Supporting Information for

Iridium-Catalyzed Asymmetric Cascade Allylation/Lactonization of Methyl Salicylates: Enantioselective Construction of Chiral Benzodioxepinones

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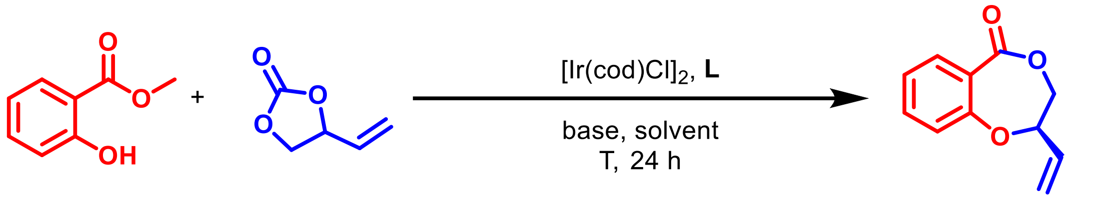
1. General considerations

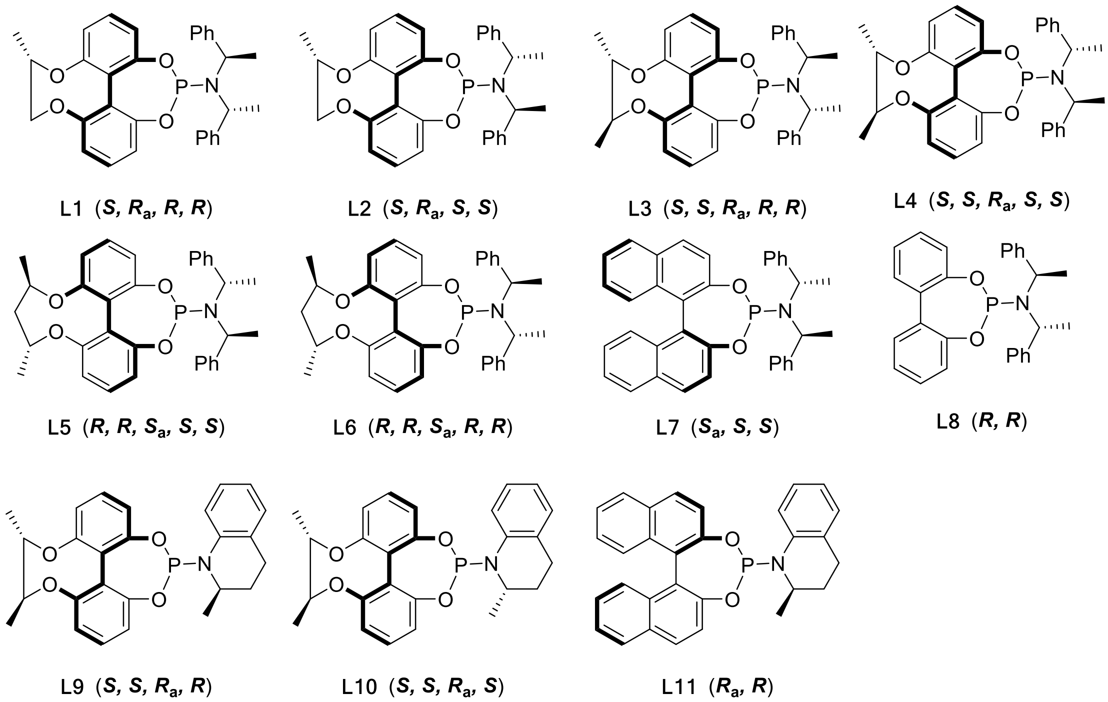
Unless otherwise stated, all syntheses and manipulations of air- and moisture-sensitive materials were carried out in a nitrogen-filled glovebox or under nitrogen atmosphere using standard Schlenk techniques. All glassware was oven-dried prior to use. The heat source for all reactions is oil bath. All solvents were freshly distilled and degassed according to standard methods. Reactions were magnetically stirred and monitored by analytical thin-layer chromatography (TLC). TLC was performed on Merck silica gel 60 F254 TLC glass plates and visualized by exposure to ultraviolet light. Organic solutions were concentrated by rotary evaporation at 20 − 45 °C.

All chemicals and reagents available from commercial sources were directly used without further purification. Chromatographic purification of products was accomplished using forced-flow chromatography on silica gel (200 − 300 mesh). ^{1}H, ^{19}F, and ^{13}C NMR spectra were recorded on a Bruker Ascend 400 MHz or 600 MHz spectrometer at ambient temperature. High-resolution mass spectra (HRMS) were obtained with Shimazu LC-20AT mass spectrometer. The mass analyzer type is ion trap. Optical rotations were measured on SGW®-5 automatic polarimeter. Enantiomeric excesses (*ee* values) of the products were determined by chiral HPLC analysis using an Aglient HP 1200 instrument (n-hexane/2-propanol as eluent) with a Chiralpak IC-3 or IA-3 Column. The phosphoramidite ligands **L1 − L11** were known compounds and prepared according to the reported procedures[1].

2. Table S1 Optimization of Reaction Conditions[a]



1a 0.2 mmol　　0.6 mmol　　2a



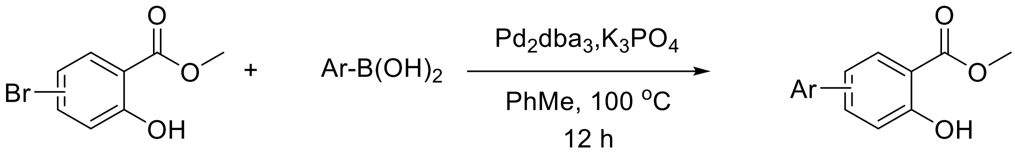
entry	ligand	$[Ir(cod)Cl]_2$ loading [mol %]	base	T [°C]	solvent	yield[b] [%]	ee[c] [%]
1	**L3**	2	DBU	50	THF	64	86
2	**L1**	2	DBU	50	THF	60	74
3	**L2**	2	DBU	50	THF	61	58
4	**L4**	2	DBU	50	THF	70	63
5	**L5**	2	DBU	50	THF	69	-83
6	**L6**	2	DBU	50	THF	67	-80
7	**L7**	2	DBU	50	THF	63	-80
8	**L8**	2	DBU	50	THF	51	50
9	**L9**	2	DBU	50	THF	53	8
10	**L10**	2	DBU	50	THF	57	1
11	**L11**	2	DBU	50	THF	54	19
12	**L3**	4	DBU	50	THF	65	72
13	**L3**	6	DBU	50	THF	70	58
14	**L3**	2	Cs_2CO_3	50	THF	37	46
15	**L3**	2	K_3PO_4	50	THF	ND	
16	**L3**	2	DBN	50	THF	66	59

17	**L3**	2	Et_3N	50	THF	ND	
18	**L3**	2	DABCO	50	THF	ND	
19	**L3**	2	DBU	25	THF	39	73
20	**L3**	2	DBU	40	THF	61	62
21	**L3**	2	DBU	60	THF	73	76
22	**L3**	2	DBU	65	THF	77	85
23	**L3**	2	DBU	70	THF	83	86
24	**L3**	2	DBU	75	THF	84	85
25	**L3**	2	DBU	80	THF	87	82
26	**L3**	2	DBU	70	1,4-dioxane	61	77
27	**L3**	2	DBU	70	PhMe	67	74
28	**L3**	2	DBU	70	DCE	trace	
29	**L3**	2	DBU	70	MeCN	90	64
30	**L3**	2	DBU	70	DME	87	80
31	**L3**	2	DBU	70	CH_3CH_2OH	ND	
32	**L3**[d]	2	DBU	70	THF	82	85
33	**L3**[e]	2	DBU	70	THF	70	81
34	**L3**[f]	2	DBU	70	THF	82	86
35	**L3**	1	DBU	70	THF	82	90
36	**L3**	0.5	DBU	70	THF	69	80
37	**L3**[g]	1	DBU	70	THF	78	83
38	**L7**	1	DBU	70	THF	80	-88
39	**L3**[h]	1	DBU	70	THF	84	73
40	**L3**[i,j]	1	DBU	70	THF	81	93
41	**L3**[j,k]	1	DBU	70	THF	82	95

[a] Conditions: $[Ir(cod)Cl]_2$, **L**, base, **1a** (0.2 mmol), VEC in solvent for 24 h. [b] Isolated yields. [c] Determined by HPLC analysis. [d] 0.2 mmol of DBU was used. [e] 0.4 mmol of VEC was used. [f] 0.8 mmol of VEC was used. [g] ethyl 2-hydroxybenzoate was used instead of **1a**. [h] 0.5 mL of THF was used. [i] 4.0 mL of THF was used. [j] 36 hours reaction time. [k] 5.0 mL of THF was used.

3. Experimental Procedures

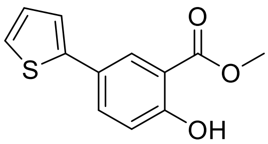
3.1 General Procedure for the Synthesis of Substituted Methyl Salicylates 1



1k-1t, 1w, 1x

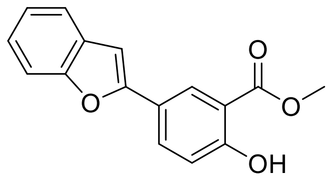
In a dry Schlenk tube filled with argon, methyl bromosalicylate (230.0 mg, 1 mmol, 1.0 equiv), Ar-B$(OH)_2$ (2 mmol, 2.0 equiv), Pd_2dba_3 (45.8 mg, 0.05 mmol, 0.05 equiv), S-Phos (41.0 mg, 0.1 mmol, 0.1 equiv) and K_3PO_4 (530.7 mg, 2.5 mmol, 2.5 equiv) were dissolved in PhMe (5.0 mL). The reaction mixture was heated at 100 °C for 24 h. Then the solvent was evaporated under reduced pressure and the residue was purified by silica gel column chromatography using petroleum/EtOAc (10 : 1) as the eluent to give the desired product **1k-1t**, **1w** and **1x**. The synthesis of **1k-1p, 1w** has been reported in previous literature[2].

Methyl 2-hydroxy-5-(thiophen-2-yl)benzoate (1q)



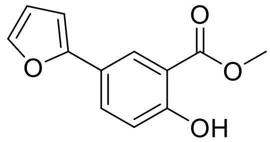
Yellow oil, 0.21 g, 90% yield; ^{1}H NMR (600 MHz, Chloroform-*d*) δ 10.80 (s, 1H), 8.08 (d, *J* = 2.3 Hz, 1H), 7.72 (dd, *J* = 8.8, 2.3 Hz, 1H), 7.28 – 7.23 (m, 2H), 7.09 (ddd, *J* = 5.1, 3.4, 1.5 Hz, 1H), 7.05 – 7.02 (m, 1H), 4.01 (s, 3H). ^{13}C NMR (151 MHz, Chloroform-*d*) δ 170.30, 161.03, 143.26, 133.40, 127.98, 127.04, 126.12, 124.26, 122.59, 118.18, 112.57, 52.40. HRMS (ESI) calcd for $C_{12}H_9O_3S$ $[M-H]^-$: 233.0278, Found: 233.0281.

Methyl 5-(benzofuran-2-yl)-2-hydroxybenzoate (1r)



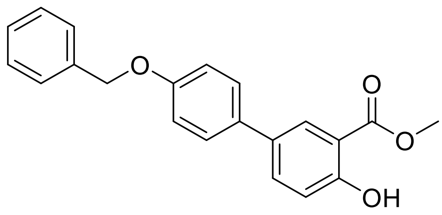
Light red oil, 0.23 g, 86% yield; ^{1}H NMR (600 MHz, Chloroform-*d*) δ 10.93 (s, 1H), 8.36 (d, *J* = 2.3 Hz, 1H), 7.95 (dd, *J* = 8.7, 2.3 Hz, 1H), 7.60 – 7.57 (m, 1H), 7.55 – 7.52 (m, 1H), 7.31 – 7.28 (m, 1H), 7.25 (td, *J* = 7.4, 1.1 Hz, 1H), 7.09 (d, *J* = 8.7 Hz, 1H), 6.94 (d, *J* = 1.0 Hz, 1H), 4.04 (s, 3H). ^{13}C NMR (151 MHz, Chloroform-*d*) δ 170.29, 161.82, 154.96, 154.76, 138.40, 132.23, 129.29, 126.41, 124.09, 122.99, 120.73, 119.57, 118.27, 111.04, 100.27, 52.47. HRMS (ESI) calcd for $C_{16}H_{11}O_4$ $[M\text{-}H]^-$: 267.0663, Found: 267.0670.

Methyl 5-(furan-2-yl)-2-hydroxybenzoate (1s)



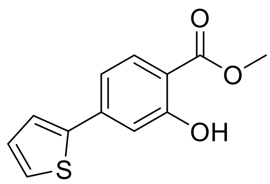
Light red oil, 0.19 g, 87% yield; ^{1}H NMR (600 MHz, Chloroform-*d*) δ 10.80 (s, 1H), 8.16 (d, *J* = 2.3 Hz, 1H), 7.77 (dd, *J* = 8.7, 2.3 Hz, 1H), 7.46 (dd, *J* = 1.8, 0.8 Hz, 1H), 7.03 (d, *J* = 8.7 Hz, 1H), 6.57 (dd, *J* = 3.4, 0.8 Hz, 1H), 6.48 (dd, *J* = 3.4, 1.8 Hz, 1H), 4.00 (s, 3H). ^{13}C NMR (151 MHz, Chloroform-*d*) δ 170.37, 160.89, 153.06, 141.69, 131.34, 125.10, 122.85, 118.04, 112.47, 111.60, 103.91, 52.35. HRMS (ESI) calcd for $C_{12}H_9O_4$ $[M\text{-}H]^-$: 217.0506, Found: 217.0507.

Methyl 4'-(benzyloxy)-4-hydroxy-[1,1'-biphenyl]-3-carboxylate (1t)



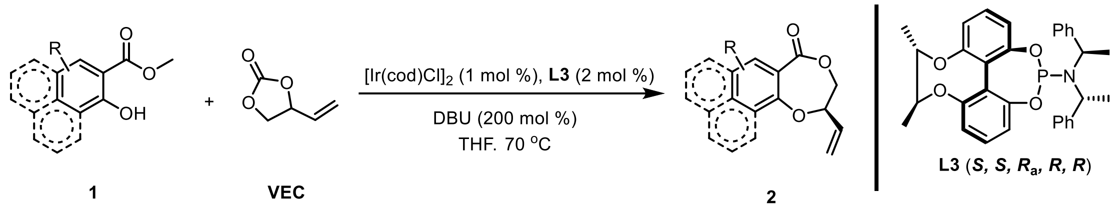
White oil, 0.25 g, 75% yield; ^{1}H NMR (600 MHz, Chloroform-*d*) δ 10.73 (s, 1H), 8.04 (d, *J* = 2.5 Hz, 1H), 7.68 (dd, *J* = 8.6, 2.4 Hz, 1H), 7.49 (dd, *J* = 9.2, 7.2 Hz, 4H), 7.44 – 7.41 (m, 2H), 7.38 – 7.35 (m, 1H), 7.06 (d, *J* = 8.7 Hz, 3H), 5.14 (s, 2H), 4.00 (s, 3H). ^{13}C NMR (151 MHz, Chloroform-*d*) δ 170.55, 160.61, 158.22, 136.99, 134.10, 132.84, 132.16, 128.95, 128.60, 128.37, 127.98, 127.69, 127.65, 127.43, 117.97, 115.29, 112.50, 70.18, 52.29. HRMS (ESI) calcd for $C_{21}H_{17}O_4$ [M-H]$^-$: 333.1132, Found: 333.1139.

Methyl 2-hydroxy-4-(thiophen-2-yl)benzoate (1x)



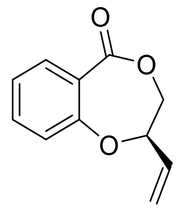
Yellow oil, 0.21 g, 90% yield; ^{1}H NMR (600 MHz, Chloroform-*d*) δ 10.84 (s, 1H), 7.84 (d, *J* = 8.3 Hz, 1H), 7.44 (d, *J* = 3.6 Hz, 1H), 7.38 (d, *J* = 5.1 Hz, 1H), 7.16 (dd, *J* = 8.4, 1.9 Hz, 1H), 7.13 (t, *J* = 4.3 Hz, 1H), 3.98 (s, 3H). ^{13}C NMR (151 MHz, Chloroform-*d*) δ 170.27, 161.87, 142.74, 141.31, 130.50, 128.25, 126.60, 124.91, 116.80, 113.99, 111.13, 52.27. HRMS (ESI) calcd for $C_{12}H_9O_3S$ [M-H]$^-$: 233.0278, Found: 233.0281.

3.2 General Procedure for the Asymmetric Cascade Allylation/Lactonization of 1



In a dry Schlenk tube filled with argon, $[Ir(cod)Cl]_2$ (2.7 mg, 0.004 mmol, 1 mol %), phosphoramidite ligand **L3** (4.2 mg, 0.008 mmol, 2 mol %), and *n*propylamine (0.5 mL) were dissolved in THF (1.0 mL). The reaction mixture was heated at 50 °C for 30 min and then the volatile solvents were removed in vacuum to give a yellow solid. Subsequently, (substituted) methyl salicylate **1** (0.4 mmol), VEC **2** (137.0 mg, 3.0 equiv.), DBU (121.8 mg, 200 mol %) and THF (5.0 mL) were added to the tube. The system was stirred at 70 °C until the reaction was completed. Then the solvent was evaporated and the residue was purified by silica gel column chromatography using petroleum/EtOAc (8 : 1) as the eluent to give the desired products **2**.

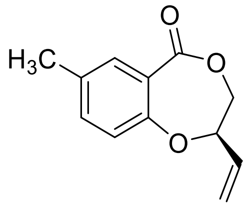
(*R*)-2-vinyl-2,3-dihydro-5*H*-benzo[*e*][1,4]dioxepin-5-one (2a)



R_f = 0.40 (petroleum/EtOAc = 4 : 1, v/v); colorless oil, 62.3 mg, 82% yield; 95% ee [Daicel Chiralcel IC-3 (0.46 cm x 25 cm), *n*-hexane/2-propanol = 70/30, *v* = 1.0 mL•min^{-1}, T = 25 °C, λ = 254 nm, t_R (minor) = 14.777 min, t_R (major) = 17.954 min]; $[\alpha]_D^{25}$ = +175.6° (c = 0.75, CH_2Cl_2). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.81 (dd, *J* = 7.0, 4.6 Hz, 1H), 7.56 – 7.49 (m, 1H), 7.20 – 7.16

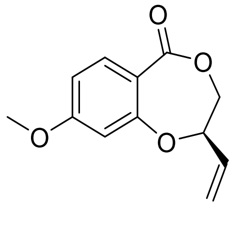
(m, 1H), 7.07 (dd, J = 8.5, 2.9 Hz, 1H), 5.97 – 5.89 (m, 1H), 5.51 (dd, J = 17.3, 2.6 Hz, 1H), 5.39 (dd, J = 10.8, 3.2 Hz, 1H), 5.08 – 5.02 (m, 1H), 4.42 – 4.36 (m, 1H), 4.32 – 4.27 (m, 1H). ^{13}C NMR (151 MHz, Chloroform-*d*) δ 169.11, 153.62, 134.84, 132.68, 132.16, 123.60, 122.09, 121.51, 119.30, 81.47, 67.69. HRMS(ESI) calcd for $C_{11}H_{11}O_3$ [M+H]$^+$: 191.0703, Found: 191.0702.

(*R*)-7-methyl-2-vinyl-2,3-dihydro-5*H*-benzo[*e*][1,4]dioxepin-5-one (2b)



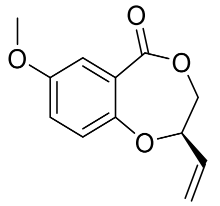
R_f = 0.40 (petroleum/EtOAc = 4 : 1, v/v); colorless oil, 69.4 mg, 85% yield; 94% ee [Daicel Chiralcel IC-3 (0.46 cm x 25 cm), *n*-hexane/2-propanol = 65/35, v = 1.0 mL•min^{-1}, T = 25 °C, λ = 254 nm, t_R (minor) = 16.374 min, t_R (major) = 24.532 min]; $[\alpha]_D^{25}$ = +163.2° (c = 0.75, CH_2Cl_2). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.60 (d, J = 2.3 Hz, 1H), 7.33 (dd, J = 8.3, 2.3 Hz, 1H), 6.97 (d, J = 8.3 Hz, 1H), 5.96 – 5.89 (m, 1H), 5.54 – 5.47 (m, 1H), 5.41 – 5.36 (m, 1H), 5.04 – 4.99 (m, 1H), 4.40 – 4.36 (m, 1H), 4.30 – 4.25 (m, 1H), 2.36 (s, 3H). ^{13}C NMR (151 MHz, Chloroform-*d*) δ 169.40, 151.33, 135.62, 133.46, 132.42, 132.30, 121.99, 121.47, 119.23, 81.36, 67.69, 20.38. HRMS(ESI) calcd for $C_{12}H_{13}O_3$ [M+H]$^+$: 205.0859, Found: 205.0859.

(*R*)-8-methoxy-2-vinyl-2,3-dihydro-5*H*-benzo[*e*][1,4]dioxepin-5-one (2c)



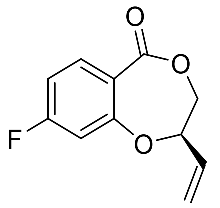
R_f = 0.30 (petroleum/EtOAc = 4 : 1, v/v); colorless oil, 45.8 mg, 52% yield; 90% ee [Daicel Chiralcel IC-3 (0.46 cm x 25 cm), *n*-hexane/2-propanol = 65/35, *v* = 1.0 mL•min^{-1}, T = 25 °C, λ = 254 nm, t_R (minor) = 21.060 min, t_R (major) = 24.869 min]; $[\alpha]_D^{25}$ = +132.9° (c = 0.75, CH_2Cl_2). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.83 (d, *J* = 8.9 Hz, 1H), 6.72 (dd, *J* = 8.8, 2.5 Hz, 1H), 6.55 (d, *J* = 2.5 Hz, 1H), 5.98 – 5.92 (m, 1H), 5.54 – 5.50 (m, 1H), 5.43 – 5.39 (m, 1H), 5.08 – 5.03 (m, 1H), 4.44 – 4.39 (m, 1H), 4.37 – 4.31 (m, 1H), 3.86 (s, 3H). ^{13}C NMR (151 MHz, Chloroform-*d*) δ 168.74, 165.09, 155.88, 134.93, 132.16, 119.17, 112.55, 110.42, 105.56, 81.38, 67.97, 55.62. HRMS(ESI) calcd for $C_{12}H_{13}O_4$ [M+H]$^+$: 221.0808, Found: 221.0809.

(*R*)-7-methoxy-2-vinyl-2,3-dihydro-5*H*-benzo[*e*][1,4]dioxepin-5-one (2d)



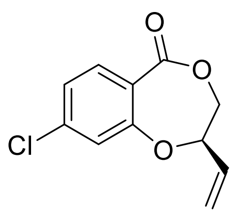
R_f = 0.35 (petroleum/EtOAc = 4 : 1, v/v); colorless oil, 73.1 mg, 83% yield; 91% ee [Daicel Chiralcel IC-3 (0.46 cm x 25 cm), *n*-hexane/2-propanol = 65/35, *v* = 1.0 mL•min^{-1}, T = 25 °C, λ = 254 nm, t_R (minor) = 16.206 min, t_R (major) = 22.926 min]; $[\alpha]_D^{25}$ = +152.5° (c = 0.75, CH_2Cl_2). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.28 – 7.24 (m, 1H), 7.10 – 7.06 (m, 1H), 7.03 – 6.99 (m, 1H), 5.96 – 5.88 (m, 1H), 5.52 – 5.47 (m, 1H), 5.41 – 5.36 (m, 1H), 5.01 – 4.96 (m, 1H), 4.40 – 4.35 (m, 1H), 4.28 – 4.23 (m, 1H), 3.83 (s, 3H). ^{13}C NMR (151 MHz, Chloroform-*d*) δ 169.15, 155.80, 147.12, 132.32, 123.50, 122.84, 121.92, 119.37, 114.82, 81.42, 67.69, 55.84. HRMS(ESI) calcd for $C_{12}H_{13}O_4$ [M+H]$^+$: 221.0808, Found: 221.0808.

(*R*)-8-fluoro-2-vinyl-2,3-dihydro-5*H*-benzo[*e*][1,4]dioxepin-5-one (2e)



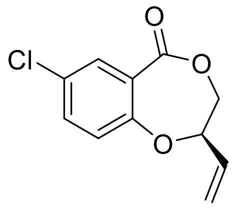
R_f = 0.40 (petroleum/EtOAc = 4 : 1, v/v); colorless oil, 59.1 mg, 71% yield; 82% ee [Daicel Chiralcel IC-3 (0.46 cm x 25 cm), *n*-hexane/2-propanol = 65/35, *v* = 1.0 mL•min^{-1}, T = 25 °C, λ = 254 nm, t_R (minor) = 11.065 min, t_R (major) = 11.908 min]; $[\alpha]_D^{25}$ = +100.3° (c = 0.75, CH_2Cl_2). ^1H NMR (600 MHz, Chloroform-*d*) δ 7.90 (dd, *J* = 8.9, 6.5 Hz, 1H), 6.90 (ddd, *J* = 8.8, 7.5, 2.5 Hz, 1H), 6.79 (dd, *J* = 9.6, 2.5 Hz, 1H), 5.98 – 5.90 (m, 1H), 5.52 (dt, *J* = 17.2, 1.2 Hz, 1H), 5.43 (dt, *J* = 10.6, 1.2 Hz, 1H), 5.12 – 5.07 (m, 1H), 4.44 (dd, *J* = 13.9, 2.5 Hz, 1H), 4.35 (dd, *J* = 13.9, 6.9 Hz, 1H). ^{13}C NMR (151 MHz, Chloroform-*d*) δ 167.96, 167.48, 165.79, 135.45 (d, *J* = 10.6 Hz), 131.64, 119.54, 116.79 (d, *J* = 3.0 Hz), 111.21 (d, *J* = 21.1 Hz), 108.74 (d, *J* = 24.2 Hz), 81.65, 67.80. ^{19}F NMR (377 MHz, $CDCl_3$) δ -103.20. HRMS(ESI) calcd for $C_{11}H_{10}FO_3$ $[M+H]^+$: 209.0609, Found: 209.0608.

(*R*)-8-chloro-2-vinyl-2,3-dihydro-5*H*-benzo[*e*][1,4]dioxepin-5-one (2f)



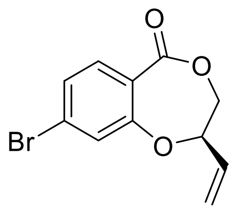
R_f = 0.40 (petroleum/EtOAc = 4 : 1, v/v); colorless oil, 60.9 mg, 68% yield; 83% ee [Daicel Chiralcel IC-3 (0.46 cm x 25 cm), *n*-hexane/2-propanol = 65/35, *v* = 1.0 mL•min^{-1}, T = 25 °C, λ = 254 nm, t_R (minor) = 11.428 min, t_R (major) = 12.469 min]; $[\alpha]_D^{25}$ = +97.9° (c = 0.75, CH_2Cl_2). ^1H NMR (600 MHz, Chloroform-*d*) δ 7.80 (d, *J* = 8.5 Hz, 1H), 7.16 (dd, *J* = 8.5, 2.0 Hz, 1H), 7.11 (d, *J* = 2.0 Hz, 1H), 5.96 – 5.89 (m, 1H), 5.54 – 5.49 (m, 1H), 5.45 – 5.40 (m, 1H), 5.11 – 5.06 (m, 1H), 4.43 (dd, *J* = 13.9, 2.6 Hz, 1H), 4.34 (dd, *J* = 13.9, 7.0 Hz, 1H). ^{13}C NMR (151 MHz, Chloroform-*d*) δ 168.02, 154.42, 140.69, 134.20, 131.60, 123.84, 122.00, 119.62, 119.14, 81.64, 67.75. HRMS(ESI) calcd for $C_{11}H_{10}ClO_3$ $[M+H]^+$: 225.0313, Found: 225.0312.

(*R*)-7-chloro-2-vinyl-2,3-dihydro-5*H*-benzo[*e*][1,4]dioxepin-5-one (2g)



R_f = 0.40 (petroleum/EtOAc = 4 : 1, v/v); colorless oil, 74.4 mg, 83% yield; 84% ee [Daicel Chiralcel IC-3 (0.46 cm x 25 cm), *n*-hexane/2-propanol = 65/35, *v* = 1.0 mL•min^{-1}, T = 25 °C, λ = 254 nm, t_R (minor) = 11.228 min, t_R (major) = 12.791 min]; $[\alpha]_D^{25}$ = +108.2° (c = 0.75, CH_2Cl_2). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.81 (dd, *J* = 2.8, 1.6 Hz, 1H), 7.48 (dd, *J* = 8.7, 2.6 Hz, 1H), 7.03 (d, *J* = 8.7 Hz, 1H), 5.95 – 5.88 (m, 1H), 5.51 (dt, *J* = 17.2, 1.2 Hz, 1H), 5.42 (dt, *J* = 10.6, 1.2 Hz, 1H), 5.09 – 5.04 (m, 1H), 4.42 (dd, *J* = 13.9, 2.8 Hz, 1H), 4.32 (dd, *J* = 13.9, 7.1 Hz, 1H). ^{13}C NMR (151 MHz, Chloroform-*d*) δ 167.63, 152.25, 134.78, 132.14, 131.69, 128.80, 123.58, 122.39, 119.63, 81.52, 67.74. HRMS(ESI) calcd for $C_{11}H_{10}ClO_3$ $[M+H]^+$: 225.0313, Found: 225.0312.

