Enantioselective Copper-Catalyzed Formal [4+2] Cycloaddition of *o*-Aminophenol Derivatives with Propargylic Esters for Synthesis of Optically Active 3,4-Dihydro-*2H*-1,4-benzoxazines

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Supporting Information

General Information

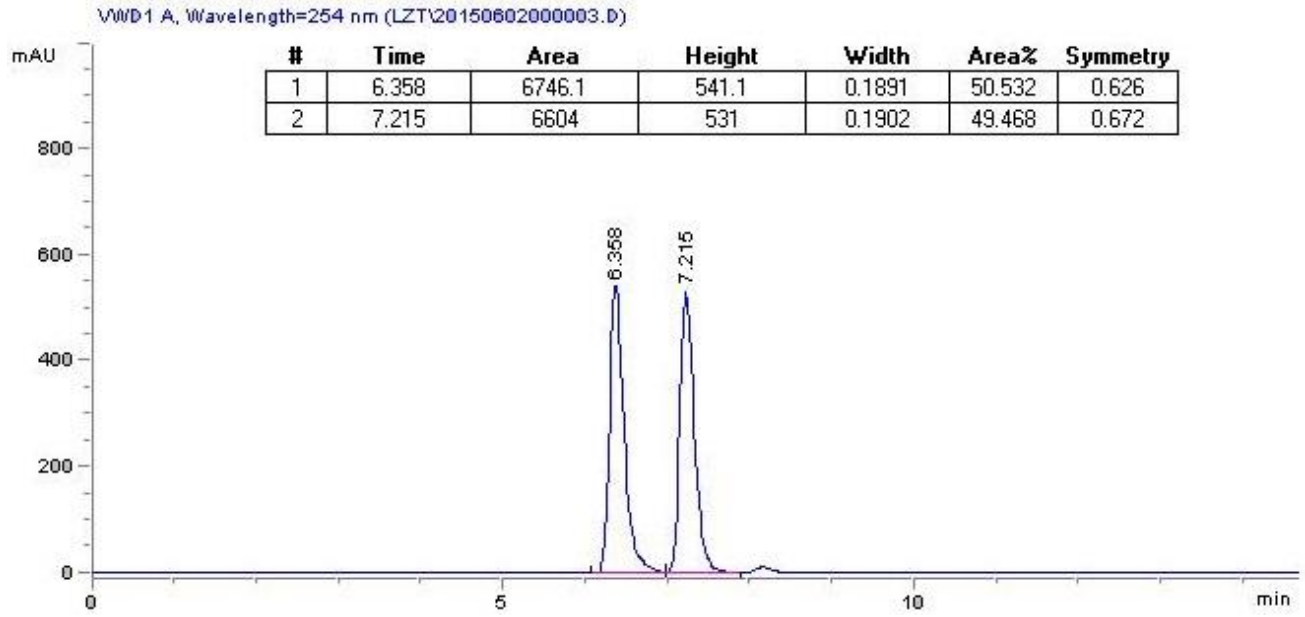
All reactions were carried out under a nitrogen atmosphere. Solvents were purified by standard procedure before use. Commercial reagents were used without further purification. Flash chromatography was performed on silica gel 60 (40-63μm, 60Å). Thin layer chromatography (TLC) was performed on glass plates coated with silica gel 60 with F254 indicator. Proton nuclear magnetic resonance (^{1}H NMR) spectra were recorded on a Bruker 400 MHz spectrometer. Chemical shifts for protons are reported in parts per million downfield from tetramethylsilane and are referenced to residual protium in the NMR solvent ($CHCl_3$ = δ 7.28). Carbon nuclear magnetic resonance (^{13}C NMR) spectra were recorded on a Bruker 100 MHz spectrometer. Chemical shifts for carbon are reported in parts per million downfield from tetramethylsilane and are referenced to the carbon resonances of the solvent ($CDCl_3$ = δ 77.07). Data are represented as follows: chemical shift, multiplicity (br = broad, s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet), coupling constants in Hertz (Hz), integration. Only the most important and relevant frequencies are reported. Enantiomeric ratios were determined by chiral HPLC with hexane and *i*-PrOH as solvents. Optical rotations were recorded on a JASCO P-1020 polarimeter. *o*-Aminnophenol derivatives **1**[1] and propargylic esters **2**[2] were prepared following the method from the literature.

General Procedure for Copper-Catalyzed Asymmetric Formal [4+2] Cycloaddition of *o*-Aminnophenol Derivatives with Propargylic Esters

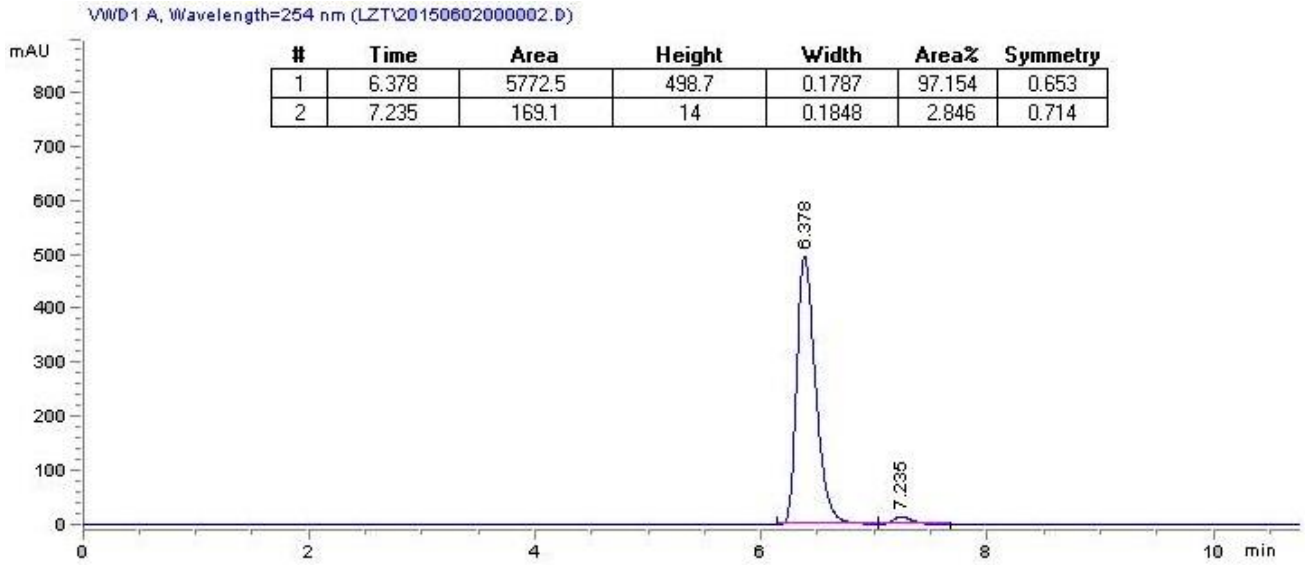
A solution of $Cu(OTf)_2$ (5.4 mg, 0.015 mmol) and (*S*)-**L4e** (7.2 mg, 0.0165 mmol) in 1 mL of anhydrous methanol placed in an oven-dried Schlenk flask was stirred at room temperature under a nitrogen atmosphere for 1 h. After lowering the reaction temperature to -40 ^{o}C, a solution of *o*-aminophenol derivatives **1** (0.3 mmol), propargylic esters **2** (0.3 mmol) and K_2CO_3 (49.8 mg, 0.36 mmol) in 2 mL of anhydrous methanol was added. The mixture was stirred at -40 ^{o}C for 24 h. The reaction mixture was then concentrated under vaccum, and the residue was purified by silica gel chromatography to afford 2*H*-1,4-benzoxazines **3**.

(*S*)-4-benzyl-2-methylene-3-phenyl-3,4-dihydro-*2H*-benzo[*b*][1,4]oxazine (3aa). 91 mg (97% yield) was obtained as a colorless oil after purification with column chromatography on silica gel (hexanes/ethyl acetate, 100/1). 94% ee was determined by chiral HPLC (Chiralcel AD-H, *n*-hexane/*i*-PrOH = 98/2, 0.8 mL/min, 254 nm, 40 ^{o}C): t_R (major) = 6.4 min, t_R (minor) = 7.2 min. $[\alpha]_D^{28}$ = -58.5 (*c* 0.99, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.23–7.17 (m, 4H), 7.16–7.04 (m, 6H), 6.81–6.78 (m, 1H), 6.75–6.71 (m, 1H), 6.65–6.60 (m, 2H), 4.71 (s, 1H), 4.62 (d, *J* = 1.1 Hz, 1H), 4.42 (d, *J* = 15.7 Hz, 1H), 4.20 (d, *J* = 1.4 Hz, 1H), 4.12 (d, *J* = 15.7 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ 153.1, 143.7, 139.3, 137.7, 134.0, 128.8, 128.7, 127.8, 127.5, 127.5, 127.3, 122.7, 119.4, 115.8, 114.8, 91.5, 61.2, 54.6. HRMS calc. for $C_{22}H_{19}NO$ $[M+H]^+$: 314.1545, found: 314.1527.

3aa

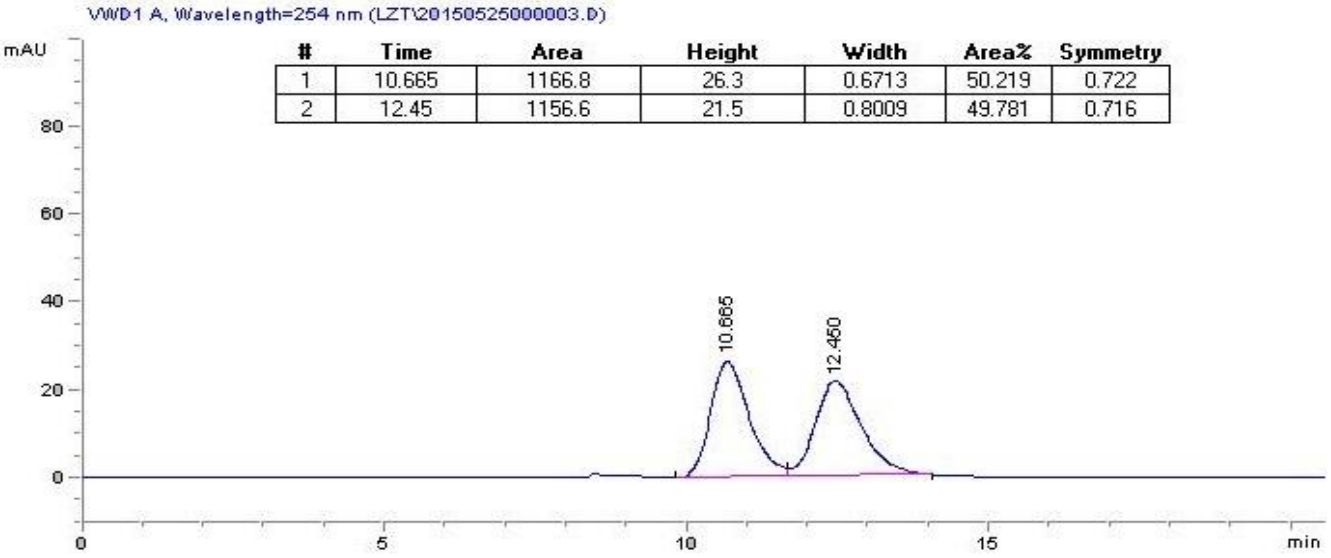


#	Time	Area	Height	Width	Area%	Symmetry
1	6.358	6746.1	541.1	0.1891	50.532	0.626
2	7.215	6604	531	0.1902	49.468	0.672

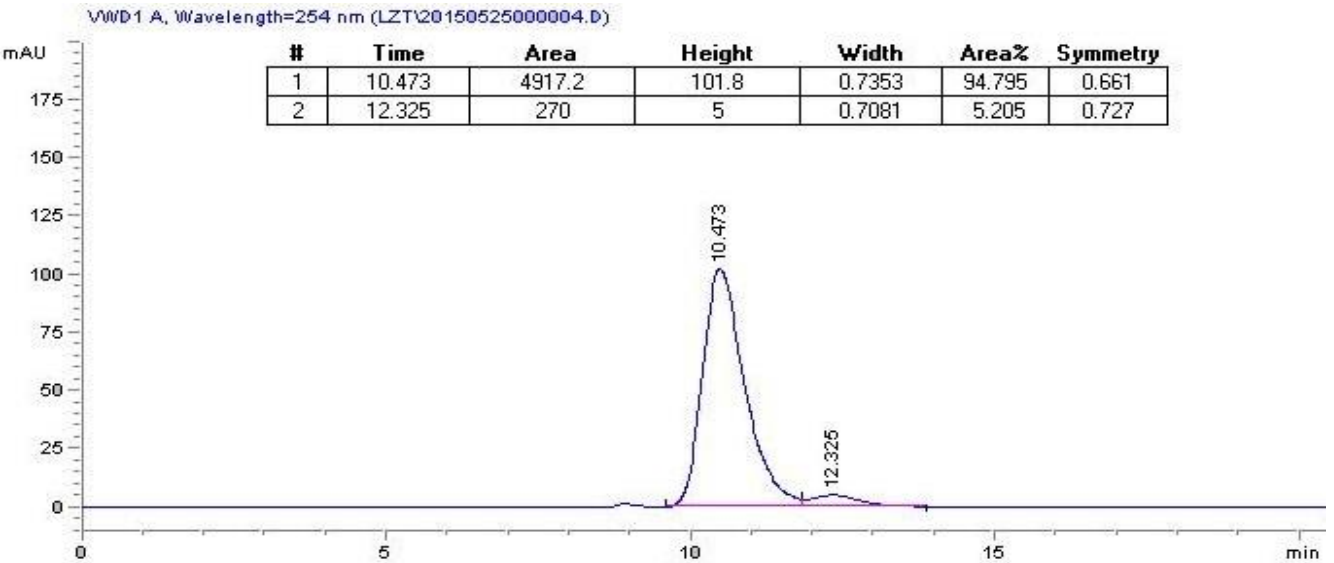


#	Time	Area	Height	Width	Area%	Symmetry
1	6.378	5772.5	498.7	0.1787	97.154	0.653
2	7.235	169.1	14	0.1848	2.846	0.714

(*S*)-4-benzyl-5-methyl-2-methylene-3-phenyl-3,4-dihydro-*2H*-benzo[*b*][1,4]oxazine (3ba). 95 mg (97% yield) was obtained as a colorless oil after purification with column chromatography on silica gel (hexanes/ethyl acetate, 100/1). 90% ee was determined by chiral HPLC (Chiralcel OJ-H, *n*-hexane/*i*-PrOH = 99/1, 0.5 mL/min, 254 nm, 40 ^{o}C): t_R (major) = 10.5 min, t_R (minor) = 12.3 min. $[\alpha]_D^{29}$ = 117.2 (*c* 1.02, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.61–7.59 (m, 2H), 7.42–7.35 (m, 4H), 7.30–7.26 (m, 1H), 7.16–7.12 (m, 2H), 7.08–7.04 (m, 1H), 6.84–6.81 (m, 1H), 6.76–6.74 (m, 1H), 6.68–6.66 (m, 1H), 5.04 (s, 1H), 4.49 (s, 1H), 4.28–4.24 (m, 2H), 3.87 (d, *J* = 14.4 Hz, 1H), 2.51 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ 149.7, 148.4, 138.3, 138.2, 134.1, 132.1, 128.9, 128.7, 128.2, 127.8, 127.2, 127.0, 124.7, 124.0, 114.0, 93.7, 58.9, 58.7, 17.6. HRMS calc. for $C_{23}H_{21}NO$ $[M+H]^+$: 328.1701, found: 328.1695.

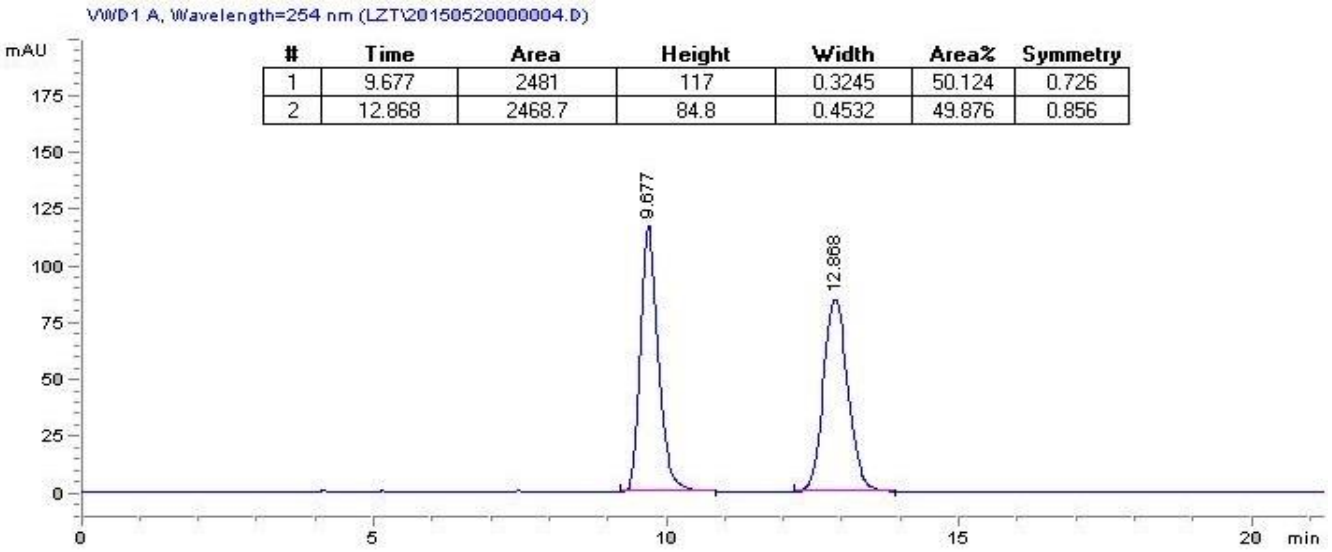


#	Time	Area	Height	Width	Area%	Symmetry
1	10.665	1166.8	26.3	0.6713	50.219	0.722
2	12.45	1156.6	21.5	0.8009	49.781	0.716

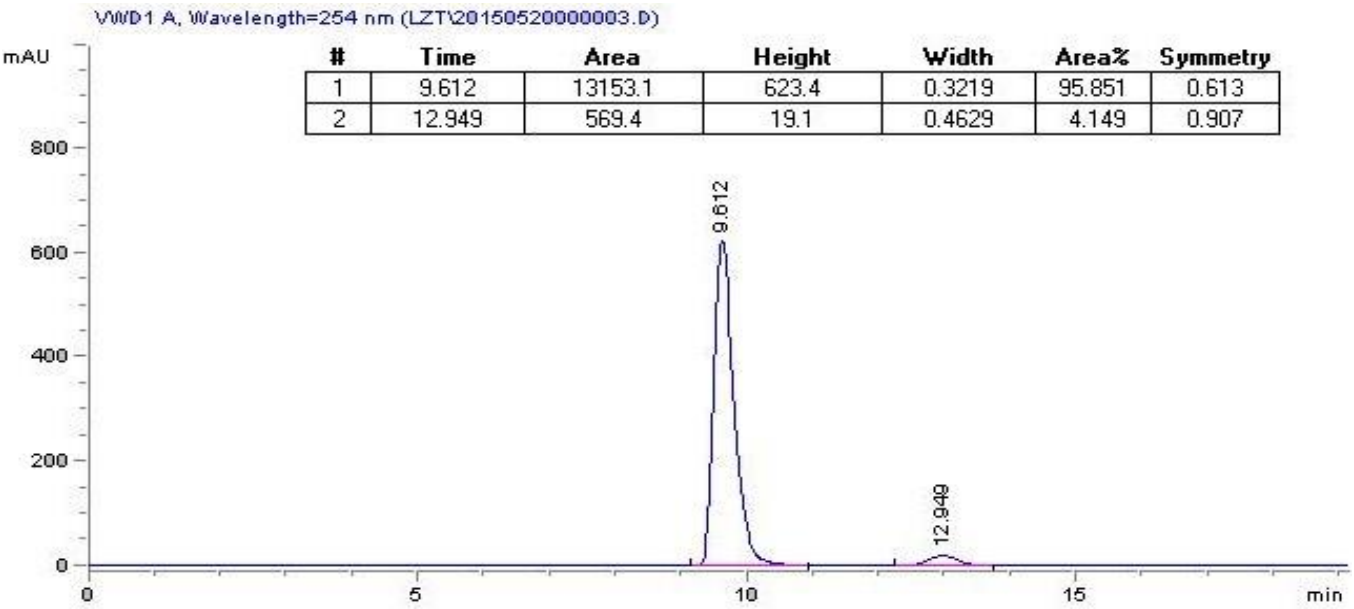


#	Time	Area	Height	Width	Area%	Symmetry
1	10.473	4917.2	101.8	0.7353	94.795	0.661
2	12.325	270	5	0.7081	5.205	0.727

(*S*)-4-benzyl-6-methyl-2-methylene-3-phenyl-3,4-dihydro-*2H*-benzo[*b*][1,4]oxazine (3ca). 83 mg (84% yield) was obtained as a colorless oil after purification with column chromatography on silica gel (hexanes/ethyl acetate, 100/1). 92% ee was determined by chiral HPLC (Chiralcel OJ-H, *n*-hexane/*i*-PrOH = 95/5, 0.8 mL/min, 254 nm, 40 ^{o}C): t_R (major) = 9.6 min, t_R (minor) = 12.9 min. $[\alpha]_D^{29}$ = -38.3 (*c* 1.10, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.25–7.22 (m, 4H), 7.19–7.10 (m, 6H), 6.70–6.68 (m, 1H), 6.51–6.44 (m, 2H), 4.68 (s, 1H), 4.61 (d, *J* = 0.9 Hz, 1H), 4.45 (d, *J* = 15.6 Hz, 1H), 4.20 (d, *J* = 1.3 Hz, 1H), 4.12 (d, *J* = 15.6 Hz, 1H), 2.12 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ 153.0, 141.7, 139.3, 137.7, 133.6, 131.9, 128.7, 128.6, 127.7, 127.6, 127.4, 127.2, 120.0, 115.4, 115.4, 91.1, 60.9, 54.5, 21.2. HRMS calc. for $C_{23}H_{21}NO$ $[M+H]^+$: 328.1701, found: 328.1692.

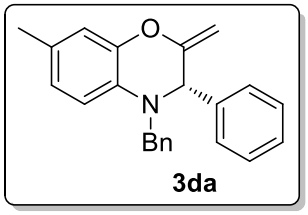


#	Time	Area	Height	Width	Area%	Symmetry
1	9.677	2481	117	0.3245	50.124	0.726
2	12.868	2468.7	84.8	0.4532	49.876	0.856

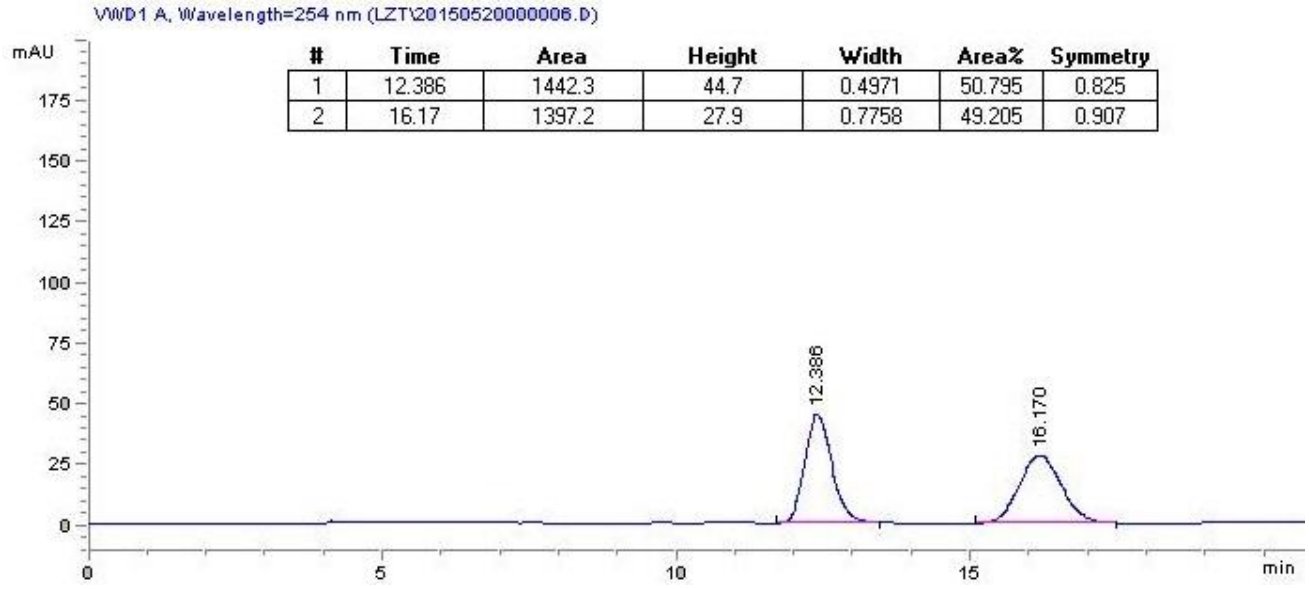


#	Time	Area	Height	Width	Area%	Symmetry
1	9.612	13153.1	623.4	0.3219	95.851	0.613
2	12.949	569.4	19.1	0.4629	4.149	0.907

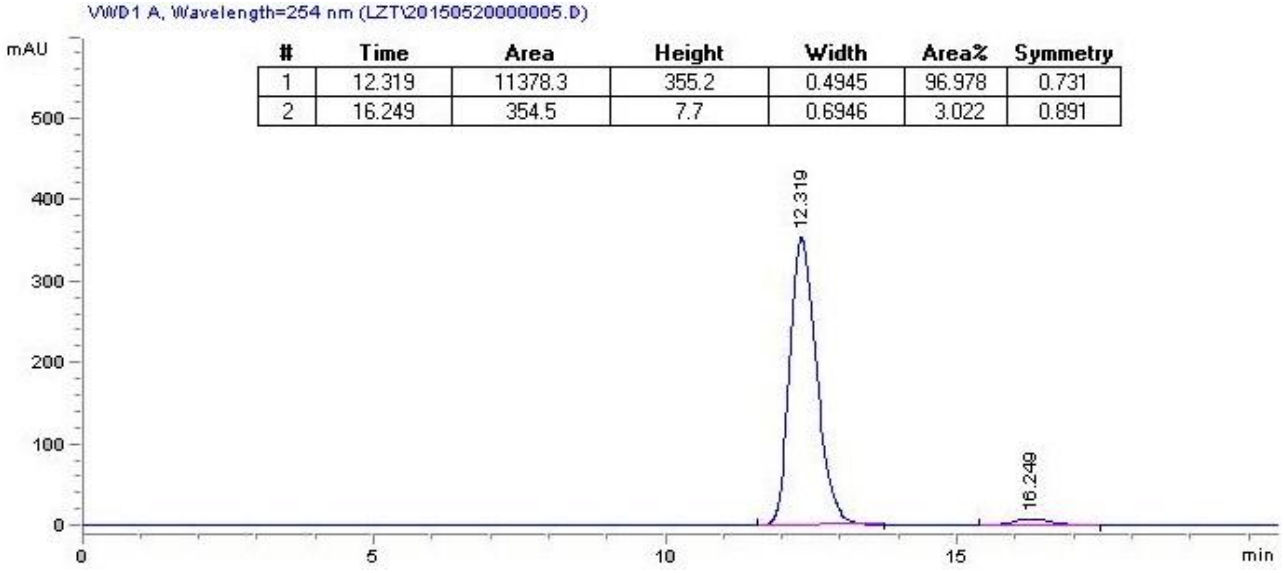
(*S*)-4-benzyl-7-methyl-2-methylene-3-phenyl-3,4-dihydro-*2H*-benzo[*b*][1,4]oxazine (3da). 88 mg (90% yield) was obtained as a colorless oil after purification with column chromatography on silica gel (hexanes/ethyl acetate, 100/1). 94% ee was determined by chiral HPLC (Chiralcel OJ-H, *n*-hexane/*i*-PrOH = 95/5, 0.8 mL/min, 254 nm, 40 ^{o}C): t_R (major) = 12.3 min, t_R (minor) = 16.2 min. $[\alpha]_D^{29}$ = -48.0 (*c* 1.00, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.35–7.28 (m, 4H), 7.27–7.12 (m, 6H), 6.74–6.59 (m, 3H), 4.73 (s, 2H), 4.43 (d, *J* = 15.5 Hz, 1H), 4.27 (s, 1H), 4.20 (d, *J* = 15.5 Hz, 1H), 2.20 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ 152.9, 144.0, 139.2, 138.0, 131.5, 129.7, 128.8, 128.6, 127.7, 127.7, 127.4, 127.3, 123.1, 116.4, 116.0, 91.6, 61.0, 55.6, 20.7. HRMS calc. for $C_{23}H_{21}NO$ $[M+H]^+$: 328.1701, found: 328.1694.



3da

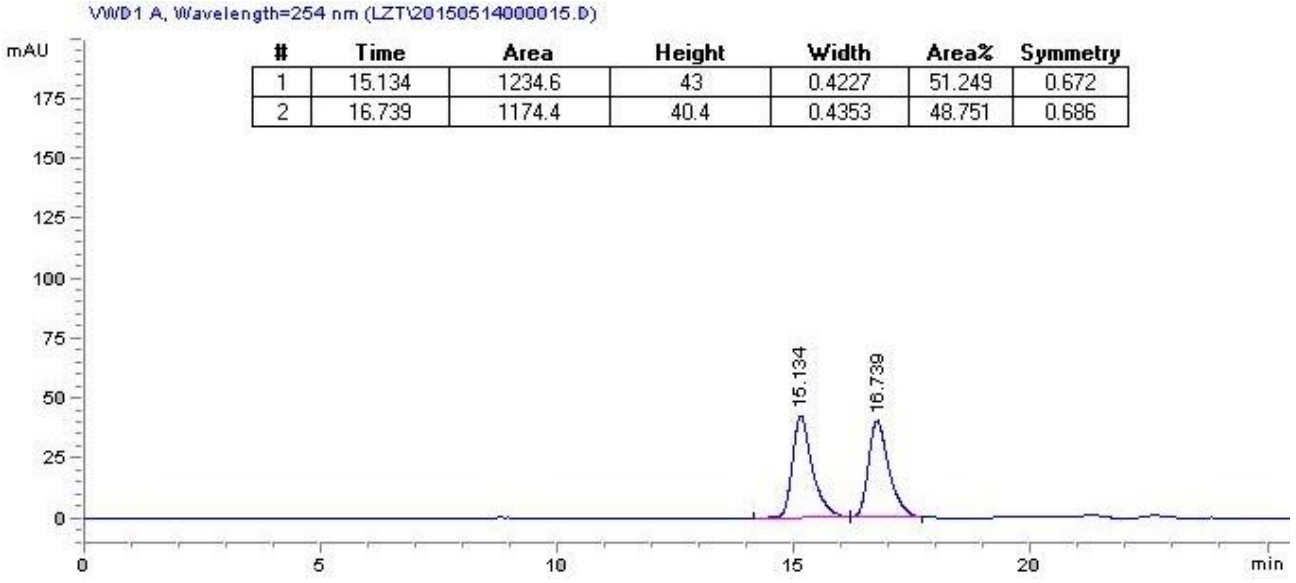


#	Time	Area	Height	Width	Area%	Symmetry
1	12.386	1442.3	44.7	0.4971	50.795	0.825
2	16.17	1397.2	27.9	0.7758	49.205	0.907

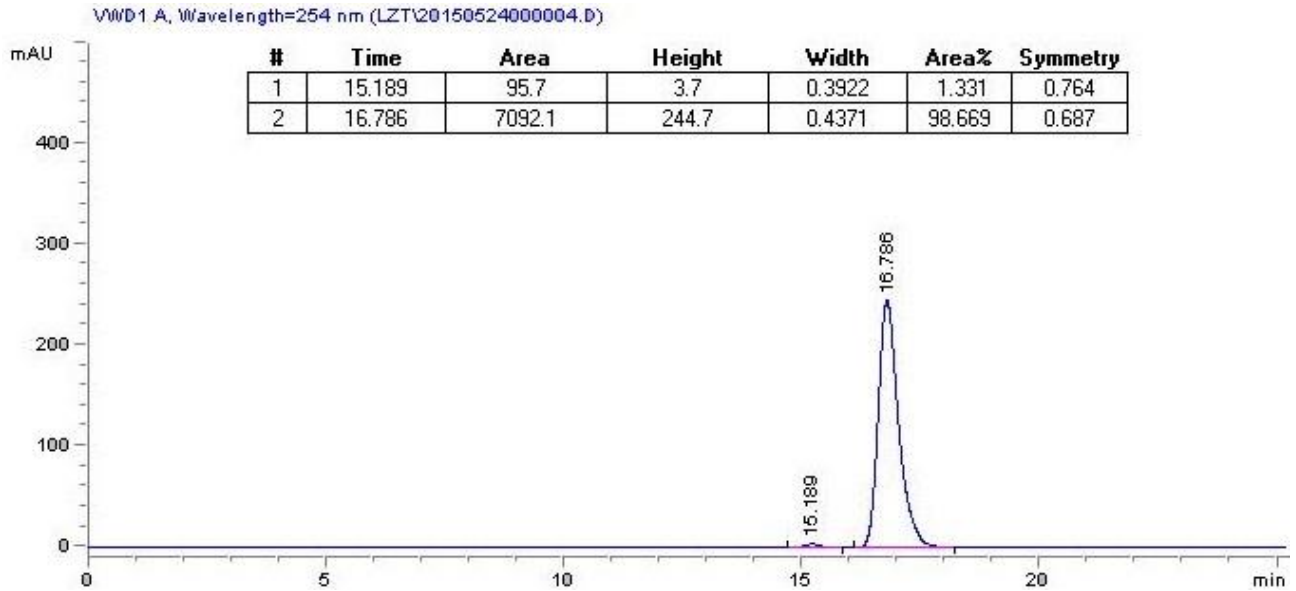


#	Time	Area	Height	Width	Area%	Symmetry
1	12.319	11378.3	355.2	0.4945	96.978	0.731
2	16.249	354.5	7.7	0.6946	3.022	0.891

(*S*)-4-benzyl-8-methyl-2-methylene-3-phenyl-3,4-dihydro-*2H*-benzo[*b*][1,4]oxazine (3ea). 78 mg (79% yield) was obtained as a colorless oil after purification with column chromatography on silica gel (hexanes/ethyl acetate, 100/1). 97% ee was determined by chiral HPLC (Chiralcel OD-H, *n*-hexane/*i*-PrOH = 99/1, 0.5 mL/min, 254 nm, 40 ^{o}C): t_R (minor) = 15.2 min, t_R (major) = 16.8 min. $[\alpha]_D^{29}$ = -52.1 (*c* 1.00, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.48–7.43 (m, 4H), 7.40–7.32 (m, 6H), 6.90–6.86 (m, 1H), 6.77–6.75 (m, 2H), 4.95 (s, 1H), 4.89 (d, *J* = 0.8 Hz, 1H), 4.66 (d, *J* = 15.7 Hz, 1H), 4.45 (d, *J* = 1.2 Hz, 1H), 4.36 (d, *J* = 15.7 Hz, 1H), 2.39 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ 153.2, 141.9, 139.45, 137.9, 133.6, 128.8, 128.7, 127.7, 127.5, 127.4, 127.3, 125.0, 121.8, 121.3, 112.8, 91.3, 61.1, 54.9, 16.0. HRMS calc. for $C_{23}H_{21}NO$ $[M+H]^+$: 328.1701, found: 328.1694.

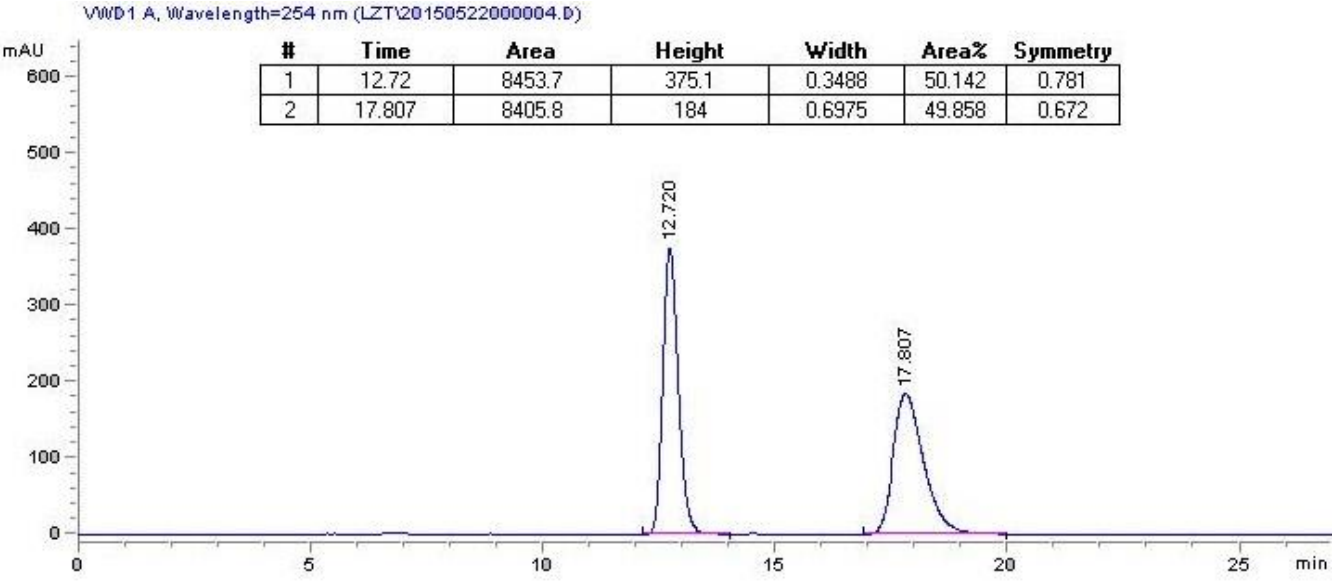


#	Time	Area	Height	Width	Area%	Symmetry
1	15.134	1234.6	43	0.4227	51.249	0.672
2	16.739	1174.4	40.4	0.4353	48.751	0.686

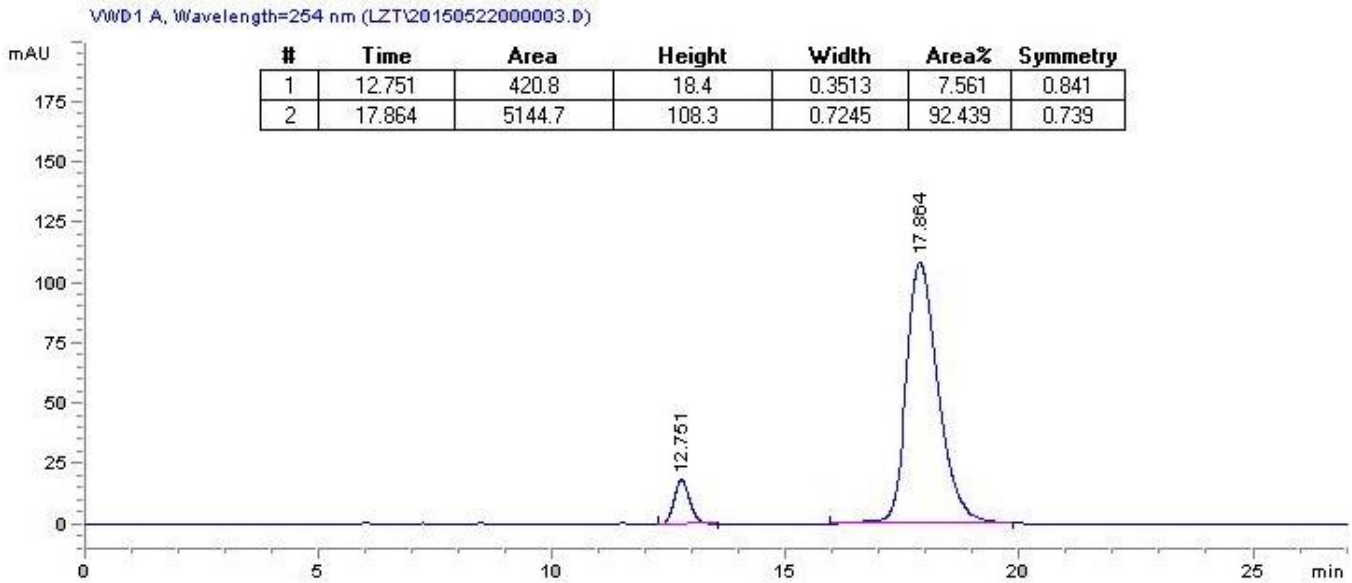


#	Time	Area	Height	Width	Area%	Symmetry
1	15.189	95.7	3.7	0.3922	1.331	0.764
2	16.786	7092.1	244.7	0.4371	98.669	0.687

(*S*)-4-benzyl-2-methylene-6-nitro-3-phenyl-3,4-dihydro-*2H*-benzo[*b*][1,4]oxazine (3fa). 105 mg (98% yield) was obtained as a yellow oil after purification with column chromatography on silica gel (hexanes/ethyl acetate, 20/1). 85% ee was determined by chiral HPLC (Chiralcel OJ-H, *n*-hexane/*i*-PrOH = 50/50, 0.8 mL/min, 254 nm, 40 ^{o}C): t_R (minor) = 12.8 min, t_R (major) = 17.9 min. $[\alpha]_D^{29}$ = -17.2 (*c* 1.09, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.65–7.63 (m, 2H), 7.37–7.22 (m, 8H), 7.17–7.14 (m, 2H), 6.94–6.92 (m, 1H), 4.94 (s, 1H), 4.81 (d, *J* = 1.7 Hz, 1H), 4.69 (d, *J* = 15.6 Hz, 1H), 4.47 (d, *J* = 1.9 Hz, 1H), 4.27 (d, *J* = 15.6 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ 152.1, 147.9, 143.2, 138.1, 135.9, 134.1, 129.0, 129.0, 128.3, 128.0, 127.5, 126.9, 115.5, 115.1, 108.5, 93.2, 60.3, 53.5. HRMS calc. for $C_{22}H_{18}N_2O_3$ $[M+H]^+$: 359.1396, found: 359.1389.

