Supporting Information

1,6-Conjugated Addition-Mediated [4+1] Annulation: Approach to 2,3-Dihydrobenzofurans

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Contents

1. General Information

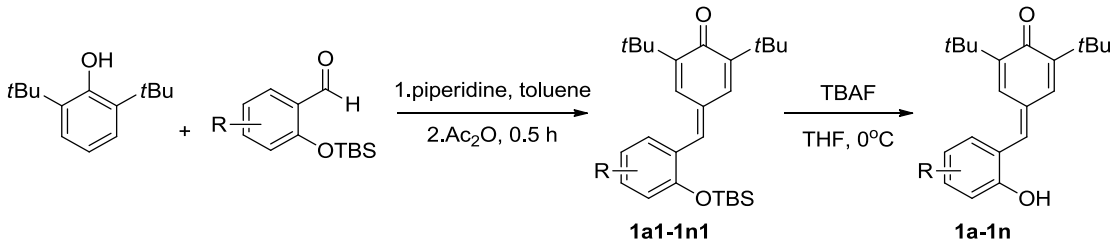
Reagents and Solvents: PE refers to petroleum ether b.p. 60-90 ℃ and EA refers to ethyl acetate. All other starting materials and solvents were commercially available and were used without further purification unless otherwise stated.

Chromatography: Flash column chromatography was carried out using commercially available 200-300 mesh under pressure unless otherwise indicated. Gradient flash chromatography was conducted eluting with PE/EA, they are listed as volume/volume ratios.

Data collection: ^{1}H and ^{13}C NMR spectra were collected on BRUKER AV-300 (300 MHz) spectrometer using $CDCl_3$ as solvent. Chemical shifts of ^{1}H NMR were recorded in parts per million (ppm, δ) relative to tetramethylsilane (δ = 0.00 ppm) with the solvent resonance as an internal standard ($CDCl_3$: δ = 7.26 ppm). Data are reported as follows: chemical shift in ppm (δ), multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, brs = broad singlet, m = multiplet), coupling constant (Hz), and integration. Chemical shifts of ^{13}C NMR were reported in ppm with the solvent as the internal standard ($CDCl_3$: δ = 77.16 ppm). High Resolution Mass measurement was performed on Agilent Q-TOF 6520 mass spectrometer with electron spray ionization (ESI) as the ion source. Melting point (m.p.) was measured on a microscopic melting point apparatus.

2. Preparation of *ortho*-Hydroxyphenyl-substituted *para*-Quinone Methides

ortho-Hydroxyphenyl-substituted *para*-quinone methides were synthesized from the corresponding aldehydes as shown in Scheme S1.



Scheme S1. Preparation of ortho-hydroxyphenyl-substituted para-quinone methides

A solution of phenols (1.1 equiv.) and aldehydes (1.0 equiv.) in toluene (5 mL/mmol substrate) was placed in a Dean-Stark apparatus which was heated to reflux. Piperidine (2.0 equiv.) was added dropwise slowly. Then, the temperature was raised to 140 ^{o}C and stirred for 12 h. After that, the reaction mixture was cooled to 120 ^{o}C and acetic anhydride (2.0 equiv.) was dropwise added. The stirring was continued for 30 min and the solution was poured on ice-water and extracted with CH_2Cl_2 (3 × 50 mL). The organic phases were combined, washed with brine and dried over anhydrous Na_2SO_4. Then the solvent was evaporated under reduced pressure and the corresponding products **1a1**–**1n1** were obtained after flash column chromatography (PE/EA = 200/1 to 50/1).

To a solution of **1a1**–**1n1** (1.0 equiv.) in THF (10 mL/mmol substrate) at 0 ^{o}C was added tetrabutylammonium fluoride trihydrate (1.1 equiv.). The reaction mixture was stirred for 10 min and a saturated NH4Cl solution was added dropwise to quench the reaction. The resulting solution was extracted with Et_2O (3 × 20 mL). Then the combined organic phases were washed with brine and dried over anhydrous Na_2SO_4. The solvent was removed to give the crude product which was purified by flash column chromatography (PE/EA = 20/1 to 4/1) to afford the desired compounds

1a–**1n**. **1o** was prepared according to the literature.[1] All structures of *ortho*-hydroxyphenyl-substituted *para*-quinone methides were listed in Figure S1.

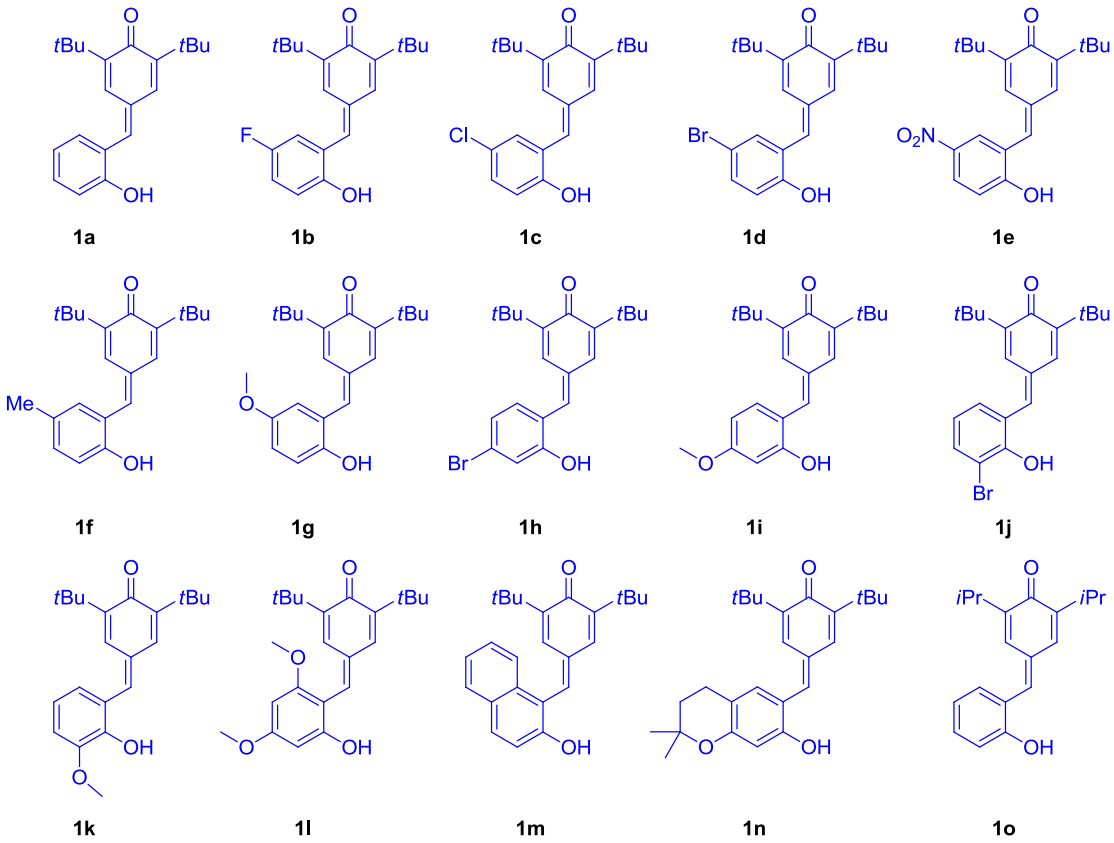
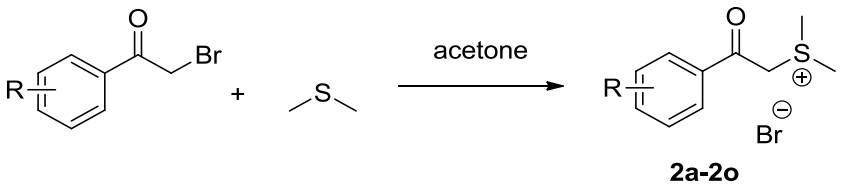


Figure S1. Substrates of *ortho*-hydroxyphenyl-substituted *para*-quinone methides

3. Preparation of Sulfonium Salts and Ammonium Salts

Sulfonium salts were synthesized from the corresponding aldehydes as shown in Scheme S2.



Scheme S2. Preparation of sulfonium salts

Dimethyl sulfide (10 mmol) was added to a solution of 2-bromoacetophenone derivatives (10 mmol) in acetone (15 mL). After the mixture had been stirred for 12 h, the residue was filtered and washed with acetone. The solid product (**2a**–**2o**) was used as sulfonium bromide without further purification. (Scheme S2) All sulfonium salts were prepared according to the previous reported method.[2] All structures of sulfonium salts were listed in Figure S2.

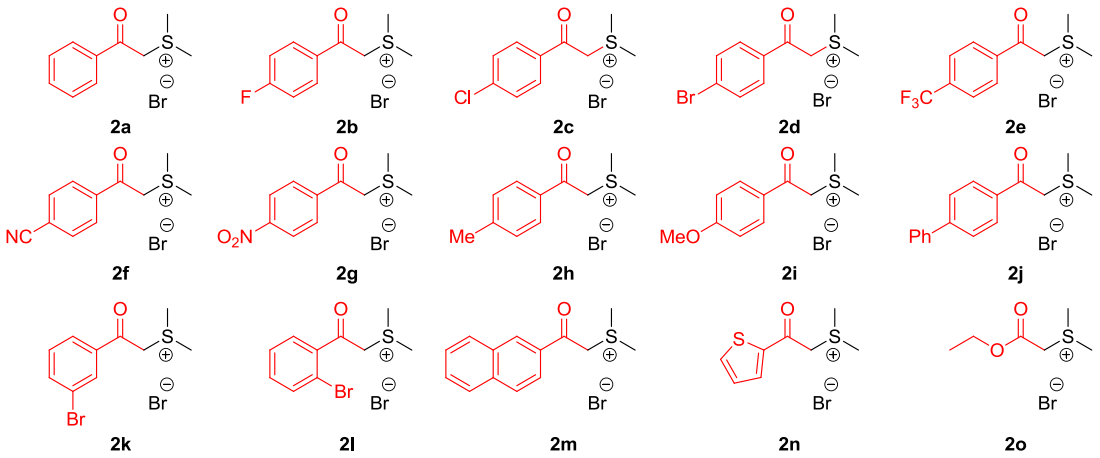
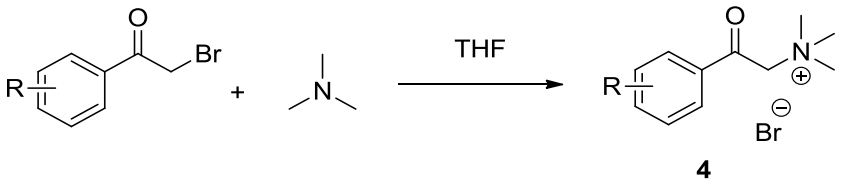


Figure S2. Substrates of sulfonium salts

Ammonium salts were synthesized from the corresponding aldehydes as shown in Scheme S3.



Scheme S3. Preparation of ammonium salts

To a solution of 2-bromoacetophenone derivatives (1 equiv.) in THF (3.3 mL per mmol starting material) trimethylamine (33% in EtOH - 1 equiv.) was added and the mixture was stirred overnight. The product was filtered off and washed twice with EtOAc and dried under *vacuo* to get a series of compound **4**. All ammonium salts were prepared according to the previous reported method.[3] All structures of ammonium salts were listed in Figure S3.

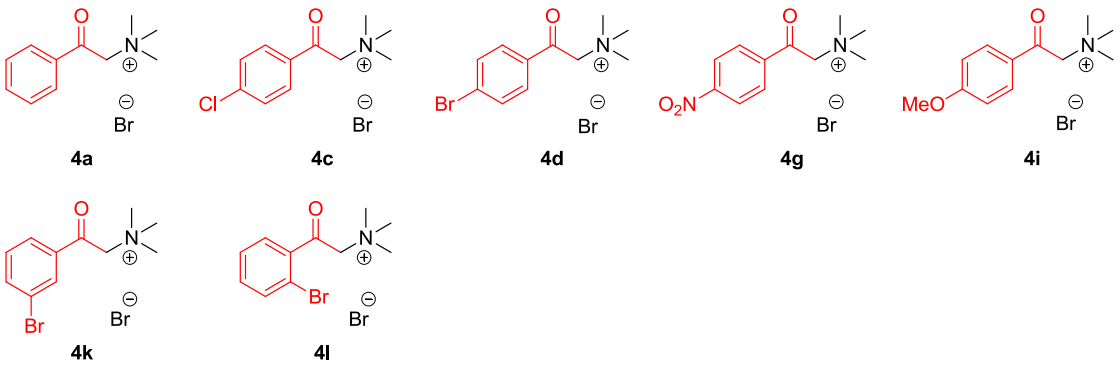
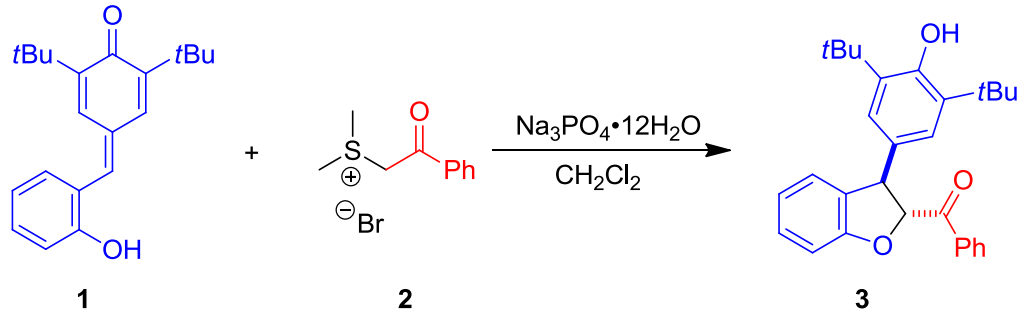


Figure S3. Substrates of ammonium salts

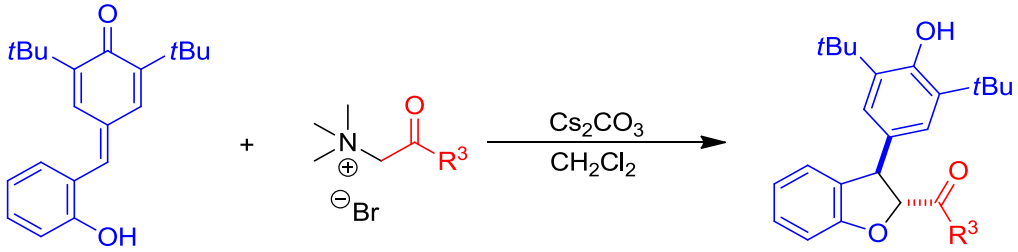
4. Synthesis of 2,3-Dihydrobenzofurans



1 **2** **3**

Scheme S4. Synthesis of compounds 3 from sulfonium salts 2

A sealed tube was charged with *ortho*-hydroxyphenyl-substituted *para*-quinone methides (0.2 mmol, 1 equiv.), sulfonium salts (0.24 mmol, 1.2 equiv.), $Na_3PO_4 \cdot 12H_2O$ (0.30 mmol, 1.5 equiv.). Dichloromethane (1.0 mL) was added in the tube. Then the reaction mixture was stirred at room temperature for 12 h. When the reaction was completed, the solution was concentrated in *vacuo* and purified by careful chromatography on silica gel (PE/EA = 200/1) to afford the desired product **3**.

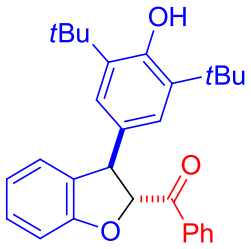


1a **4** **3**

Scheme S5. Synthesis of compoud 3 from ammonium salts 4

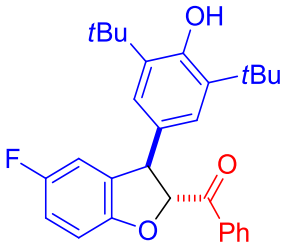
A sealed tube was charged with *ortho*-hydroxyphenyl-substituted *para*-quinone methides (0.2 mmol, 1 equiv.), ammonium salts (0.24 mmol, 1.2 equiv.), Cs_2CO_3 (0.30 mmol, 1.5 equiv.). Dichloromethane (1.0 mL) was added in the tube. Then the reaction mixture was stirred at room temperature for 12 h. When the reaction was completed, the solution was concentrated in *vacuo* and purified by careful chromatography on silica gel (PE/EA = 200/1) to afford the desired product **3**. (Scheme S5)

(3-(3,5-di-tert-butyl-4-hydroxyphenyl)-2,3-dihydrobenzofuran-2-yl)(phenyl)methanone (3aa)



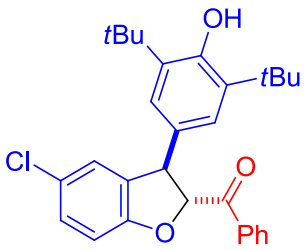
91% yield (77.9 mg). White solid, m.p. 152 – 154 °C. Rf = 0.5 (PE/EA = 10/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.93 (d, *J* = 7.0 Hz, 2H), 7.58 (t, *J* = 7.3 Hz, 1H), 7.43 (t, *J* = 7.6 Hz, 2H), 7.19 (t, *J* = 7.6 Hz, 1H), 7.04 (d, *J* = 7.3 Hz, 1H), 6.98 (s, 1H), 6.95 (s, 2H), 6.88 (d, *J* = 7.2 Hz, 1H), 5.77 (d, *J* = 6.7 Hz, 1H), 5.17 (s, 1H), 4.85 (d, *J* = 6.7 Hz, 1H), 1.38 (s, 18H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 194.7, 158.7, 152.5, 135.8, 134.1, 133.2, 132.1, 128.8, 128.2, 128.1, 125.0, 124.3, 121.0, 109.3, 90.3, 50.8, 33.9, 29.8 ppm. IR (KBr): 3609, 3065, 3012, 2964, 2882, 1698, 1597, 1459, 1433, 1261, 1228, 1103, 1051, 1022, 956, 863, 802, 753, 699, 671, 645, 596, 510 cm^{-1}. HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{29}H_{33}O_3$ 429.2424; Found 429.2431.

(3-(3,5-di-tert-butyl-4-hydroxyphenyl)-5-fluoro-2,3-dihydrobenzofuran-2-yl)(phenyl)methanone (3ba)



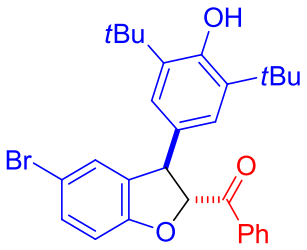
95% yield (84.4 mg). White solid, m.p. 146 – 148 °C. Rf = 0.5 (PE/EA = 10/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.93 – 7.90 (m, 2H), 7.58 (t, *J* = 7.4 Hz, 1H), 7.43 (t, *J* = 7.7 Hz, 2H), 6.95 (s, 2H), 6.88 (d, *J* = 4.8 Hz, 2H), 6.74 (d, *J* = 6.5 Hz, 1H), 5.80 (d, *J* = 6.6 Hz, 1H), 5.20 (s, 1H), 4.84 (d, *J* = 6.6 Hz, 1H), 1.39 (s, 18H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 194.3, 157.6 (d, *J* = 238.0 Hz), 153.7 (d, *J* = 142.2 Hz), 136.0, 134.0, 133.3, 131.4, 130.5 (d, *J* = 8.4 Hz), 128.8, 128.1, 124.2, 114.6 (d, *J* = 24.4 Hz), 112.0, 111.7, 109.6 (d, *J* = 8.4 Hz), 90.8, 50.9 (d, J = 1.8 Hz), 33.9, 29.8 ppm. ^{19}F NMR (282 MHz, $CDCl_3$) δ -121.97, -121.99 ppm. IR (KBr): 3624, 3602, 3065, 2958, 2922, 2872, 1687, 1597, 1571, 1481, 1434, 1231, 1212, 1120, 960, 900, 781, 762, 688, 644 cm^{-1}. HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{29}H_{32}FO_3$ 447.2330; Found 447.2335.

(5-chloro-3-(3,5-di-tert-butyl-4-hydroxyphenyl)-2,3-dihydrobenzofuran-2-yl)(phenyl)methanone (3ca)



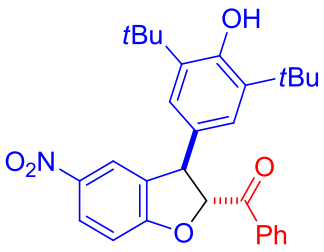
61% yield (56.5 mg). White solid, m.p. 138 – 140 °C. Rf = 0.5 (PE/EA = 10/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.92 – 7.89 (m, 2H), 7.59 (t, *J* = 7.4 Hz, 1H), 7.44 (t, *J* = 7.6 Hz, 2H), 7.15 (dd, *J* = 8.5, 2.3 Hz, 1H), 7.00 (s, 1H), 6.94 (s, 2H), 6.89 (d, *J* = 8.6 Hz, 1H), 5.81 (d, *J* = 6.5 Hz, 1H), 5.20 (s, 1H), 4.81 (d, *J* = 6.5 Hz, 1H), 1.39 (s, 18H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 194.6, 157.8, 153.3, 136.5, 134.4, 133.8, 131.9, 131.5, 129.3, 128.6, 126.2, 125.5, 124.6, 110.8, 91.3, 51.2, 34.4, 30.3 ppm. IR (KBr): 3583, 3134, 3061, 3004, 2965, 2918, 2872, 1695, 1592, 1474, 1435, 1401, 1298, 1227, 1165, 1118, 1081, 1058, 961, 869, 816, 771, 730, 695, 678, 465 cm^{-1}. HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{29}H_{32}ClO_3$ 463.2035; Found 463.2037.

(5-bromo-3-(3,5-di-tert-butyl-4-hydroxyphenyl)-2,3-dihydrobenzofuran-2-yl)(phenyl)methanone (3da)



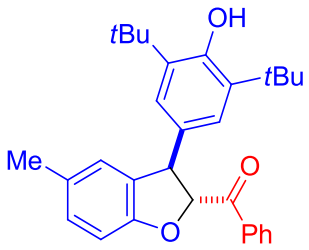
84% yield (85.0 mg). White solid, m.p. 156 – 158 °C. Rf = 0.5 (PE/EA = 10/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.90 (d, *J* = 7.5 Hz, 2H), 7.59 (t, *J* = 7.2 Hz, 1H), 7.43 (t, *J* = 7.5 Hz, 2H), 7.31 – 7.27 (m, 1H), 7.14 (s, 1H), 6.93 (s, 2H), 6.85 (d, *J* = 8.5 Hz, 1H), 5.81 (d, *J* = 6.5 Hz, 1H), 5.21 (s, 1H), 4.81 (d, *J* = 6.4 Hz, 1H), 1.39 (s, 18H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 194.5, 158.3, 153.3, 136.5, 134.3, 133.8, 132.0, 131.9, 131.6, 129.3, 128.7, 128.4, 124.7, 113.3, 111.5, 91.2, 51.1, 34.4, 30.3 ppm. IR (KBr): 3589, 3065, 2956, 2924, 2871, 1698, 1471, 1434, 1364, 1230, 1155, 1112, 1053, 871, 862, 773, 696, 668 cm^{-1}. HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{29}H_{32}BrO_3$ 507.1530; Found 507.1531.

(3-(3,5-di-tert-butyl-4-hydroxyphenyl)-5-nitro-2,3-dihydrobenzofuran-2-yl)(phenyl)methanone (3ea)



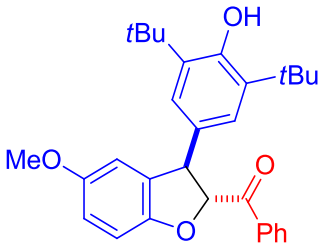
62% yield (58.8 mg). White solid, m.p. 126 – 127 °C. Rf = 0.3 (PE/EA = 10/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.19 (dd, *J* = 8.9, 2.5 Hz, 1H), 7.95 – 7.90 (m, 3H), 7.63 (t, *J* = 7.3 Hz, 1H), 7.47 (t, *J* = 7.6 Hz, 2H), 7.05 (d, *J* = 8.9 Hz, 1H), 6.92 (s, 2H), 5.98 (d, *J* = 6.3 Hz, 1H), 5.25 (s, 1H), 4.85 (d, *J* = 6.3 Hz, 1H), 1.39 (s, 18H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 193.0, 163.7, 153.1, 142.4, 136.3, 133.7, 133.3, 131.0, 130.6, 128.8, 128.3, 125.7, 124.1, 121.5, 109.4, 91.8, 50.0, 33.9, 29.7 ppm. IR (KBr): 3576, 3964, 2922, 2865, 1692, 1597, 1478, 1435, 1338, 1235, 1115, 1071, 1042, 967, 900, 829, 776, 750, 694, 670 cm^{-1}. HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{29}H_{32}NO_5$ 474.2275; Found 474.2284.

(3-(3,5-di-tert-butyl-4-hydroxyphenyl)-5-methyl-2,3-dihydrobenzofuran-2-yl)(phenyl)methanone (3fa)



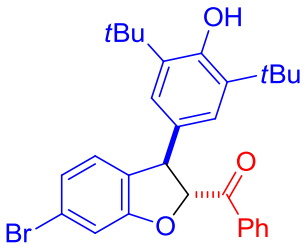
68% yield (60.2 mg). White solid, m.p. 149 – 150 °C. Rf = 0.5 (PE/EA = 10/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.91 (d, *J* = 7.1 Hz, 2H), 7.56 (t, *J* = 7.3 Hz, 1H), 7.41 (t, *J* = 7.7 Hz, 2H), 6.99 – 6.96 (m, 3H), 6.86 – 6.84 (m, 2H), 5.75 (d, *J* = 6.5 Hz, 1H), 5.17 (s, 1H), 4.80 (d, *J* = 6.5 Hz, 1H), 2.23 (s, 3H), 1.39 (s, 18H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 195.3, 157.2, 153.0, 136.3, 134.7, 133.6, 132.8, 130.7, 129.3, 129.1, 128.6, 125.9, 124.8, 109.3, 91.0, 51.4, 34.4, 30.3, 20.8 ppm. IR (KBr): 3629, 3607, 3066, 3013, 2966, 2869, 1690, 1488, 1434, 1236, 1199, 1152, 1114, 1057, 963, 886, 869, 803, 774, 759, 703, 694 cm^{-1}. HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{30}H_{35}O_3$ 443.2581; Found 443.2589.

(3-(3,5-di-tert-butyl-4-hydroxyphenyl)-5-methoxy-2,3-dihydrobenzofuran-2-yl)(phenyl)methanone (3ga)



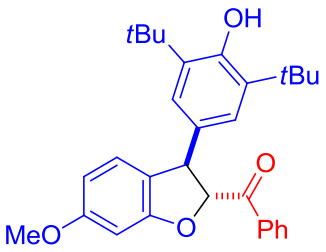
73% yield (67.3mg). White solid, m.p. 137 – 138 °C. Rf = 0.4 (PE/EA = 10/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.92 (d, *J* = 7.1 Hz, 2H), 7.58 (t, *J* = 7.5 Hz, 1H), 7.43 (t, *J* = 7.7 Hz, 2H), 6.97 (s, 2H), 6.87 (d, *J* = 8.7 Hz, 1H), 6.75 (dd, *J* = 8.7, 2.7 Hz, 1H), 6.61 (d, *J* = 2.2 Hz, 1H), 5.74 (d, *J* = 6.7 Hz, 1H), 5.18 (s, 1H), 4.84 (d, *J* = 6.7 Hz, 1H), 3.70 (s, 3H), 1.38 (s, 18H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 195.3, 154.9, 153.4, 153.1, 136.3, 134.7, 133.6, 132.3, 130.2, 129.3, 128.6, 124.8, 114.3, 111.1, 109.9, 91.1, 56.1, 51.6, 34.4, 30.3 ppm. IR (KBr): 3636, 3065, 2952, 2925, 2865, 1696, 1596, 1484, 1433, 1362, 1203 ,1179 ,1116, 1082, 1005, 967, 802, 866, 763, 748, 702 cm^{-1}. HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{30}H_{35}O_4$ 459.2530; Found 459.2539.

(6-bromo-3-(3,5-di-tert-butyl-4-hydroxyphenyl)-2,3-dihydrobenzofuran-2-yl)(phenyl)methanone (3ha)



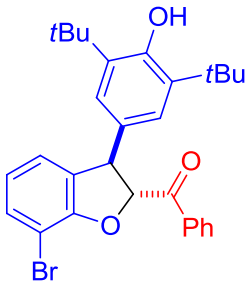
93% yield (94.4 mg). White solid, m.p. 167 – 170 °C. Rf = 0.6 (PE/EA = 10/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.91 (d, *J* = 7.3 Hz, 2H), 7.59 (t, *J* = 7.3 Hz, 1H), 7.44 (t, *J* = 7.7 Hz, 2H), 7.13 (s, 1H), 7.02 (d, *J* = 8.6 Hz, 1H), 6.92 (s, 2H), 6.89 (d, *J* = 8.0 Hz, 1H), 5.80 (d, *J* = 6.6 Hz, 1H), 5.19 (s, 1H), 4.78 (d, *J* = 6.5 Hz, 1H), 1.38 (s, 18H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 194.4, 159.9, 153.0, 136.3, 134.2, 133.6, 131.8, 129.1, 128.7, 128.5, 126.3, 124.5, 124.4, 121.5, 113.3, 91.2, 50.6, 34.2, 30.1 ppm. IR (KBr): 3581, 3072, 2953, 2924, 2871, 1701, 1593, 1474, 1435, 1414, 1297, 1224, 1116, 1051, 959, 874, 841, 788, 769, 692 cm^{-1}. HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{29}H_{32}BrO_3$ 507.1530; Found 507.1531.

(3-(3,5-di-tert-butyl-4-hydroxyphenyl)-6-methoxy-2,3-dihydrobenzofuran-2-yl)(phenyl)methanone (3ia)



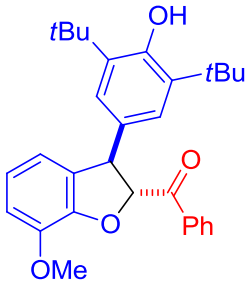
85% yield (78.2 mg). White solid, m.p. 152 – 154 °C. Rf = 0.4 (PE/EA = 10/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.91 (d, *J* = 6.9 Hz, 2H), 7.57 (t, *J* = 7.4 Hz, 1H), 7.42 (t, *J* = 7.7 Hz, 2H), 6.94 (s, 2H), 6.91 (d, *J* = 8.5 Hz, 1H), 6.57 (d, *J* = 2.3 Hz, 1H), 6.45 (dd, *J* = 8.3, 2.3 Hz, 1H), 5.78 (d, *J* = 6.4 Hz, 1H), 5.17 (s, 1H), 4.75 (d, *J* = 6.4 Hz, 1H), 3.78 (s, 3H), 1.38 (s, 18H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 195.2, 160.8, 160.6, 153.0, 136.3, 134.6, 133.6, 132.9, 129.3, 128.6, 125.6, 124.7, 121.3, 107.6, 96.1, 91.7, 55.5, 50.9, 34.4, 30.3 ppm. IR (KBr): 3580, 3065, 2955, 2925, 2961, 2833, 1701, 1624, 1597, 1498, 1446, 1436, 1282, 1234, 1173, 1147, 1109, 967, 833, 771, 637 cm^{-1}. HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{30}H_{35}O_4$ 459.2530; Found 459.2536.

(7-bromo-3-(3,5-di-tert-butyl-4-hydroxyphenyl)-2,3-dihydrobenzofuran-2-yl)(phenyl)methanone (3ja)



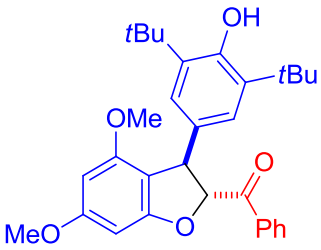
99% yield (101.2 mg). White solid, m.p. 169 – 170 °C. Rf = 0.5 (PE/EA = 10/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.96 (d, *J* = 7.4 Hz, 2H), 7.59 (t, *J* = 7.2 Hz, 1H), 7.45 (d, *J* = 7.5 Hz, 2H), 7.35 (d, *J* = 7.8 Hz, 1H), 6.99 (s, 1H), 6.95 (s, 2H), 6.78 (t, *J* = 7.6 Hz, 1H), 5.83 (d, *J* = 7.0 Hz, 1H), 5.21 (s, 1H), 4.96 (d, *J* = 6.9 Hz, 1H), 1.38 (s, 18H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 194.4, 156.5, 153.2, 136.4, 134.5, 133.8, 131.8, 130.9, 129.4, 128.6, 124.7, 124.5, 122.8, 102.8, 90.9, 52.1, 34.4, 30.3 ppm. IR (KBr): 3569, 3069, 2962, 2923, 2873, 2853, 1698, 1595, 1580, 1453, 1435, 1220, 1116, 1056, 964, 918, 882, 863, 748, 695 cm^{-1}. HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{29}H_{32}BrO_3$ 507.1530; Found 507.1534.

