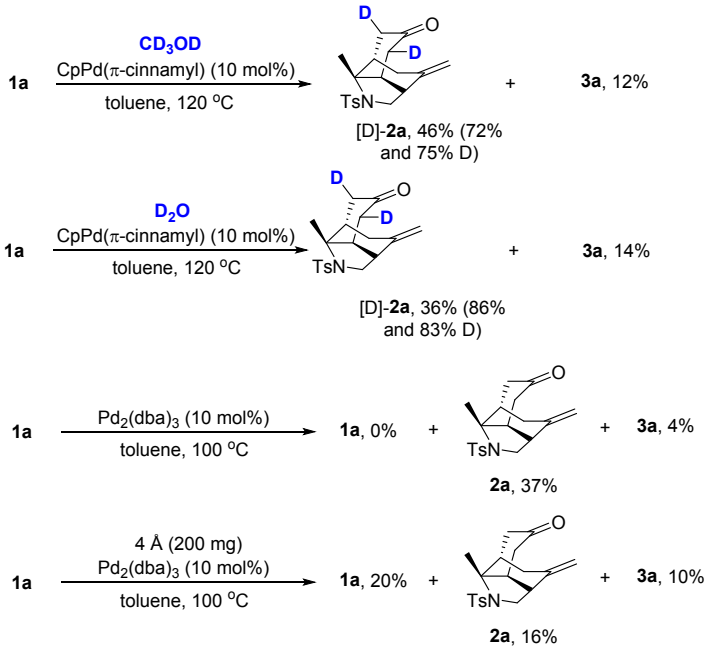
A solution of **1a** (0.15 mmol, 1.0 equiv), CpPd (π-cinnamyl) (0.015 mmol, 10 mol%) and CD_3OD (0.60 mmol, 4.0 equiv), or D_2O in toluene (0.20 mL) was stirred at 120 °C under argon atmosphere for 12 hours. After the reaction completed, the mixture was concentrated in vacuo to yield the crude product, which was purified by a flash chromatography on silica gel (eluent: PE/EtOAc = 10/1 ~ 8/1) to furnish the desired product [D]-**2a**.




7.768
7.748
7.312
7.292
7.268
4.826
4.799
3.633
3.610
3.471
3.459
3.448
3.436
2.820
2.814
2.805
2.783
2.778
2.769
2.765
2.748
2.737
2.726
2.676
2.664
2.651
2.514
2.508
2.480
2.468
2.432
2.305
2.271
2.074
2.037
1.711
0.000
D2O
CpPd(π-cinnamyl)
toluene, 120 °C
TsN
1a
D
D
TsN
[D]-2a 36%
(86% and 83% D)
1.92
2.03
1.89
0.96
0.95
2.05
0.97
5.17
1.14
1.13
3.00
f1 (ppm)