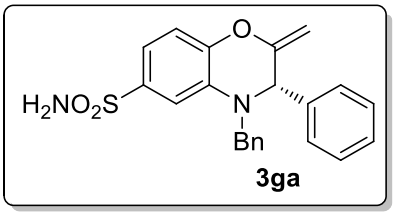


#	Time	Area	Height	Width	Area%	Symmetry
1	12.72	8453.7	375.1	0.3488	50.142	0.781
2	17.807	8405.8	184	0.6975	49.858	0.672

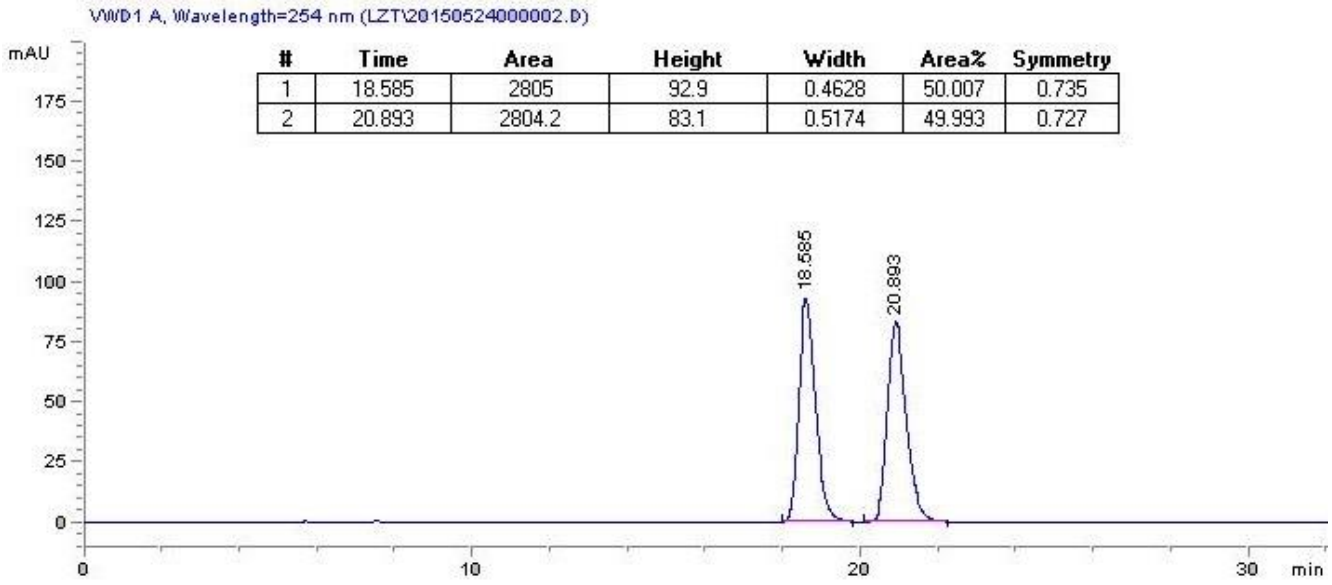


#	Time	Area	Height	Width	Area%	Symmetry
1	12.751	420.8	18.4	0.3513	7.561	0.841
2	17.864	5144.7	108.3	0.7245	92.439	0.739

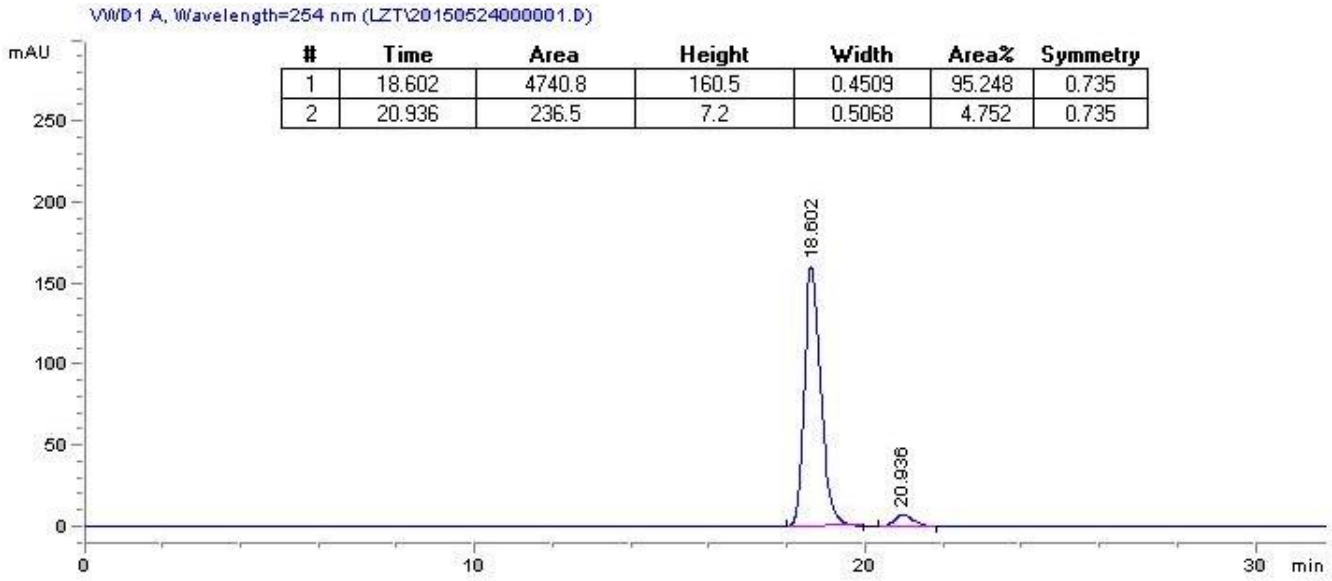
***(S)*-4-benzyl-2-methylene-3-phenyl-3,4-dihydro-*2H*-benzo[*b*][1,4]oxazine-6-sulfonamide (3ga).** 114



mg (97% yield) was obtained as a white solid after purification with column chromatography on silica gel (hexanes/ethyl acetate, 5/1). M.p.: 140-142 ^{o}C. 91% ee was determined by chiral HPLC (Chiralcel AD-H, *n*-hexane/*i*-PrOH = 90/10, 0.8 mL/min, 254 nm, 40 ^{o}C): t_R (major) = 18.6 min, t_R (minor) = 20.9 min. $[\alpha]_D^{28}$ = -23.7 (*c* 1.01, CH_2Cl_2). ^{1}H NMR (400 MHz, DMSO-d^6): δ 7.41–7.36 (m, 4H), 7.34–7.29 (m, 4H), 7.28–7.25 (m, 3H), 7.22–7.19 (m, 1H), 7.04–7.06 (m, 1H), 5.39 (s, 1H), 4.79 (s, 1H), 4.77–4.73 (m, 2H), 4.47 (d, *J* = 16.2 Hz, 1H); ^{13}C NMR (101 MHz, DMSO-d^6): δ 152.4, 144.8, 139.5, 138.9, 138.9, 137.6, 133.7, 129.2, 128.3, 127.9, 127.6, 127.1, 116.5, 115.6, 110.8, 92.7, 60.6, 53.4. HRMS calc. for $C_{22}H_{20}N_2O_3S$ $[M+H]^+$: 393.1273, found: 393.1264.

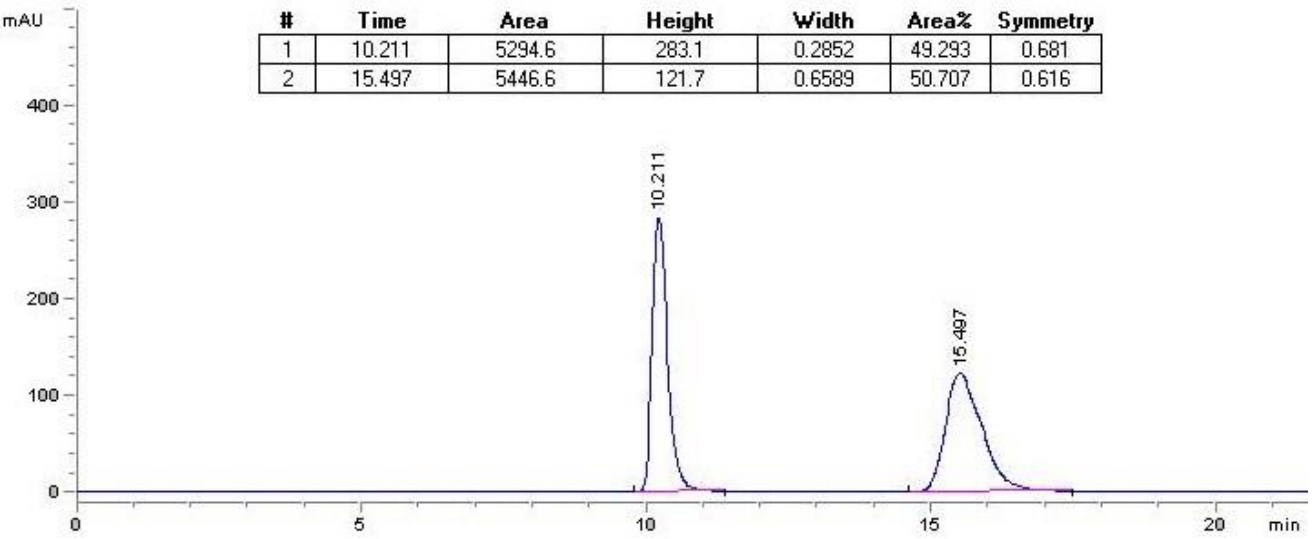


#	Time	Area	Height	Width	Area%	Symmetry
1	18.585	2805	92.9	0.4628	50.007	0.735
2	20.893	2804.2	83.1	0.5174	49.993	0.727

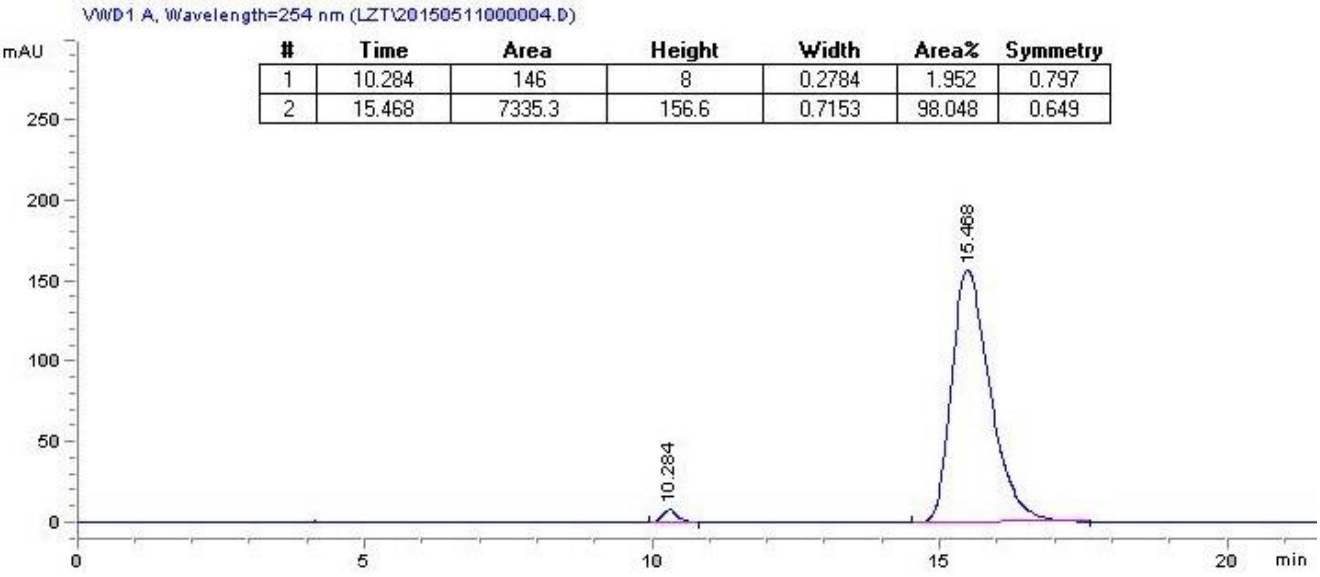


#	Time	Area	Height	Width	Area%	Symmetry
1	18.602	4740.8	160.5	0.4509	95.248	0.735
2	20.936	236.5	7.2	0.5068	4.752	0.735

(*S*)-4-benzyl-6-bromo-2-methylene-3-phenyl-3,4-dihydro-*2H*-benzo[*b*][1,4]oxazine (3ha). 114 mg (97% yield) was obtained as a colorless oil after purification with column chromatography on silica gel (hexanes/ethyl acetate, 100/1). 96% ee was determined by chiral HPLC (Chiralcel OJ-H, *n*-hexane/*i*-PrOH = 95/5, 0.8 mL/min, 254 nm, 40 ^{o}C): t_R (minor) = 10.3 min, t_R (major) = 15.5 min. $[\alpha]_D^{28}$ = -23.7 (*c* 1.01, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.35–7.31 (m, 2H), 7.28–7.26 (m, 3H), 7.25–7.21 (m, 3H), 7.19–7.16 (m, 2H), 6.86–6.79 (m, 2H), 6.75–6.73 (m, 1H), 4.81 (s, 1H), 4.70 (d, *J* = 0.9 Hz, 1H), 4.54 (d, *J* = 15.7 Hz, 1H), 4.34 (d, *J* = 1.4 Hz, 1H), 4.18 (d, *J* = 15.7 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ 152.5, 142.5, 138.8, 136.7, 135.2, 128.9, 128.8, 128.0, 127.7, 127.5, 127.0, 121.6, 117.0, 116.4, 114.9, 91.8, 60.6, 53.7. HRMS calc. for $C_{22}H_{18}BrNO$ $[M+H]^+$: 392.0650, found: 392.0642.

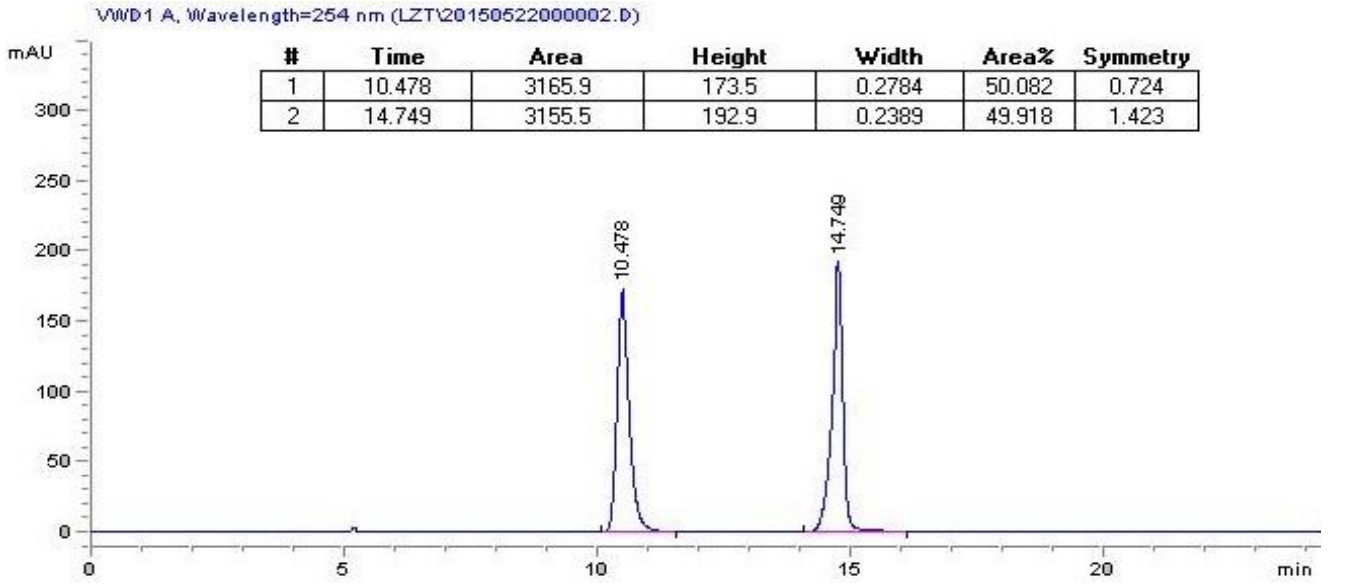


#	Time	Area	Height	Width	Area%	Symmetry
1	10.211	5294.6	283.1	0.2852	49.293	0.681
2	15.497	5446.6	121.7	0.6589	50.707	0.616

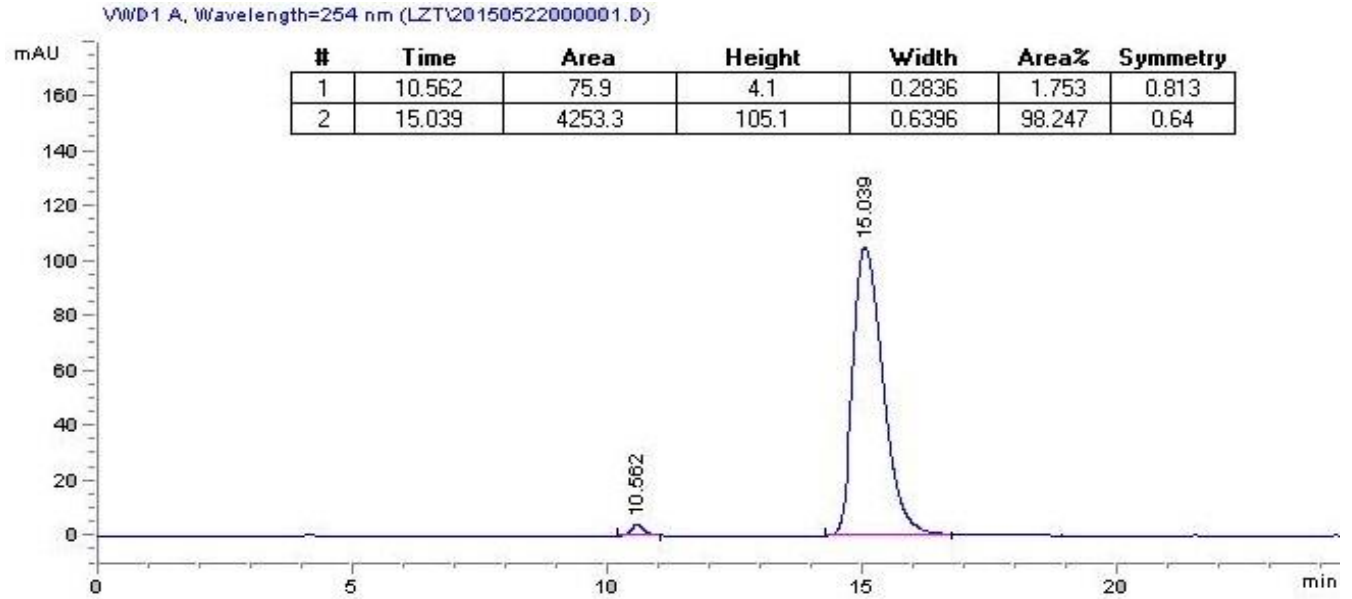


#	Time	Area	Height	Width	Area%	Symmetry
1	10.284	146	8	0.2784	1.952	0.797
2	15.468	7335.3	156.6	0.7153	98.048	0.649

(*S*)-4-benzyl-6-chloro-2-methylene-3-phenyl-3,4-dihydro-*2H*-benzo[*b*][1,4]oxazine (3ia). 102 mg (98% yield) was obtained as a colorless oil after purification with column chromatography on silica gel (hexanes/ethyl acetate, 100/1). 96% ee was determined by chiral HPLC (Chiralcel OJ-H, *n*-hexane/*i*-PrOH = 95/5, 0.8 mL/min, 254 nm, 40 ^{o}C): t_R (minor) = 10.6 min, t_R (major) = 15.0 min. $[\alpha]_D^{29}$ = -45.6 (*c* 1.04, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.35–7.31 (m, 2H), 7.29–7.20 (m, 6H), 7.19–7.16 (m, 2H), 6.81–6.79 (m, 1H), 6.72–6.71 (m, 1H), 6.68–6.65 (m, 1H), 4.82 (s, 1H), 4.70 (d, *J* = 1.3 Hz, 1H), 4.54 (d, *J* = 15.8 Hz, 1H), 4.34 (d, *J* = 1.6 Hz, 1H), 4.19 (d, *J* = 15.8 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ 152.6, 141.9, 138.8, 136.7, 134.8, 128.9, 128.8, 127.9, 127.7, 127.4, 127.4, 127.0, 118.6, 116.5, 113.6, 91.7, 60.7, 53.7. HRMS calc. for $C_{22}H_{18}ClNO$ $[M+H]^+$: 348.1155, found: 348.1148.

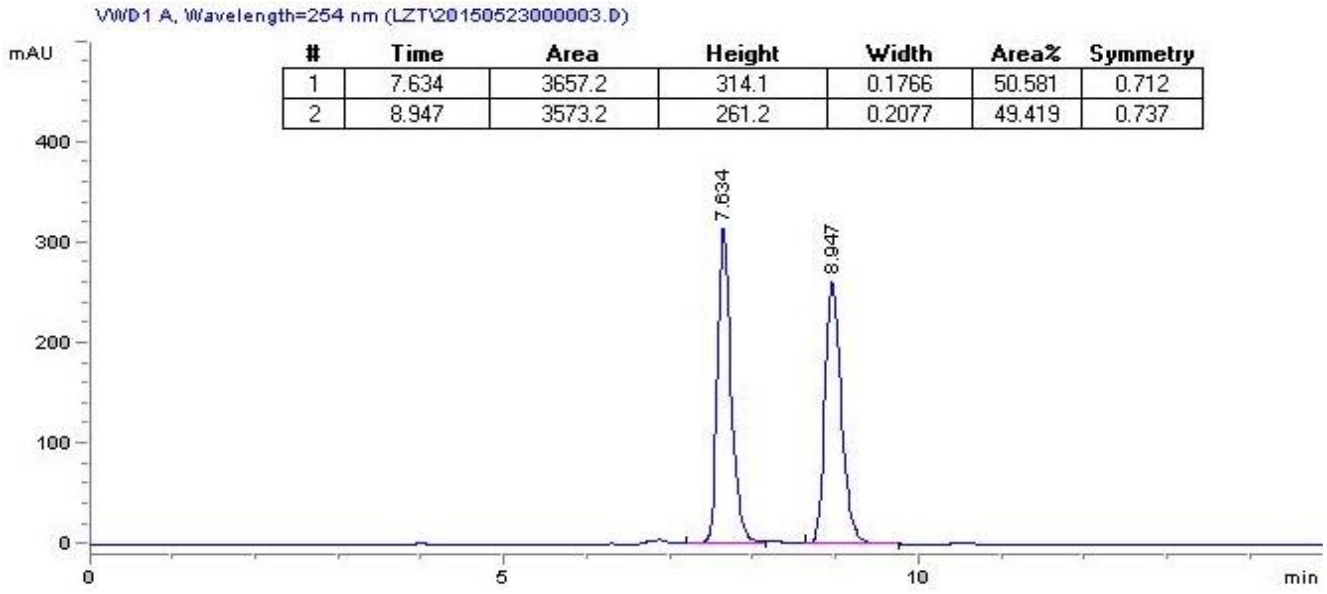


#	Time	Area	Height	Width	Area%	Symmetry
1	10.478	3165.9	173.5	0.2784	50.082	0.724
2	14.749	3155.5	192.9	0.2389	49.918	1.423

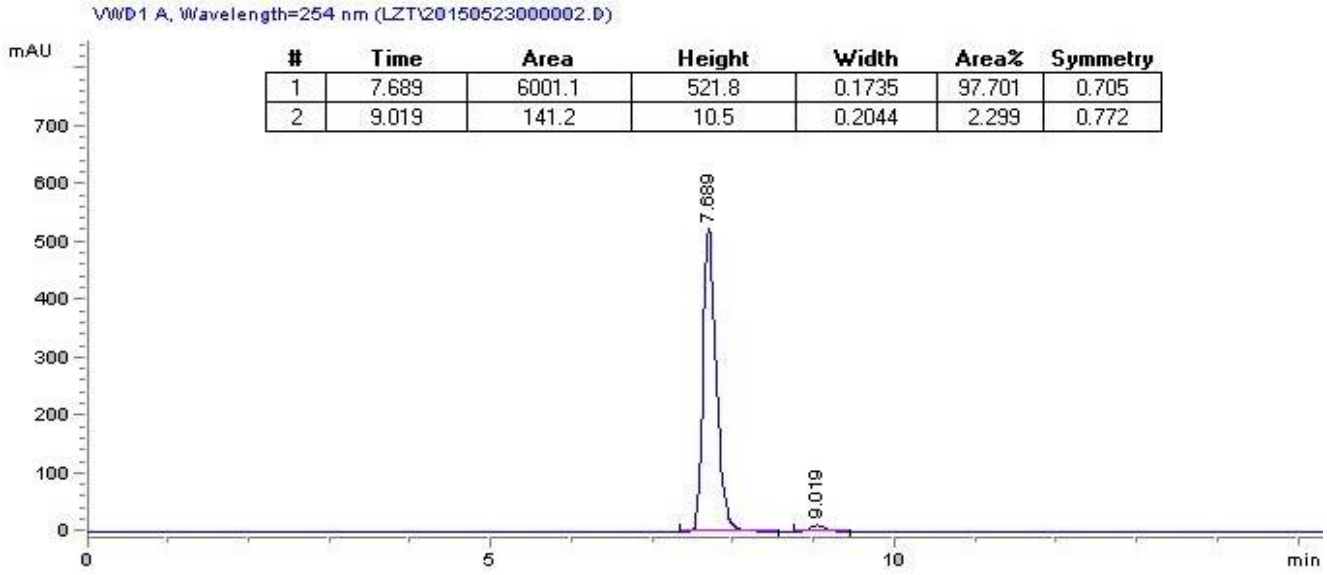


#	Time	Area	Height	Width	Area%	Symmetry
1	10.562	75.9	4.1	0.2836	1.753	0.813
2	15.039	4253.3	105.1	0.6396	98.247	0.64

(*S*)-4-benzyl-7-chloro-2-methylene-3-phenyl-3,4-dihydro-*2H*-benzo[*b*][1,4]oxazine (3ja). 101 mg (97% yield) was obtained as a colorless oil after purification with column chromatography on silica gel (hexanes/ethyl acetate, 100/1). 95% ee was determined by chiral HPLC (Chiralcel OD-H, *n*-hexane/*i*-PrOH = 95/5, 0.8 mL/min, 254 nm, 40 °C): t_R (major) = 7.7 min, t_R (minor) = 9.0 min. $[\alpha]_D^{29}$ = -68.3 (*c* 1.02, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.23–7.18 (m, 4H), 7.17–7.09 (m, 6H), 6.80–6.79 (m, 1H), 6.69–6.67 (m, 1H), 6.53–6.51 (m, 1H), 4.71 (s, 1H), 4.64 (s, 1H), 4.37 (d, *J* = 15.7 Hz, 1H), 4.24 (s, 1H), 4.11 (d, *J* = 15.7 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ 152.5, 144.0, 138.8, 137.1, 132.7, 128.9, 128.8, 128.0, 127.6, 127.5, 127.2, 123.9, 122.4, 116.0, 115.5, 92.2, 61.1, 54.7. HRMS calc. for $C_{22}H_{18}ClNO$ $[M+H]^+$: 348.1155, found: 348.1146.

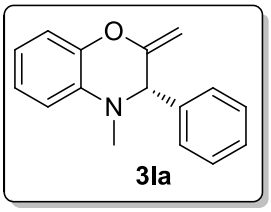


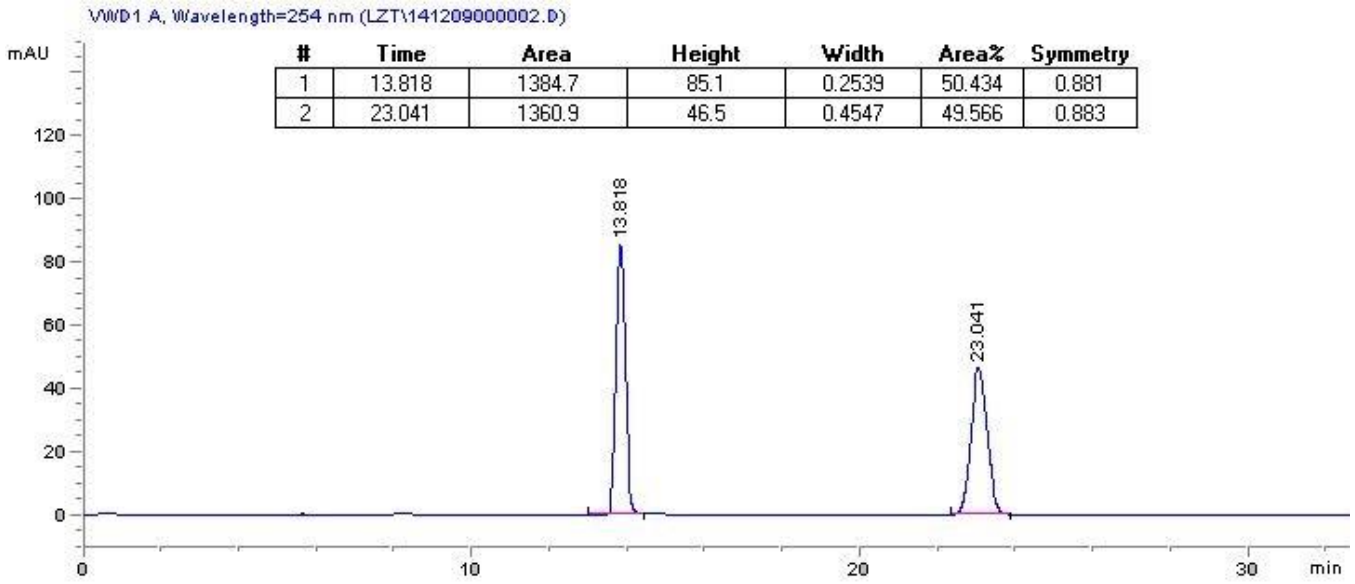
#	Time	Area	Height	Width	Area%	Symmetry
1	7.634	3657.2	314.1	0.1766	50.581	0.712
2	8.947	3573.2	261.2	0.2077	49.419	0.737



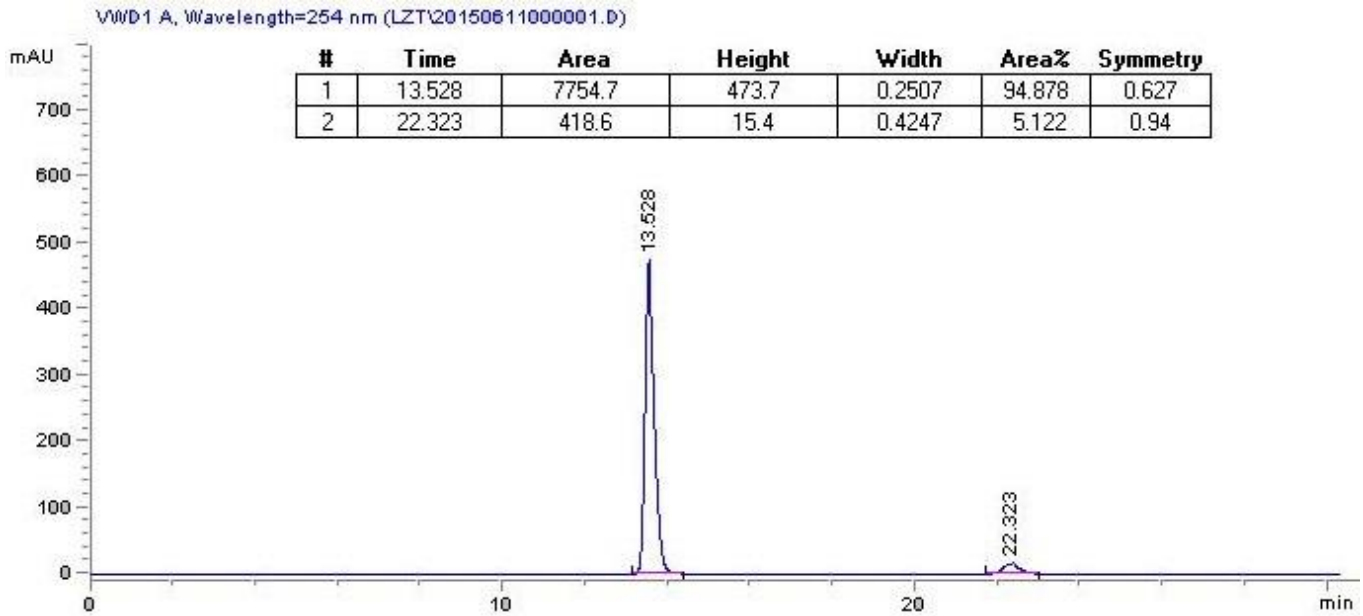
#	Time	Area	Height	Width	Area%	Symmetry
1	7.689	6001.1	521.8	0.1735	97.701	0.705
2	9.019	141.2	10.5	0.2044	2.299	0.772

(*S*)-4-methyl-2-methylene-3-phenyl-3,4-dihydro-*2H*-benzo[*b*][1,4]oxazine (3la). 68 mg (95% yield) was obtained as a colorless oil after purification with column chromatography on silica gel (hexanes/ethyl acetate, 100/1). 90% ee was determined by chiral HPLC (Chiralcel OJ-H, *n*-hexane/*i*-PrOH = 70/30, 0.8 mL/min, 254 nm, 40 ^{o}C): t_R (major) = 13.5 min, t_R (minor) = 22.3 min. $[\alpha]_D^{29}$ = -253.2 (*c* 1.00, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.27–7.17 (m, 5H), 6.91–6.89 (m, 2H), 6.75–6.67 (m, 2H), 4.72 (s, 1H), 4.65 (d, *J* = 1.1 Hz, 1H), 4.22 (d, *J* = 1.1 Hz, 1H), 2.79 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ 154.2, 142.9, 139.0, 134.7, 128.7, 127.9, 127.4, 122.7, 118.6, 115.2, 112.6, 91.0, 63.4, 36.8. HRMS calc. for $C_{16}H_{15}NO$ $[M+H]^+$: 238.1232, found: 238.1216.





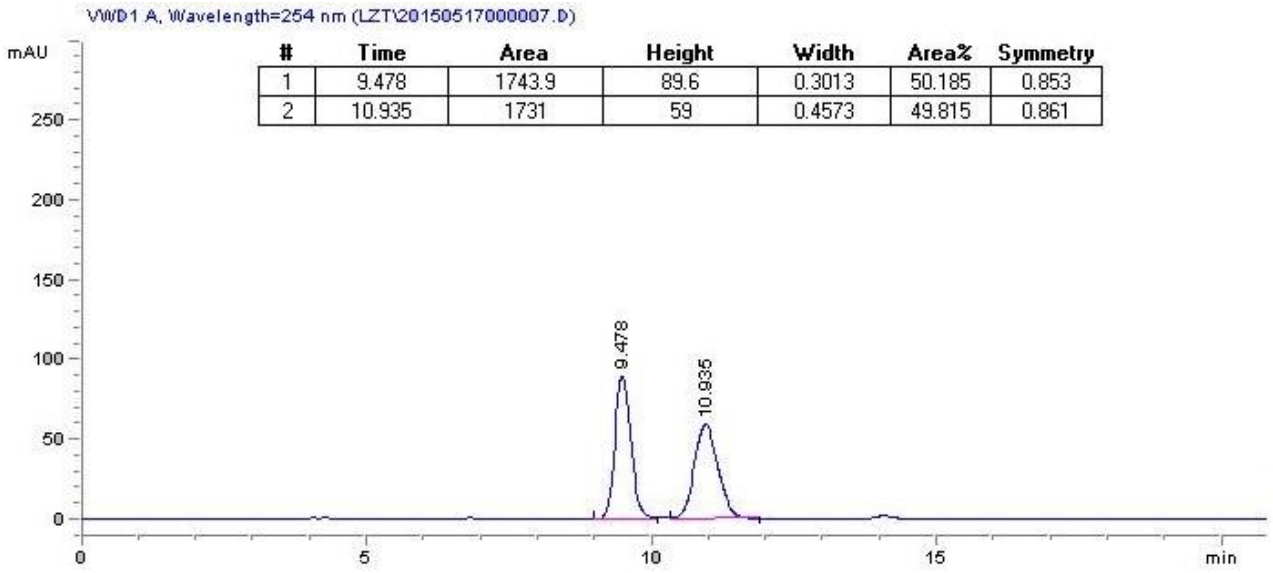
#	Time	Area	Height	Width	Area%	Symmetry
1	13.818	1384.7	85.1	0.2539	50.434	0.881
2	23.041	1360.9	46.5	0.4547	49.566	0.883



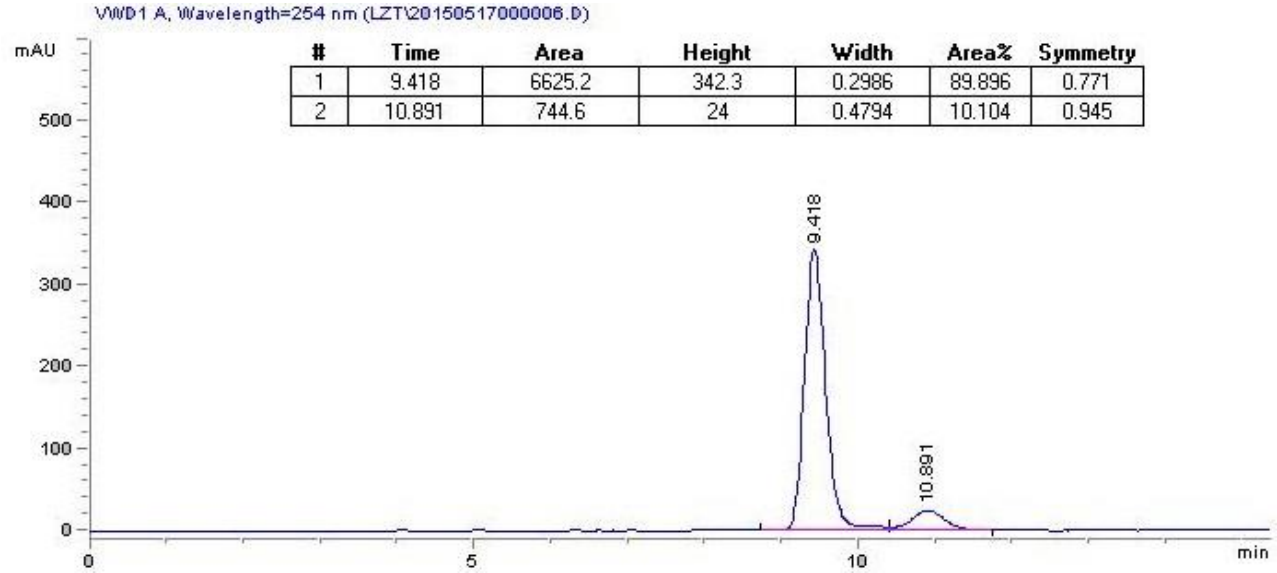
#	Time	Area	Height	Width	Area%	Symmetry
1	13.528	7754.7	473.7	0.2507	94.878	0.627
2	22.323	418.6	15.4	0.4247	5.122	0.94

(*S*)-4-benzyl-3-(2-chlorophenyl)-2-methylene-3,4-dihydro-*2H*-benzo[*b*][1,4]oxazine (3ab). 99 mg (95% yield) was obtained as a colorless oil after purification with column chromatography on silica gel (hexanes/ethyl acetate, 100/1). 80% ee was determined by chiral HPLC (Chiralcel OJ-H, *n*-hexane/*i*-PrOH = 90/10, 0.8 mL/min, 254 nm, 40 ^{o}C): t_R (major) = 9.4 min, t_R (minor) = 10.9 min. $[\alpha]_D^{28}$ = -101.2 (*c* 1.00, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.24–7.11 (m, 7H), 7.15–7.11 (m, 2H), 6.86–6.84 (m, 1H), 6.77–6.72 (m, 1H), 6.64–6.60 (m, 1H), 6.56–6.53 (m, 1H), 5.40 (s, 1H), 4.62 (d, *J* = 1.3 Hz, 1H), 4.48 (d, *J* = 1.4 Hz, 1H), 4.41 (d, *J* = 16.2 Hz, 1H), 4.06 (d, *J* = 16.2 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ 151.4, 142.6, 137.8, 137.3, 134.0, 133.3, 130.0, 129.0, 128.8, 127.9, 127.5, 127.4, 127.1, 122.9, 118.3, 115.7, 112.4, 92.73, 58.0, 53.1. HRMS calc. for $C_{22}H_{18}ClNO$ $[M+H]^+$: 348.1155, found: 348.1136.