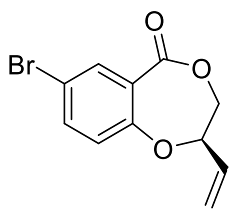
(*R*)-8-bromo-2-vinyl-2,3-dihydro-5*H*-benzo[*e*][1,4]dioxepin-5-one (2h)



R_f = 0.40 (petroleum/EtOAc = 4 : 1, v/v); colorless oil, 75.0 mg, 70% yield; 81%

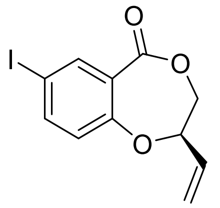
ee [Daicel Chiralcel IC-3 (0.46 cm x 25 cm), *n*-hexane/2-propanol = 65/35, *v* = 1.0 mL•min^{-1}, T = 25 °C, λ = 254 nm, t_R (minor) = 11.970 min, t_R (major) = 13.076 min]; $[\alpha]_D^{25}$ = +90.3° (c = 0.75, CH_2Cl_2). ^1H NMR (600 MHz, Chloroform-*d*) δ 7.72 (d, *J* = 8.4 Hz, 1H), 7.31 (dd, *J* = 8.4, 1.9 Hz, 1H), 7.29 – 7.27 (m, 1H), 5.96 – 5.89 (m, 1H), 5.52 (dt, *J* = 17.2, 1.2 Hz, 1H), 5.42 (dt, *J* = 10.6, 1.2 Hz, 1H), 5.11 – 5.06 (m, 1H), 4.42 (dd, *J* = 13.9, 2.6 Hz, 1H), 4.33 (dd, *J* = 13.9, 7.0 Hz, 1H). ^{13}C NMR (151 MHz, Chloroform-*d*) δ 168.13, 154.27, 134.18, 131.59, 128.92, 126.76, 125.01, 119.65, 81.68, 67.72. HRMS(ESI) calcd for $C_{11}H_{10}BrO_3$ $[M+H]^+$: 268.9808, Found: 268.9809.

(*R*)-7-bromo-2-vinyl-2,3-dihydro-5*H*-benzo[*e*][1,4]dioxepin-5-one (2i)



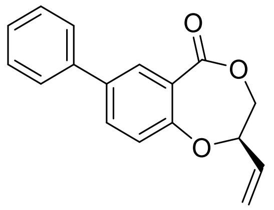
R_f = 0.40 (petroleum/EtOAc = 4 : 1, v/v); colorless oil, 83.6 mg, 78% yield; 85% ee [Daicel Chiralcel IC-3 (0.46 cm x 25 cm), *n*-hexane/2-propanol = 65/35, *v* = 1.0 mL•min^{-1}, T = 25 °C, λ = 254 nm, t_R (minor) = 11.591 min, t_R (major) = 13.401 min]; $[\alpha]_D^{25}$ = +101.3° (c = 0.75, CH_2Cl_2). ^1H NMR (600 MHz, Chloroform-*d*) δ 7.94 (d, *J* = 2.5 Hz, 1H), 7.61 (dd, *J* = 8.7, 2.5 Hz, 1H), 6.97 (d, *J* = 8.7 Hz, 1H), 5.95 – 5.87 (m, 1H), 5.50 (dt, *J* = 17.2, 1.2 Hz, 1H), 5.41 (dt, *J* = 10.7, 1.2 Hz, 1H), 5.09 – 5.04 (m, 1H), 4.42 (dd, *J* = 13.9, 2.7 Hz, 1H), 4.32 (dd, *J* = 13.9, 7.0 Hz, 1H). ^{13}C NMR (151 MHz, Chloroform-*d*) δ 167.50, 152.80, 137.69, 135.13, 131.66, 123.89, 122.69, 119.63, 115.88, 81.49, 67.74. HRMS(ESI) calcd for $C_{11}H_{10}BrO_3$ $[M+H]^+$: 268.9808, Found: 268.9806.

(*R*)-7-iodo-2-vinyl-2,3-dihydro-5*H*-benzo[*e*][1,4]dioxepin-5-one (2j)



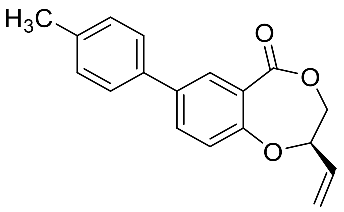
R_f = 0.40 (petroleum/EtOAc = 4 : 1, v/v); colorless oil, 102.4 mg, 81% yield; 84% ee [Daicel Chiralcel IC-3 (0.46 cm x 25 cm), *n*-hexane/2-propanol = 65/35, *v* = 1.0 mL•min^{-1}, T = 25 °C, λ = 254 nm, t_R (minor) = 12.020 min, t_R (major) = 14.210 min]; $[\alpha]_D^{25}$ = +100.2° (c = 0.75, CH_2Cl_2). ^1H NMR (600 MHz, Chloroform-*d*) δ 8.14 – 8.10 (m, 1H), 7.82 – 7.74 (m, 1H), 5.95 – 5.85 (m, 1H), 5.53 – 5.47 (m, 1H), 5.45 – 5.38 (m, 1H), 5.11 – 5.03 (m, 1H), 4.42 (dd, *J* = 14.0, 2.6 Hz, 1H), 4.32 (dd, *J* = 13.9, 7.0 Hz, 1H). ^{13}C NMR (151 MHz, Chloroform-*d*) δ 167.37, 153.58, 143.53, 141.13, 131.65, 124.13, 122.92, 119.61, 85.70, 81.48, 67.74. HRMS(ESI) calcd for $C_{11}H_{10}IO_3$ $[M+H]^+$: 316.9669, Found: 316.9669.

(*R*)-7-phenyl-2-vinyl-2,3-dihydro-5*H*-benzo[*e*][1,4]dioxepin-5-one (2k)



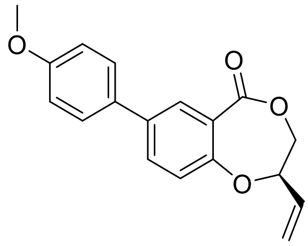
R_f = 0.40 (petroleum/EtOAc = 4 : 1, v/v); colorless oil, 75.6 mg, 71% yield; 93% ee [Daicel Chiralcel IC-3 (0.46 cm x 25 cm), *n*-hexane/2-propanol = 65/35, *v* = 1.0 mL•min^{-1}, T = 25 °C, λ = 254 nm, t_R (minor) = 14.233 min, t_R (major) = 20.439 min]; $[\alpha]_D^{25}$ = +143.9° (c = 0.75, CH_2Cl_2). ^1H NMR (600 MHz, Chloroform-*d*) δ 8.07 (d, *J* = 2.4 Hz, 1H), 7.77 (dd, *J* = 8.4, 2.4 Hz, 1H), 7.61 – 7.58 (m, 2H), 7.46 (dd, *J* = 8.5, 7.0 Hz, 2H), 7.40 – 7.36 (m, 1H), 7.16 (d, *J* = 8.5 Hz, 1H), 6.01 – 5.93 (m, 1H), 5.55 (dt, *J* = 17.3, 1.3 Hz, 1H), 5.43 (dt, *J* = 10.5, 1.3 Hz, 1H), 5.10 (dddt, *J* = 7.3, 5.9, 3.0, 1.5 Hz, 1H), 4.46 (dd, *J* = 13.8, 2.9 Hz, 1H), 4.37 (dd, *J* = 13.8, 7.1 Hz, 1H). ^{13}C NMR (151 MHz, Chloroform-*d*) δ 169.05, 153.01, 139.09, 136.78, 133.40, 132.12, 131.10, 128.93, 127.64, 126.81, 122.56, 121.49, 119.40, 81.54, 67.81. HRMS(ESI) calcd for $C_{17}H_{15}O_3$ [M+H]$^+$: 267.1016, Found: 267.1017.

(*R*)-7-(*p*-tolyl)-2-vinyl-2,3-dihydro-5*H*-benzo[*e*][1,4]dioxepin-5-one (2l)



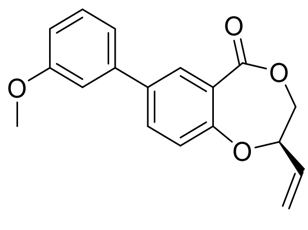
R_f = 0.40 (petroleum/EtOAc = 4 : 1, v/v); colorless oil, 86.3 mg, 77% yield; 93% ee [Daicel Chiralcel IC-3 (0.46 cm x 25 cm), *n*-hexane/2-propanol = 65/35, *v* = 1.0 mL•min^{-1}, T = 25 °C, λ = 254 nm, t_R (minor) = 14.674 min, t_R (major) = 21.687 min]; $[\alpha]_D^{25}$ = +137.7° (c = 0.75, CH_2Cl_2). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.05 (d, *J* = 2.4 Hz, 1H), 7.75 (dd, *J* = 8.5, 2.4 Hz, 1H), 7.50 (d, *J* = 8.0 Hz, 2H), 7.29 – 7.26 (m, 2H), 7.15 (d, *J* = 8.4 Hz, 1H), 6.01 – 5.93 (m, 1H), 5.55 (dt, *J* = 17.2, 1.3 Hz, 1H), 5.43 (dt, *J* = 10.6, 1.2 Hz, 1H), 5.10 (dddt, *J* = 7.3, 6.0, 3.0, 1.4 Hz, 1H), 4.45 (dd, *J* = 13.8, 2.9 Hz, 1H), 4.37 (dd, *J* = 13.8, 7.2 Hz, 1H), 2.42 (s, 3H). ^{13}C NMR (151 MHz, Chloroform-*d*) δ 169.13, 152.73, 137.49, 136.80, 136.21, 133.20, 132.16, 130.79, 129.64, 126.64, 122.51, 121.55, 119.38, 81.53, 67.79, 21.08. HRMS(ESI) calcd for $C_{18}H_{17}O_3$ [M+H]$^+$: 281.1172, Found: 281.1173.

(*R*)-7-(4-methoxyphenyl)-2-vinyl-2,3-dihydro-5*H*-benzo[*e*][1,4]dioxepin-5-one (2m)



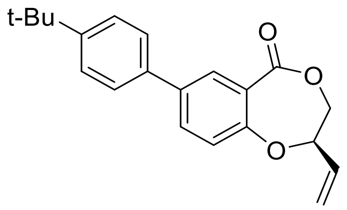
R_f = 0.30 (petroleum/EtOAc = 4 : 1, v/v); colorless oil, 87.6 mg, 74% yield; 93% ee [Daicel Chiralcel IC-3 (0.46 cm x 25 cm), *n*-hexane/2-propanol = 65/35, *v* = 1.0 mL•min^{-1}, T = 25 °C, λ = 254 nm, t_R (minor) = 20.310 min, t_R (major) = 30.318 min]; $[\alpha]_D^{25}$ = +133.8° (c = 0.75, CH_2Cl_2). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.01 (d, *J* = 2.4 Hz, 1H), 7.72 (dd, *J* = 8.4, 2.4 Hz, 1H), 7.55 – 7.51 (m, 2H), 7.14 (d, *J* = 8.4 Hz, 1H), 7.01 – 6.99 (m, 2H), 6.01 – 5.93 (m, 1H), 5.55 (dt, *J* = 17.2, 1.3 Hz, 1H), 5.43 (dt, *J* = 10.6, 1.3 Hz, 1H), 5.11 – 5.06 (m, 1H), 4.45 (dd, *J* = 13.8, 2.9 Hz, 1H), 4.39 – 4.34 (m, 1H), 3.87 (s, 3H). ^{13}C NMR (151 MHz, Chloroform-*d*) δ 169.18, 159.43, 152.45, 136.53, 132.95, 132.18, 131.62, 130.42, 127.87, 122.53, 121.63, 121.17, 119.36, 114.39, 81.51, 67.78, 55.36. HRMS(ESI) calcd for $C_{18}H_{17}O_4$ $[M+H]^+$: 297.1121, Found: 297.1122.

(*R*)-7-(3-methoxyphenyl)-2-vinyl-2,3-dihydro-5*H*-benzo[*e*][1,4]dioxepin-5-one (2n)



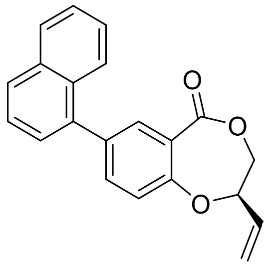
R_f = 0.30 (petroleum/EtOAc = 4 : 1, v/v); colorless oil, 85.3 mg, 72% yield; 92% ee [Daicel Chiralcel IC-3 (0.46 cm x 25 cm), *n*-hexane/2-propanol = 65/35, *v* = 1.0 mL•min^{-1}, T = 25 °C, λ = 254 nm, t_R (minor) = 18.821 min, t_R (major) = 25.349 min]; $[\alpha]_D^{25}$ = +122.2° (c = 0.75, CH_2Cl_2). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.07 (d, *J* = 2.4 Hz, 1H), 7.76 (dd, *J* = 8.5, 2.4 Hz, 1H), 7.40 – 7.36 (m, 1H), 7.20 – 7.14 (m, 2H), 7.12 (t, *J* = 2.1 Hz, 1H), 6.96 – 6.91 (m, 1H), 6.01 – 5.93 (m, 1H), 5.55 (dt, *J* = 17.2, 1.2 Hz, 1H), 5.43 (dt, *J* = 10.6, 1.2 Hz, 1H), 5.14 – 5.08 (m, 1H), 4.46 (dd, *J* = 13.8, 2.9 Hz, 1H), 4.38 (dd, *J* = 13.8, 7.1 Hz, 1H), 3.89 (s, 3H). ^{13}C NMR (151 MHz, Chloroform-*d*) δ 169.02, 160.10, 153.09, 140.59, 136.67, 133.46, 132.09, 131.16, 129.95, 122.52, 121.43, 119.42, 119.32, 113.17, 112.53, 81.55, 67.80, 55.37. HRMS(ESI) calcd for $C_{18}H_{17}O_4$ $[M+H]^+$: 297.1121, Found: 297.1121.

(*R*)-7-(4-(tert-butyl)phenyl)-2-vinyl-2,3-dihydro-5*H*-benzo[*e*][1,4]dioxepin-5-one (2o)



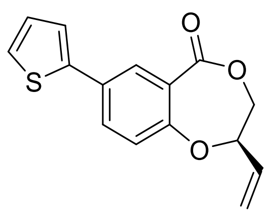
R_f = 0.45 (petroleum/EtOAc = 4 : 1, v/v); colorless oil, 104.4 mg, 81% yield; 92% ee [Daicel Chiralcel IC-3 (0.46 cm x 25 cm), *n*-hexane/2-propanol = 65/35, *v* = 1.0 mL•min^{-1}, T = 25 °C, λ = 254 nm, t_R (minor) = 12.235 min, t_R (major) = 17.568 min]; $[\alpha]_D^{25}$ = +169.9° (c = 0.75, CH_2Cl_2). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.07 (d, *J* = 2.4 Hz, 1H), 7.76 (dd, *J* = 8.4, 2.4 Hz, 1H), 7.57 – 7.53 (m, 2H), 7.51 – 7.48 (m, 2H), 7.15 (d, *J* = 8.4 Hz, 1H), 6.01 – 5.94 (m, 1H), 5.55 (dt, *J* = 17.2, 1.2 Hz, 1H), 5.43 (dt, *J* = 10.5, 1.2 Hz, 1H), 5.10 (dddt, *J* = 7.3, 5.9, 2.9, 1.3 Hz, 1H), 4.45 (dd, *J* = 13.8, 2.9 Hz, 1H), 4.37 (dd, *J* = 13.8, 7.1 Hz, 1H), 1.39 (s, 9H). ^{13}C NMR (151 MHz, Chloroform-*d*) δ 169.11, 152.76, 150.75, 136.69, 136.17, 133.23, 132.19, 130.85, 126.46, 125.88, 122.50, 121.54, 119.37, 81.54, 67.80, 34.57, 31.33. HRMS(ESI) calcd for $C_{21}H_{23}O_3$ $[M+H]^+$: 323.1642, Found: 323.1641.

(*R*)-7-(naphthalen-1-yl)-2-vinyl-2,3-dihydro-5*H*-benzo[*e*][1,4]dioxepin-5-one (2p)



R_f = 0.40 (petroleum/EtOAc = 4 : 1, v/v); colorless oil, 92.3 mg, 73% yield; 92% ee [Daicel Chiralcel IC-3 (0.46 cm x 25 cm), *n*-hexane/2-propanol = 65/35, *v* = 1.0 mL•min^{-1}, T = 25 °C, λ = 254 nm, t_R (minor) = 14.073 min, t_R (major) = 20.631 min]; $[\alpha]_D^{25}$ = +155.3° (c = 0.75, CH_2Cl_2). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.00 (d, *J* = 2.3 Hz, 1H), 7.94 (dd, *J* = 8.2, 1.4 Hz, 1H), 7.90 (d, *J* = 8.3 Hz, 1H), 7.87 (d, *J* = 8.8 Hz, 1H), 7.68 (dd, *J* = 8.3, 2.3 Hz, 1H), 7.56 – 7.51 (m, 2H), 7.50 – 7.46 (m, 1H), 7.44 (dd, *J* = 7.0, 1.3 Hz, 1H), 7.22 (d, *J* = 8.3 Hz, 1H), 6.06 – 5.98 (m, 1H), 5.60 (dt, *J* = 17.2, 1.2 Hz, 1H), 5.46 (dt, *J* = 10.6, 1.2 Hz, 1H), 5.16 (dddt, *J* = 7.4, 6.0, 3.0, 1.4 Hz, 1H), 4.52 (dd, *J* = 13.9, 2.9 Hz, 1H), 4.45 (dd, *J* = 13.8, 7.1 Hz, 1H). ^{13}C NMR (151 MHz, Chloroform-*d*) δ 168.93, 152.98, 138.06, 136.53, 136.28, 133.99, 133.85, 132.17, 131.39, 128.44, 128.17, 127.13, 126.37, 125.45, 125.36, 121.98, 121.17, 119.42, 81.60, 67.86. HRMS(ESI) calcd for $C_{21}H_{17}O_3$ [M+H]$^+$: 317.1172, Found: 317.1166.

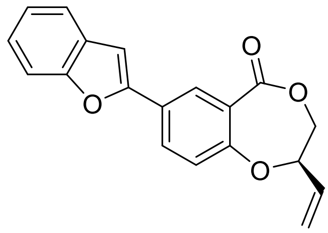
(*R*)-7-(thiophen-2-yl)-2-vinyl-2,3-dihydro-5*H*-benzo[*e*][1,4]dioxepin-5-one (2q)



R_f = 0.40 (petroleum/EtOAc = 4 : 1, v/v); colorless oil, 74.0 mg, 68% yield; 88% ee [Daicel Chiralcel IC-3 (0.46 cm x 25 cm), *n*-hexane/2-propanol = 65/35, *v* = 1.0 mL•min^{-1}, T = 25 °C, λ = 254 nm, t_R (minor) = 15.265 min, t_R (major) =

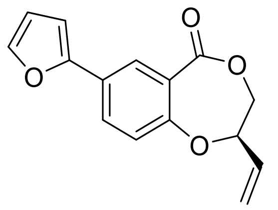
18.993 min]; $[\alpha]_D^{25}$ = +125.8° (c = 0.75, CH_2Cl_2). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.06 (d, *J* = 2.4 Hz, 1H), 7.75 (dd, *J* = 8.5, 2.4 Hz, 1H), 7.35 – 7.29 (m, 2H), 7.14 – 7.06 (m, 2H), 5.95 (ddd, *J* = 16.9, 10.6, 6.0 Hz, 1H), 5.53 (dt, *J* = 17.2, 1.2 Hz, 1H), 5.42 (dt, *J* = 10.6, 1.2 Hz, 1H), 5.08 (dddt, *J* = 7.5, 6.1, 3.0, 1.4 Hz, 1H), 4.44 (dd, *J* = 13.8, 2.9 Hz, 1H), 4.35 (dd, *J* = 13.8, 7.1 Hz, 1H). ^{13}C NMR (151 MHz, Chloroform-*d*) δ 168.74, 152.85, 142.23, 132.20, 132.01, 130.34, 129.77, 128.17, 125.22, 123.51, 122.70, 121.62, 119.47, 81.56, 67.78. HRMS(ESI) calcd for $C_{15}H_{13}O_3S$ $[M+H]^+$: 273.0580, Found: 273.0578.

(*R*)-7-(benzofuran-2-yl)-2-vinyl-2,3-dihydro-5*H*-benzo[*e*][1,4]dioxepin-5-one (2r)



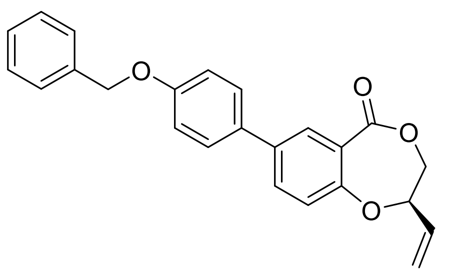
R_f = 0.40 (petroleum/EtOAc = 4 : 1, v/v); colorless oil, 77.1 mg, 63% yield; 89% ee [Daicel Chiralcel IC-3 (0.46 cm x 25 cm), *n*-hexane/2-propanol = 65/35, *v* = 1.0 mL•min^{-1}, T = 25 °C, λ = 254 nm, t_R (minor) = 16.685 min, t_R (major) = 20.248 min]; $[\alpha]_D^{25}$ = +122.7° (c = 0.75, CH_2Cl_2). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.35 (d, *J* = 2.3 Hz, 1H), 8.02 (dd, *J* = 8.5, 2.3 Hz, 1H), 7.63 – 7.60 (m, 1H), 7.55 – 7.52 (m, 1H), 7.34 – 7.30 (m, 1H), 7.28 – 7.24 (m, 1H), 7.18 (d, *J* = 8.5 Hz, 1H), 7.04 (d, *J* = 0.9 Hz, 1H), 5.97 (ddd, *J* = 16.9, 10.6, 6.0 Hz, 1H), 5.56 (dt, *J* = 17.3, 1.2 Hz, 1H), 5.44 (dt, *J* = 10.6, 1.2 Hz, 1H), 5.13 (dddt, *J* = 7.3, 5.8, 2.9, 1.4 Hz, 1H), 4.48 (dd, *J* = 13.9, 2.7 Hz, 1H), 4.40 (dd, *J* = 13.9, 7.0 Hz, 1H). ^{13}C NMR (151 MHz, Chloroform-*d*) δ 168.57, 154.93, 154.09, 153.69, 131.90, 131.09, 129.47, 129.06, 126.31, 124.56, 123.12, 122.63, 121.32, 121.03, 119.53, 111.21, 101.61, 81.63, 67.85. HRMS(ESI) calcd for $C_{19}H_{15}O_4$ $[M+H]^+$: 307.0965, Found: 307.0966.

(*R*)-7-(furan-2-yl)-2-vinyl-2,3-dihydro-5*H*-benzo[*e*][1,4]dioxepin-5-one (2s)



R_f = 0.40 (petroleum/EtOAc = 4 : 1, v/v); colorless oil, 74.8 mg, 73% yield; 90% ee [Daicel Chiralcel IC-3 (0.46 cm x 25 cm), *n*-hexane/2-propanol = 65/35, *v* = 1.0 mL•min^{-1}, T = 25 °C, λ = 254 nm, t_R (minor) = 16.215 min, t_R (major) = 20.156 min]; $[\alpha]_D^{25}$ = +121.1° (c = 0.75, CH_2Cl_2). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.10 (d, *J* = 2.4 Hz, 1H), 7.82 (dd, *J* = 8.5, 2.3 Hz, 1H), 7.47 (d, *J* = 1.6 Hz, 1H), 7.10 (d, *J* = 8.5 Hz, 1H), 6.68 – 6.63 (m, 1H), 6.48 (dd, *J* = 3.4, 1.8 Hz, 1H), 5.94 (ddd, *J* = 16.9, 10.6, 6.0 Hz, 1H), 5.52 (dt, *J* = 17.2, 1.3 Hz, 1H), 5.41 (dt, *J* = 10.6, 1.2 Hz, 1H), 5.07 (dddt, *J* = 7.3, 5.9, 2.9, 1.4 Hz, 1H), 4.43 (dd, *J* = 13.8, 2.9 Hz, 1H), 4.33 (dd, *J* = 13.8, 7.1 Hz, 1H). ^{13}C NMR (151 MHz, Chloroform-*d*) δ 168.82, 152.62, 152.24, 142.37, 132.04, 130.05, 127.91, 126.92, 122.56, 121.59, 119.43, 111.79, 105.36, 81.55, 67.77. HRMS(ESI) calcd for $C_{15}H_{13}O_4$ $[M+H]^+$: 257.0808, Found: 257.0808.

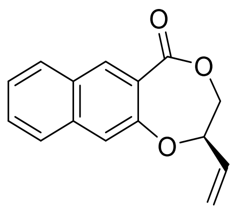
(*R*)-7-(4-(benzyloxy)phenyl)-2-vinyl-2,3-dihydro-5H-benzo[e][1,4]dioxepin-5-one (2t)



R_f = 0.20 (petroleum/EtOAc = 4 : 1, v/v); colorless oil, 105.7 mg, 71% yield; 93% ee [Daicel Chiralcel IC-3 (0.46 cm x 25 cm), *n*-hexane/2-propanol = 65/35, *v* =

1.0 mL•min^{-1}, T = 25 °C, λ = 254 nm, t_R (minor) = 23.267 min, t_R (major) = 34.316 min]; $[\alpha]_D^{25}$ = +156.4° (c = 0.75, CH_2Cl_2). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.01 (d, *J* = 2.5 Hz, 1H), 7.72 (dd, *J* = 8.5, 2.5 Hz, 1H), 7.53 (d, *J* = 8.5 Hz, 2H), 7.48 (d, *J* = 7.7 Hz, 2H), 7.43 (t, *J* = 7.6 Hz, 2H), 7.36 (t, *J* = 7.4 Hz, 1H), 7.14 (d, *J* = 8.5 Hz, 1H), 7.07 (d, *J* = 8.6 Hz, 2H), 6.02 – 5.92 (m, 1H), 5.55 (d, *J* = 17.2 Hz, 1H), 5.43 (d, *J* = 10.6 Hz, 1H), 5.14 (s, 2H), 5.10 (d, *J* = 7.2 Hz, 1H), 4.45 (dd, *J* = 13.8, 2.9 Hz, 1H), 4.36 (dd, *J* = 13.8, 7.2 Hz, 1H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 169.09, 158.64, 152.50, 136.88, 136.49, 132.95, 132.19, 131.92, 130.53, 128.60, 128.01, 127.90, 127.45, 122.49, 121.57, 119.35, 115.37, 81.51, 70.16, 67.79. HRMS(ESI) calcd for $C_{24}H_{21}O_4$ $[M+H]^+$: 373.1434, Found: 373.1435.

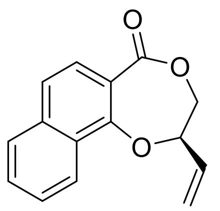
(*R*)-2-vinyl-2,3-dihydro-5*H*-naphtho[2,3-*e*][1,4]dioxepin-5-one (2u)



R_f = 0.45 (petroleum/EtOAc = 4 : 1, v/v); colorless oil, 80.7 mg, 84% yield; 92% ee [Daicel Chiralcel IC-3 (0.46 cm x 25 cm), *n*-hexane/2-propanol = 65/35, *v* = 1.0 mL•min^{-1}, T = 25 °C, λ = 254 nm, t_R (minor) = 19.214 min, t_R (major) = 22.156 min]; $[\alpha]_D^{25}$ = +138.9° (c = 0.75, CH_2Cl_2). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.35 (s, 1H), 7.93 (d, *J* = 8.2 Hz, 1H), 7.81 (d, *J* = 8.3 Hz, 1H), 7.60 (ddd, *J* = 8.2, 6.8, 1.3 Hz, 1H), 7.51 (q, *J* = 2.5, 1.4 Hz, 2H), 6.00 (ddd, *J* = 17.2, 10.6, 6.7 Hz, 1H), 5.55 (dd, *J* = 17.3, 1.3 Hz, 1H), 5.43 (dd, *J* = 10.5, 1.3 Hz, 1H), 5.05 (td, *J* = 7.0, 3.6 Hz, 1H), 4.41 (dd, *J* = 13.8, 3.8 Hz, 1H), 4.26 (dd, *J* = 13.7, 7.7 Hz, 1H). ^{13}C NMR (151 MHz, Chloroform-*d*) δ 169.30, 148.92, 136.54, 133.62, 132.29, 130.08, 128.94, 128.85, 127.00, 126.05, 124.29, 119.76, 119.46, 81.56, 67.40. HRMS(ESI) calcd for $C_{15}H_{13}O_3$ $[M+H]^+$: 241.0859, Found:

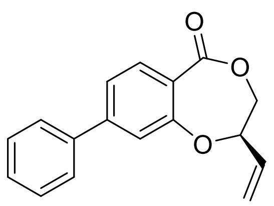
241.0858.