9. Control experiment

Scheme SI-1. Control experiments

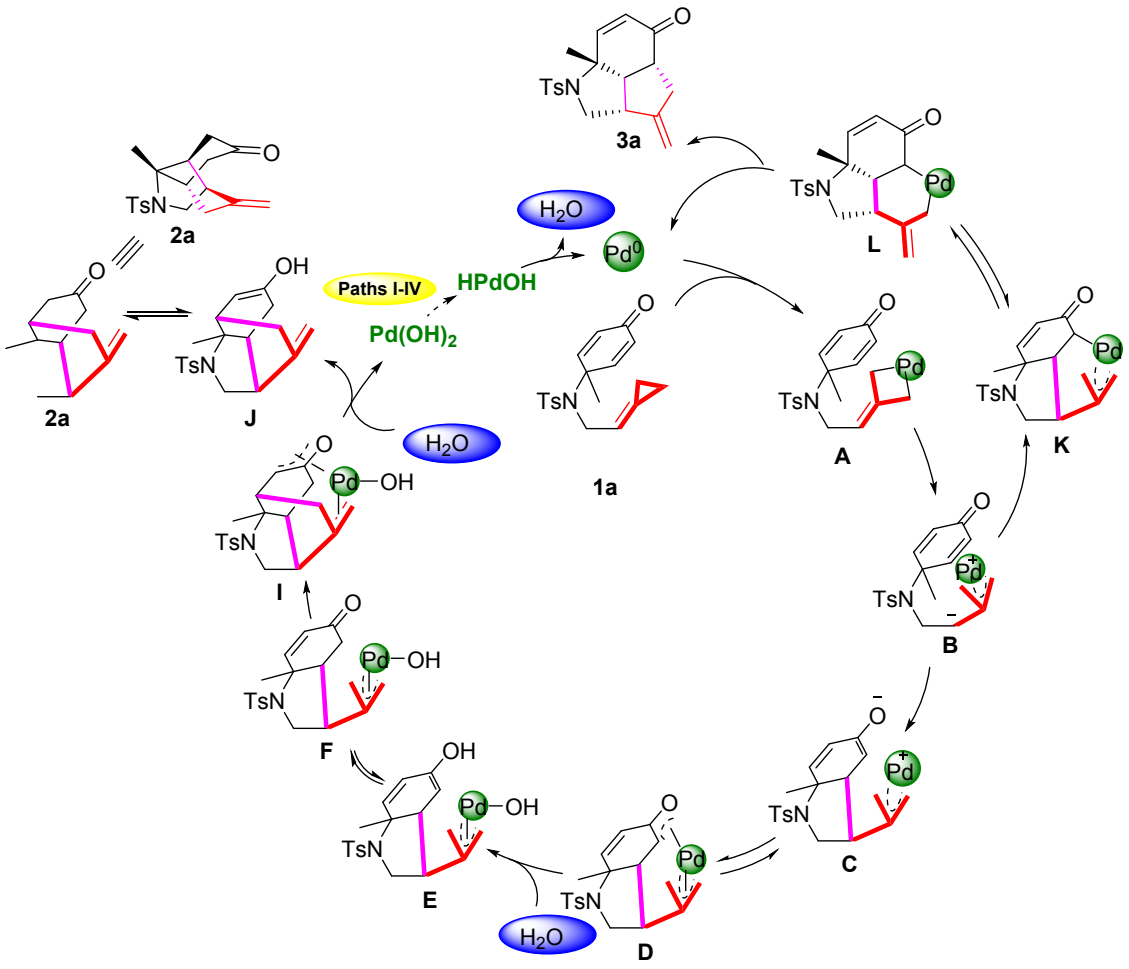


In order to further investigate the reaction mechanism, the deuterium-labeling experiment was conducted. The reaction of **1a** was performed in standard conditions with addition of the deuterated methanol and D_2O, respectively. The use of CD_3OD as a hydrogen source afforded the product [D]-**2a** in 46% yield with 72% and 75% D content on the cyclohexenone ring (Scheme SI-1). On the other hand, the addition of D_2O in the system also provided [D]-**2a** in 36% yield with 86% and 83% D content (Scheme SI-1). In the case of employing water, the water played as a proton source, and the substrate or ligand probably served as a reductant.

When the reaction was conducted with $Pd_2(dba)_3$ as catalyst, toluene as solvent at 120 °C for 12 hours, **1a** was fully converted, and 37% of **2a** and 4% **3a** was obtained. However, when 4Å molecular sieves were added in the system to decrease the content of H_2O, the 20% of **1a** was remained under the standard conditions, and the yield of **2a** was decreased to 16%. This result demonstrates that trace amount of ambient water affected the yield of **2a** dramatically. If the yield of **2a** was obtained in 40%, the H_2O requirement was only 0.06 mmol. It is very difficult to avoid such a trace amount of water under standard conditions since substrate, solvents or catalyst may contain trace amount of water.