3ab

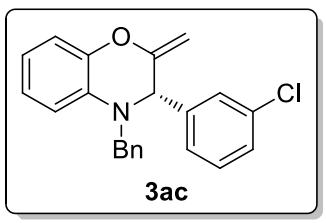


#	Time	Area	Height	Width	Area%	Symmetry
1	9.478	1743.9	89.6	0.3013	50.185	0.853
2	10.935	1731	59	0.4573	49.815	0.861

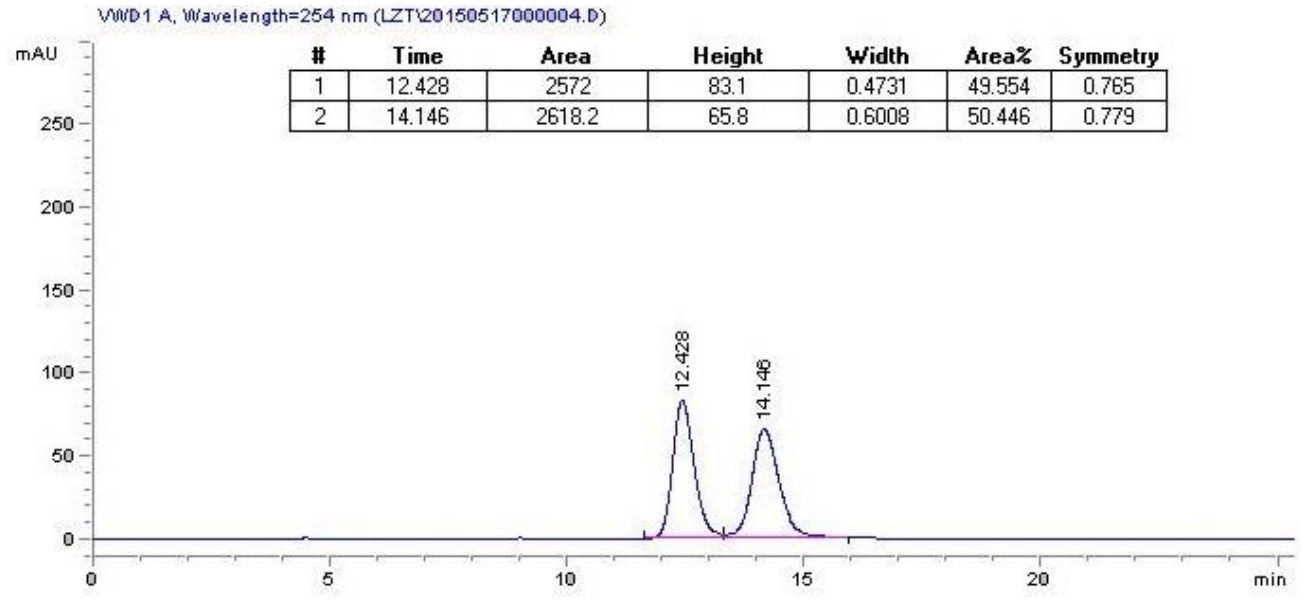


#	Time	Area	Height	Width	Area%	Symmetry
1	9.418	6625.2	342.3	0.2986	89.896	0.771
2	10.891	744.6	24	0.4794	10.104	0.945

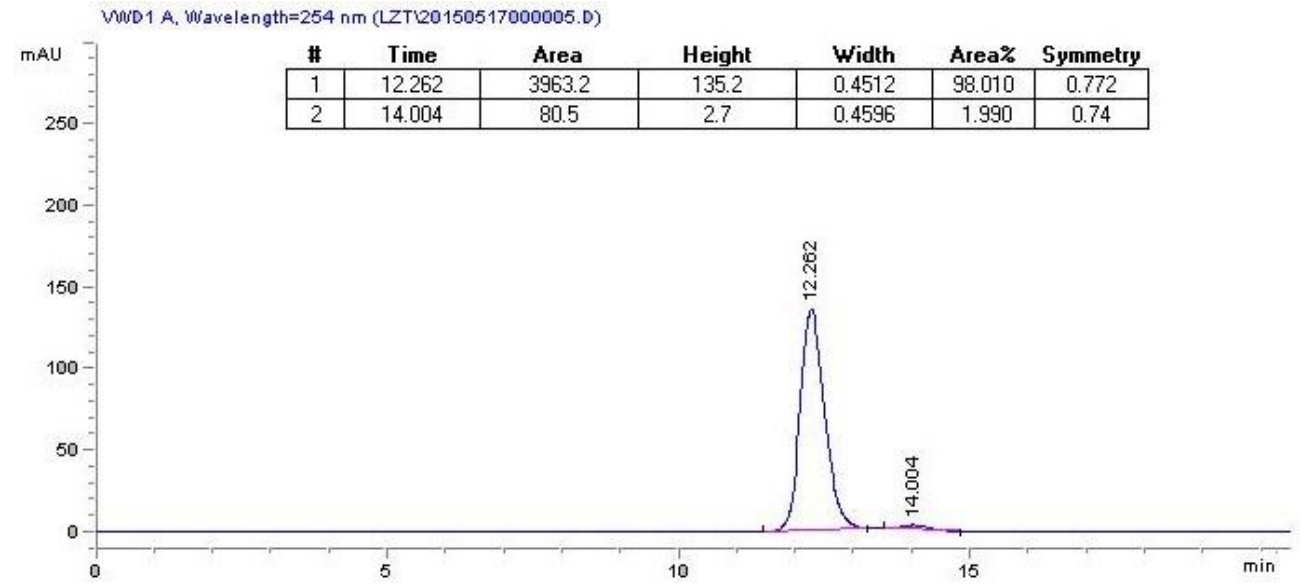
(*S*)-4-benzyl-3-(3-chlorophenyl)-2-methylene-3,4-dihydro-*2H*-benzo[*b*][1,4]oxazine (3ac). 94 mg (90% yield) was obtained as a colorless oil after purification with column chromatography on silica gel (hexanes/ethyl acetate, 100/1). 96% ee was determined by chiral HPLC (Chiralcel OJ-H, *n*-hexane/*i*-PrOH = 98/2, 0.8 mL/min, 254 nm, 40 ^{o}C): t_R (major) = 12.3 min, t_R (minor) = 14.0 min. $[\alpha]_D^{28}$ = -34.7 (*c* 1.00, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.23–7.20 (m, 4H), 7.18–7.14 (m, 2H), 7.07–7.01 (m, 3H), 6.80–6.63 (m, 4H), 4.67–4.64 (m, 2H), 4.40 (d, *J* = 15.5 Hz, 1H), 4.22 (d, *J* = 1.3 Hz, 1H), 4.14 (d, *J* = 15.5 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ 151.9, 143.9, 141.3, 137.3, 134.5, 133.5, 129.9, 128.9, 127.9, 127.7, 127.6, 127.5, 125.3, 122.8, 120.1, 115.9, 115.9, 92.2, 60.5, 55.4. HRMS calc. for $C_{22}H_{18}ClNO$ $[M+H]^+$: 348.1155, found: 348.1137.



3ac



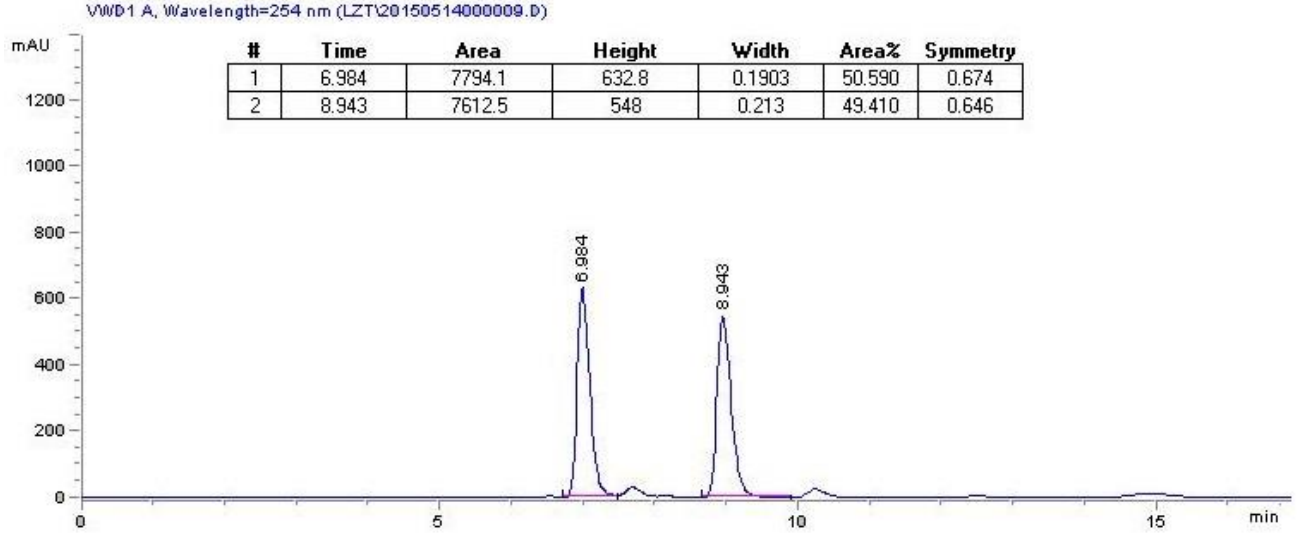
#	Time	Area	Height	Width	Area%	Symmetry
1	12.428	2572	83.1	0.4731	49.554	0.765
2	14.146	2618.2	65.8	0.6008	50.446	0.779



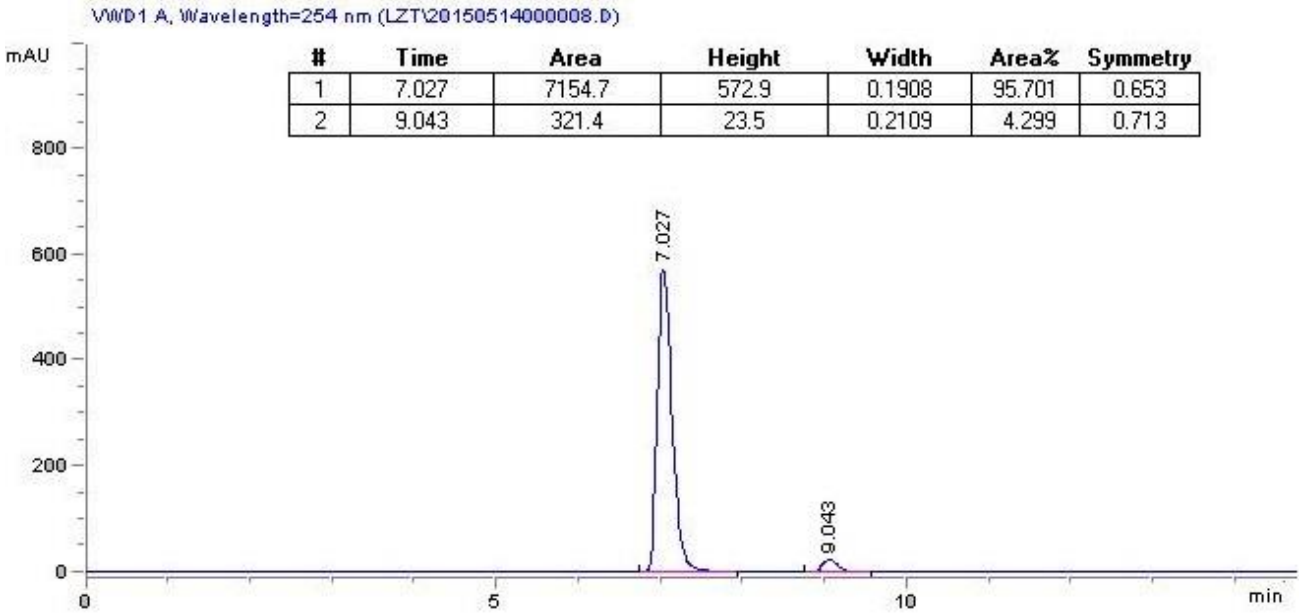
#	Time	Area	Height	Width	Area%	Symmetry
1	12.262	3963.2	135.2	0.4512	98.010	0.772
2	14.004	80.5	2.7	0.4596	1.990	0.74

***(S)*-4-benzyl-3-(4-chlorophenyl)-2-methylene-3,4-dihydro-*2H*-benzo[*b*][1,4]oxazine (3ad).** 100 mg (96% yield) was obtained as a colorless oil after purification with column chromatography on silica gel (hexanes/ethyl acetate, 100/1). 91% ee was determined by chiral HPLC (Chiralcel AD-H, *n*-hexane/*i*-PrOH = 98/2, 0.8 mL/min, 254 nm, 40 ^{o}C): t_R (major) = 7.0 min, t_R (minor) = 9.0 min. $[\alpha]_D^{29}$ = -37.6 (*c* 1.00, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.31 (dd, *J* = 12.2, 4.0 Hz, 4H), 7.27 (dd, *J* = 8.4, 4.1 Hz, 1H), 7.21–7.13 (m, 4H), 6.86 (dd, *J* = 15.0, 7.8 Hz, 2H), 6.82–6.71 (m, 2H), 4.74 (d, *J* = 4.0 Hz, 2H), 4.49 (d, *J* = 15.5 Hz, 1H), 4.29 (s, 1H), 4.22 (d, *J* = 15.4 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ 152.2, 143.9, 137.6, 137.4, 133.6, 133.5, 128.8, 128.8, 128.6, 127.7, 127.6, 122.7, 120.1, 115.8, 115.8, 91.9, 60.2, 55.2. HRMS calc. for $C_{22}H_{18}ClNO$ $[M+H]^+$: 348.1155, found: 348.1138.

3ad

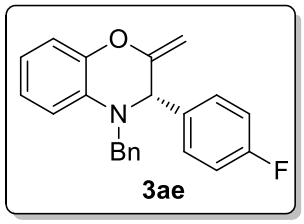


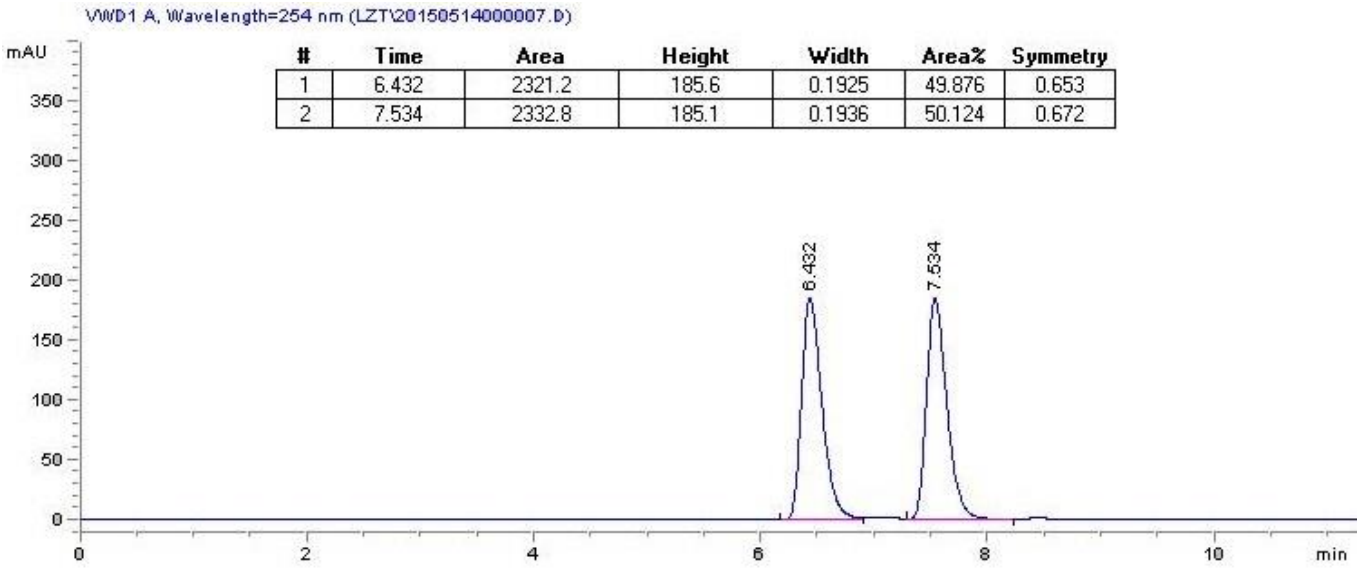
#	Time	Area	Height	Width	Area%	Symmetry
1	6.984	7794.1	632.8	0.1903	50.590	0.674
2	8.943	7612.5	548	0.213	49.410	0.646



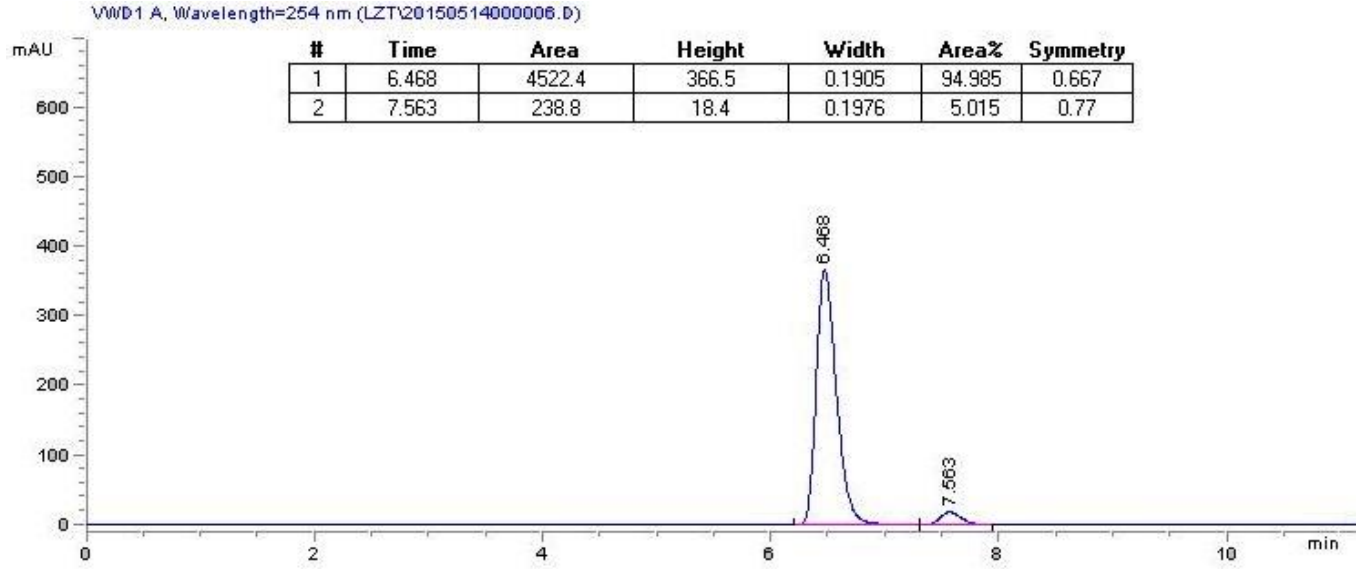
#	Time	Area	Height	Width	Area%	Symmetry
1	7.027	7154.7	572.9	0.1908	95.701	0.653
2	9.043	321.4	23.5	0.2109	4.299	0.713

(*S*)-4-benzyl-3-(4-fluorophenyl)-2-methylene-3,4-dihydro-*2H*-benzo[*b*][1,4]oxazine (3ae). 96 mg (97% yield) was obtained as a colorless oil after purification with column chromatography on silica gel (hexanes/ethyl acetate, 100/1). 90% ee was determined by chiral HPLC (Chiralcel AD-H, *n*-hexane/*i*-PrOH = 98/2, 0.8 mL/min, 254 nm, 40 ^{o}C): t_R (major) = 6.4 min, t_R (minor) = 7.5 min. $[\alpha]_D^{29}$ = -41.6 (*c* 1.09, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.25–7.15 (m, 5H), 7.13–7.08 (m, 2H), 6.84–6.75 (m, 4H), 6.71–6.65 (m, 2H), 4.67 (s, 1H), 4.65 (d, *J* = 1.3 Hz, 1H), 4.41 (d, *J* = 15.5 Hz, 1H), 4.20 (d, *J* = 1.5 Hz, 1H), 4.13 (d, *J* = 15.5 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ 162.25 (d, *J* = 246.2 Hz), 152.6, 143.9, 137.5, 134.8 (d, *J* = 3.2 Hz), 133.7, 128.9 (d, *J* = 8.1 Hz), 128.8, 127.6, 127.5, 122.7, 119.9, 115.8, 115.6, 115.5 (d, *J* = 21.4 Hz), 91.7, 60.2, 55.0. HRMS calc. for $C_{22}H_{18}FNO$ $[M+H]^+$: 332.1451, found: 332.1435.



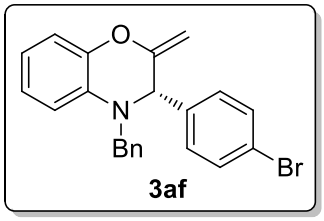


#	Time	Area	Height	Width	Area%	Symmetry
1	6.432	2321.2	185.6	0.1925	49.876	0.653
2	7.534	2332.8	185.1	0.1936	50.124	0.672

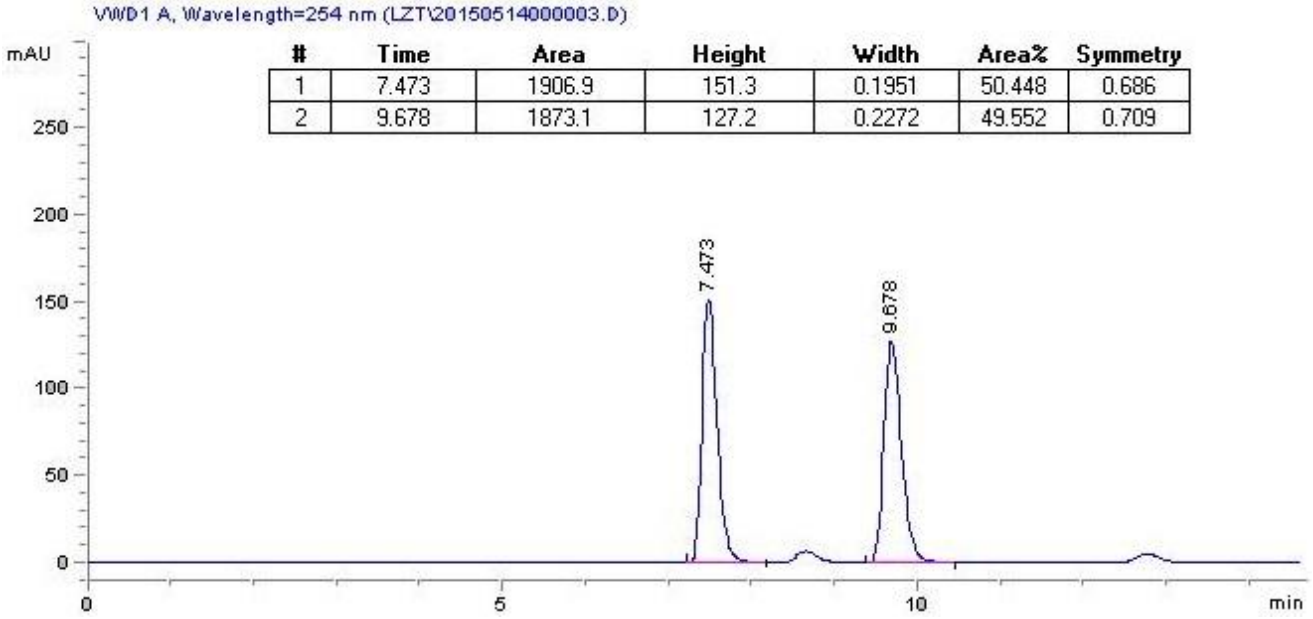


#	Time	Area	Height	Width	Area%	Symmetry
1	6.468	4522.4	366.5	0.1905	94.985	0.667
2	7.563	238.8	18.4	0.1976	5.015	0.77

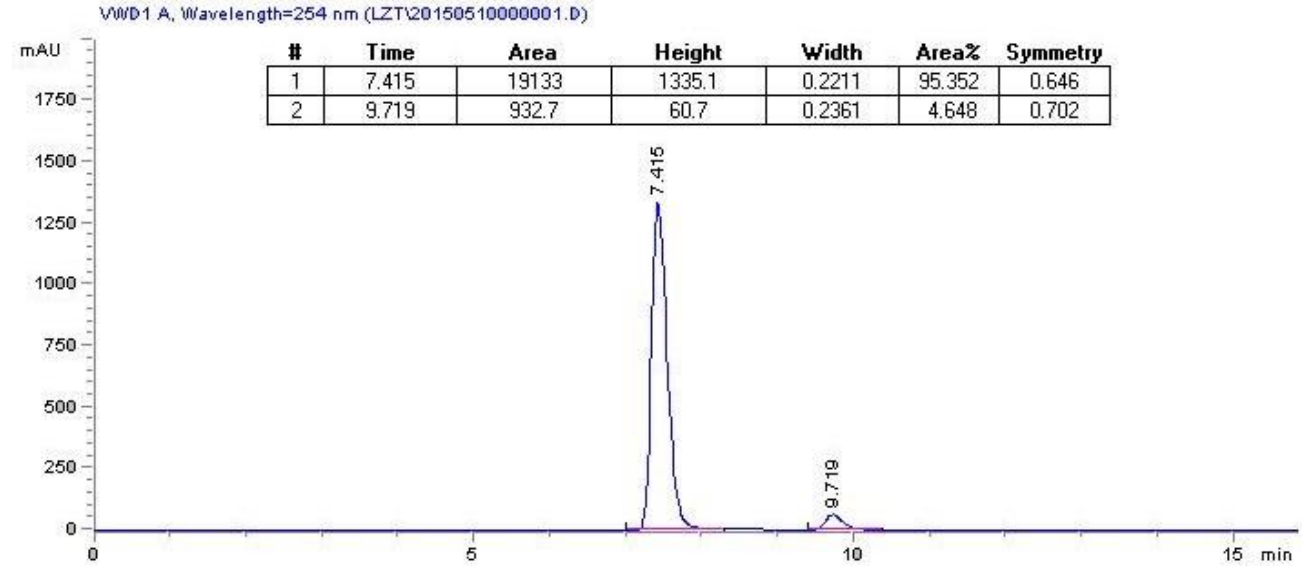
(*S*)-4-benzyl-3-(4-bromophenyl)-2-methylene-3,4-dihydro-*2H*-benzo[*b*][1,4]oxazine (3af). 114 mg



(97% yield) was obtained as a white solid after purification with column chromatography on silica gel (hexanes/ethyl acetate, 100/1). M.p.: 68-70 ^{o}C. 91% ee was determined by chiral HPLC (Chiralcel AD-H, *n*-hexane/*i*-PrOH = 98/2, 0.8 mL/min, 254 nm, 40 ^{o}C): t_R (major) = 7.4 min, t_R (minor) = 9.7 min. $[\alpha]_D^{28}$ = -41.2 (*c* 1.15, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.35–7.22 (m, 7H), 7.12–7.10 (m, 2H), 6.90–6.84 (m, 2H), 6.81–6.74 (m, 2H), 4.75 (d, *J* = 1.3 Hz, 1H), 4.72 (s, 1H), 4.49 (d, *J* = 15.4 Hz, 1H), 4.30 (d, *J* = 1.4 Hz, 1H), 4.23 (d, *J* = 15.4 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ 152.1, 143.9, 138.1, 137.3, 133.5, 131.7, 128.9, 128.8, 127.6, 127.6, 122.7, 121.6, 120.1, 115.8, 115.8, 91.9, 60.2, 55.3. HRMS calc. for $C_{22}H_{18}BrNO$ $[M+H]^+$: 392.0650, found: 392.0640.

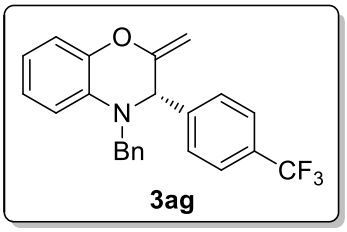


#	Time	Area	Height	Width	Area%	Symmetry
1	7.473	1906.9	151.3	0.1951	50.448	0.686
2	9.678	1873.1	127.2	0.2272	49.552	0.709



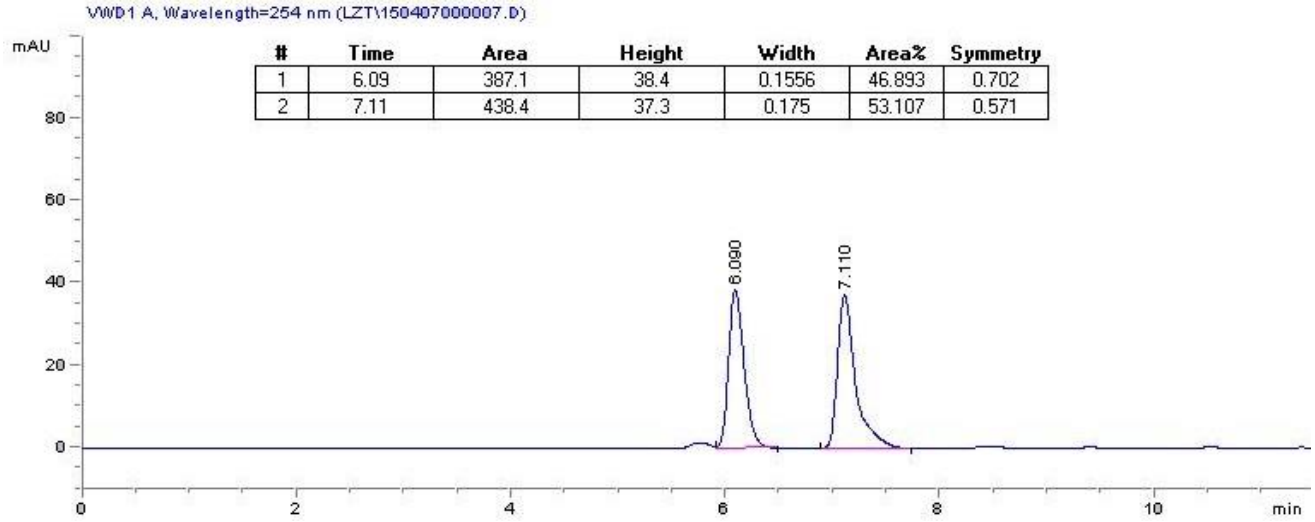
#	Time	Area	Height	Width	Area%	Symmetry
1	7.415	19133	1335.1	0.2211	95.352	0.646
2	9.719	932.7	60.7	0.2361	4.648	0.702

(*S*)-4-benzyl-2-methylene-3-(4-(trifluoromethyl)phenyl)-3,4-dihydro-*2H*-benzo[*b*][1,4]oxazine

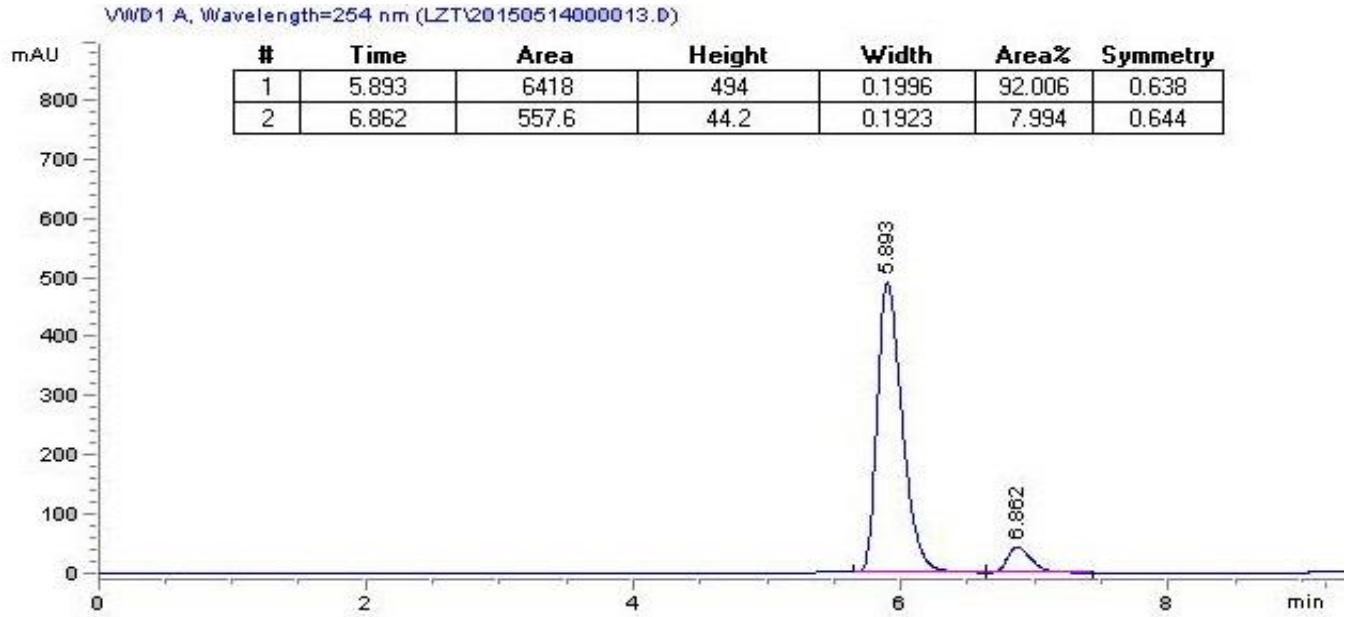


3ag

(3ag). 87 mg (76% yield) was obtained as a white solid after purification with column chromatography on silica gel (hexanes/ethyl acetate, 100/1). M.p.: 56-58 ^{o}C. 84% ee was determined by chiral HPLC (Chiralcel AD-H, *n*-hexane/*i*-PrOH = 98/2, 0.8 mL/min, 254 nm, 40 ^{o}C): t_R (major) = 5.9 min, t_R (minor) = 6.9 min. $[\alpha]_D^{28}$ = -33.5 (*c* 1.13, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.41–7.39 (m, 2H), 7.29–7.17 (m, 7H), 6.82–6.75 (m, 3H), 6.72–6.68 (m, 1H), 4.73 (s, 1H), 4.71 (d, *J* = 1.2 Hz, 1H), 4.43 (d, *J* = 15.4 Hz, 1H), 4.27 (d, *J* = 1.5 Hz, 1H), 4.18 (d, *J* = 15.4 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ 151.6, 144.0, 143.1, 137.2, 133.4, 129.8 (q, *J* = 32.4 Hz), 128.9, 127.7, 127.7, 127.52, 125.5 (q, *J* = 3.7 Hz), 124.1 (q, *J* = 268.9 Hz), 122.8, 120.3, 116.1, 115.9, 92.2, 60.4, 55.6. HRMS calc. for $C_{23}H_{18}F_3NO$ $[M+H]^+$: 382.1419, found: 382.1408.

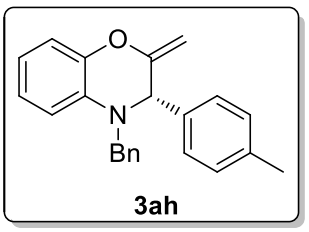


#	Time	Area	Height	Width	Area%	Symmetry
1	6.09	387.1	38.4	0.1556	46.893	0.702
2	7.11	438.4	37.3	0.175	53.107	0.571

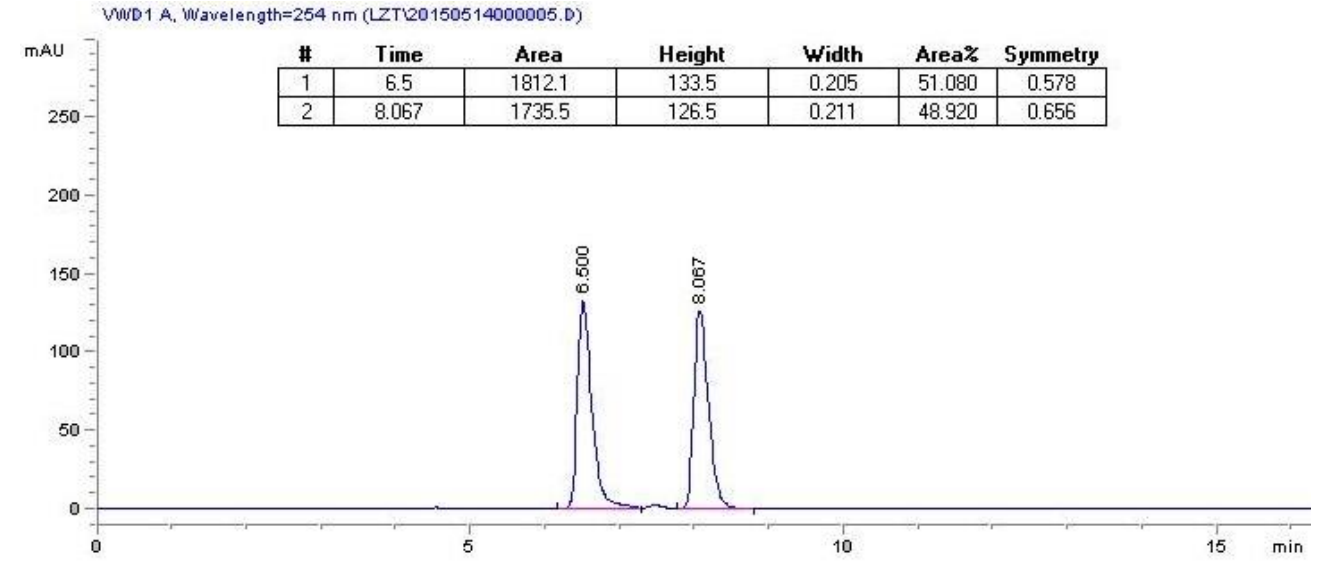


#	Time	Area	Height	Width	Area%	Symmetry
1	5.893	6418	494	0.1996	92.006	0.638
2	6.862	557.6	44.2	0.1923	7.994	0.644

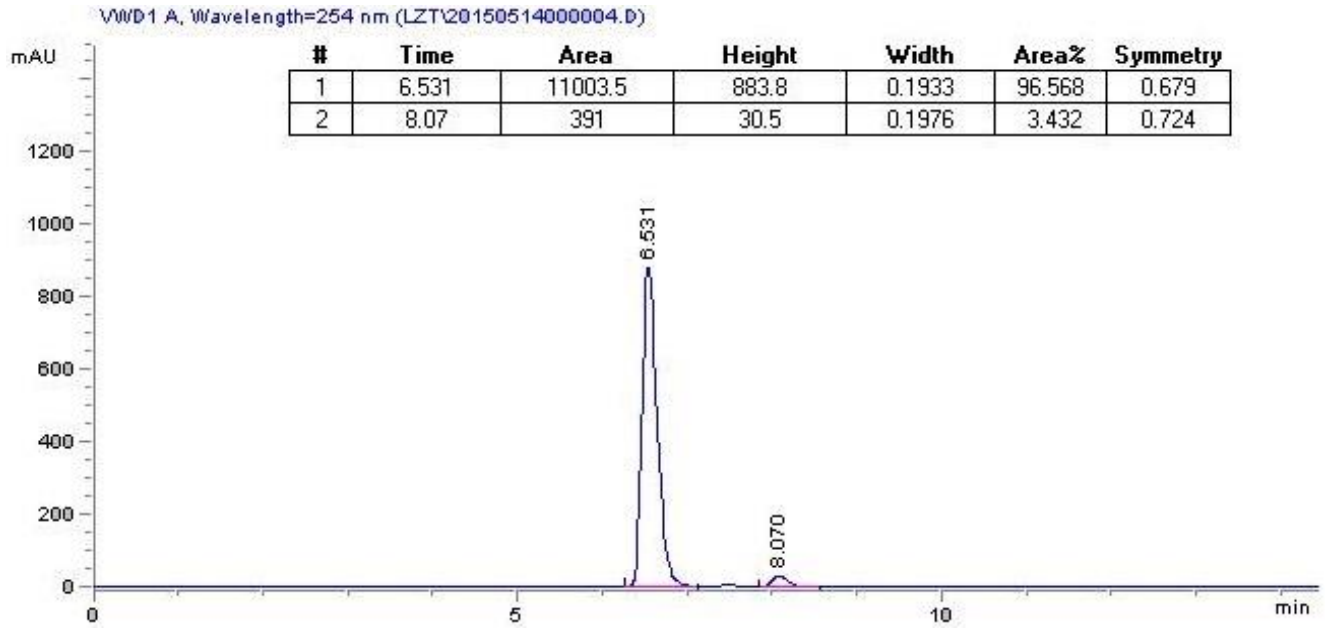
(*S*)-4-benzyl-2-methylene-3-(p-tolyl)-3,4-dihydro-*2H*-benzo[*b*][1,4]oxazine (3ah). 95 mg (97% yield) was obtained as a white solid after purification with column chromatography on silica gel (hexanes/ethyl acetate, 100/1). M.p.: 48-50 ^{o}C. 93% ee was determined by chiral HPLC (Chiralcel AD-H, *n*-hexane/*i*-PrOH = 98/2, 0.8 mL/min, 254 nm, 40 ^{o}C): t_R (major) = 6.5 min, t_R (minor) = 8.1 min. $[\alpha]_D^{28}$ = 69.2 (*c* 1.01, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.24–7.16 (m, 5H), 7.03–7.01 (m, 2H), 6.96–6.94 (m, 2H), 6.81–6.79 (m, 1H), 6.76–6.72 (m, 1H), 6.65–6.63 (m, 2H), 4.70 (s, 1H), 4.61 (s, 1H), 4.43 (d, *J* = 15.7 Hz, 1H), 4.19 (s, 1H), 4.12 (d, *J* = 15.7 Hz, 1H), 2.17 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ 153.4, 143.6, 137.7, 137.4, 136.2, 134.0, 129.4, 128.8, 127.5, 127.4, 127.1, 122.5, 119.3, 115.7, 114.6, 91.2, 60.9, 54.3, 21.2. HRMS calc. for $C_{23}H_{21}NO$ $[M+H]^+$: 328.1701, found: 328.1694.