(*R*)-2-vinyl-2,3-dihydro-5*H*-naphtho[1,2-*e*][1,4]dioxepin-5-one (2v)



R_f = 0.45 (petroleum/EtOAc = 4 : 1, v/v); colorless oil, 46.1 mg, 48% yield; 83% ee [Daicel Chiralcel IC-3 (0.46 cm x 25 cm), *n*-hexane/2-propanol = 65/35, *v* = 1.0 mL•min^{-1}, T = 25 °C, λ = 254 nm, t_R (minor) = 14.369 min, t_R (major) = 20.983 min]; $[\alpha]_D^{25}$ = +110.8° (c = 0.75, CH_2Cl_2). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.32 (dd, *J* = 8.6, 1.1 Hz, 1H), 8.01 (d, *J* = 8.8 Hz, 1H), 7.90 – 7.85 (m, 1H), 7.62 (ddd, *J* = 8.5, 6.9, 1.3 Hz, 1H), 7.52 (ddd, *J* = 8.1, 6.9, 1.2 Hz, 1H), 7.23 (d, *J* = 8.8 Hz, 1H), 5.96 (ddd, *J* = 17.3, 10.6, 6.7 Hz, 1H), 5.53 (dt, *J* = 17.3, 1.1 Hz, 1H), 5.42 (dt, *J* = 10.6, 1.0 Hz, 1H), 5.13 – 5.08 (m, 1H), 4.40 (dd, *J* = 13.5, 4.1 Hz, 1H), 4.29 (dd, *J* = 13.4, 7.7 Hz, 1H). ^{13}C NMR (151 MHz, Chloroform-*d*) δ 168.14, 151.74, 134.52, 132.42, 131.84, 131.07, 128.35, 128.24, 125.78, 125.14, 122.04, 119.87, 118.39, 82.20, 66.68. HRMS(ESI) calcd for $C_{15}H_{13}O_3$ $[M+H]^+$: 241.0859, Found: 241.0858.

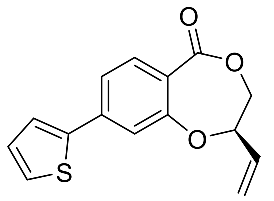
(*R*)-8-phenyl-2-vinyl-2,3-dihydro-5H-benzo[e][1,4]dioxepin-5-one (2w)



R_f = 0.40 (petroleum/EtOAc = 4 : 1, v/v); colorless oil, 71.3 mg, 67% yield; 90% ee [Daicel Chiralcel IA-3 (0.46 cm x 25 cm), *n*-hexane/2-propanol = 95/5, *v* = 1.0 mL•min^{-1}, T = 25 °C, λ = 254 nm, t_R (minor) = 17.173 min, t_R (major) =

17.827 min]; $[\alpha]_D^{25}$ = +135.6° (c = 0.75, CH_2Cl_2). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.92 (d, *J* = 8.1 Hz, 1H), 7.63 (d, *J* = 7.6 Hz, 2H), 7.49 (t, *J* = 7.5 Hz, 2H), 7.43 (dd, *J* = 11.3, 7.9 Hz, 2H), 7.32 (s, 1H), 5.98 (ddd, *J* = 17.0, 10.7, 6.0 Hz, 1H), 5.56 (d, *J* = 17.2 Hz, 1H), 5.42 (d, *J* = 10.6 Hz, 1H), 5.12 (d, *J* = 6.8 Hz, 1H), 4.45 (dd, *J* = 13.9, 2.6 Hz, 1H), 4.37 (dd, *J* = 13.9, 7.0 Hz, 1H). HRMS(ESI) calcd for $C_{17}H_{15}O_3$ $[M+H]^+$: 267.1016, Found: 267.1010.

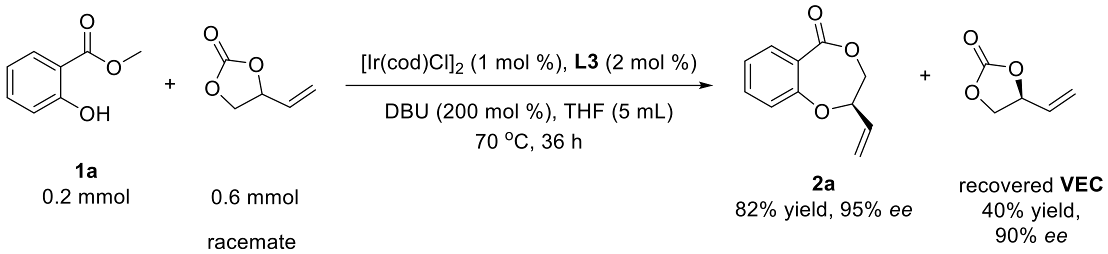
(*R*)-8-(thiophen-2-yl)-2-vinyl-2,3-dihydro-5H-benzo[e][1,4]dioxepin-5-one (2x)

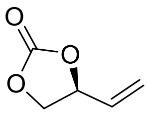


R_f = 0.40 (petroleum/EtOAc = 4 : 1, v/v); colorless oil, 79.4 mg, 73% yield; 90% ee [Daicel Chiralcel IC-3 (0.46 cm x 25 cm), *n*-hexane/2-propanol = 65/35, *v* = 1.0 mL•min^{-1}, T = 25 °C, λ = 254 nm, t_R (minor) = 18.535 min, t_R (major) = 21.395 min]; $[\alpha]_D^{25}$ = +117.8° (c = 0.75, CH_2Cl_2). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.86 (d, *J* = 8.1 Hz, 1H), 7.46 – 7.38 (m, 3H), 7.31 (d, *J* = 1.8 Hz, 1H), 7.13 (t, *J* = 4.4 Hz, 1H), 5.97 (ddd, *J* = 16.9, 10.6, 6.0 Hz, 1H), 5.58 – 5.52 (m, 1H), 5.45 – 5.40 (m, 1H), 5.09 (tt, *J* = 5.2, 2.1 Hz, 1H), 4.44 (dd, *J* = 13.9, 2.7 Hz, 1H), 4.36 (dd, *J* = 13.9, 6.9 Hz, 1H). ^{13}C NMR (151 MHz, Chloroform-*d*) δ 168.66, 154.29, 141.96, 140.94, 133.79, 132.08, 128.38, 126.81, 125.02, 120.61, 119.44, 119.08, 118.45, 81.50, 67.87. HRMS(ESI) calcd for $C_{15}H_{13}O_3S$ $[M+H]^+$: 273.0580, Found: 273.0574.

3.3 Control Experiments on Kinetic Resolution

To gain insight into the possible reaction mechanism, the Ir-catalyzed asymmetric cascade allylic etherification/lactonization between methyl salicylate **1a** (0.2 mmol) and excessive racemic VEC (0.4 mmol) was further investigated, and it was found **2a** could be available in 82% yield with 95% *ee*, accompanied by recovered VEC in 40% yield with 90% *ee*. These results display that racemic VEC should go through a kinetic resolution (KR) process in this transformation.

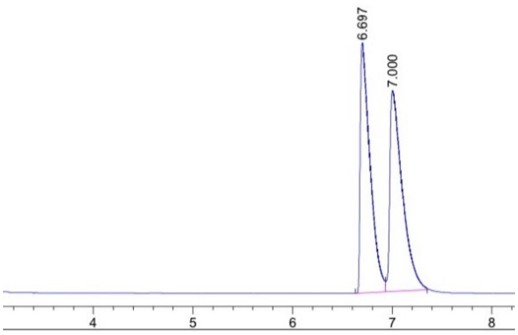




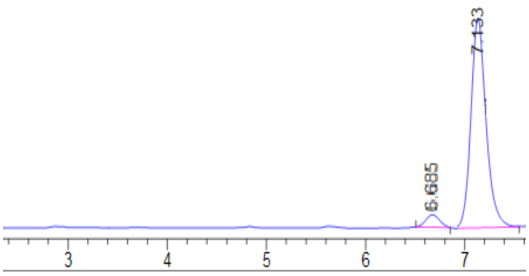
(*S*)-4-vinyl-1,3-dioxolan-2-one: 18.2 mg (based on the substrate racemic VEC), colorless oil. The recovered VEC was analyzed by GC to determine the enantiomeric excess: 90% *ee*.

GC (Beta DEX-390, N_2 flow rate 1.0 mL/min, 20 min at 150 °C): t_R = 6.69 min (minor), 7.13 min (major), 90% *ee*. The NMR data are in accordance with the previously reported data.[3]

GC chromatogram of compound (*S*)-4-vinyl-1,3-dioxolan-2-one:

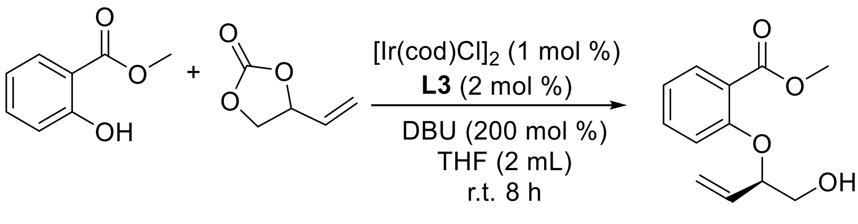


Peak #	RetTime [min]	Type	Width (min)	Area [pA*s]	Height [pA]	Area %
1	6.697	BV	0.0900	1091.50562	159.24478	49.45939
2	7.000	VB	0.1157	1115.36682	127.99700	50.54061



Peak #	RetTime [min]	Type	Width (min)	Area [pA*s]	Height [pA]	Area %
1	6.685	BV	0.0915	76.89745	12.46783	5.07525
2	7.133	VB	0.1326	1438.24825	139.25687	94.92475

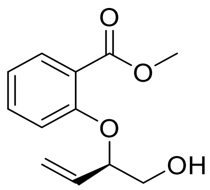
3.4 Stepwise Experiments: Investigation of the Reaction Pathways



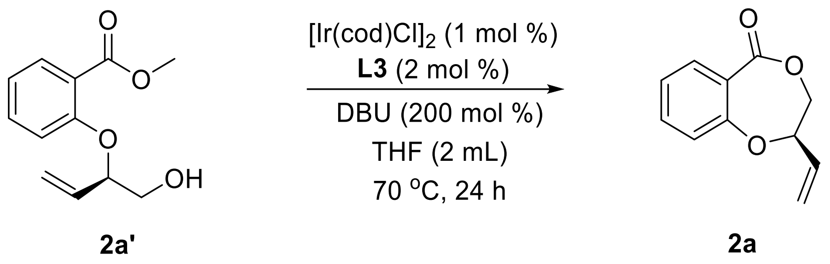
1a **2a'**

In a dry Schlenk tube filled with argon, $[Ir(cod)Cl]_2$ (2.7 mg, 0.004 mmol, 1 mol %), phosphoramidite ligand **L3** (4.2 mg, 0.008 mmol, 2 mol %), and *n*-propylamine (0.5 mL) were dissolved in THF (1.0 mL). The reaction mixture was heated at 50 °C for 30 min and then the volatile solvents were removed in vacuum to give a yellow solid. Subsequently, (substituted) methyl salicylate **1** (0.4 mmol), VEC **2** (137.0 mg, 3.0 equiv.), DBU (121.8 mg, 200 mol %) and THF (5.0 mL) were added to this tube. The system was stirred at room temperature until the reaction was completed. Then the solvent was evaporated and the residue was purified by silica gel column chromatography using petroleum/EtOAc (5:1) as the eluent to give the desired products **2a'**.

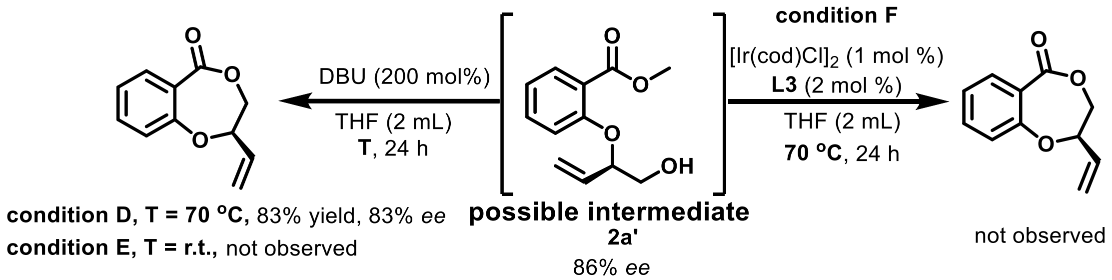
(*R*)-methyl 2-((1-hydroxybut-3-en-2-yl)oxy)benzoate (2a')



R_f = 0.30 (petroleum/EtOAc = 4 : 1, v/v); colorless oil, 77.3 mg, 87% yield; 86% ee [Daicel Chiralcel IC-3 (0.46 cm x 25 cm), *n*-hexane/2-propanol = 65/35, v = 1.0 mL•min^{-1}, T = 25 °C, λ = 254 nm, t_R (major) = 7.989 min, t_R (minor) = 8.382 min]; $[\alpha]_D^{25}$ = 89.3° (c = 0.75, CH_2Cl_2). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.81 (dd, *J* = 7.8, 1.8 Hz, 1H), 7.47 – 7.42 (m, 1H), 7.08 (dd, *J* = 8.3, 1.0 Hz, 1H), 7.05 – 7.01 (m, 1H), 6.00 (ddd, *J* = 17.4, 10.8, 5.5 Hz, 1H), 5.50 – 5.44 (m, 1H), 5.39 – 5.34 (m, 1H), 4.75 – 4.69 (m, 1H), 3.92 (s, 3H), 3.79 (dd, *J* = 11.9, 8.6 Hz, 1H), 3.73 (dd, *J* = 12.0, 3.4 Hz, 1H). ^{13}C NMR (151 MHz, Chloroform-*d*) δ 167.06, 159.41, 134.40, 133.81, 131.41, 121.31, 120.63, 118.04, 116.90, 84.60, 65.45, 52.21. HRMS(ESI) calcd for $C_{12}H_{15}O_4$ $[M+H]^+$: 223.0965, Found: 223.0964.



In a dry Schlenk tube filled with argon, [Ir(cod)Cl]$_2$ (1.4 mg, 0.002 mmol, 1 mol %), phosphoramidite ligand **L3** (2.1 mg, 0.004 mmol, 2 mol %), and *n*propylamine (0.5 mL) were dissolved in THF (1.0 mL). The reaction mixture was heated at 50 °C for 30 min and then the volatile solvents were removed in vacuum to give a yellow solid. Subsequently, **2a'** (44.4 mg, 0.2 mmol), DBU (60.9 mg, 200 mol %) and THF (2.0 mL) were added to this tube. The system was stirred at 70 °C until the reaction was completed. Then the solvent was evaporated and the residue was purified by silica gel column chromatography using petroleum/EtOAc (8:1) as the eluent to give the desired products **2a** (82% yield, 83% *ee*).



Intermediate **2a'** reacted under condition E (room temperature) and condition F (no DBU added), condition D (without Ir complex) in a similar way as above. Further control experiments showed that when intermediate **2a'** reacted under condition E (room temperature) and condition F (no DBU added), the corresponding product **2a** could not be obtained. However, **2a** could be conveniently given when intermediate **2a'** was exposed to condition D (without Ir complex). From the results obtained in the one-pot reaction (condition C) and the stepwise experiments, it can be concluded that the reaction proceeds through a relay catalytic pathway and DBU catalyzes the lactonization step at 70 °C.

References

[1] (a) Arnold, L. A.; Naasz, R.; Minnaard, A. J.; Feringa, B. L. Catalytic Enantioselective Synthesis of Prostaglandin E1 Methyl Ester Using a Tandem 1,4-Addition-Aldol Reaction to a Cyclopenten-3,5-dione Monoacetal. *J. Am. Chem. Soc.* **2001**, *123*, 5841–5842. (b) Defieber, C.; Ariger, M. A.; Moriel, P.; Carreira, E. M. Iridium-Catalyzed Synthesis of Primary Allylic Amines from Allylic Alcohols: Sulfamic Acid as Ammonia Equivalent. *Angew. Chem. Int. Ed.* **2007**, *46*, 3139–3143. (c) Zhuang, Y.; He, Y.; Zhou, Z.; Xia, W.; Cheng, C.; Wang, M.; Chen, B.; Zhou, Z.; Pang, J.; Qiu, L. Synthesis of a Class of Chiral-Bridged Phosphoramidite Ligands and Their Applications in the First Iridium-Catalyzed Asymmetric Addition of Arylboronic Acids to Isatins. *J. Org. Chem.* **2015**, *80*, 6968–6975. (d) Jiang, X.; Chen, X.; Li, Y.; Liang, H.; Zhang, Y.; He, X.; Chen, B.; Chan, W. T. K; Chan, A. S. C.; Qiu, L. Enantioselective Syntheses of Tricyclic Benzimidazoles via Intramolecular Allylic Aminations with Chiral-Bridged Biphenyl Phosphoramidite Ligands, *Org. Lett.* **2019**, *21*, 608–613.

[2] (a) Schulz, J.; Císařová, I.; Štěpnička, P. Preparation, Coordination Properties and Catalytic Use of 1′-(Diphenylphosphanyl)-1-Ferrocenecarboxamides Bearing 2-Hydroxyethyl Pendant Groups. *J. Organometall. Chem.* **2009**, *694*, 2519–2530. (b) Petros, A.; Swann, S.; Song, D.; Swinger, K.; Park, C.; Zhang, H.; Wendt, M.; Kunzer, A.; Souers, A.; Sun, C. Fragment-Based Discovery of Potent Inhibitors of the Anti-Apoptotic MCL-1 Protein. *Bioorg. Med. Chem. Lett.* **2014**, *24*, 1484–1488. (c) Gu, Y.; Wu, F,; Yang, J. Oxidative [3+3] Annulation of Atropaldehyde Acetals with 1,3-Bisnucleophiles: An Efficient Method of Constructing Six-Membered Aromatic Rings, Including Salicylates and Carbazoles. *Adv. Synth. Catal.* **2018**, *360*, 2727–

2741. (d) Prévost**,** S.; Dezaire, A.; Escargueil, A. Intramolecular Aryne-Furan Cycloadditions for the Synthesis of Anticancer Naphthalimides. *J. Org. Chem.* **2018**, *83*, 4871−4881.

[3] Xiao, L.; Wei, L.; Wang, C.-J. Stereodivergent Synthesis of Enantioenriched γButyrolactones Bearing Two Vicinal Stereocenters Enabled by Synergistic Copper and Iridium Catalysis. *Angew. Chem., Int. Ed.* **2021**, *60*, 24930−24940.