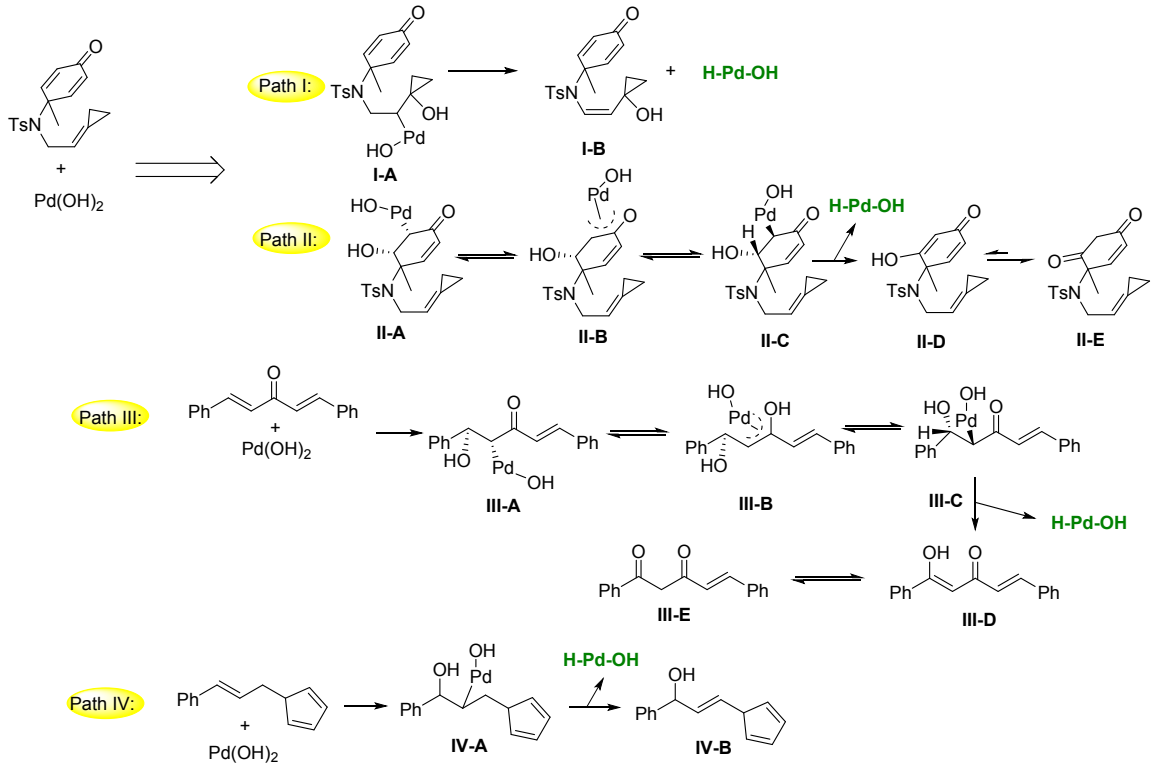
10. Proposed mechanism

Scheme SI-2. Proposed mechanism for the reaction in the absence of alcohol.



Proposed mechanism for the reaction in the absence of alcohol is shown in **Scheme SI-2**. Instead of alcohol, H_2O plays a proton source to promote the generation of intermediate **F** from an intermediate **D**, and also promote to give an intermediate **J** by protonolysis. These steps can be supported by our deuterium-labeling experiments and the related references ((a) *J. Am. Chem. Soc.*, 2016, **138**, 6107-6110; (b) *Org. Lett.*, 2016, **18**, 4250-4253; (c) *Org. Lett.*, 2007, **9**, 2195-2198). Without alcohol, substrate **1**, or ligands (dba, or Cp–cinnamyl moiety) in the reaction system probably played as a reductant. We proposed four possible pathways **Paths I-IV** for the regeneration of Pd(0) species which are illustrated in the **Scheme SI-3**.