(3-(3,5-di-tert-butyl-4-hydroxyphenyl)-7-methoxy-2,3-dihydrobenzofuran-2-yl)(phenyl)methanone (3ka)



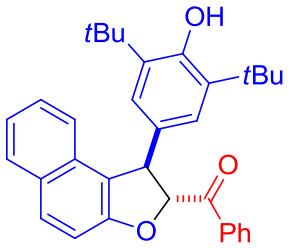
93% yield (85.1 mg). White solid, m.p. 148 – 149 °C. Rf = 0.4 (PE/EA = 10/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.94 (d, *J* = 7.4 Hz, 2H), 7.56 (t, *J* = 7.3 Hz, 1H), 7.42 (t, *J* = 7.6 Hz, 2H), 6.95 (s, 2H), 6.84 (d, *J* = 6.8 Hz, 2H), 6.66 (d, *J* = 7.1 Hz, 1H), 5.81 (d, *J* = 6.8 Hz, 1H), 5.16 (s, 1H), 4.88 (d, *J* = 6.8 Hz, 1H), 3.91 (s, 3H), 1.37 (s, 18H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 194.8, 153.1, 147.8, 144.6, 136.3, 134.7, 133.6, 132.4, 130.6, 129.3, 128.6, 124.8, 122.1, 117.6, 112.0, 91.2, 56.2, 51.9, 34.4, 30.3 ppm. IR (KBr): 3598, 3053, 3004, 2954, 2924, 2853, 1684, 1492, 1621, 1595, 1435, 1279, 1178, 1118, 1086, 926, 886, 653, 734, 684 cm^{-1}. HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{30}H_{35}O_4$ 459.2530; Found 459.2533.

(3-(3,5-di-tert-butyl-4-hydroxyphenyl)-4,6-dimethoxy-2,3-dihydrobenzofuran-2-yl)(phenyl)methanone (3la)



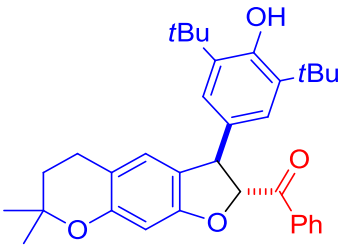
67% yield (65.7 mg). White solid, m.p. 126 – 128 °C. Rf = 0.4 (PE/EA = 10/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.94 (d, *J* = 7.0 Hz, 2H), 7.59 (t, *J* = 7.4 Hz, 1H), 7.46 (t, *J* = 7.6 Hz, 2H), 6.95 (s, 2H), 6.27 (d, *J* = 2.0 Hz, 1H), 6.01 (d, *J* = 2.0 Hz, 1H), 5.80 (d, *J* = 4.0 Hz, 1H), 5.11 (s, 1H), 4.68 (d, *J* = 4.0 Hz, 1H), 3.80 (s, 3H), 3.59 (s, 3H), 1.39 (s, 18H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 195.3, 162.2, 161.5, 156.9, 152.7, 135.9, 134.2, 133.5, 132.8, 129.1, 128.6, 123.9, 108.1, 92.4, 91.6, 88.4, 55.5, 55.3, 49.0, 34.3, 30.3 ppm. IR (KBr): 3605, 2958, 2927, 1679, 1628, 1598, 1502, 1433, 1233, 1216, 1202, 1143, 1097, 1046, 955, 882, 813, 767, 739, 678 cm^{-1}. HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{31}H_{37}O_5$ 489.2636; Found 489.2639.

(1-(3,5-di-tert-butyl-4-hydroxyphenyl)-1,2-dihydronaphtho[2,1-b]furan-2-yl)(phenyl)methanone (3ma)



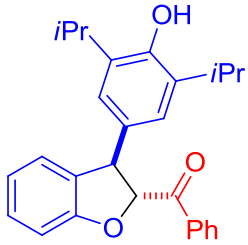
89% yield (85.3 mg). White solid, m.p. 165 – 166 °C. Rf = 0.4 (PE/EA = 10/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.99 – 7.96 (m, 2H), 7.77 (dd, *J* = 8.5, 4.7 Hz, 2H), 7.60 (t, *J* = 7.4 Hz, 1H), 7.46 (t, *J* = 7.5 Hz, 2H), 7.29 (d, *J* = 8.9 Hz, 2H), 7.25 – 7.21 (m, 2H), 6.99 (s, 2H), 5.92 (d, *J* = 5.3 Hz, 1H), 5.16 (d, *J* = 5.4 Hz, 1H), 5.13 (s, 1H), 1.34 (s, 18H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 195.1, 157.1, 153.0, 136.4, 134.5, 133.7, 132.8, 130.6, 130.3, 130.1, 129.4, 128.7, 128.6, 126.5, 124.5, 123.1, 123.0, 120.1, 112.1, 91.8, 51.1, 34.4, 30.3 ppm. IR (KBr): 3607, 3061, 2954, 2870, 1698, 1632, 1600, 1522, 1433, 1238, 1140, 1119, 979, 857, 751, 704, 692 cm^{-1}. HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{33}H_{35}O_3$ 479.2581; Found 479.2581.

(3-(3,5-di-tert-butyl-4-hydroxyphenyl)-7,7-dimethyl-3,5,6,7-tetrahydro-2H-furo[3,2-g]chromen-2-yl)(phenyl)methanone (3na)



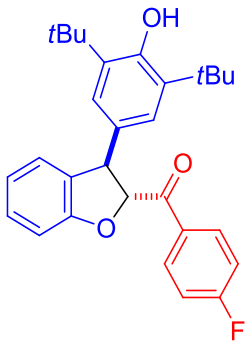
62% yield (63.1 mg). White solid, m.p. 144 – 146 °C. Rf = 0.6 (PE/EA = 10/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.89 (d, *J* = 7.0 Hz, 2H), 7.57 (t, *J* = 7.4 Hz, 1H), 7.42 (t, *J* = 7.7 Hz, 2H), 6.95 (s, 2H), 6.70 (s, 1H), 6.42 (s, 1H), 5.71 (d, *J* = 6.3 Hz, 1H), 5.16 (s, 1H), 4.69 (d, *J* = 6.2 Hz, 1H), 2.64 (t, *J* = 6.7 Hz, 2H), 1.75 (t, *J* = 6.8 Hz, 2H), 1.39 (s, 18H), 1.33 (s, 3H), 1.30 (s, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 195.5, 158.7, 154.5, 152.9, 136.2, 134.7, 133.5, 133.2, 129.3, 128.5, 125.3, 124.7, 120.9, 113.8, 98.7, 91.4, 74.2, 51.1, 34.4, 32.9, 30.3, 27.2, 26.5, 22.2 ppm. IR (KBr): 3587, 3135, 2959, 2922, 2878, 1692, 1627, 1599, 1478, 1435, 1399, 1237, 1151, 1121, 1097, 965, 906, 873, 842, 690, 663 cm^{-1}. HRMS (ESI-TOF) m/z: $[M + Na]^+$ Calcd for $C_{34}H_{40}O_4Na$ 535.2819; Found 535.2820.

(3-(4-hydroxy-3,5-diisopropylphenyl)-2,3-dihydrobenzofuran-2-yl)(phenyl)methanone (3oa)



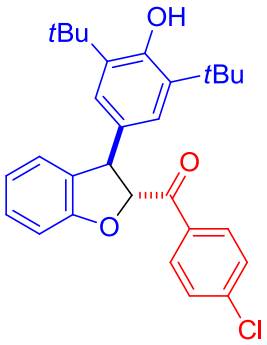
78% yield (62.8 mg). White solid, m.p. 130– 132 °C. Rf = 0.4 (PE/EA = 10/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.93 (d, *J* = 7.9 Hz, 2H), 7.58 (t, *J* = 7.4 Hz, 1H), 7.43 (t, *J* = 7.7 Hz, 2H), 7.20 (t, *J* = 8.0 Hz, 1H), 7.02 – 6.97 (m, 2H), 6.91 – 6.85 (m, 3H), 5.78 (d, *J* = 6.7 Hz, 1H), 4.85 (d, *J* = 6.7 Hz, 1H), 4.78 (s, 1H), 3.19 – 3.05 (m, 2H), 1.23 (d, *J* = 6.9 Hz, 6H), 1.18 (d, *J* = 6.8 Hz, 6H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 195.1, 159.1, 149.3, 134.5, 134.1, 133.9, 133.6, 129.4, 129.3, 128.6, 128.5, 125.3, 123.3, 121.4, 109.8, 90.8, 51.2, 27.3, 22.6, 22.6 ppm. IR (KBr): 3435, 3422, 2962, 2928, 1692, 1595, 1447, 1260, 1211, 1196, 1184, 1152, 1184, 1123, 962, 856, 773, 745, 691 cm^{-1}. HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{27}H_{29}O_3$ 401.2111; Found 401.2107.

(3-(3,5-di-tert-butyl-4-hydroxyphenyl)-2,3-dihydrobenzofuran-2-yl)(4-fluorophenyl)methanone (3ab)



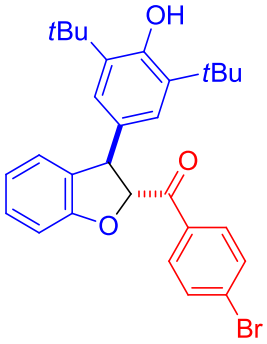
90% yield (80.3 mg). White solid, m.p. 166 – 168 °C. Rf = 0.5 (PE/EA = 10/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.97 (s, 2H), 7.19 – 6.89 (m, 8H), 5.70 (d, *J* = 6.9 Hz, 1H), 5.17 (s, 1H), 4.90 (d, *J* = 6.9 Hz, 1H), 1.38 (s, 18H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 193.7, 167.7, 164.3, 157.6 (d, *J* = 238.0 Hz), 136.4, 132.4, 132.1 (d, J = 9.3 Hz), 131.2, 129.4, 128.7, 125.5, 124.8, 121.5, 115.7 (d, *J* = 21.8 Hz), 109.8, 90.9, 51.1, 34.4, 30.3 ppm. ^{19}F NMR (282 MHz, $CDCl_3$) δ -102.75 ppm. IR (KBr): 3613, 2958, 2924, 2969, 1686, 1596, 1505, 1435, 1228, 1156, 1119, 962, 865, 754, 653 cm^{-1}. HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{29}H_{32}FO_3$ 447.2330; Found 447.2322.

(4-chlorophenyl)(3-(3,5-di-tert-butyl-4-hydroxyphenyl)-2,3-dihydrobenzofuran-2-yl)methanone (3ac)



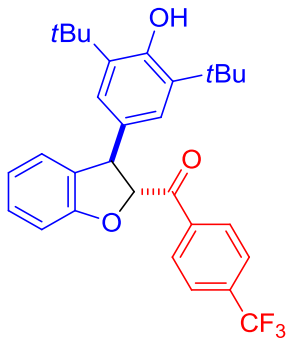
87% yield (80.7 mg). White solid, m.p. 179 – 180 °C. Rf = 0.5 (PE/EA = 10/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.87 (d, *J* = 8.2 Hz, 2H), 7.39 (d, *J* = 8.2 Hz, 2H), 7.19 (t, *J* = 7.5 Hz, 1H), 7.04 (d, *J* = 7.4 Hz, 1H), 6.96 – 6.87 (m, 4H), 5.69 (d, *J* = 6.9 Hz, 1H), 5.17 (s, 1H), 4.89 (d, *J* = 6.9 Hz, 1H), 1.38 (s, 18H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 194.1, 159.0, 153.1, 140.2, 136.4, 133.1, 132.4, 130.8, 129.3, 128.9, 128.7, 125.5, 124.8, 121.6, 109.8, 90.9, 51.1, 34.4, 30.3 ppm. IR (KBr): 3615, 2963, 2926, 2865, 1687, 1588, 1478, 1460, 1435, 1401, 1304, 1223, 1120, 1090, 1012, 963, 864, 820, 654 cm^{-1}. HRMS (ESI-TOF) m/z: $[M + Na]^+$ Calcd for $C_{29}H_{31}ClO_3Na$ 485.1854; Found 485.1855.

(4-bromophenyl)(3-(3,5-di-tert-butyl-4-hydroxyphenyl)-2,3-dihydrobenzofuran-2-yl)methanone (3ad)



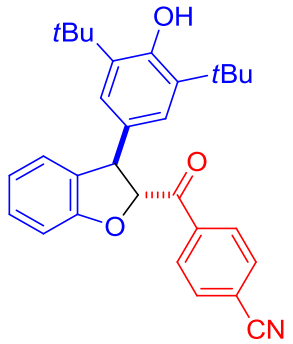
82% yield (83.5 mg). White solid, m.p. 172 – 174 °C. Rf = 0.5 (PE/EA = 10/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.78 (d, *J* = 8.3 Hz, 2H), 7.56 (d, *J* = 8.2 Hz, 2H), 7.18 (t, *J* = 7.4 Hz, 1H), 7.04 (d, *J* = 7.1 Hz, 1H), 6.95 – 6.86 (m, 4H), 5.68 (d, *J* = 7.0 Hz, 1H), 5.17 (s, 1H), 4.88 (d, *J* = 7.0 Hz, 1H), 1.37 (s, 18H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 194.4, 159.0, 153.1, 136.4, 133.5, 132.3, 131.9, 130.9, 129.3, 128.9, 128.7, 125.5, 124.8, 121.6, 109.8, 90.9, 51.1, 34.4, 30.3 ppm. IR (KBr): 3602, 3432, 3188, 2963, 2922, 2865, 1386, 1584, 1478, 1459, 1434, 1399, 1371, 1225, 1161, 1099, 1070, 1009, 863, 812, 784, 753, 649 cm^{-1}. HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{29}H_{32}BrO_3$ 507.1530; Found 507.1523.

(3-(3,5-di-tert-butyl-4-hydroxyphenyl)-2,3-dihydrobenzofuran-2-yl)(4-(trifluoromethyl)phenyl) methanone (3ae)



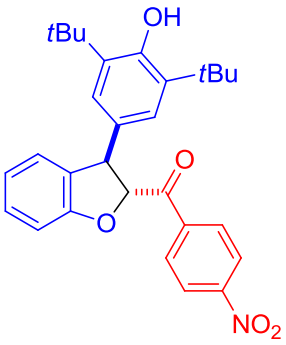
88% yield (87.3 mg). White solid, m.p. 141 – 142 °C. Rf = 0.6 (PE/EA = 10/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.05 (d, *J* = 8.1 Hz, 2H), 7.70 (d, *J* = 8.2 Hz, 2H), 7.20 (t, *J* = 7.7 Hz, 1H), 7.06 (d, *J* = 7.4 Hz, 1H), 6.96 – 6.89 (m, 4H), 5.73 (d, *J* = 6.9 Hz, 1H), 5.18 (s, 1H), 4.92 (d, *J* = 6.9 Hz, 1H), 1.38 (s, 18H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 194.6, 158.8, 153.2, 137.6, 136.5, 134.8 (d, *J* = 32.8 Hz), 132.2, 129.7, 129.2, 128.8, 125.6 (d, *J* = 3.7 Hz), 152.5, 124.7, 121.7, 109.9, 91.1, 50.9, 34.4, 30.2 ppm. ^{19}F NMR (282 MHz, $CDCl_3$) δ -62.12 ppm. IR (KBr): 3608, 2958, 2927, 2873, 1698, 1596, 1478, 1460, 1435, 1327, 1226, 1172, 1134, 1068, 1015, 955, 867, 845, 753, 657 cm^{-1}. HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{30}H_{32}F_3O_3$ 497.2298; Found 497.2294.

4-(3-(3,5-di-tert-butyl-4-hydroxyphenyl)-2,3-dihydrobenzofuran-2-carbonyl)benzonitrile (3af)



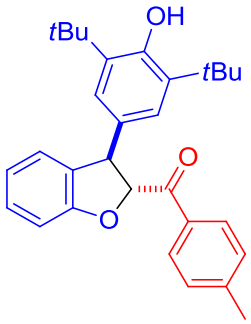
85% yield (77.1 mg). White solid, m.p. 208 – 210 °C. Rf = 0.4 (PE/EA = 10/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.05 (d, *J* = 8.0 Hz, 2H), 7.74 (d, *J* = 8.0 Hz, 2H), 7.20 (t, *J* = 7.6 Hz, 1H), 7.07 (d, *J* = 7.3 Hz, 1H), 6.97 (s, 2H), 6.95 – 6.90 (m, 2H), 5.70 (d, *J* = 6.9 Hz, 1H), 5.21 (s, 1H), 4.94 (d, *J* = 6.9 Hz, 1H), 1.39 (s, 18H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 194.3, 158.7, 153.2, 137.9, 136.5, 132.3, 132.1, 129.8, 129.1, 128.8, 125.6, 124.7, 121.8, 117.8, 116.8, 109.9, 91.1, 50.7, 34.4, 30.3 ppm. IR (KBr): 3606, 3004, 2954, 2922, 2872, 1696, 1597, 1480, 1460, 1435, 1409, 1290, 1229, 1218, 1122, 977, 961, 965, 847, 754, 682, 653 cm^{-1}. HRMS (ESI-TOF) m/z: $[M - H]^-$ Calcd for $C_{30}H_{30}NO_3$ 452.2231; Found 452.2230.

(3-(3,5-di-tert-butyl-4-hydroxyphenyl)-2,3-dihydrobenzofuran-2-yl)(4-nitrophenyl)methanone (3ag)



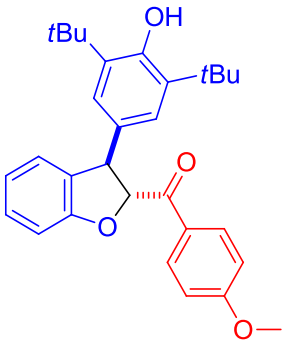
82% yield (77.7 mg). Yellow solid, m.p. 190 – 192 °C. Rf = 0.4 (PE/EA = 10/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.29 (d, *J* = 8.8 Hz, 2H), 8.13 (d, *J* = 8.9 Hz, 2H), 7.23 – 7.18 (m, 1H), 7.08 (d, *J* = 7.9 Hz, 1H), 6.99 (s, 2H), 6.95 – 6.90 (m, 2H), 5.72 (d, *J* = 6.9 Hz, 1H), 5.21 (s, 1H), 4.97 (d, *J* = 6.9 Hz, 1H), 1.39 (s, 18H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 194.2, 158.6, 153.2, 150.5, 139.4, 136.5, 132.1, 130.5, 129.1, 128.8, 125.6, 124.7, 123.7, 121.9, 109.9, 91.2, 50.6, 34.4, 30.3 ppm. IR (KBr): 3596, 3111, 3080, 2957, 2921, 2870, 1705, 1605, 1594, 1491, 1436, 1344, 1225, 1154, 1053, 984, 958, 857, 845, 753, 700, 645 cm^{-1}. HRMS (ESI-TOF) m/z: $[M + Na]^+$ Calcd for $C_{29}H_{31}NO_5Na$ 496.2094; Found 496.2095.

(3-(3,5-di-tert-butyl-4-hydroxyphenyl)-2,3-dihydrobenzofuran-2-yl)(p-tolyl)methanone (3ah)



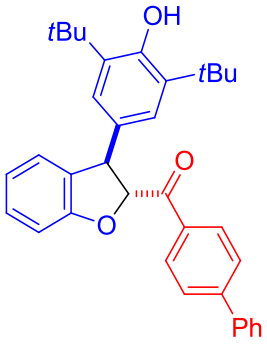
92% yield (81.8 mg). White solid, m.p. 166 – 168 °C. Rf = 0.5 (PE/EA = 10/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.82 (d, *J* = 7.9 Hz, 2H), 7.23 – 7.16 (m, 3H), 7.03 (d, *J* = 7.3 Hz, 1H), 6.97 – 6.95 (m, 3H), 6.88 (t, *J* = 7.4 Hz, 1H), 5.75 (d, *J* = 6.8 Hz, 1H), 5.16 (s, 1H), 4.85 (d, *J* = 6.7 Hz, 1H), 2.40 (s, 3H), 1.38 (s, 18H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 194.8, 159.3, 153.0, 144.6, 136.3, 132.6, 132.2, 129.5, 129.4, 129.3, 128.6, 125.5, 124.8, 121.4, 109.8, 90.8, 51.4, 34.4, 30.3, 21.7 ppm. IR (KBr): 3597, 2962, 2922, 2861, 1678, 1606, 1477, 1460, 1434, 1303, 1233, 1185, 1116, 1012, 963, 950, 863, 773, 753, 739, 655 cm^{-1}. HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{30}H_{35}O_3$ 443.2581; Found 443.2582.

(3-(3,5-di-tert-butyl-4-hydroxyphenyl)-2,3-dihydrobenzofuran-2-yl)(4-methoxyphenyl)methanone (3ai)



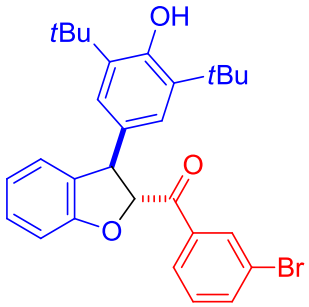
78% yield (71.5 mg). White solid, m.p. 152 – 154 °C. Rf = 0.4 (PE/EA = 10/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.82 (d, *J* = 8.0 Hz, 2H), 7.23 – 7.16 (m, 3H), 7.03 (d, *J* = 7.3 Hz, 1H), 6.97 – 6.95 (m, 3H), 6.88 (t, *J* = 7.4 Hz, 1H), 5.75 (d, *J* = 6.8 Hz, 1H), 5.16 (s, 1H), 4.85 (d, *J* = 6.7 Hz, 1H), 2.40 (s, 3H), 1.38 (s, 18H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 193.6, 163.9, 159.3, 153.0, 136.3, 132.7, 131.7, 129.5, 128.6, 127.7, 125.4, 124.8, 121.4, 113.8, 109.8, 90.7, 55.5, 51.4, 34.4, 30.3 ppm. IR (KBr): 3597, 2959, 2925, 2869, 1675, 1594, 1510, 1479, 1435, 1306, 1262, 1234, 1172, 1113, 1024, 863, 835, 755 cm^{-1}. HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{30}H_{35}O_4$ 459.2530; Found 459.2534.

[1,1'-biphenyl]-4-yl(3-(3,5-di-tert-butyl-4-hydroxyphenyl)-2,3-dihydrobenzofuran-2-yl)methanone (3aj)



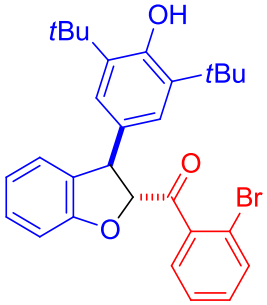
82% yield (83.1 mg). White solid, m.p. 155 – 156 °C. Rf = 0.6 (PE/EA = 10/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.01 (d, *J* = 8.1 Hz, 2H), 7.67 – 7.60 (m, 4H), 7.49 – 7.37 (m, 3H), 7.20 (t, *J* = 7.5 Hz,1H), 7.07 – 6.98 (m, 4H), 6.90 (t, *J* = 7.3 Hz, 1H), 5.80 (d, *J* = 6.7 Hz, 1H), 5.17 (s, 1H), 4.91 (d, *J* = 6.7 Hz, 1H), 1.38 (s, 18H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 194.8, 159.2, 153.1, 146.4, 139.8, 136.3, 133.4, 132.6, 130.0, 129.4, 129.0, 128.7, 128.4, 127.3, 127.2, 125.5, 124.8, 121.5, 109.9, 90.9, 51.3, 34.4, 30.3 ppm. IR (KBr): 3587, 3012, 2951, 2923, 2873, 1683, 1603, 1477, 1457, 1435, 1232, 1162, 1119, 950, 867, 837, 820, 747, 690 cm^{-1}. HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{35}H_{37}O_3$ 505.2737; Found 505.2748.

(3-bromophenyl)(3-(3,5-di-tert-butyl-4-hydroxyphenyl)-2,3-dihydrobenzofuran-2-yl)methanone (3ak)



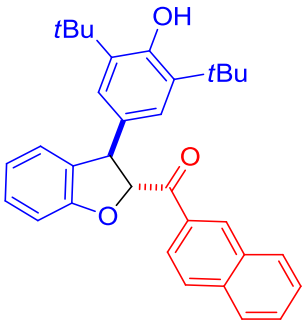
78% yield (79.0 mg). White solid, m.p. 152 – 154 °C. Rf = 0.6 (PE/EA = 10/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.00 (s, 1H), 7.86 (d, *J* = 7.8 Hz, 1H), 7.68 (d, *J* = 1.9 Hz, 1H), 7.31 (t, *J* = 7.9 Hz, 1H), 7.20 (t, *J* = 7.6 Hz, 1H), 7.04 (d, *J* = 7.3 Hz, 1H), 6.95 – 6.98 (m, 3H), 6.90 (t, *J* = 7.4 Hz, 1H), 5.70 (d, *J* = 7.0 Hz, 1H), 5.18 (s, 1H), 4.84 (d, *J* = 6.9 Hz, 1H), 1.38 (s, 18H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 194.0, 158.9, 153.1, 136.4, 132.2, 132.2, 130.1, 129.2, 128.7, 127.8, 125.4, 124.7, 122.8, 121.6, 109.8, 90.8, 51.2, 34.3, 30.2 ppm. IR (KBr): 3635, 3128, 3072, 3003, 2961, 2907, 2873, 1696, 1597, 1567, 1478, 1461, 1433, 1400, 1222, 1209, 1144, 1105, 1016, 967, 863, 787, 751, 732, 693, 637 cm^{-1}. HRMS (ESI-TOF) m/z: $[M + NH_4]^+$ Calcd for $C_{29}H_{35}NBrO_3$ 524.1795; Found 524.1798.

(2-bromophenyl)(3-(3,5-di-tert-butyl-4-hydroxyphenyl)-2,3-dihydrobenzofuran-2-yl)methanone (3al)



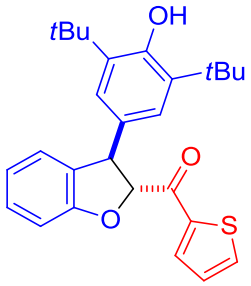
55% yield (55.8mg). White solid, m.p. 136 – 138 °C. Rf = 0.5 (PE/EA = 10/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.60 (d, *J* = 4.4 Hz, 1H), 7.31 – 7.27 (m, 3H), 7.17 (t, *J* = 7.7 Hz, 1H), 7.05 (d, *J* = 7.4 Hz, 1H), 6.90 (dd, *J* = 7.2, 4.2 Hz, 2H), 6.85 (s, 2H), 5.67 (d, *J* = 6.5 Hz, 1H), 5.11 (s, 1H), 4.85 (d, *J* = 6.6 Hz, 1H), 1.34 (s, 18H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 200.4, 159.0, 152.9, 139.1, 136.1, 133.6, 132.3, 131.9, 129.2, 128.8, 128.7, 127.0, 125.5, 124.4, 121.5, 119.6, 109.9, 92.5, 51.3, 34.3, 30.2 ppm. IR (KBr): 3614, 3007, 2956, 2906, 2865, 1705, 1595, 1480, 1462, 1434, 1306, 1234, 1211, 1120, 1020, 971, 837, 752, 732, 690, 639 cm^{-1}. HRMS (ESI-TOF) m/z: $[M + NH_4]^+$ Calcd for $C_{29}H_{35}NBrO_3$ 524.1795; Found 524.1798.

(3-(3,5-di-tert-butyl-4-hydroxyphenyl)-2,3-dihydrobenzofuran-2-yl)(naphthalen-2-yl)methanone (3am)



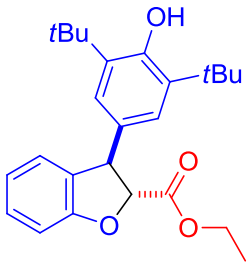
88% yield (83.3 mg). White solid, m.p. 156 – 158 °C. Rf = 0.4 (PE/EA = 10/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.24 (d, *J* = 1.7 Hz, 1H), 8.05 (d, *J* = 1.4 Hz, 1H), 7.88 – 7.83 (m, 2H), 7.75 (d, *J* = 8.0 Hz, 1H), 7.57 (t, *J* = 6.8 Hz, 1H), 7.49 (t, *J* = 7.1 Hz, 1H), 7.19 (d, *J* = 7.5 Hz, 1H), 7.06 – 6.97 (m, 4H), 6.90 (t, *J* = 7.3 Hz, 1H), 5.96 (d, *J* = 7.1 Hz, 1H), 5.18 (s, 1H), 4.88 (d, *J* = 7.1 Hz, 1H), 1.34 (s, 18H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 195.1, 159.3, 153.1, 136.4, 135.8, 132.5, 132.3, 132.0, 131.5, 129.8, 129.5, 128.8, 128.7, 128.4, 127.8, 126.8, 125.5, 124.9, 124.5, 121.5, 109.9, 91.1, 51.9, 34.4, 30.3 ppm. IR (KBr): 3579, 3053, 2965, 2912, 2871, 1684, 1628, 1598, 1477, 1434, 1400, 1302, 1236, 1224, 1197, 1124, 1058, 970, 897, 864, 825, 776, 755, 641 cm^{-1}. HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{33}H_{35}O_3$ 479.2581; Found 479.2586.

(3-(3,5-di-tert-butyl-4-hydroxyphenyl)-2,3-dihydrobenzofuran-2-yl)(thiophen-2-yl)methanone (3an)



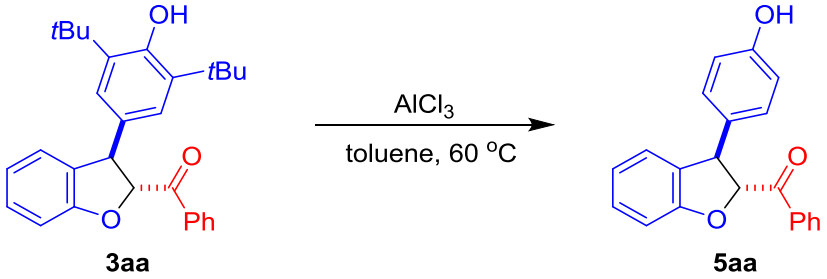
92% yield (79.6 mg). White solid, m.p. 157 – 158 °C. Rf = 0.5 (PE/EA = 10/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.70 (d, *J* = 3.8 Hz, 1H), 7.66 (d, *J* = 5.0 Hz, 1H), 7.18 (t, *J* = 8.2 Hz, 1H), 7.07 – 7.03 (m, 2H), 6.97 – 6.95 (m, 3H), 6.89 (t, *J* = 7.4 Hz, 1H), 5.48 (d, *J* = 6.8 Hz, 1H), 5.15 (s, 1H), 4.88 (d, *J* = 6.8 Hz, 1H), 1.36 (s, 18H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 189.4, 159.1, 153.1, 141.1, 136.3, 135.0, 134.2, 132.4, 129.2, 128.7, 128.2, 125.6, 124.8, 121.6, 109.9, 92.0, 52.1, 34.4, 30.3 ppm. IR (KBr): 3604, 3126, 3086, 3068, 3010, 2951, 2923, 2873, 2849, 1675, 1596, 1515, 1479, 1460, 1433, 1411, 1361, 1303, 1234, 1160, 1118, 1032, 984, 932, 832, 755, 734, 694, 649 cm^{-1}. HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{27}H_{31}O_3S$ 435.1989; Found 435.1996.

ethyl 3-(3,5-di-tert-butyl-4-hydroxyphenyl)-2,3-dihydrobenzofuran-2-carboxylate (3ao)



37% yield (29mg). White solid, m.p. 107 – 108 ^{o}C. Rf = 0.5 (PE/EA = 10/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.20 (t, *J* = 7.8 Hz, 1H), 7.06 (d, *J* = 7.3 Hz, 1H), 6.98 – 6.96 (m, 3H), 6.91 (td, *J* = 7.4, 1.0 Hz, 1H), 5.16 (s, 1H), 4.99 (d, *J* = 6.6 Hz, 1H), 4.74 (d, *J* = 6.6 Hz, 1H), 4.35 – 4.24 (m, 2H), 1.40 (s, 18H), 1.33 (t, *J* = 7.1 Hz, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 188.6, 170.9, 159.2, 153.0, 136.1, 132.5, 128.7, 125.4, 124.4, 121.4, 109.9, 87.4, 61.6, 52.6, 34.4, 30.2, 14.3 ppm. IR (KBr): 3589, 2957, 2924, 2871, 1751, 1613, 1597, 1480, 1460, 1435, 1375, 1260, 1238, 1209, 1118, 1042, 886, 821, 751 cm^{-1}. HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{25}H_{33}O_4$ 397.2374; Found 397.2372.

5. Further Transformations of 3aa

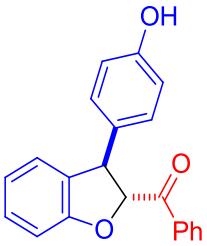


3aa **5aa**

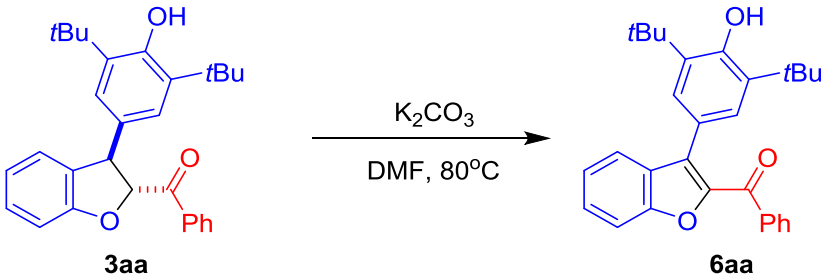
Scheme S6. Synthesis of 5aa

The compound **3aa** (85.6 mg, 0.2 mmol) was dissolved in 3 mL dry toluene. Then $AlCl_3$ (133.3 mg, 5.0 equiv.) was added. The reaction was stirred for 2 h at 60 °C and 5 mL H_2O was added. The layers were separated and the aqueous layer was extracted with ethyl acetate (3 × 10 mL). The combined extracts were washed with 20 mL brine and dried over anhydrous Na_2SO_4. The solvent was concentrated under reduced pressure. The residue obtained was purified by flash column chromatography on silica gel (PE/EA = 10/1) to afford the desired product **5aa**.