4. Copies of NMR Spectra

Figure 1. ^{1}H NMR (600 MHz, $CDCl_3$) spectrum of 1q

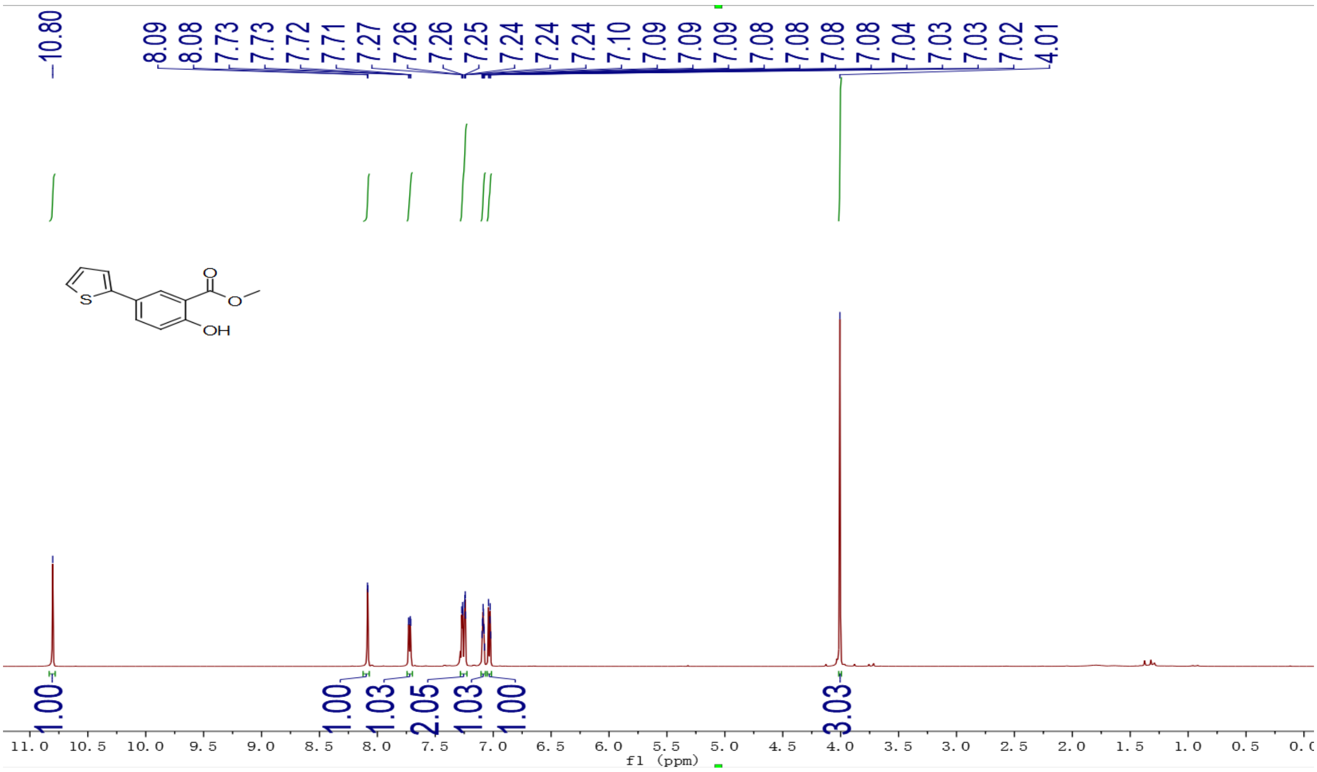


Figure 2. ^{13}C NMR (151 MHz, $CDCl_3$) spectrum of 1q

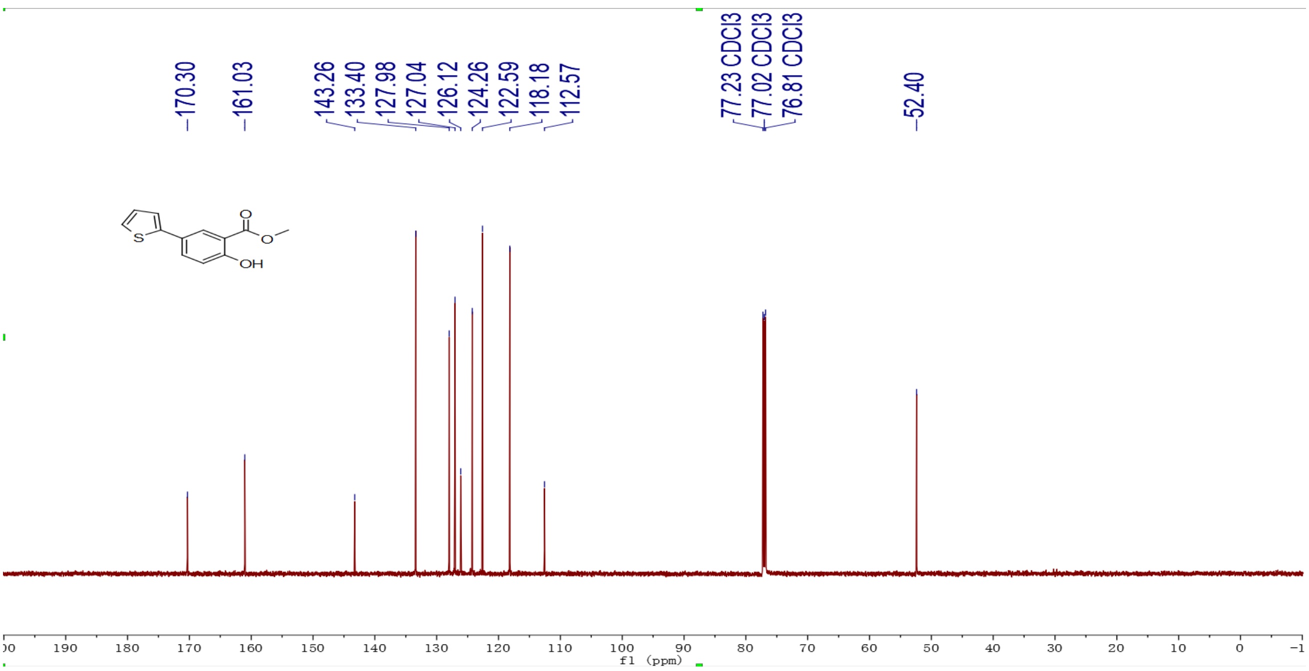


Figure 3. ^{1}H NMR (600 MHz, CDCl₃) spectrum of 1r

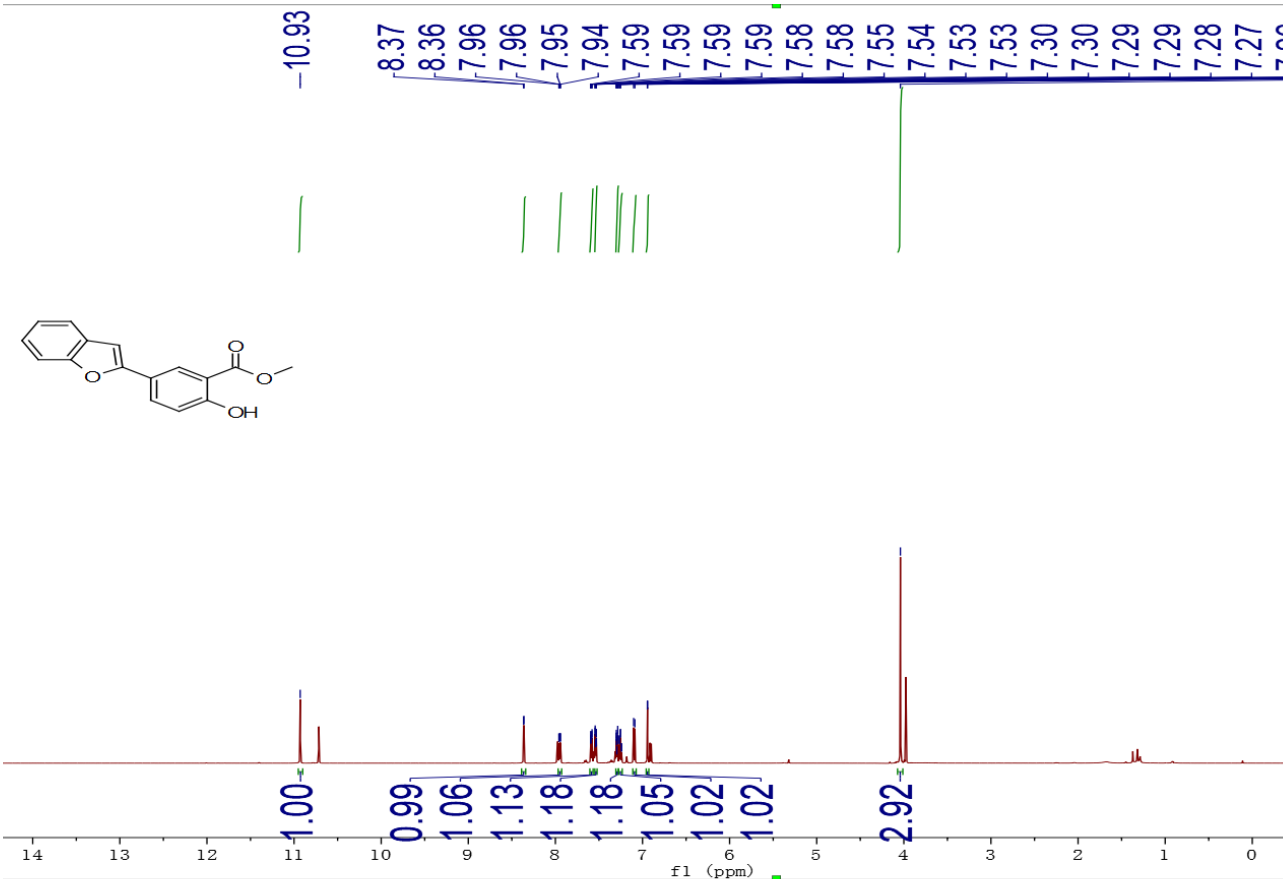


Figure 4. ^{13}C NMR (151 MHz, CDCl₃) spectrum of 1r

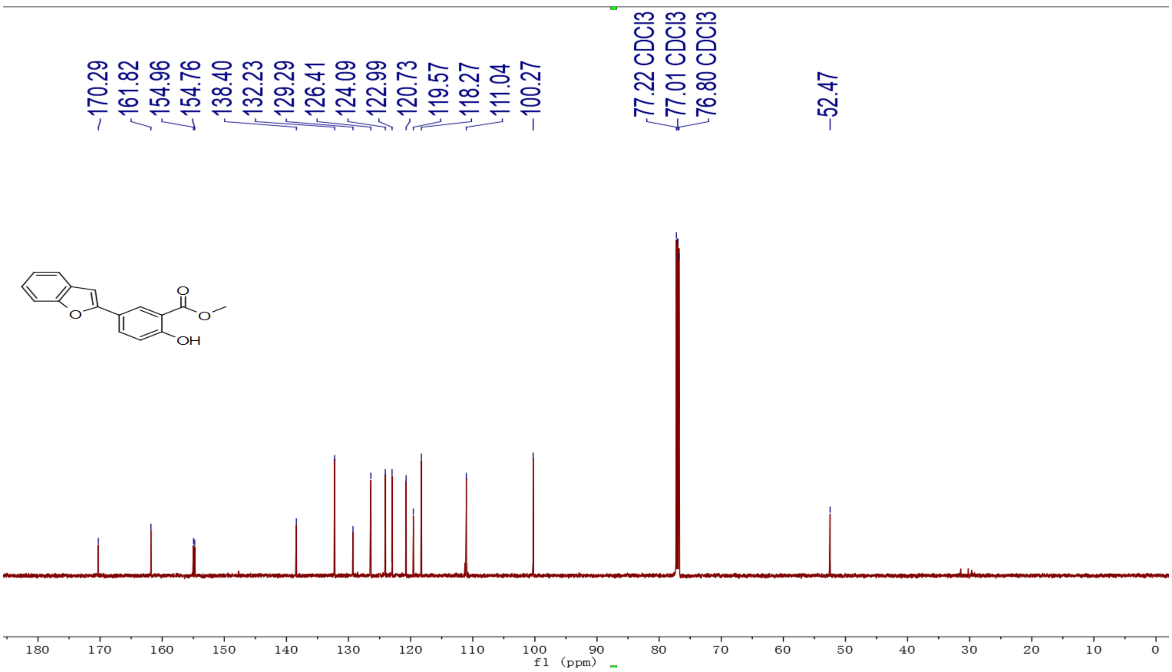


Figure 5. ^{1}H NMR (600 MHz, $CDCl_3$) spectrum of 1s

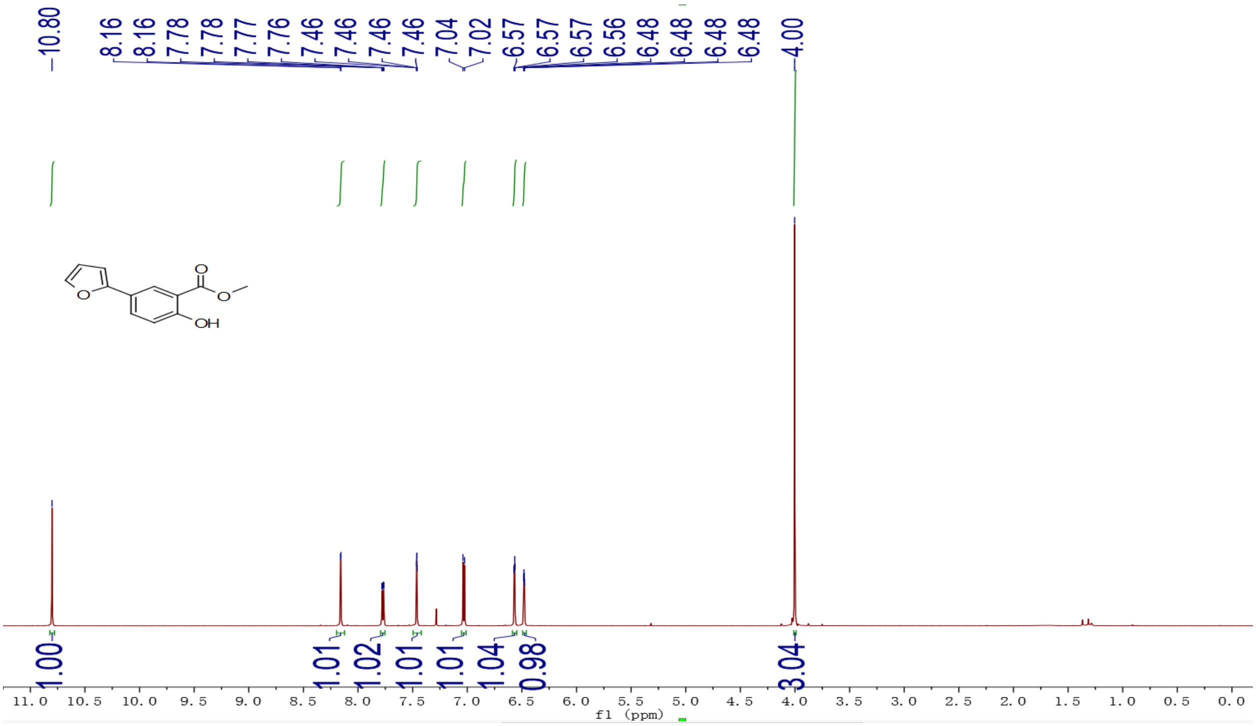


Figure 6. ^{13}C NMR (151 MHz, $CDCl_3$) spectrum of 1s

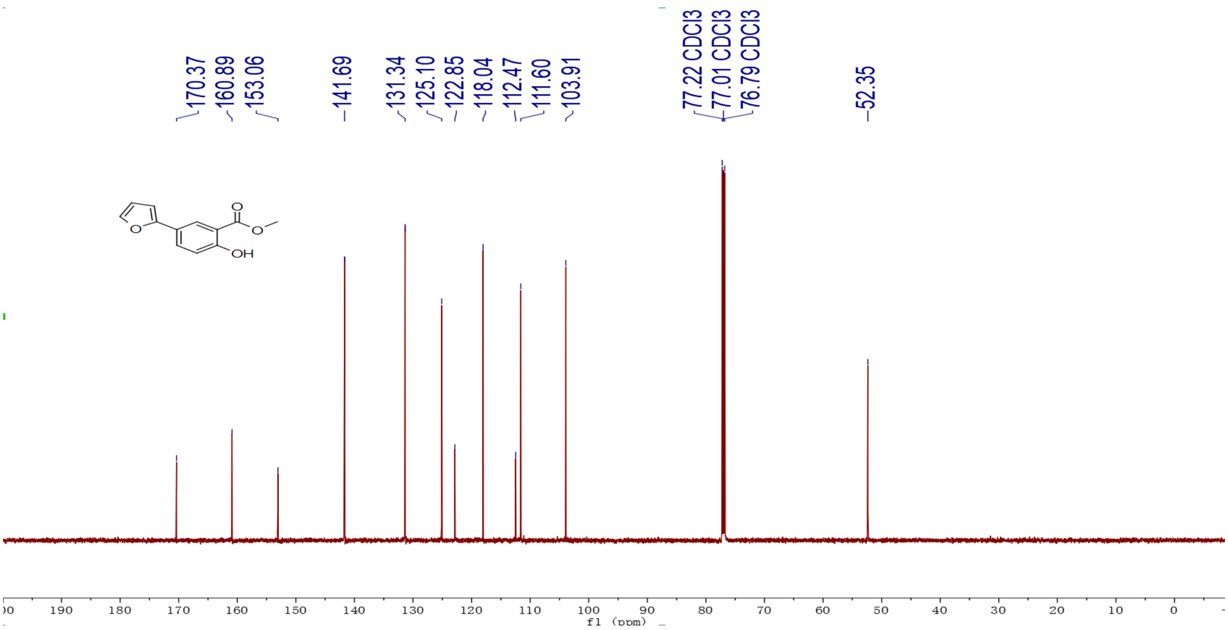


Figure 7. [1]H NMR (600 MHz, CDCl3) spectrum of 1t

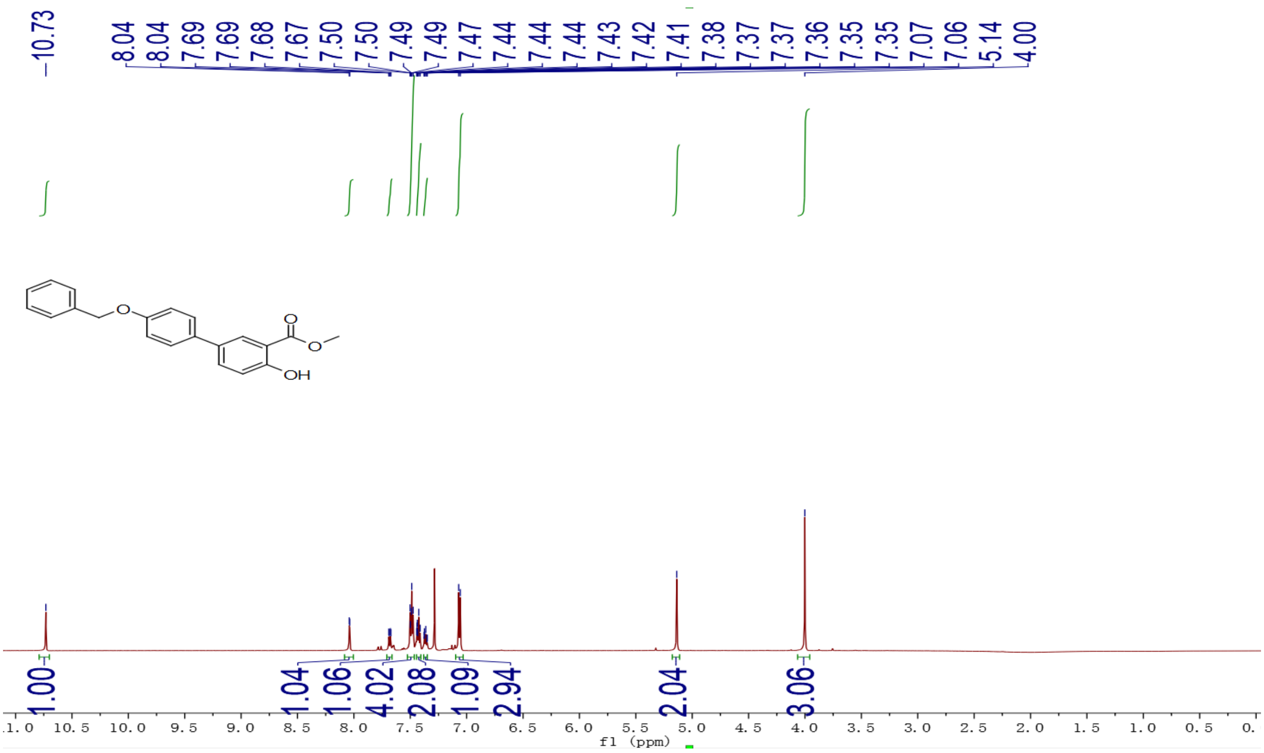


Figure 8. [13]C NMR (151 MHz, CDCl3) spectrum of 1t

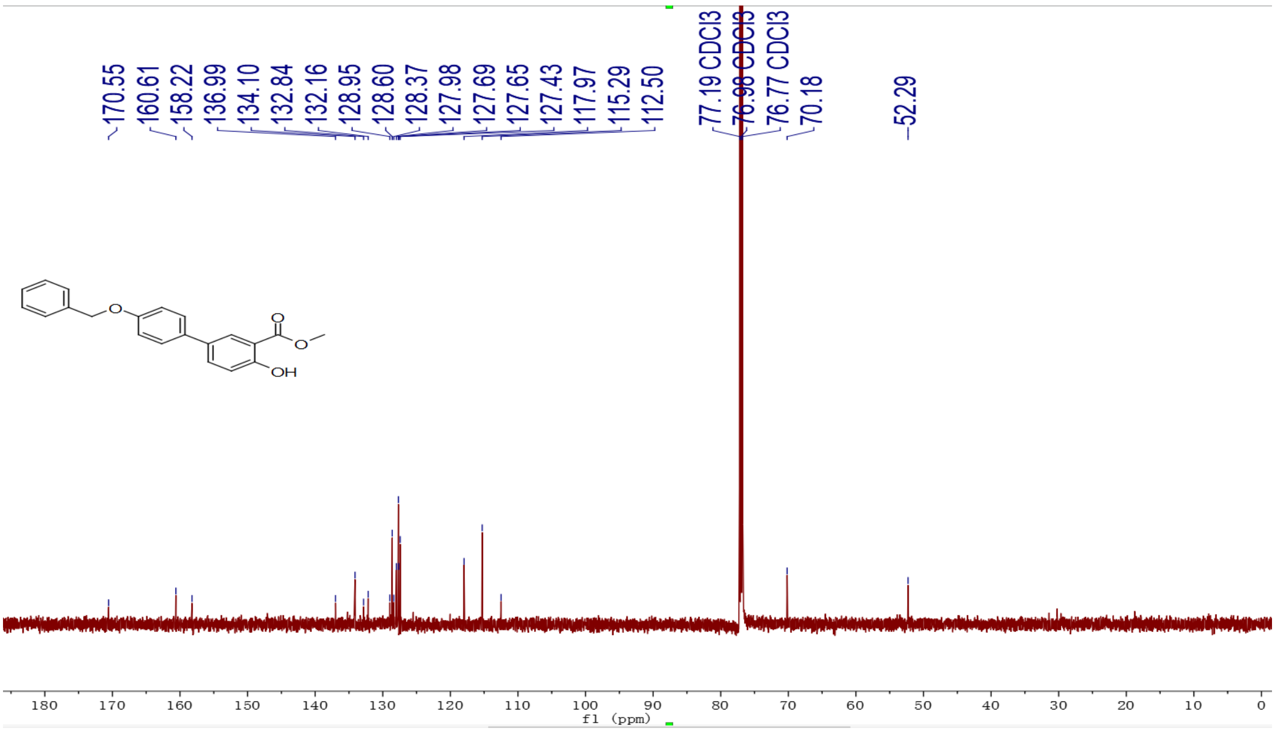


Figure 9. ^{1}H NMR (600 MHz, $CDCl_3$) spectrum of 2a

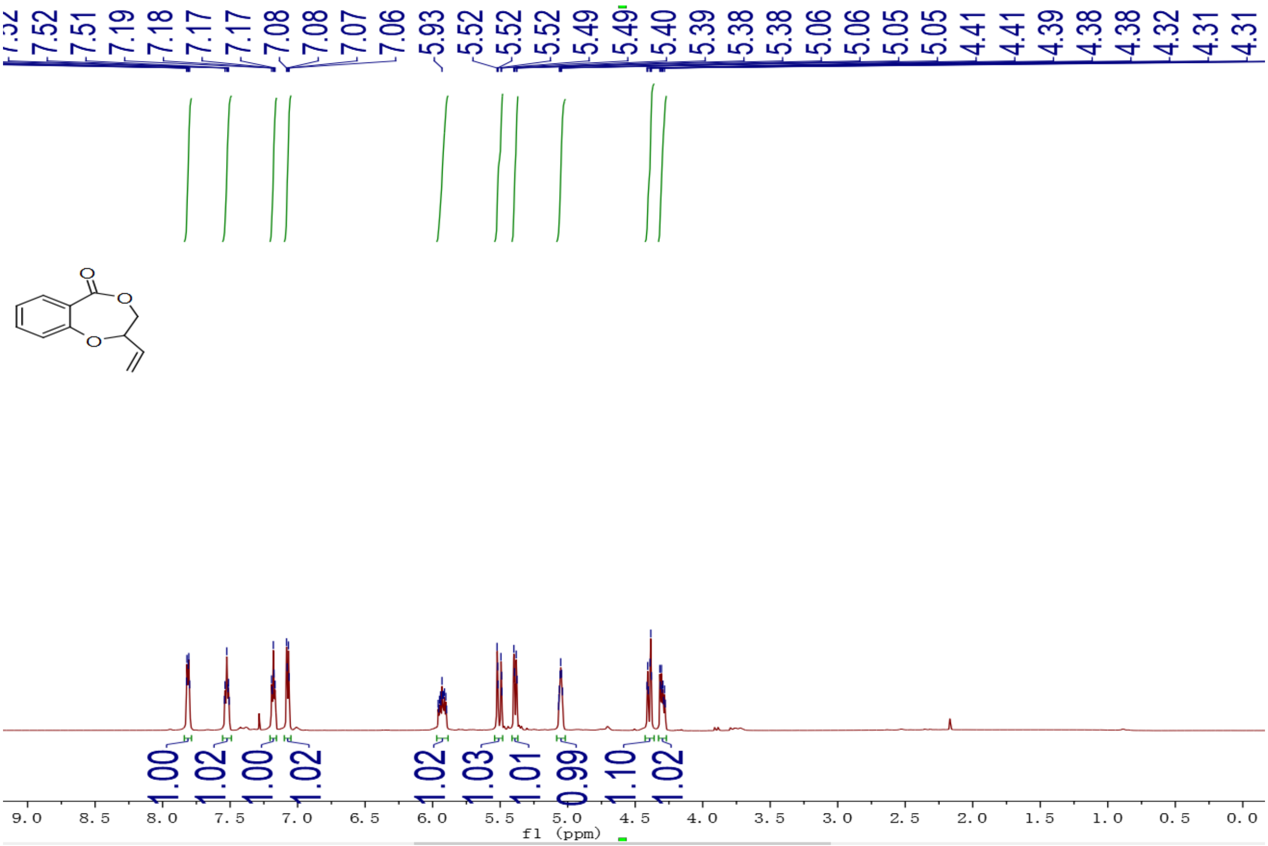


Figure 10. ^{13}C NMR (151 MHz, $CDCl_3$) spectrum of 2a

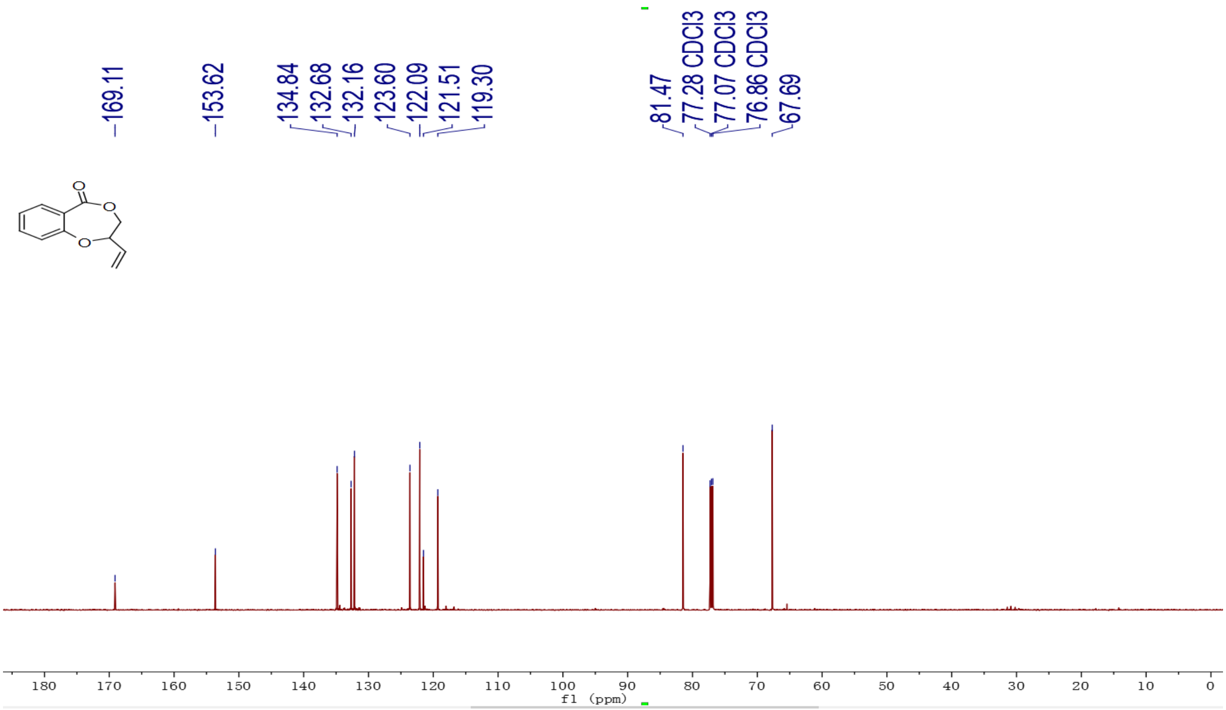


Figure 11. ^{1}H NMR (600 MHz, $CDCl_3$) spectrum of 2b