Scheme SI-3. Proposed mechanism for the generation of H-Pd-OH



From the previous reports,[3] we think the process can be explained by above four pathways:

Path I: One possible pathway is that the Pd(II) species undergoes a migratory insertion to generate intermediate **I-A**. Then the H-Pd-OH is produced through a β-hydride elimination.

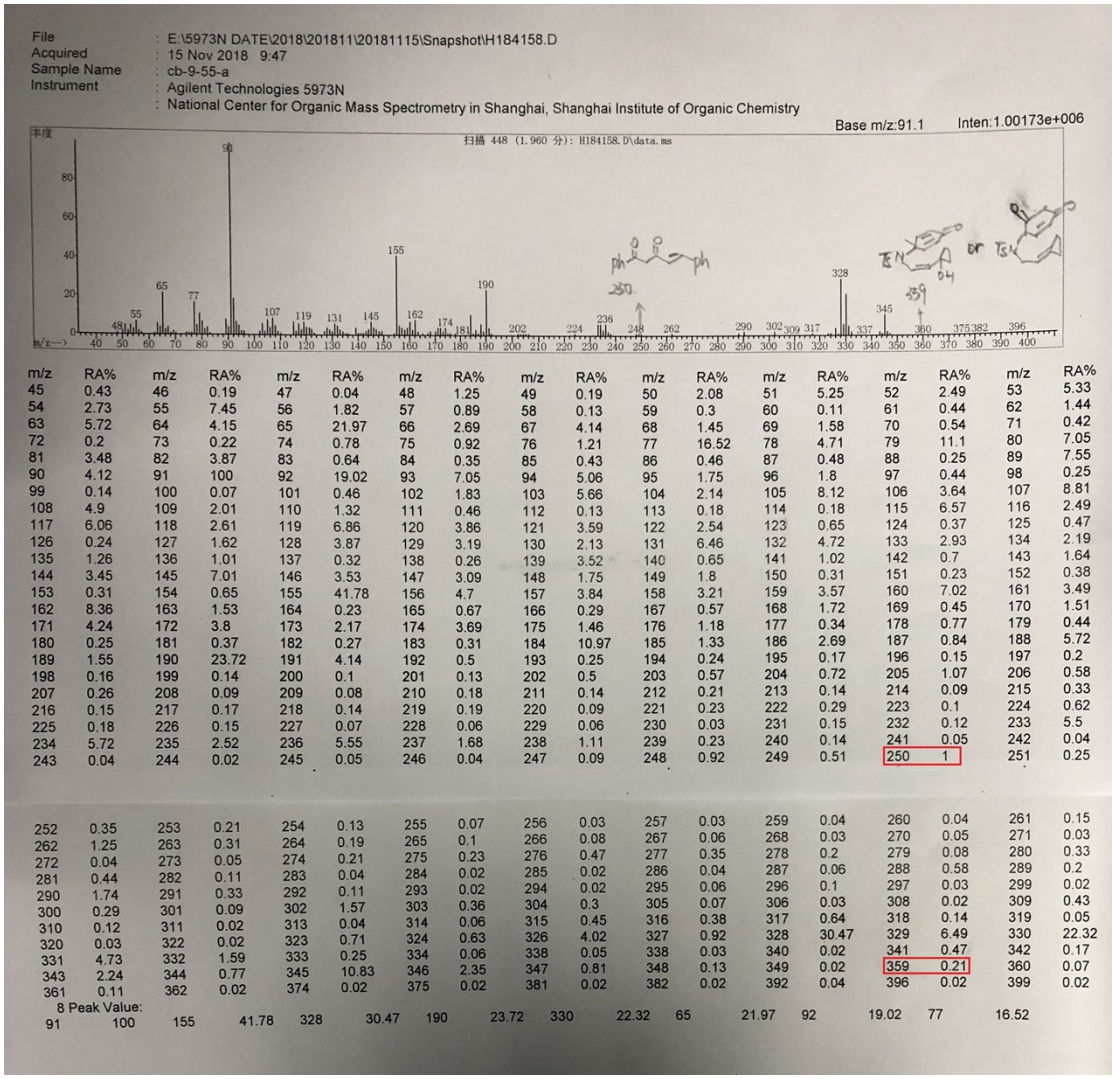
Path II: According to the previous literature,[4] the α,β-unsaturated ketone can react with H_2O and can be transformed into diketones, when Pd(II) species was used as the catalyst. We propose that the Pd(II) species can undergo a migratory insertion into the double bond of *p*-quinamine moiety of substrate **1**, and following a β-hydride elimination; the intermediate **II-D** is subsequently generated, which can be transformed into diketones through keto-enol tautomerization. From this process, the H-Pd-OH can be also obtained. Finally, HO-Pd-H can undergo reductive elimination to regenerate the Pd(0) species and subsequently re-engage in the catalytic cycle.