(3-(4-hydroxyphenyl)-2,3-dihydrobenzofuran-2-yl)(phenyl)methanone (5aa)



69% yield (43.9 mg). White solid, m.p. 188 – 190 °C. Rf = 0.5 (PE/EA = 10/1). ^{1}H NMR (300 MHz, DMSO-d_6) δ 9.38 (s, 1H), 7.88 (d, *J* = 7.3 Hz, 2H), 7.68 (t, *J* = 7.3 Hz, 1H), 7.53 (t, *J* = 7.6 Hz, 2H), 7.18 (t, *J* = 7.6 Hz, 1H), 7.02 – 6.95 (m, 4H), 6.85 (t, *J* = 7.4 Hz, 1H), 6.73 (d, *J* = 8.3 Hz, 2H), 6.12 (d, *J* = 5.6 Hz, 1H), 4.70 (d, *J* = 5.6 Hz, 1H). ^{13}C NMR (75 MHz, DMSO-d_6) δ 195.1, 158.5, 156.5, 134.0, 133.8, 132.3, 130.0, 128.8, 128.7, 128.6, 128.5, 125.1, 121.1, 115.5, 109.4, 89.2, 49.6 ppm. IR (KBr): 3385, 3180, 2960, 2924, 2851, 1679, 1613, 1513, 1400, 1234, 1105, 1049, 982, 838, 818, 773, 753, 693, 645 cm^{-1}. HRMS (ESI-TOF) m/z: [M + H]$^+$ Calcd for $C_{21}H_{17}O_3$ 317.1172; Found 317.1174.



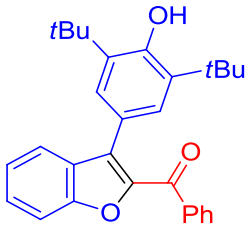
3aa **6aa**

Scheme S7. Synthesis of 6aa

To a sealing tube were added **3aa** (85.6 mg, 0.2 mmol), 3.0 equiv. K_2CO_3 (82.8 mg) and anhydrous DMF (1 mL). Then the oxidation reaction was conducted at 80 °C for 2 hours. After the

reaction was completed, the solvent was removed to give a residue which was purified by flash column chromatography (PE/EA = 100/1) to give the desired product **6aa**. (Scheme S7)

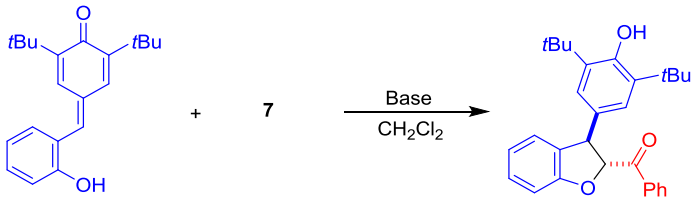
(3-(3,5-di-tert-butyl-4-hydroxyphenyl)benzofuran-2-yl)(phenyl)methanone (6aa)



68% yield (58.0 mg). White solid, m.p. 150 – 152 ^{o}C. Rf = 0.3 (PE/EA = 4/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.75 (d, *J* = 7.6 Hz, 1H), 7.70 – 7.65 (m, 3H), 7.53 (td, *J* = 8.4, 7.7, 1.3 Hz, 1H), 7.39 – 7.33 (m, 2H), 7.21 – 7.17 (m, 4H), 5.25 (s, 1H), 1.35 (s, 18H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 186.0, 154.4, 153.5, 146.2, 136.9, 135.5, 131.8, 130.1, 129.3, 127.7, 127.7, 127.2, 126.6, 123.2, 122.2, 121.3, 112.0, 33.7, 29.7 ppm. IR (KBr): 3540, 3132, 2956, 2924, 2872, 1731, 1635, 1552, 1447, 1379, 1294, 1258, 1161, 1122, 966, 882, 752, 730, 696, 657 cm^{-1}. HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{29}H_{31}O_3$ 427.2268; Found 427.2271.

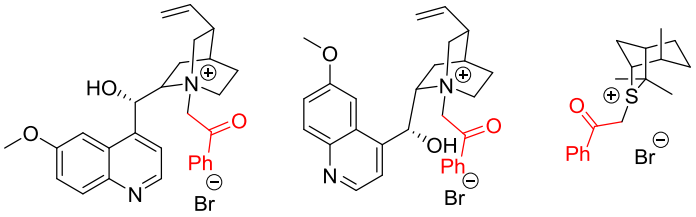
6. Screening Asymmetric Reaction Conditions

Table 1. Attempt to synthesize enantiopure 3aa [a],[b]



1a 3aa

Entry	Chiral sulfonium/ ammonium bromides **7**	Base	Yield (%)	dr	ee[c]
1	**7a**	Cs_2CO_3	37	> 20:1	73
2	**7b**	Cs_2CO_3	16	> 20:1	54
3	**7c**	$Na_3PO_4 \cdot 12H_2O$	80	> 20:1	61



7a **7b** **7c**

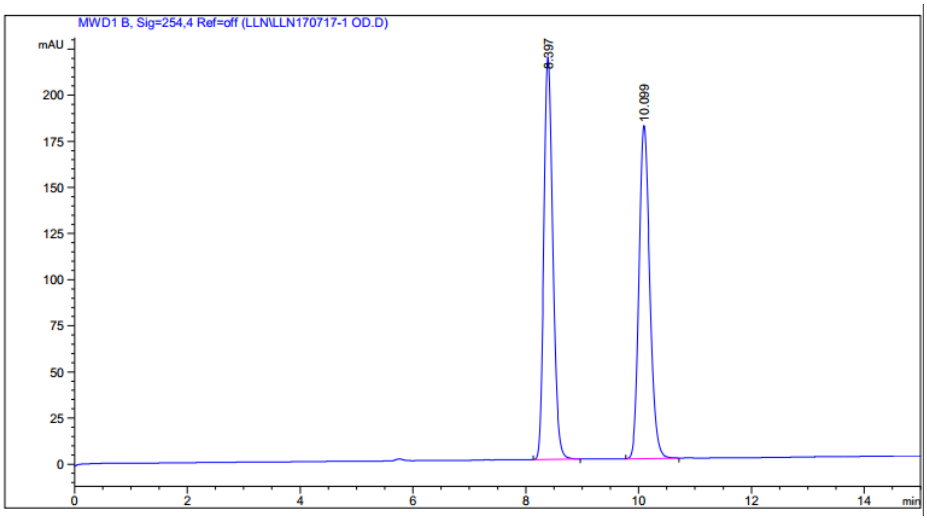
[a] Reaction Conditions: **1a** (0.20 mmol), **7** (0.24 mmol), and base (0.50 mmol) in CH_2Cl_2 (1.0 mL) at room temperature for 12 h. [b] All yields refer to the isolated yields. [c] Determined by HPLC analysis using a chiral stationary phase.

HPLC acquisition parameters：

Chiral column: CHIRALCEL ® OD-H, Wave length: 254 nm,

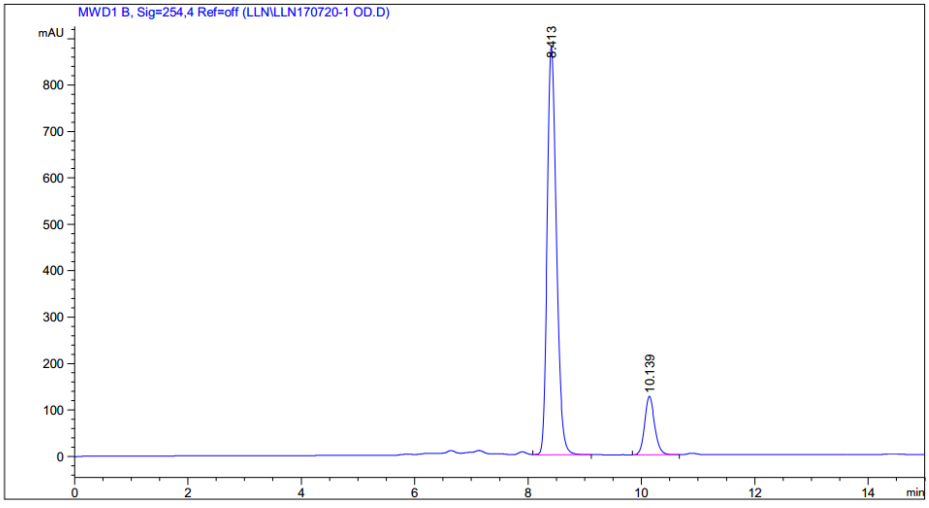
Mobile phase: *i*PrOH:Hex=20:80, Flow rate: 0.5mL/min, Temperature: 28 ^{o}C.

HPLC Spectra of racemic 3aa



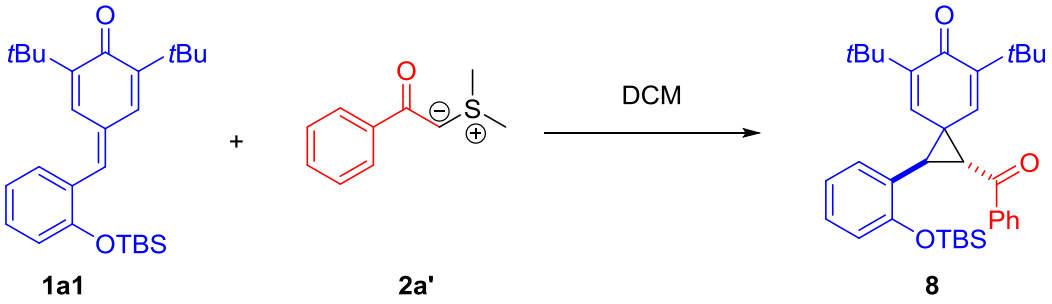
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	8.397	BB	0.1707	2401.04150	217.72502	50.0688
2	10.099	BB	0.2047	2394.44312	180.54102	49.9312
Totals :				4795.48462	398.26604	

HPLC Spectra of enantiomeric 3aa



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	8.413	VB	0.1760	9949.27051	879.59406	86.6649
2	10.139	BB	0.1859	1530.88477	125.89284	13.3351
Totals :				1.14802e4	1005.48689	

7. Synthesis of Spiro[2.5]octa-4,7-dien-6-ones

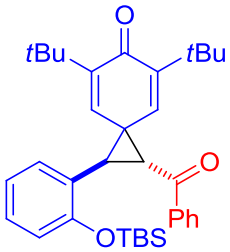


1a1 2a' 8

Scheme S8. Synthesis of 8

A sealed tube was charged with *para*-quinone methide **1a1** (0.3 mmol, 1 equiv), sulfur ylide **2a'** (0.3 mmol, 1 equiv), and dichloromethane (1.0 mL). The reaction mixture was stirred at room temperature for 12 h. Then the reaction mixture was concentrated *in vacuo* and purified by careful chromatography on silica gel to afford the desired product **8**.

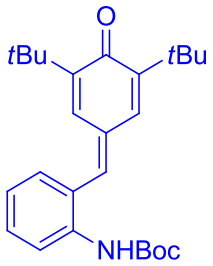
1-benzoyl-5,7-di-tert-butyl-2-(2-((tert-butyldimethylsilyl)oxy)phenyl)spiro[2.5]octa-4,7-dien-6-one (8)



37% yield (61.0 mg). White solid, m.p. 121 – 122 °C. Rf = 0.6 (PE/EA = 10/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.89 (d, *J* = 7.0 Hz, 2H), 7.63 (t, *J* = 7.2 Hz, 1H), 7.52 (t, *J* = 7.4 Hz, 2H), 7.26 (t, *J* = 6.9 Hz, 2H), 7.01 (t, *J* = 7.3 Hz, 1H), 6.90 (d, *J* = 7.8 Hz, 1H), 6.66 (d, *J* = 2.8 Hz, 1H), 6.11 (d, *J* = 2.7 Hz, 1H), 4.13 (d, *J* = 7.7 Hz, 1H), 3.98 (d, *J* = 7.7 Hz, 1H), 1.19 (d, *J* = 2.8 Hz, 18H), 0.98 (s, 9H), 0.28 (s, 3H), 0.20 (s, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 197.4, 188.1, 158.0, 152.6, 152.3, 141.1, 140.9, 140.2, 135.9, 131.9, 131.4, 131.3, 130.7, 128.5, 123.3, 121.2, 43.0, 43.0, 39.2, 37.7, 37.7, 31.8, 31.8, 28.5, 20.8 ppm. IR (KBr): 3474, 2957, 2928, 2858, 1670, 1645, 1618, 1354, 1319, 1265, 1215, 1175, 1109, 916, 783, 754 cm^{-1}. HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{35}H_{46}O_3Si$ 543.3298; Found 543.3280.

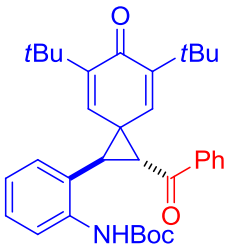
8. Characterization of 9a and 10aa

tert-butyl (2-((3,5-di-tert-butyl-4-oxocyclohexa-2,5-dien-1-ylidene)methyl)phenyl)carbamate (9a)



Yellow solid, m.p. 144 – 146 °C. Rf = 0.5 (PE/EA = 10/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.00 (d, *J* = 8.3 Hz, 1H), 7.39 (t, *J* = 7.6 Hz, 1H), 7.32 – 7.22 (m, 2H), 7.16 (d, *J* = 7.4 Hz, 1H), 7.11 (s, 1H), 7.08 (d, *J* = 2.4 Hz, 1H), 6.47 (s, 1H), 1.52 (s, 9H), 1.35 (s, 9H), 1.26 (s, 9H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 186.5, 152.6, 149.6, 148.2, 137.1, 137.0, 134.3, 133.7, 131.3, 130.1, 128.0, 123.4, 121.1, 81.1, 35.4, 35.1, 29.5, 29.5, 28.3 ppm. IR (KBr): 3413, 3127, 1635, 1614, 1508, 1400, 1252, 1151, 1077, 945, 854, 547 cm^{-1}. HRMS (ESI-TOF) m/z: $[M + Na]^+$ Calcd for $C_{26}H_{35}NNaO_3$ 432.2509; Found 432.2517.

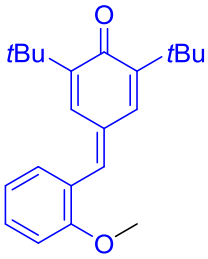
tert-butyl (2-((1R,2R)-2-benzoyl-5,7-di-tert-butyl-6-oxospiro[2.5]octa-4,7-dien-1-yl)phenyl)carbamate (10aa)



26% yield (26.9 mg). White solid, m.p. 130 – 132 °C. Rf = 0.5 (PE/EA = 10/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.08 (d, *J* = 7.8 Hz, 1H), 7.91 (d, *J* = 7.7 Hz, 2H), 7.63 (t, *J* = 7.2 Hz, 1H), 7.51 (t, *J* = 7.5 Hz, 2H), 7.32 (t, *J* = 7.7 Hz, 1H), 7.20 (d, *J* = 7.6 Hz, 1H), 7.03 (t, *J* = 7.2 Hz, 1H), 6.67 (s, 1H), 6.12 (s, 1H), 5.89 (s, 1H), 3.93 (d, *J* = 7.2 Hz, 1H), 3.80 (d, *J* = 7.2 Hz, 1H), 1.41 (s, 9H), 1.19 (s, 9H), 1.12 (s, 9H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 194.3, 185.1, 152.3, 151.2, 151.1, 138.2, 137.5, 137.2, 136.0, 133.8, 129.3, 129.1, 128.9, 128.3, 123.5, 122.8, 119.5, 80.8, 41.2, 39.5, 36.3, 35.3, 35.2, 29.4, 29.1, 28.2 ppm. IR (KBr): 3421, 3126, 3003, 1732, 1641, 1520, 1446, 1400, 1366, 1234, 1155, 907, 742 cm^{-1}. HRMS (ESI-TOF) m/z: $[M + Na]^+$ Calcd for $C_{34}H_{41}NNaO_4$ 550.2928; Found 550.2930.

9. Characterization of 11a

2,6-di-tert-butyl-4-(2-methoxybenzylidene)cyclohexa-2,5-dienone (11a)



52% yield (33.7.0 mg). Yellow solid, m.p. 137 – 138 ^{o}C. Rf = 0.7 (PE/EA = 10/1). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.47 (d, *J* = 2.4 Hz, 1H), 7.45 – 7.34 (m, 3H), 7.08 (d, *J* = 2.4 Hz, 1H), 7.03 (t, *J* = 7.5 Hz, 1H), 6.95 (d, *J* = 8.7 Hz, 1H), 3.89 (s, 3H), 1.34 (s, 9H), 1.29 (s, 9H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 186.7, 158.3, 148.9, 147.3, 138.9, 135.3, 131.8, 131.5, 130.9, 128.4, 124.9, 120.5, 110.8, 55.6, 35.4, 35.0, 29.6, 29.5 ppm. IR (KBr): 3128, 2957, 1615, 1587, 1476, 1461, 1400, 1358, 1252, 1160, 1110, 1048, 1028, 951, 892, 751 cm^{-1}. HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for C_{22} H_{29} O_2 325.2162; Found 325.2175.

10. Crystal Structure of 3aa

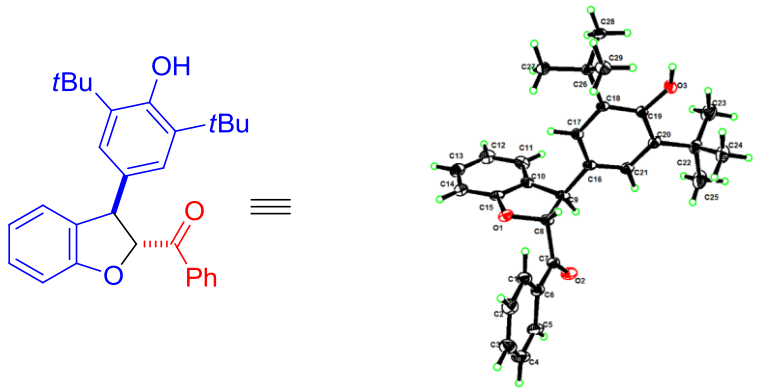


Figure S4. ORTEP plot of the crystal structure of 3aa.

X-ray crystallographic data of **3aa**

CCDC number	1562708
Empirical formula	$C_{29}H_{32}O_3$
Formula weight	428.55
Temperature	205 K
Wavelength	0.71073 Å
Space group	C2/c
Unit cell dimensions	a=30.962(5) Å =90°
	b=10.0760(18) Å = 121.016(4)°
	c=20.180(4) Å =90°
Volume	5395.5(17)Å^3
Z	8
Density	1.055 Mg/m3
F(000)	1840.0
Completeness to theta = 25.048 °	98.7%
Max. and min. transmission	0.988 and 0.993
R indices (all data)	R= 0.0602(3492) wR2= 0.1836(6152)

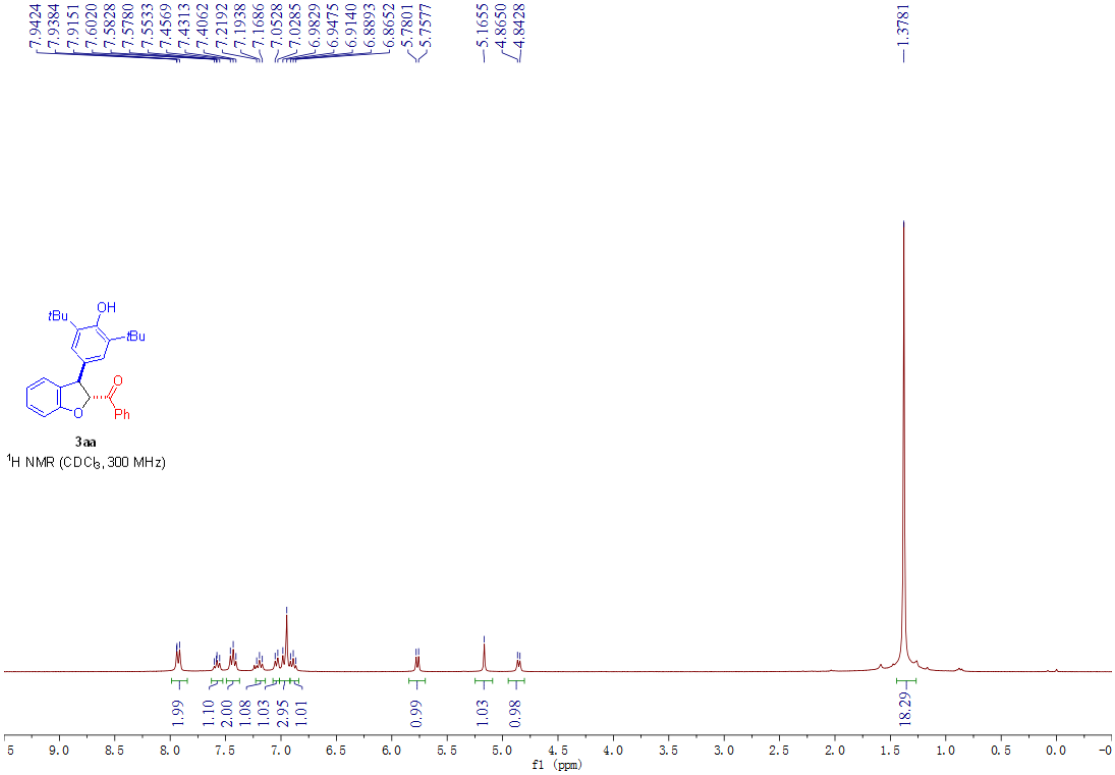
11. References

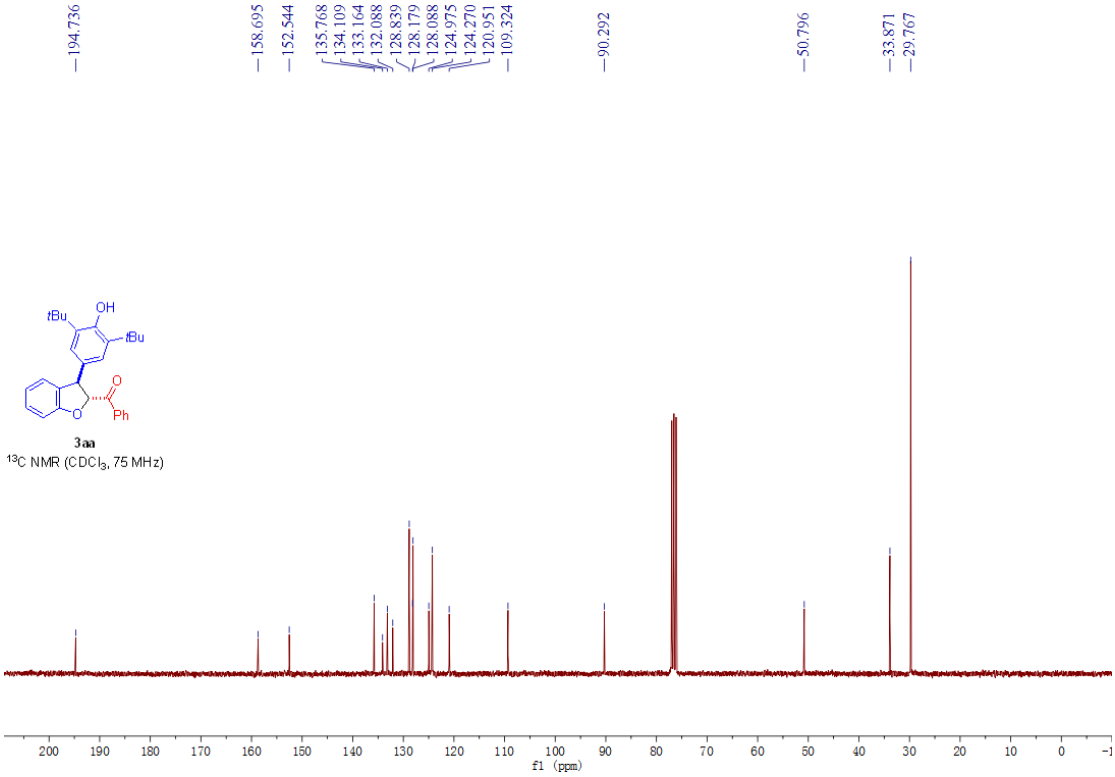
[1] K. Zhao, Y. Zhi, T. Shu, A. Valkonen, K, Rissanen, D. Enders, *Angew. Chem. Int. Ed.* **2016**, *55*, 12104.

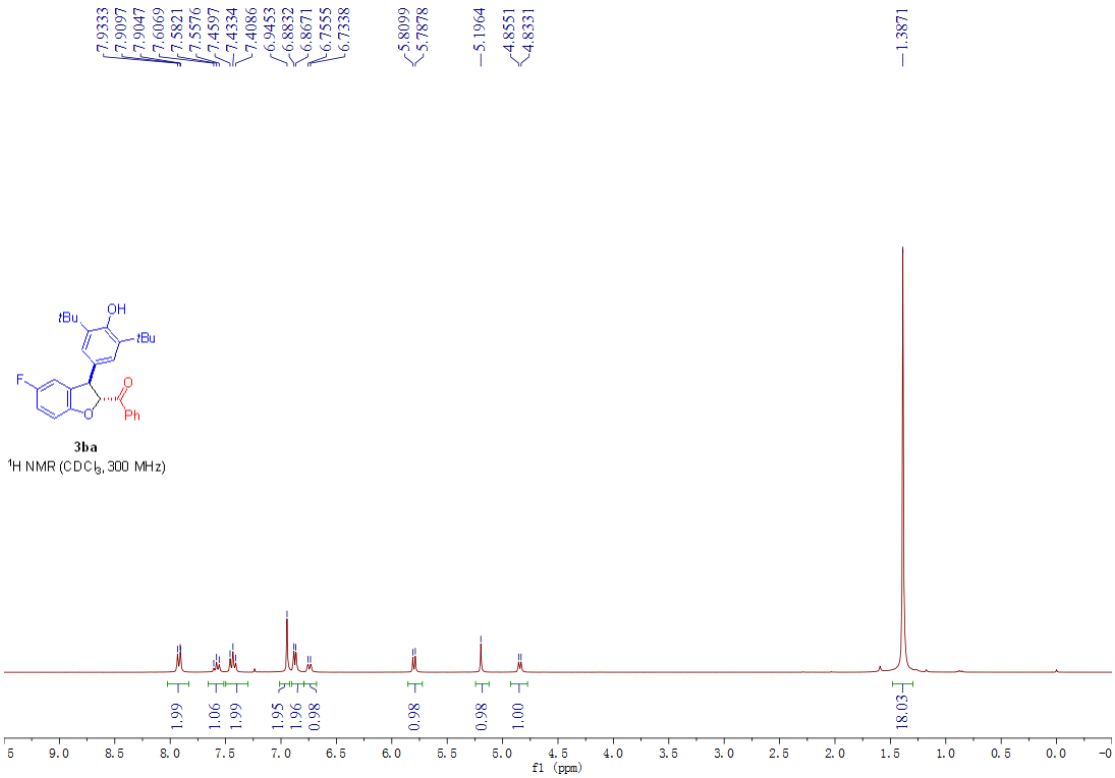
[2] Z. Yuan, X. Fang, X. Li, J. Wu, H. Yao and A. Lin, *J. Org. Chem.*, **2015**, *80*, 11123.

[3] M. Nicole, R. Lukas, M. Uwe, H. Markus, R. Raphal, and W. Mario, *Chem. Eur. J.* **2017**, *23*, 5137.

12. NMR Spectra

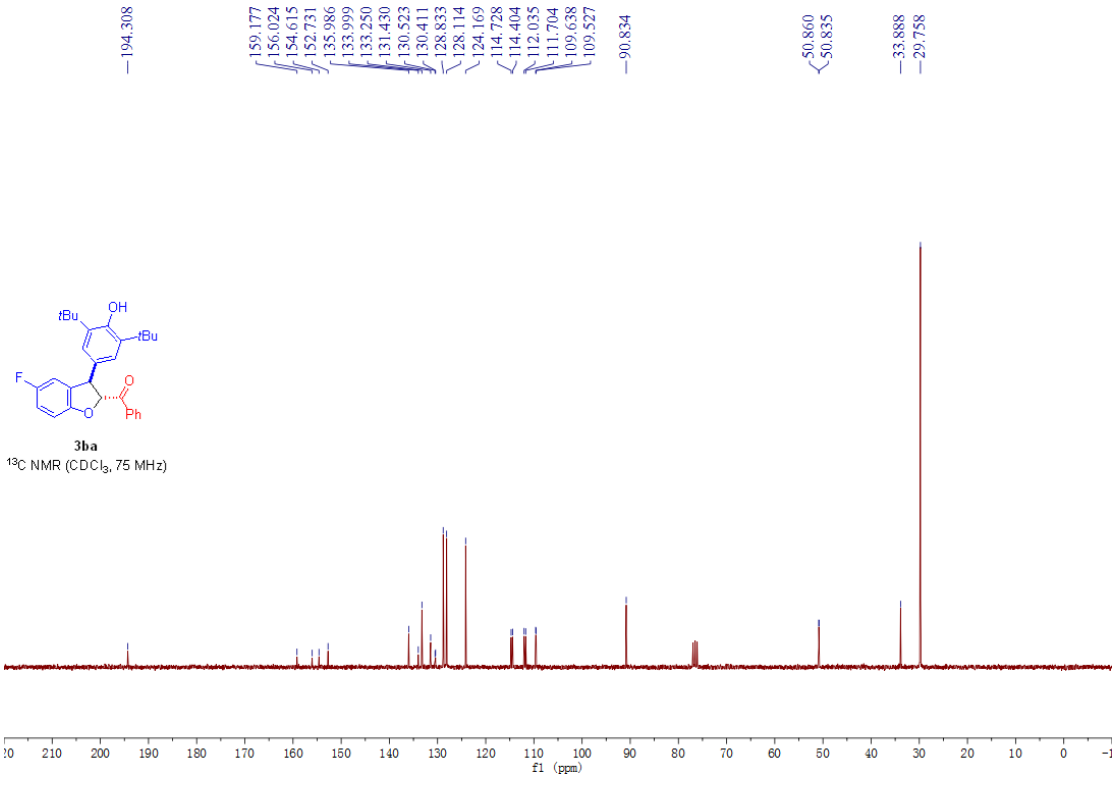






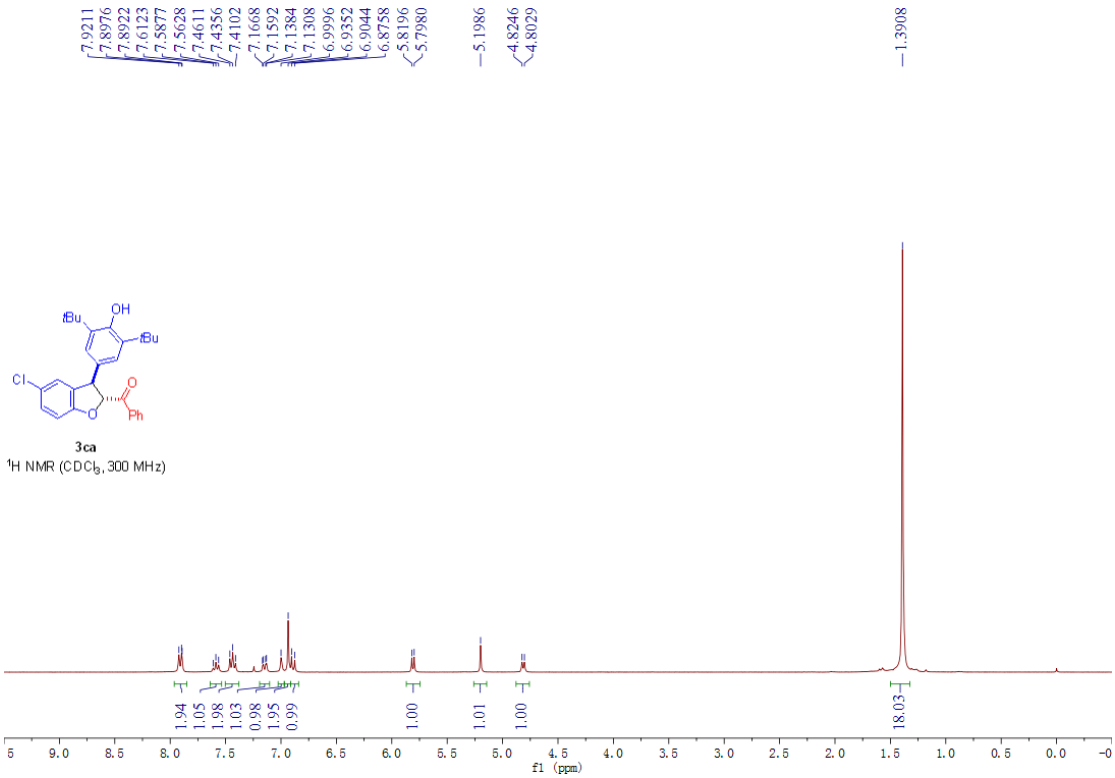
3ba

^{1}H NMR ($CDCl_3$, 300 MHz)