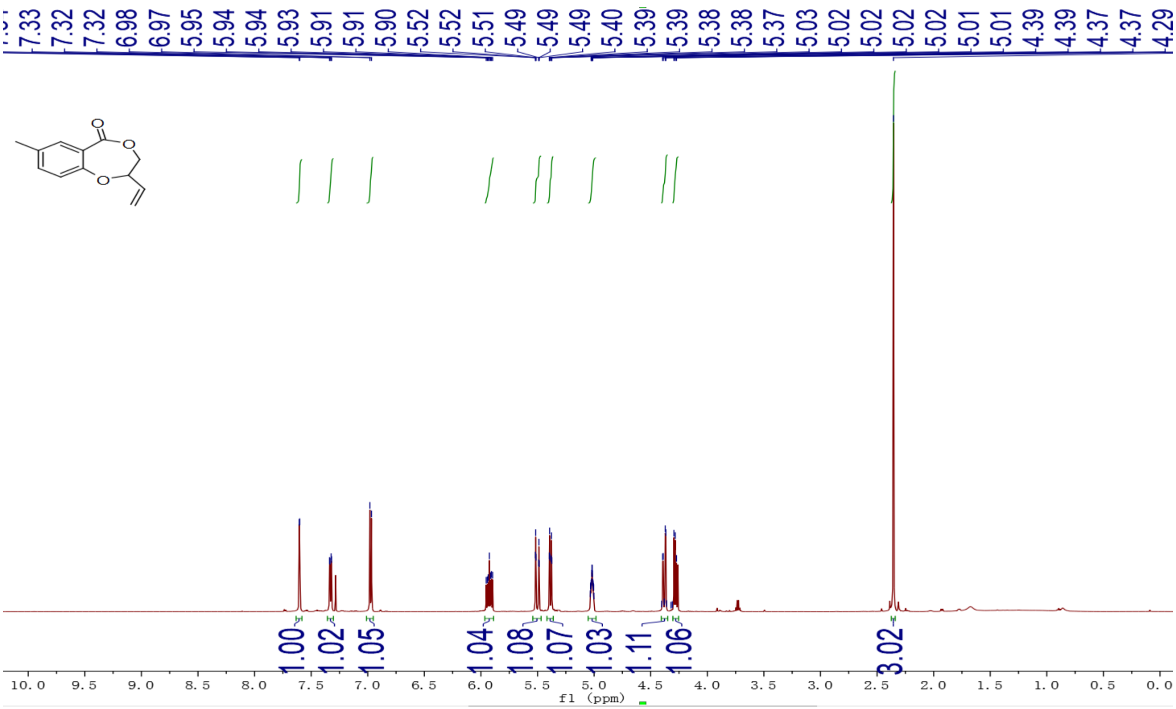


Figure 12. ^{13}C NMR (151 MHz, $CDCl_3$) spectrum of 2b

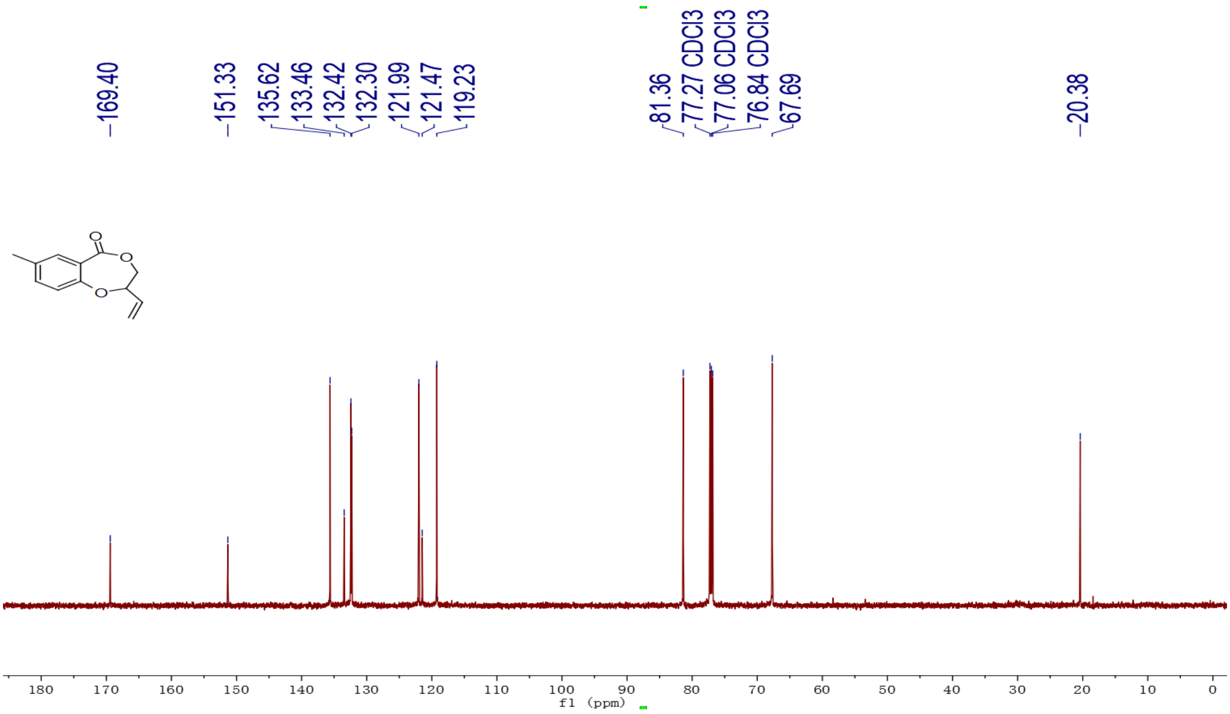


Figure 13. ^{1}H NMR (600 MHz, $CDCl_3$) spectrum of 2c

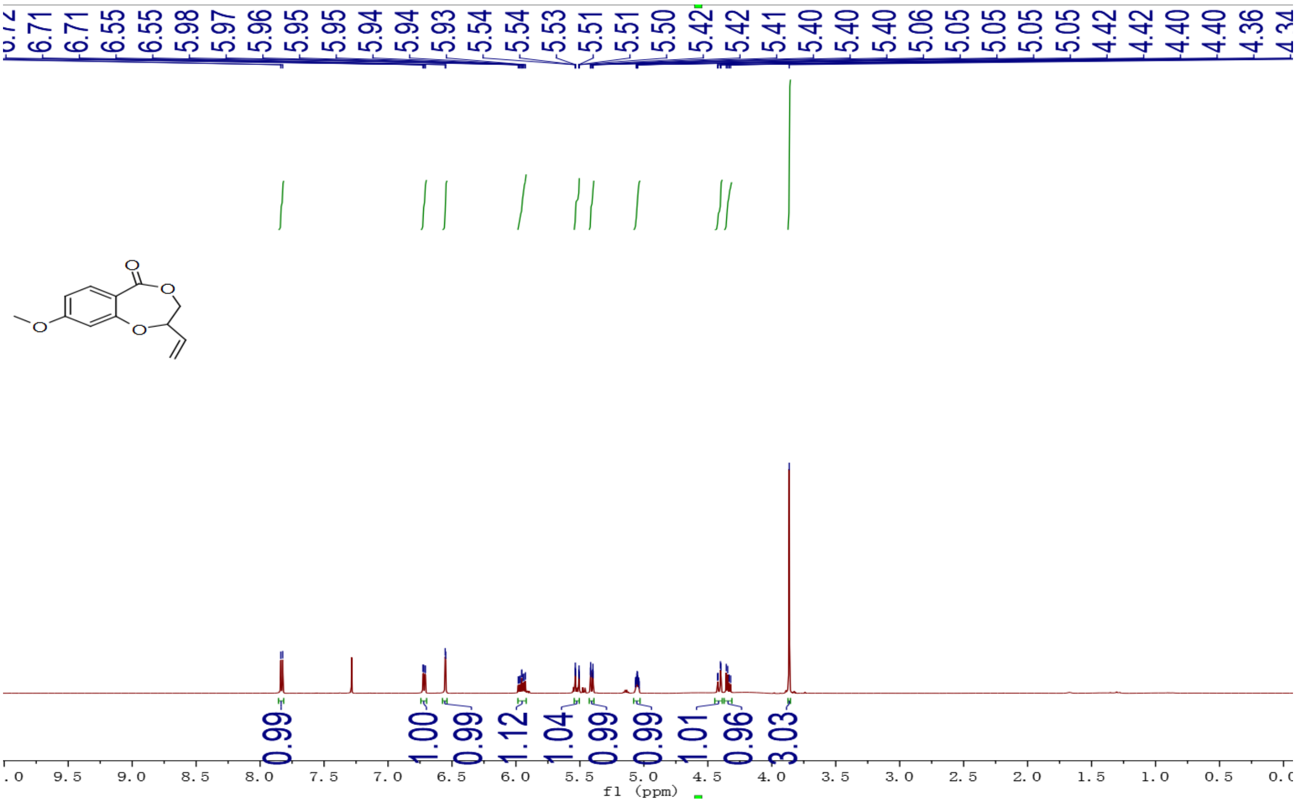


Figure 14. ^{13}C NMR (151 MHz, $CDCl_3$) spectrum of 2c

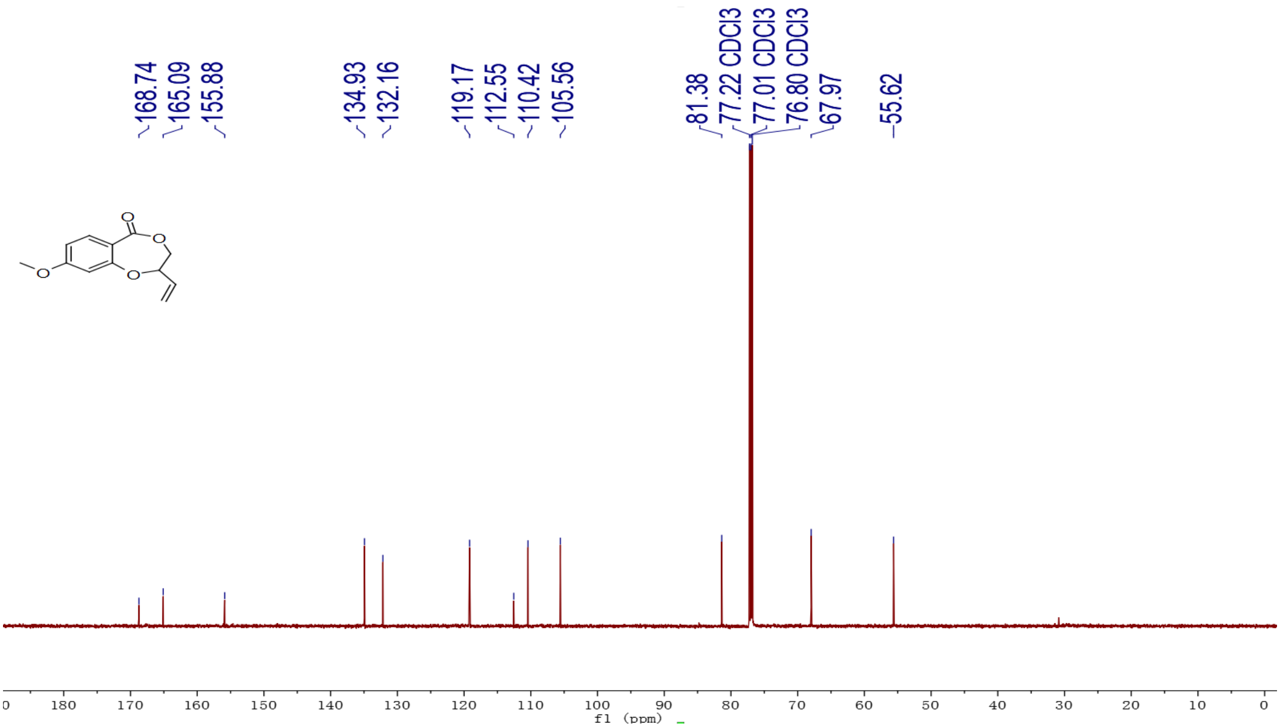


Figure 15. [1]**H NMR (600 MHz, CDCl3) spectrum of 2d**

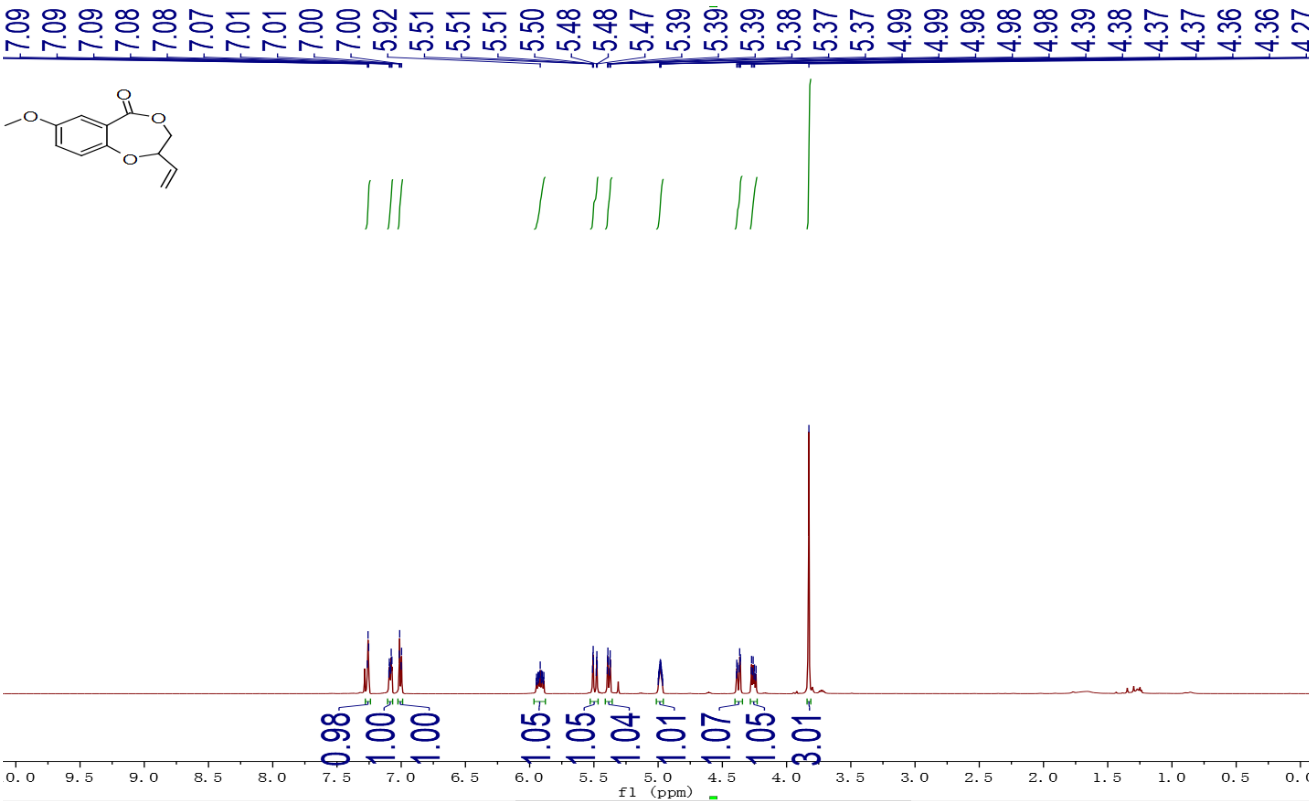


Figure 16. [13]**C NMR (151 MHz, CDCl3) spectrum of 2d**

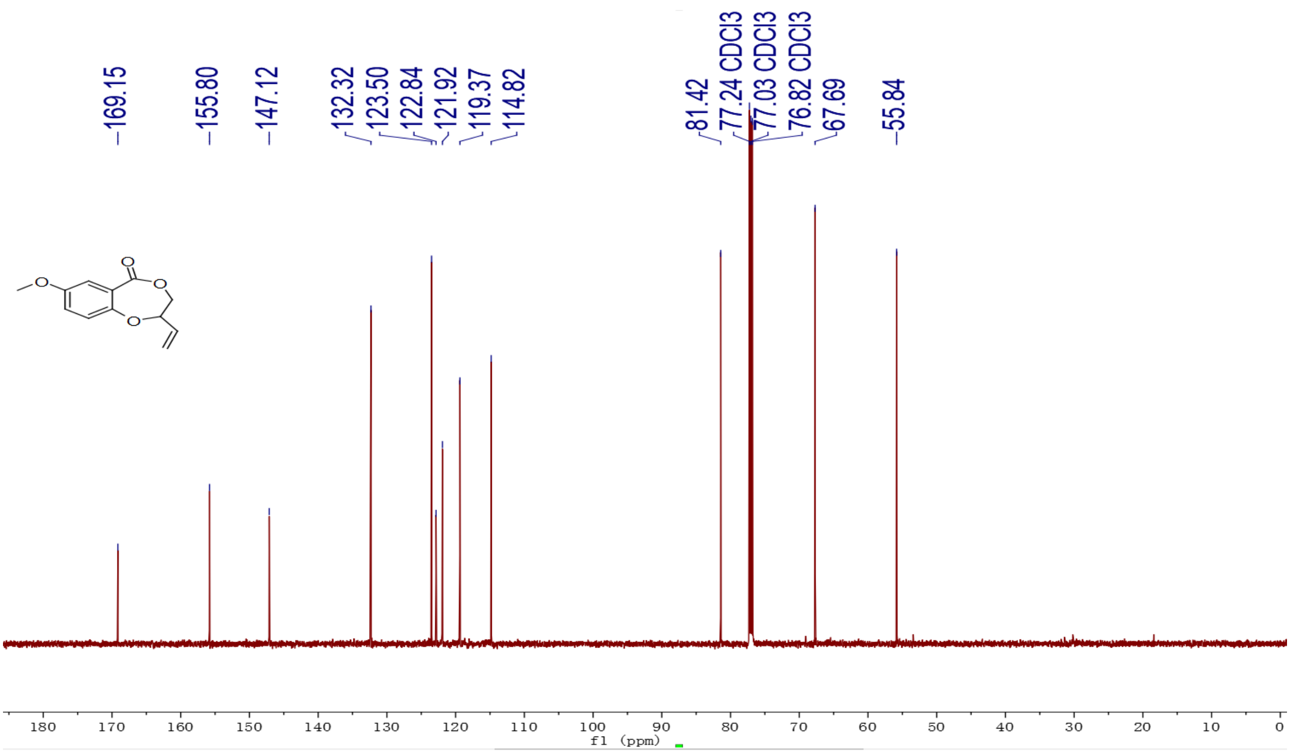


Figure 17. ^{1}H NMR (600 MHz, CDCl$_3$) spectrum of 2e

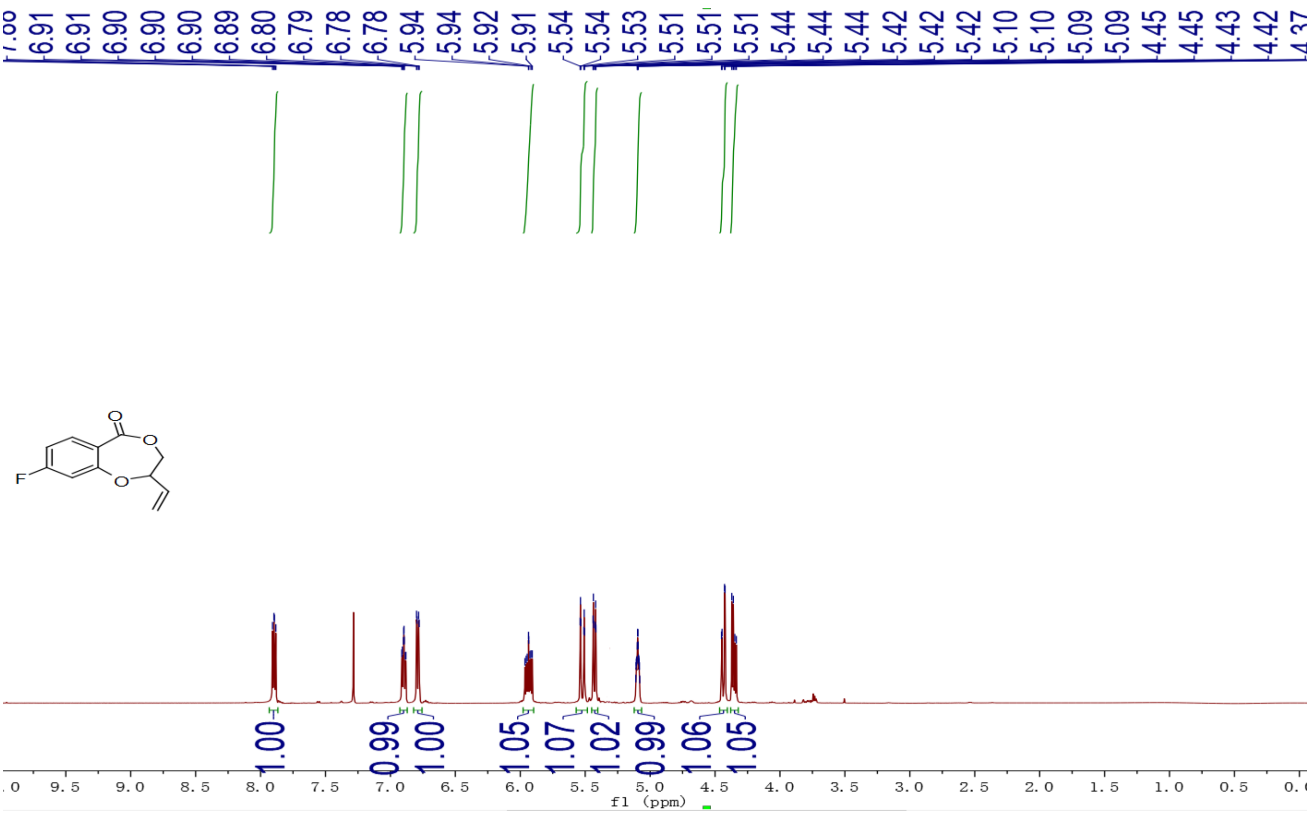


Figure 18. ^{13}C NMR (151 MHz, CDCl$_3$) spectrum of 2e

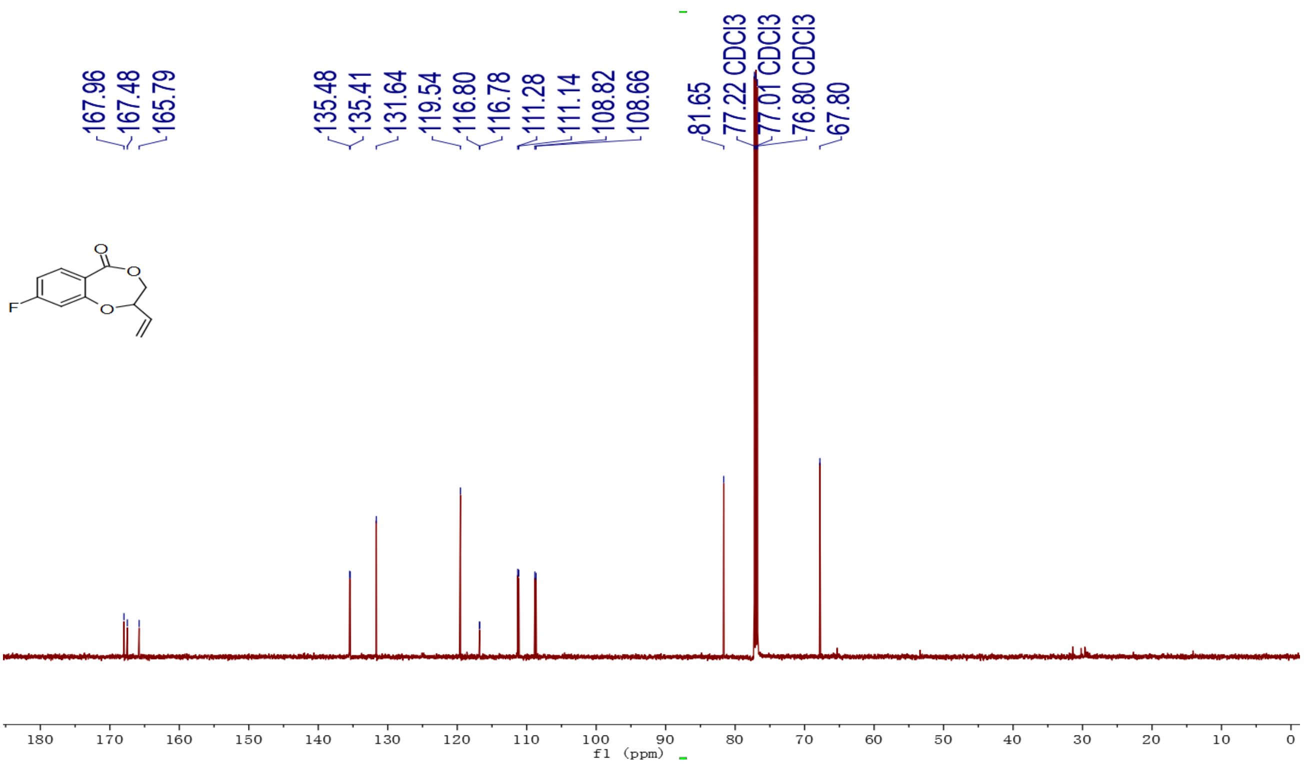


Figure 19. [19]**F NMR (565 MHz, CDCl**$_3$**) spectrum of 2e**

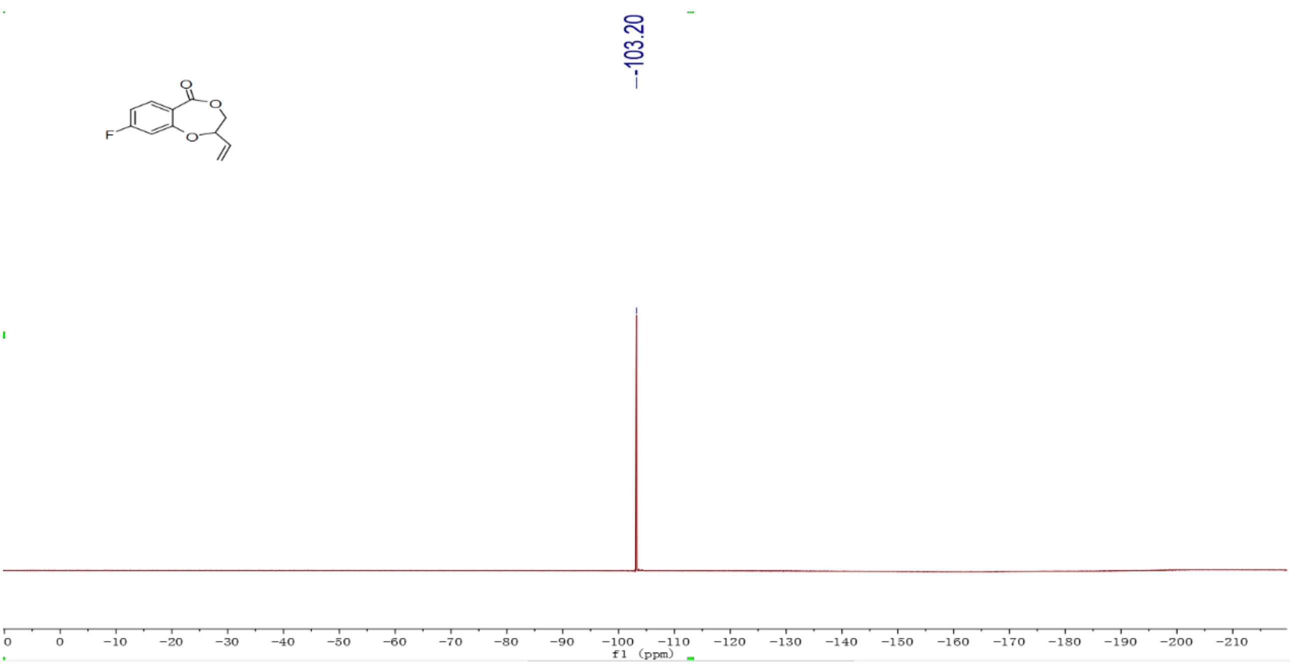


Figure 20. [1]**H NMR (600 MHz, CDCl**$_3$**) spectrum of 2f**

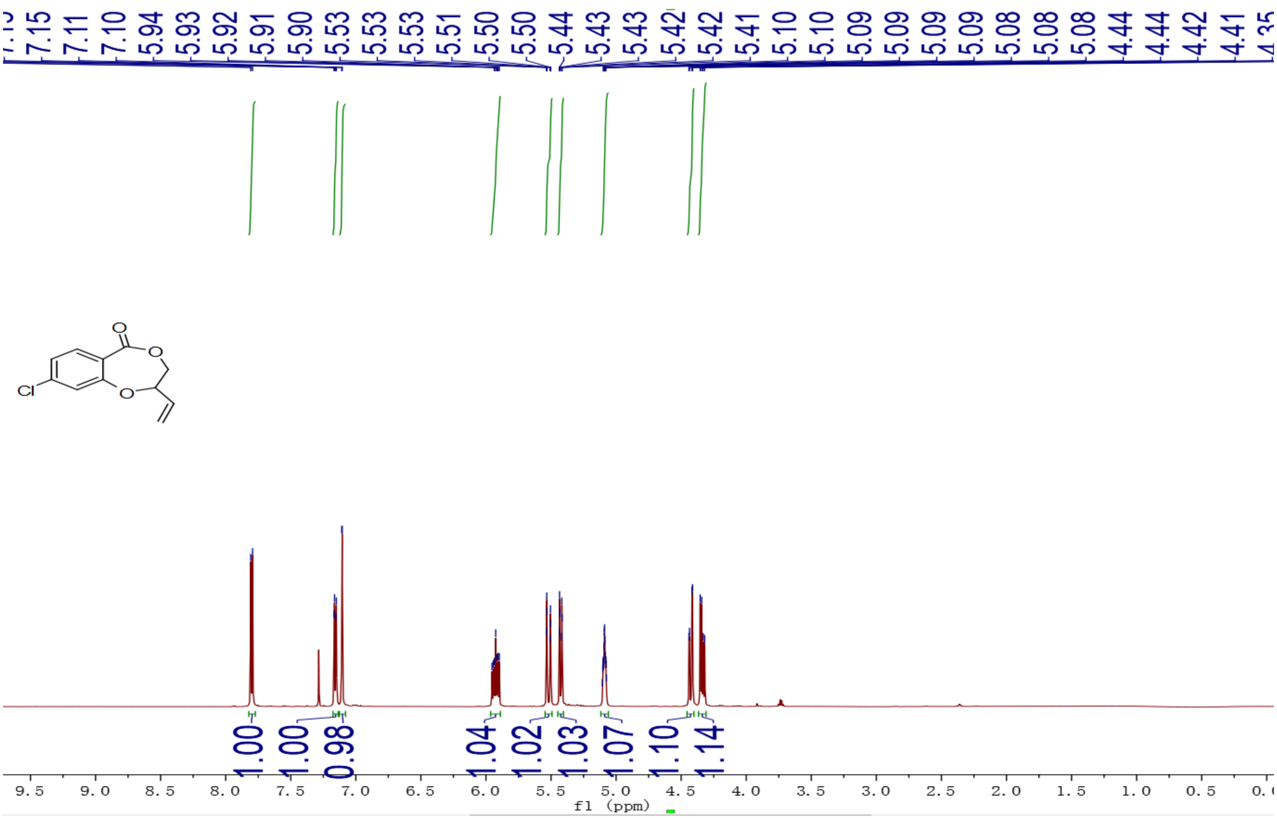


Figure 21. ^{13}C NMR (151 MHz, CDCl$_3$) spectrum of 2f