Path III and ***Path IV***: In the presence of the ligands such as dba, or Cp–cinnamyl moiety, Pd(II) species can also undergo the similar process to generate H-Pd-OH species, which can further undergo reductive elimination to regenerate the Pd(0) species and subsequently re-engage in the catalytic cycle.

We also tried to find some MS evidences to support our proposed mechanism illustrated in **Scheme SI-3**. After the reaction was completed and the solvent was removed by rotary evaporation,

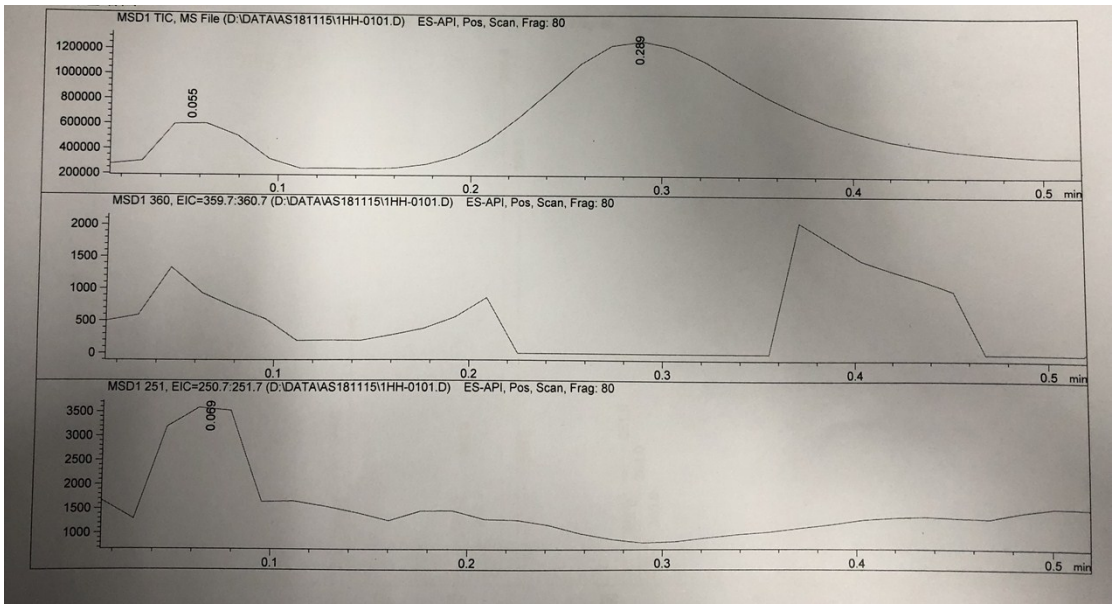
the crude reaction mixture was detected by EI and ESI. The EI-Mass spectrum is shown in **Figure SI-1**, and the ESI-Mass spectrum is shown in **Figure SI-2**. We found the peaks of 250 (belong to **III-E**) and 359 (belong to **I-B** or **II-E**) in EI-Mass spectrum shown in **Figure SI-1**; we also found the peaks of 251 (belong to **III-E**) and 360 (belong to **I-B** or **II-E**) in ESI-Mass spectrum shown in **Figure SI-2**, although the peak value is very low. These Mass spectra provide some evidences for our proposed mechanisms shown in **Scheme SI-3**.