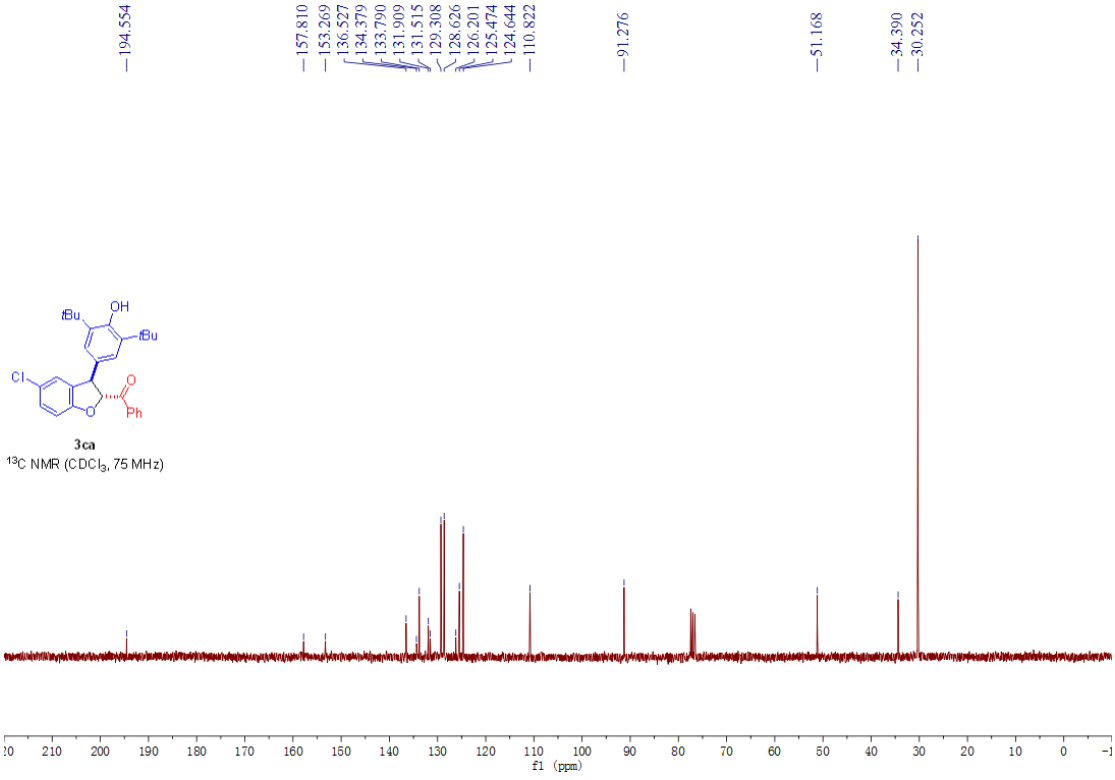
3ba

^{13}C NMR ($CDCl_3$, 75 MHz)



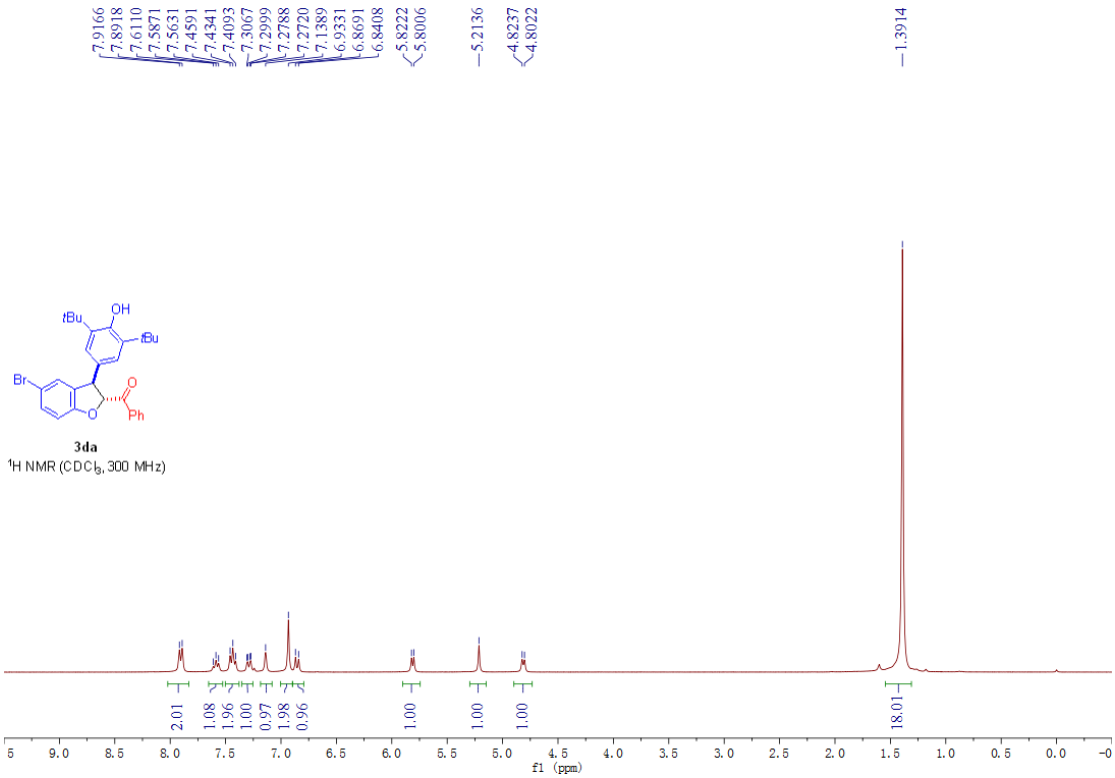
3ca

^{1}H NMR ($CDCl_3$, 300 MHz)



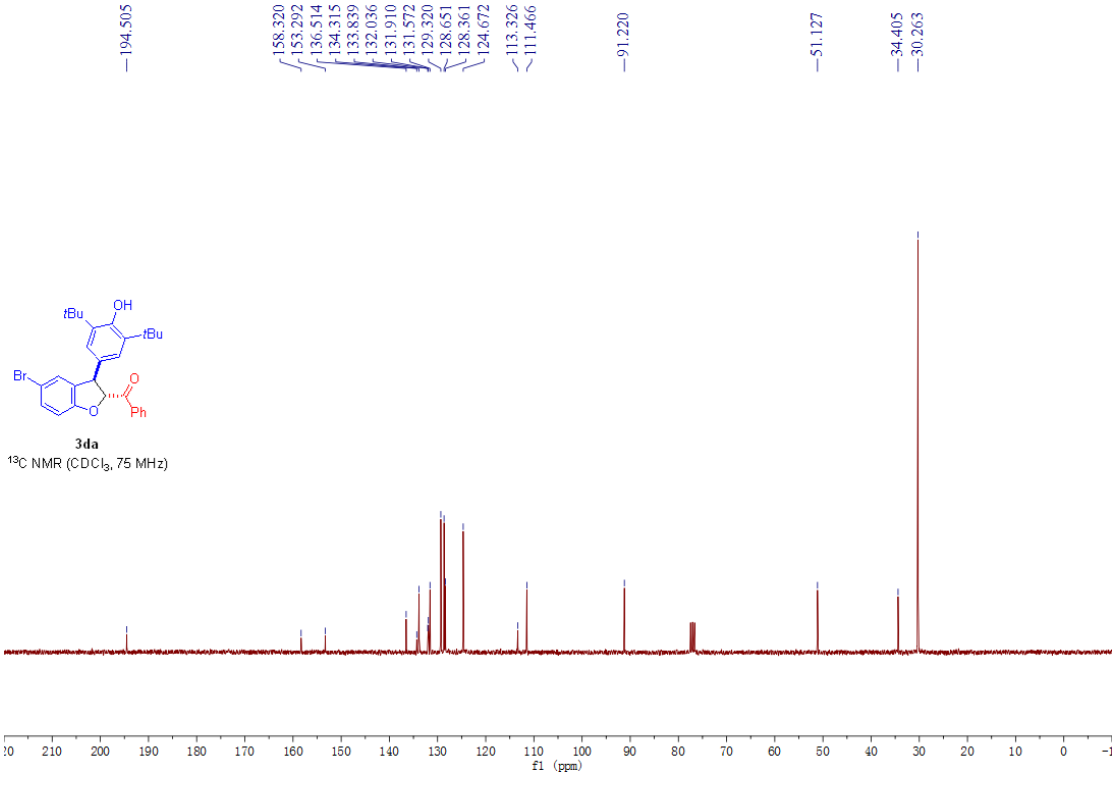
3ca

^{13}C NMR ($CDCl_3$, 75 MHz)



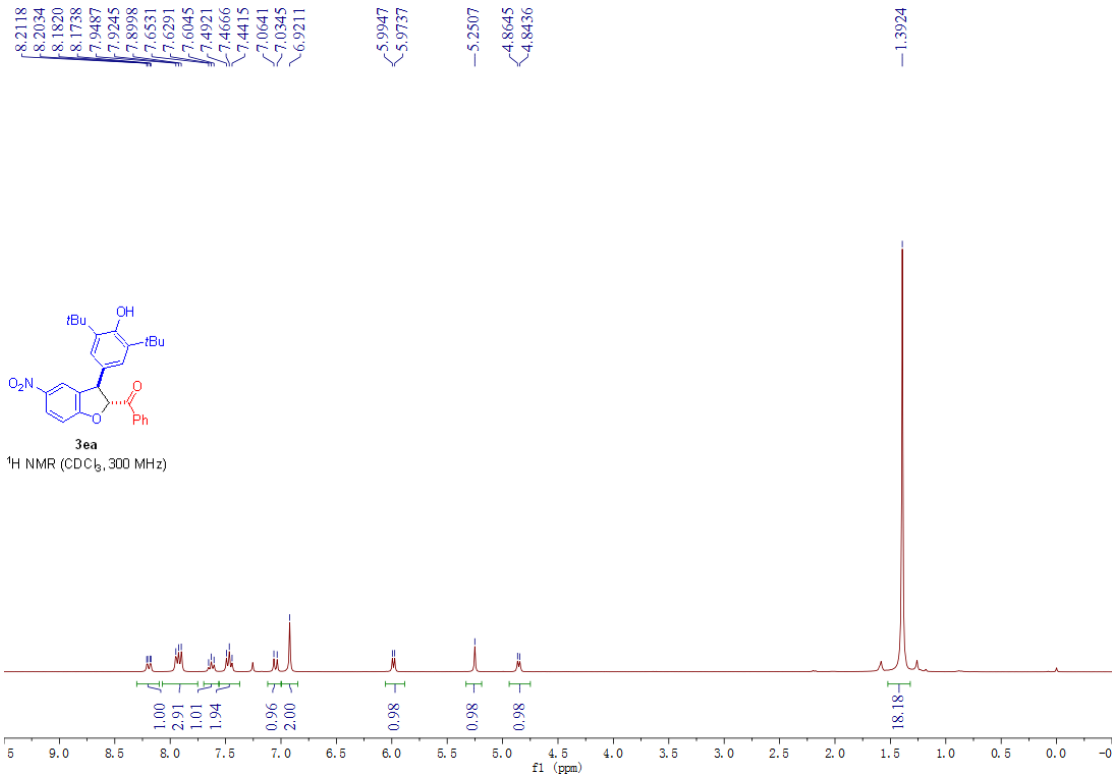
3da

^{1}H NMR ($CDCl_3$, 300 MHz)



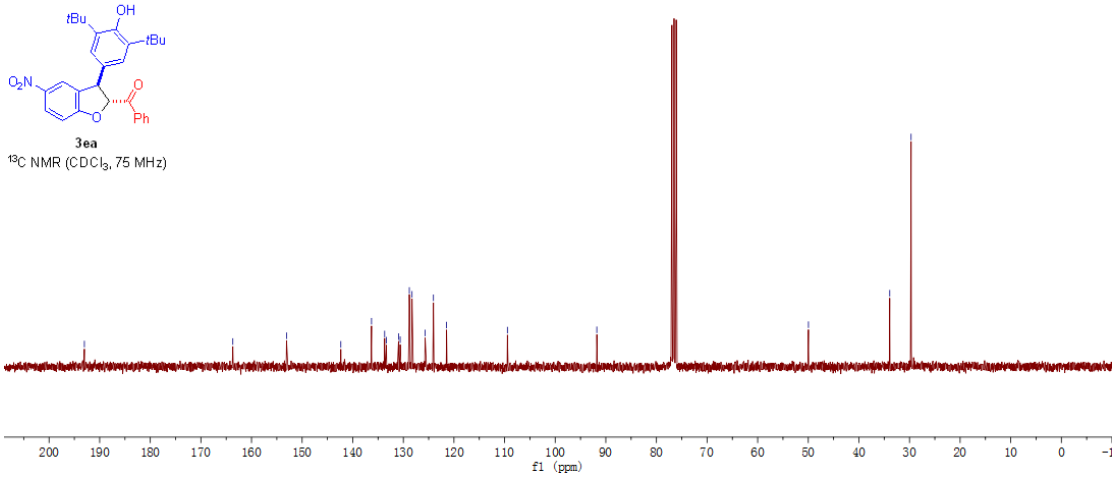
3da

^{13}C NMR ($CDCl_3$, 75 MHz)



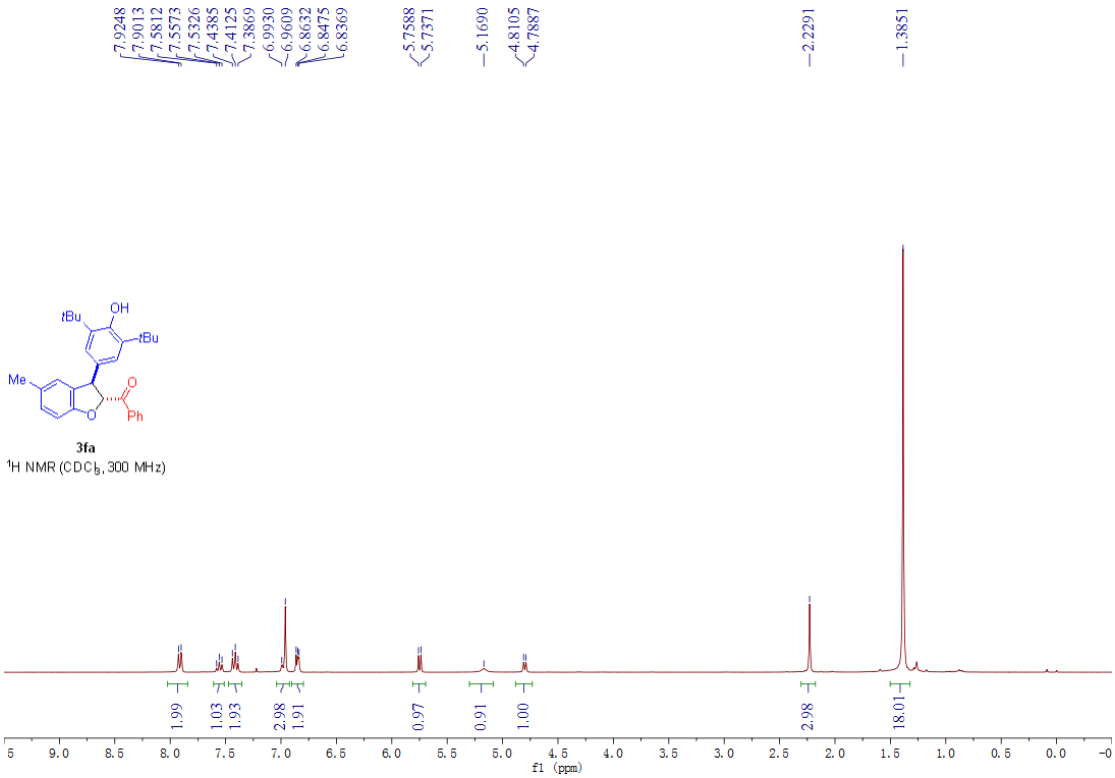
3ea

^{1}H NMR ($CDCl_3$, 300 MHz)



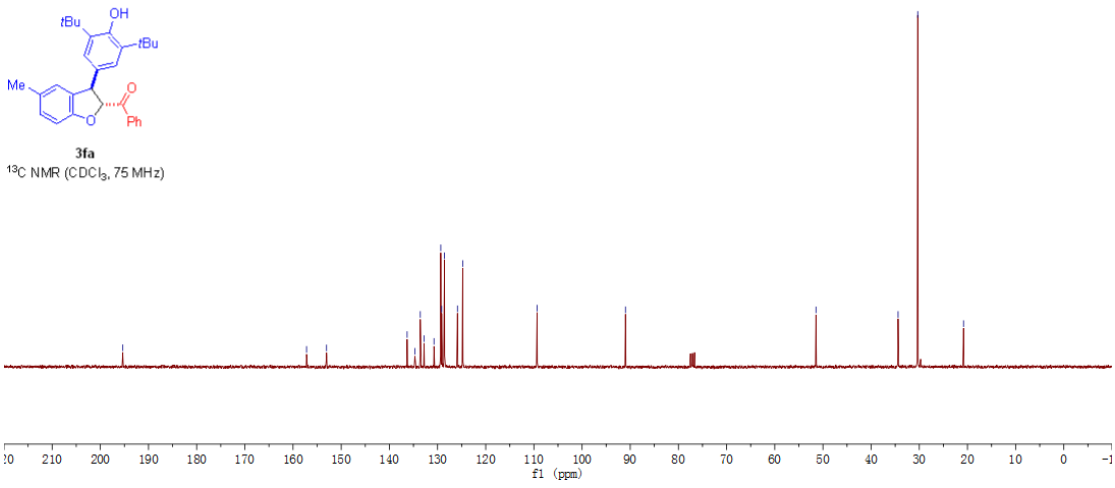
3ea

^{13}C NMR ($CDCl_3$, 75 MHz)



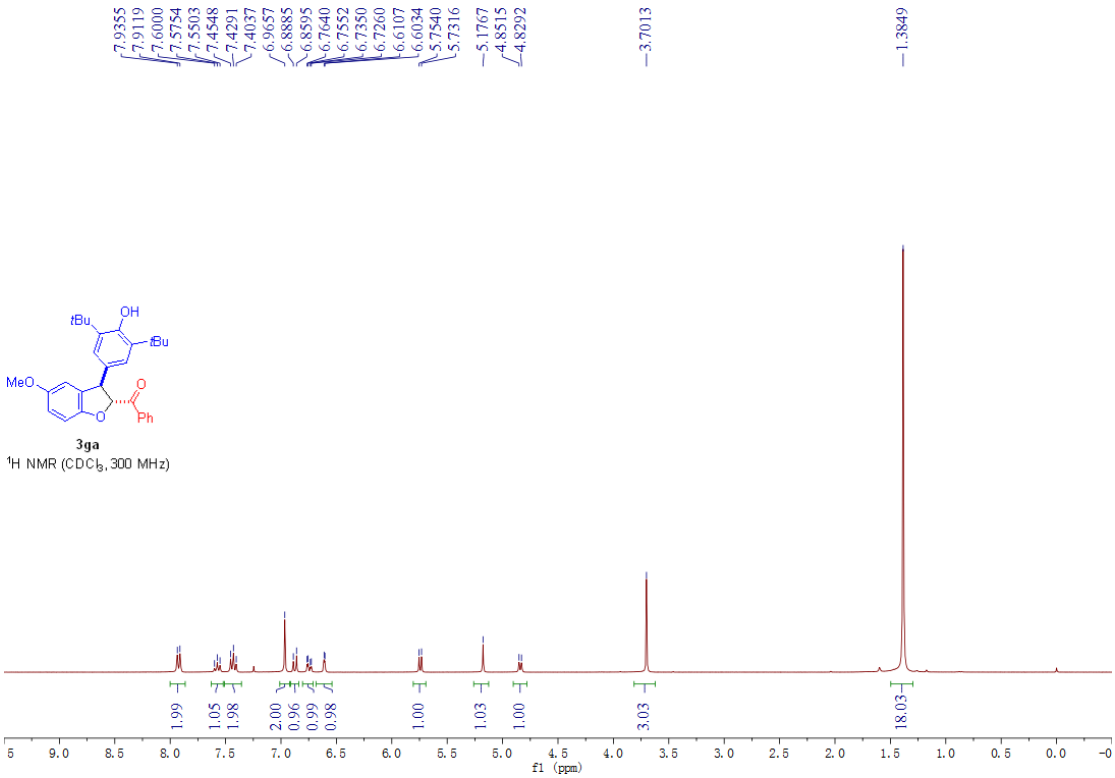
3fa

^{1}H NMR ($CDCl_3$, 300 MHz)



3fa

^{13}C NMR ($CDCl_3$, 75 MHz)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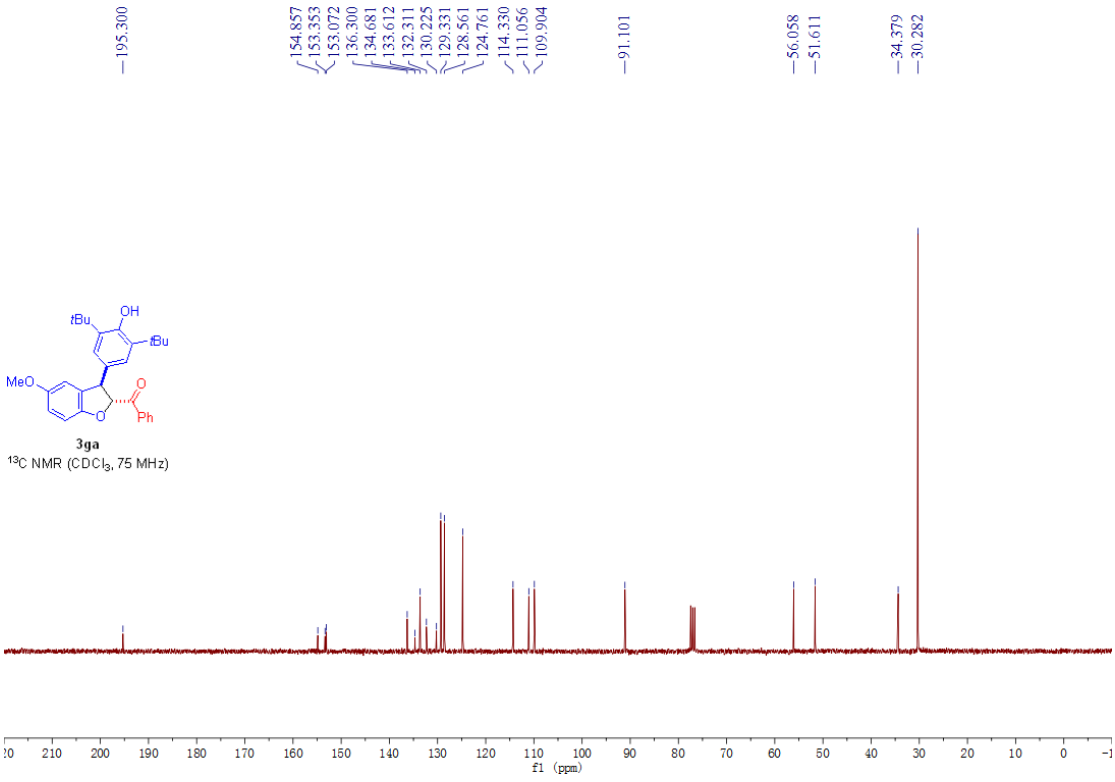
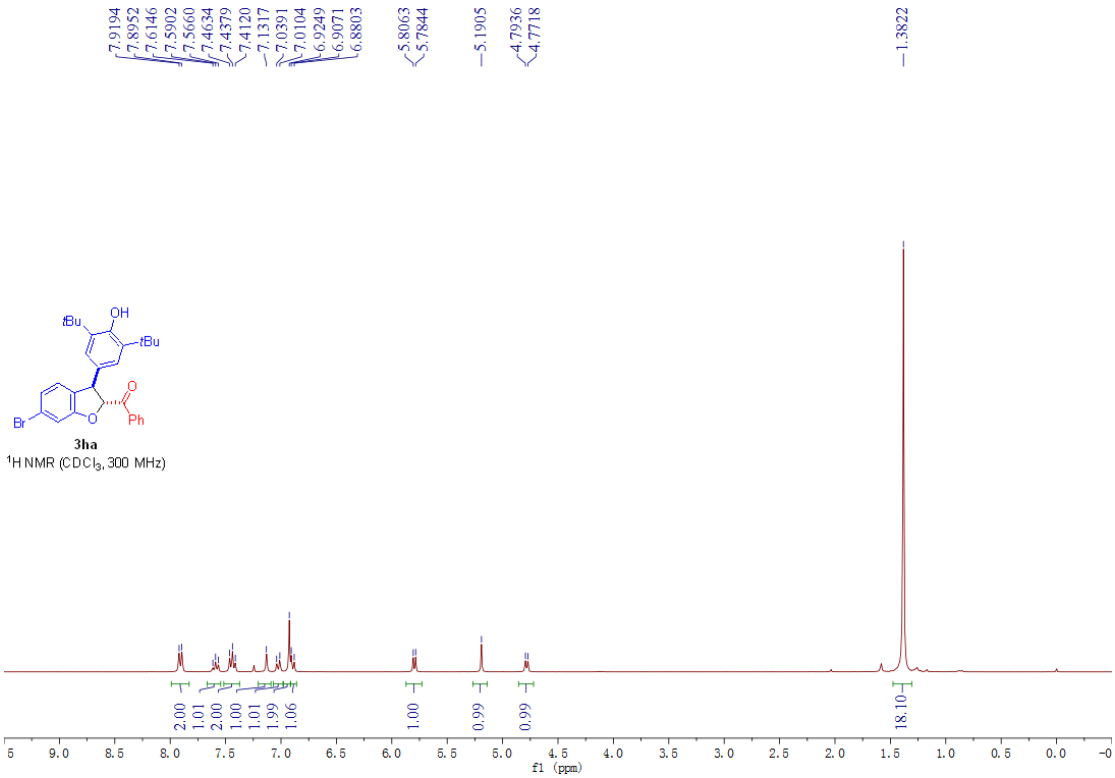
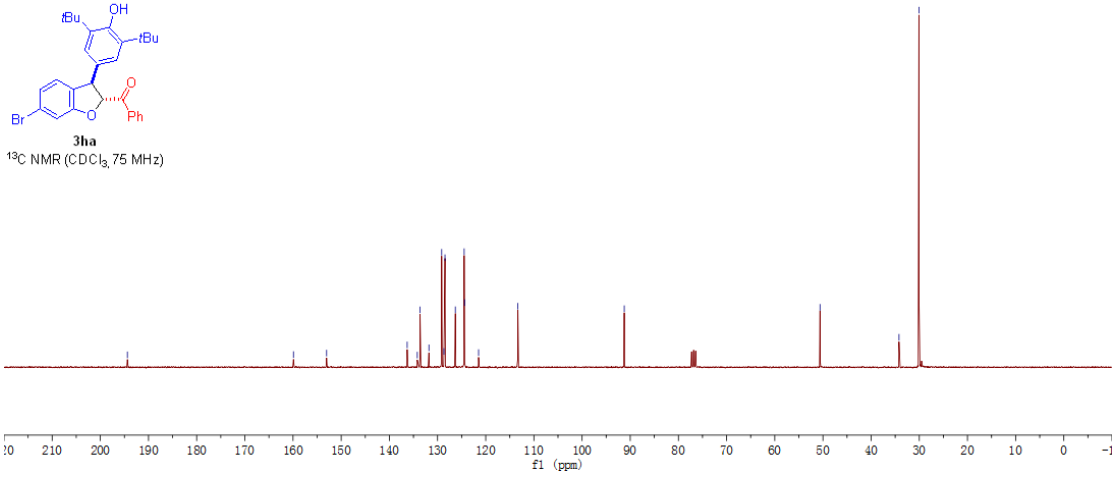
7.9119
7.6000
7.5754
7.5503
7.4548
7.4291
7.4037
6.9657
6.8885
6.8595
6.7640
6.7552
6.7350
6.7260
6.6107
6.6034
5.7540
5.7316
5.1767
4.8515
4.8292
3.7013
1.3849
tBu
OH
tBu
MeO
O
Ph
3ga
1H NMR (CDCl3, 300 MHz)
1.99
1.05
1.98
2.00
0.96
0.99
0.98
1.00
1.03
1.00
3.03
18.03
f1 (ppm)


195.300
154.857
153.353
153.072
136.300
134.681
133.612
132.311
130.225
129.331
128.561
124.761
114.330
111.056
109.904
91.101
56.058
51.611
34.379
30.282
tBu
OH
tBu
MeO
O
Ph
3ga
13C NMR (CDCl3, 75 MHz)
f1 (ppm)



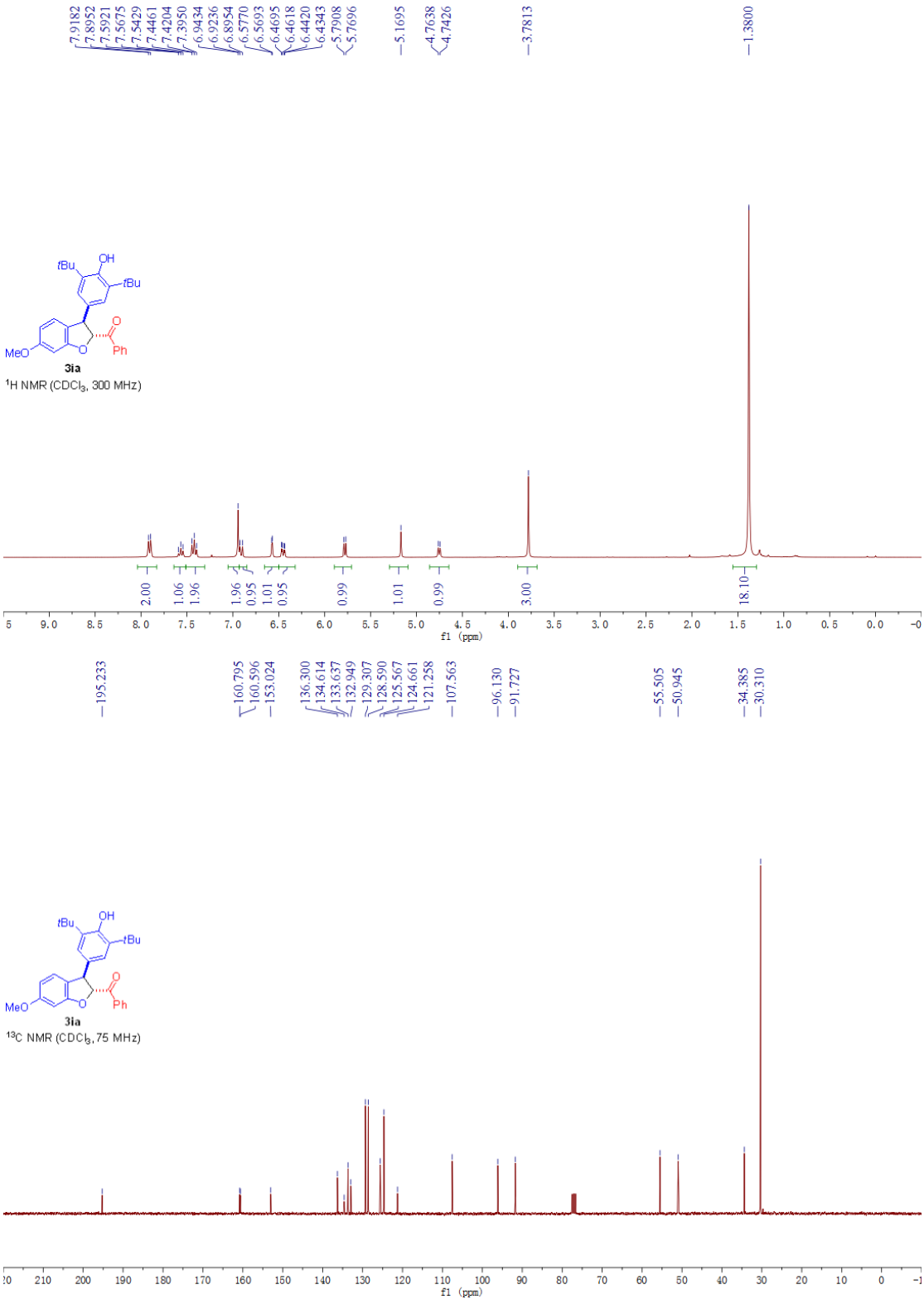
3ha

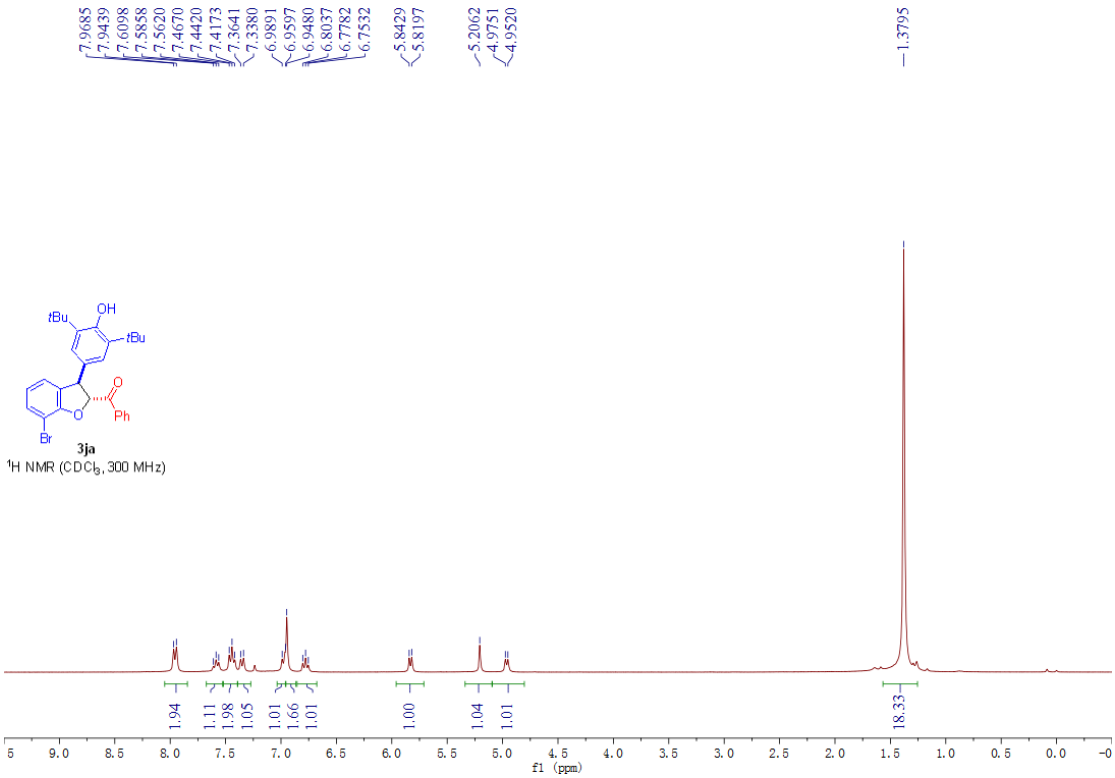
^{1}H NMR ($CDCl_3$, 300 MHz)