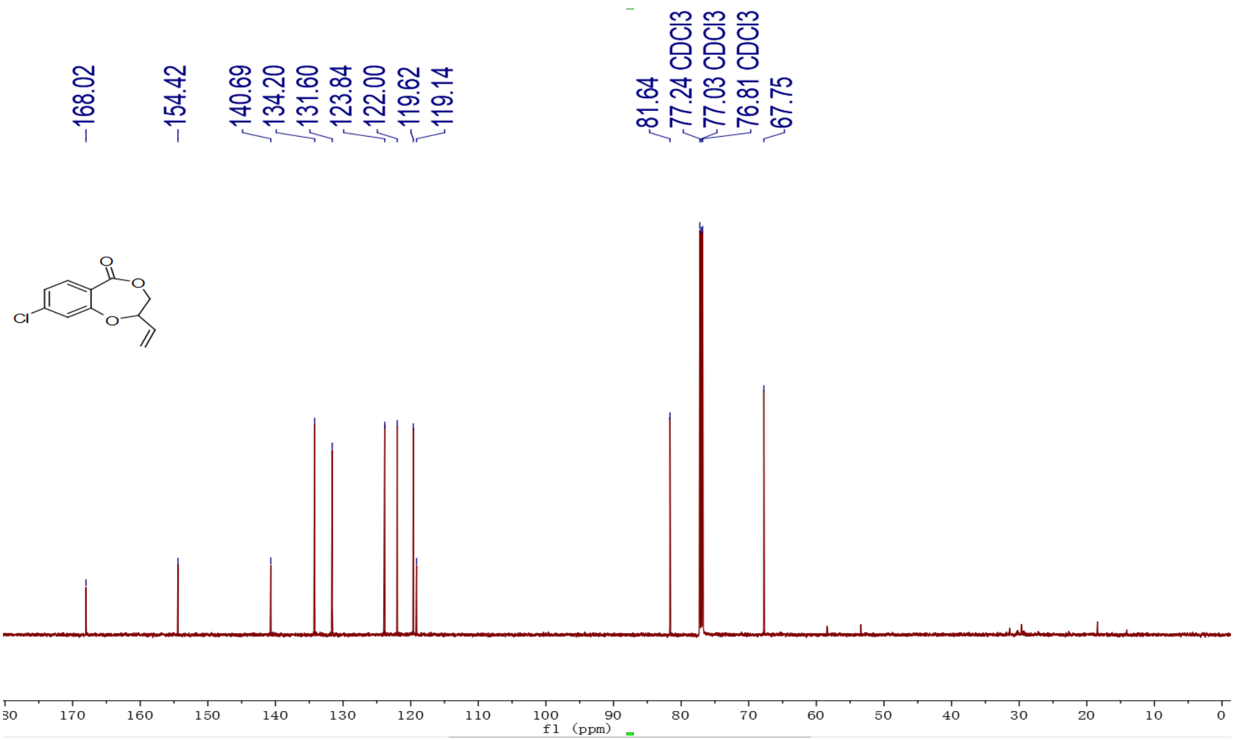


Figure 22. ^{1}H NMR (600 MHz, CDCl$_3$) spectrum of 2g

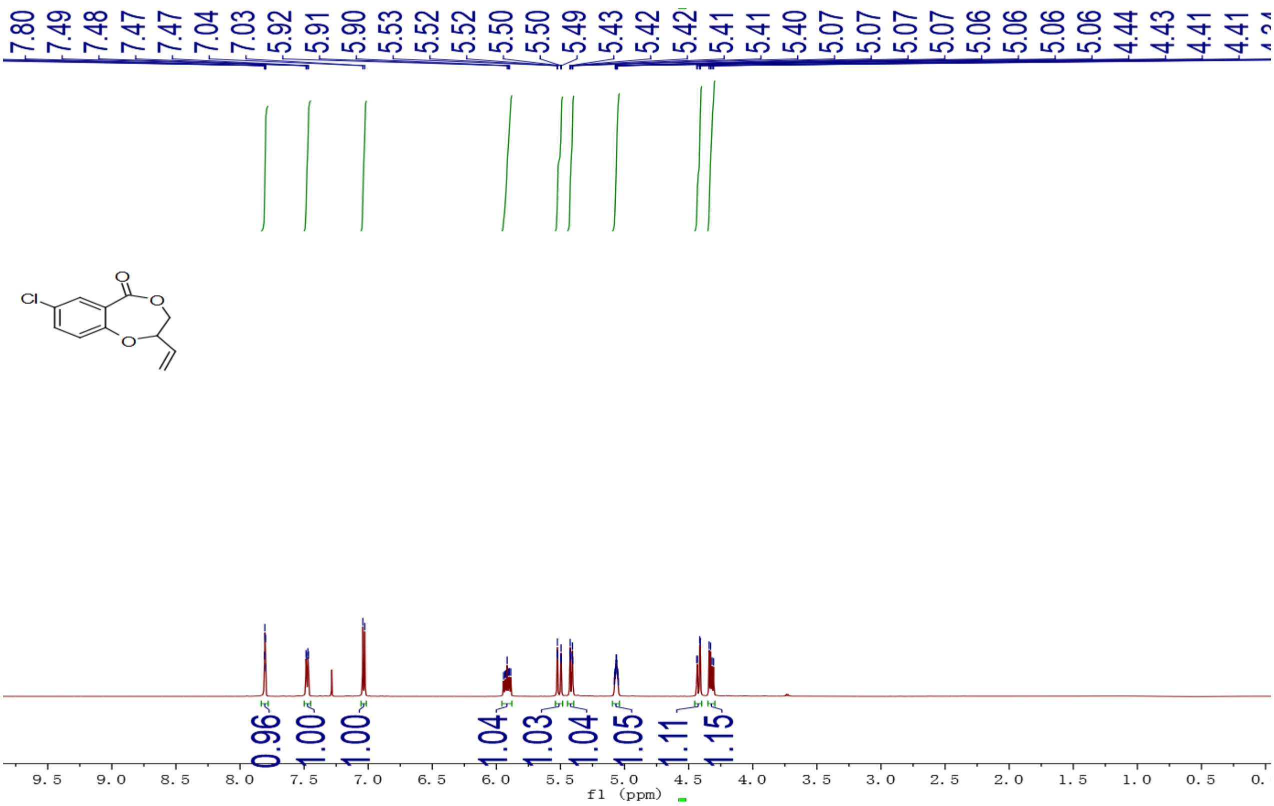


Figure 23. ^{13}**C NMR (151 MHz, CDCl**$_3$**) spectrum of 2g**

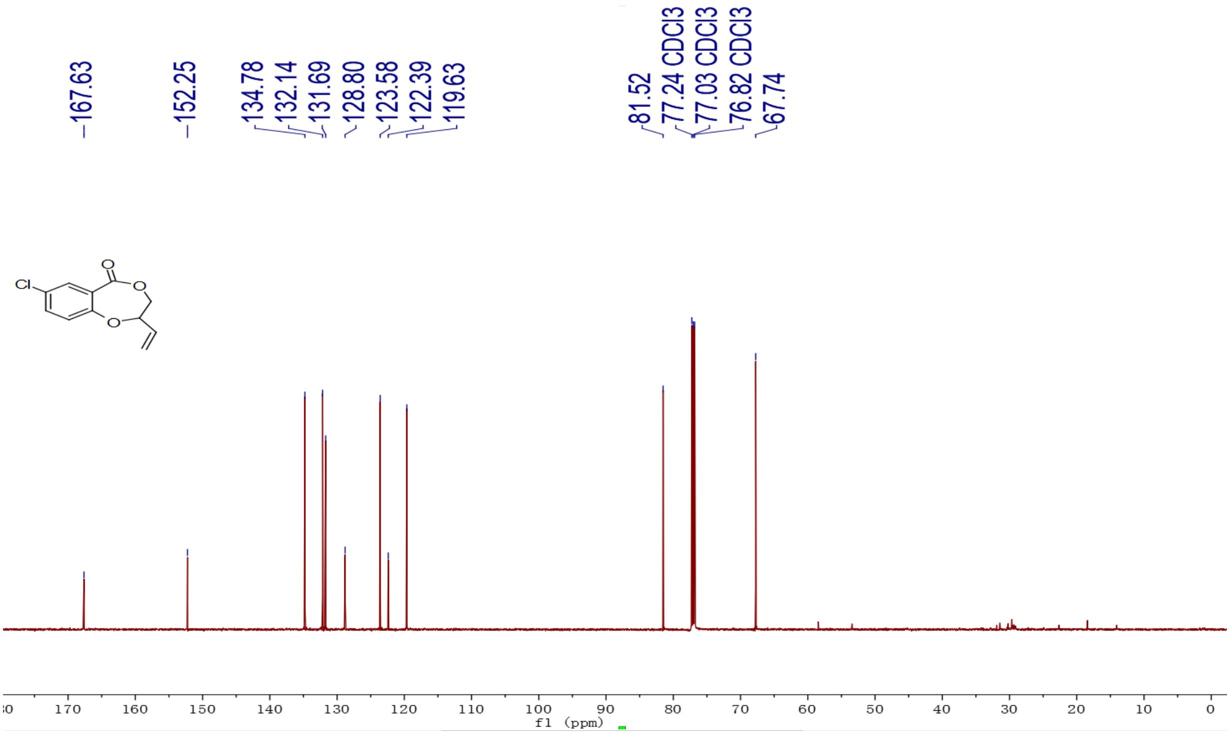


Figure 24. ^{1}**H NMR (600 MHz, CDCl**$_3$**) spectrum of 2h**

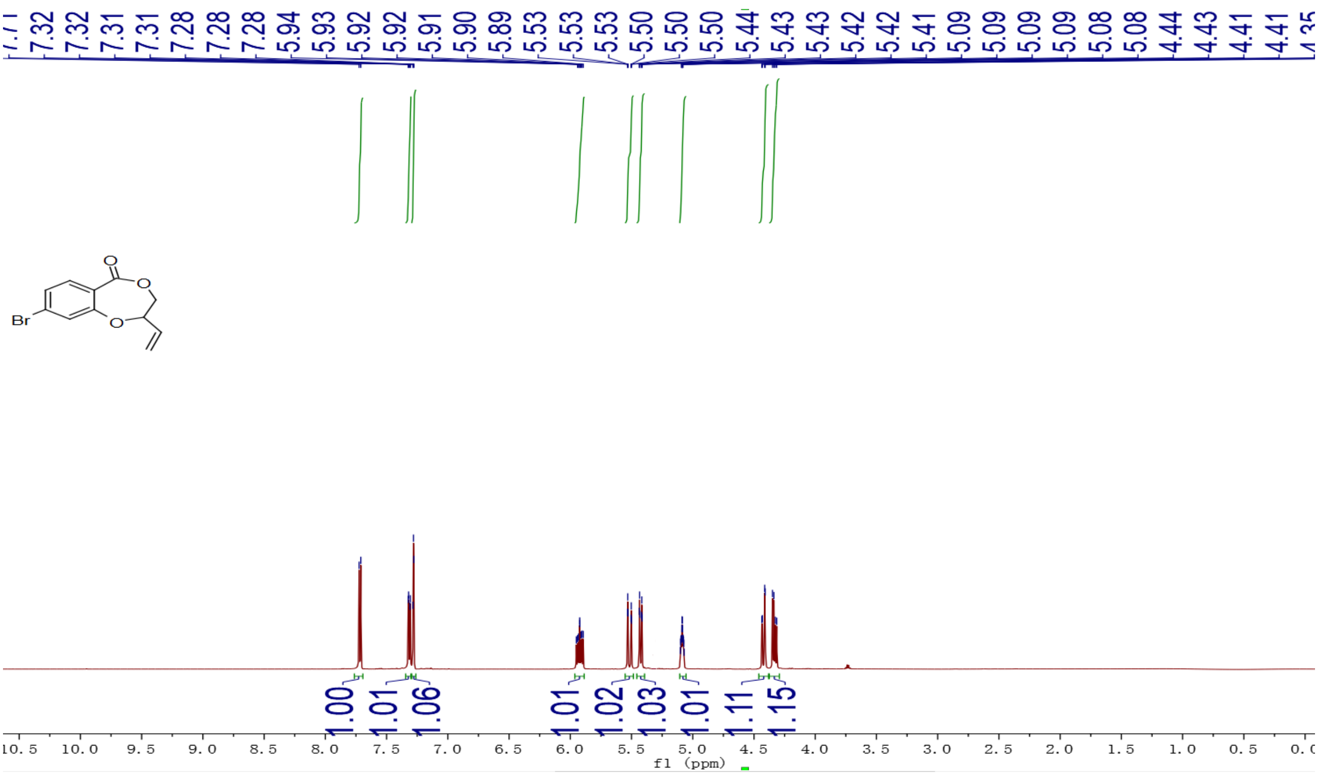


Figure 25. ^{13}C NMR (151 MHz, $CDCl_3$) spectrum of 2h

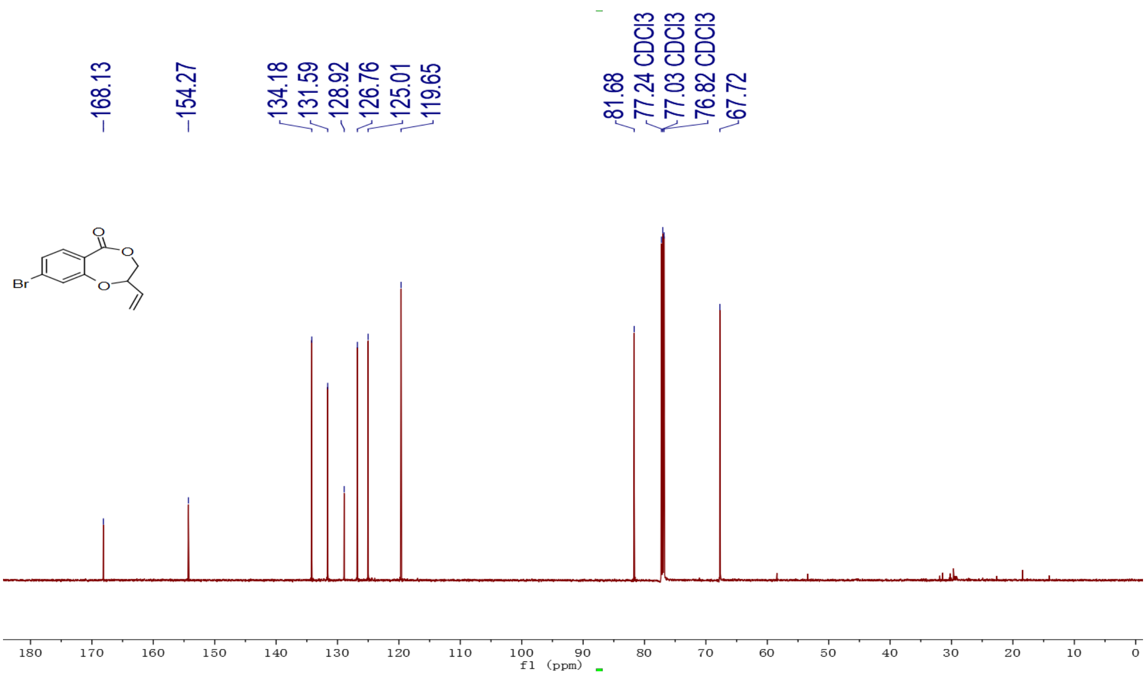


Figure 26. ^{1}H NMR (600 MHz, $CDCl_3$) spectrum of 2i

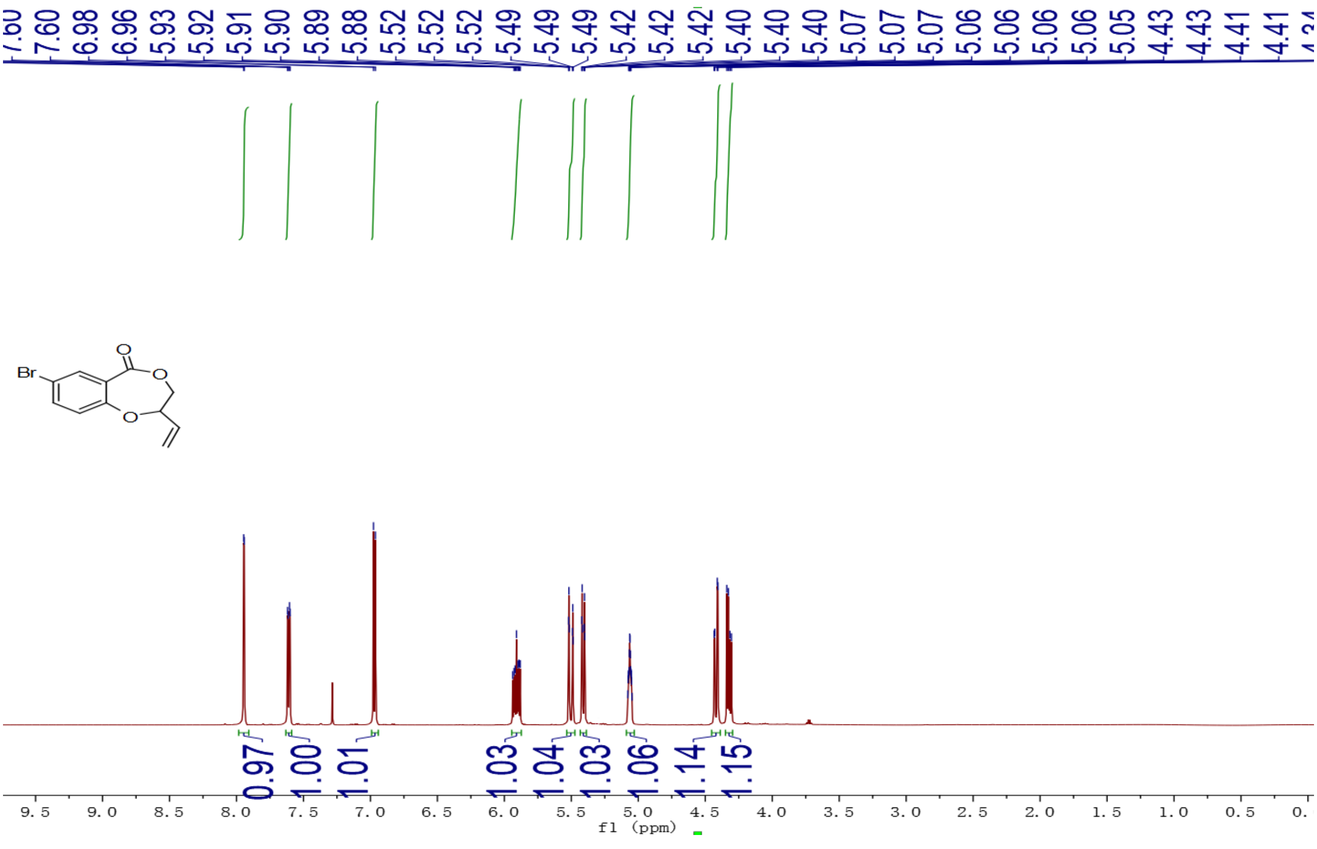


Figure 27. ^{13}C **NMR (151 MHz, CDCl$_3$) spectrum of 2i**

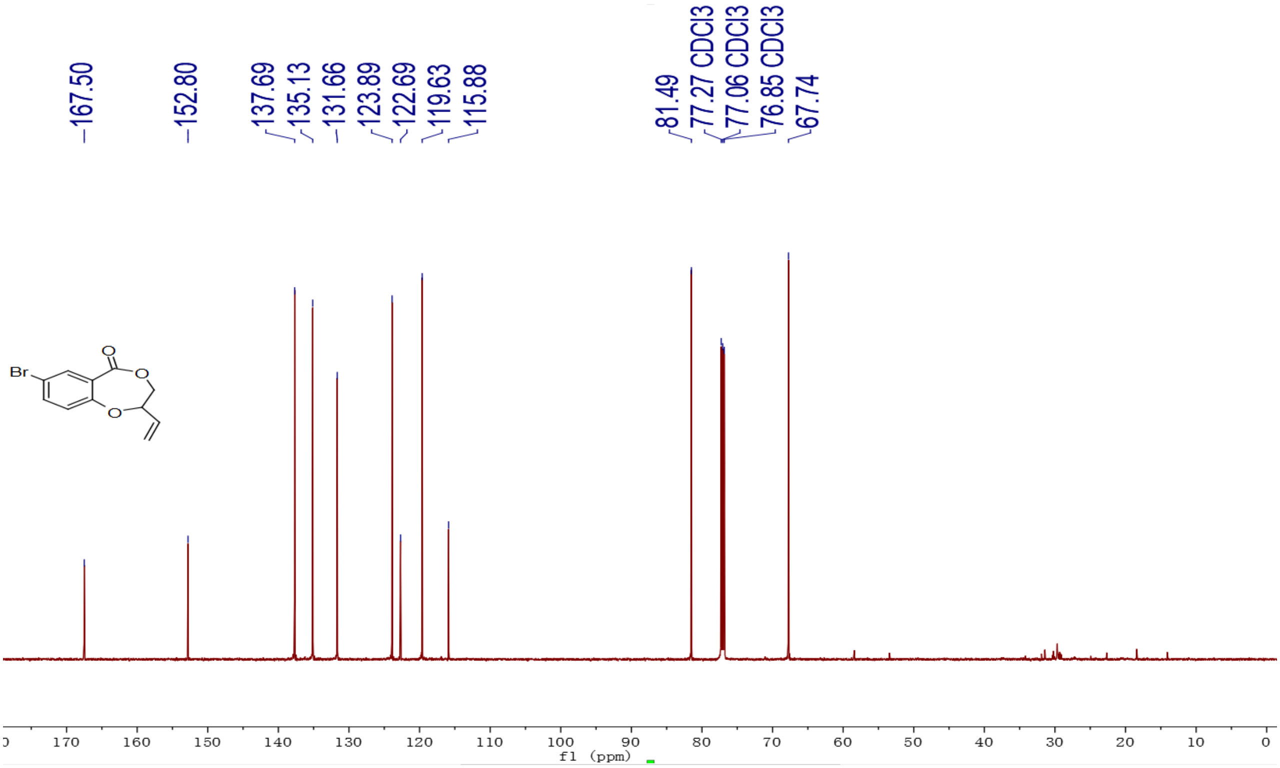


Figure 28. ^{1}H **NMR (600 MHz, CDCl$_3$) spectrum of 2j**

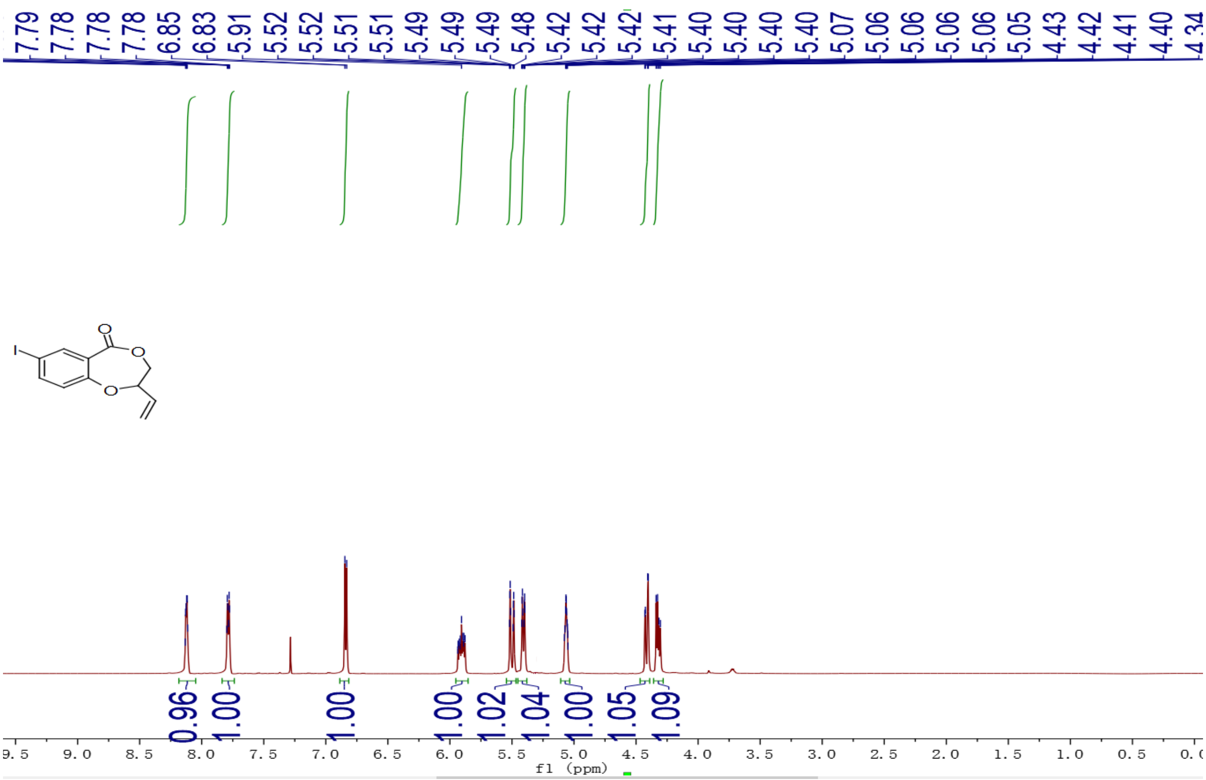


Figure 29. [13]C NMR (151 MHz, CDCl₃) spectrum of 2j

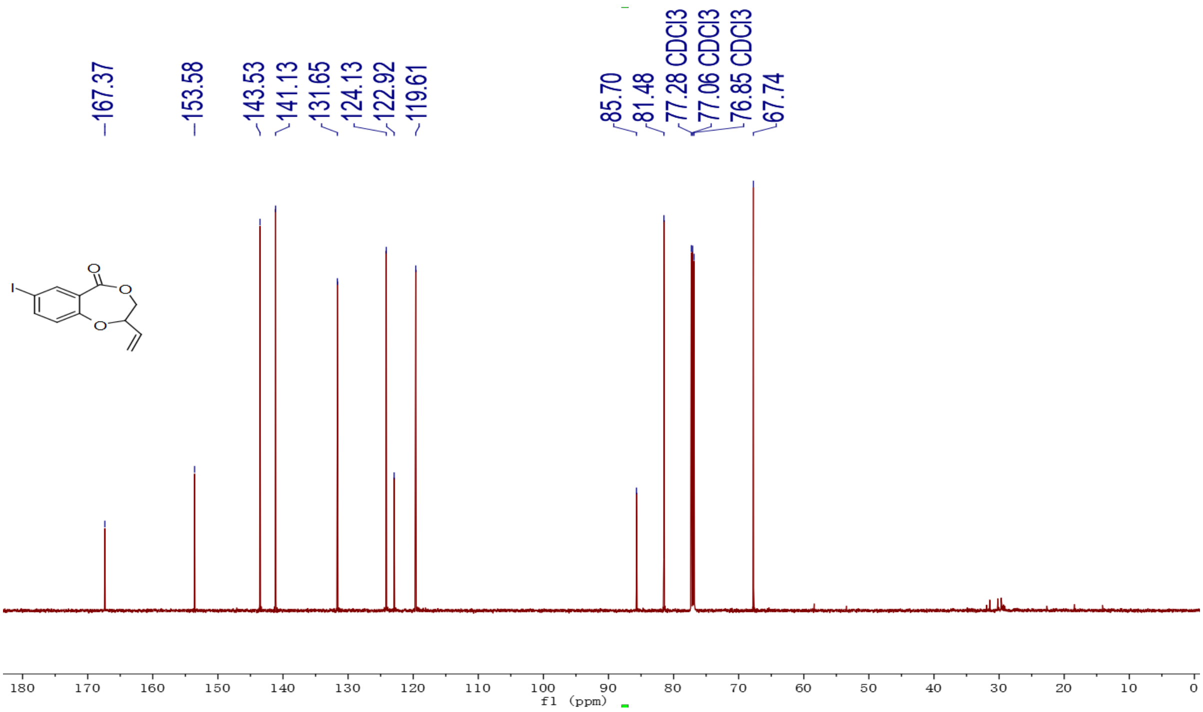


Figure 30. [1]H NMR (600 MHz, CDCl₃) spectrum of 2k

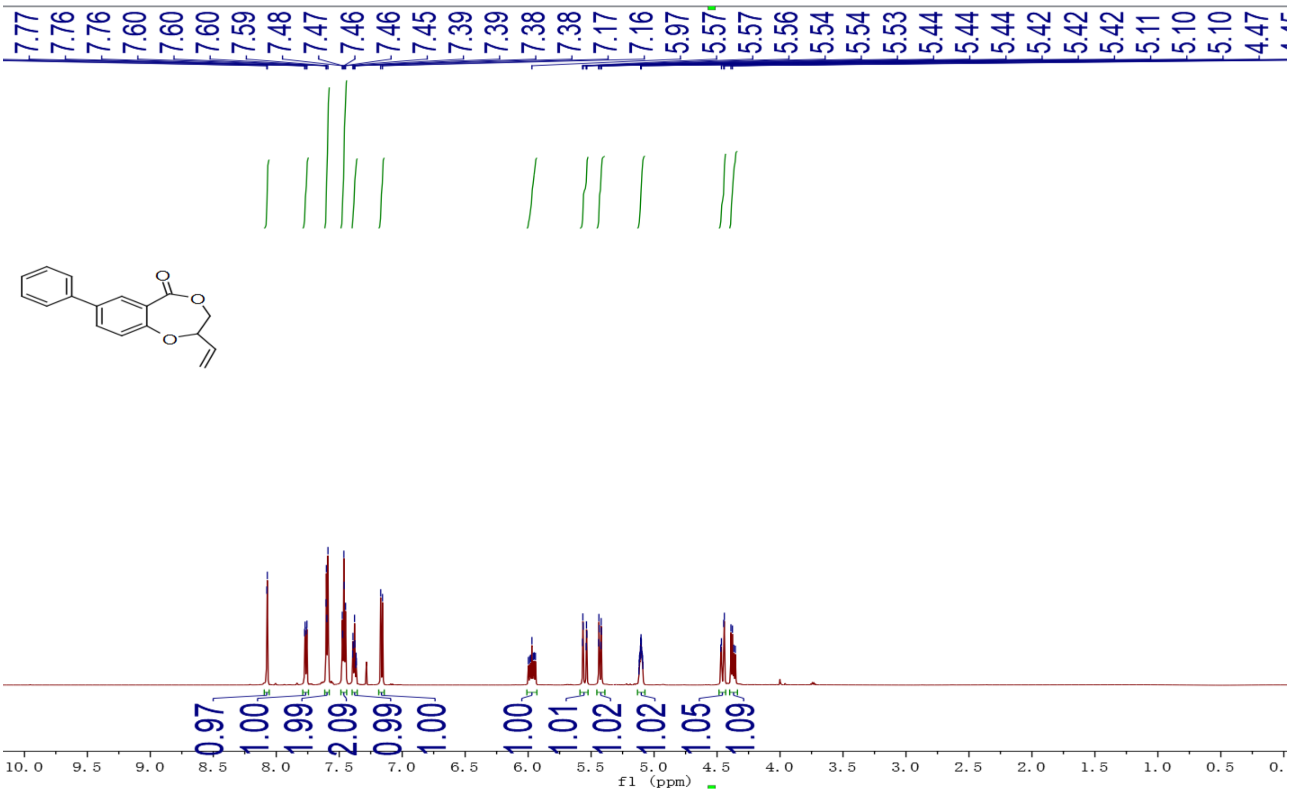


Figure 31. ^{13}C NMR (151 MHz, CDCl$_3$) spectrum of 2k

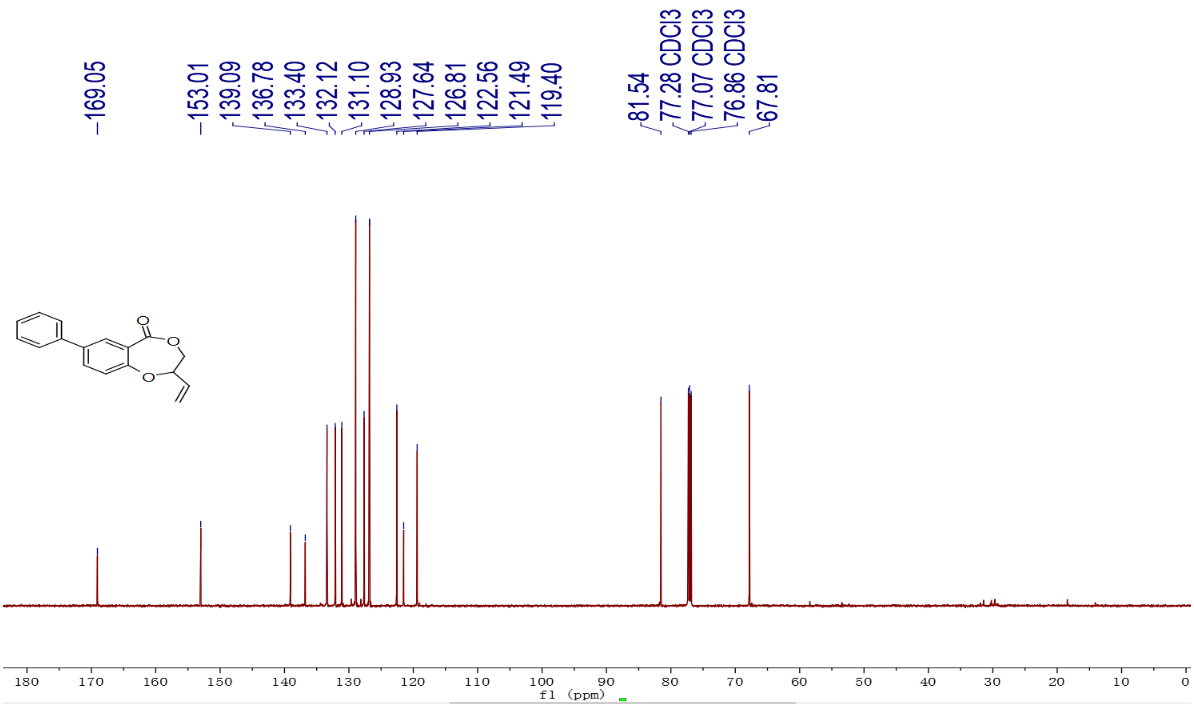