3ah

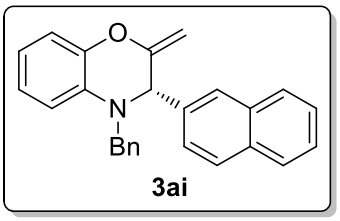


#	Time	Area	Height	Width	Area%	Symmetry
1	6.5	1812.1	133.5	0.205	51.080	0.578
2	8.067	1735.5	126.5	0.211	48.920	0.656



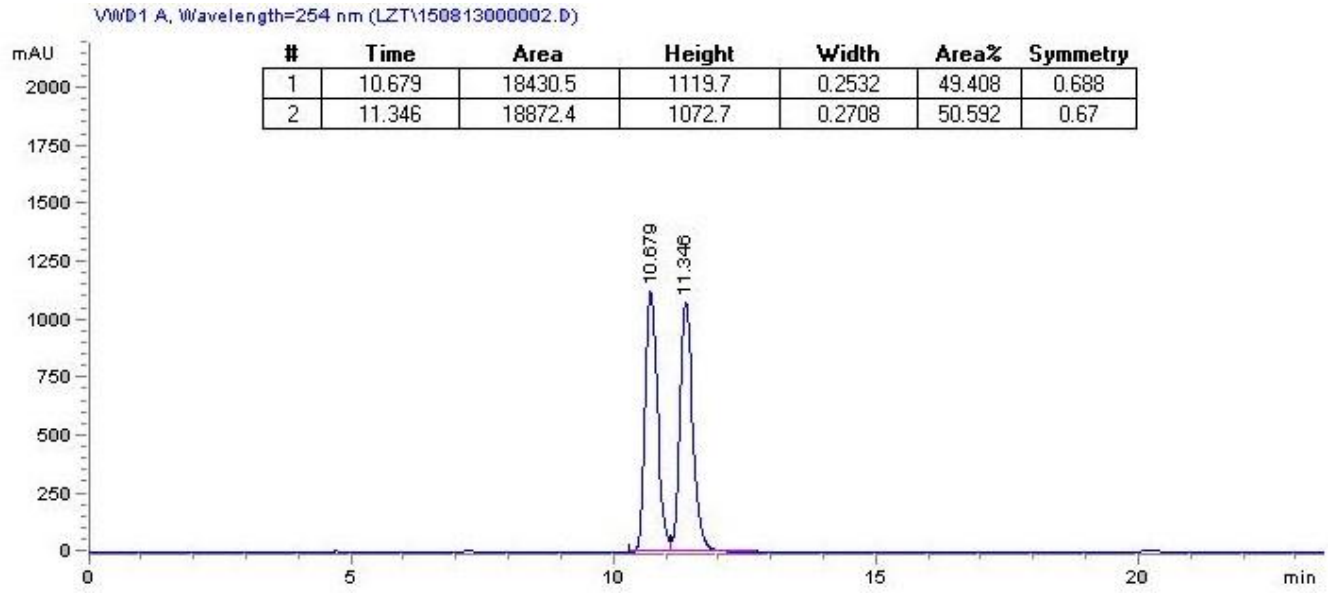
#	Time	Area	Height	Width	Area%	Symmetry
1	6.531	11003.5	883.8	0.1933	96.568	0.679
2	8.07	391	30.5	0.1976	3.432	0.724

(*S*)-4-benzyl-2-methylene-3-(naphthalen-2-yl)-3,4-dihydro-*2H*-benzo[*b*][1,4]oxazine (3ai). 76 mg

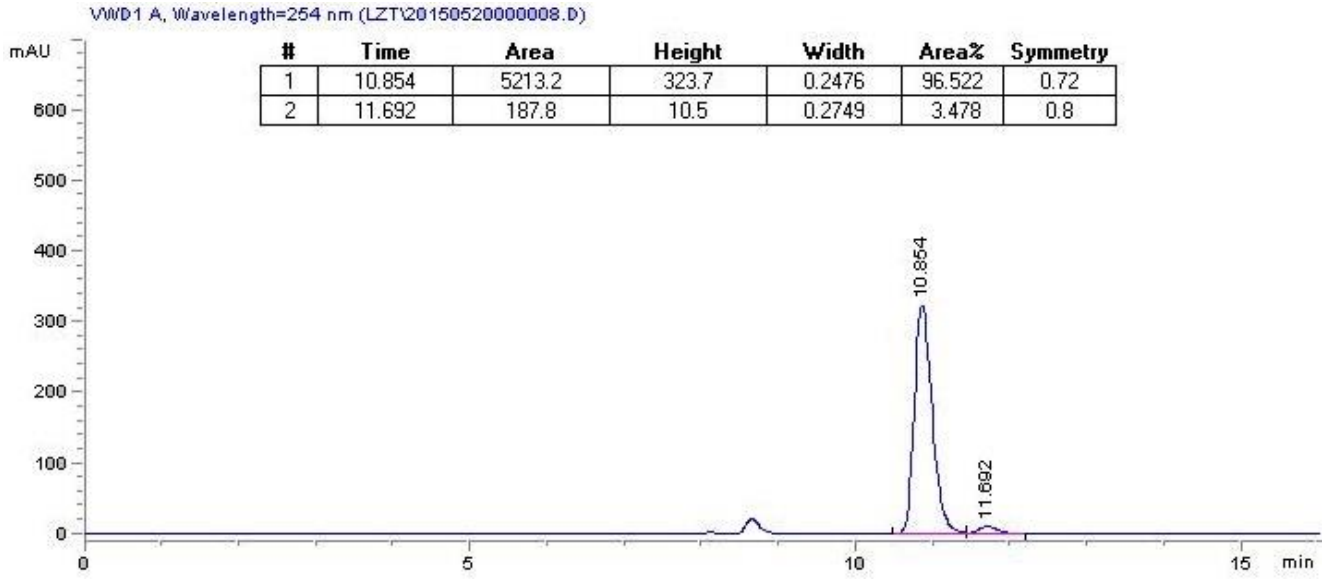


3ai

(70% yield) was obtained as a colorless oil after purification with column chromatography on silica gel (hexanes/ethyl acetate, 100/1). 93% ee was determined by chiral HPLC (Chiralcel AD-H, *n*-hexane/*i*-PrOH = 98/2, 0.8 mL/min, 254 nm, 40 ^{o}C): t_R (major) = 10.9 min, t_R (minor) = 11.7 min. $[\alpha]_D^{28}$ = -39.4 (*c* 1.00, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.75–7.64 (m, 4H), 7.42–7.25 (m, 8H), 6.92–6.72 (m, 4H), 4.96 (s, 1H), 4.77 (d, *J* = 1.4 Hz, 1H), 4.56 (d, *J* = 15.7 Hz, 1H), 4.34 (d, *J* = 1.4 Hz, 1H), 4.26 (d, *J* = 15.7 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ 153.0, 143.8, 137.6, 136.7, 134.0, 133.2, 133.0, 128.8, 128.6, 128.1, 127.7, 127.5, 127.5, 126.4, 126.2, 126.1, 125.2, 122.7, 119.6, 115.8, 115.1, 91.8, 61.3, 54.7. HRMS calc. for $C_{26}H_{21}NO$ $[M+H]^+$: 364.1701, found: 364.1690.

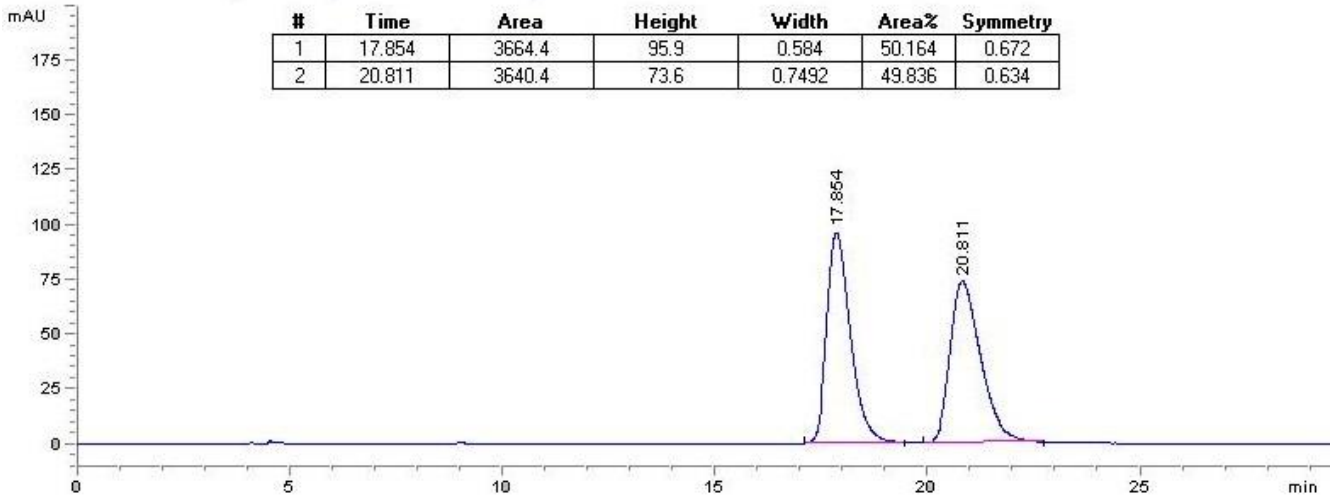


#	Time	Area	Height	Width	Area%	Symmetry
1	10.679	18430.5	1119.7	0.2532	49.408	0.688
2	11.346	18872.4	1072.7	0.2708	50.592	0.67

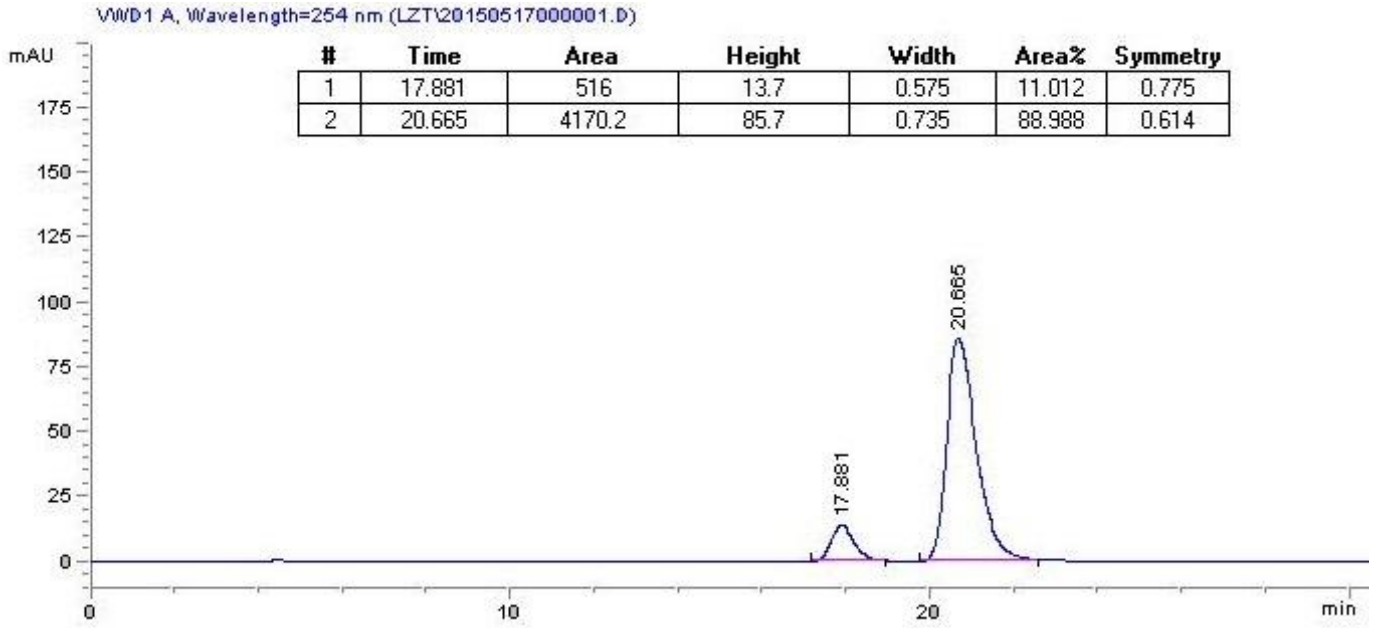


#	Time	Area	Height	Width	Area%	Symmetry
1	10.854	5213.2	323.7	0.2476	96.522	0.72
2	11.692	187.8	10.5	0.2749	3.478	0.8

(*R*)-4-benzyl-2-methylene-3-(thiophen-2-yl)-3,4-dihydro-*2H*-benzo[*b*][1,4]oxazine (3aj). 93 mg (97% yield) was obtained as a colorless oil after purification with column chromatography on silica gel (hexanes/ethyl acetate, 100/1). 78% ee was determined by chiral HPLC (Chiralcel OJ-H, *n*-hexane/*i*-PrOH = 98/2, 0.8 mL/min, 254 nm, 40 ^{o}C): t_R (minor) = 17.9 min, t_R (major) = 20.7 min. $[\alpha]_D^{29}$ = -102.4 (*c* 1.10, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.38–7.31 (m, 4H), 7.28–7.25 (m, 1H), 7.08–7.06 (m, 1H), 6.94–6.92 (m, 1H), 6.87–6.74 (m, 5H), 4.95 (s, 1H), 4.69 (d, *J* = 1.3 Hz, 1H), 4.47 (d, *J* = 15.0 Hz, 1H), 4.26 (d, *J* = 1.6 Hz, 1H), 4.18 (d, *J* = 15.0 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ 152.6, 144.0, 141.6, 137.2, 133.3, 128.9, 128.0, 127.7, 126.6, 125.7, 125.3, 122.7, 120.5, 116.1, 115.8, 90.7, 56.7, 54.6. HRMS calc. for $C_{20}H_{17}NOS$ $[M+H]^+$: 320.1109, found: 320.1094.

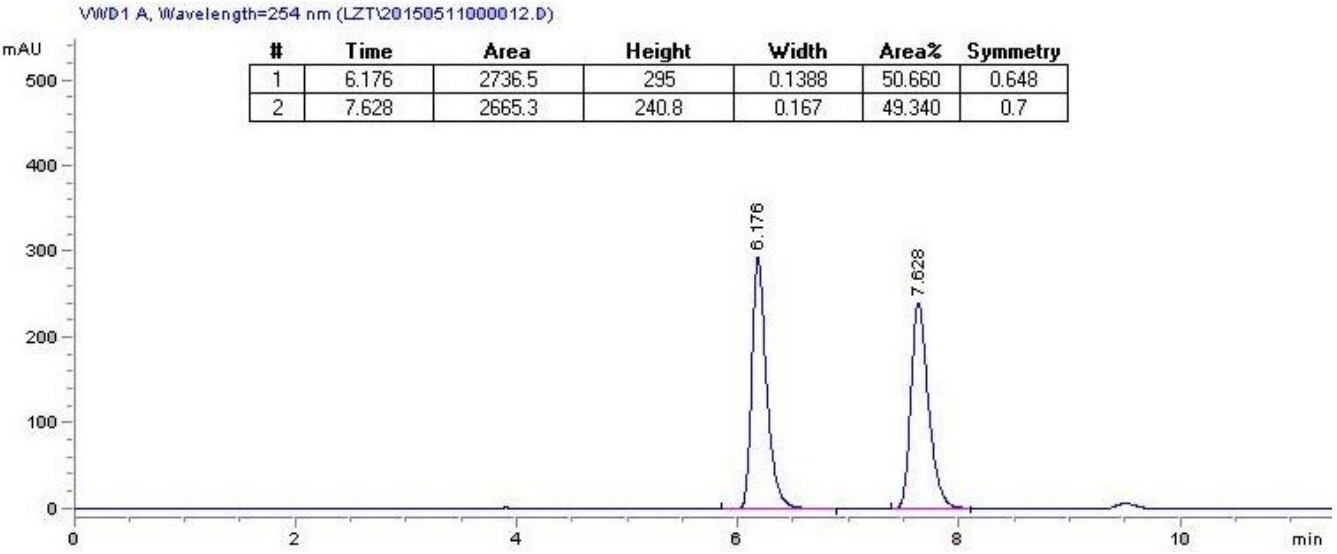


#	Time	Area	Height	Width	Area%	Symmetry
1	17.854	3664.4	95.9	0.584	50.164	0.672
2	20.811	3640.4	73.6	0.7492	49.836	0.634

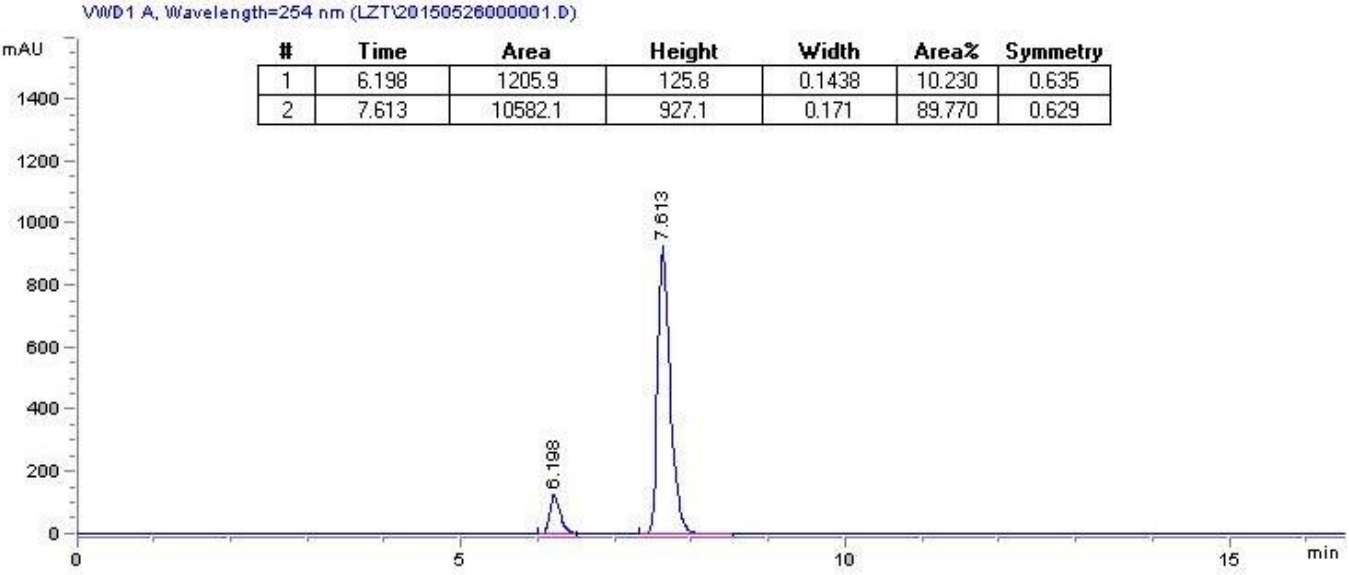


#	Time	Area	Height	Width	Area%	Symmetry
1	17.881	516	13.7	0.575	11.012	0.775
2	20.665	4170.2	85.7	0.735	88.988	0.614

(*S*)-4-benzyl-3-methyl-2-methylene-3,4-dihydro-*2H*-benzo[*b*][1,4]oxazine (3ak). 72 mg (96% yield) was obtained as a colorless oil after purification with column chromatography on silica gel (hexanes/ethyl acetate, 100/1). 80% ee was determined by chiral HPLC (Chiralcel OD-H, *n*-hexane/*i*-PrOH = 95/5, 0.8 mL/min, 254 nm, 40 ^{o}C): t_R (minor) = 6.2 min, t_R (major) = 7.6 min. $[\alpha]_D^{28}$ = -14.3 (*c* 1.00, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.35–7.30 (m, 4H), 7.27–7.24 (m, 1H), 6.92–6.90 (m, 1H), 6.84–6.80 (m, 1H), 6.76–6.73 (m, 1H), 6.67–6.65 (m, 1H), 4.51 (s, 1H), 4.42 (d, *J* = 15.2 Hz, 1H), 4.15 (d, *J* = 15.2 Hz, 1H), 4.084.07 (m, 1H), 3.79 (q, *J* = 6.7 Hz, 1H), 1.15 (d, *J* = 6.7 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ 155.3, 143.5, 137.8, 133.5, 128.7, 127.6, 127.4, 122.4, 119.4, 115.4, 115.1, 87.8, 53.9, 53.0, 15.8. HRMS calc. for $C_{17}H_{17}NO$ $[M+H]^+$: 252.1388, found: 252.1379.

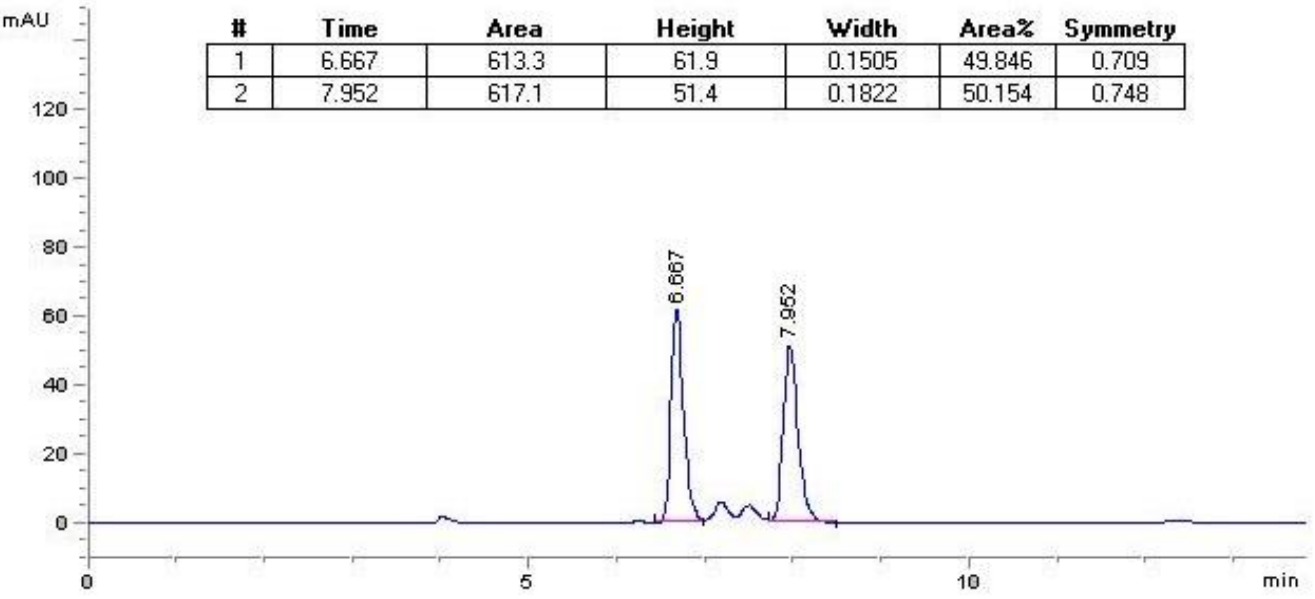


#	Time	Area	Height	Width	Area%	Symmetry
1	6.176	2736.5	295	0.1388	50.660	0.648
2	7.628	2665.3	240.8	0.167	49.340	0.7

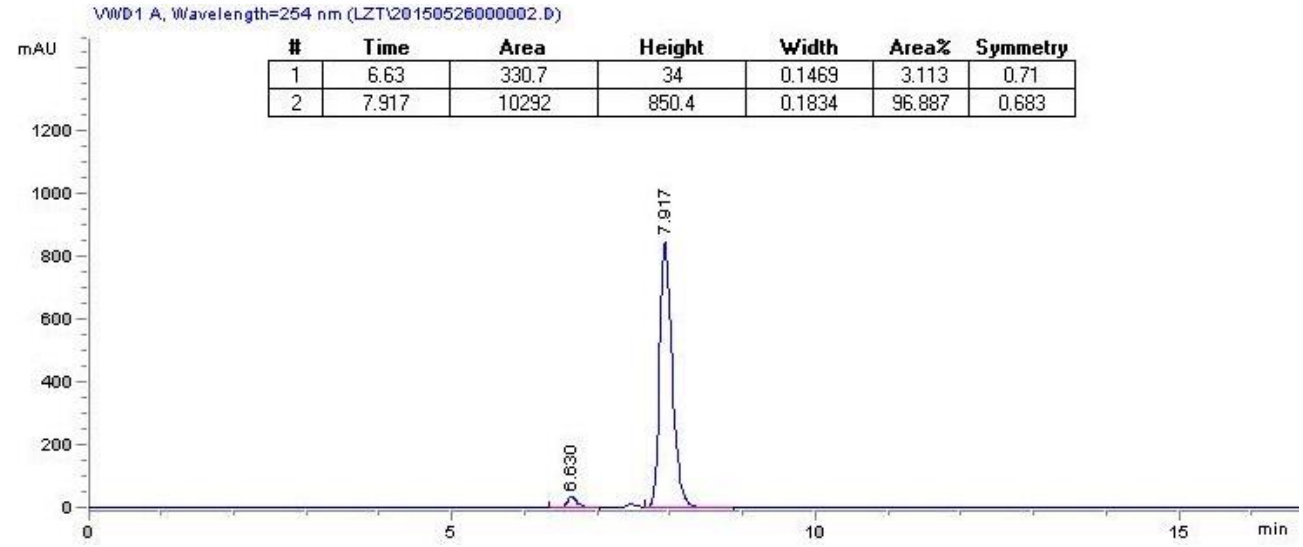


#	Time	Area	Height	Width	Area%	Symmetry
1	6.198	1205.9	125.8	0.1438	10.230	0.635
2	7.613	10582.1	927.1	0.171	89.770	0.629

(*S*)-3,4-dibenzyl-2-methylene-3,4-dihydro-*2H*-benzo[*b*][1,4]oxazine (3al). 82 mg (84% yield) was obtained as a colorless oil after purification with column chromatography on silica gel (hexanes/ethyl acetate, 100/1). 94% ee was determined by chiral HPLC (Chiralcel OD-H, *n*-hexane/*i*-PrOH = 95/5, 0.8 mL/min, 254 nm, 40 ^{o}C): t_R (minor) = 6.6 min, t_R (major) = 7.9 min. $[\alpha]_D^{29}$ = -52.1 (*c* 1.00, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.28–7.17 (m, 8H), 7.02–6.96 (m, 3H), 6.90–6.85 (m, 1H), 6.81–6.77 (m, 1H), 6.72–6.70 (m, 1H), 4.48 (d, *J* = 0.7 Hz, 1H), 4.35 (d, *J* = 15.2 Hz, 1H), 4.03 (d, *J* = 15.2 Hz, 1H), 3.79–3.75 (m, 2H), 2.83 (dd, *J* = 13.3, 6.9 Hz, 1H), 2.69 (dd, *J* = 13.3, 8.0 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$): δ 152.0, 143.8, 138.2, 137.5, 133.2, 129.63, 128.6, 128.3, 127.7, 127.4, 126.5, 122.5, 119.6, 115.7, 115.6, 89.8, 60.0, 55.1, 36.8. HRMS calc. for $C_{23}H_{21}NO$ $[M+H]^+$: 328.1701, found: 328.1696.

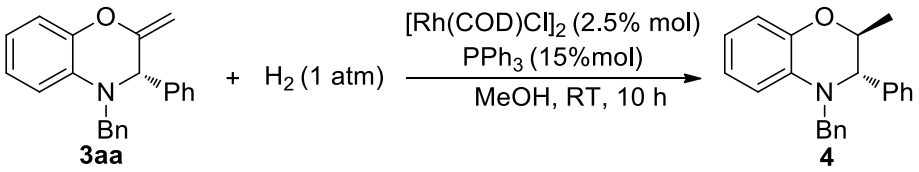


#	Time	Area	Height	Width	Area%	Symmetry
1	6.667	613.3	61.9	0.1505	49.846	0.709
2	7.952	617.1	51.4	0.1822	50.154	0.748

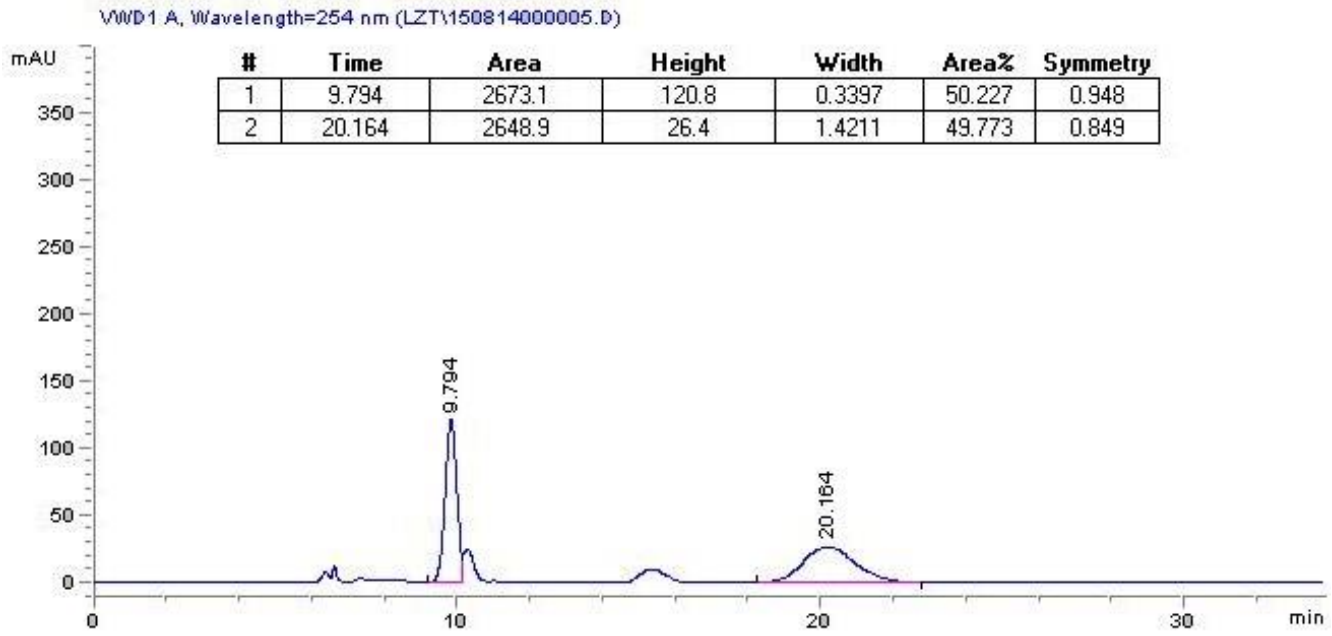


#	Time	Area	Height	Width	Area%	Symmetry
1	6.63	330.7	34	0.1469	3.113	0.71
2	7.917	10292	850.4	0.1834	96.887	0.683

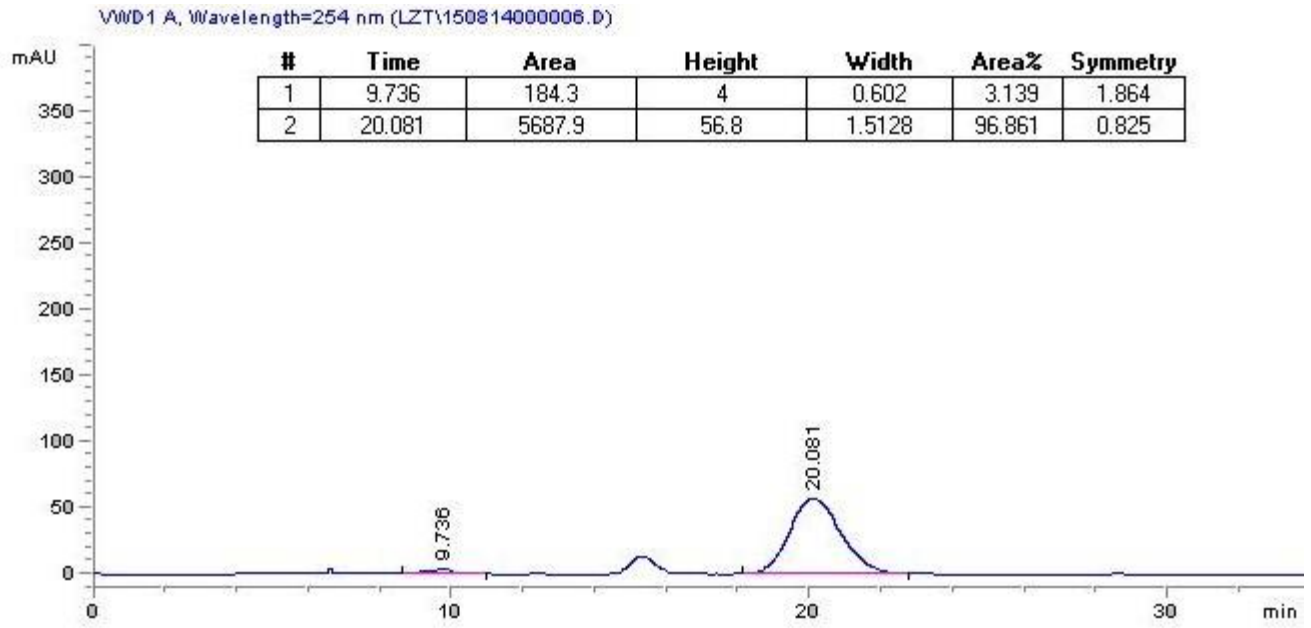
Hydrogenation of Cycloadducts 3



$[Rh(COD)Cl]_2$ (3.2 mg, 0.0065 mmol) and PPh_3 (10.2 mg, 0.039 mmol) were stirred in 1 mL of anhydrous methanol at room temperature under nitrogen atmosphere for 20 minutes. A solution of **3aa** (81.5 mg, 0.26 mmol) in 1 mL of anhydrous methanol was added. The hydrogenation was performed at room temperature under 1 atm of H_2 pressure for 10 h. After concentration of the reaction mixture under reduced pressure, the residue was purified by silica gel chromatography (hexanes/AcOEt, 100/1) to afford **4** (80 mg, 98% yield) as a white solid. M.p.: 98-100 ^oC. 94% ee was determined by chiral HPLC (Chiralcel OJ-H, *n*-hexane/*i*-PrOH = 90/10, 0.8 mL/min, 254 nm, 40 ^oC): t_R (major) = 20.1 min, t_R (minor) = 9.7 min. $[\alpha]_D^{29}$ = -169.4 (*c* 1.04, CH_2Cl_2). ^1H NMR (400 MHz, $CDCl_3$): δ 7.22–7.14 (m, 8H), 7.07–7.02 (m, 2H), 6.82–6.80 (m, 1H), 6.74–6.69 (m, 1H), 6.55–6.49 (m, 2H), 4.43–4.37 (m, 2H), 4.16 (d, *J* = 2.7 Hz, 1H), 4.08 (d, *J* = 17.0 Hz, 1H), 1.00 (d, *J* = 6.5 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$): δ 143.9, 138.6, 138.3, 135.4, 128.8, 128.8, 128.4, 127.9, 127.2, 126.8, 122.5, 116.7, 116.4, 110.8, 72.31, 64.9, 52.3, 18.2. HRMS calc. for $C_{22}H_{21}NO$ $[M+H]^+$: 316.1701, found: 316.1693.



#	Time	Area	Height	Width	Area%	Symmetry
1	9.794	2673.1	120.8	0.3397	50.227	0.948
2	20.164	2648.9	26.4	1.4211	49.773	0.849

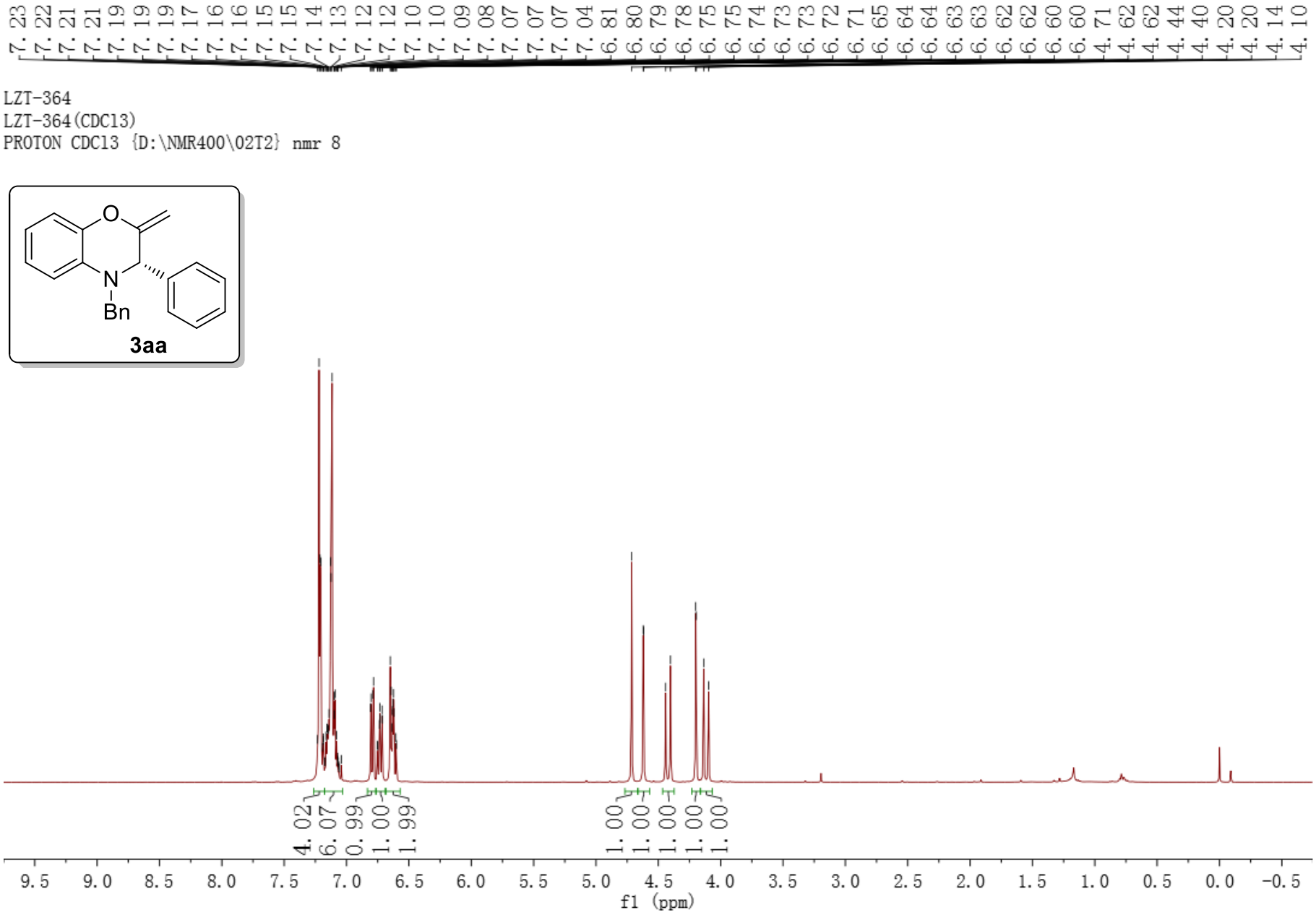


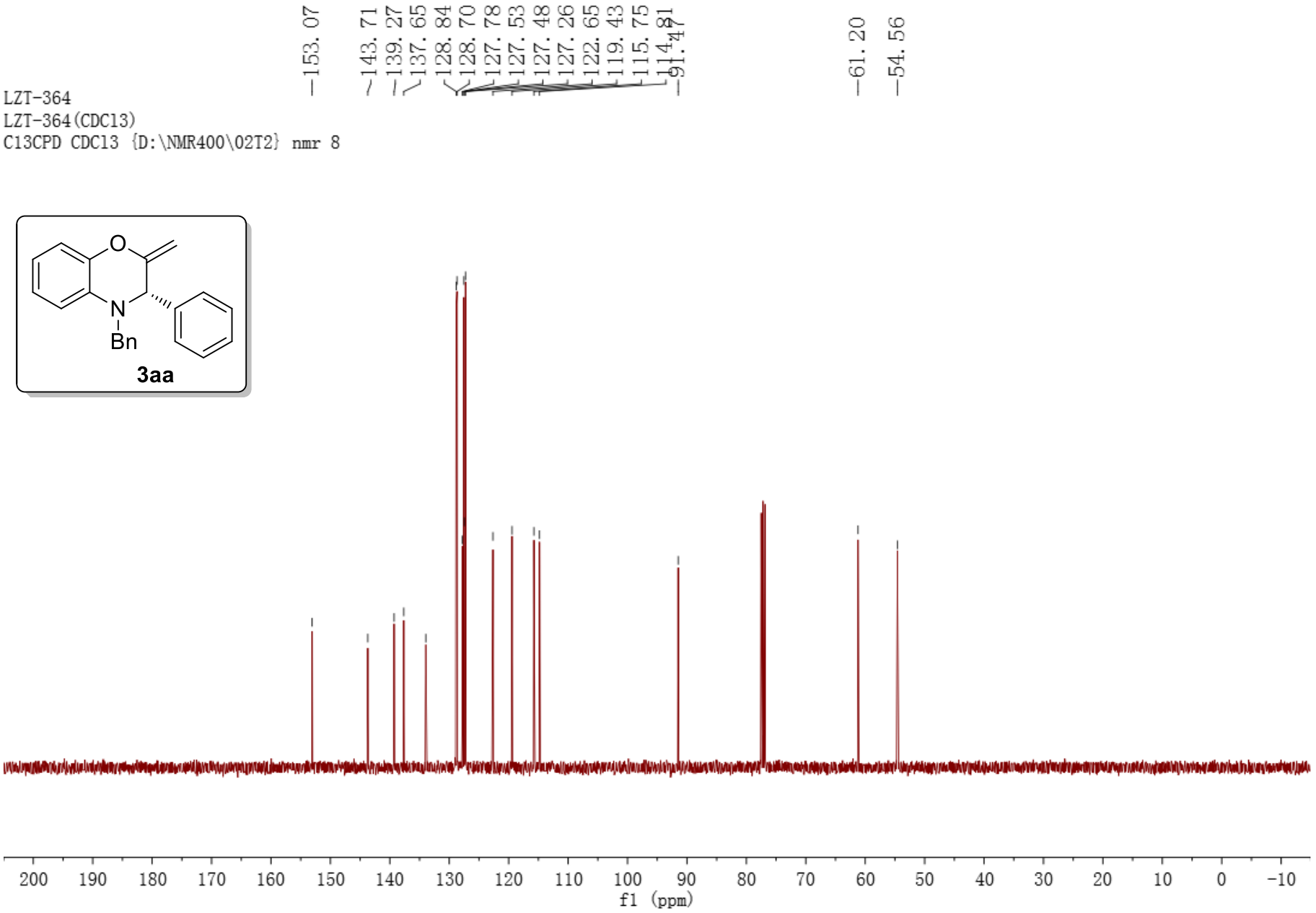
#	Time	Area	Height	Width	Area%	Symmetry
1	9.736	184.3	4	0.602	3.139	1.864
2	20.081	5687.9	56.8	1.5128	96.861	0.825

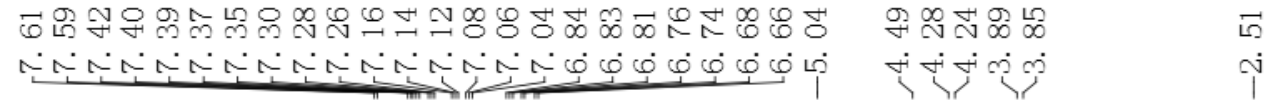
References

1. Yoo, W.-J.; Yuan, H.; Miyamura, H.; Kobayashi, S. *Can. J. Chem.* **2012**, *90*, 306–313.

2. a) Fang, P.; Hou, X.-L. *Org. Lett.* **2009**, *11*, 4612-4615; b) Bhanuchandra, M.; Kuram, M. R.; Sahoo, A. K. *J. Org. Chem.* **2013**, *78*, 11824-11834.