3ha

^{13}C NMR ($CDCl_3$, 75 MHz)


7.9182
7.8952
7.5921
7.5675
7.5429
7.4461
7.4204
7.3950
6.9434
6.9236
6.8954
6.5770
6.5693
6.4695
6.4618
6.4420
6.4343
5.7908
5.7696
5.1695
4.7638
4.7426
3.7813
1.3800
tBu
OH
tBu
MeO
O
Ph
3ia
1H NMR (CDCl3, 300 MHz)
2.00
1.06
1.96
1.96
0.95
1.01
0.95
0.99
1.01
0.99
3.00
18.10
f1 (ppm)
195.233
160.795
160.596
153.024
136.300
134.614
133.637
132.949
129.307
128.590
125.567
124.661
121.258
107.563
96.130
91.727
55.505
50.945
34.385
30.310
3ia
13C NMR (CDCl3, 75 MHz)
f1 (ppm)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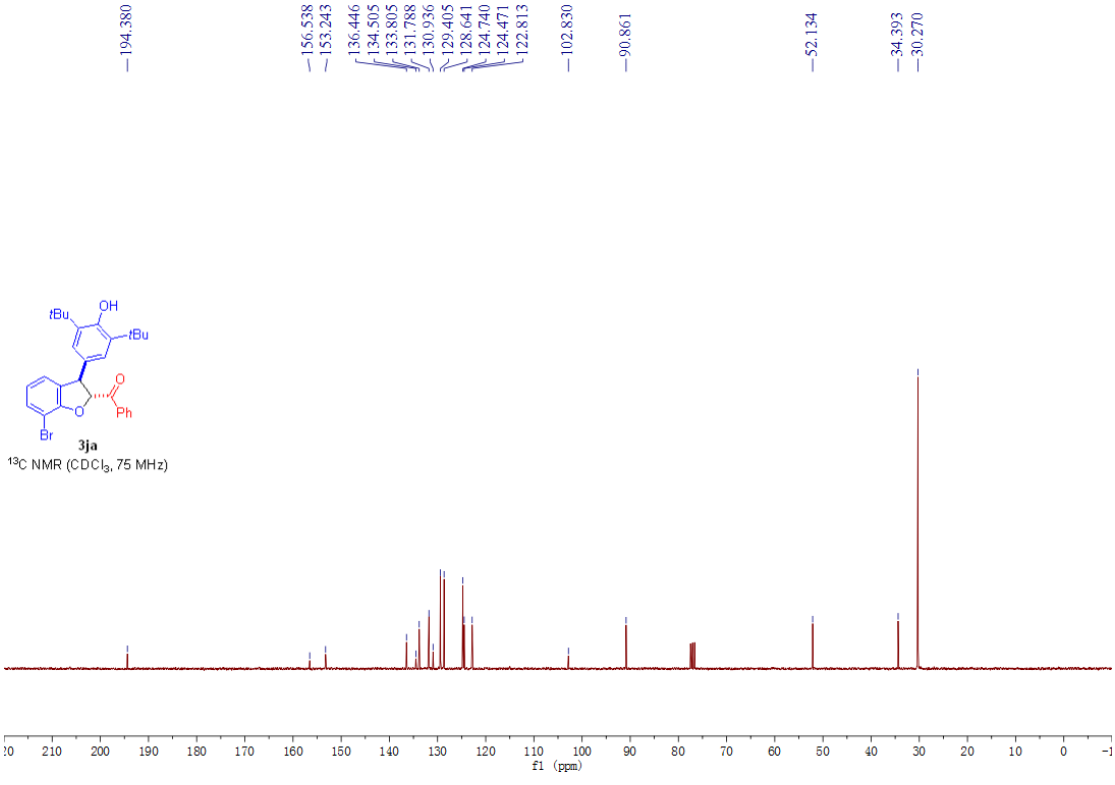
7.9439
7.6098
7.5858
7.5620
7.4670
7.4420
7.4173
7.3641
7.3380
6.9891
6.9597
6.9480
6.8037
6.7782
6.7532
5.8429
5.8197
5.2062
4.9751
4.9520
1.3795
tBu
OH
tBu
O
Ph
Br
3ja
1H NMR (CDCl3, 300 MHz)
1.94
1.11
1.98
1.05
1.01
1.66
1.01
1.00
1.04
1.01
18.33
f1 (ppm)


194.380
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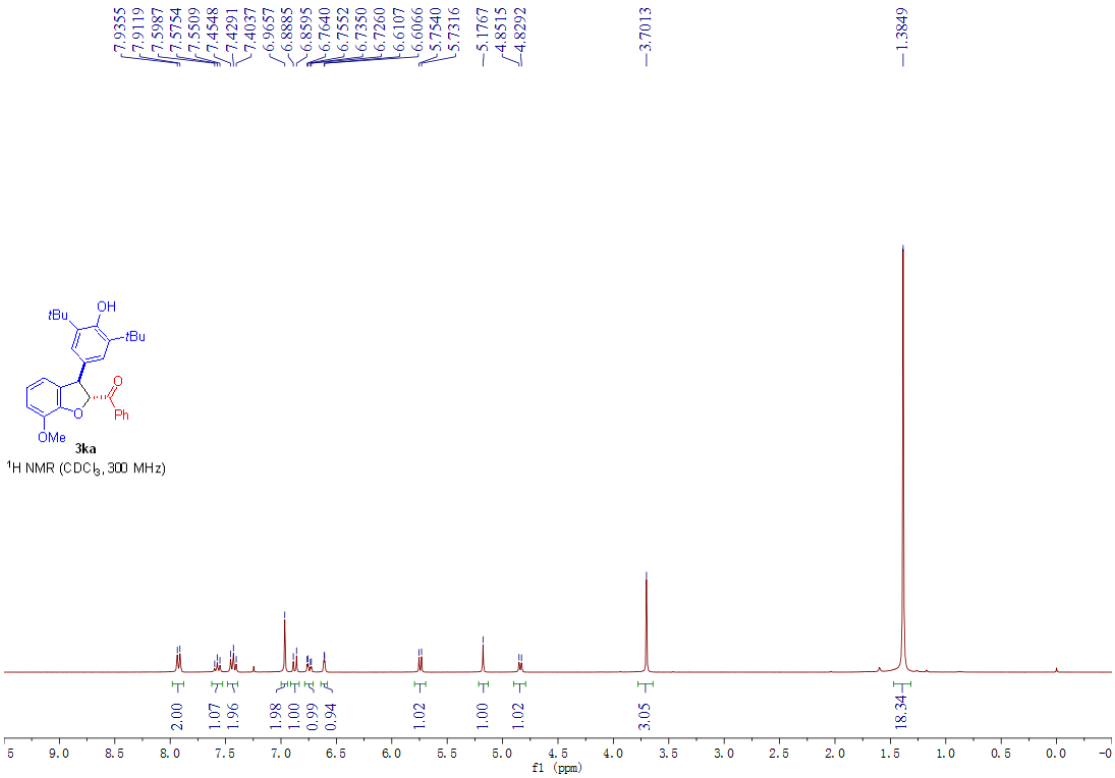
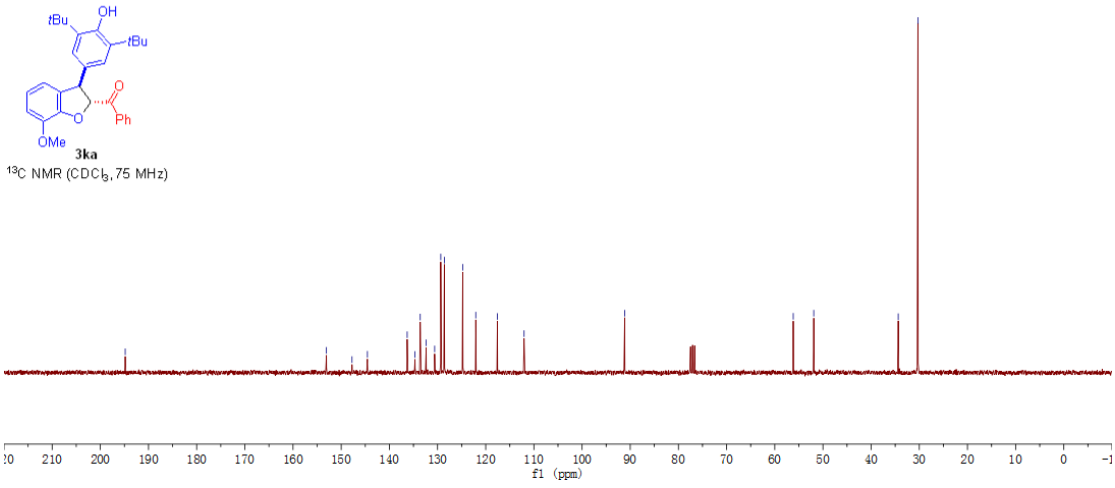
134.505
133.805
131.788
130.936
129.405
128.641
124.740
124.471
122.813
102.830
90.861
52.134
34.393
30.270
tBu
OH
tBu
O
Ph
Br
3ja
13C NMR (CDCl3, 75 MHz)
f1 (ppm)



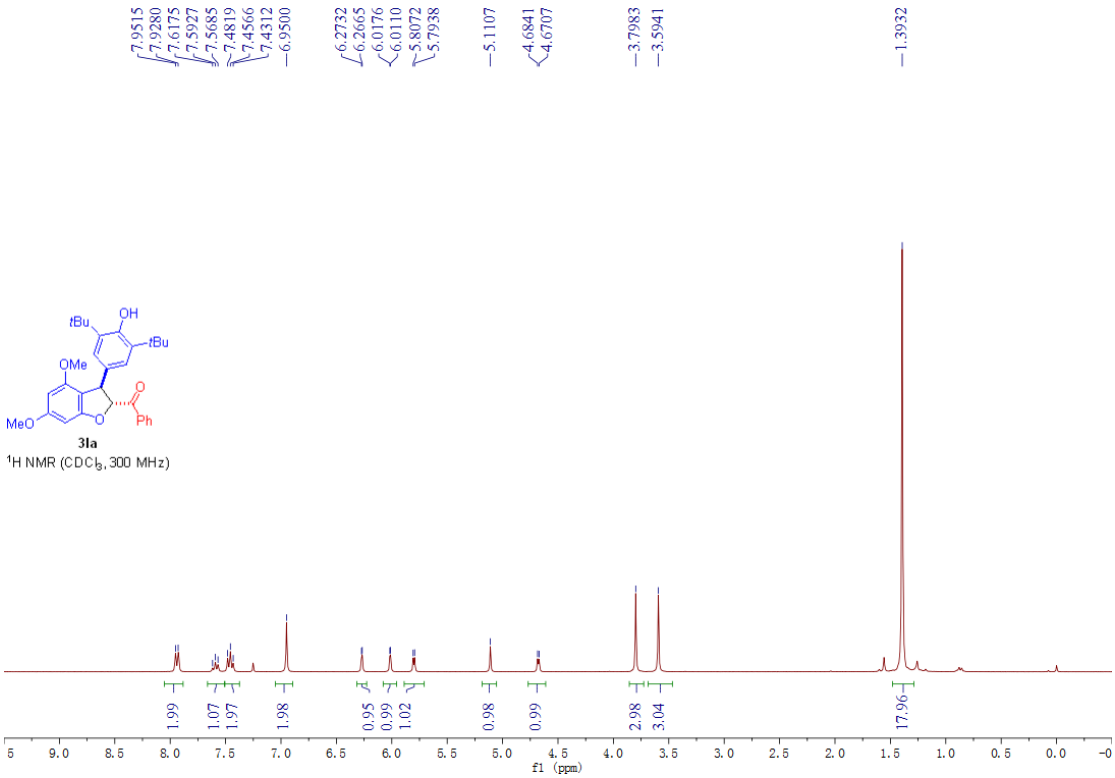
3ka

^{1}H NMR ($CDCl_3$, 300 MHz)



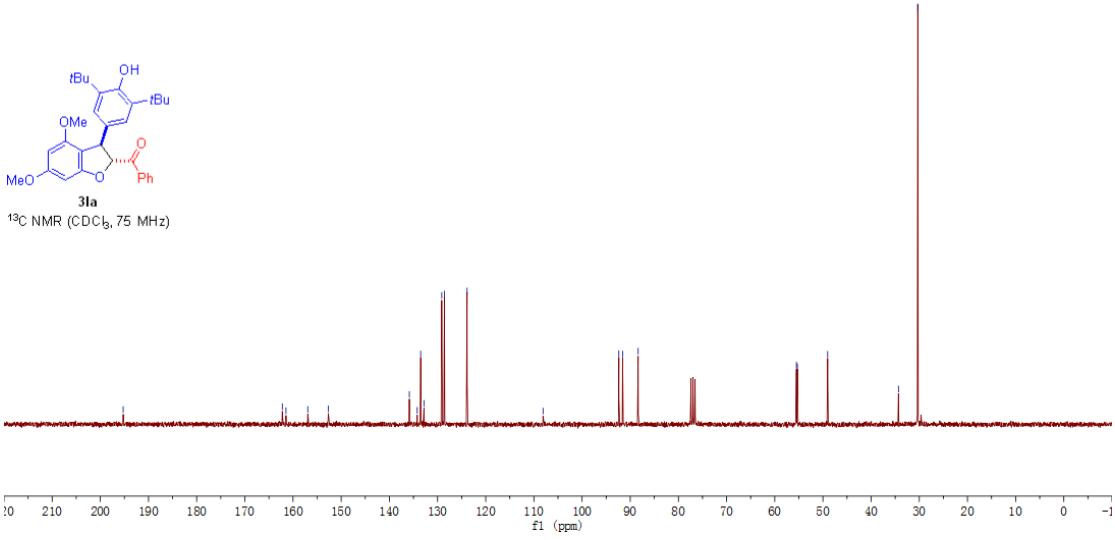
3ka

^{13}C NMR ($CDCl_3$, 75 MHz)



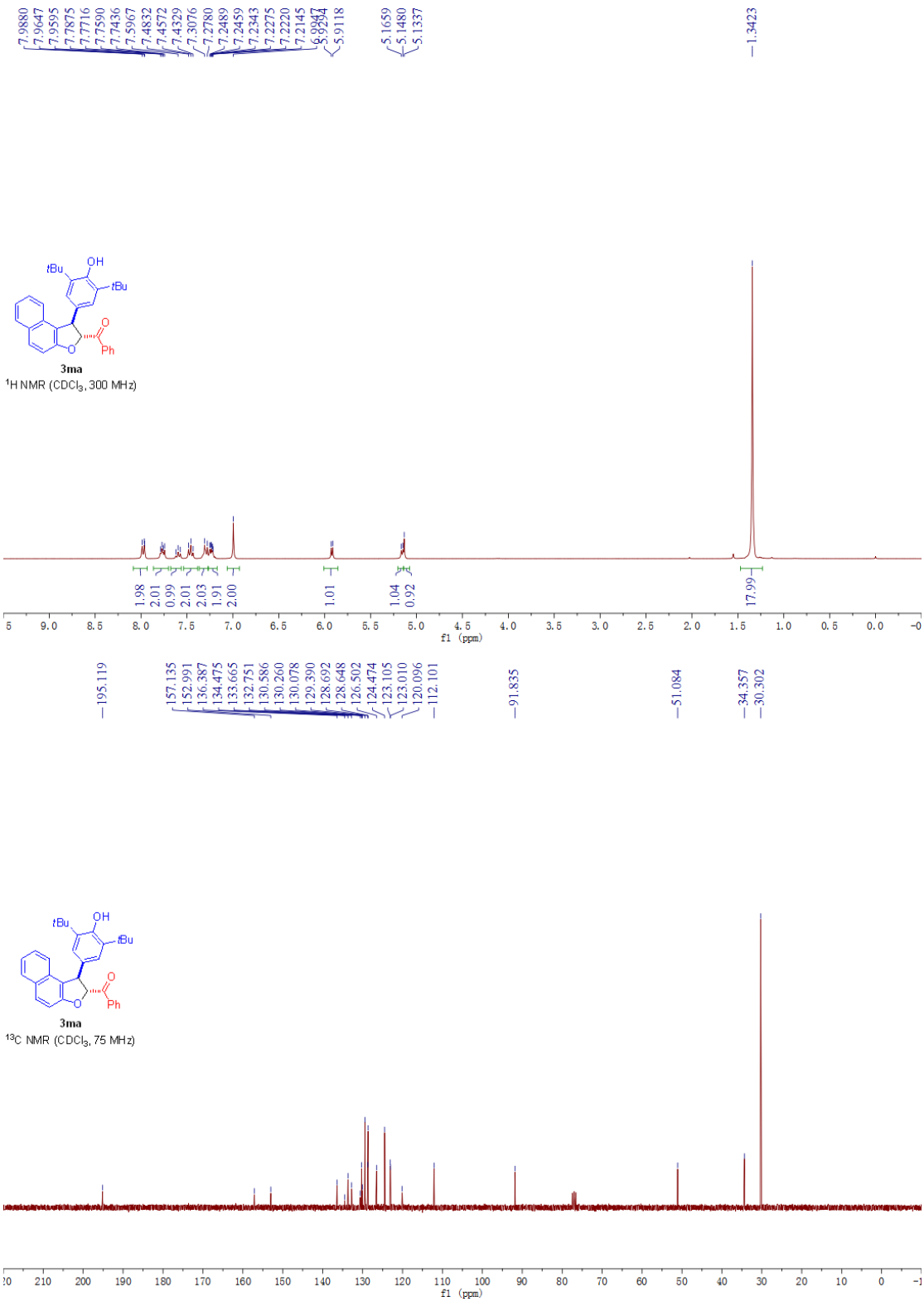
3la

^{1}H NMR ($CDCl_3$, 300 MHz)



3la

^{13}C NMR ($CDCl_3$, 75 MHz)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7.7716
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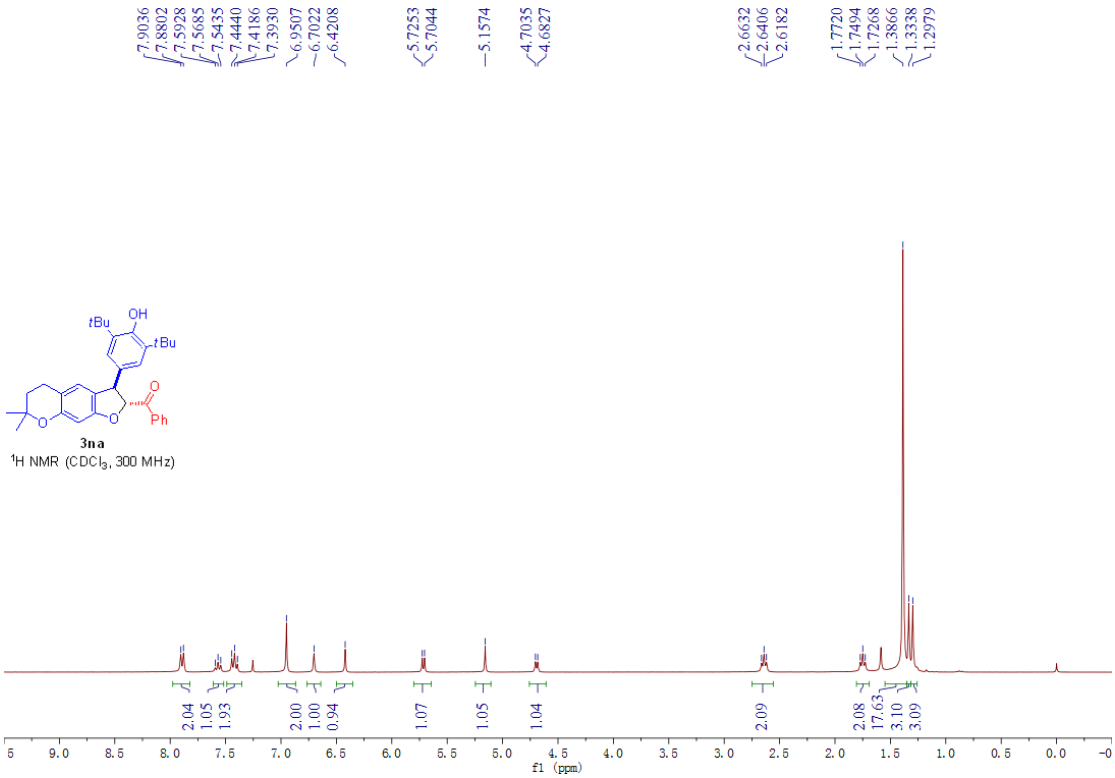
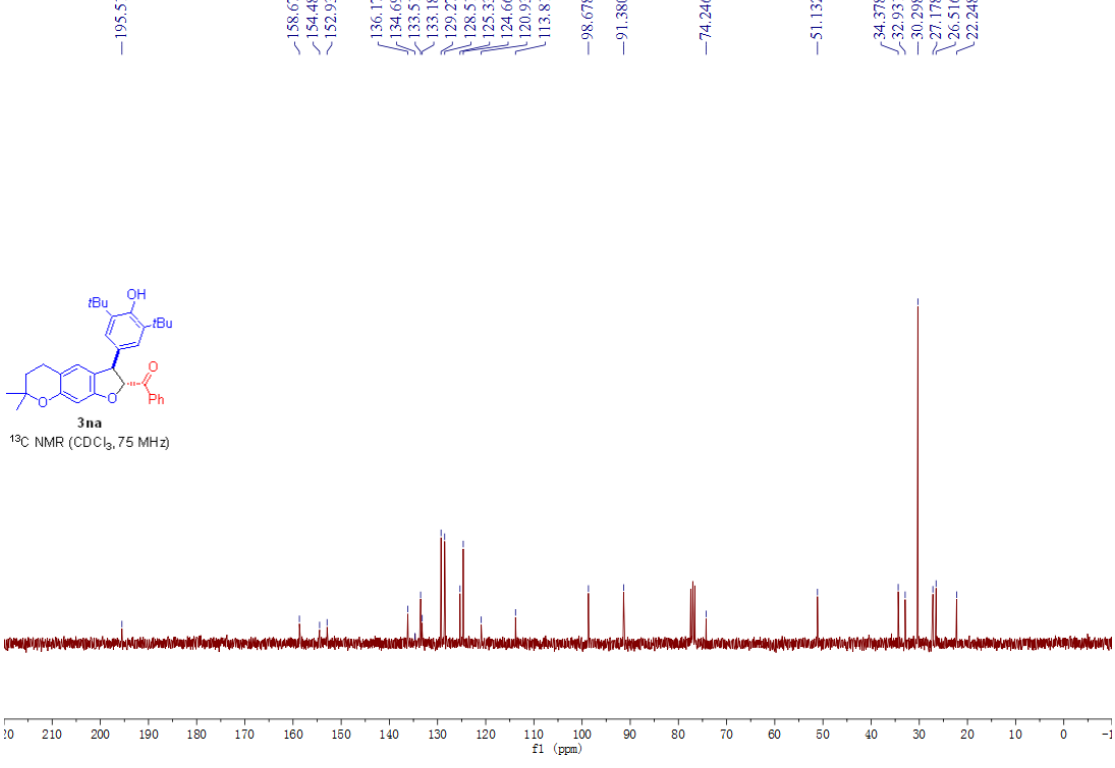
7.7436
7.5967
7.4832
7.4572
7.4329
7.3076
7.2780
7.2489
7.2459
7.2343
7.2275
7.2220
7.2145
6.8947
6.8934
5.9118
5.1659
5.1480
5.1337
1.3423
tBu
OH
tBu
O
Ph
3ma
1H NMR (CDCl3, 300 MHz)
1.98
2.01
0.99
2.01
2.03
1.91
2.00
1.01
1.04
0.92
17.99
f1 (ppm)
195.119
157.135
152.991
136.387
134.475
133.665
132.751
130.586
130.260
130.078
129.390
128.692
128.648
126.502
124.474
123.105
123.010
120.096
112.101
91.835
51.084
34.357
30.302
3ma
13C NMR (CDCl3, 75 MHz)
f1 (ppm)



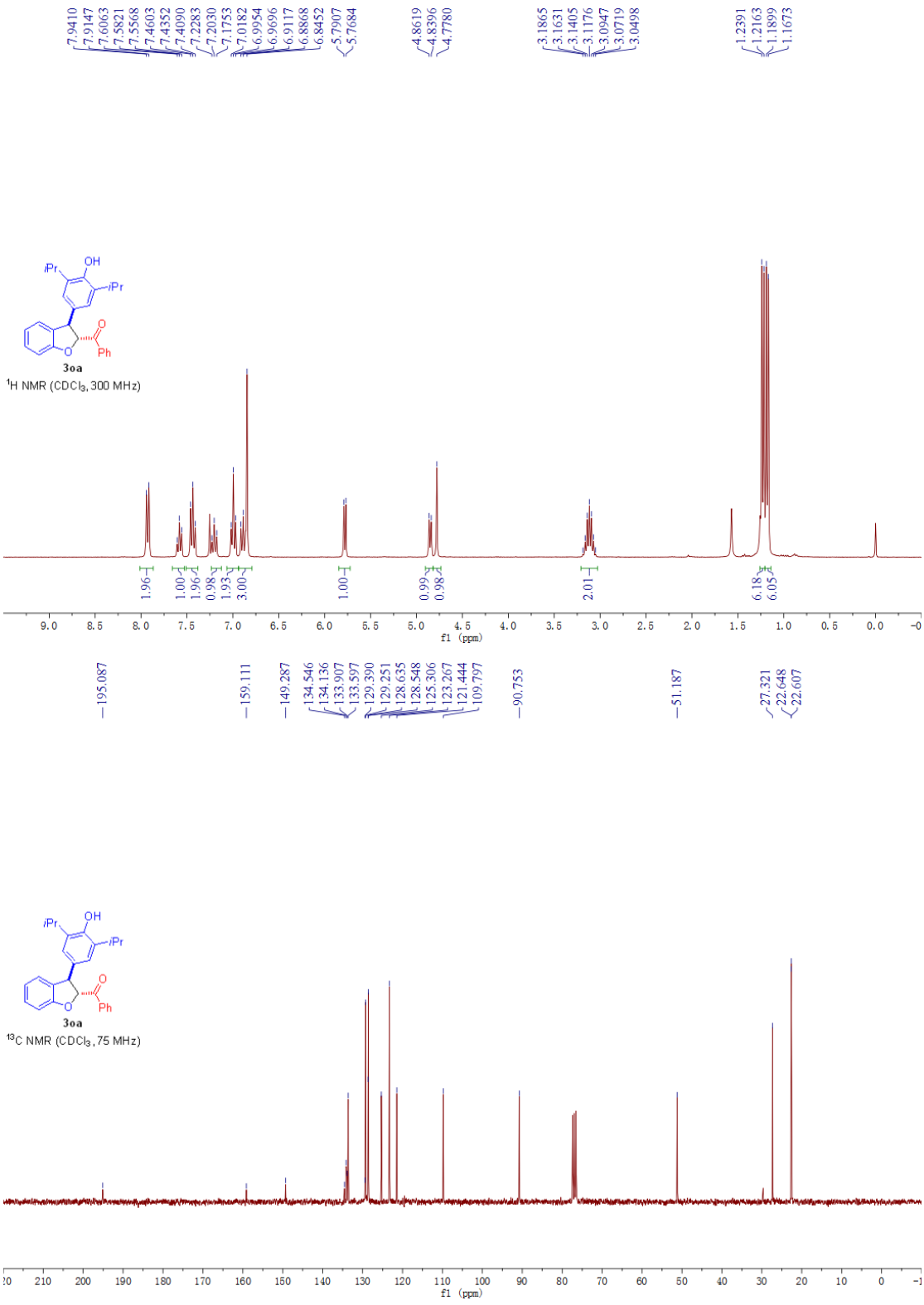
3na

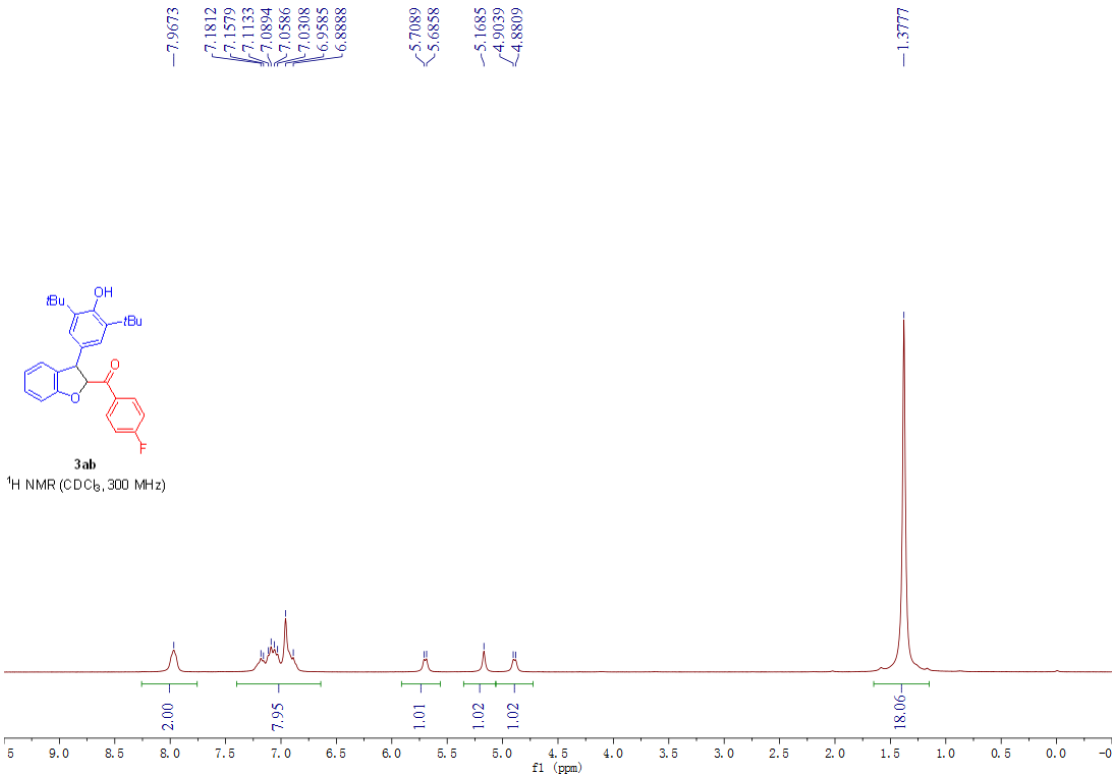
^{1}H NMR ($CDCl_3$, 300 MHz)