Figure 32. ^{1}H NMR (600 MHz, CDCl$_3$) spectrum of 2l

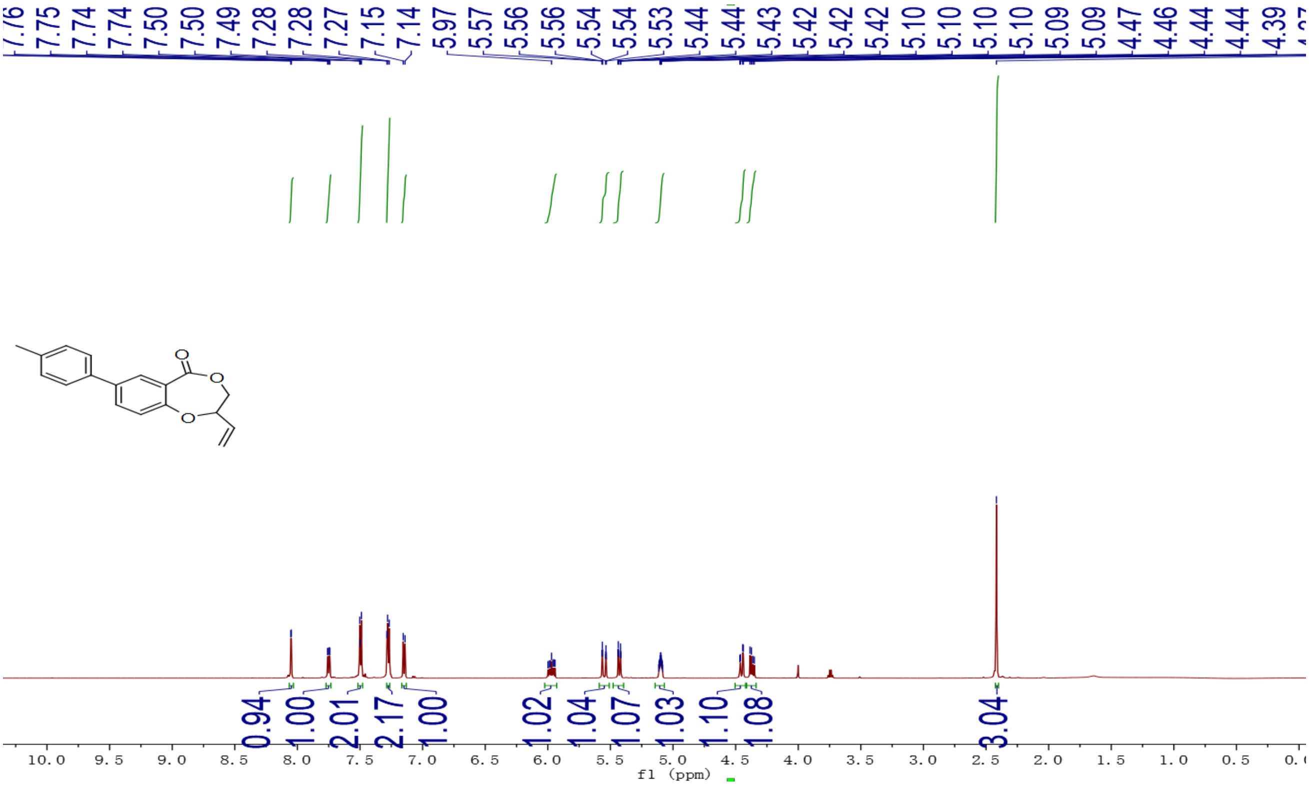


Figure 33. ^{13}C NMR (151 MHz, $CDCl_3$) spectrum of 2l

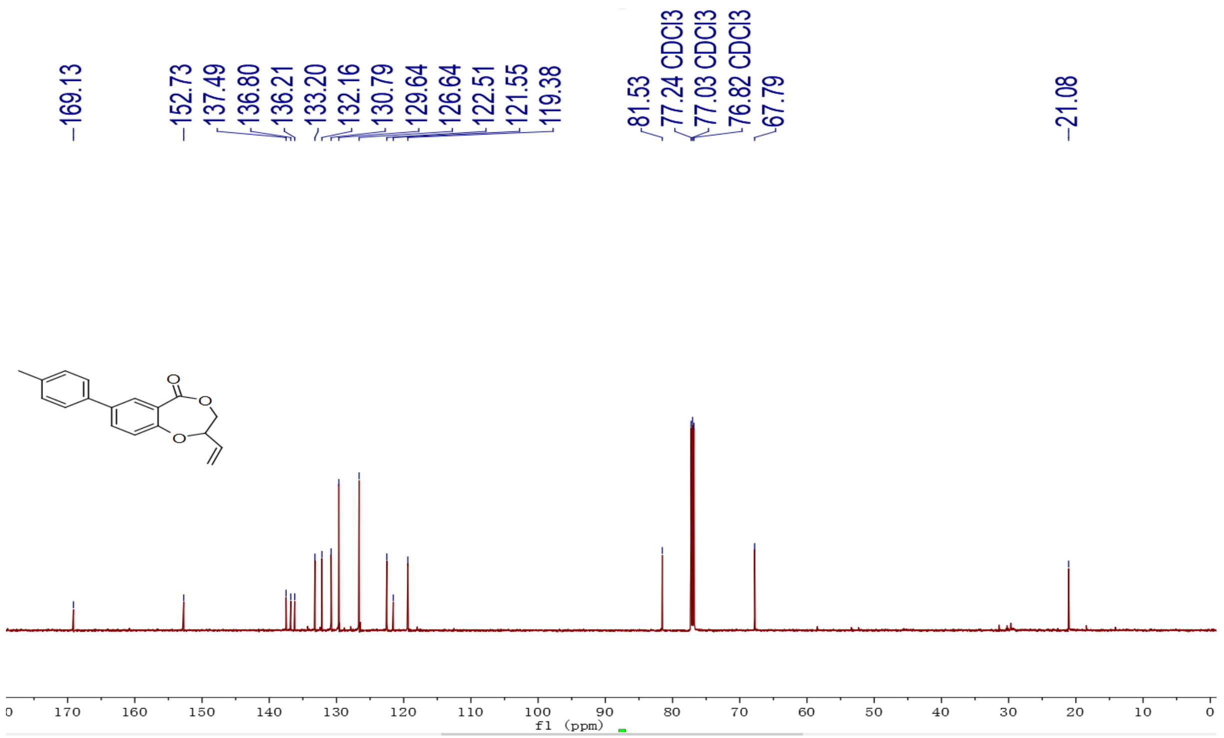


Figure 34. ^{1}H NMR (600 MHz, $CDCl_3$) spectrum of 2m

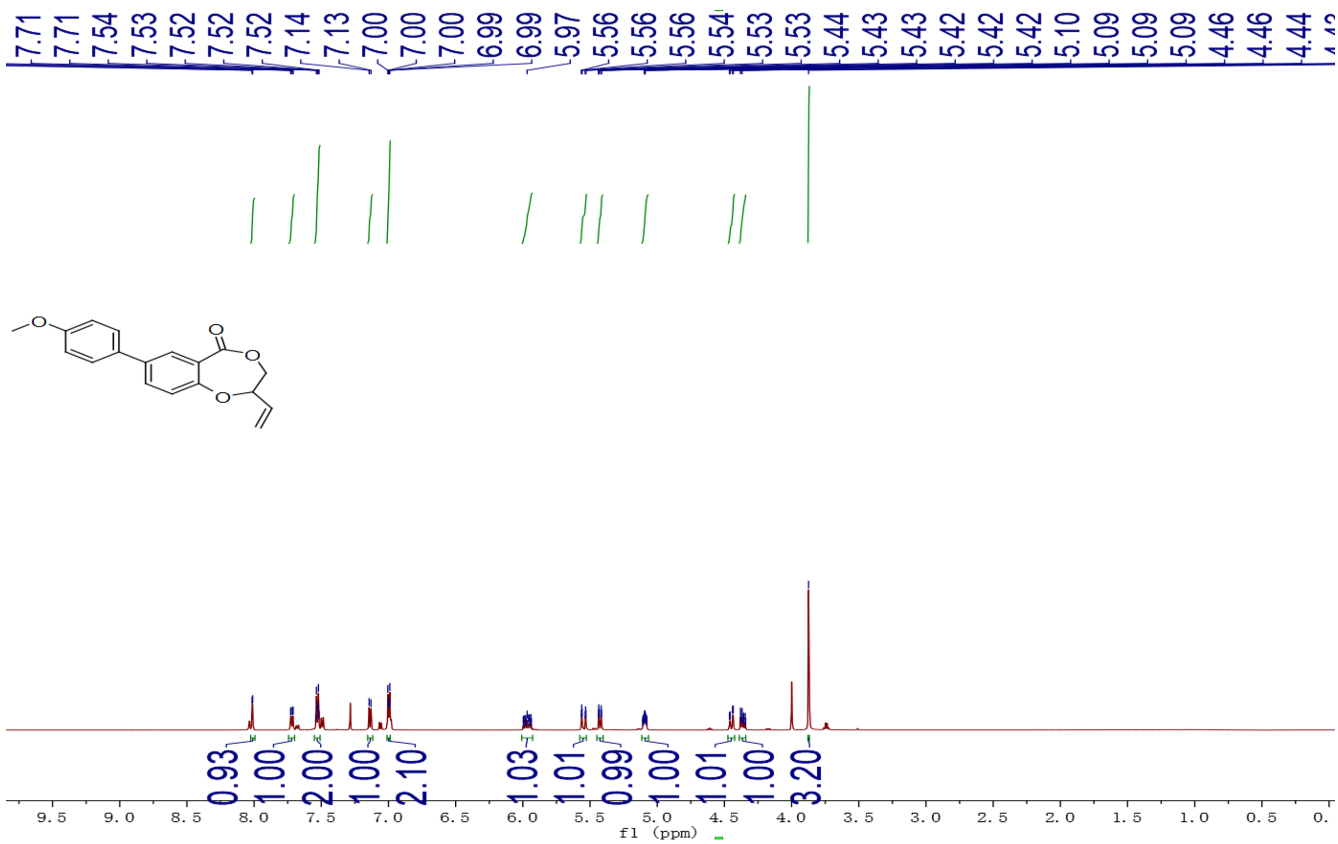


Figure 35. **^{13}C NMR (151 MHz, CDCl$_3$) spectrum of 2m**

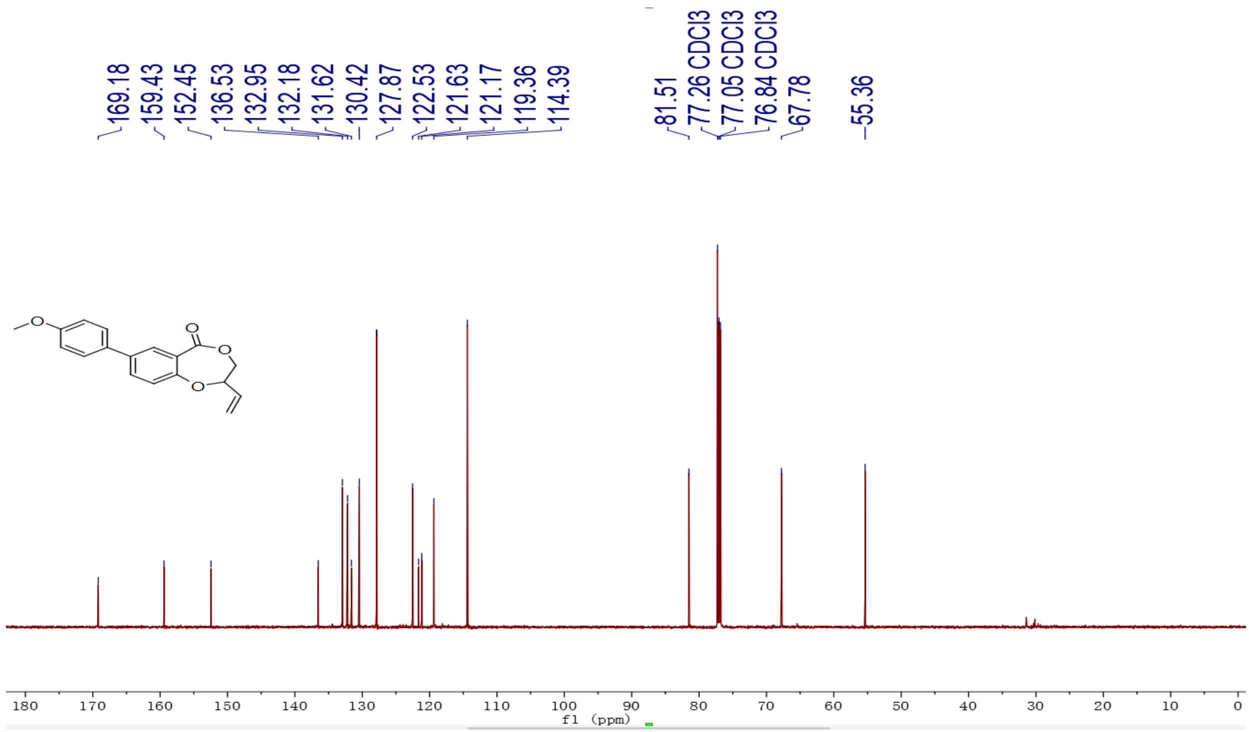


Figure 36. **^{1}H NMR (600 MHz, CDCl$_3$) spectrum of 2n**

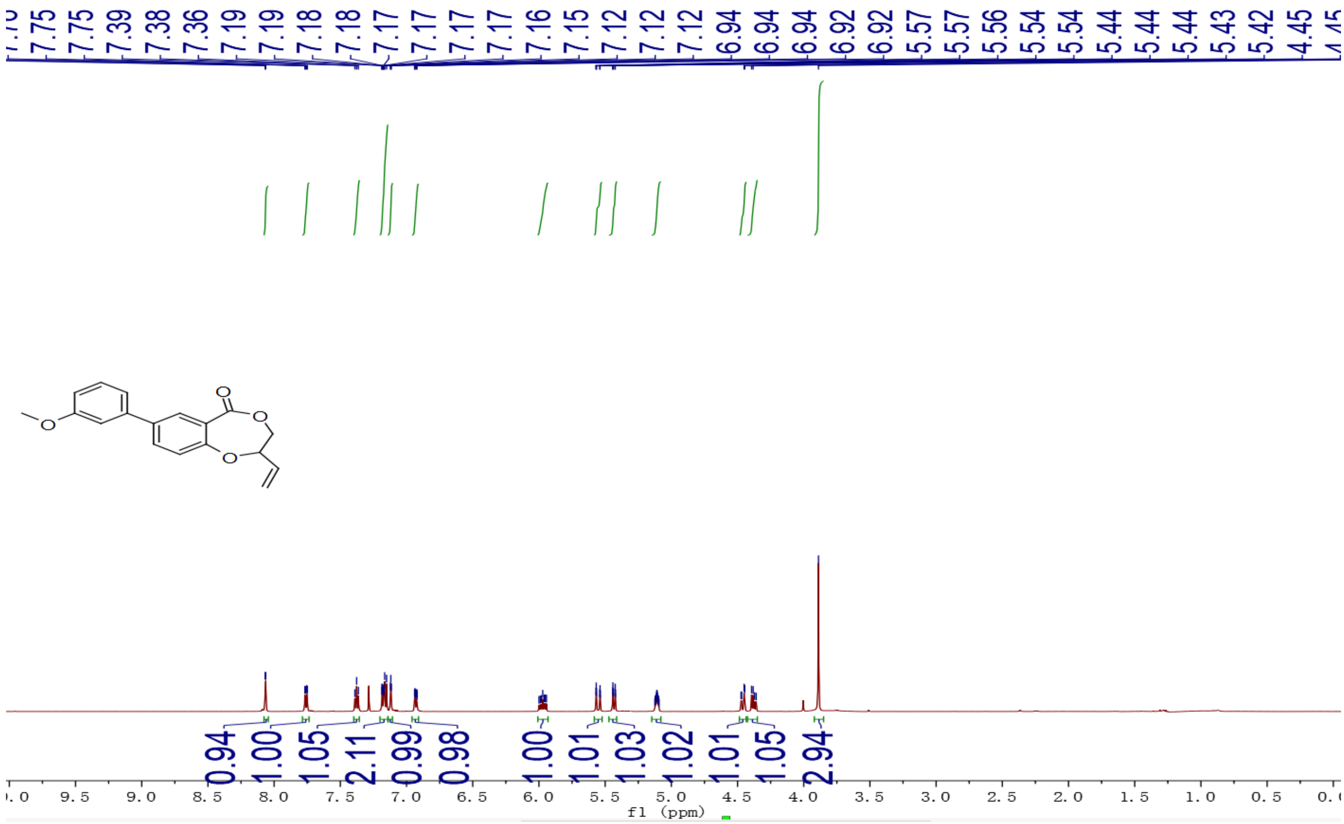


Figure 37. ^{13}C NMR (151 MHz, CDCl$_3$) spectrum of 2n

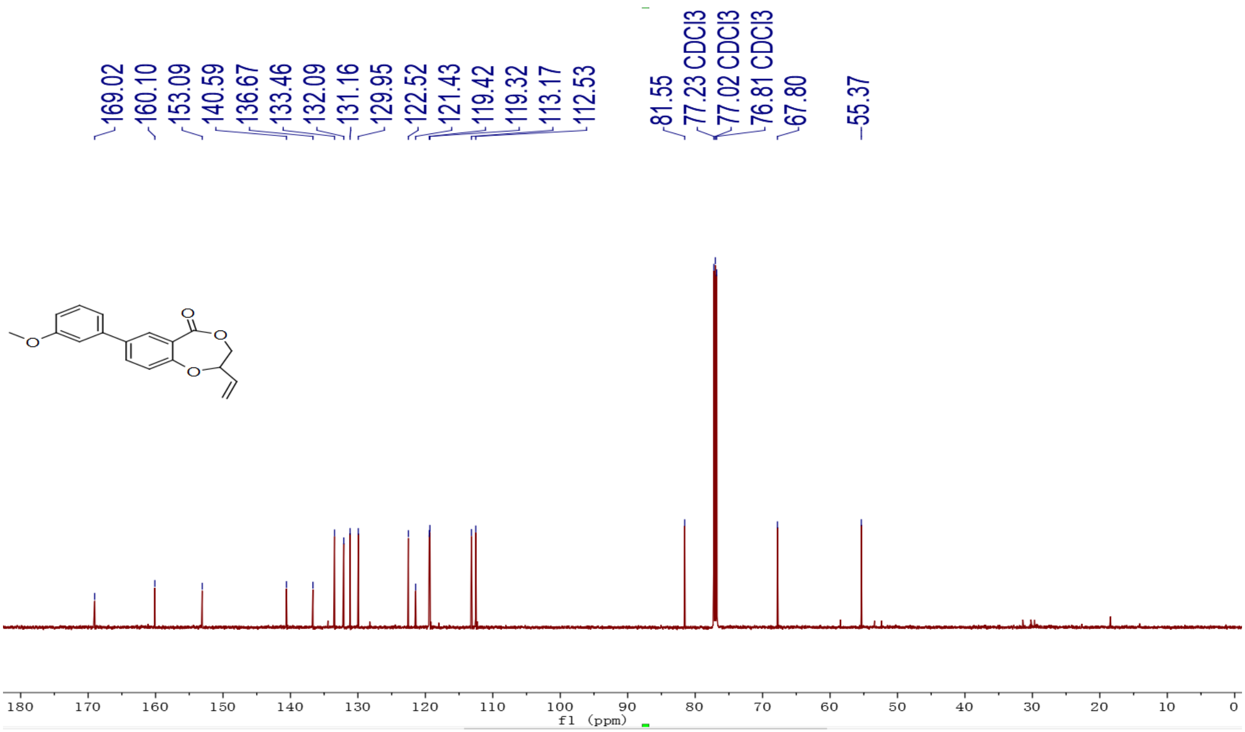


Figure 38. ^{1}H NMR (600 MHz, CDCl$_3$) spectrum of 2o

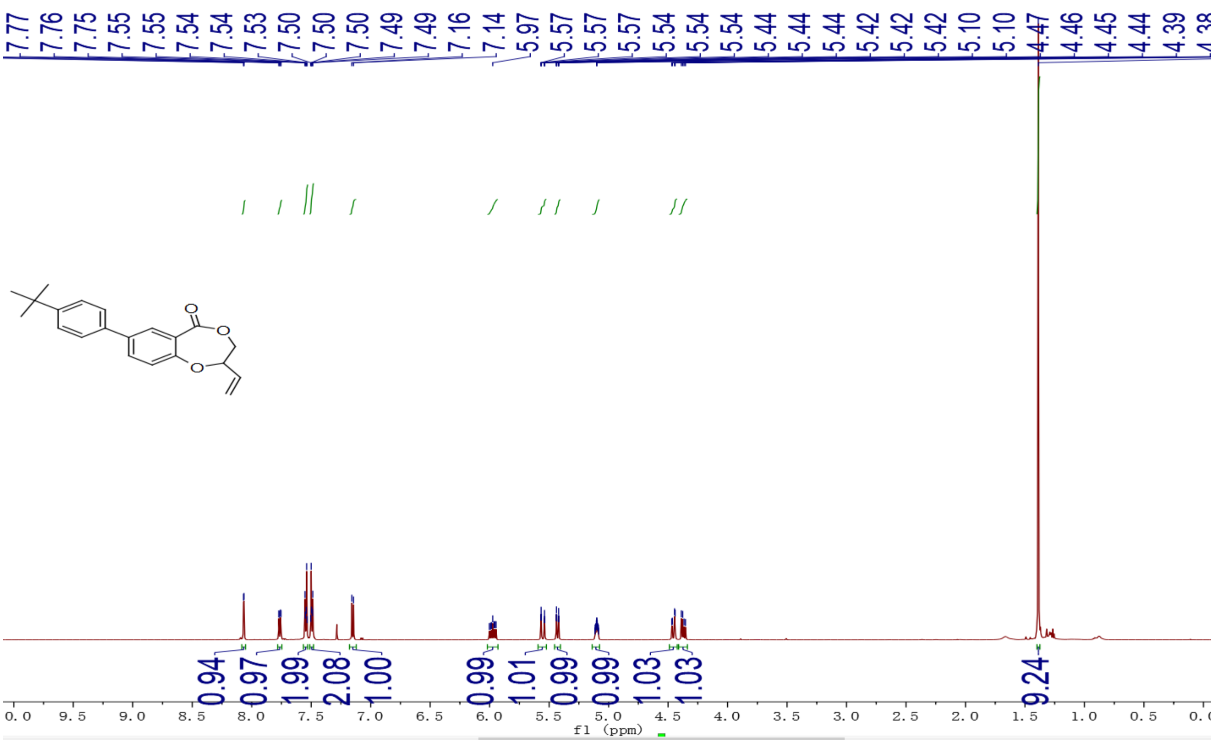


Figure 39. ^{13}C **NMR (151 MHz, CDCl$_3$) spectrum of 2o**

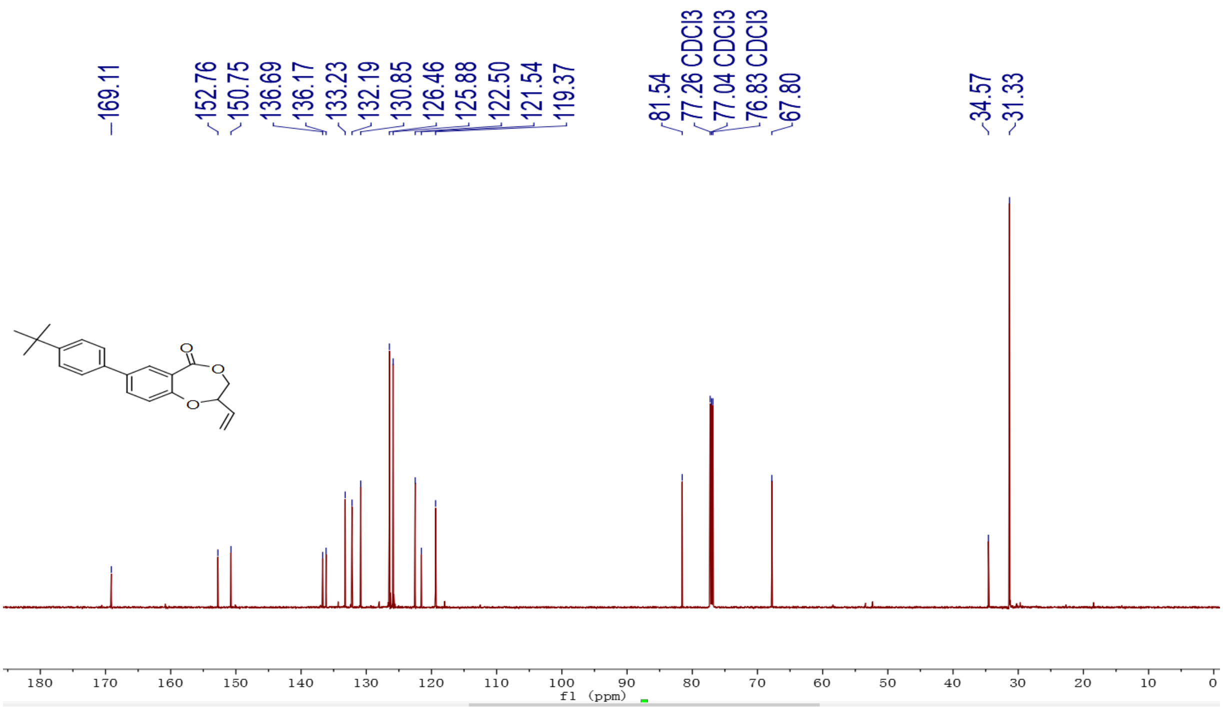


Figure 40. ^{1}H **NMR (600 MHz, CDCl$_3$) spectrum of 2p**

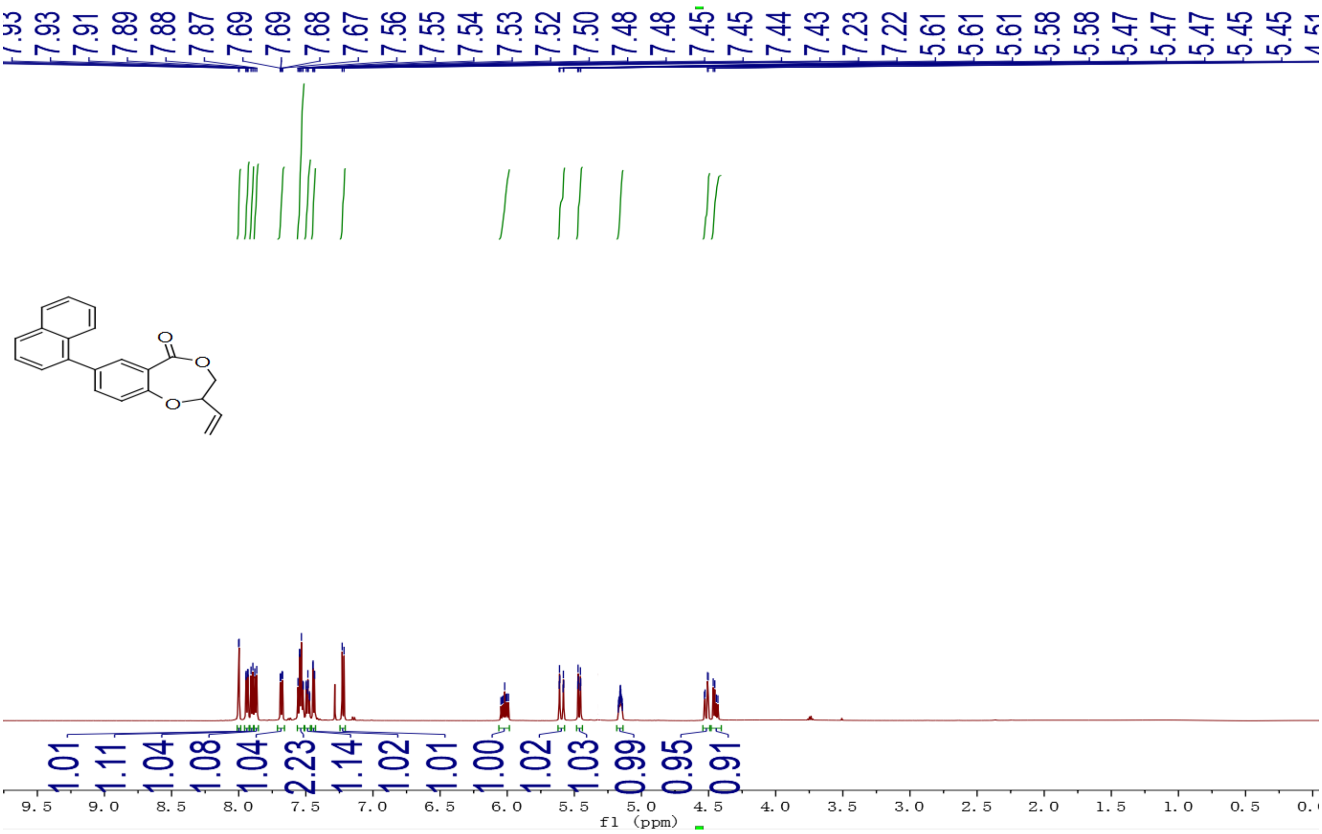


Figure 41. ^{13}C **NMR (151 MHz, CDCl$_3$) spectrum of 2p**

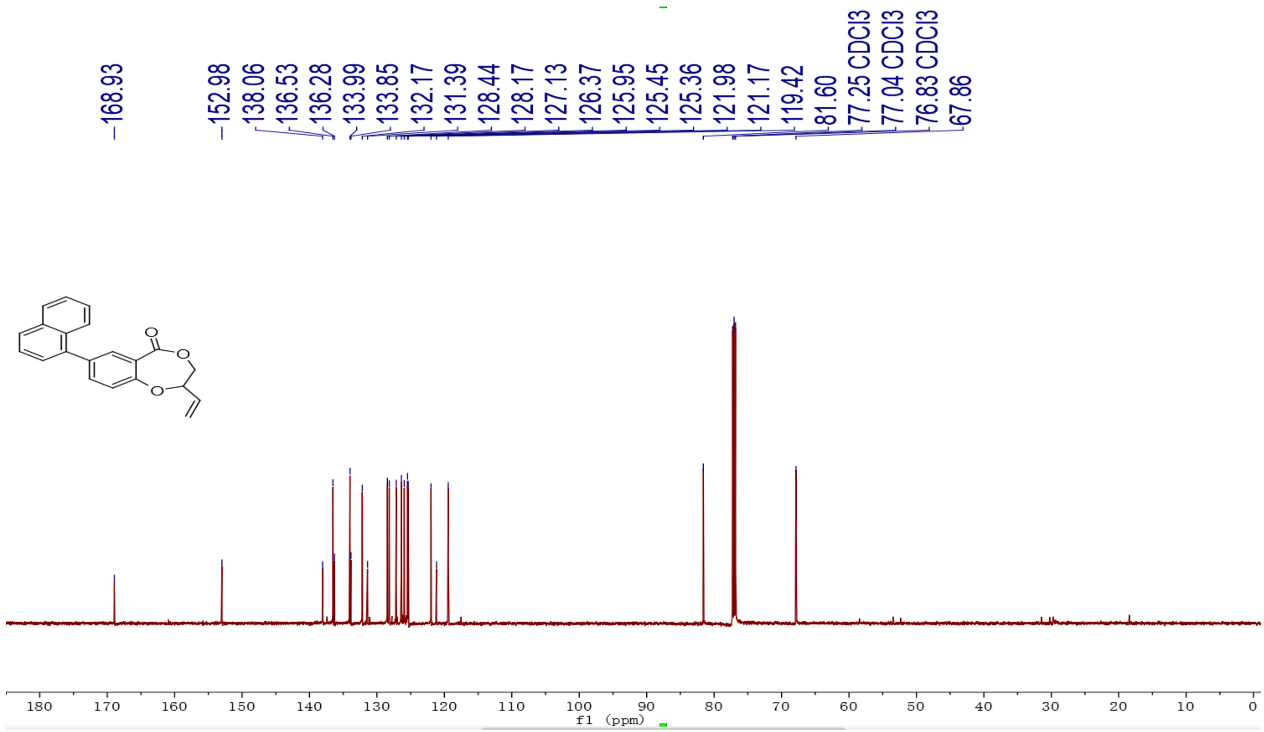