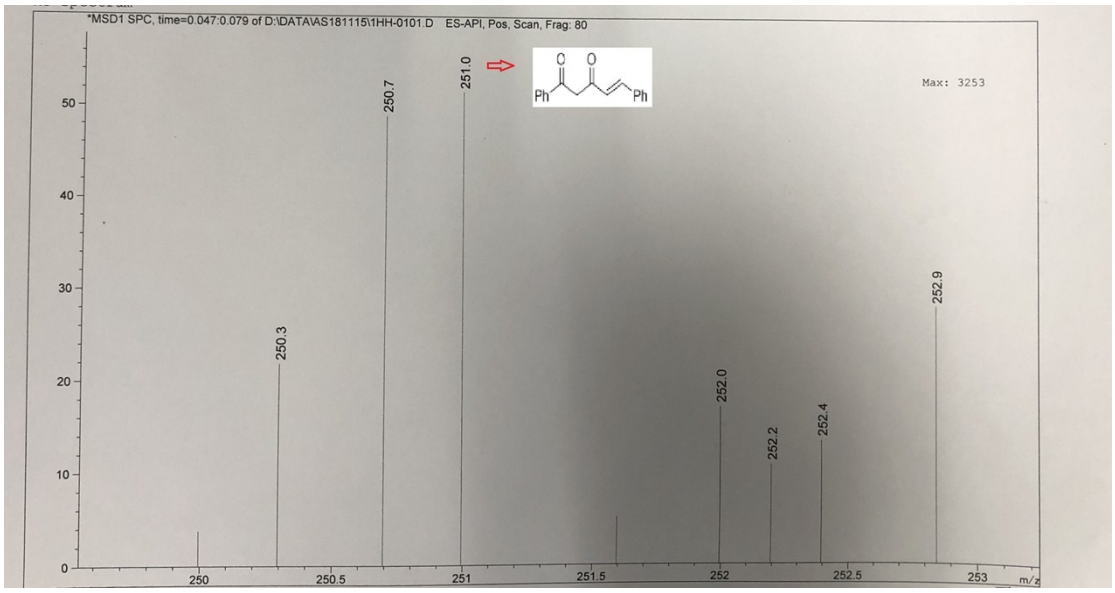
Figure SI-1. EI Spectrum

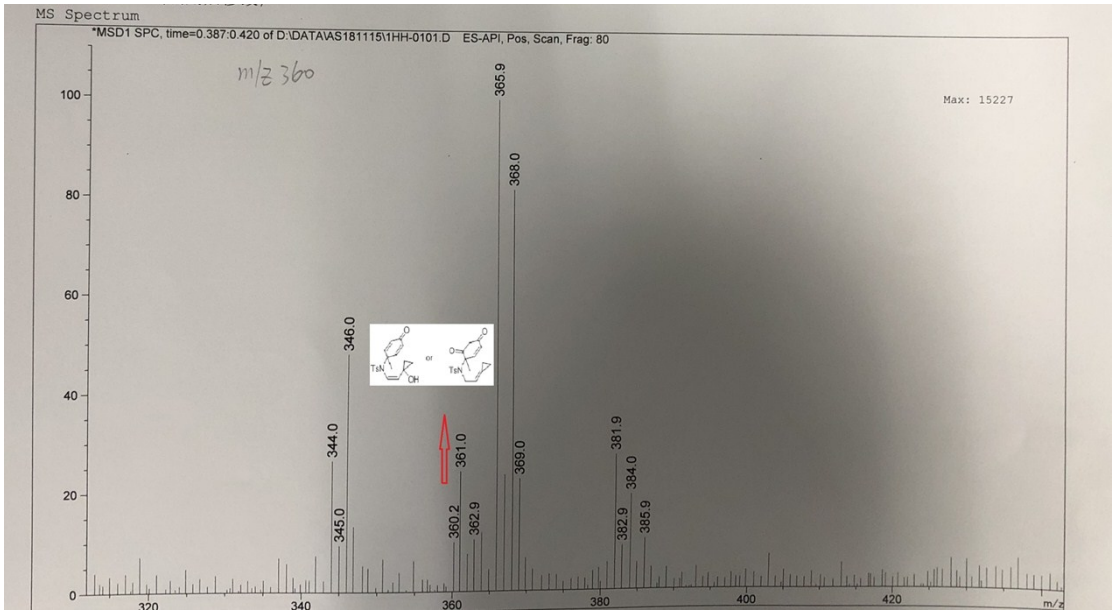


Instrument: Agilent Technologies 5973N
Ionization Method: EI Ionization Energy: 70 eV