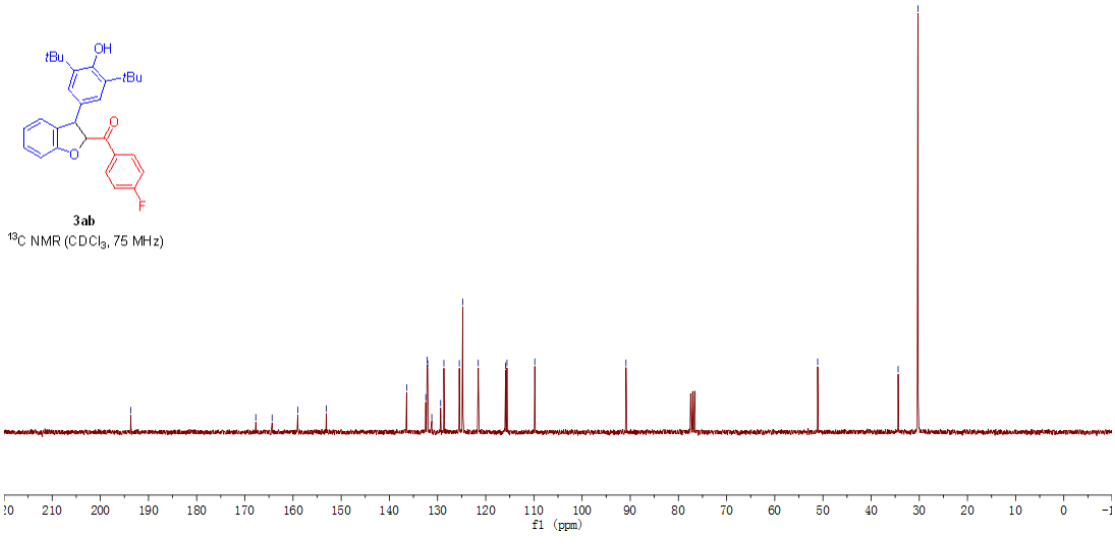


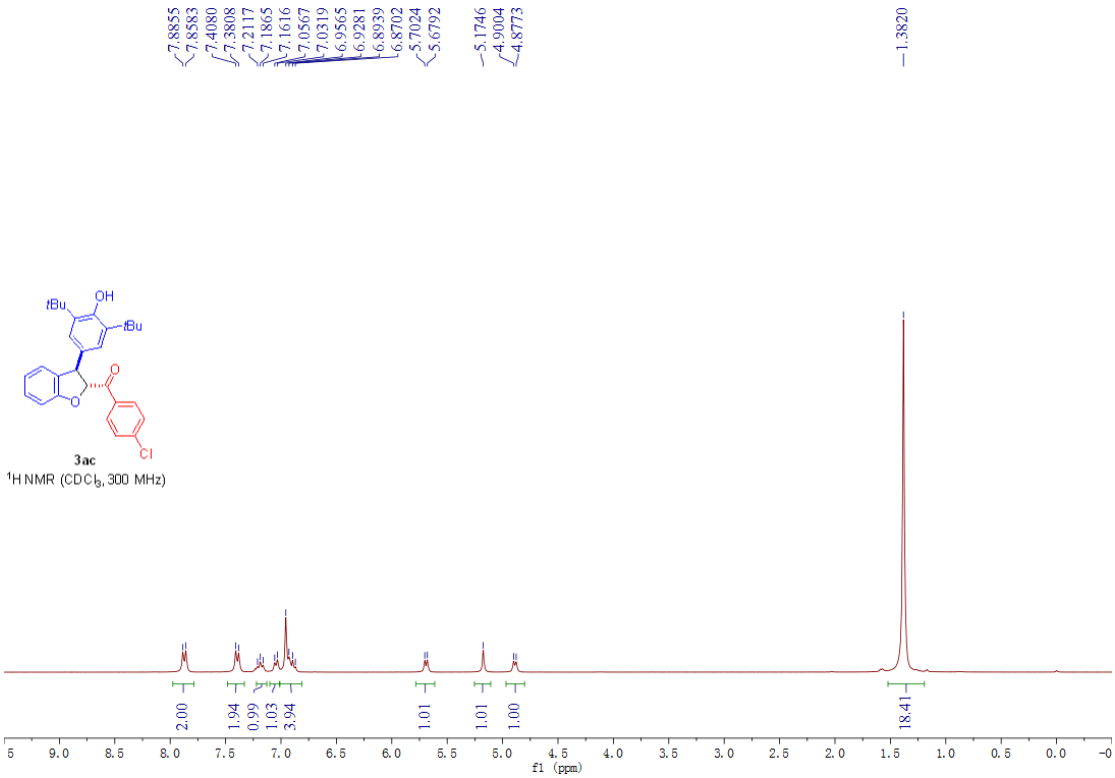
3na

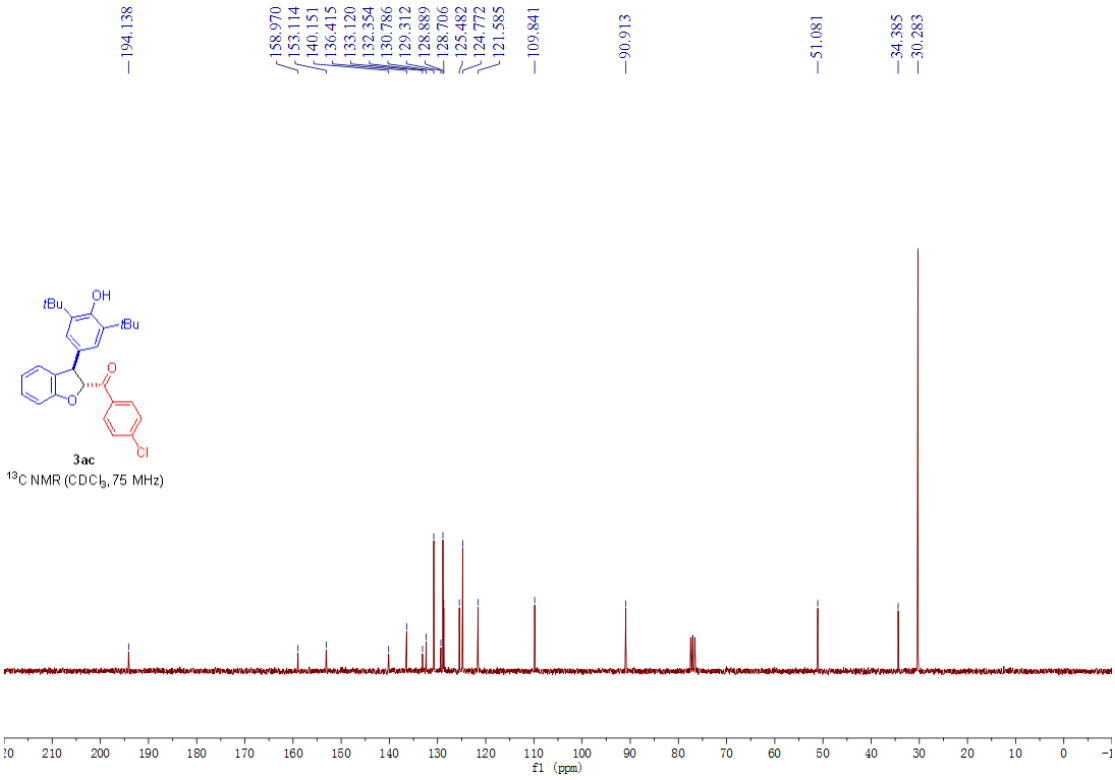
^{13}C NMR ($CDCl_3$, 75 MHz)

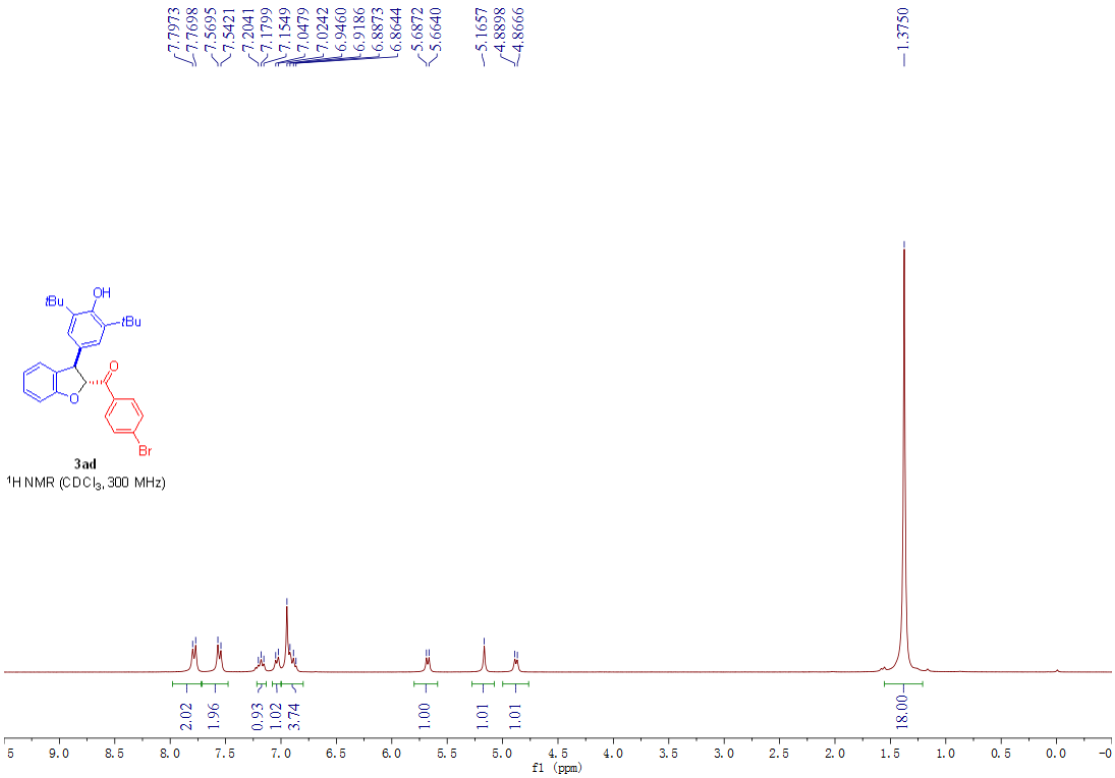

7.9410
7.9147
7.6063
7.5821
7.5568
7.4603
7.4352
7.4090
7.2283
7.2030
7.1753
7.0182
6.9954
6.9696
6.9117
6.8868
6.8452
5.7907
5.7684
4.8619
4.8396
4.7780
3.1865
3.1631
3.1405
3.1176
3.0947
3.0719
3.0498
1.2391
1.2163
1.1899
1.1673
iPr
OH
iPr
O
Ph
3oa
1H NMR (CDCl3, 300 MHz)
1.96
1.00
1.96
0.98
1.93
3.00
1.00
0.99
0.98
2.01
6.18
6.05
f1 (ppm)
195.087
159.111
149.287
134.546
134.136
133.907
133.597
129.390
129.251
128.635
128.548
125.306
123.267
121.444
109.797
90.753
51.187
27.321
22.648
22.607
3oa
13C NMR (CDCl3, 75 MHz)
f1 (ppm)

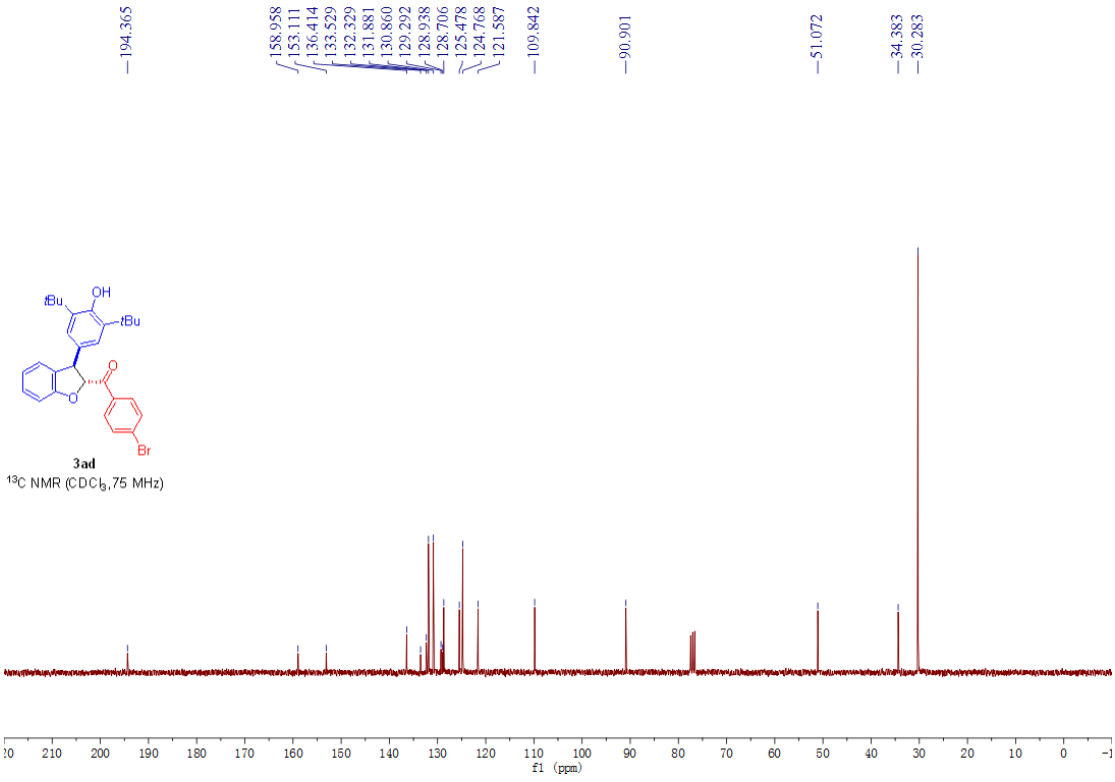

7.9673
7.1812
7.1579
7.1133
7.0894
7.0586
7.0308
6.9585
6.8888
5.7089
5.6858
5.1685
4.9039
4.8809
1.3777
tBu
OH
tBu
O
O
F
3ab
1H NMR (CDCl3, 300 MHz)
2.00
7.95
1.01
1.02
1.02
18.06
f1 (ppm)

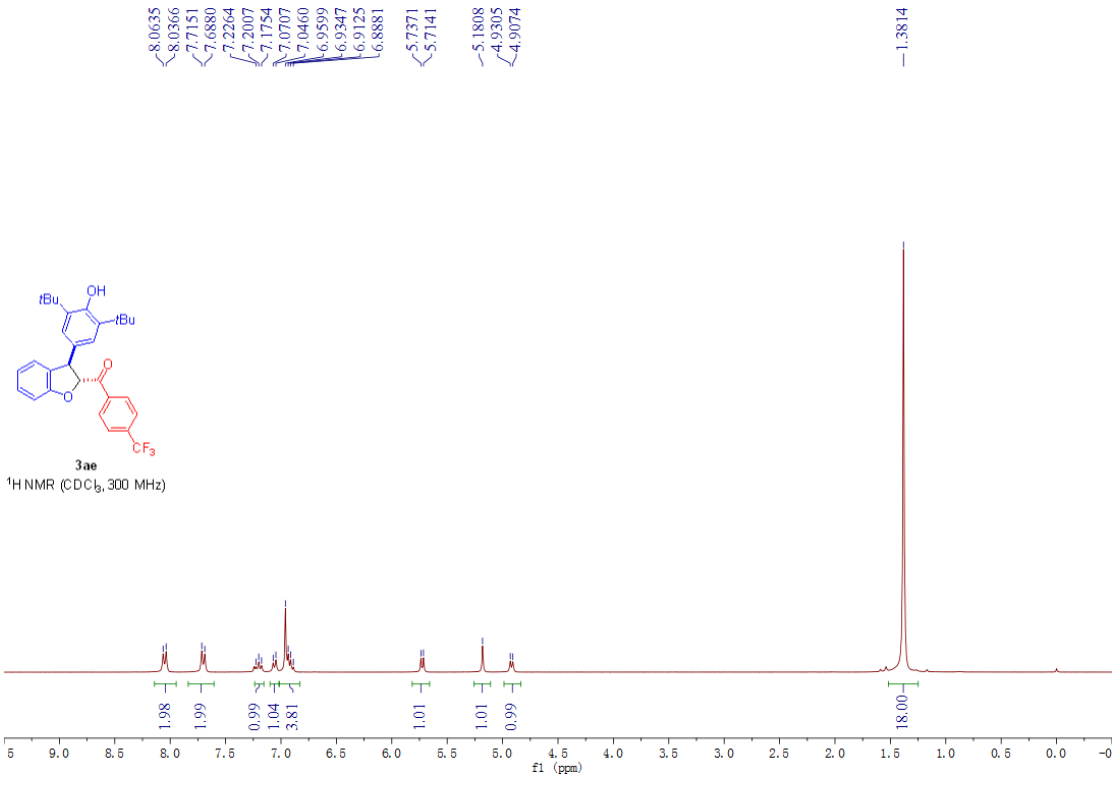

193.662
167.731
164.339
159.013
153.095
136.412
132.445
132.167
132.043
131.198
129.363
128.684
125.481
124.767
121.549
115.872
115.583
109.819
90.878
51.091
34.385
30.286
tBu
OH
tBu
O
O
F
3ab
13C NMR (CDCl3, 75 MHz)
f1 (ppm)


7.8855
7.8583
7.4080
7.3808
7.2117
7.1865
7.1616
7.0567
7.0319
6.9565
6.9281
6.8939
6.8702
5.7024
5.6792
5.1746
4.9004
4.8773
1.3820
tBu
OH
tBu
O
Cl
3ac
1H NMR (CDCl3, 300 MHz)
2.00
1.94
0.99
1.03
3.94
1.01
1.01
1.00
18.41
f1 (ppm)


194.138
158.970
153.114
140.151
136.415
133.120
132.354
130.786
129.312
128.889
128.706
125.482
124.772
121.585
109.841
90.913
51.081
34.385
30.283
tBu
OH
tBu
O
Cl
3ac
13C NMR (CDCl3, 75 MHz)
f1 (ppm)

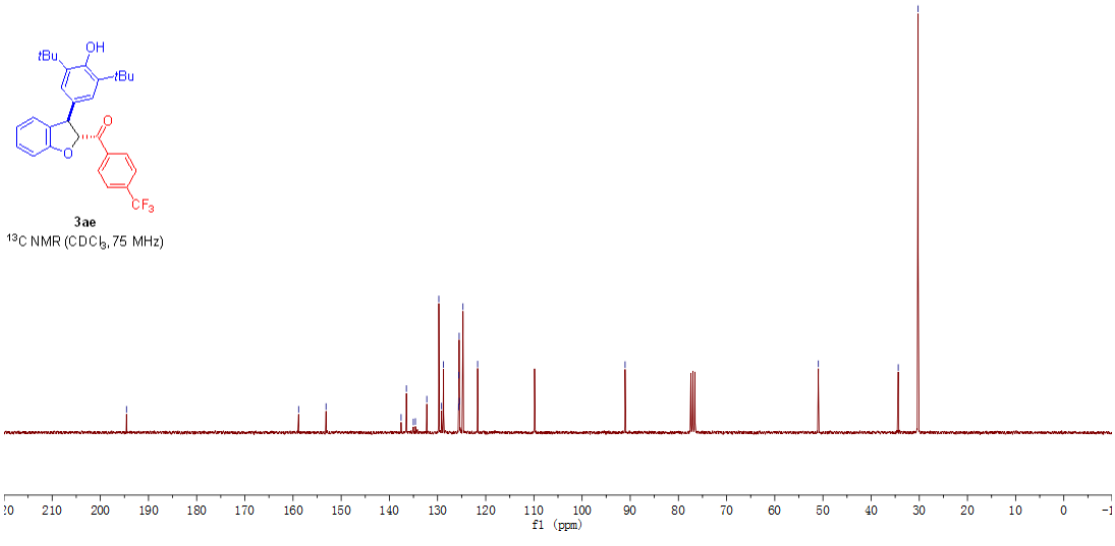

7.7973
7.7698
7.5695
7.5421
7.2041
7.1799
7.1549
7.0479
7.0242
6.9460
6.9186
6.8873
6.8644
5.6872
5.6640
5.1657
4.8898
4.8666
1.3750
tBu
OH
tBu
O
Br
3ad
1H NMR (CDCl3, 300 MHz)
2.02
1.96
0.93
1.02
3.74
1.00
1.01
1.01
18.00
f1 (ppm)


194.365
158.958
153.111
136.414
133.529
132.329
131.881
130.860
129.292
128.938
128.706
125.478
124.768
121.587
109.842
90.901
51.072
34.383
30.283
tBu
OH
tBu
O
Br
3ad
13C NMR (CDCl3, 75 MHz)
f1 (ppm)



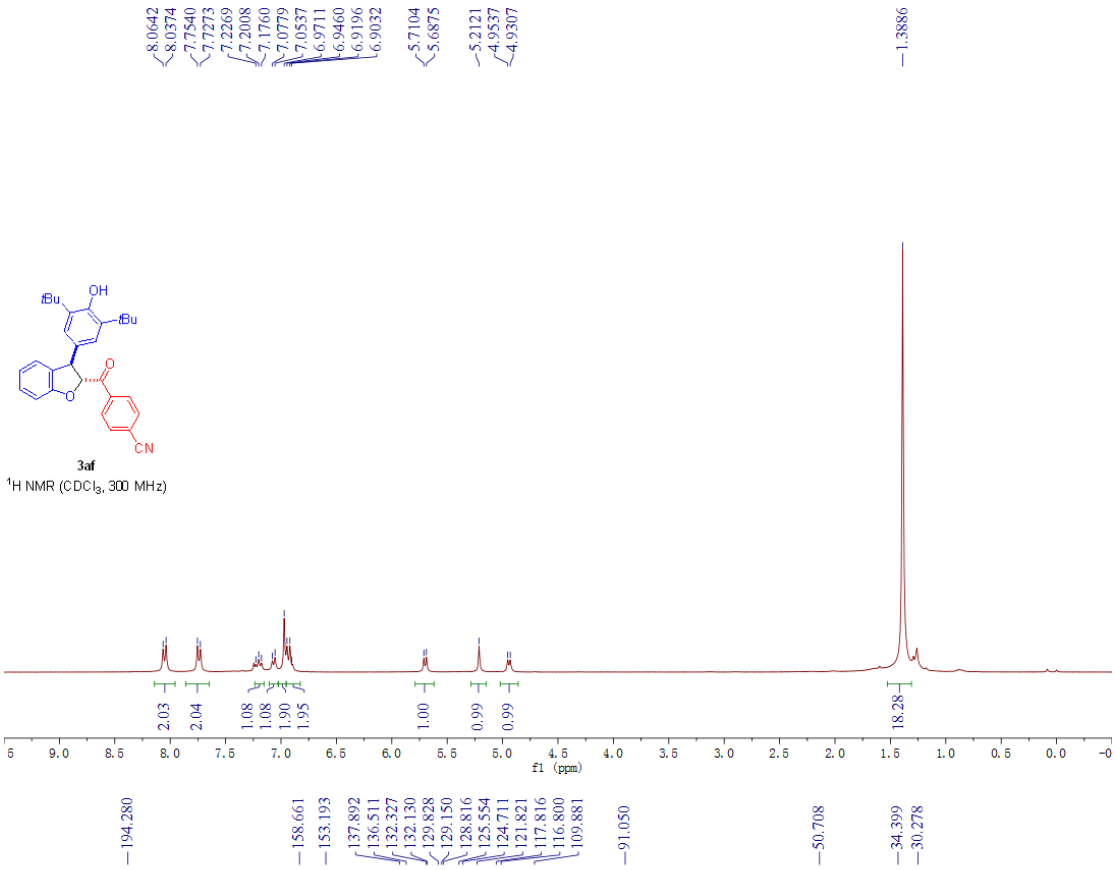
3ae

^{1}H NMR ($CDCl_3$, 300 MHz)



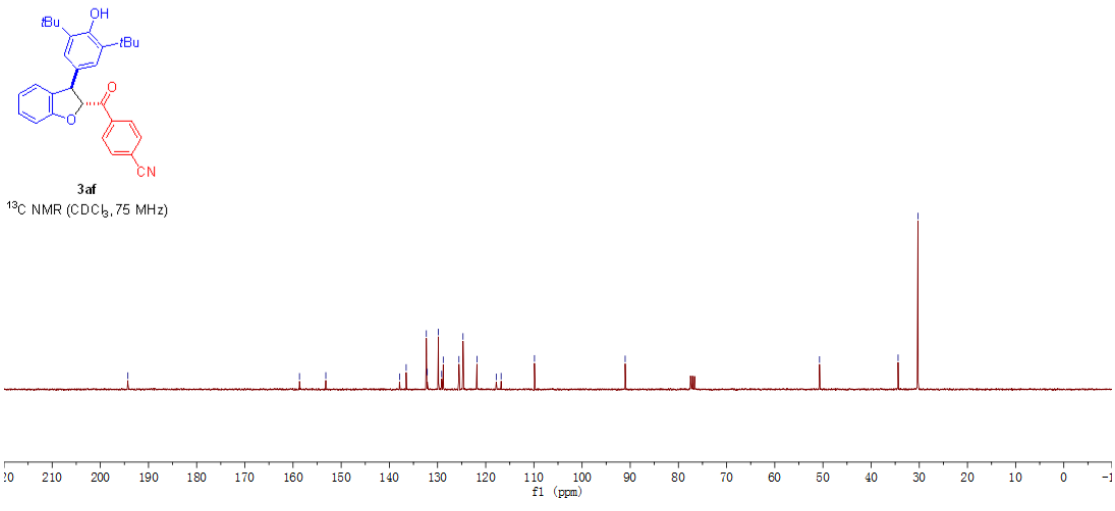
3ae

^{13}C NMR ($CDCl_3$, 75 MHz)



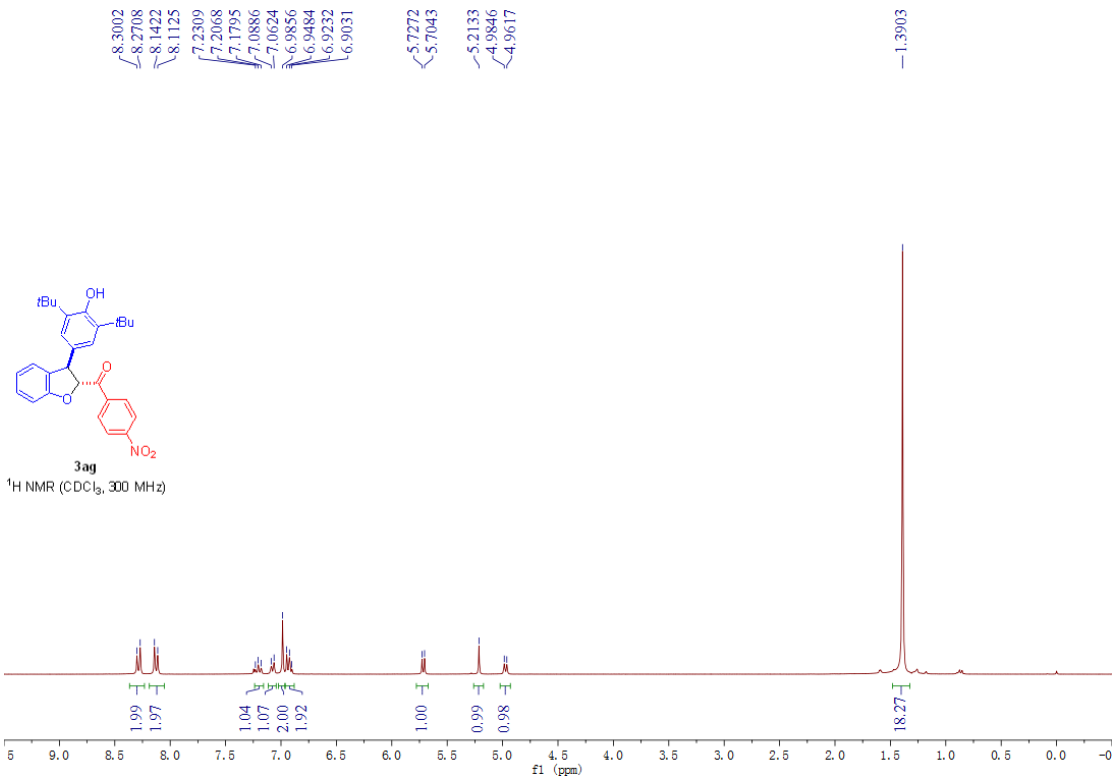
3af

^{1}H NMR ($CDCl_3$, 300 MHz)



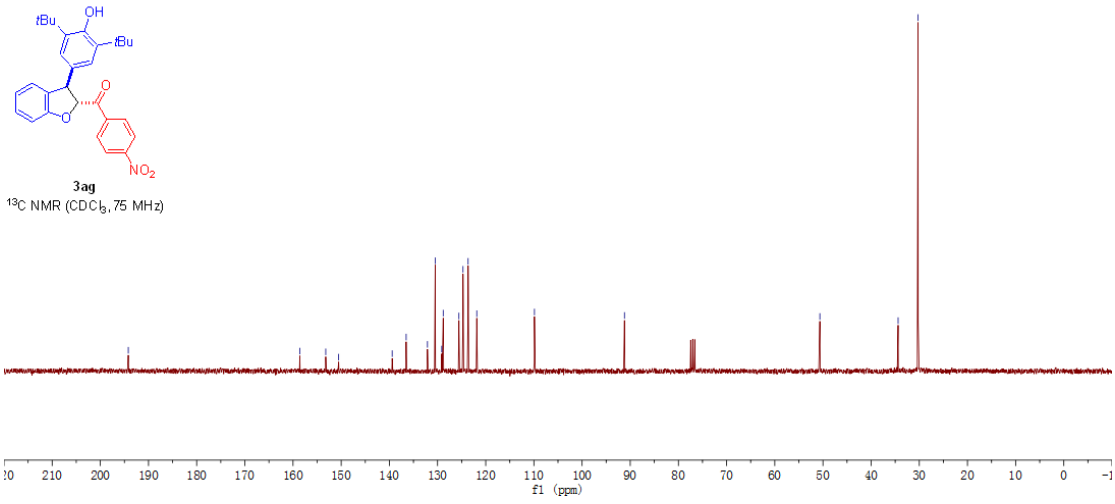
3af

^{13}C NMR ($CDCl_3$, 75 MHz)



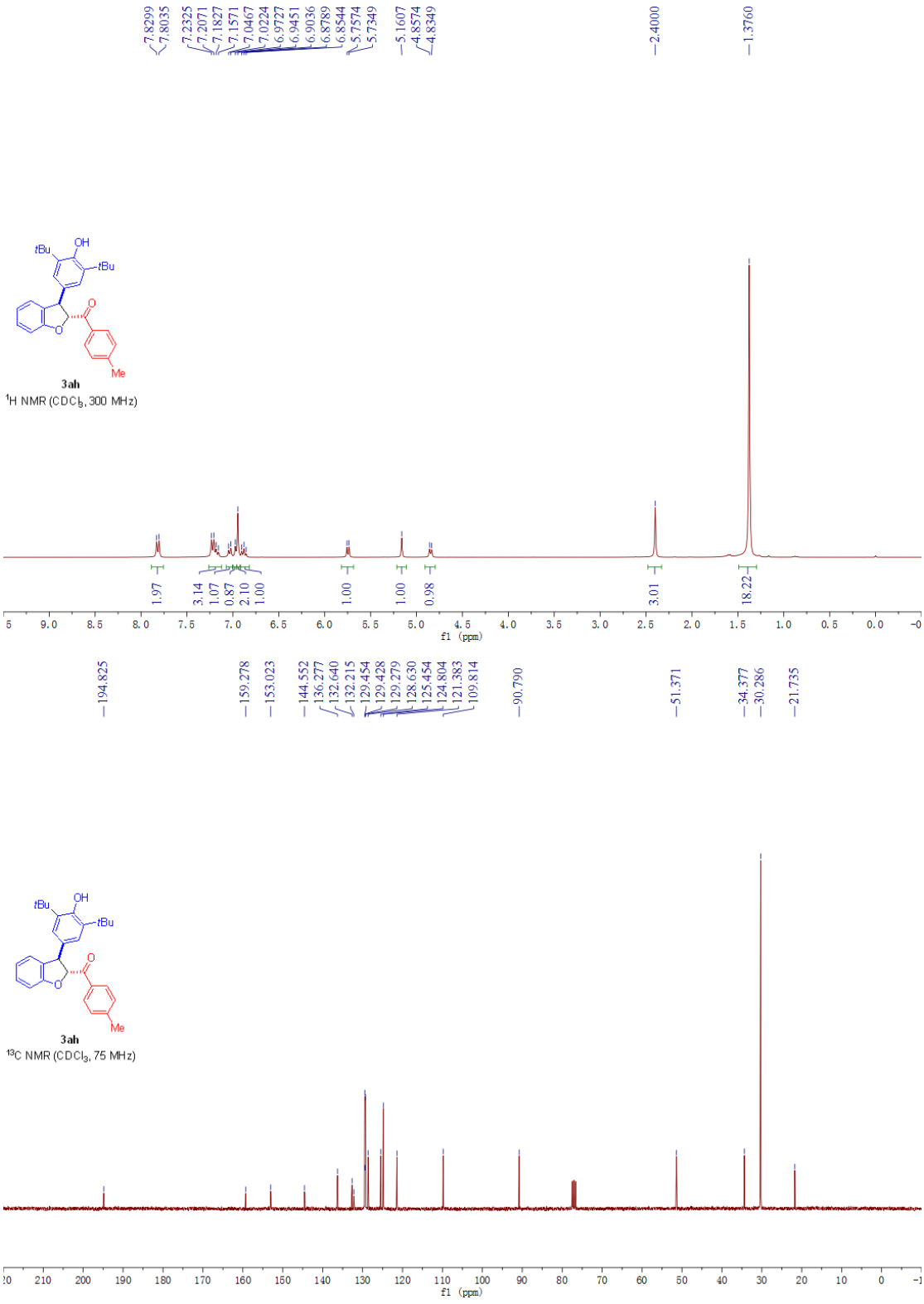
3ag

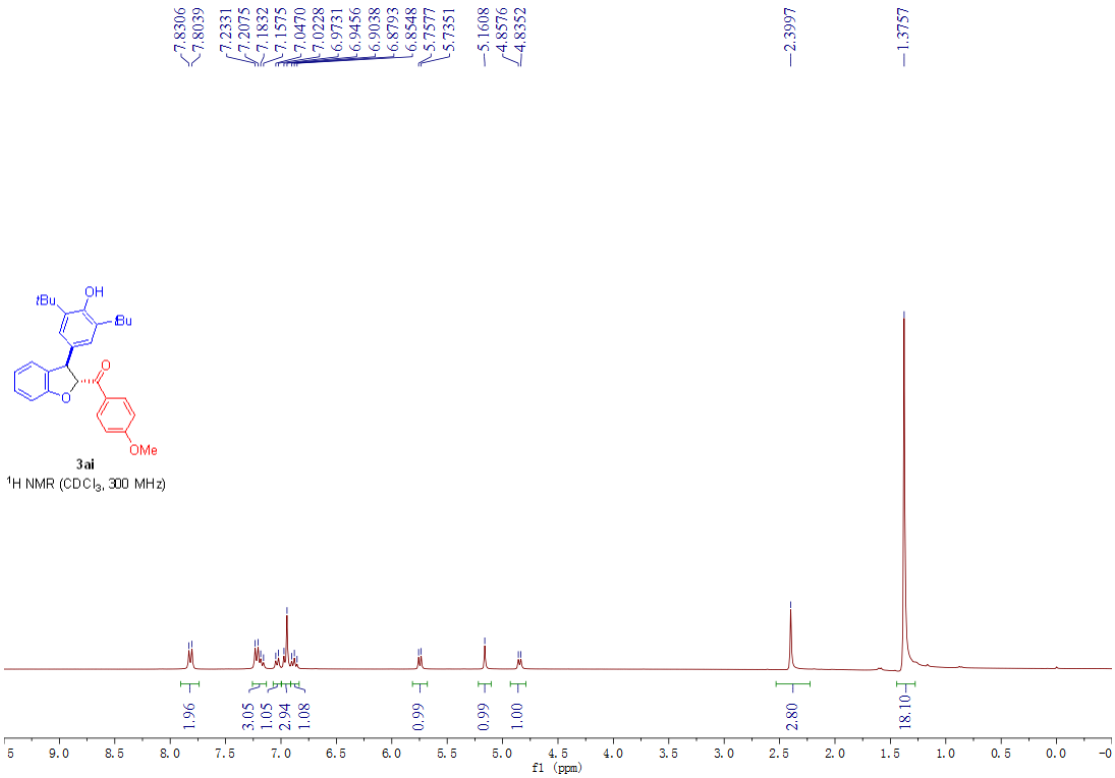
^{1}H NMR ($CDCl_3$, 300 MHz)