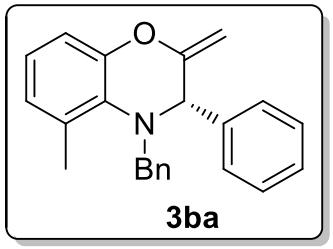

7.23 7.22 7.21 7.21 7.19 7.19 7.19 7.17 7.16 7.16 7.15 7.15 7.14 7.13 7.12 7.12 7.10 7.10 7.09 7.08 7.07 7.07 7.07 7.04 6.81 6.80 6.79 6.78 6.75 6.75 6.74 6.73 6.73 6.72 6.71 6.65 6.64 6.64 6.63 6.63 6.62 6.62 6.60 6.60 4.71 4.62 4.62 4.44 4.40 4.20 4.20 4.14 4.10
LZT-364
LZT-364(CDCl3)
PROTON CDCl3 {D:\NMR400\02T2} nmr 8
O
N
Bn
3aa
4.02 6.07 0.99 1.00 1.99 1.00 1.00 1.00 1.00 1.00
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 -0.5
f1 (ppm)


153.07
143.71
139.27
137.65
128.84
128.70
127.78
127.53
127.48
127.26
122.65
119.43
115.75
114.81
91.47
61.20
54.56
LZT-364
LZT-364(CDCl3)
C13CPD CDCl3 {D:\NMR400\02T2} nmr 8
O
N
Bn
3aa
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

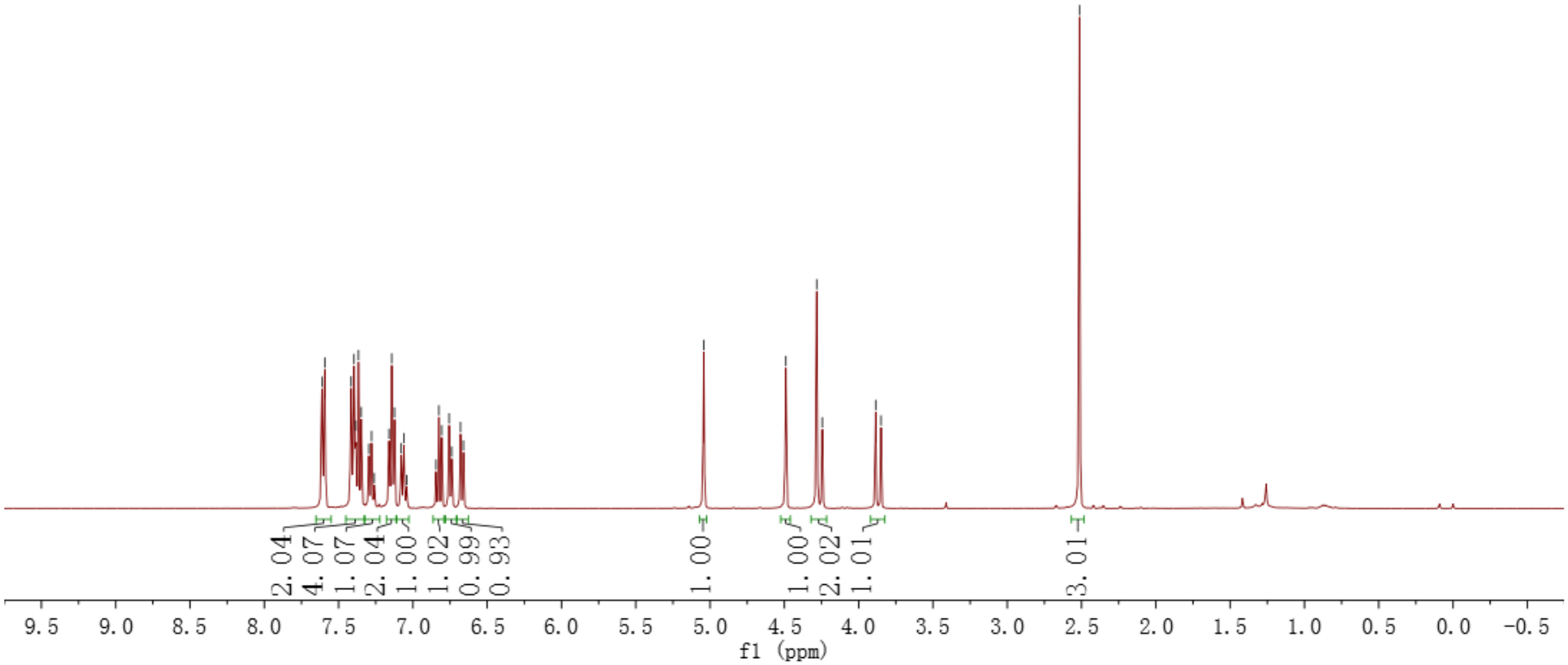


LZT-505

PROTON CDCl3 {D:\NMR400\02T2} nmr 54

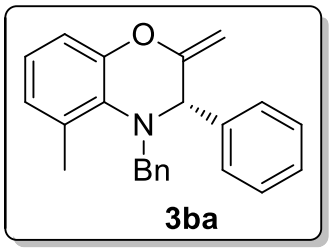


3ba



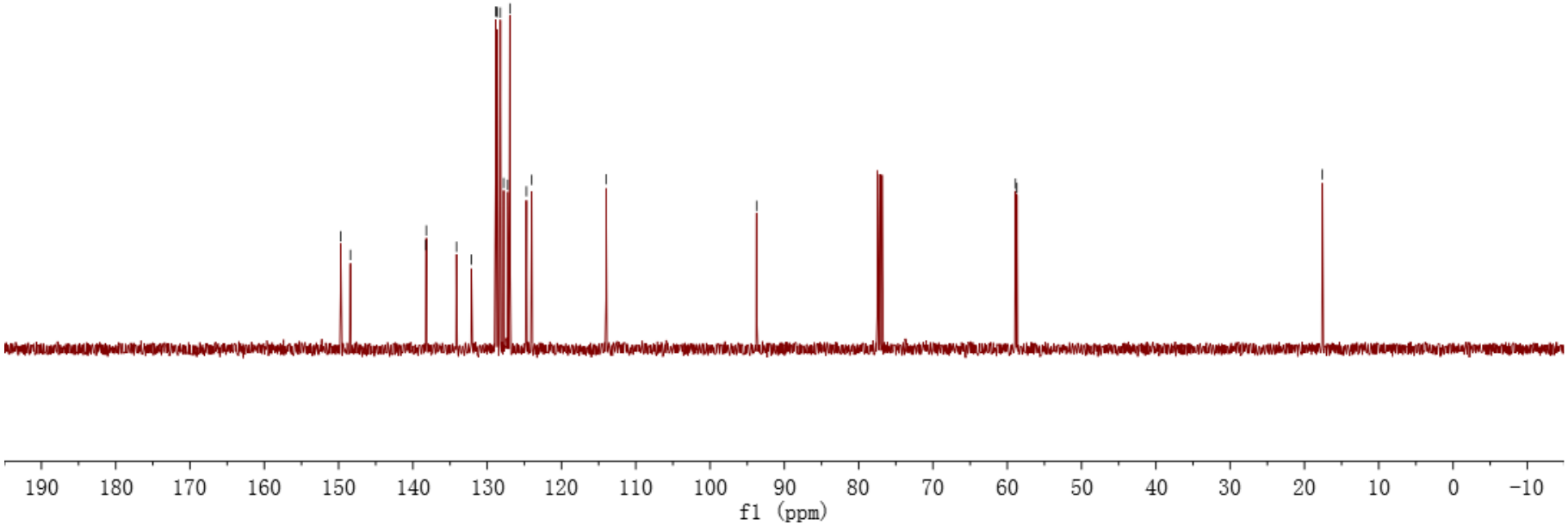
LZT-505

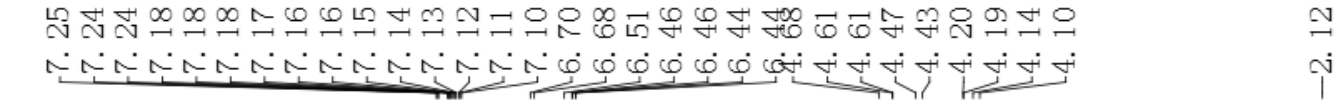
C13CPD CDCl3 {D:\NMR400\02T2} nmr 54



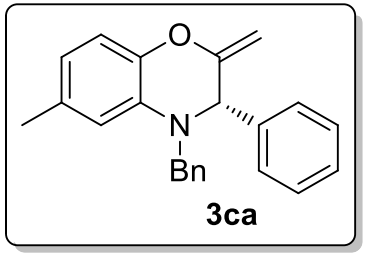
3ba

149.72
148.41
128.87
128.66
128.22
127.78
127.23
126.95
124.00
113.99
93.74
58.89
58.70
17.58

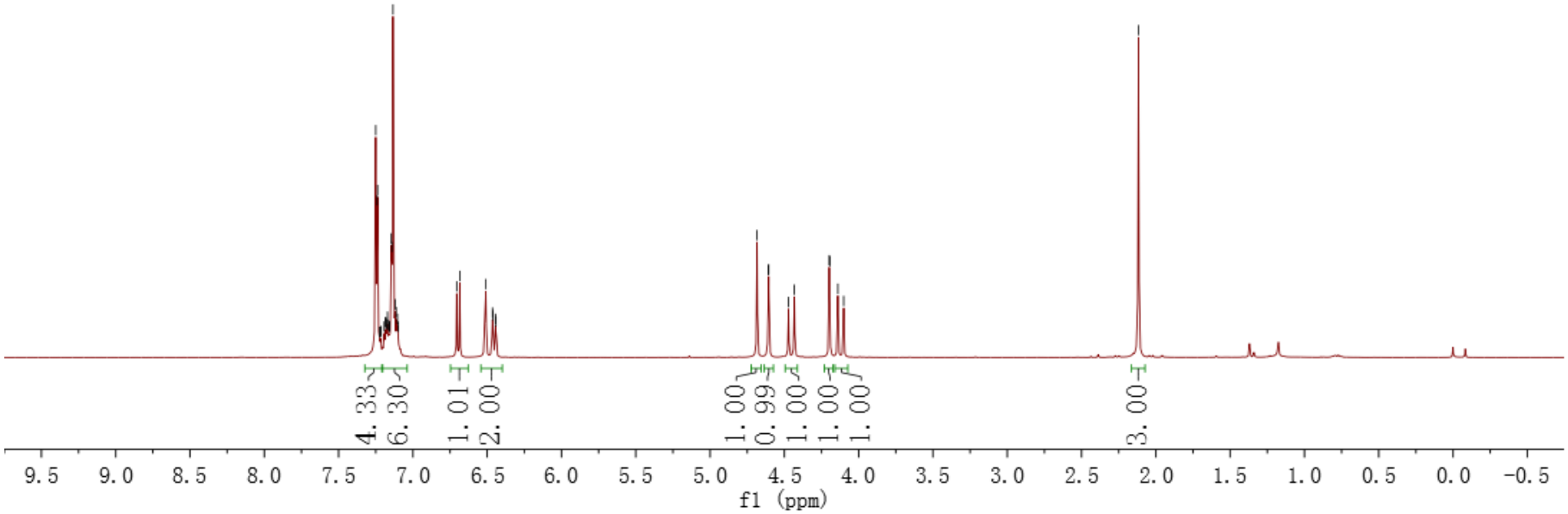




LZT-474
LZT-474(CDCl3)
PROTON CDCl3 {D:\NMR400\02T2} nmr 12

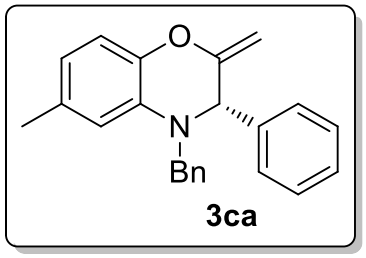


3ca

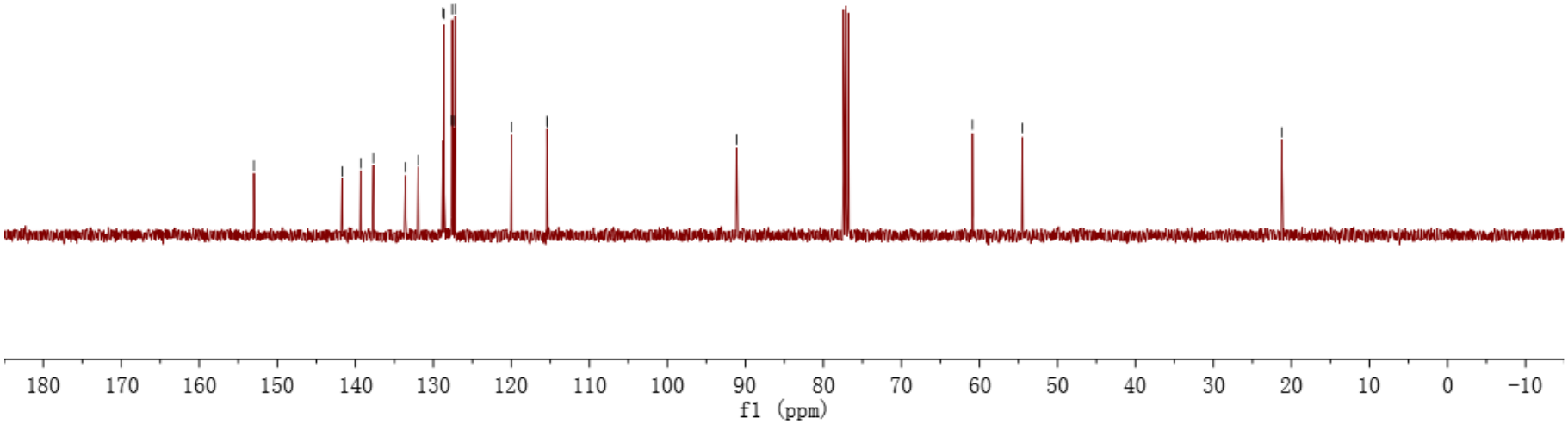


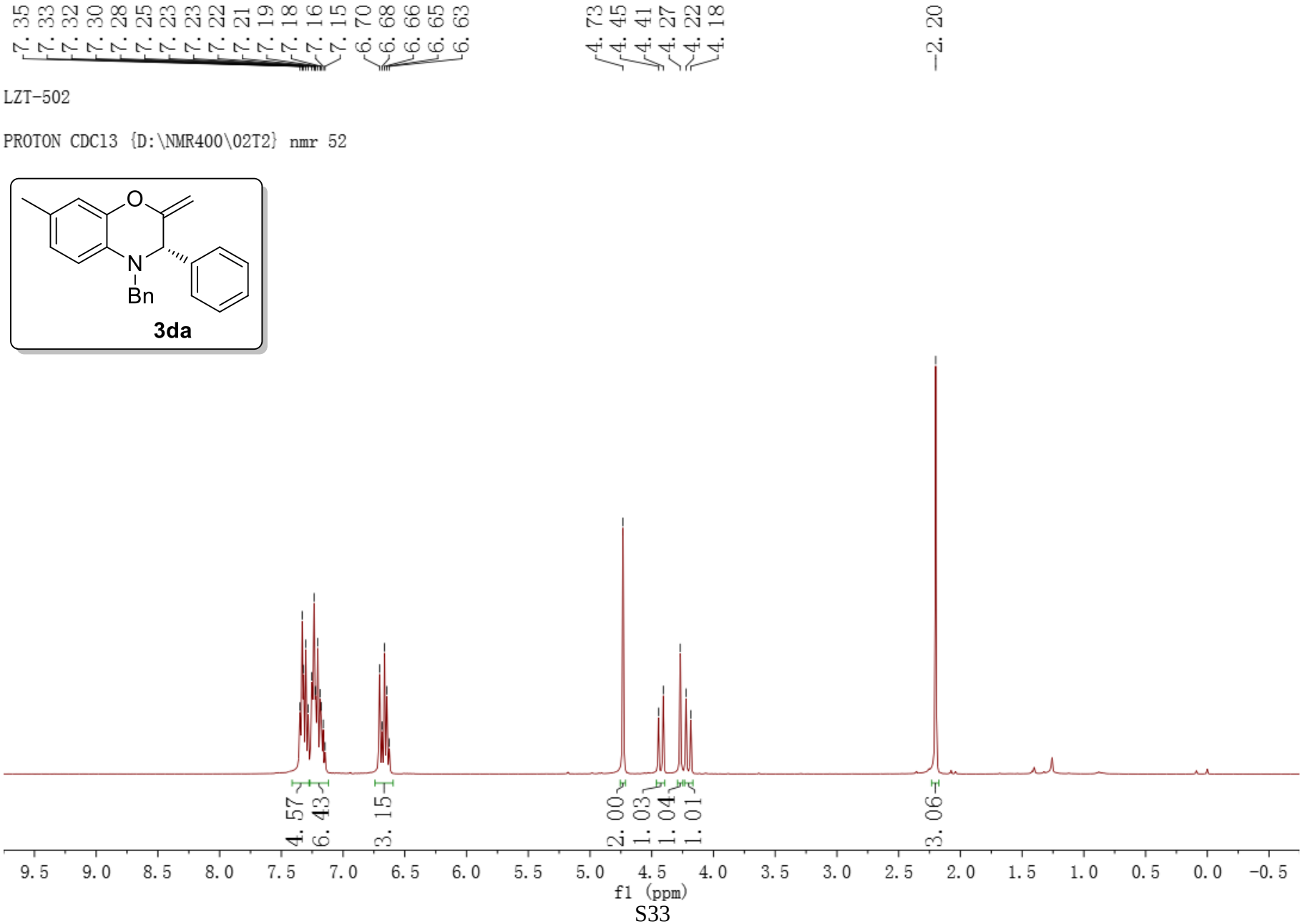
153.00
141.70
139.32
137.70
133.56
131.94
128.76
128.60
127.65
127.59
127.41
127.20
119.97
115.42
115.39
91.11
60.88
54.50
21.24

LZT-474
LZT-474(CDCl3)
C13CPD CDCl3 {D:\NMR400\02T2} nmr 12



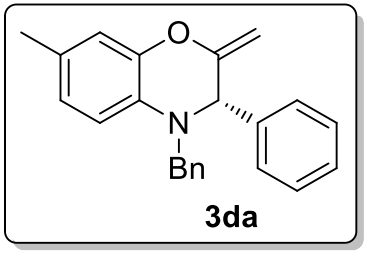
3ca




7.35
7.33
7.32
7.30
7.28
7.25
7.23
7.23
7.22
7.21
7.19
7.18
7.16
7.15
6.70
6.68
6.66
6.65
6.63
4.73
4.45
4.41
4.27
4.22
4.18
2.20
LZT-502
PROTON CDCl3 {D:\NMR400\02T2} nmr 52
O
N
Bn
3da
4.57
6.43
3.15
2.00
1.03
1.04
1.01
3.06
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
-0.5
f1 (ppm)

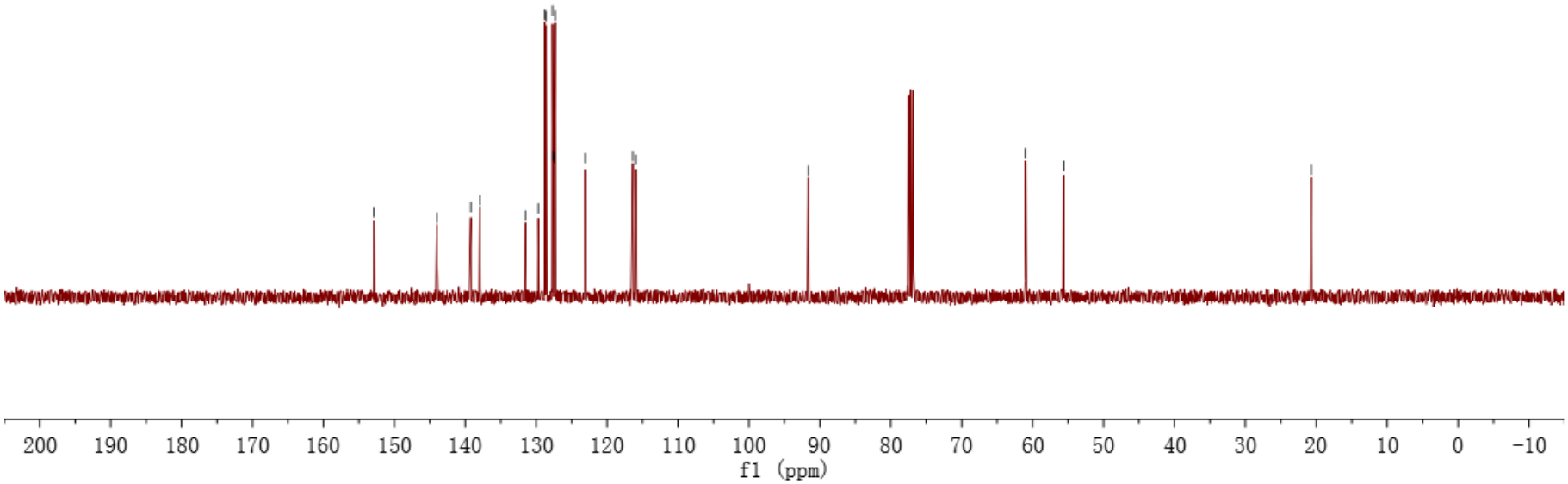
LZT-502

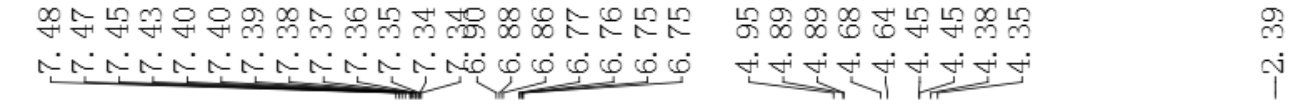
C13CPD CDCl3 {D:\NMR400\02T2} nmr 52



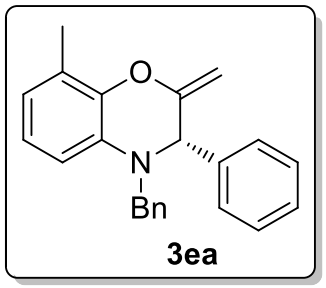
3da

152.88
139.22
137.95
131.52
129.70
128.77
128.58
127.70
127.65
127.42
127.31
123.07
116.38
115.96
91.63
61.00
55.61
20.71

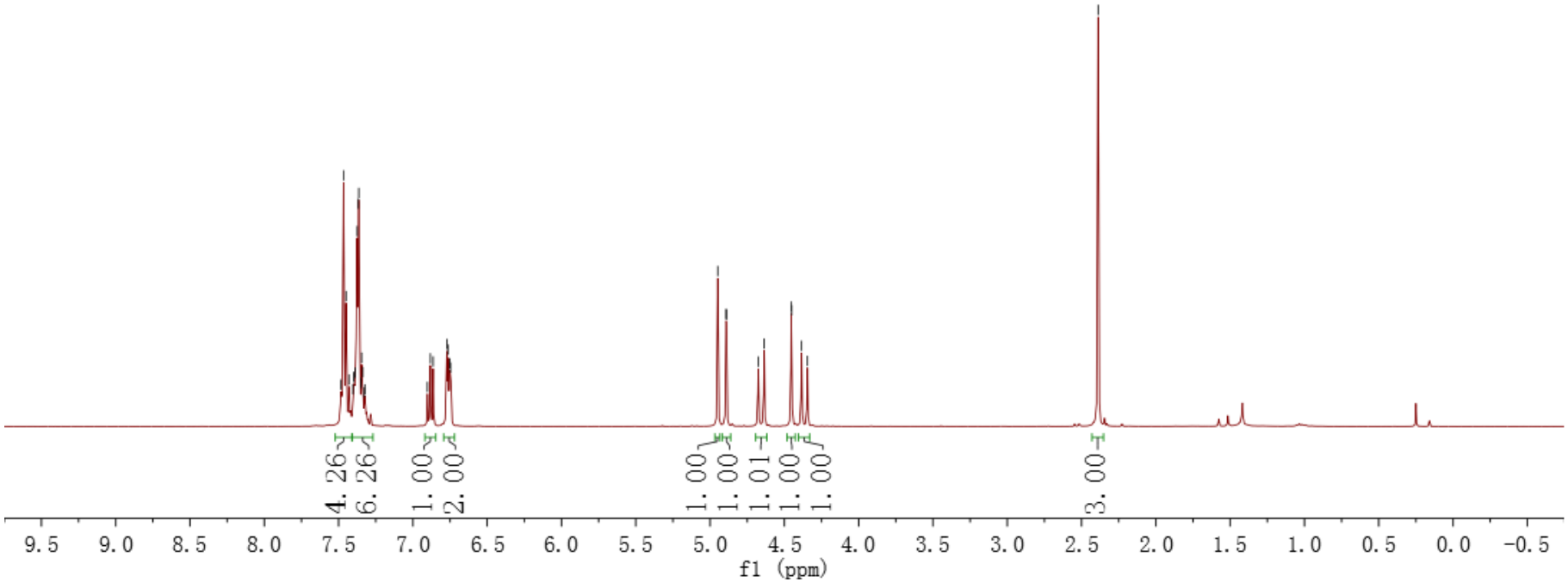




LZT-514
LZT-514(CDCl3)
PROTON CDCl3 {D:\NMR400\02T2} nmr 15

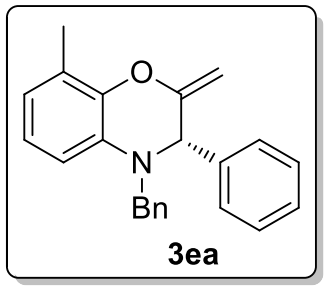


3ea

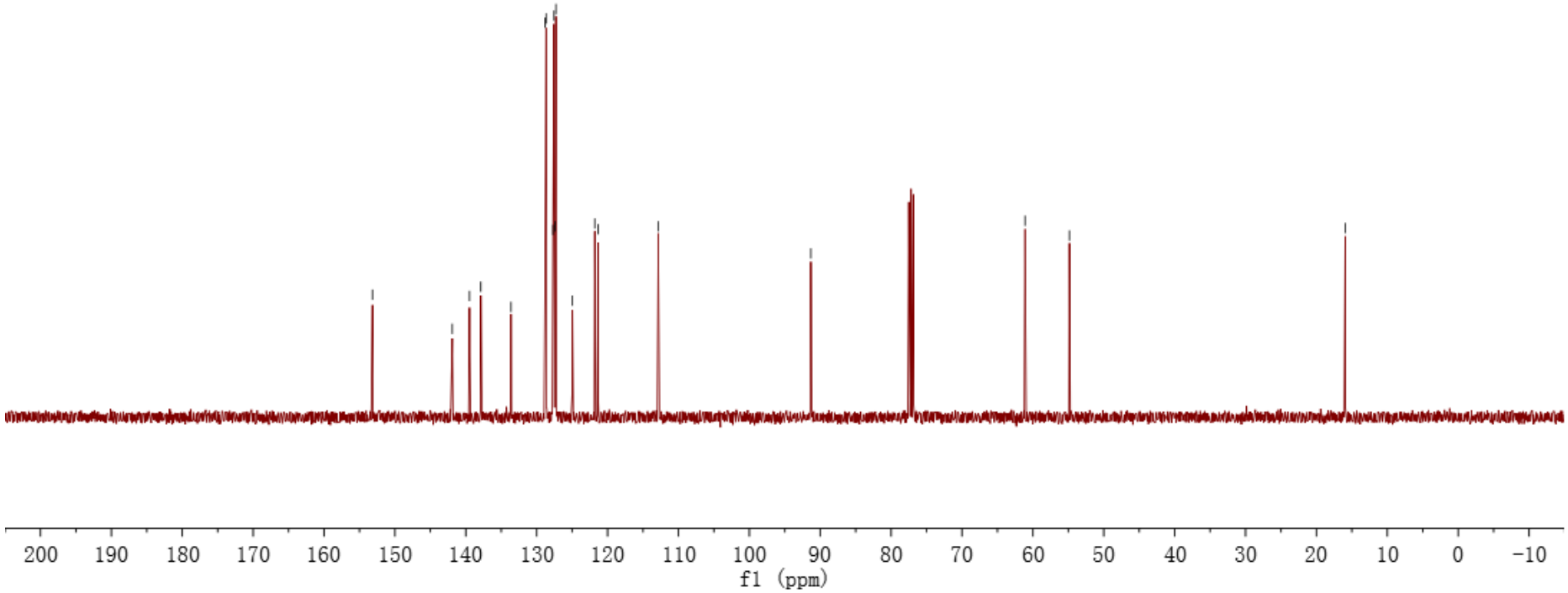


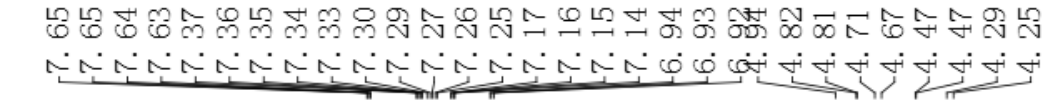
153.16
128.80
128.66
127.70
127.54
127.41
127.28
121.80
121.34
112.83
91.31
61.11
54.85
15.94

LZT-514
LZT-514(CDC13)
C13CPD CDC13 {D:\NMR400\02T2} nmr 15

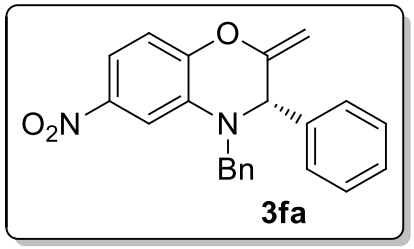


3ea

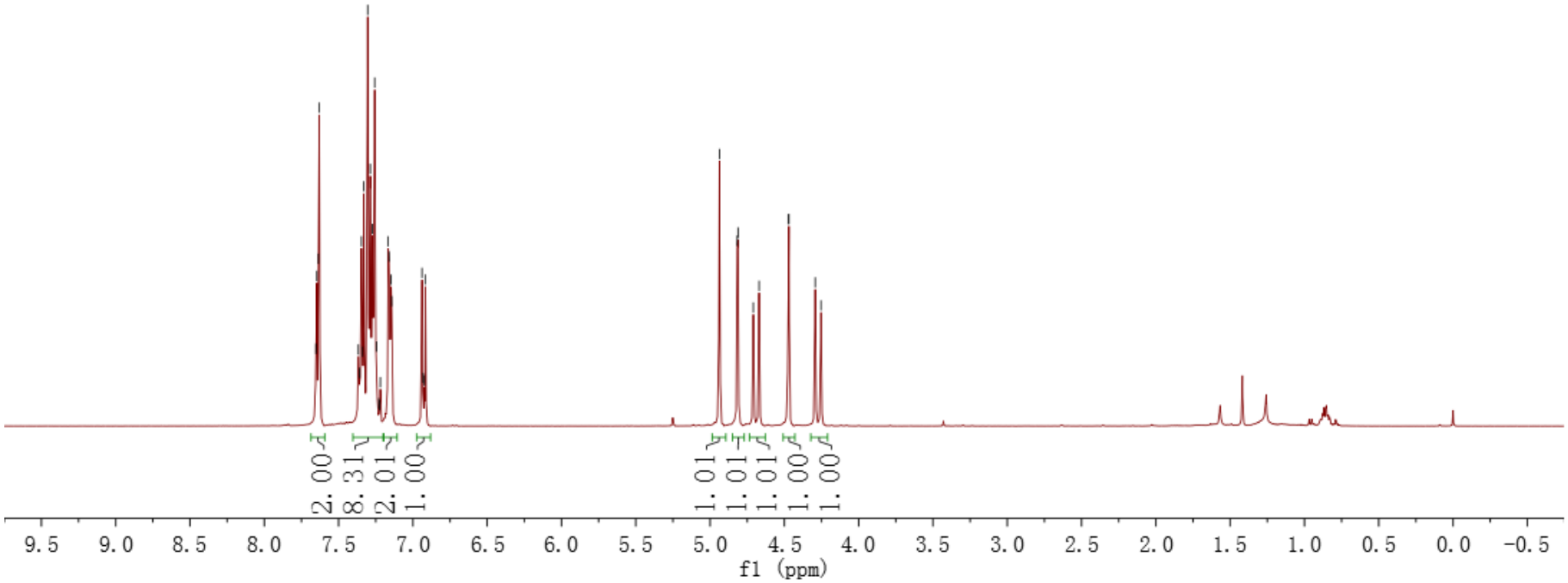


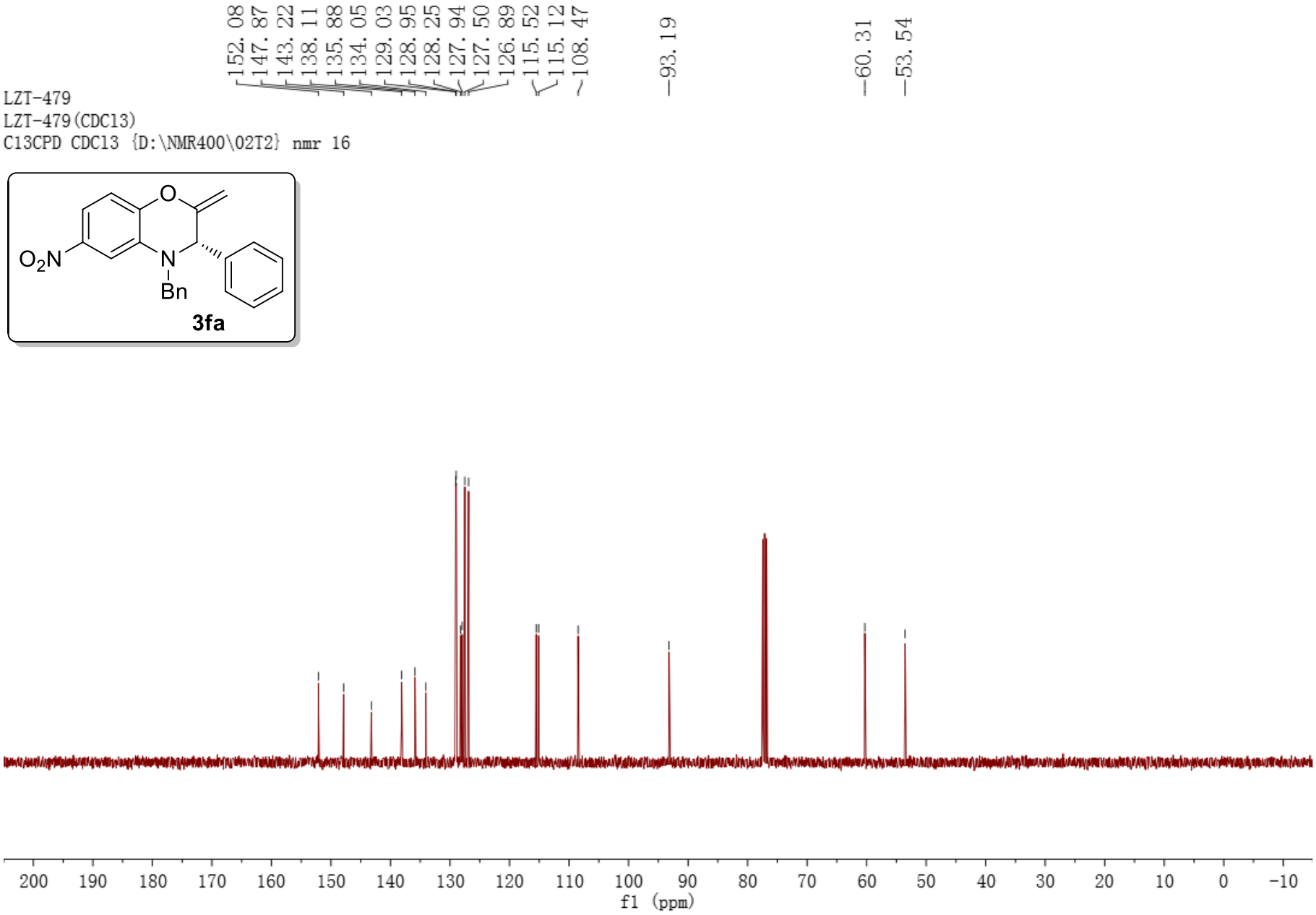


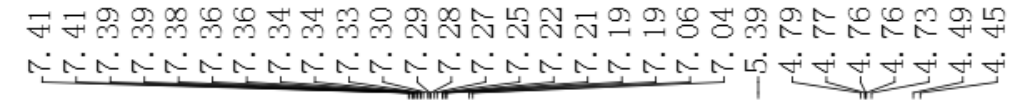
LZT-479
LZT-479(CDCl3)
PROTON CDCl3 {D:\NMR400\02T2} nmr 16



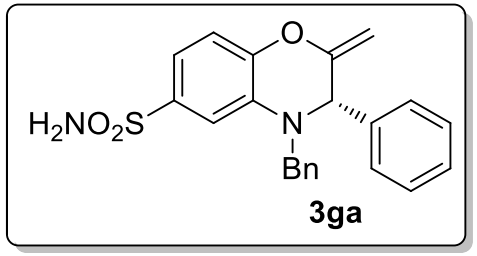
3fa



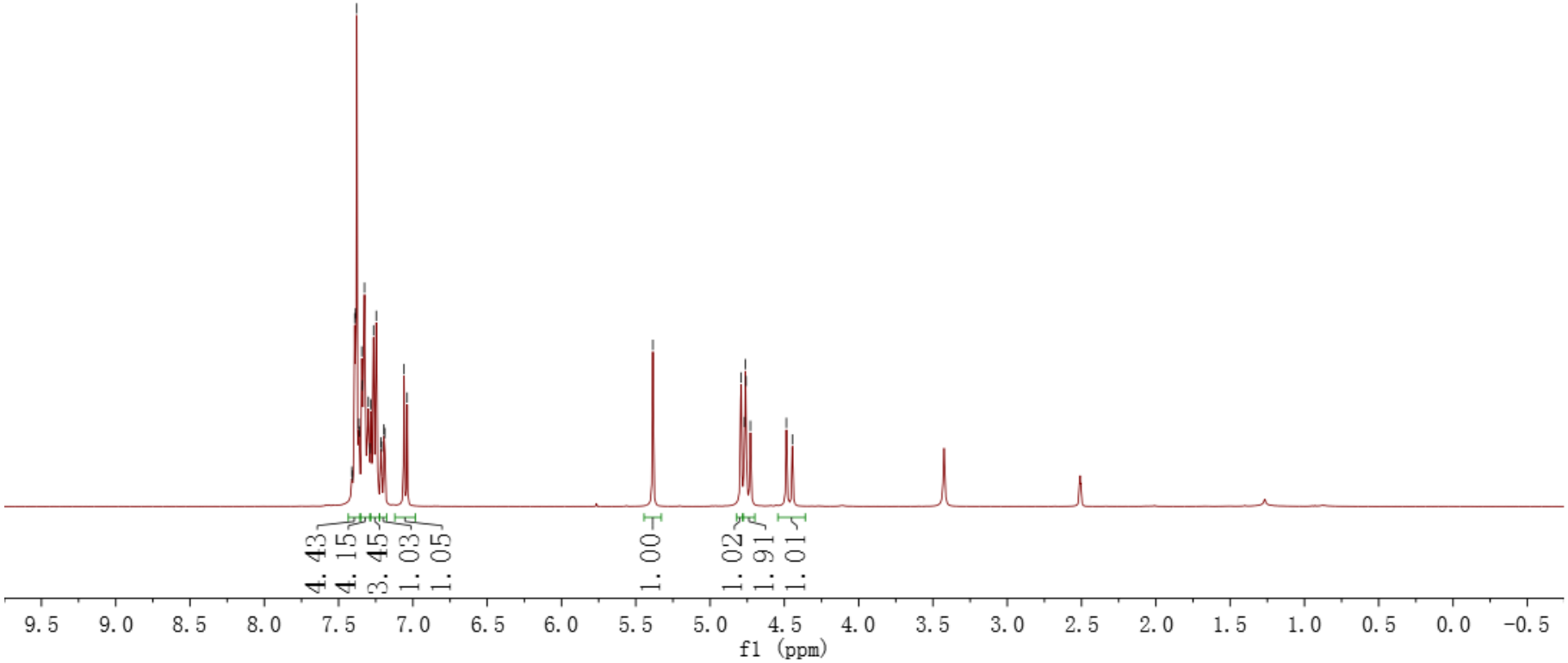

152.08
147.87
143.22
138.11
135.88
134.05
129.03
128.95
128.25
127.94
127.50
126.89
115.52
115.12
108.47
93.19
60.31
53.54
LZT-479
LZT-479(CDCl3)
C13CPD CDCl3 {D:\NMR400\02T2} nmr 16
O
O2N
N
Bn
3fa
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