Ion source: 230 °C MS Quard: 150 °C

Figure SI-2. ESI Spectrum



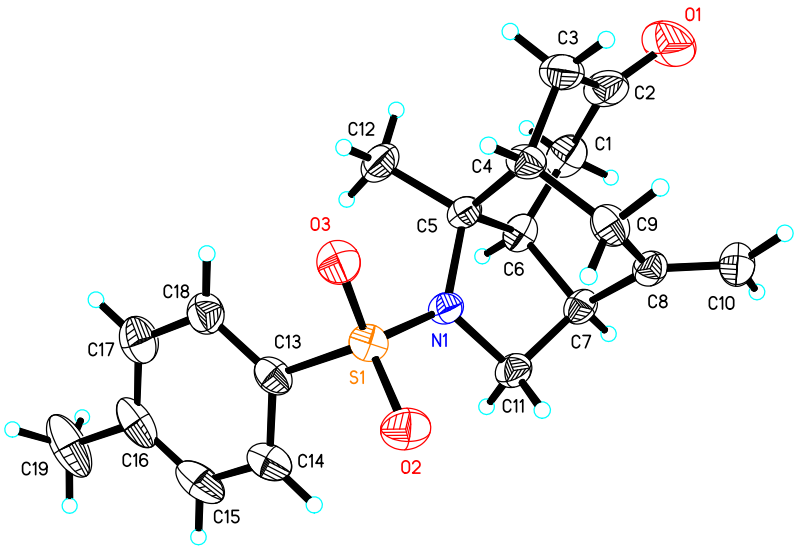




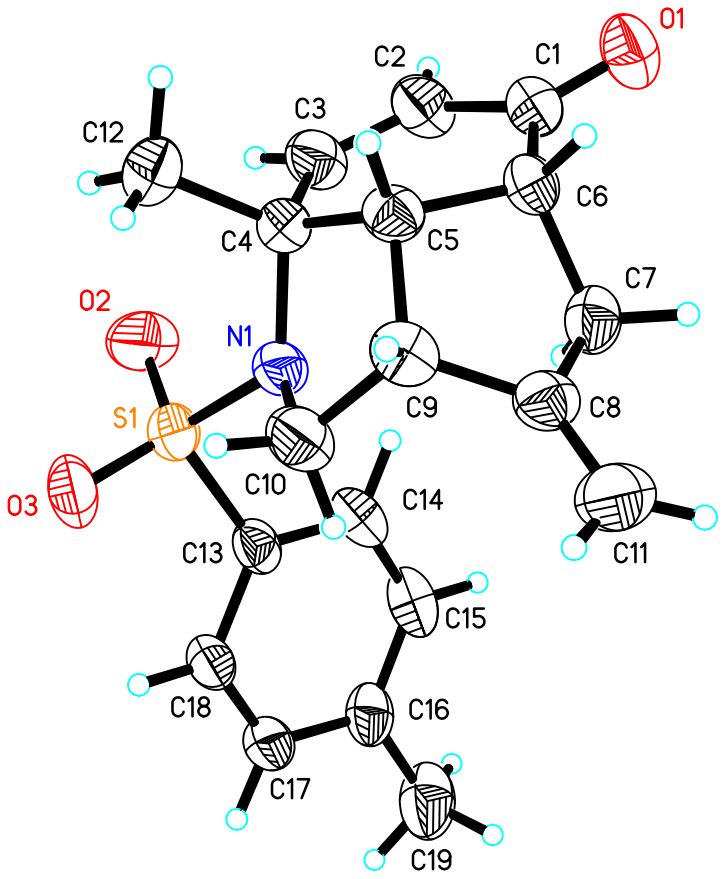
Instrument: Agilent Technologies 1100 LC/MSDSL