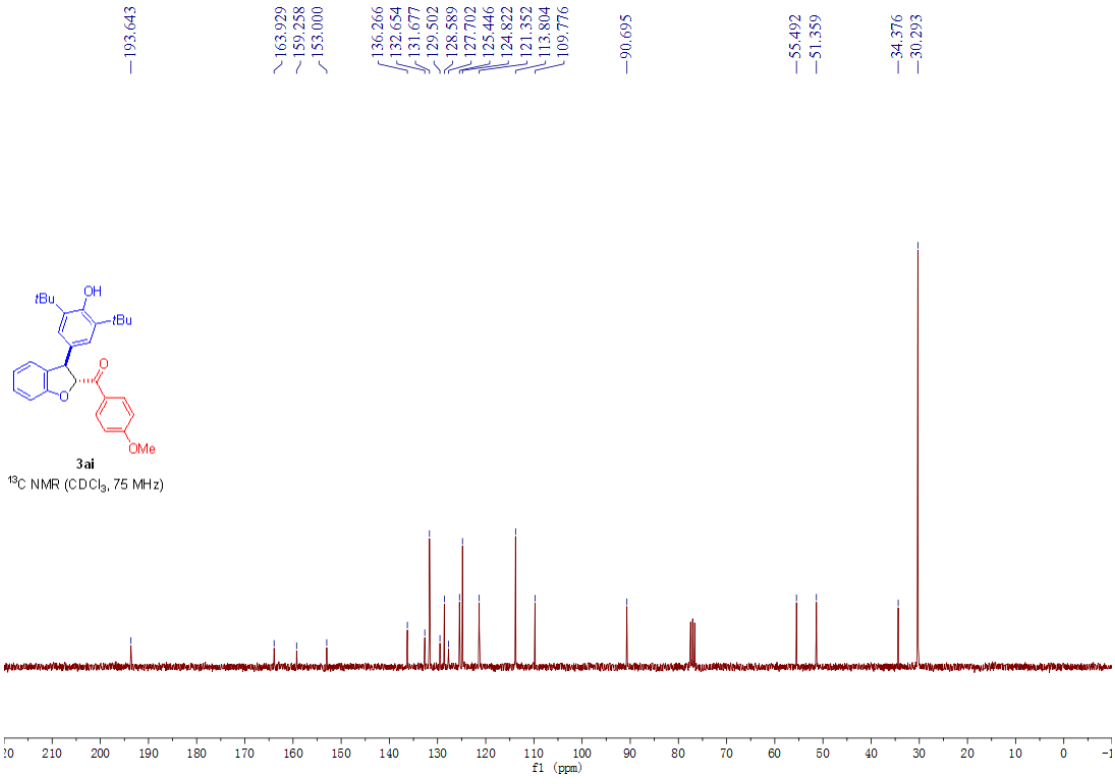


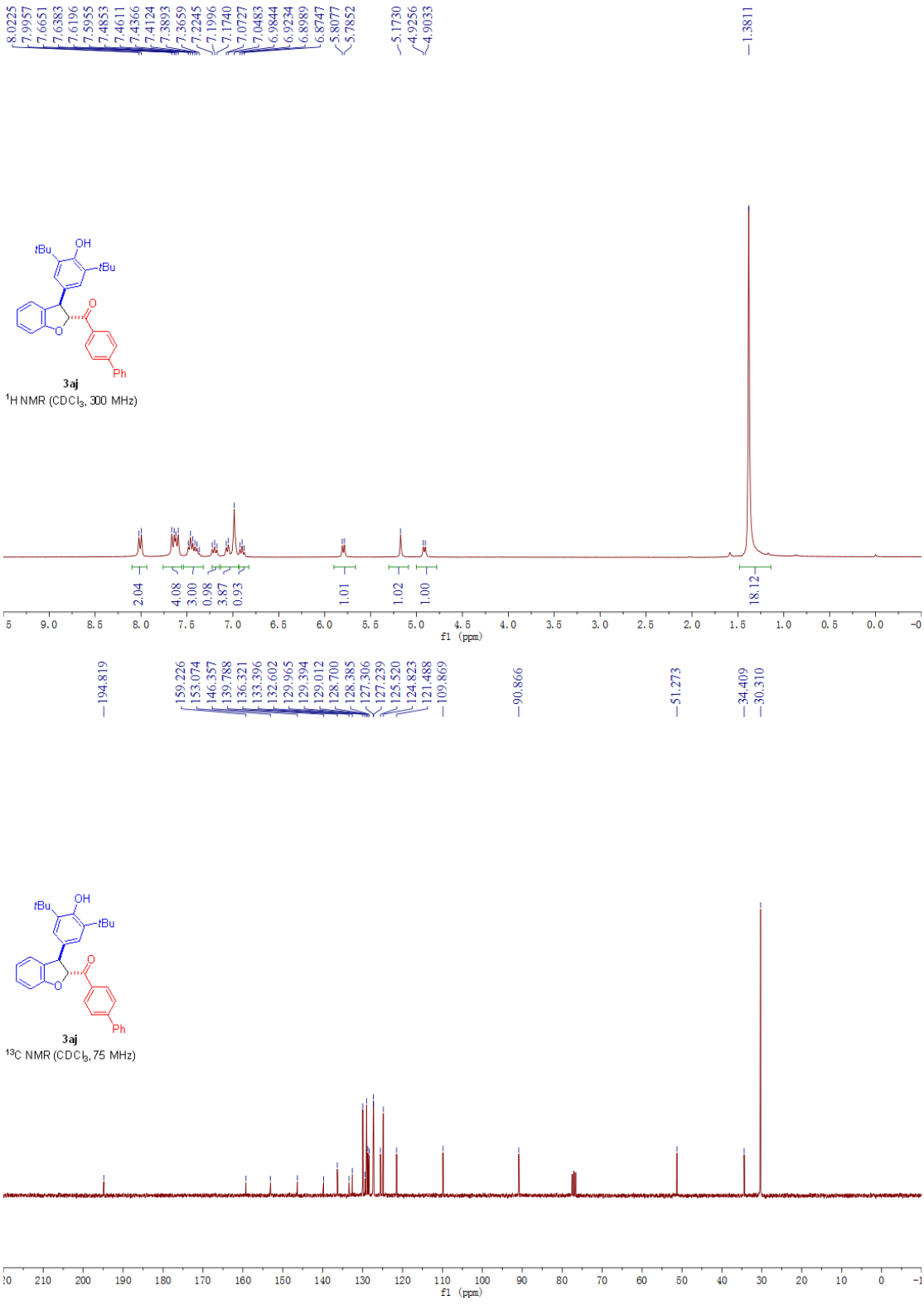
3ag

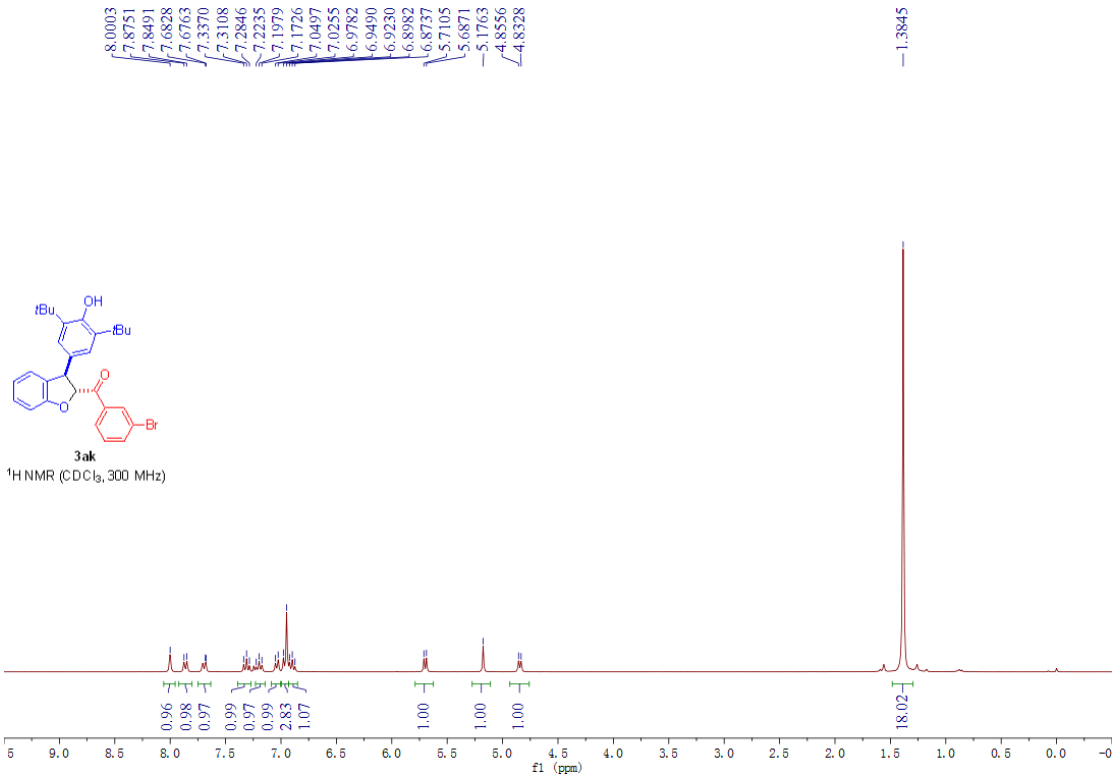
^{13}C NMR ($CDCl_3$, 75 MHz)

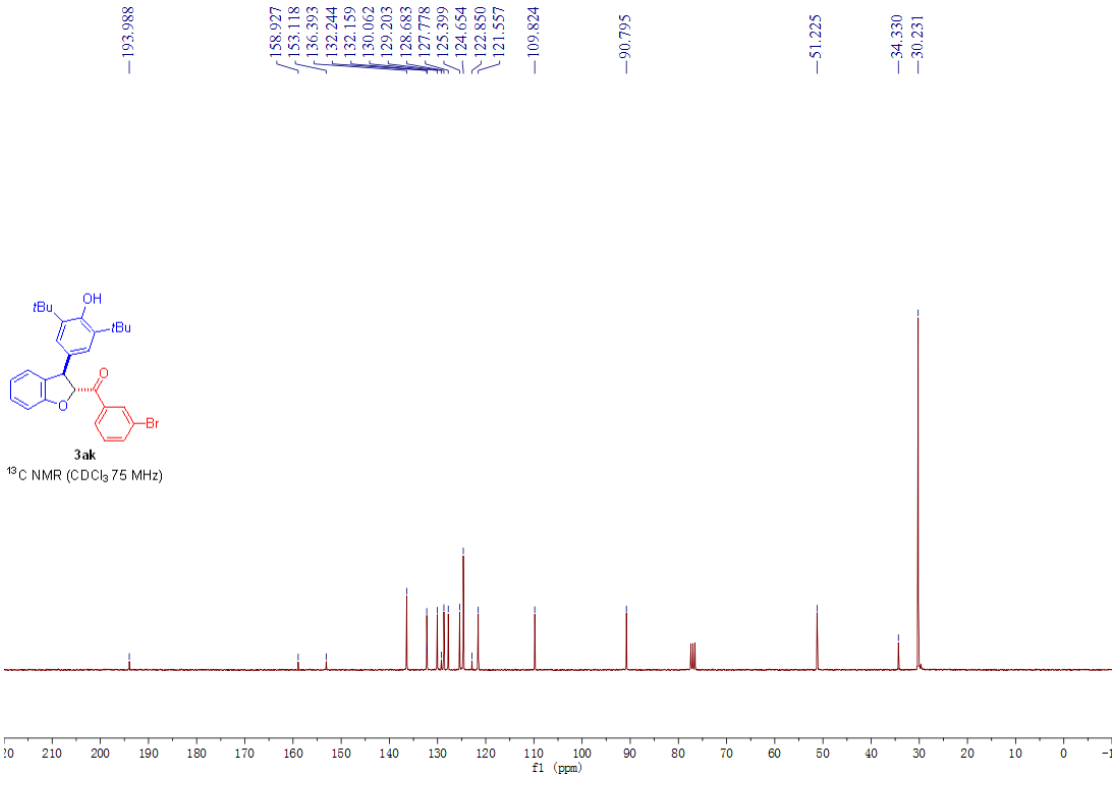

7.8299
7.8035
7.2325
7.2071
7.1827
7.1571
7.0467
7.0224
6.9727
6.9451
6.9036
6.8789
6.8544
5.7574
5.7349
5.1607
4.8574
4.8349
2.4000
1.3760
tBu
OH
tBu
O
Me
3ah
1H NMR (CDCl3, 300 MHz)
1.97
3.14
1.07
0.87
2.10
1.00
1.00
1.00
0.98
3.01
18.22
f1 (ppm)
194.825
159.278
153.023
144.552
136.277
132.640
132.215
129.454
129.428
129.279
128.630
125.454
124.804
121.383
109.814
90.790
51.371
34.377
30.286
21.735
3ah
13C NMR (CDCl3, 75 MHz)
f1 (ppm)

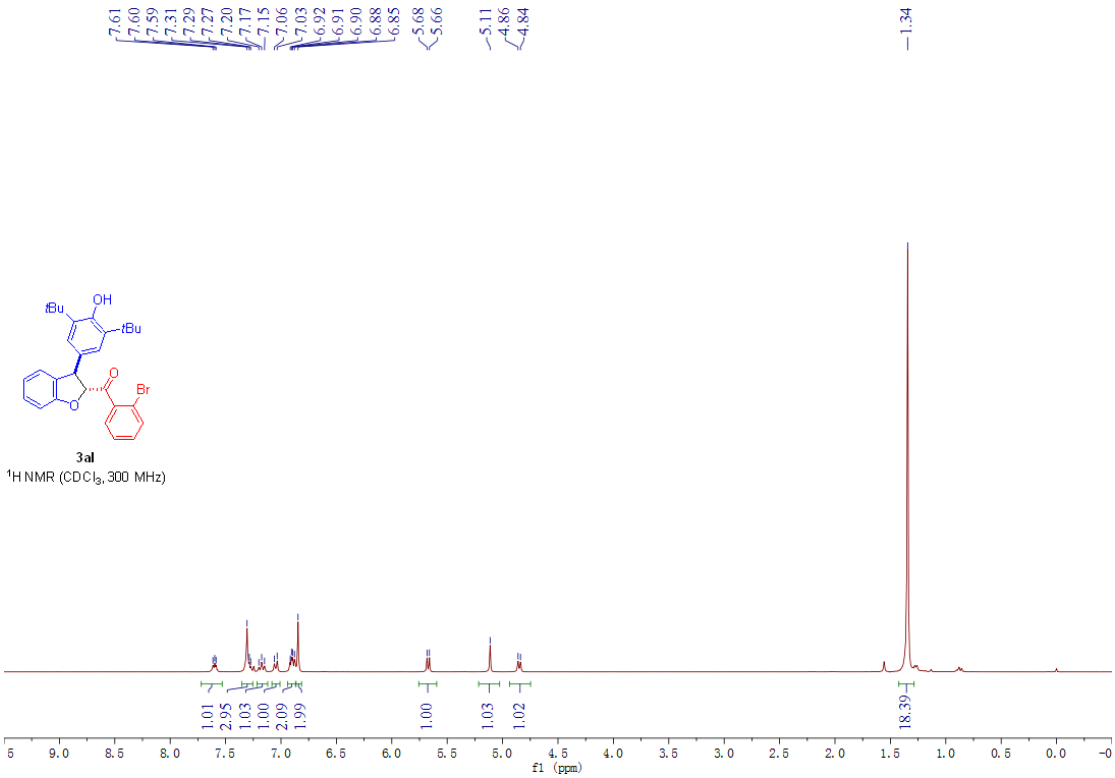

7.8306
7.8039
7.2331
7.2075
7.1832
7.1575
7.0470
7.0228
6.9731
6.9456
6.9038
6.8793
6.8548
5.7577
5.7351
5.1608
4.8576
4.8352
2.3997
1.3757
tBu
OH
tBu
O
O
OMe
3ai
1H NMR (CDCl3, 300 MHz)
1.96
3.05
1.05
2.94
1.08
0.99
0.99
1.00
2.80
18.10
f1 (ppm)


193.643
163.929
159.258
153.000
136.266
132.654
131.677
129.502
128.589
127.702
125.446
124.822
121.352
113.804
109.776
90.695
55.492
51.359
34.376
30.293
tBu
OH
tBu
O
O
OMe
3ai
13C NMR (CDCl3, 75 MHz)
f1 (ppm)


8.0225
7.9957
7.6651
7.6383
7.6196
7.5955
7.4853
7.4611
7.4366
7.4124
7.3893
7.3659
7.2245
7.1996
7.1740
7.0727
7.0483
6.9844
6.9234
6.8989
6.8747
5.8077
5.7852
5.1730
4.9256
4.9033
1.3811
tBu
OH
tBu
O
Ph
3aj
1H NMR (CDCl3, 300 MHz)
2.04
4.08
3.00
0.98
3.87
0.93
1.01
1.02
1.00
18.12
f1 (ppm)
194.819
159.226
153.074
146.357
139.788
136.321
133.396
132.602
129.965
129.394
129.012
128.700
128.385
127.306
127.239
125.520
124.823
121.488
109.869
90.866
51.273
34.409
30.310
3aj
13C NMR (CDCl3, 75 MHz)
f1 (ppm)

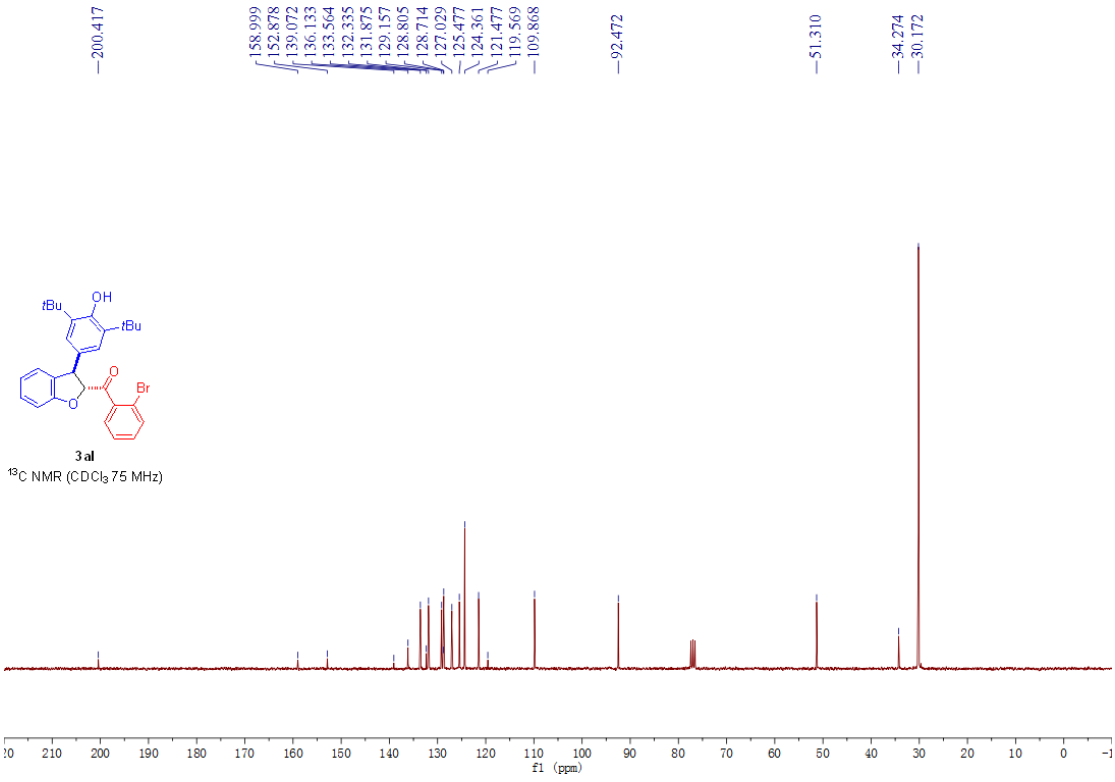

8.0003
7.8751
7.8491
7.6828
7.6763
7.3370
7.3108
7.2846
7.2235
7.1979
7.1726
7.0497
7.0255
6.9782
6.9490
6.9230
6.8982
6.8737
5.7105
5.6871
5.1763
4.8556
4.8328
1.3845
tBu
OH
tBu
O
Br
3ak
1H NMR (CDCl3, 300 MHz)
0.96
0.98
0.97
0.99
0.97
0.99
2.83
1.07
1.00
1.00
1.00
18.02
f1 (ppm)


193.988
158.927
153.118
136.393
132.244
132.159
130.062
129.203
128.683
127.778
125.399
124.654
122.850
121.557
109.824
90.795
51.225
34.330
30.231
tBu
OH
tBu
O
Br
3ak
13C NMR (CDCl3 75 MHz)
f1 (ppm)



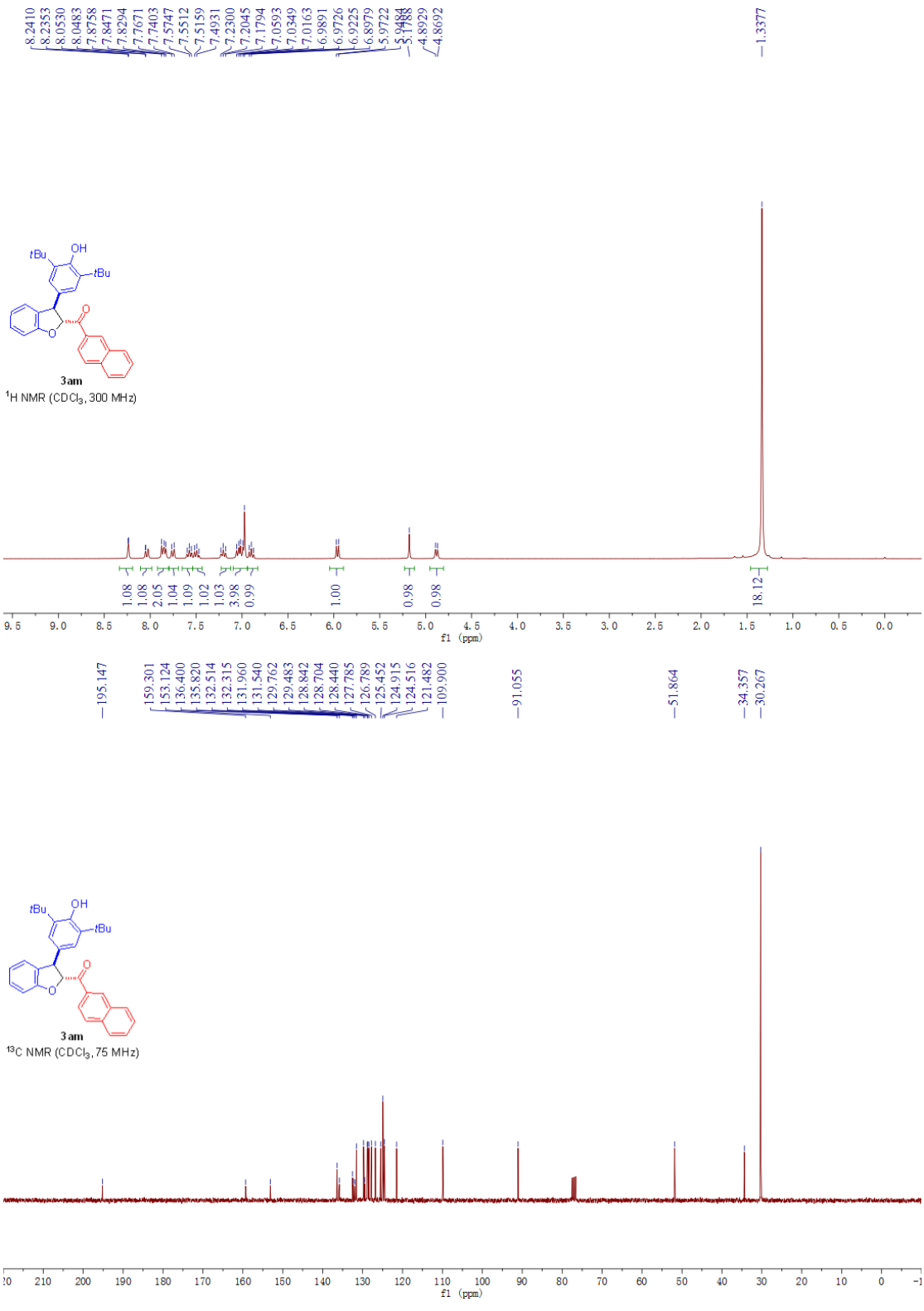
3al

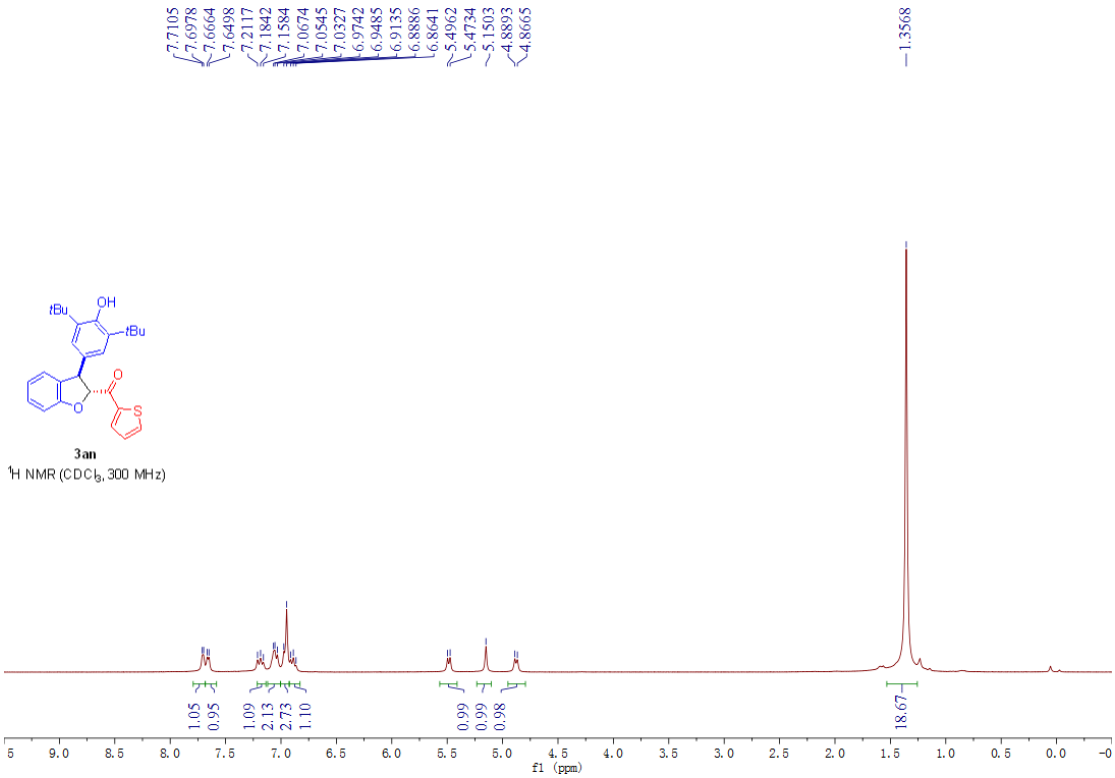
^{1}H NMR ($CDCl_3$, 300 MHz)



3al

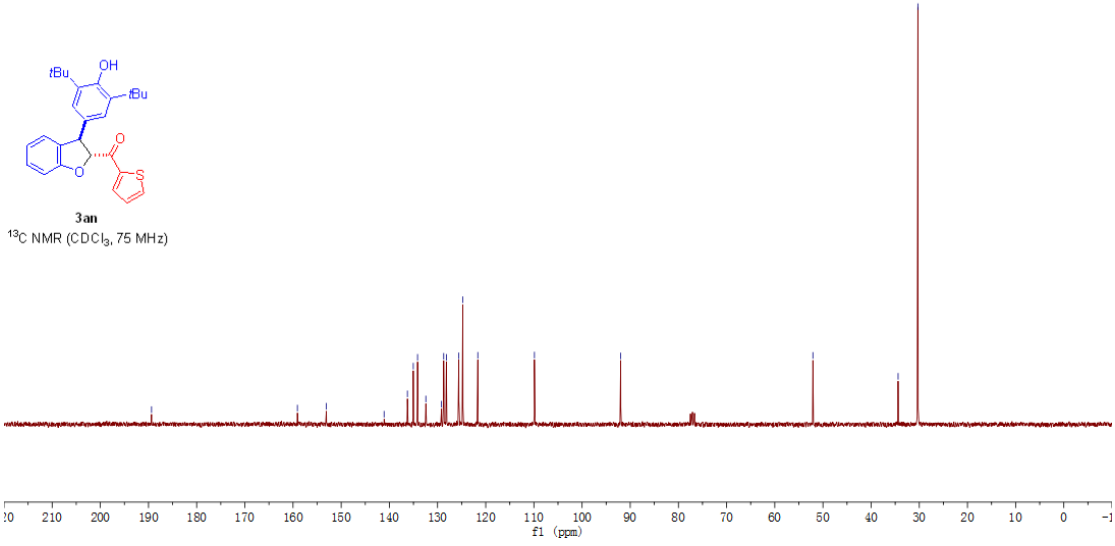
^{13}C NMR ($CDCl_3$ 75 MHz)


8.2410
8.2353
8.0530
8.0483
7.8758
7.8471
7.8294
7.7671
7.7403
7.5747
7.5512
7.5159
7.4931
7.2300
7.2045
7.1794
7.0593
7.0349
7.0163
6.9891
6.9726
6.9225
6.8979
5.9722
4.8929
4.8692
1.3377
tBu
OH
tBu
O
O
3am
1H NMR (CDCl3, 300 MHz)
1.08
1.08
2.05
1.04
1.09
1.02
1.03
3.98
0.99
1.00
0.98
0.98
18.12
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)
195.147
159.301
153.124
136.400
135.820
132.514
132.315
131.960
131.540
129.762
129.483
128.842
128.704
128.440
127.785
126.789
125.452
124.915
124.516
121.482
109.900
91.055
51.864
34.357
30.267
tBu
OH
tBu
O
O
3am
13C NMR (CDCl3, 75 MHz)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)



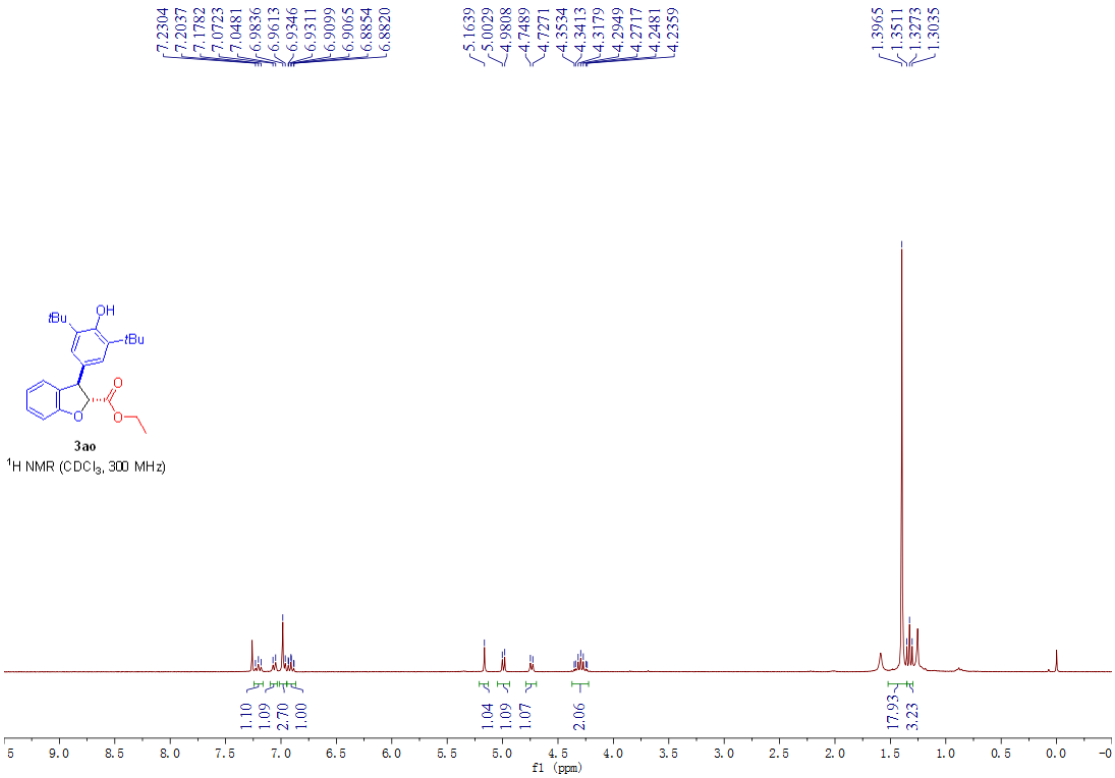
3an

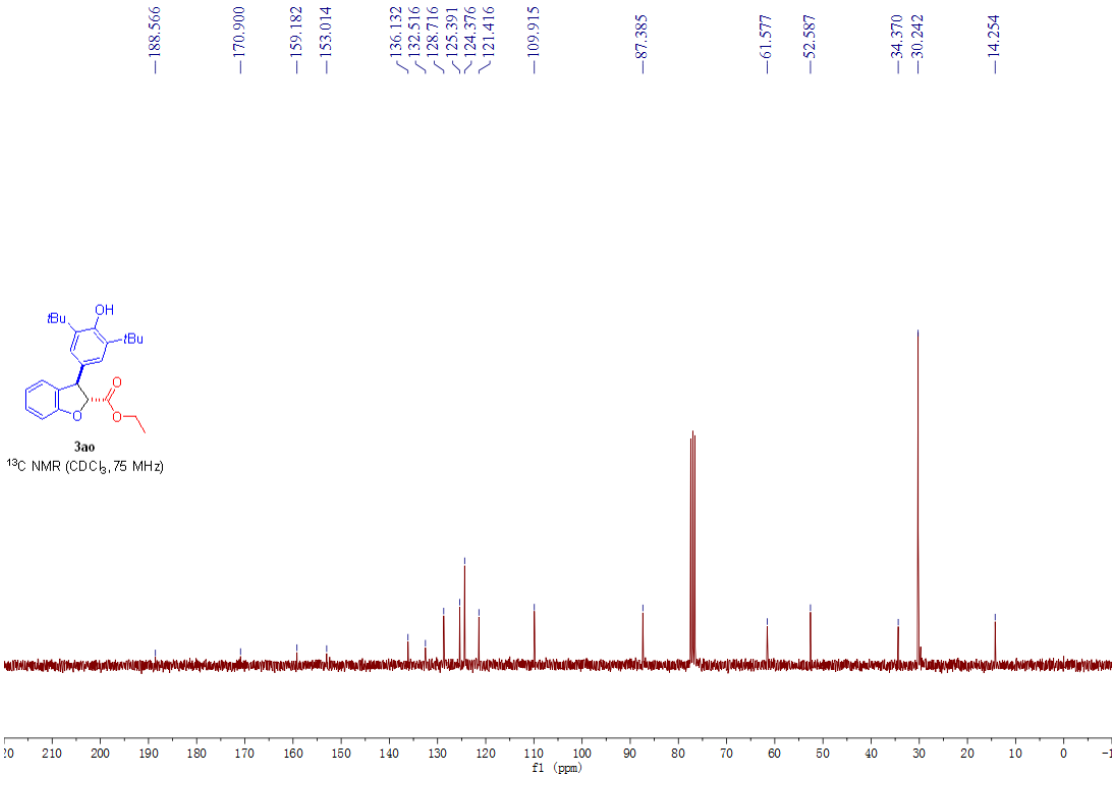
^{1}H NMR ($CDCl_3$, 300 MHz)