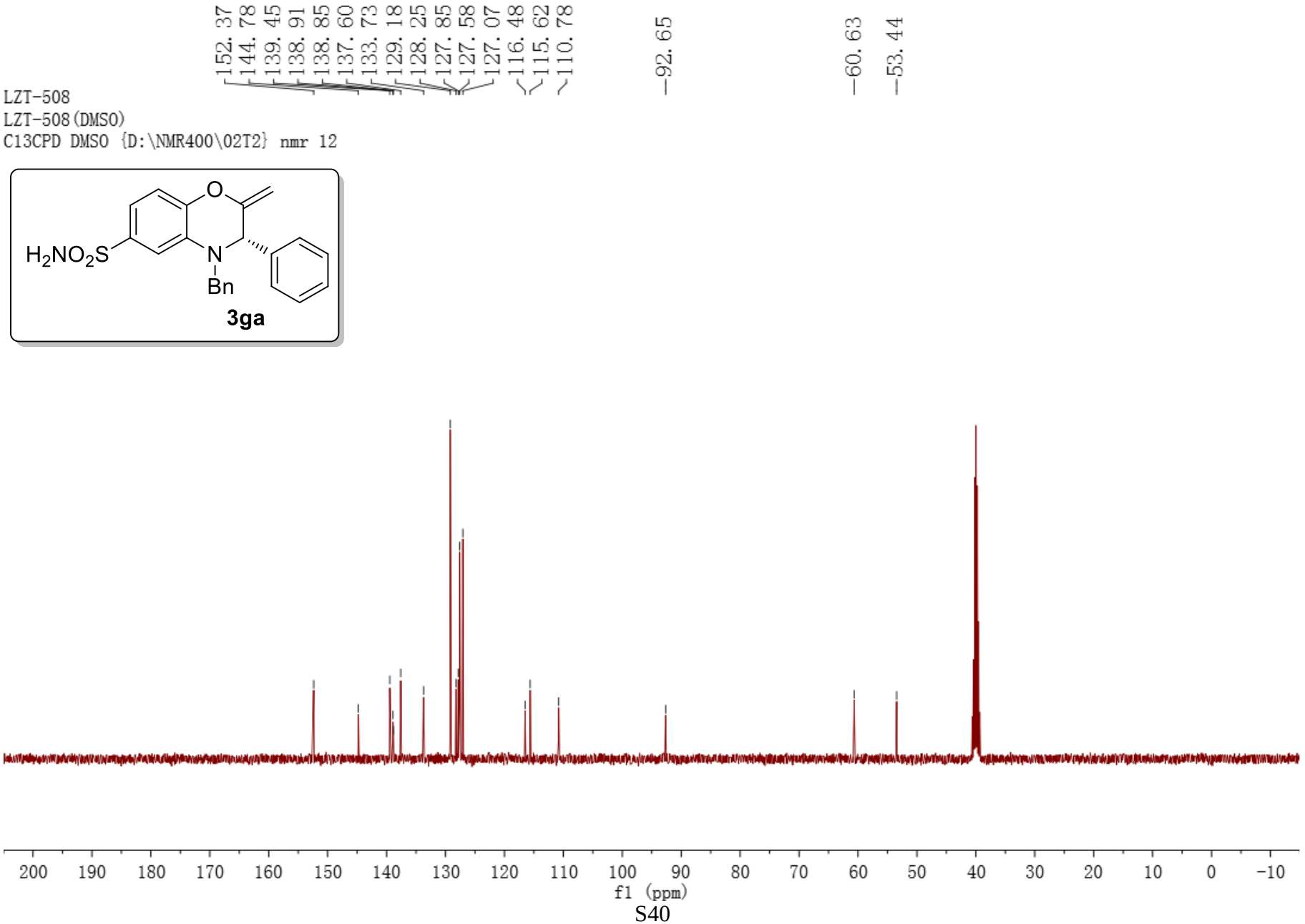


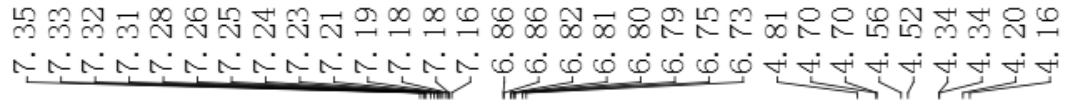
LZT-508
LZT-508(DMSO)
PROTON DMSO {D:\NMR400\02T2} nmr 12



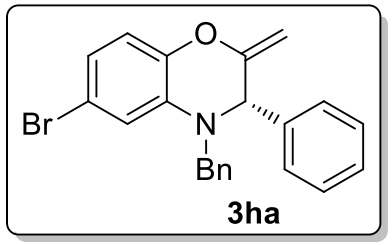
3ga



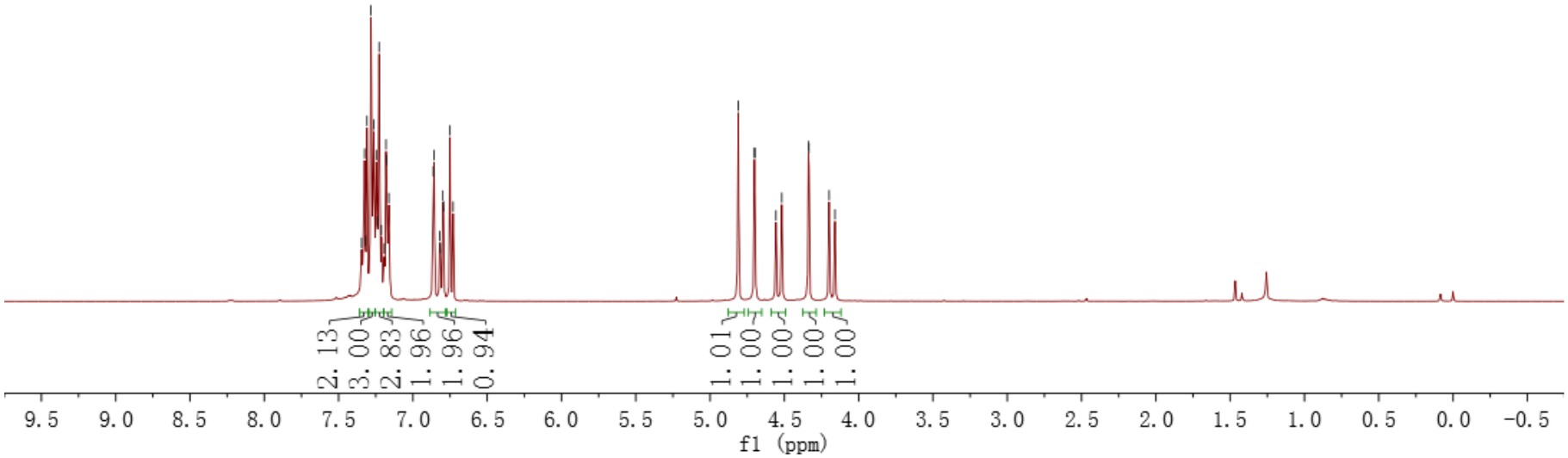

152.37
144.78
139.45
138.91
138.85
137.60
133.73
129.18
128.25
127.85
127.58
127.07
116.48
115.62
110.78
92.65
60.63
53.44
LZT-508
LZT-508(DMSO)
C13CPD DMSO {D:\NMR400\02T2} nmr 12
O
H2NO2S
N
Bn
3ga
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)



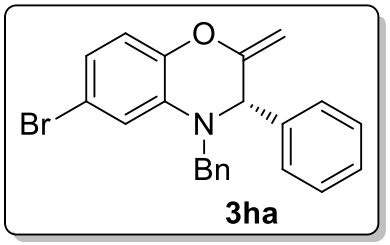
LZT-478
LZT-478(CDCl3)
PROTON CDCl3 {D:\NMR400\02T2} nmr 15



3ha

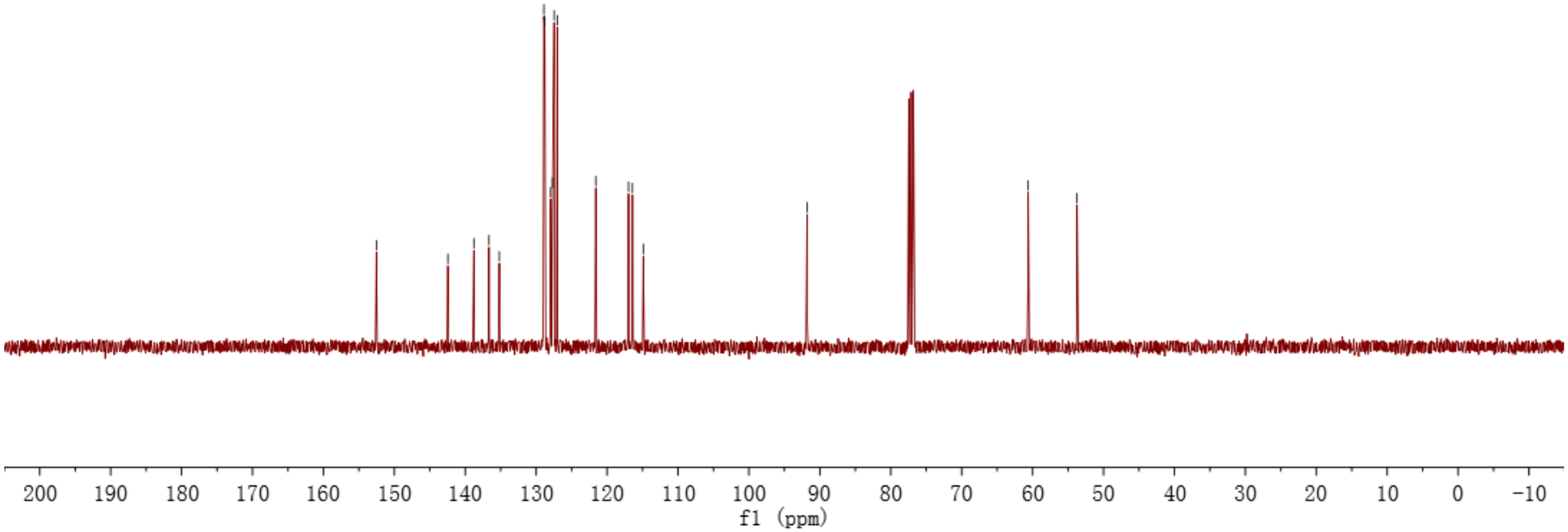


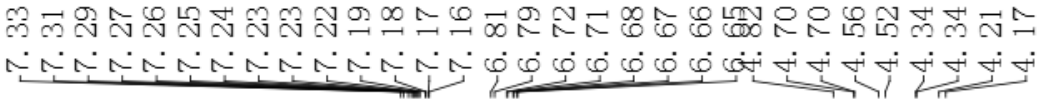
LZT-478
LZT-478(CDCl3)
C13CPD CDCl3 {D:\NMR400\02T2} nmr 15



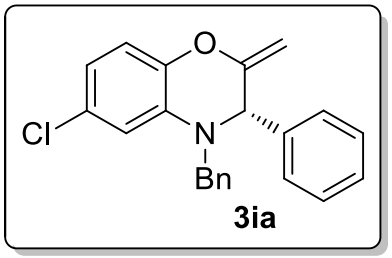
3ha

152.53
138.78
136.65
135.20
128.91
128.79
127.96
127.69
127.46
127.03
121.60
116.98
116.42
114.89
91.80
60.62
53.73

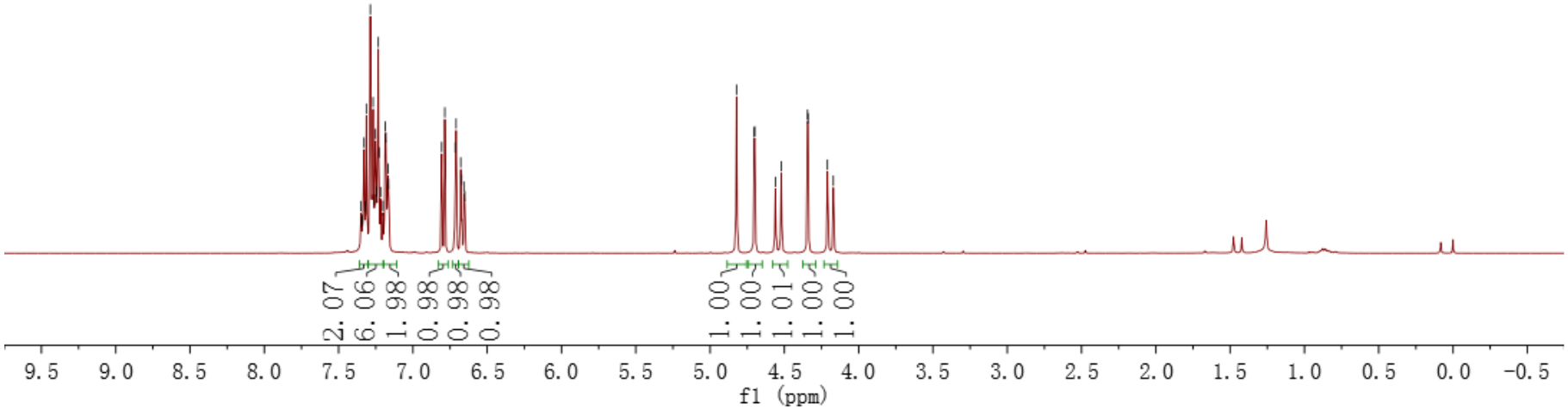


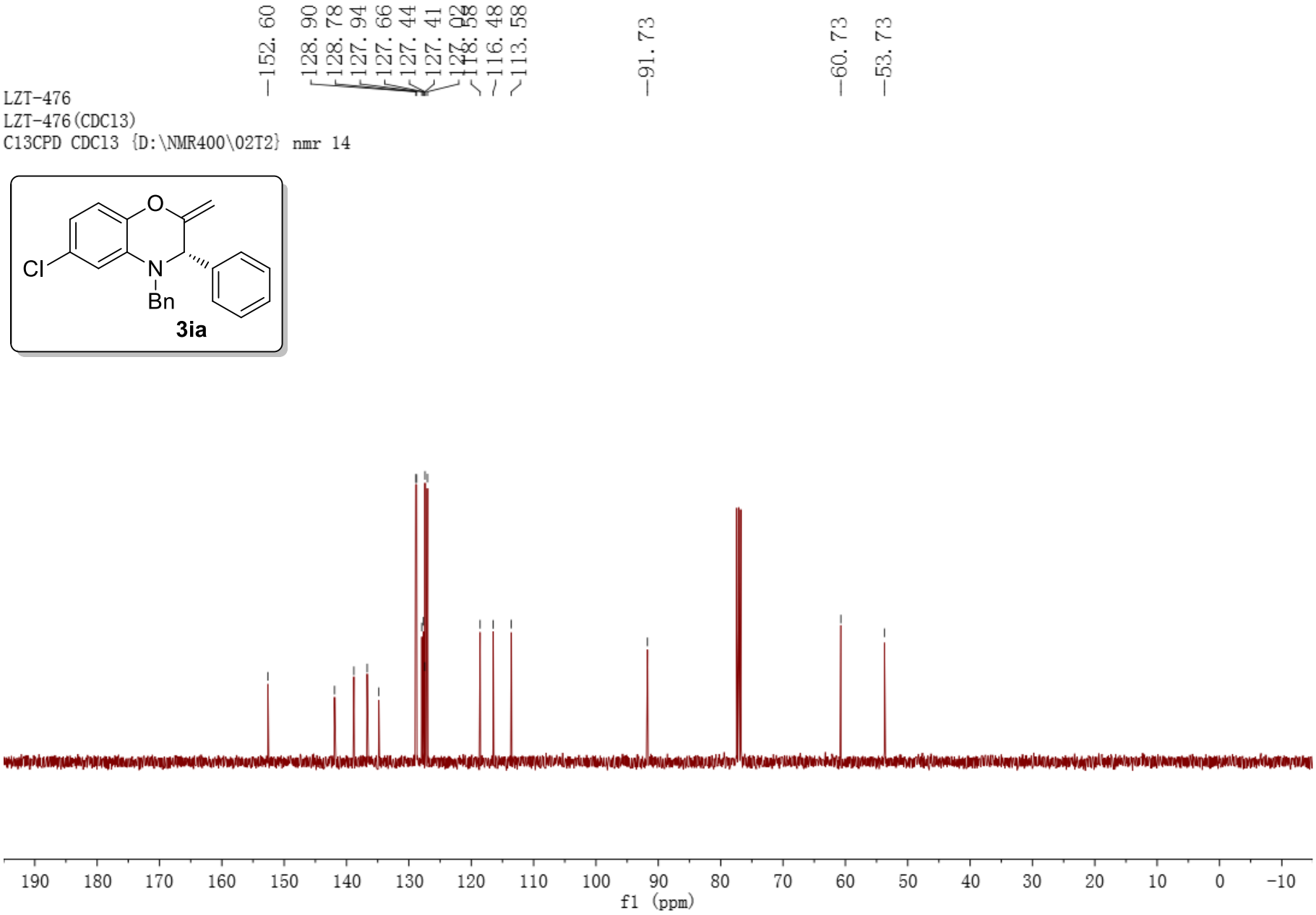


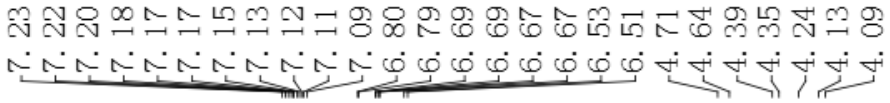
LZT-476
LZT-476(CDCl3)
PROTON CDCl3 {D:\NMR400\02T2} nmr 14



3ia

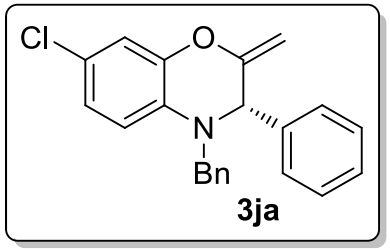



152.60
128.90
128.78
127.94
127.66
127.44
127.41
118.58
116.48
113.58
91.73
60.73
53.73
LZT-476
LZT-476(CDCl3)
C13CPD CDCl3 {D:\NMR400\02T2} nmr 14
O
Cl
N
Bn
3ia
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

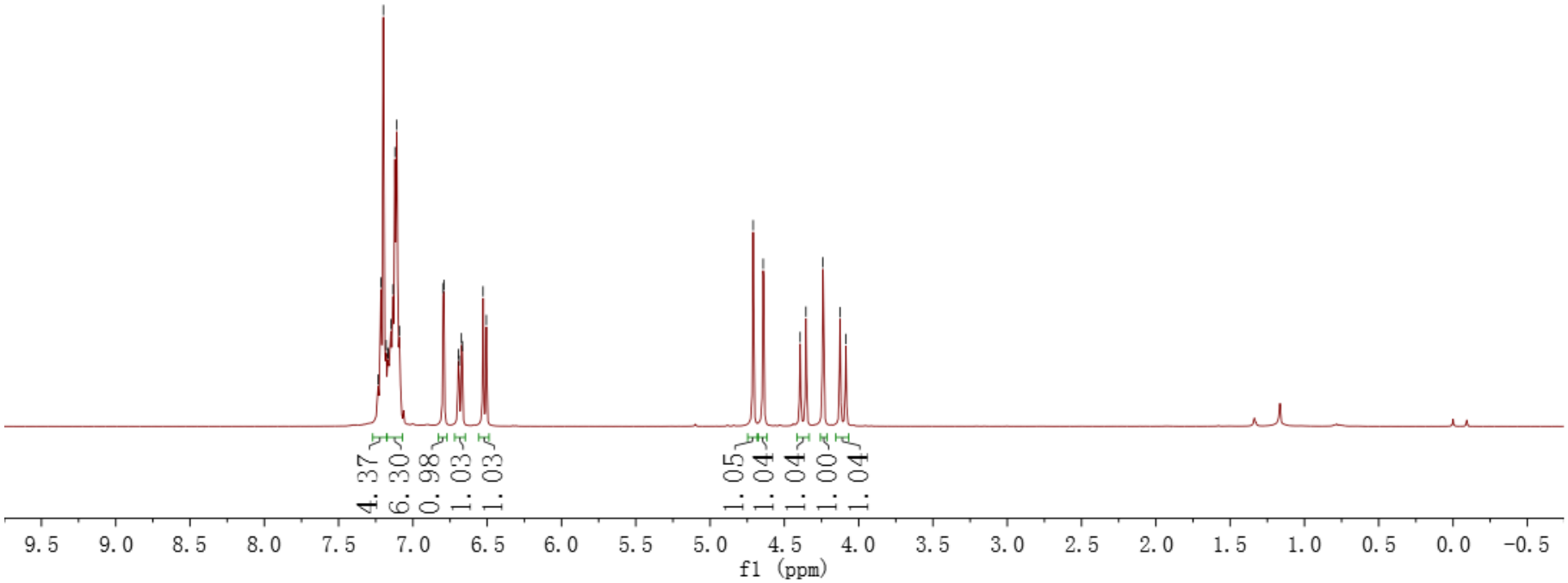


LZT-504

PROTON CDCl3 {D:\NMR400\02T2} nmr 53



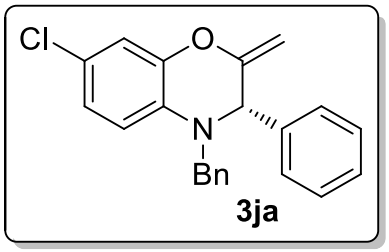
3ja



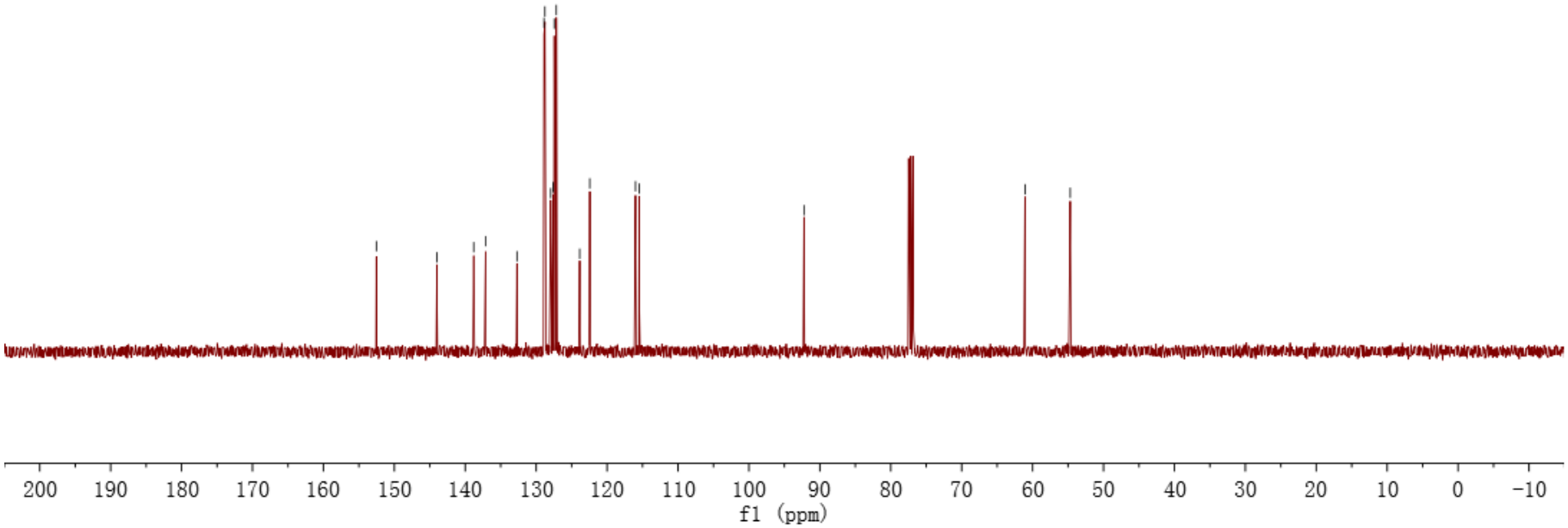
LZT-504

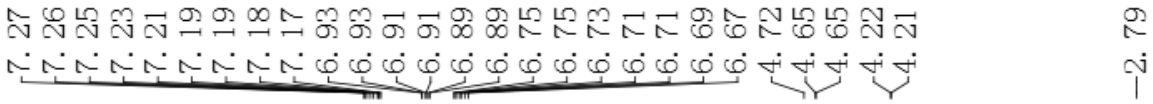
C13CPD CDCl3 {D:\NMR400\02T2} nmr 53

152.53
138.80
137.14
132.70
128.89
128.77
127.95
127.62
127.46
127.15
123.86
122.44
115.99
115.47
92.23
61.07
54.69



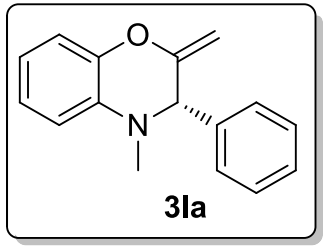
3ja

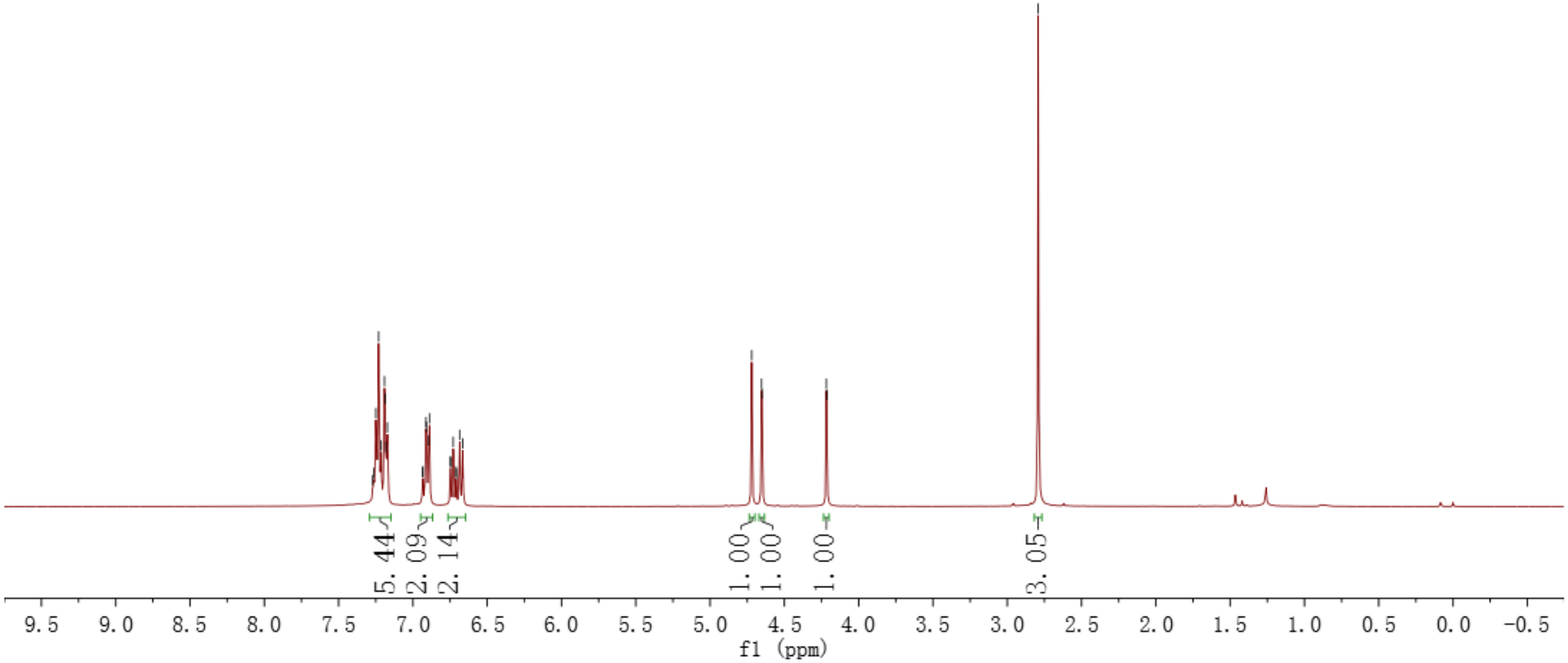




lzt-544

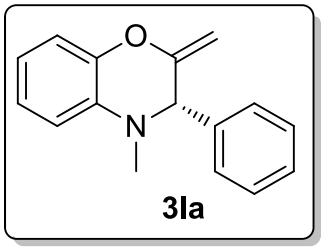
PROTON CDCl3 {D:\NMR400\02T2} nmr 8





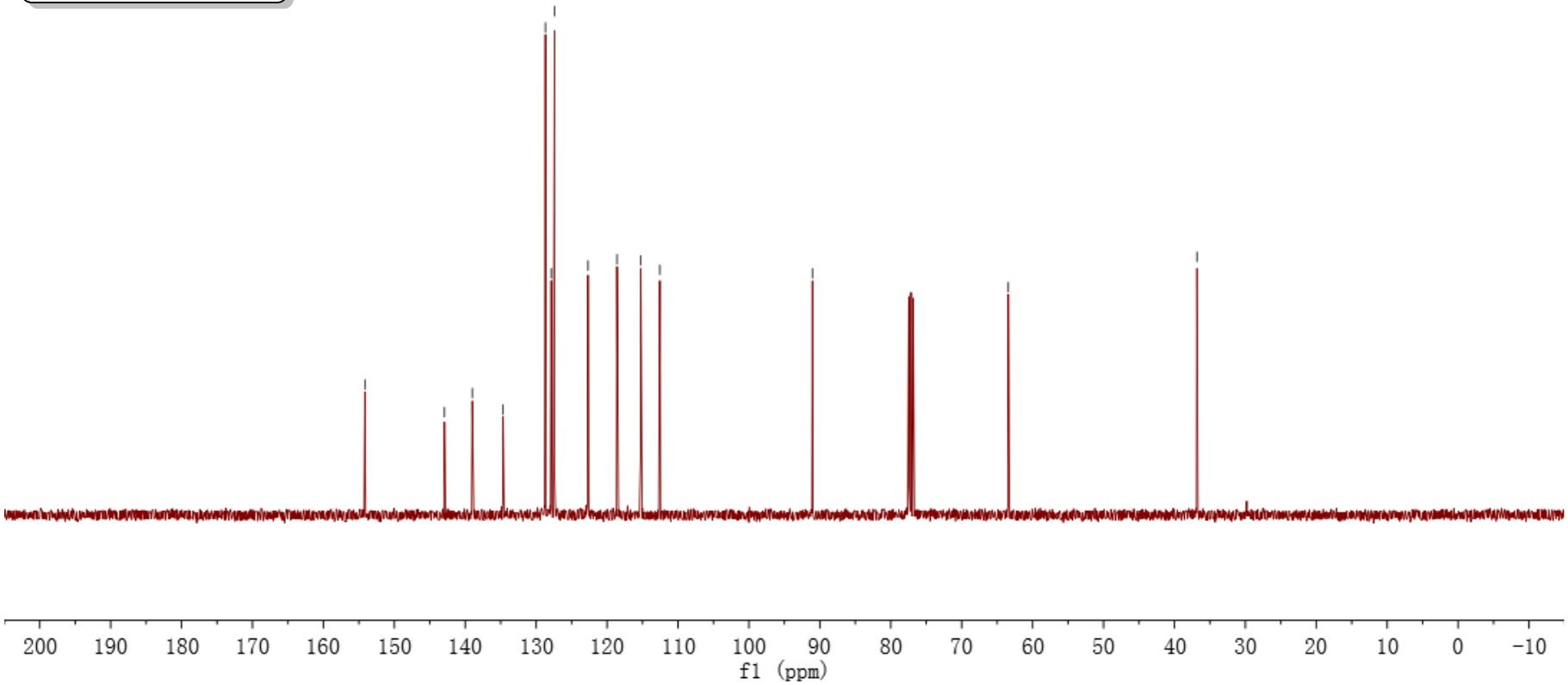
lzt-544

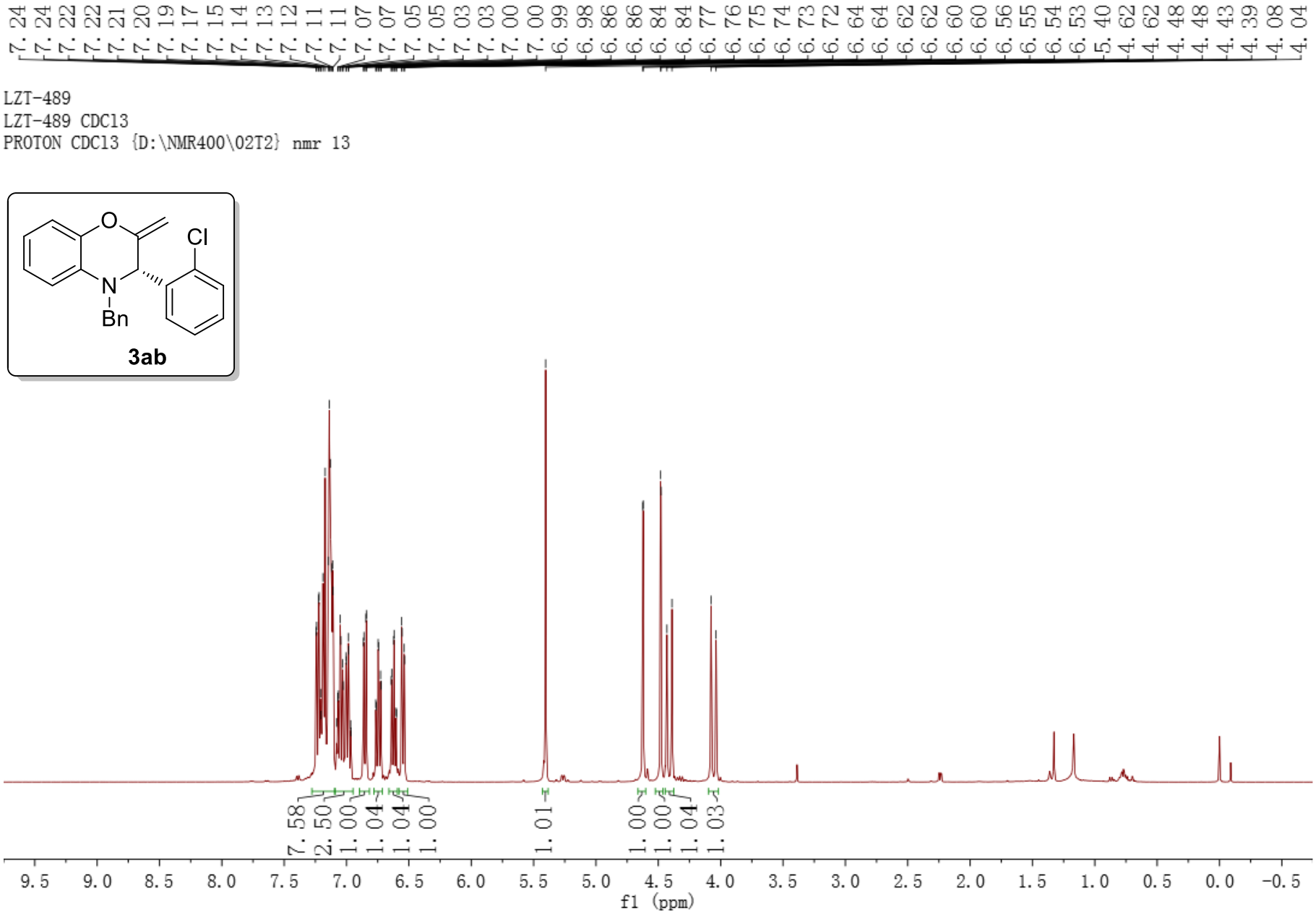
C13CPD CDCl3 {D:\NMR400\02T2} nmr 8

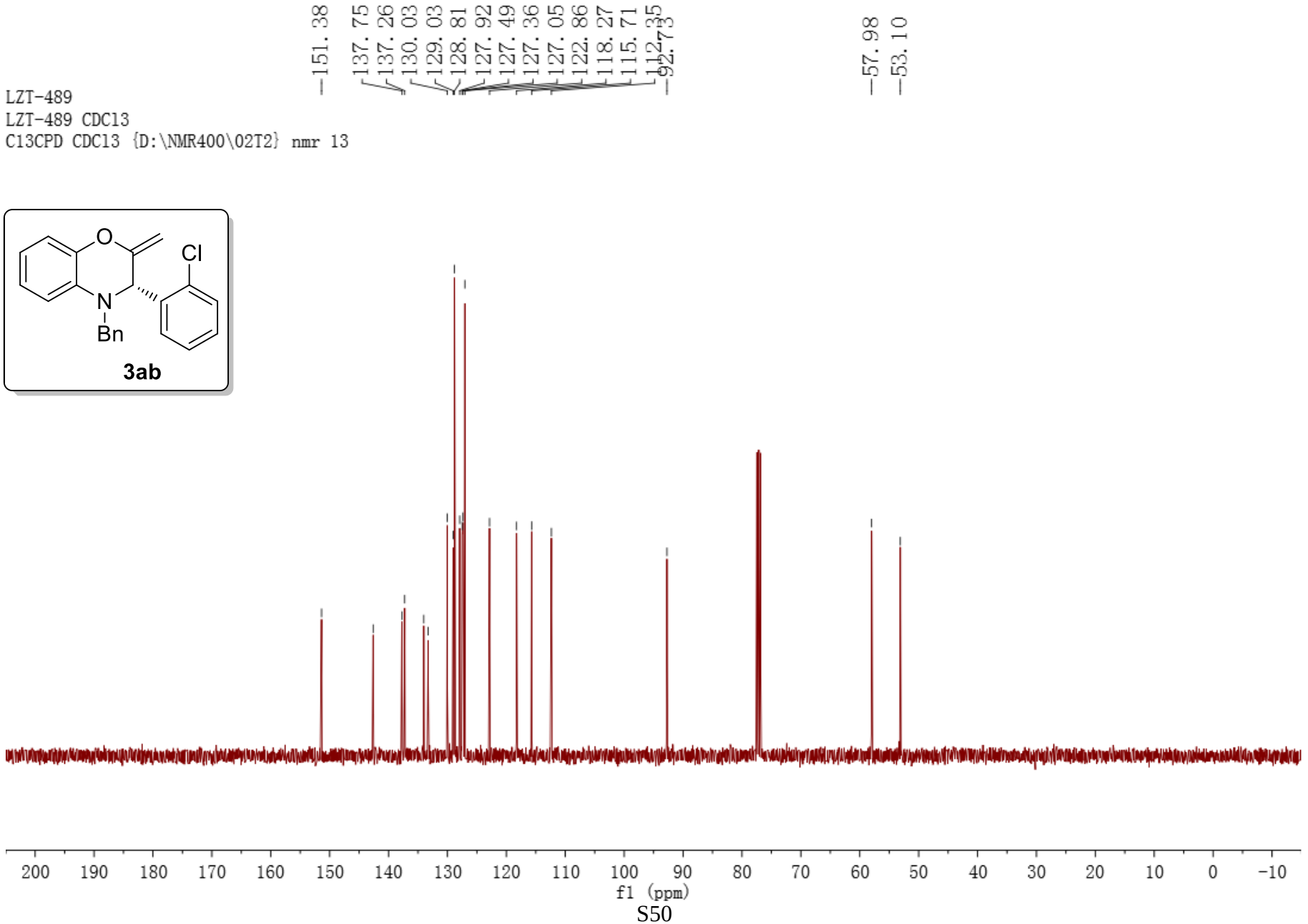


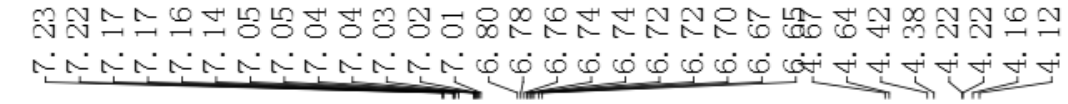
3la

154.15
142.93
139.01
134.66
128.70
127.88
127.42
122.68
118.60
115.24
112.55
91.04
63.42
36.83

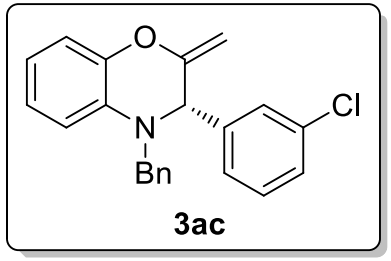



7.24 7.24 7.22 7.22 7.21 7.20 7.19 7.17 7.15 7.14 7.13 7.12 7.11 7.11 7.07 7.07 7.05 7.05 7.03 7.03 7.00 7.00 6.99 6.98 6.86 6.86 6.84 6.84 6.77 6.76 6.75 6.74 6.73 6.72 6.64 6.64 6.62 6.62 6.60 6.60 6.56 6.55 6.54 6.53 5.40 4.62 4.62 4.48 4.48 4.43 4.39 4.08 4.04
LZT-489
LZT-489 CDCl3
PROTON CDCl3 {D:\NMR400\02T2} nmr 13
O
Cl
N
Bn
3ab
7.58 2.50 1.00 1.04 1.04 1.00 1.01 1.00 1.00 1.04 1.03
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 -0.5
f1 (ppm)