Ionization Method: ES-API Ionization Energy: 80 eV
Collecting Techniques: CHEM32\1\METHODS\ANAL.M
Analytical Method: CHEM32\1\METHODS\ANAL2.M

11. X-ray crystallographic information of products 2a and 3a.



The crystal data of **2a** have been deposited in CCDC with number 1834287. Empirical Formula: $C_{19}H_{23}NO_3S$; Formula Weight: 345.44; Crystal Color, Habit: colorless, Crystal Dimensions: 0.140 x 0.100 x 0.060 mm^3; Crystal System: Monoclinic; Lattice Parameters: a = 7.0366(5)Å, b = 20.3622(13)Å, c = 12.3027(10)Å, α = 90°, β = 96.424(3)°, γ = 90°, V = 1751.7(2)$Å^3$; Space group: P 21/n; Z = 4; D_{calc} = 1.310 g/cm^3; F_{000} = 736; Final R indices [I>2sigma(I)] R1 = 0.0725, wR2 = 0.2099.



The crystal data of **3a** have been deposited in CCDC with number 1836527. Empirical Formula: $C_{19}H_{21}NO_3S$; Formula Weight: 343.43; Crystal Color, Habit: colorless, Crystal Dimensions: 0.200 x 0.180 x 0.070 mm^3; Crystal System: Monoclinic; Lattice Parameters: a = 35.236(4)Å, b = 7.3453(8)Å, c = 13.4985(13)Å, α = 90°, β = 96.077(3)°, γ = 90°, V = 3474.1(6)$Å^3$; Space group: C 2/c; Z = 8; D_{calc} = 1.313 g/cm^3; F_{000} = 1456; Final R indices [I>2sigma(I)] R1 = 0.0583, wR2 = 0.1279.

12. **References.**

[1] (a) S. C. Banfield, M. A. Kerr, *Can. J. Chem.* 2004, **82**, 131; (b) P. Jia, Q. Zhang, Jin, H. Y. Huang, *Org. Lett.* 2017, **19**, 412.

[2] A. Shigeru, K. Yuka, H. Hirohiko, N. Atsushi, *J. Org. Chem.* 2010, **75**, 7573.

[3] (a) S. P. Cummings, T.-N. Le, G. E. Fernandez, L. G. Quiambao, and Benjamin J. Stokes, *J. Am. Chem. Soc.*, 2016, **138**, 6107; (b) Q. Xuan, Q. Song, *Org. Lett.*, 2016, **18**, 4250; (c) A. G. Campaña, R. E. Estévez, N. Fuentes, R. Robles, J. M. Cuerva, E. Buñuel, D. Cárdenas, J. Enrique Oltra, *Org. Lett.*, 2007, **9**, 2195.

[4] T. Mitsudome, S. Yoshida, T. Mizugaki, K. Jitsukawa, K. Kaneda, *Angew. Chem., Int. Ed.*, 2013, **52**, 5961.