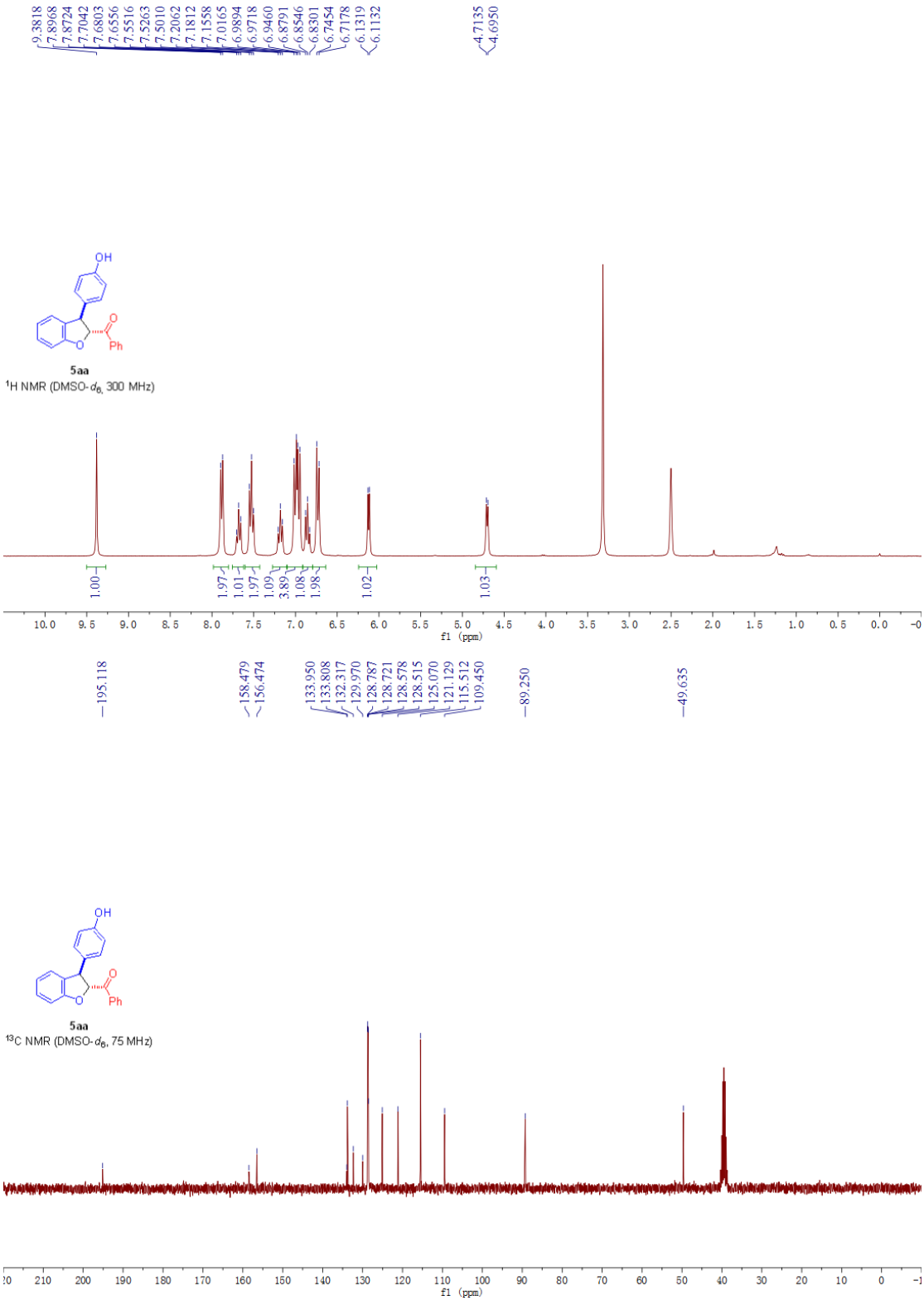


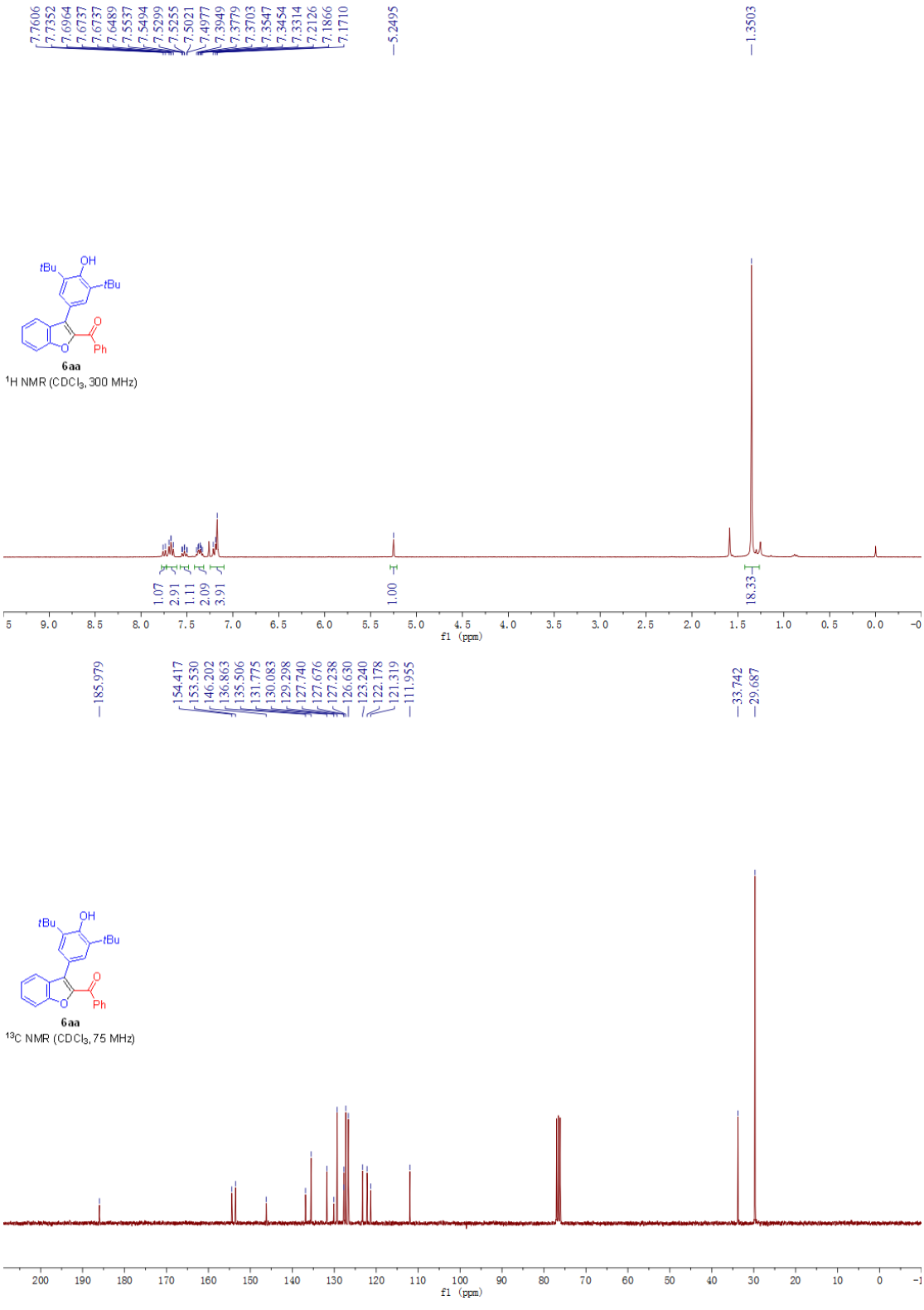
3an

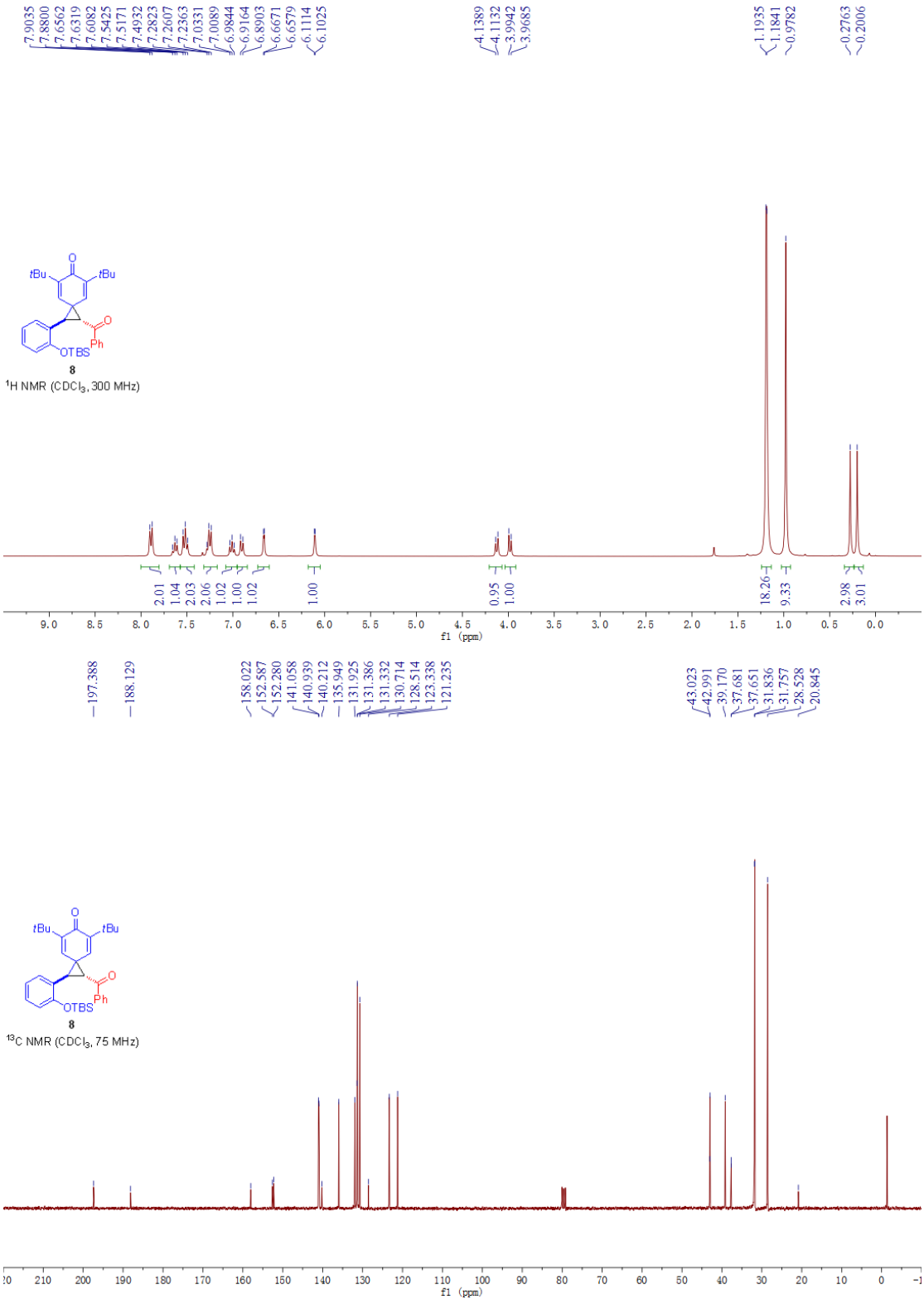
^{13}C NMR ($CDCl_3$, 75 MHz)

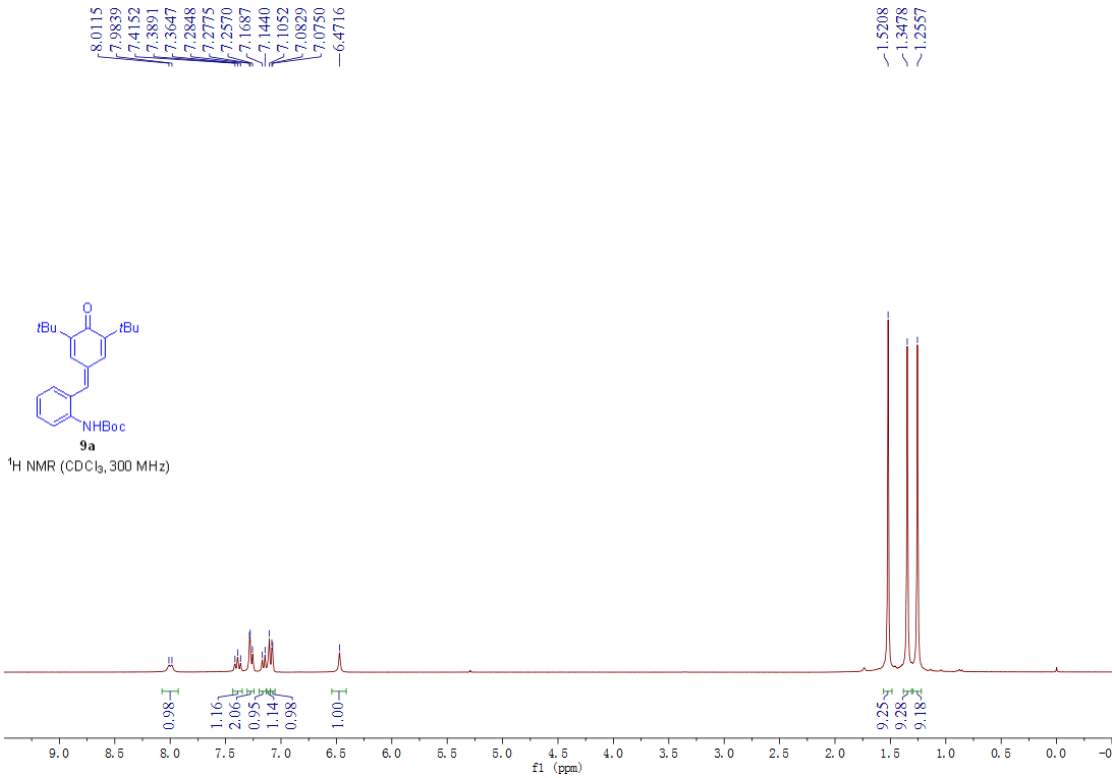

7.2304
7.2037
7.1782
7.0723
7.0481
6.9836
6.9613
6.9346
6.9311
6.9099
6.9065
6.8854
6.8820
5.1639
5.0029
4.9808
4.7489
4.7271
4.3534
4.3413
4.3179
4.2949
4.2717
4.2481
4.2359
1.3965
1.3511
1.3273
1.3035
tBu
OH
tBu
O
O
O
3ao
1H NMR (CDCl3, 300 MHz)
1.10
1.09
2.70
1.00
1.04
1.09
1.07
2.06
17.93
3.23
f1 (ppm)

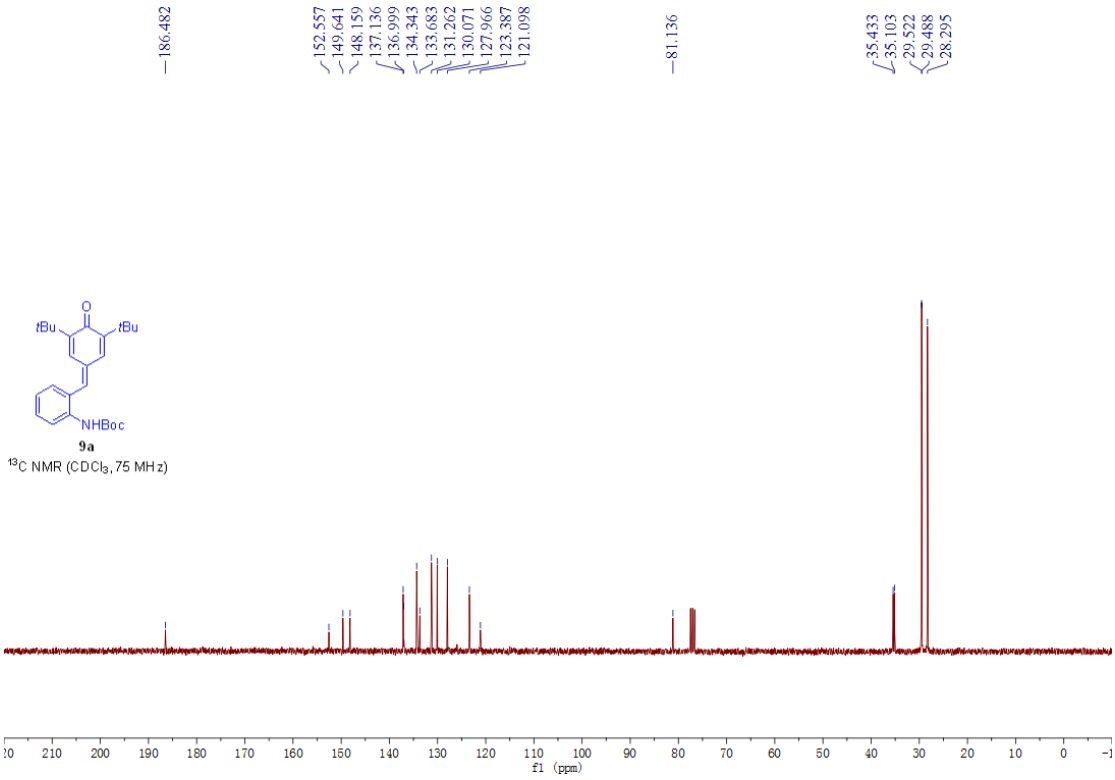

188.566
170.900
159.182
153.014
136.132
132.516
128.716
125.391
124.376
121.416
109.915
87.385
61.577
52.587
34.370
30.242
14.254
tBu
OH
tBu
O
O
O
3ao
13C NMR (CDCl3, 75 MHz)
f1 (ppm)

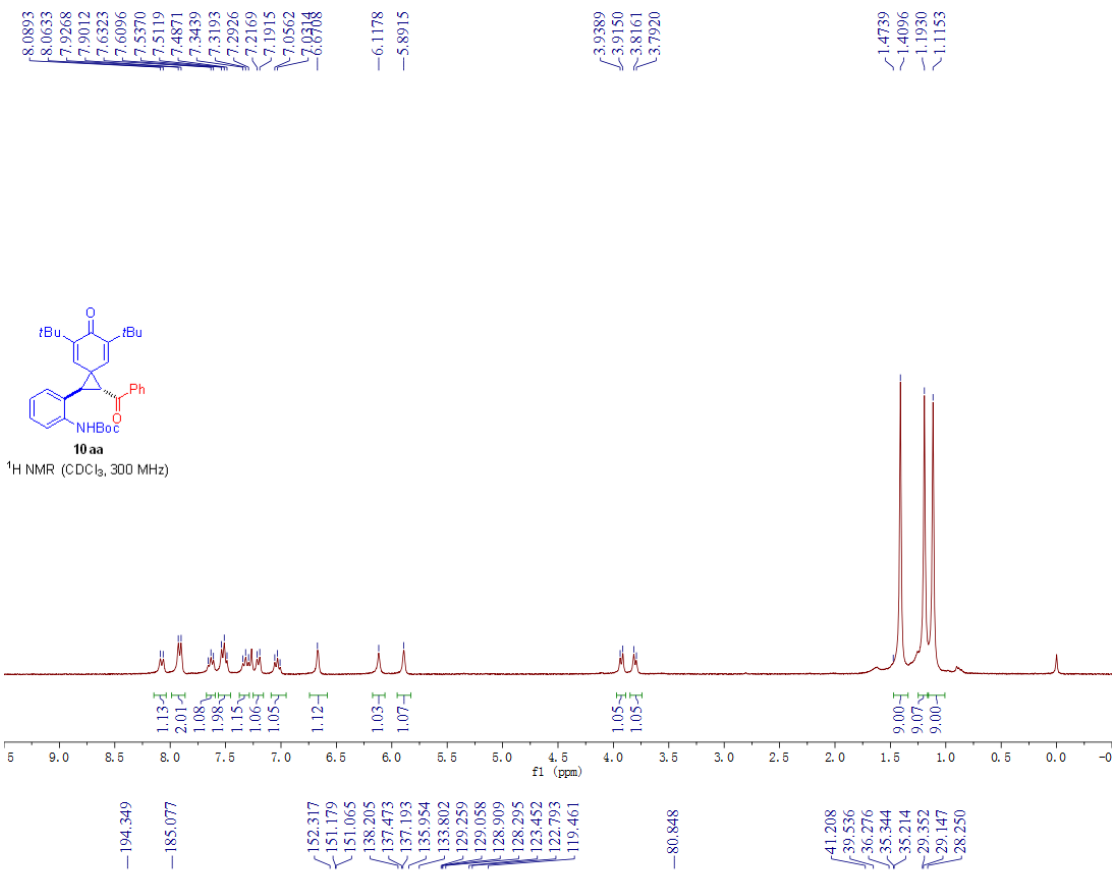

9.3818
7.8968
7.8724
7.7042
7.6803
7.6556
7.5516
7.5263
7.5010
7.2062
7.1812
7.1558
7.0165
6.9894
6.9718
6.9460
6.8791
6.8546
6.8301
6.7454
6.7178
6.1319
6.1132
4.7135
4.6950
OH
O
Ph
5aa
1H NMR (DMSO-d6, 300 MHz)
1.00
1.97
1.01
1.97
1.09
3.89
1.08
1.98
1.02
1.03
f1 (ppm)
195.118
158.479
156.474
133.950
133.808
132.317
129.970
128.787
128.721
128.578
128.515
125.070
121.129
115.512
109.450
89.250
49.635
OH
O
Ph
5aa
13C NMR (DMSO-d6, 75 MHz)
f1 (ppm)

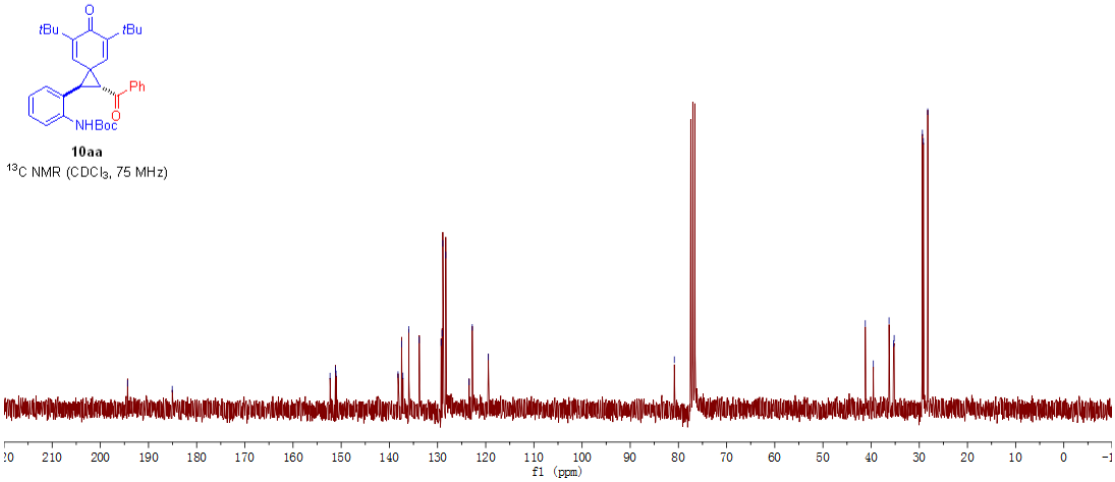

7.7606
7.7352
7.6964
7.6737
7.6737
7.6489
7.5537
7.5494
7.5299
7.5255
7.5021
7.4977
7.3949
7.3779
7.3703
7.3547
7.3454
7.3314
7.2126
7.1866
7.1710
5.2495
1.3503
tBu
OH
tBu
O
Ph
6aa
1H NMR (CDCl3, 300 MHz)
1.07
2.91
1.11
2.09
3.91
1.00
18.33
f1 (ppm)
185.979
154.417
153.530
146.202
136.863
135.506
131.775
130.083
129.298
127.740
127.676
127.238
126.630
123.240
122.178
121.319
111.955
33.742
29.687
13C NMR (CDCl3, 75 MHz)

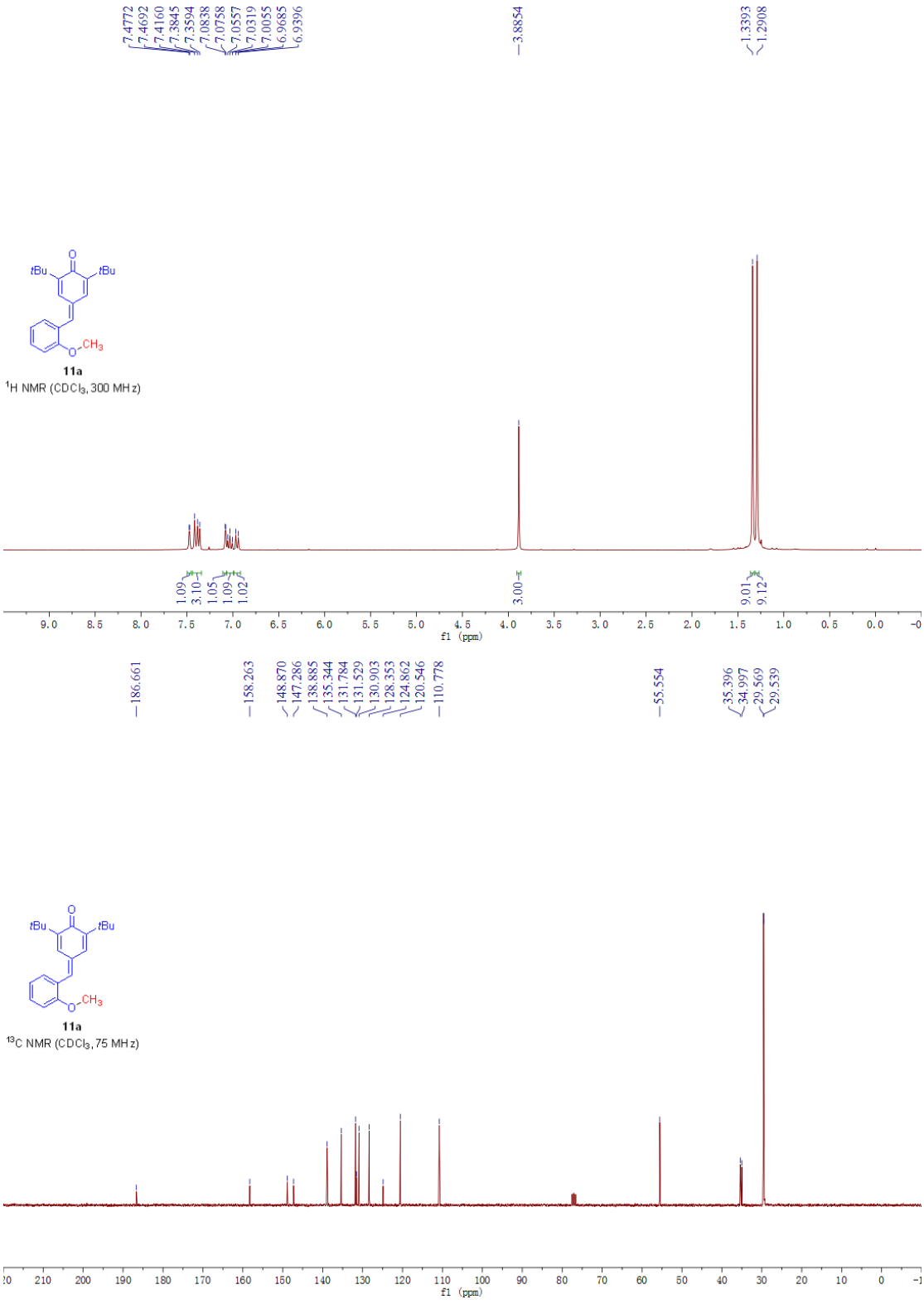

7.9035
7.8800
7.6562
7.6319
7.6082
7.5425
7.5171
7.4932
7.2823
7.2607
7.2363
7.0331
7.0089
6.9844
6.9164
6.8903
6.6671
6.6579
6.1114
6.1025
4.1389
4.1132
3.9942
3.9685
1.1935
1.1841
0.9782
0.2763
0.2006
tBu
tBu
O
OTBS
Ph
8
1H NMR (CDCl3, 300 MHz)
2.01
1.04
2.03
2.06
1.02
1.00
1.02
1.00
0.95
1.00
18.26
9.33
2.98
3.01
f1 (ppm)
197.388
188.129
158.022
152.587
152.280
141.058
140.939
140.212
135.949
131.925
131.386
131.332
130.714
128.514
123.338
121.235
43.023
42.991
39.170
37.681
37.651
31.836
31.757
28.528
20.845
13C NMR (CDCl3, 75 MHz)
f1 (ppm)


8.0115
7.9839
7.4152
7.3891
7.3647
7.2848
7.2775
7.2570
7.1687
7.1440
7.1052
7.0829
7.0750
6.4716
1.5208
1.3478
1.2557
tBu
tBu
NHBoc
9a
1H NMR (CDCl3, 300 MHz)
0.98
1.16
2.06
0.95
1.14
0.98
1.00
9.25
9.28
9.18
f1 (ppm)


186.482
152.557
149.641
148.159
137.136
136.999
134.343
133.683
131.262
130.071
127.966
123.387
121.098
81.136
35.433
35.103
29.522
29.488
28.295
tBu
tBu
NHBoc
9a
13C NMR (CDCl3, 75 MHz)
f1 (ppm)


8.0893
8.0633
7.9268
7.9012
7.6323
7.6096
7.5370
7.5119
7.4871
7.3439
7.3193
7.2926
7.2169
7.1915
7.0562
7.0314
6.6708
6.1178
5.8915
3.9389
3.9150
3.8161
3.7920
1.4739
1.4096
1.1930
1.1153
tBu
tBu
Ph
O
NHBoc
10aa
1H NMR (CDCl3, 300 MHz)
1.13
2.01
1.08
1.98
1.15
1.06
1.05
1.12
1.03
1.07
1.05
1.05
9.00
9.07
9.00
f1 (ppm)


194.349
185.077
152.317
151.179
151.065
138.205
137.473
137.193
135.954
133.802
129.259
129.058
128.909
128.295
123.452
122.793
119.461
80.848
41.208
39.536
36.276
35.344
35.214
29.352
29.147
28.250
tBu
tBu
Ph
O
NHBoc
10aa
13C NMR (CDCl3, 75 MHz)
f1 (ppm)


7.4772
7.4692
7.4160
7.3845
7.3594
7.0838
7.0758
7.0557
7.0319
7.0055
6.9685
6.9396
3.8854
1.3393
1.2908
tBu
tBu
O
CH3
11a
1H NMR (CDCl3, 300 MHz)
1.09
3.10
1.05
1.09
1.02
3.00
9.01
9.12
f1 (ppm)
186.661
158.263
148.870
147.286
138.885
135.344
131.784
131.529
130.903
128.353
124.862
120.546
110.778
55.554
35.396
34.997
29.569
29.539
11a
13C NMR (CDCl3, 75 MHz)
f1 (ppm)