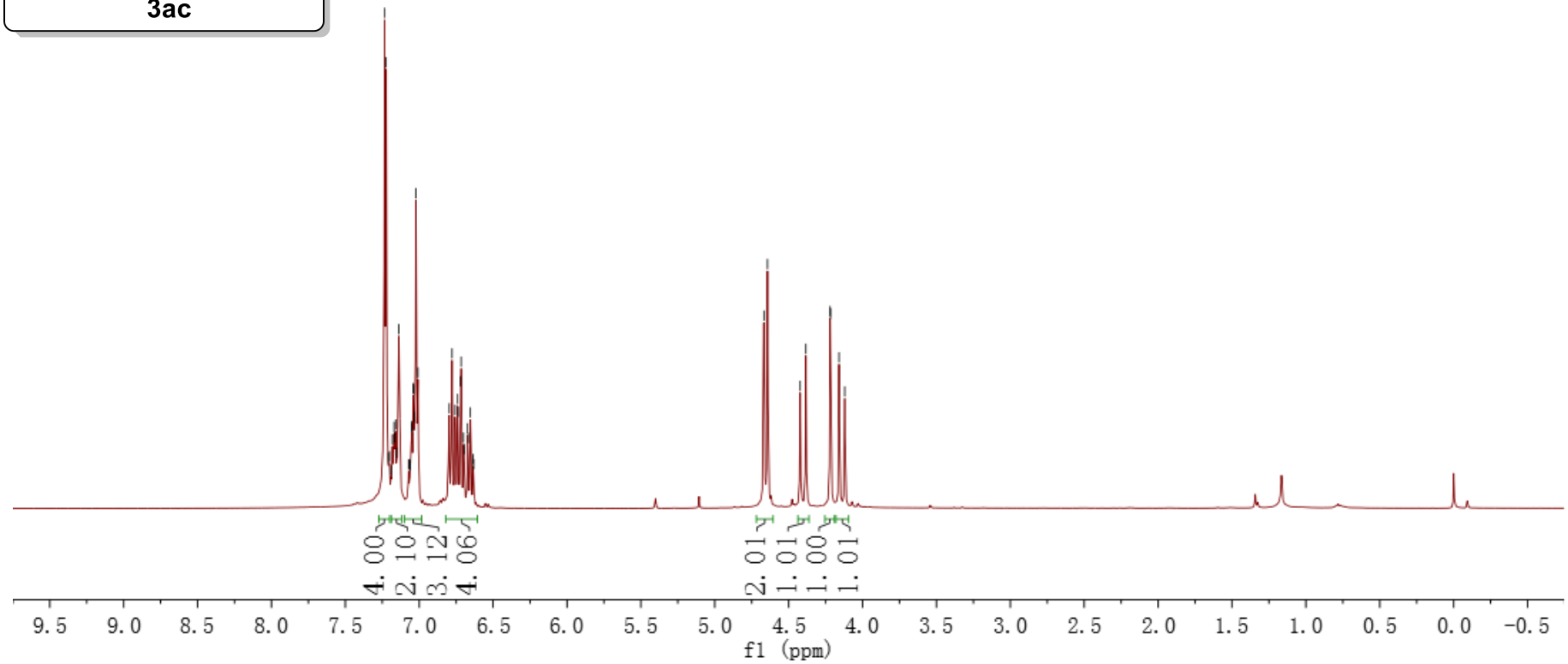

151.38
137.75
137.26
130.03
129.03
128.81
127.92
127.49
127.36
127.05
122.86
118.27
115.71
112.35
92.73
57.98
53.10
LZT-489
LZT-489 CDCl3
C13CPD CDCl3 {D:\NMR400\02T2} nmr 13
O
Cl
N
Bn
3ab
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

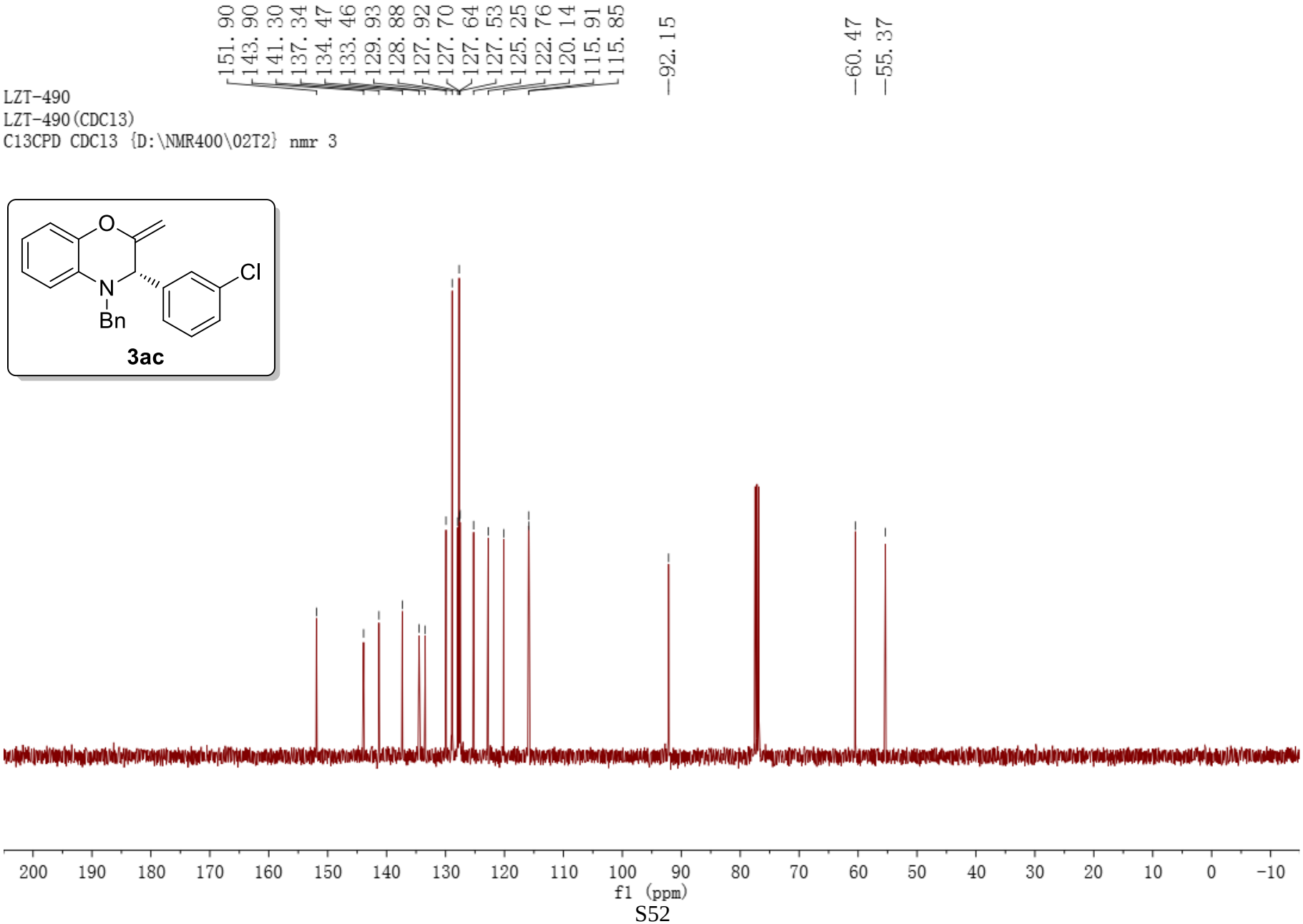


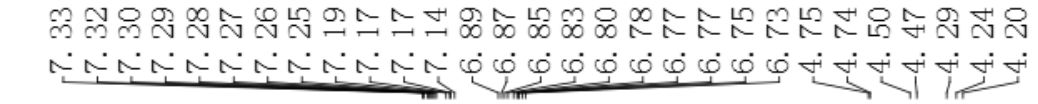
LZT-490
LZT-490(CDCl3)
PROTON CDCl3 {D:\NMR400\02T2} nmr 3



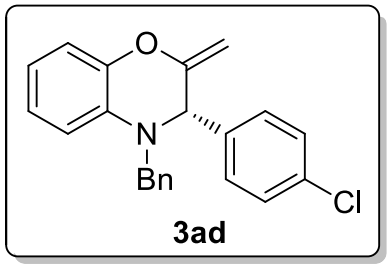
3ac



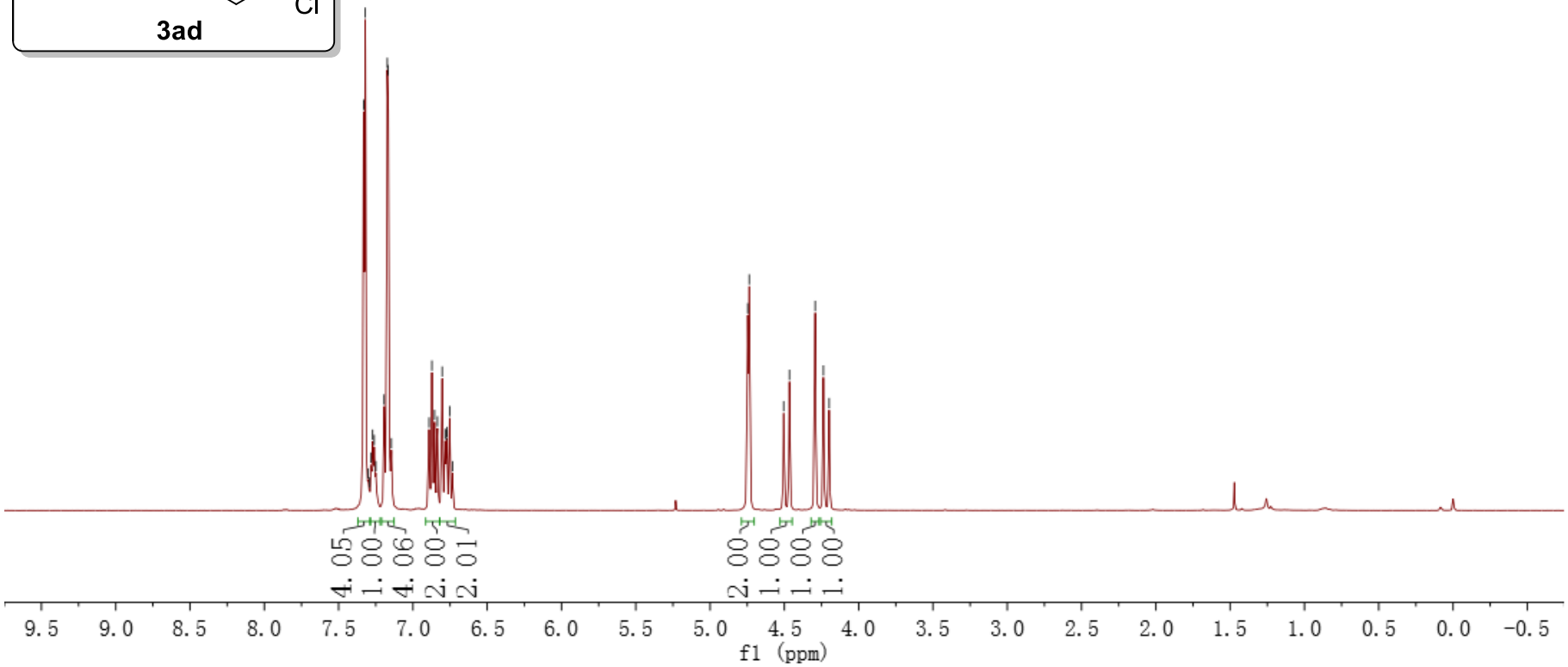

151.90
143.90
141.30
137.34
134.47
133.46
129.93
128.88
127.92
127.70
127.64
127.53
125.25
122.76
120.14
115.91
115.85
92.15
60.47
55.37
LZT-490
LZT-490(CDCl3)
C13CPD CDCl3 {D:\NMR400\02T2} nmr 3
O
N
Bn
Cl
3ac
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)



LZT-418
LZT-418(CDCl3)
PROTON CDCl3 {D:\NMR400\02T2} nmr 51

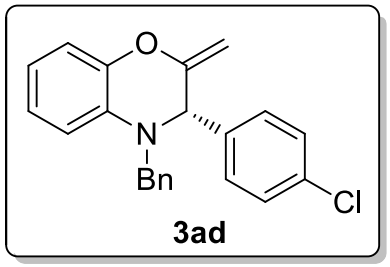


3ad

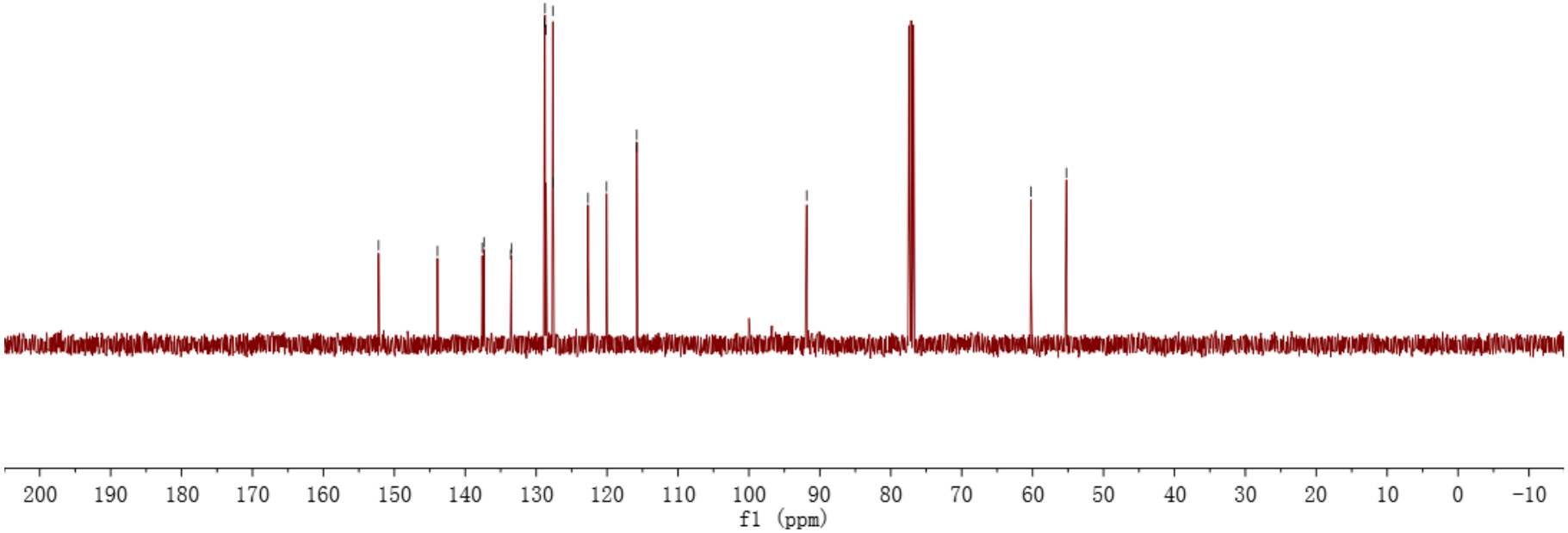


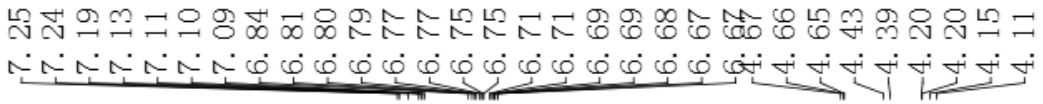
LZT-418
LZT-418(CDCl3)
C13CPD CDCl3 {D:\NMR400\02T2} nmr 51

152.23
143.91
137.59
137.37
133.49
128.83
128.75
128.61
127.65
127.59
122.68
120.07
115.83
115.81
91.88
60.23
55.23

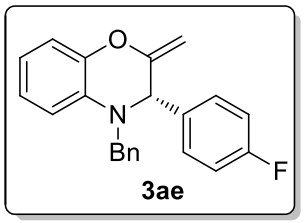


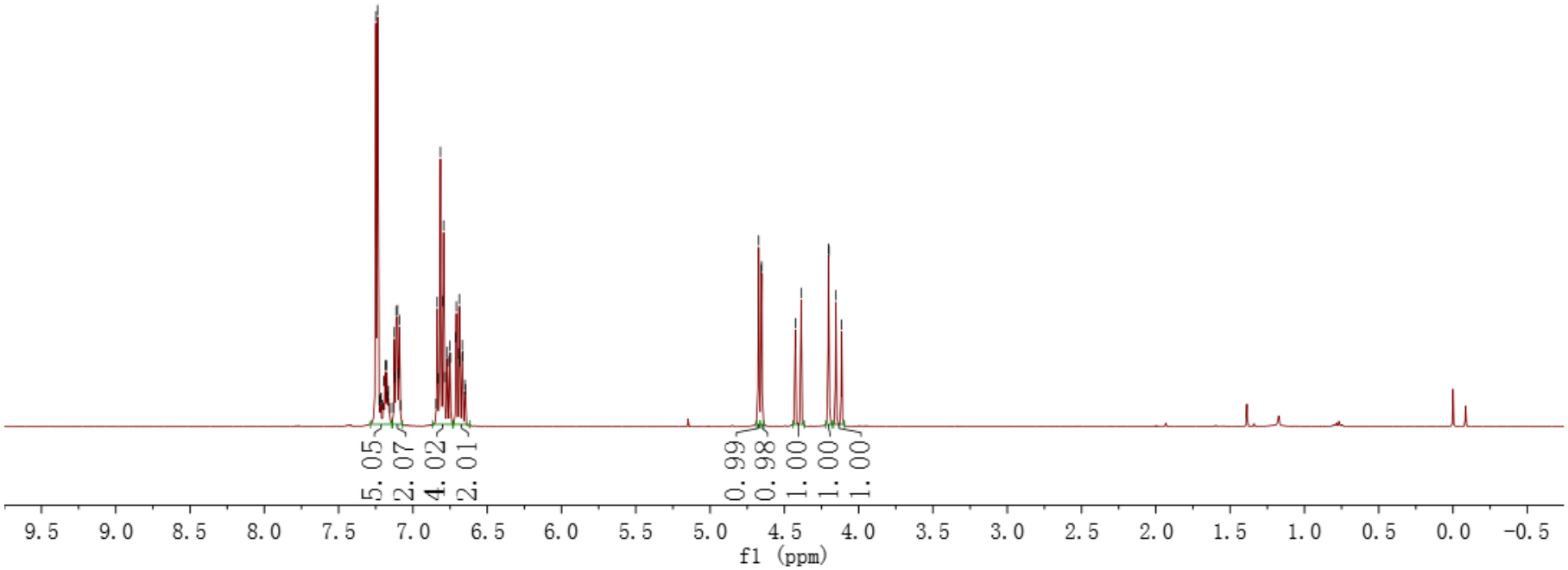
3ad





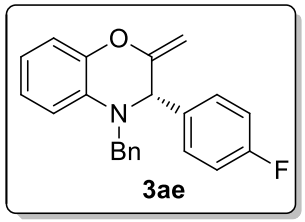
LZT-419
LZT-419(CDCl3)
PROTON CDCl3 {D:\NMR400\02T2} nmr 20



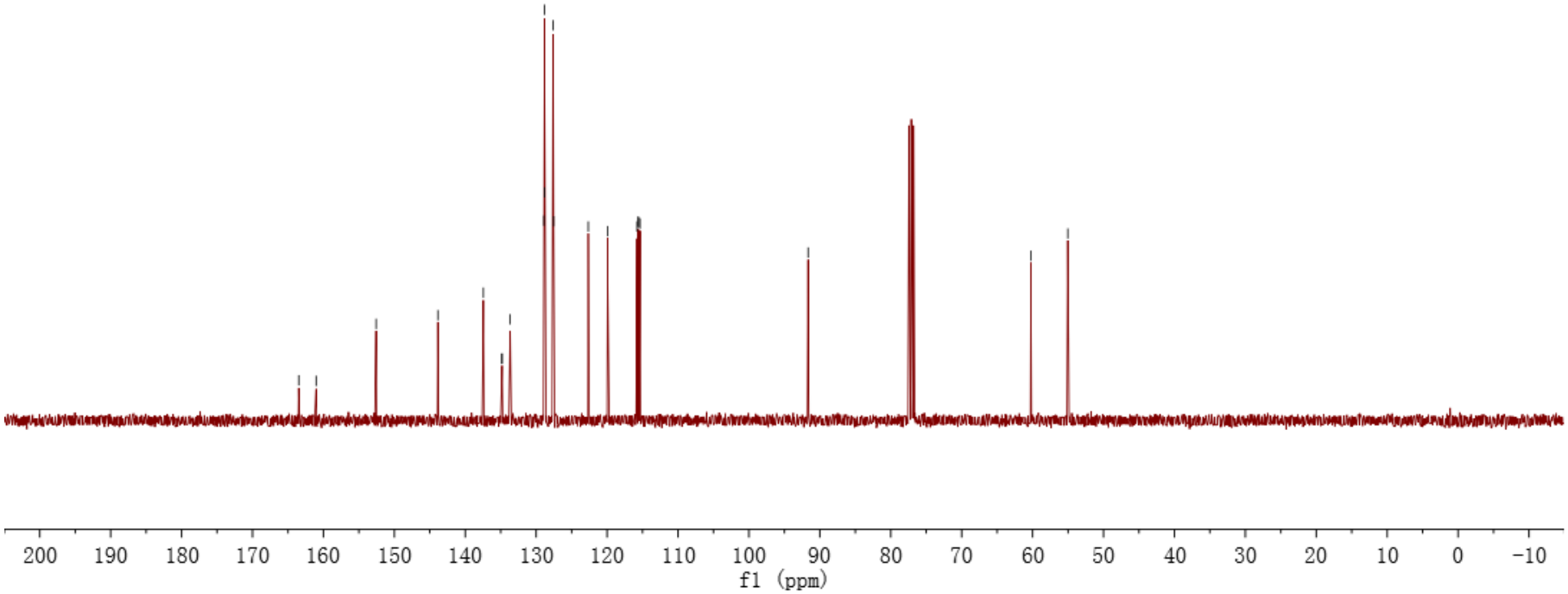


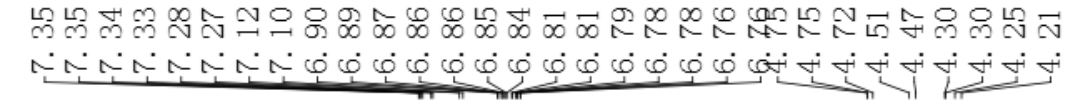
LZT-419
LZT-419(CDCl3)
C13CPD CDCl3 {D:\NMR400\02T2} nmr 20

163.48
161.03
152.57
143.85
137.45
128.91
128.83
128.81
127.61
127.54
122.65
119.91
115.78
115.61
115.57
115.35
91.65
60.23
55.04

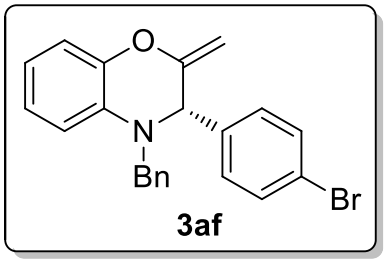


3ae

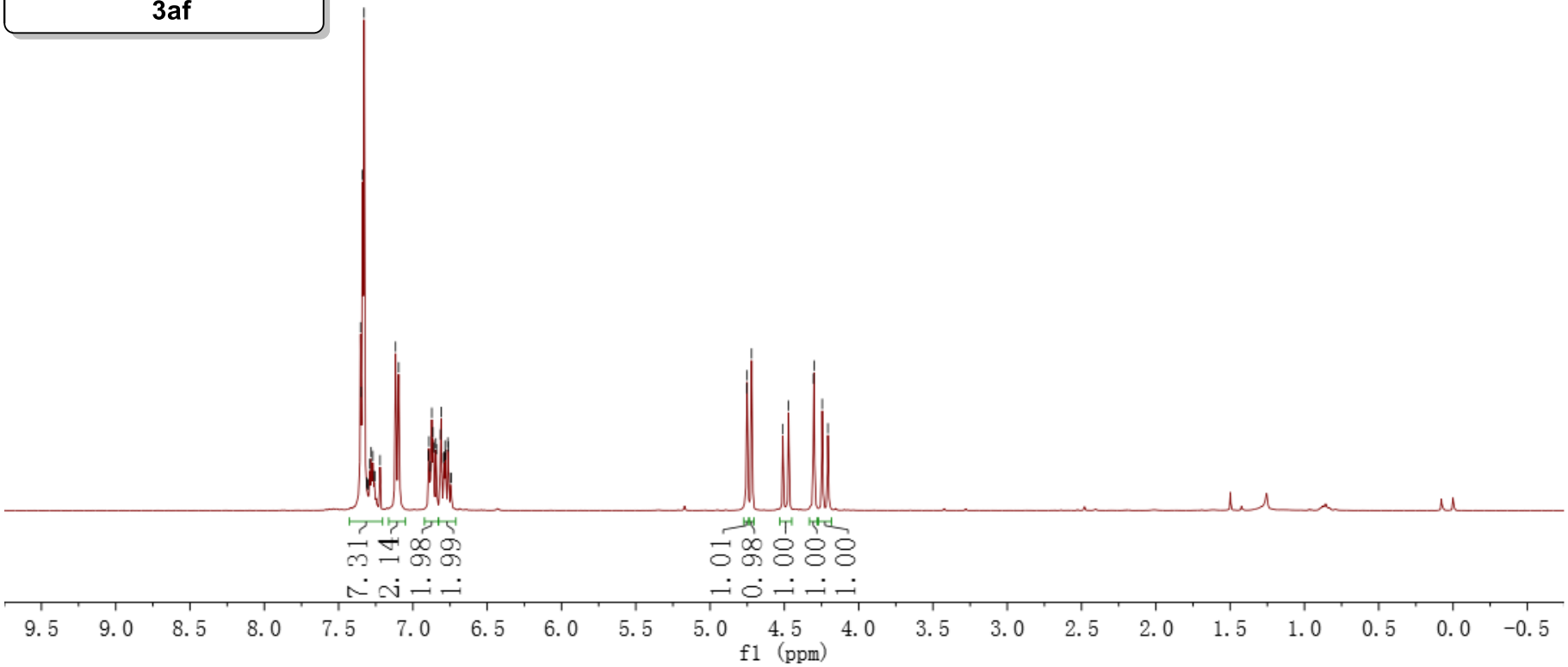


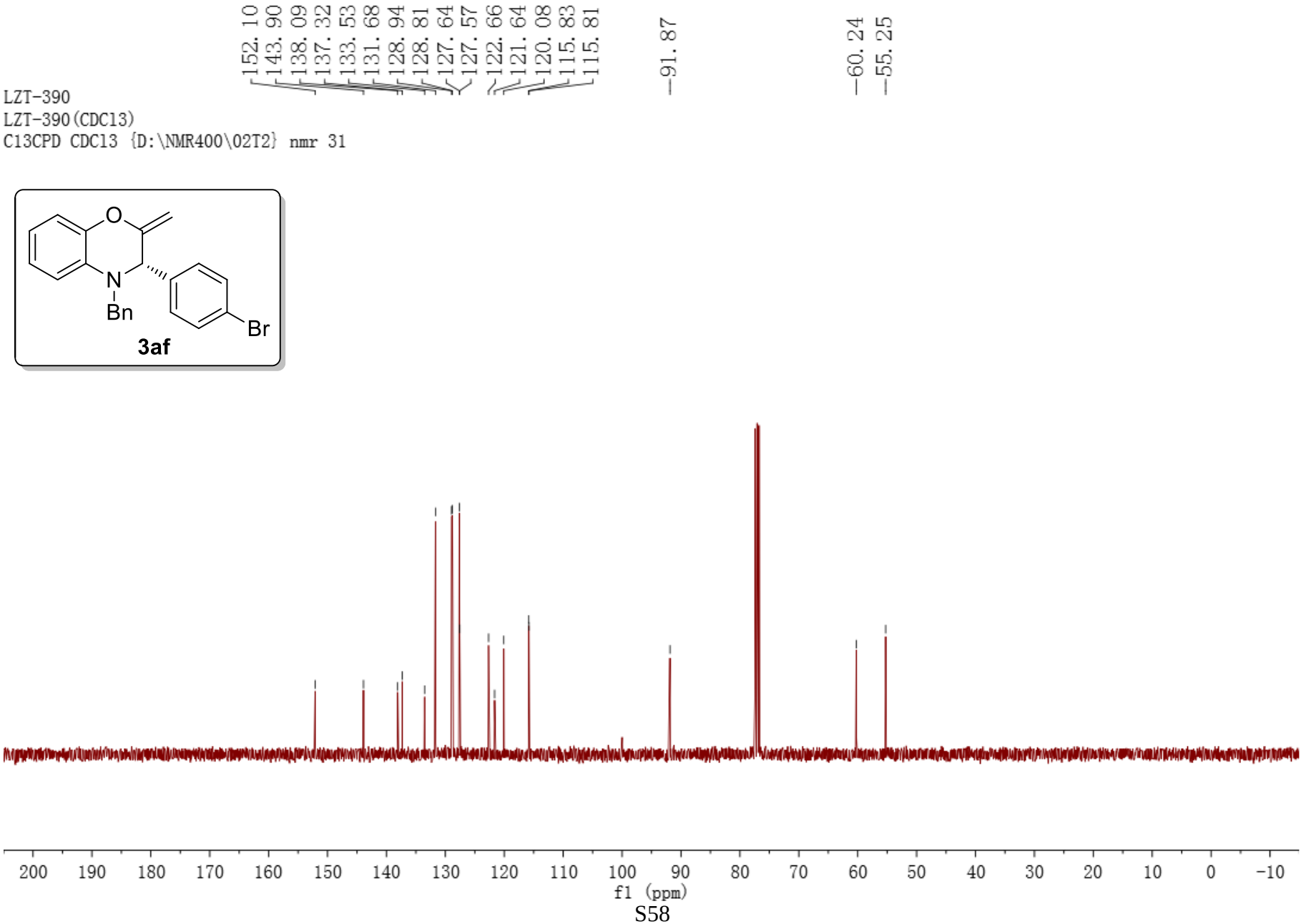


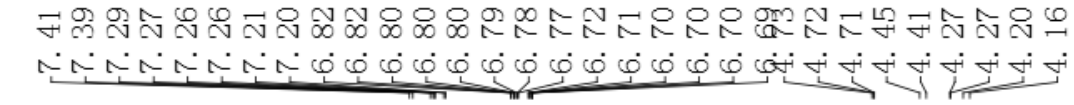
LZT-390
LZT-390(CDCl3)
PROTON CDCl3 {D:\NMR400\02T2} nmr 31



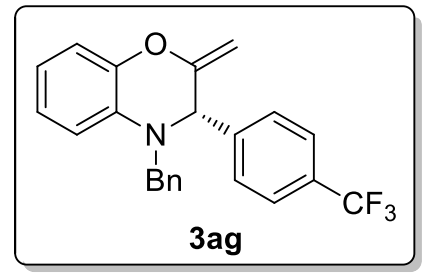
3af



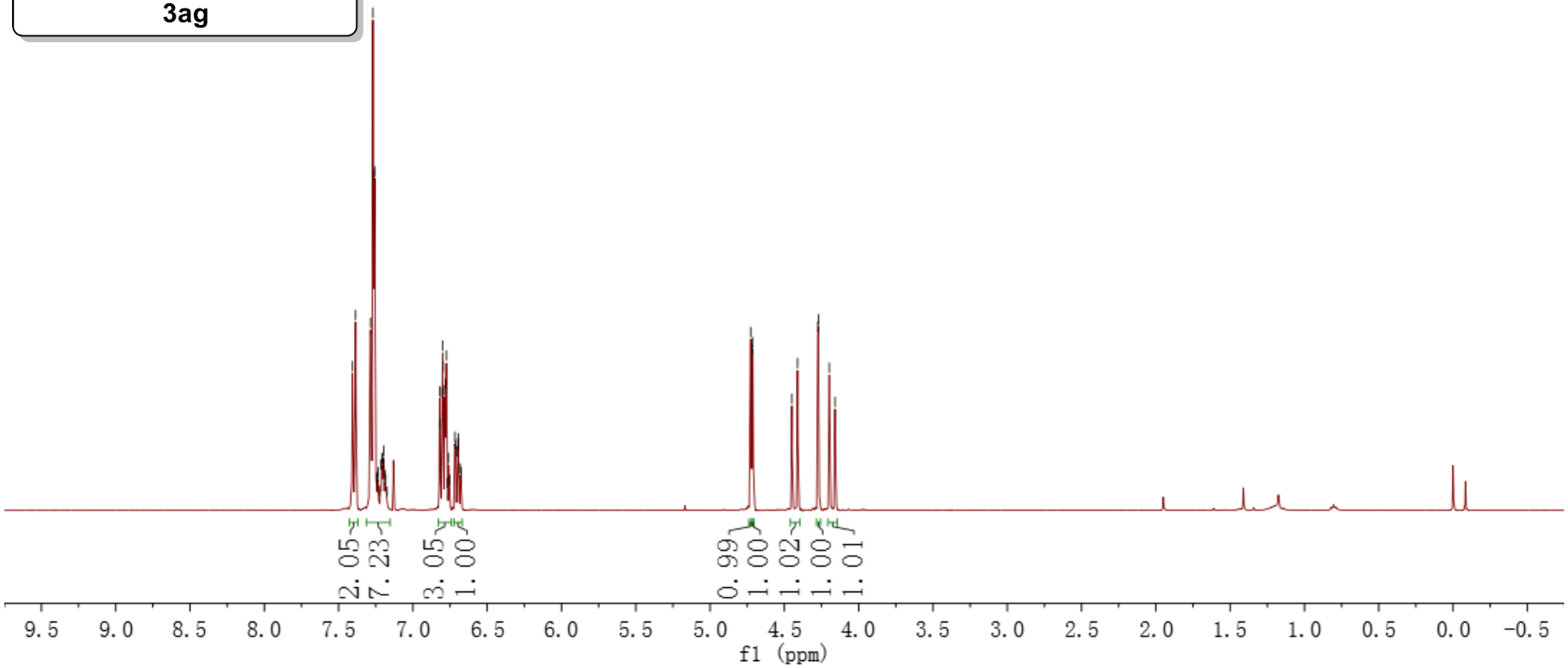

152.10
143.90
138.09
137.32
133.53
131.68
128.94
128.81
127.64
127.57
122.66
121.64
120.08
115.83
115.81
91.87
60.24
55.25
LZT-390
LZT-390(CDCl3)
C13CPD CDCl3 {D:\NMR400\02T2} nmr 31
O
N
Bn
Br
3af
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)



LZT-421
LZT-421(CDCl3)
PROTON CDCl3 {D:\NMR400\02T2} nmr 52



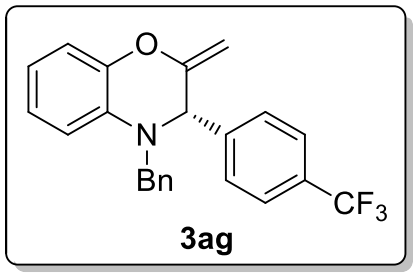
3ag



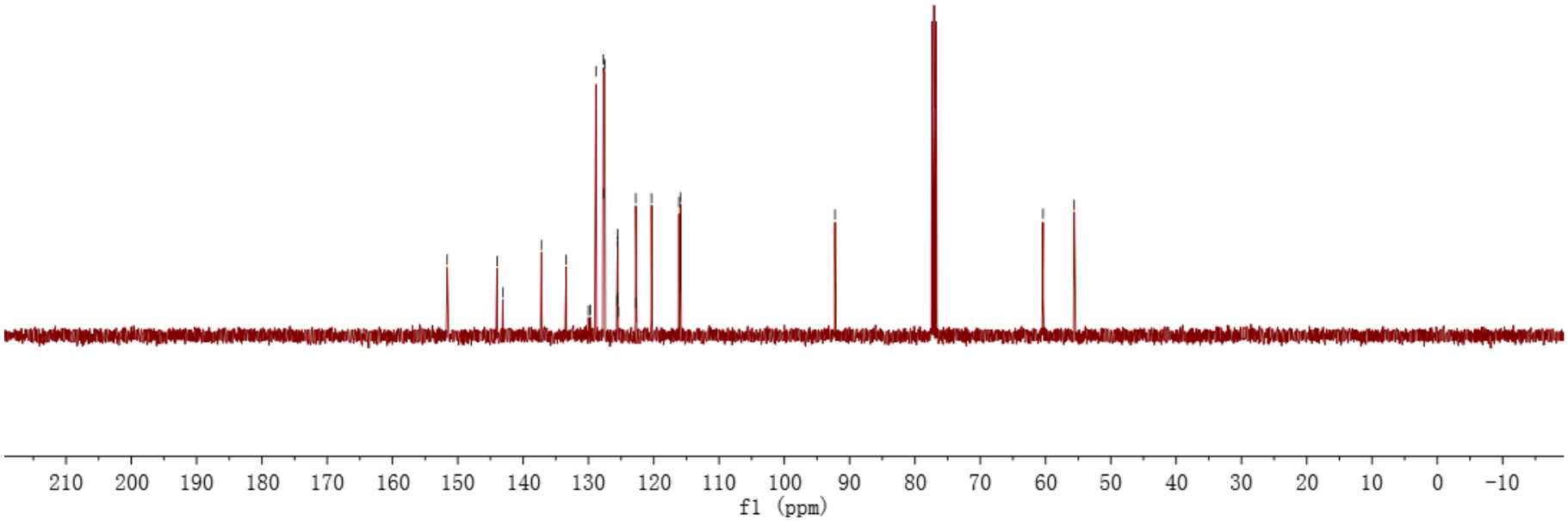
151.63
143.99
143.12
137.21
133.40
130.00
129.68
128.85
127.71
127.67
127.52
125.60
125.56
125.52
125.49
125.43
122.75
122.72
120.33
116.14
115.91
92.23

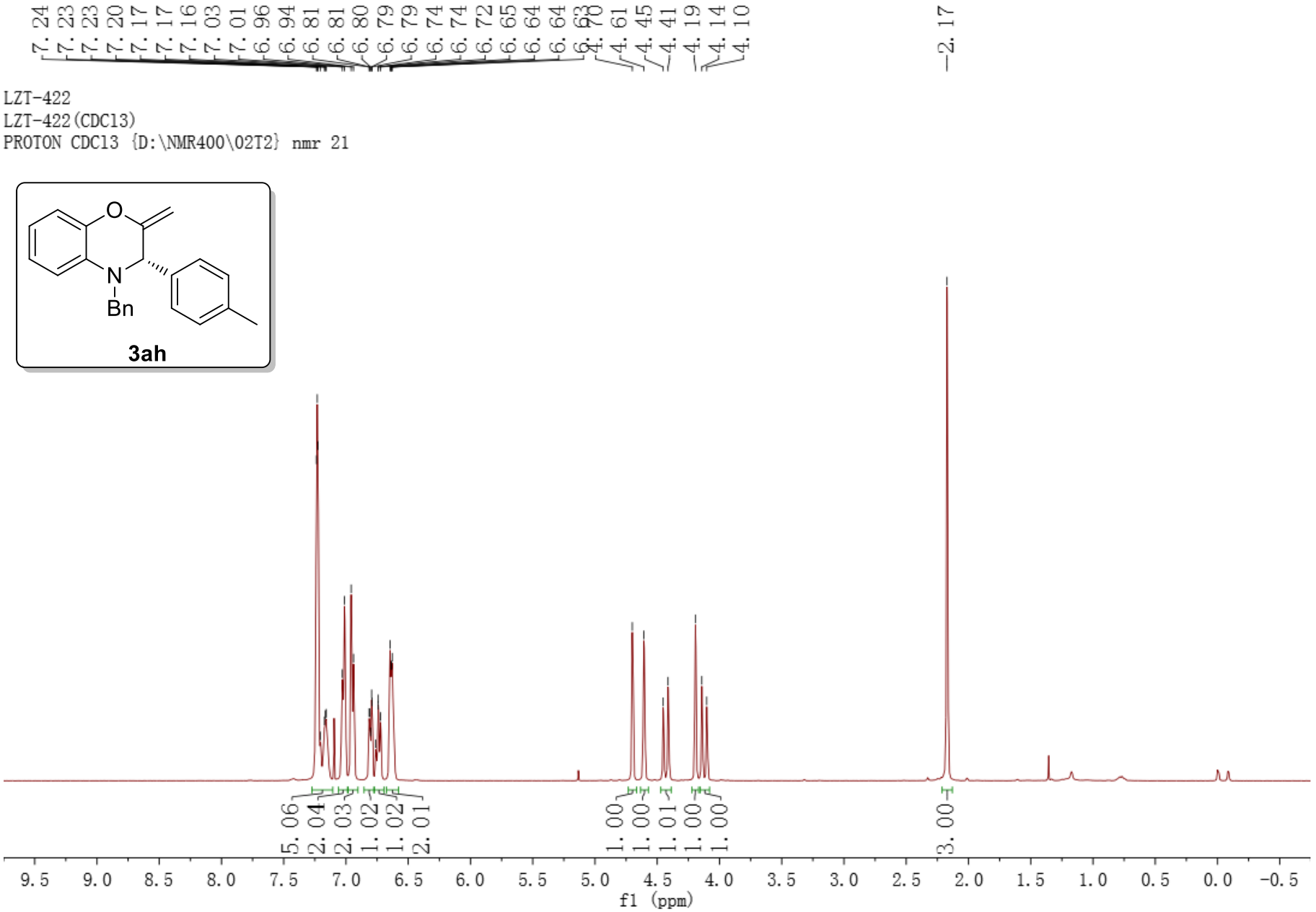
60.38
55.61

LZT-421
LZT-421(CDCl3)
C13CPD CDCl3 {D:\NMR400\02T2} nmr 52



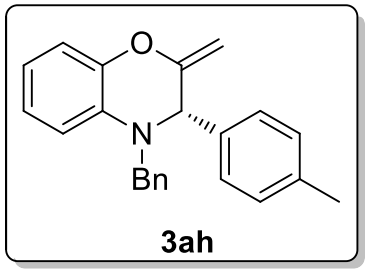
3ag



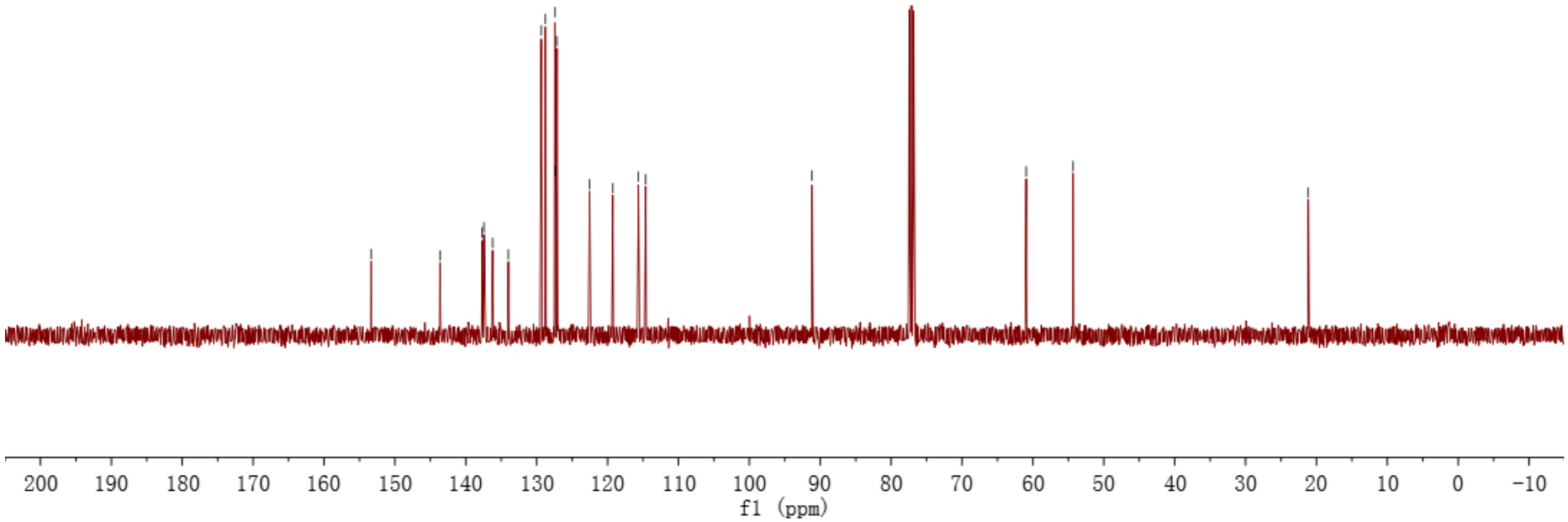

7.24
7.23
7.23
7.20
7.17
7.17
7.16
7.03
7.01
6.96
6.94
6.81
6.81
6.80
6.79
6.79
6.74
6.74
6.72
6.65
6.64
6.64
6.63
6.61
4.61
4.45
4.41
4.19
4.14
4.10
2.17
LZT-422
LZT-422(CDCl3)
PROTON CDCl3 {D:\NMR400\02T2} nmr 21
O
N
Bn
3ah
5.06
2.04
2.03
1.02
1.02
2.01
1.00
1.00
1.01
1.00
1.00
3.00
9.5
9.0
8.5
8.0
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
-0.5
f1 (ppm)

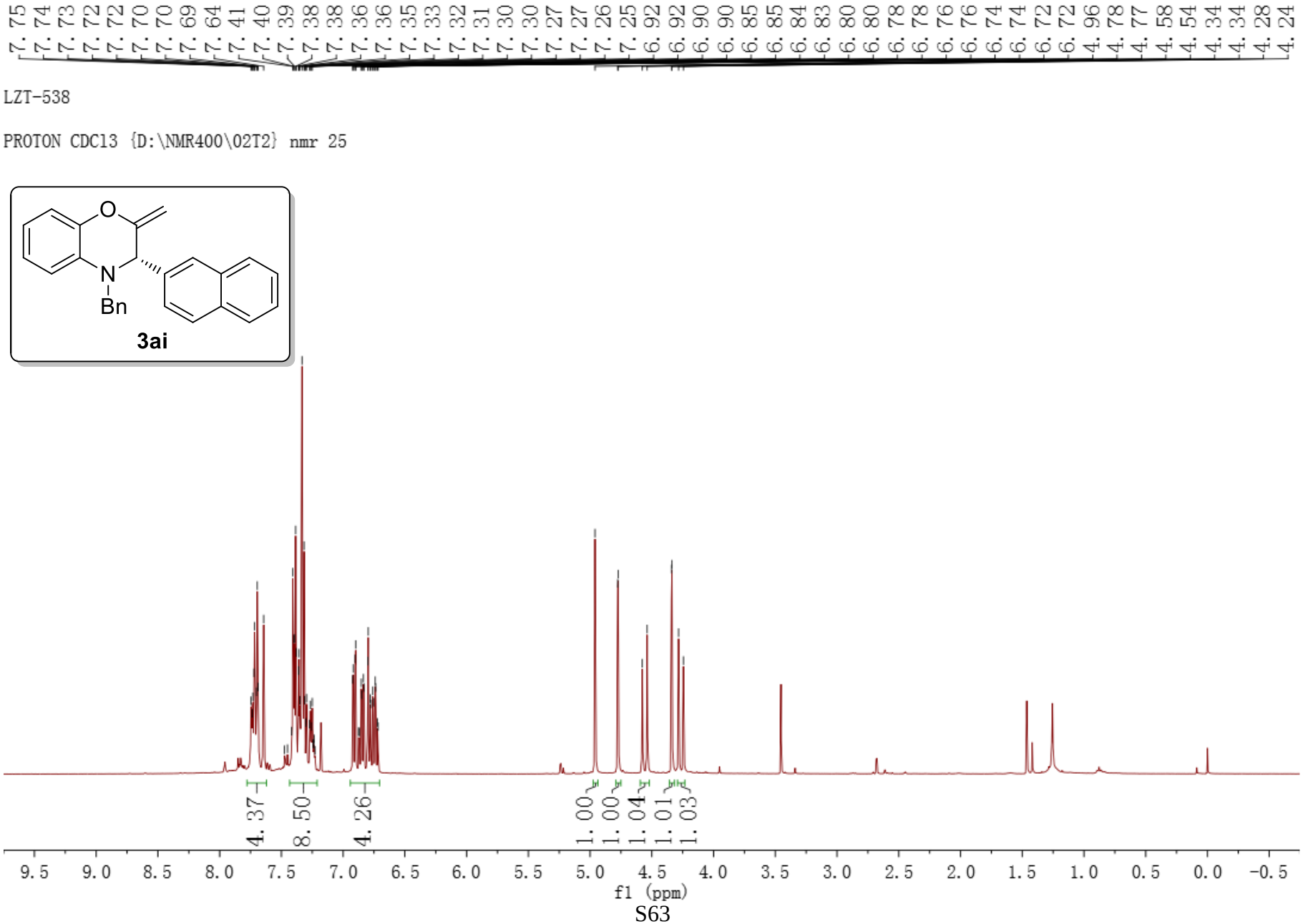
153.35
143.64
137.69
137.43
136.21
133.99
129.35
128.77
127.45
127.38
127.14
122.54
119.25
115.65
114.61
91.16
60.94
54.33
21.15

LZT-422
LZT-422(CDC13)
C13CPD CDC13 {D:\NMR400\02T2} nmr 21



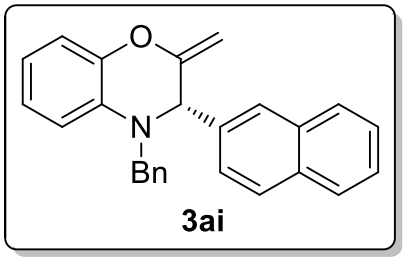
3ah



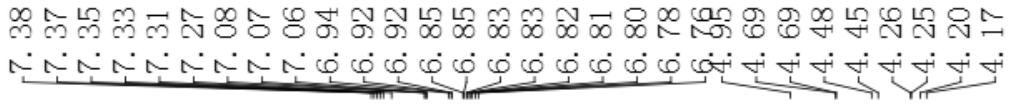

7.75 7.74 7.73 7.72 7.72 7.70 7.70 7.69 7.64 7.41 7.40 7.39 7.38 7.38 7.36 7.36 7.35 7.33 7.32 7.31 7.30 7.30 7.27 7.27 7.26 7.25 6.92 6.92 6.90 6.90 6.85 6.85 6.84 6.83 6.80 6.80 6.78 6.78 6.76 6.76 6.74 6.74 6.72 6.72 4.96 4.78 4.77 4.58 4.54 4.34 4.34 4.28 4.24
LZT-538
PROTON CDCl3 {D:\NMR400\02T2} nmr 25
O
N
Bn
3ai
4.37
8.50
4.26
1.00
1.00
1.04
1.01
1.03
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 -0.5
f1 (ppm)

LZT-538

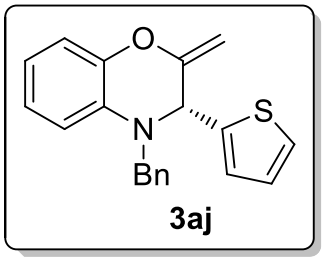
C13CPD CDCl3 {D:\NMR400\02T2} nmr 25



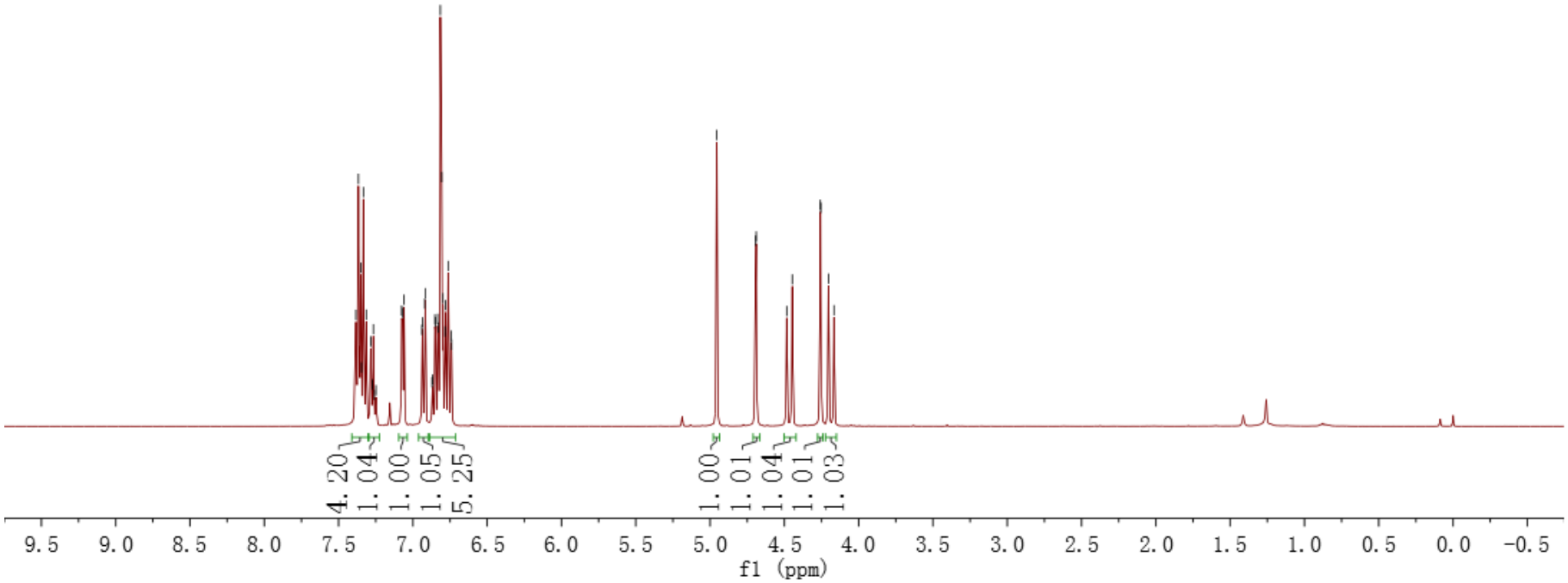
3ai



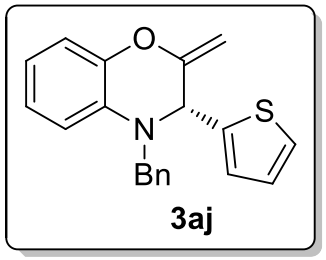
LZT-497
LZT-497(CDCl3)
PROTON CDCl3 {D:\NMR400\02T2} nmr 4



3aj

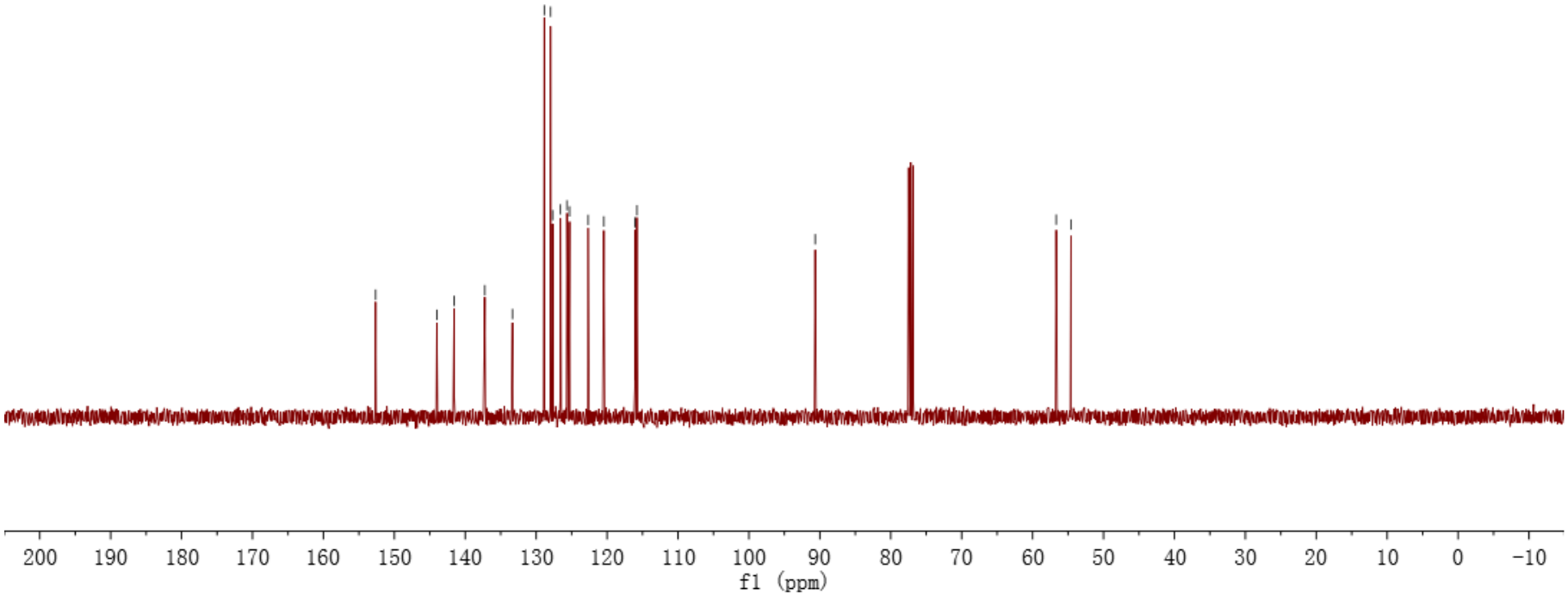


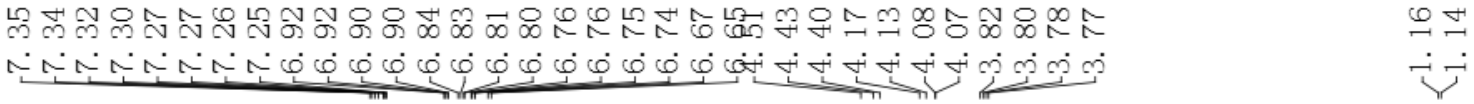
LZT-497
LZT-497(CDCl3)
C13CPD CDCl3 {D:\NMR400\02T2} nmr 4



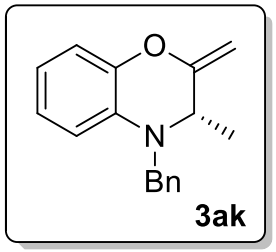
3aj

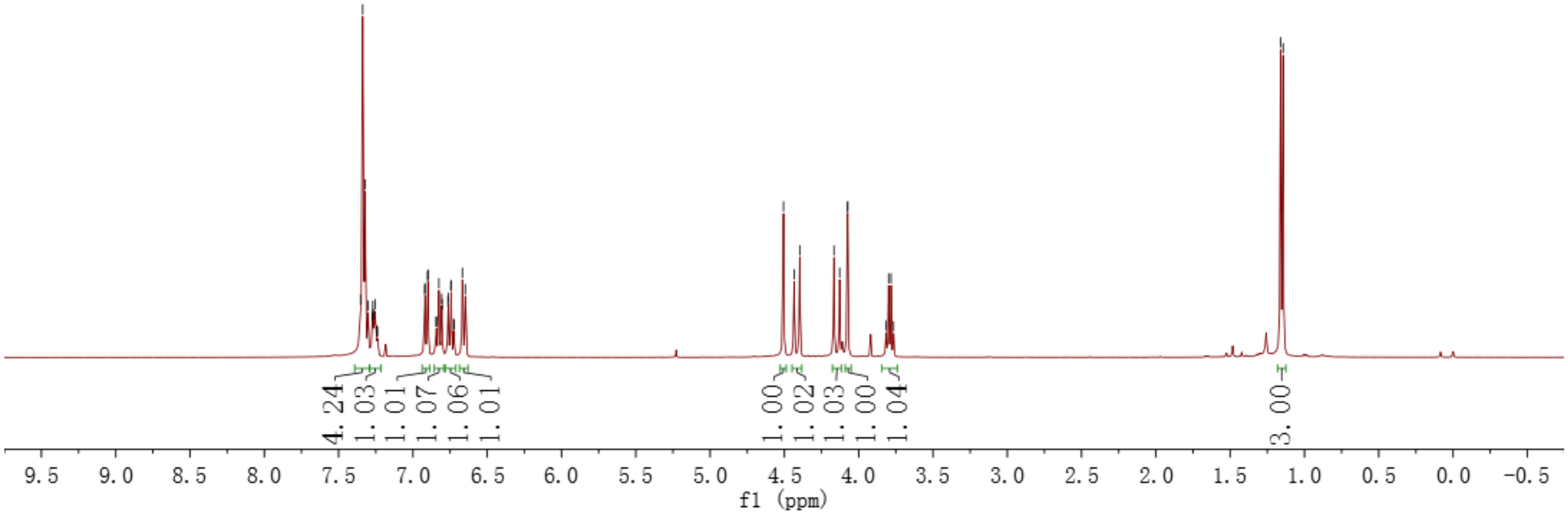
152.63
141.57
137.24
133.34
128.86
127.96
127.68
126.56
125.66
125.29
122.67
120.45
116.05
115.79
90.66
56.67
54.59

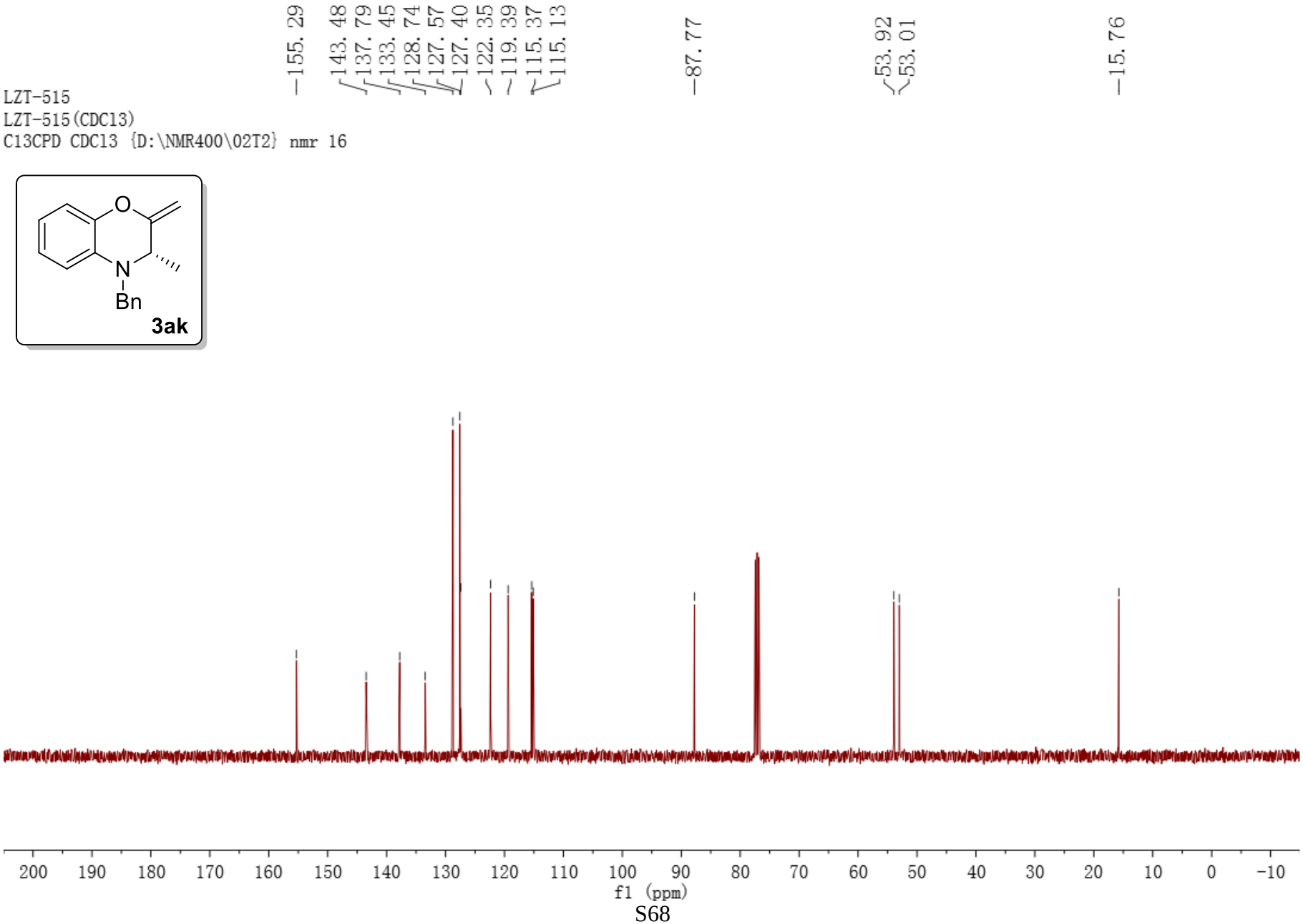


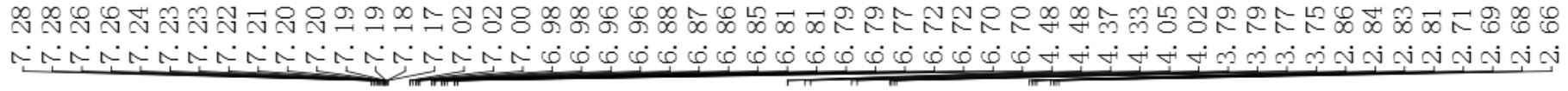


LZT-515
LZT-515(CDCl3)
PROTON CDCl3 {D:\NMR400\02T2} nmr 16



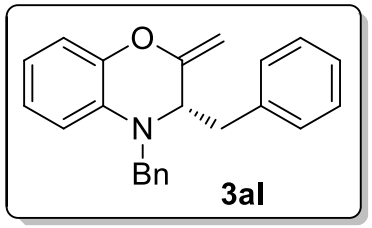


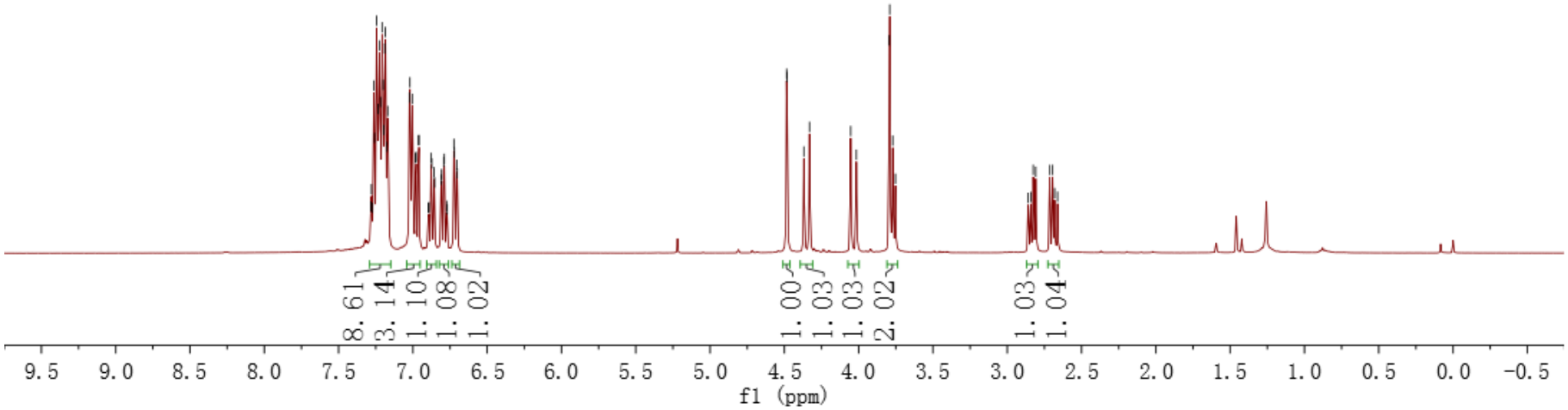

155.29
143.48
137.79
133.45
128.74
127.57
127.40
122.35
119.39
115.37
115.13
87.77
53.92
53.01
15.76
LZT-515
LZT-515(CDCl3)
C13CPD CDCl3 {D:\NMR400\02T2} nmr 16
O
N
Bn
3ak
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

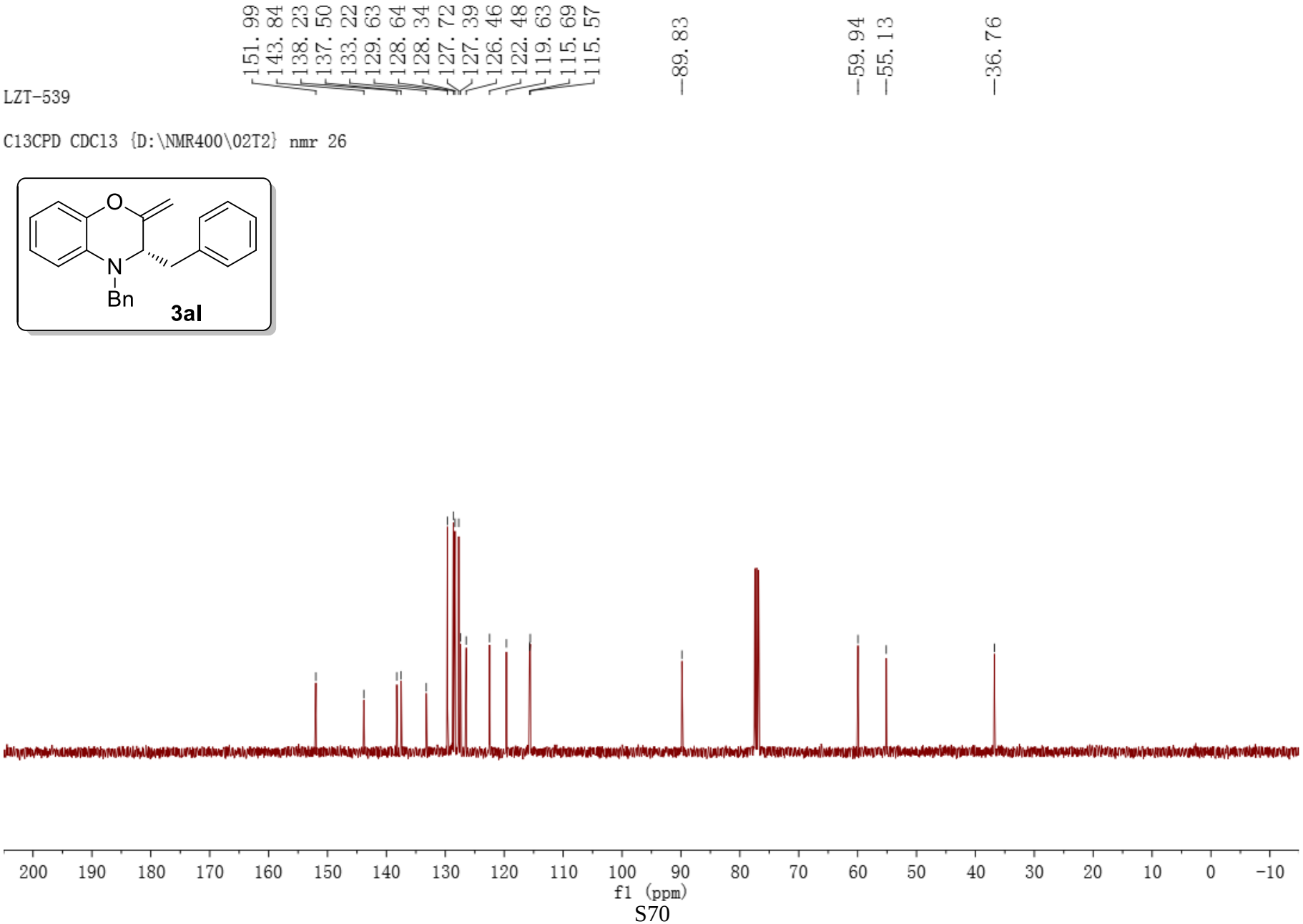


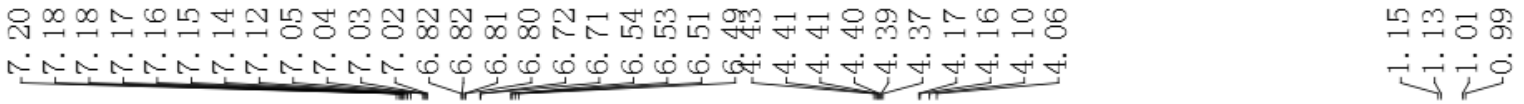
LZT-539

PROTON CDCl3 {D:\NMR400\02T2} nmr 26



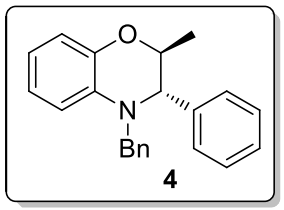


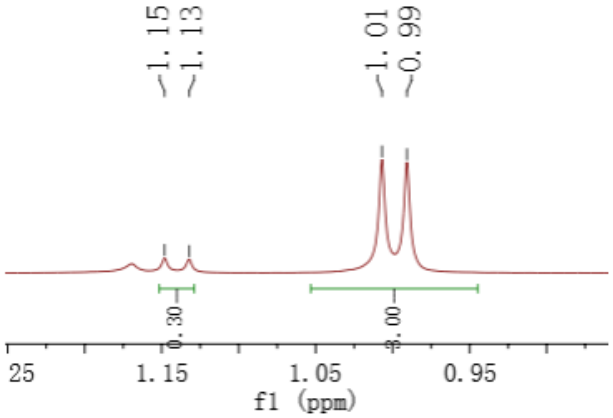

151.99
143.84
138.23
137.50
133.22
129.63
128.64
128.34
127.72
127.39
126.46
122.48
119.63
115.69
115.57
89.83
59.94
55.13
36.76
LZT-539
C13CPD CDCl3 {D:\NMR400\02T2} nmr 26
O
N
Bn
3al
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

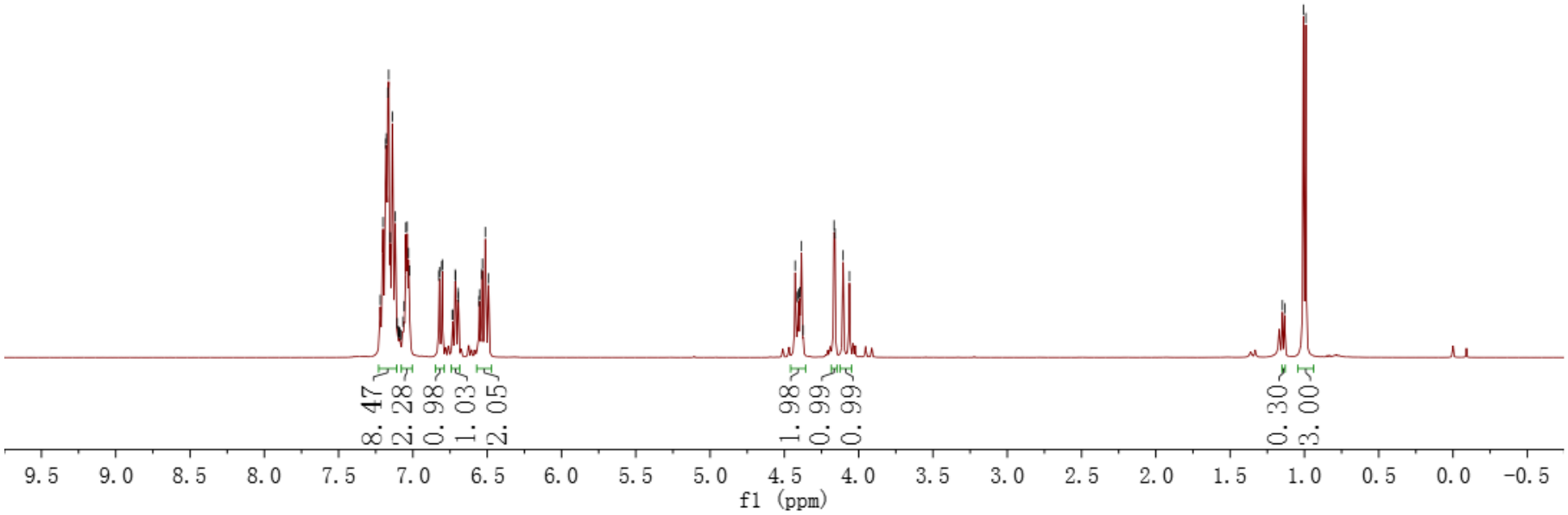


LZT-532

PROTON CDCl3 {D:\NMR400\02T2} nmr 49





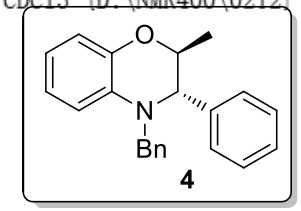


143.94
138.59
138.29
135.39
128.84
128.84
128.44
127.88
127.17
126.77
122.52
116.74
116.38
110.84

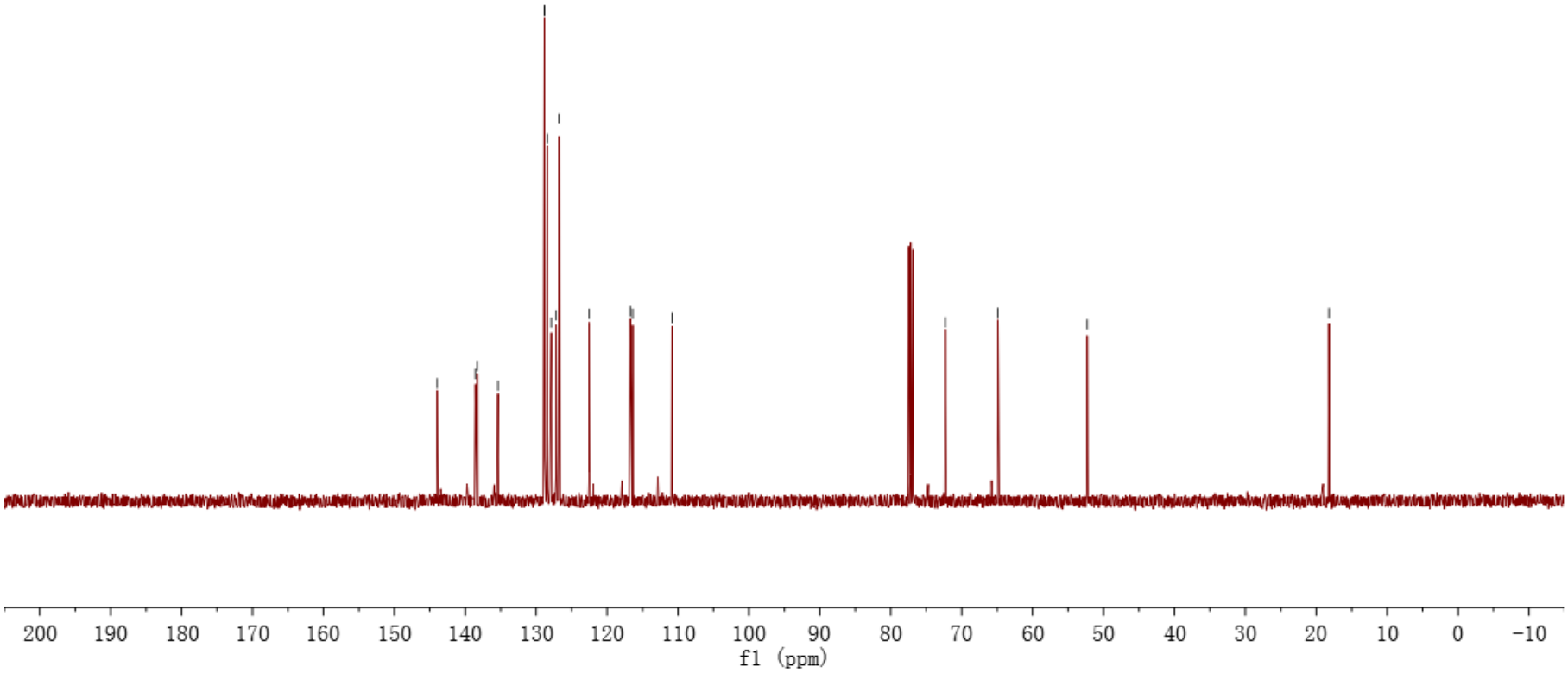
72.31
64.87
52.29
18.22

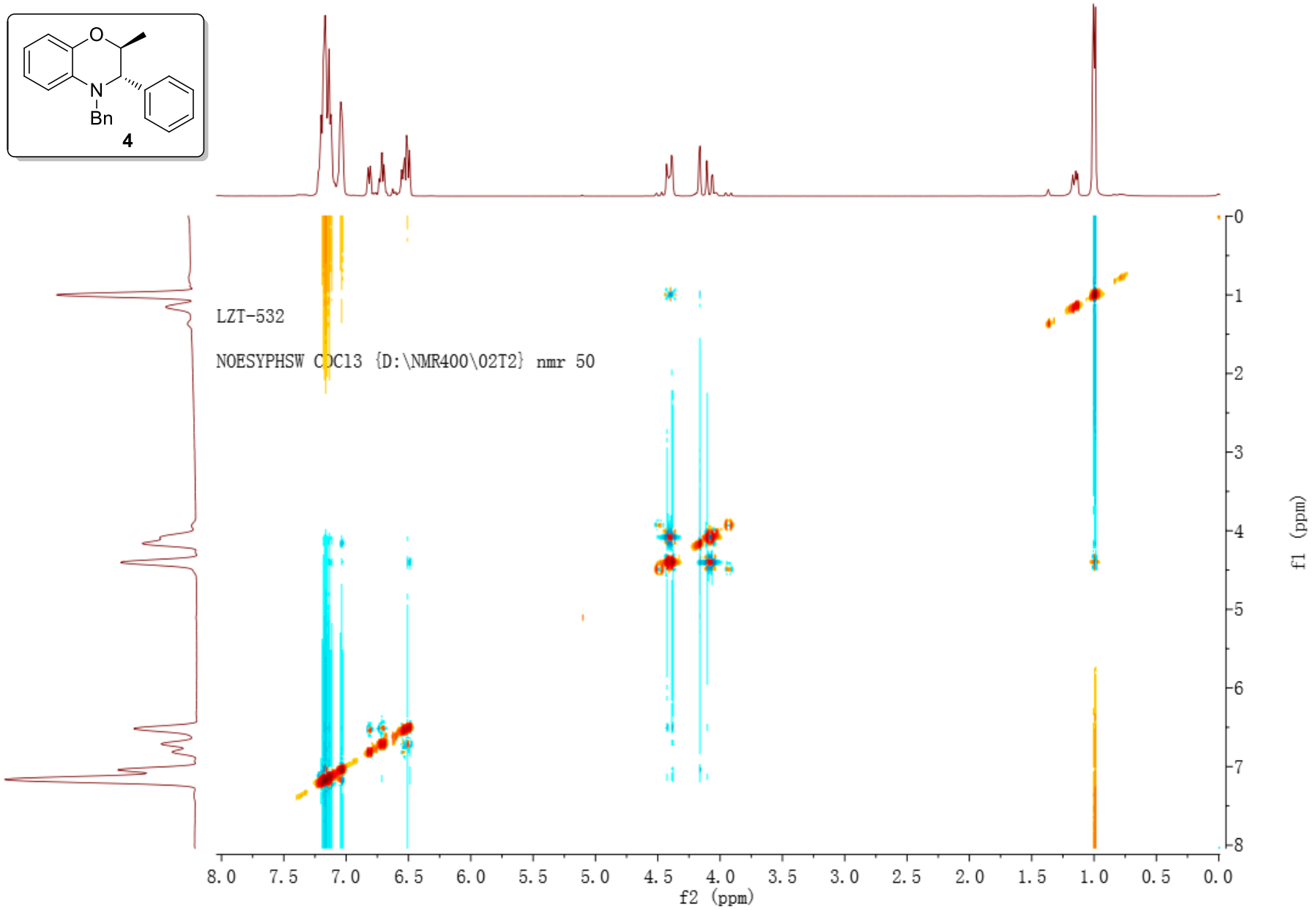
LZT-532

C13CPD CDCl3 {D:\NMR400\02T2} nmr 49



4




O
N
Bn
4
LZT-532
NOESYPHSW CDC13 {D:\NMR400\02T2} nmr 50
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
f2 (ppm)
0
1
2
3
4
5
6
7
8
f1 (ppm)