Figure 42. ^{1}H **NMR (600 MHz, CDCl$_3$) spectrum of 2q**

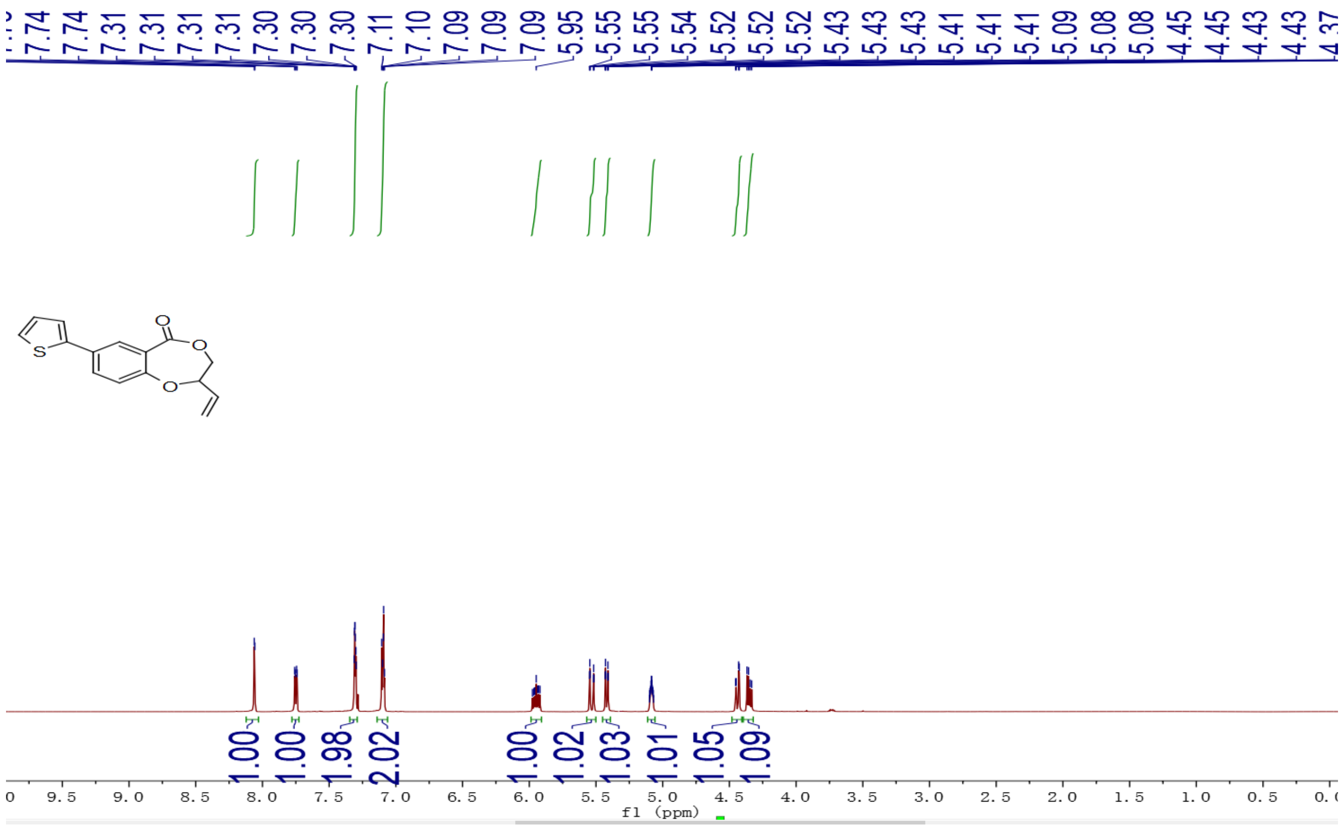


Figure 43. ^{13}C NMR (151 MHz, CDCl₃) spectrum of 2q

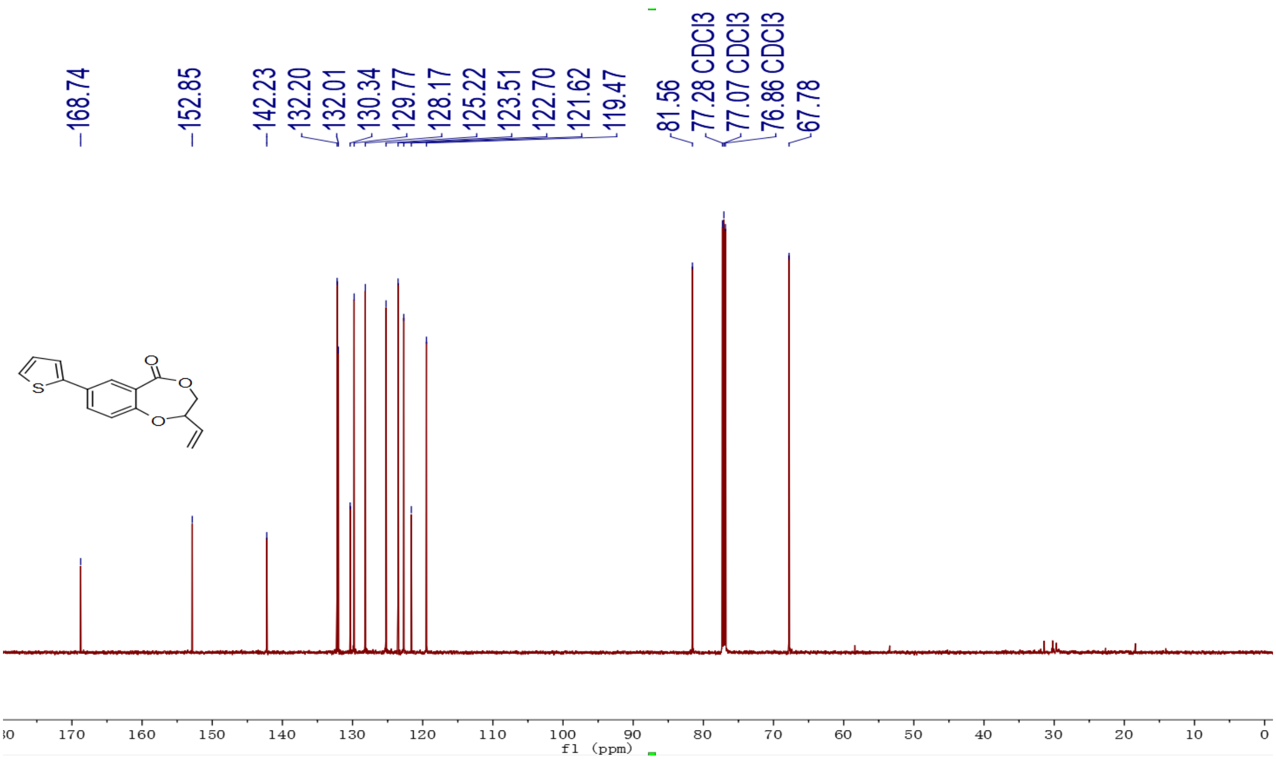


Figure 44. ^{1}H NMR (600 MHz, CDCl₃) spectrum of 2r

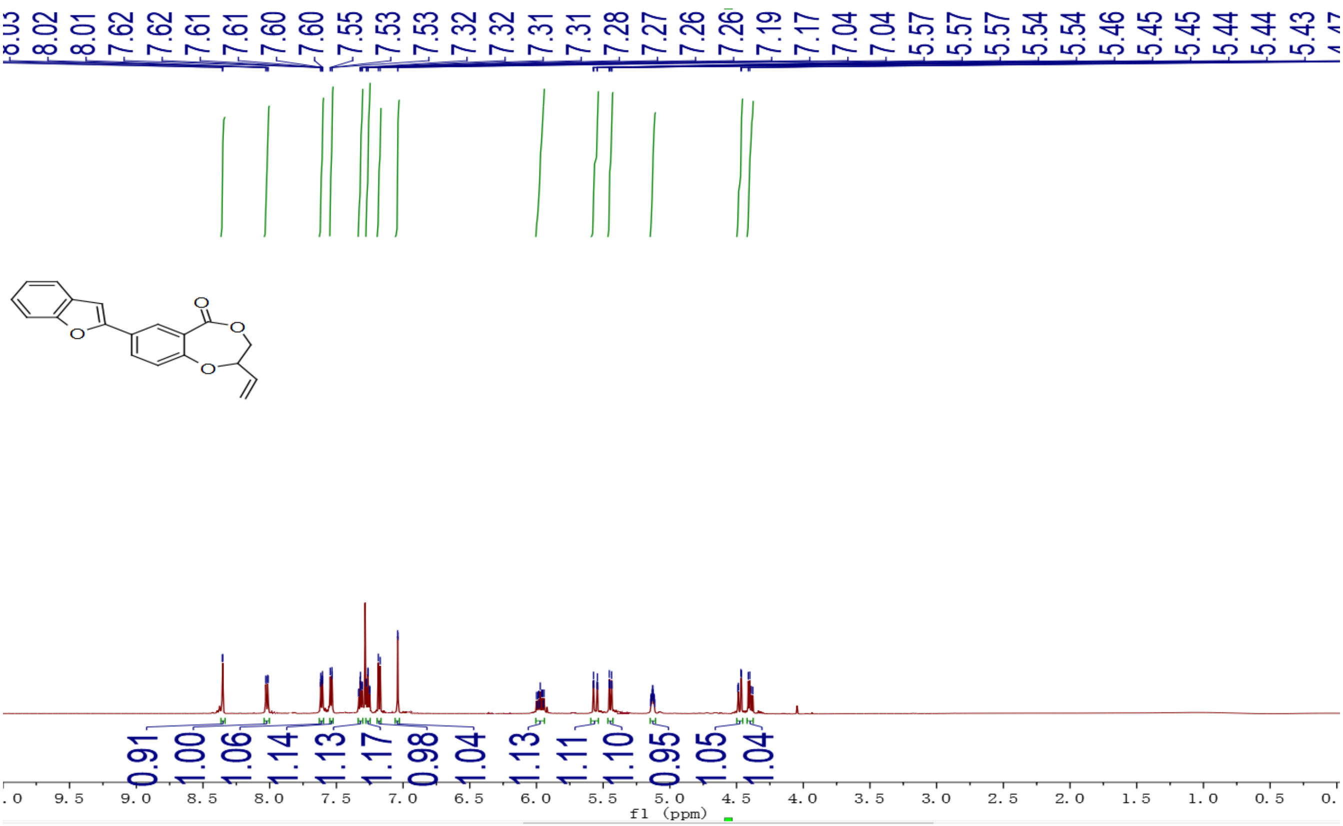


Figure 45. ^{13}C NMR (151 MHz, $CDCl_3$) spectrum of 2r

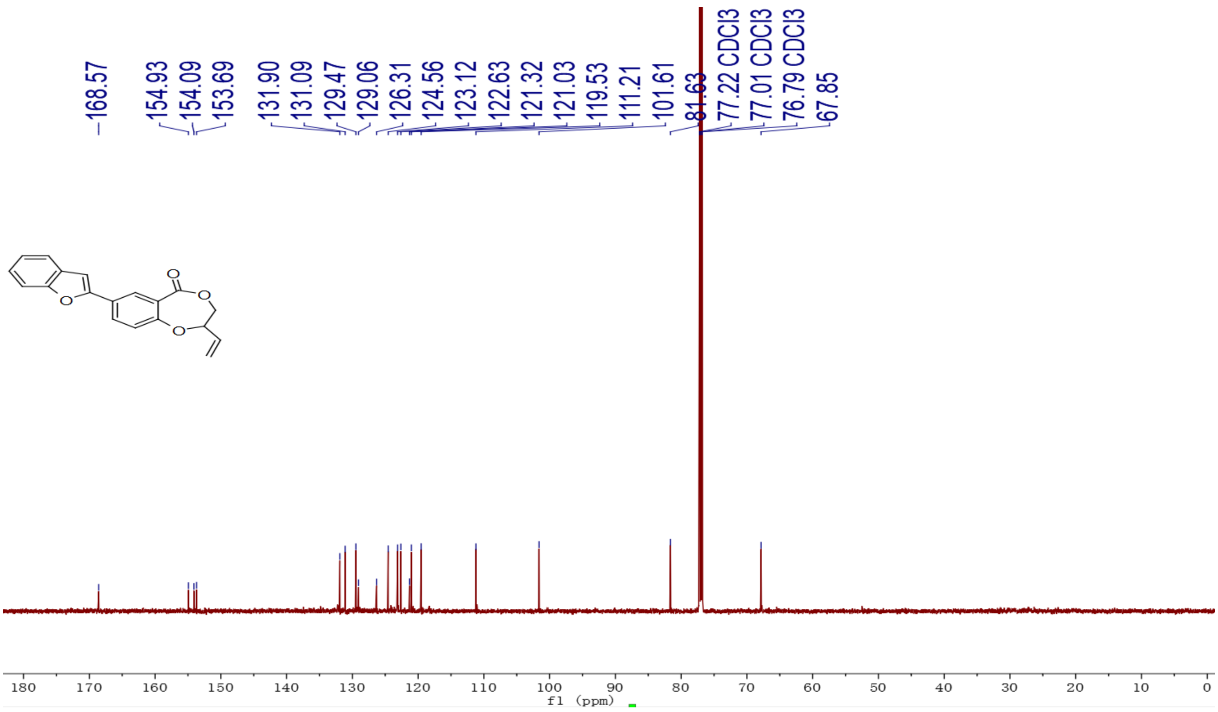


Figure 46. ^{1}H NMR (600 MHz, $CDCl_3$) spectrum of 2s

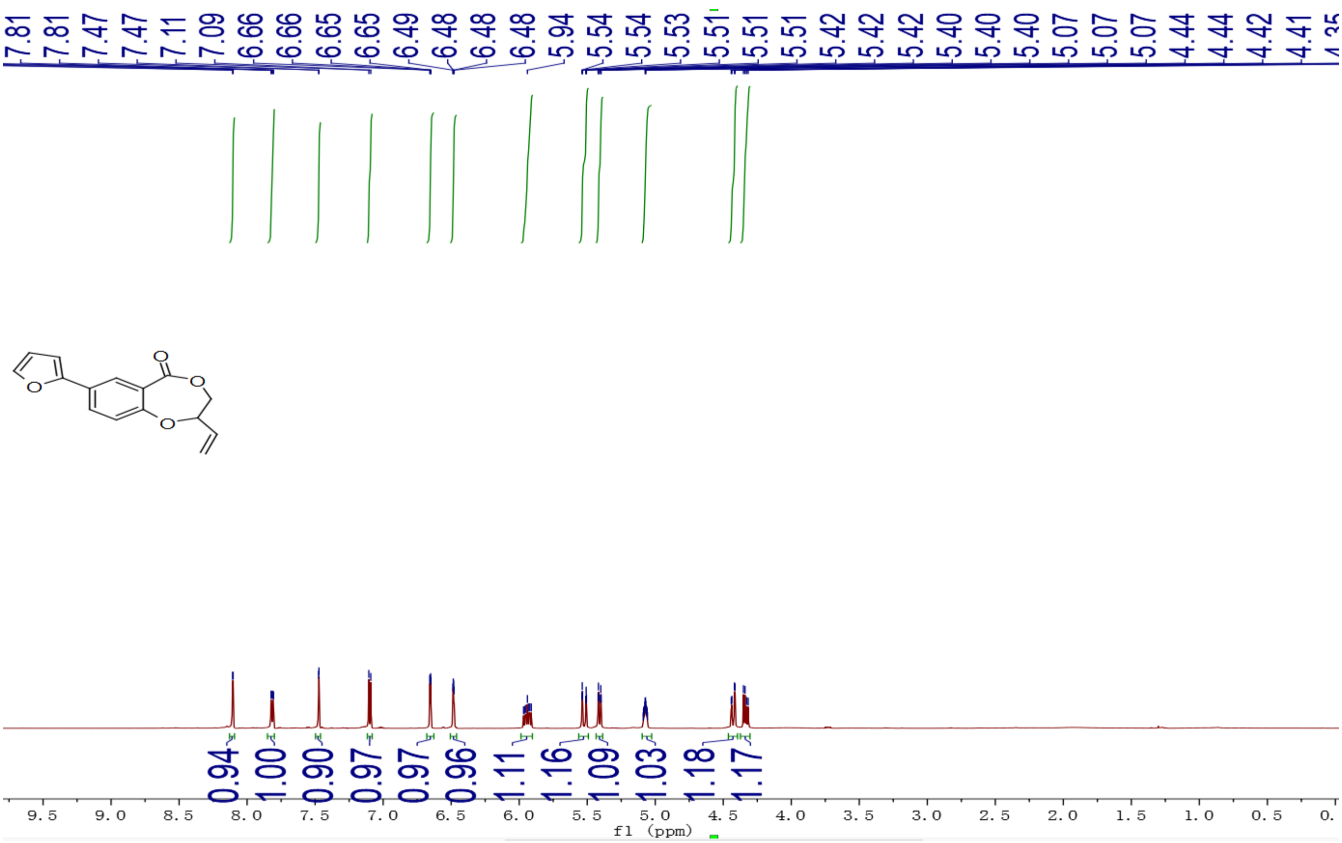


Figure 47. ^{13}C NMR (151 MHz, $CDCl_3$) spectrum of 2s

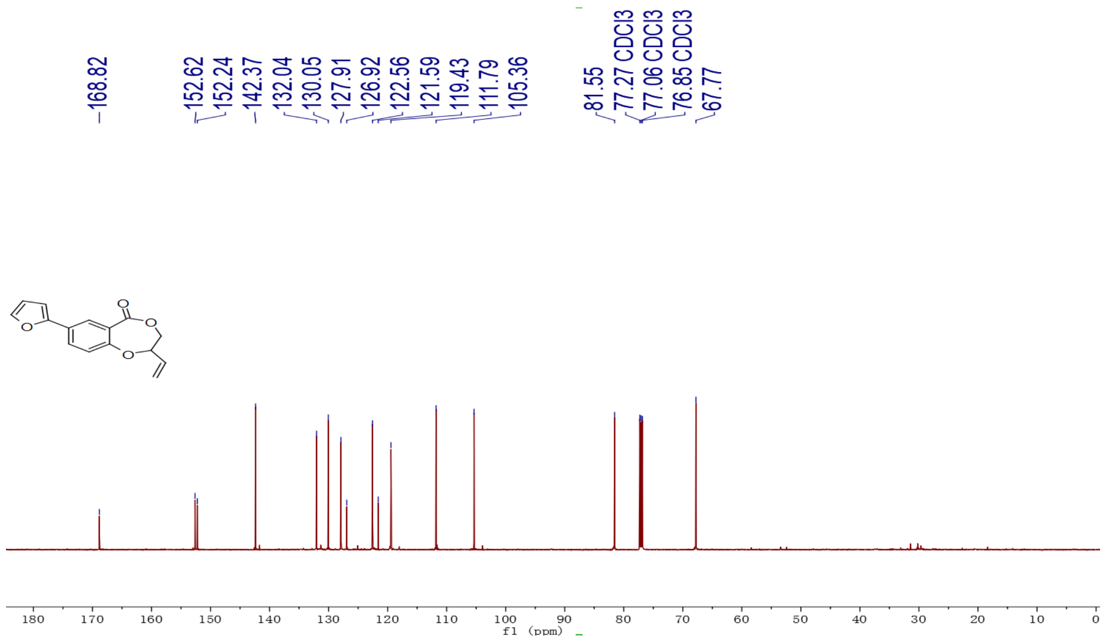


Figure 48. ^{1}H NMR (600 MHz, $CDCl_3$) spectrum of 2t

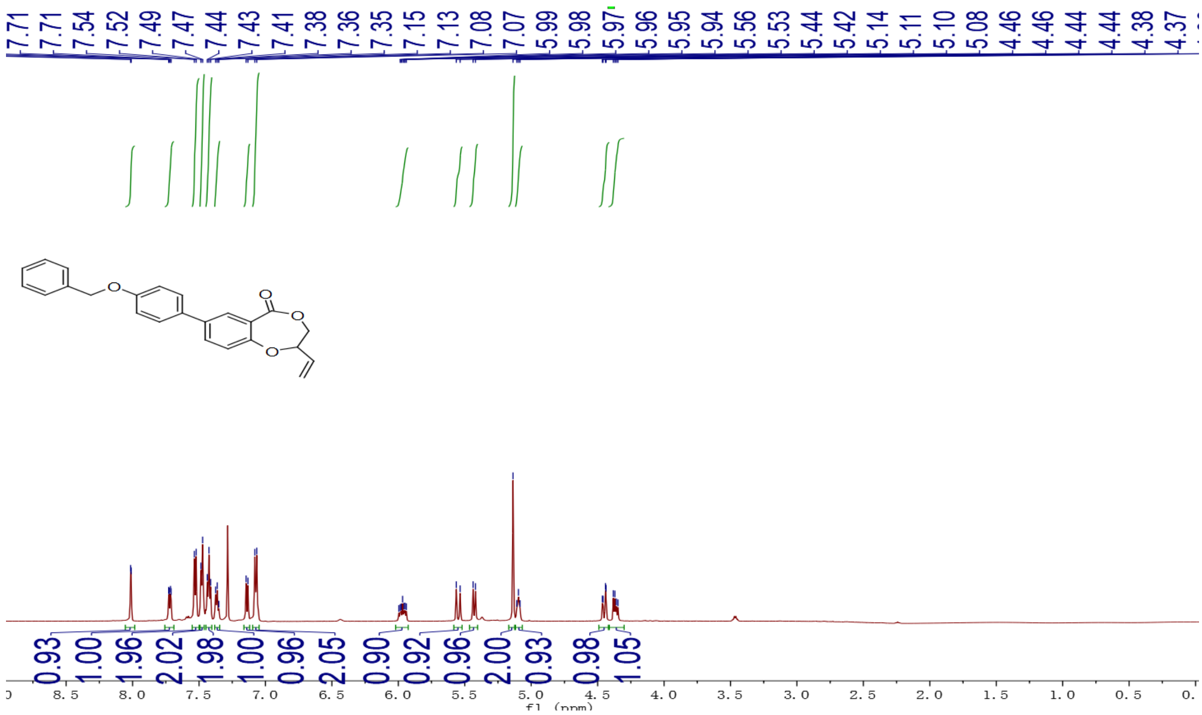


Figure 49. ^{13}**C NMR (151 MHz, CDCl**$_3$**) spectrum of 2t**

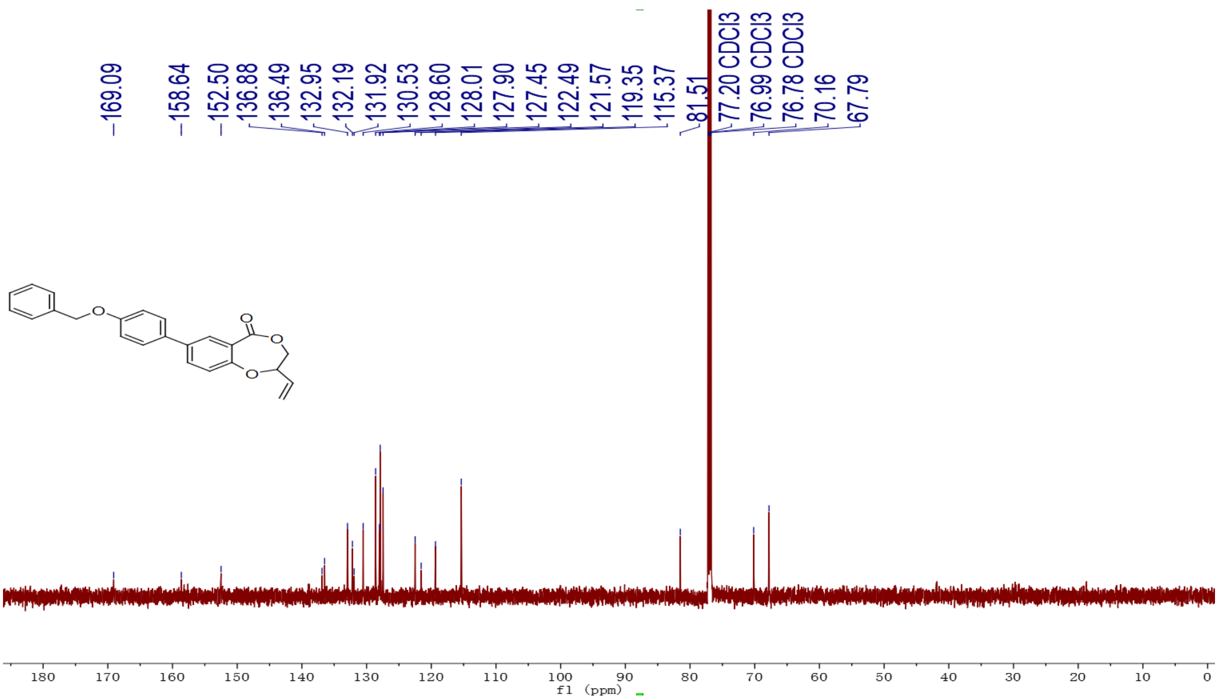


Figure 50. ^{1}**H NMR (600 MHz, CDCl**$_3$**) spectrum of 2u**

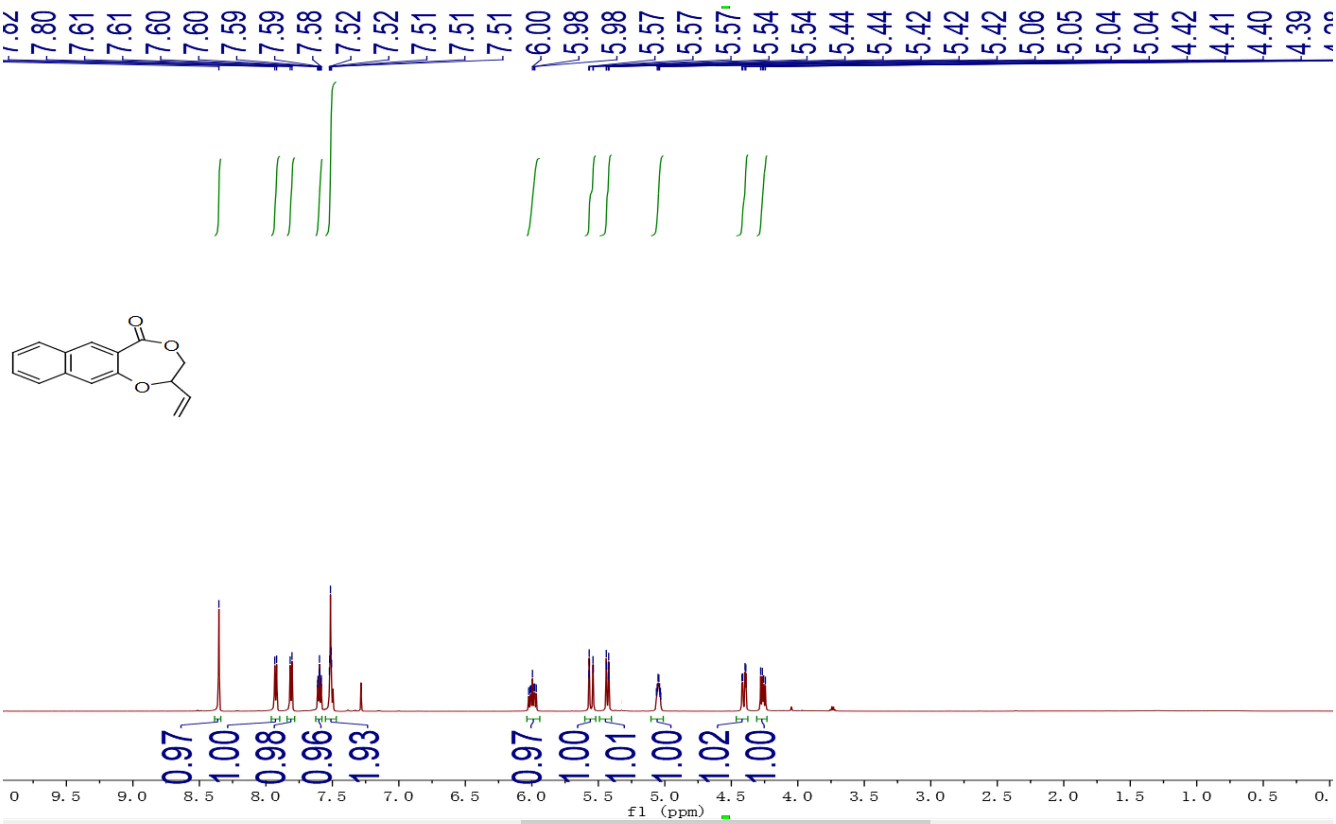


Figure 51. **^{13}C NMR (151 MHz, CDCl₃) spectrum of 2u**

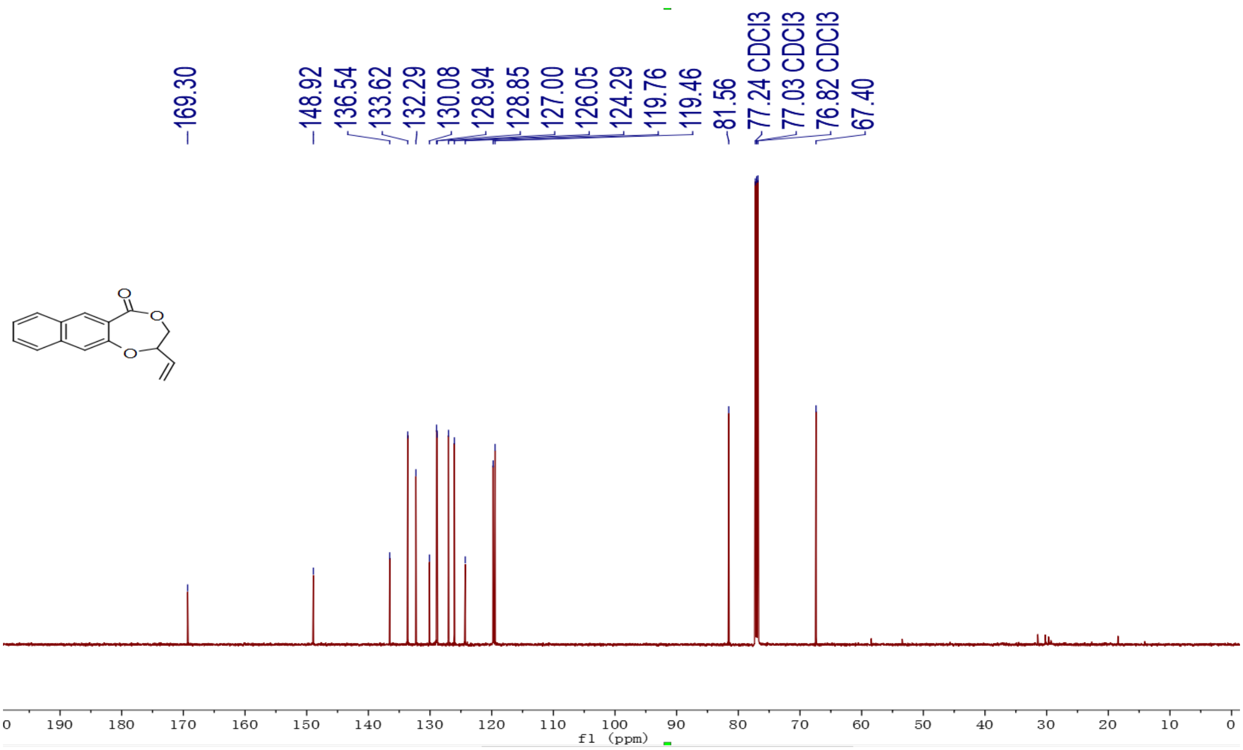


Figure 52. **^{1}H NMR (600 MHz, CDCl₃) spectrum of 2v**

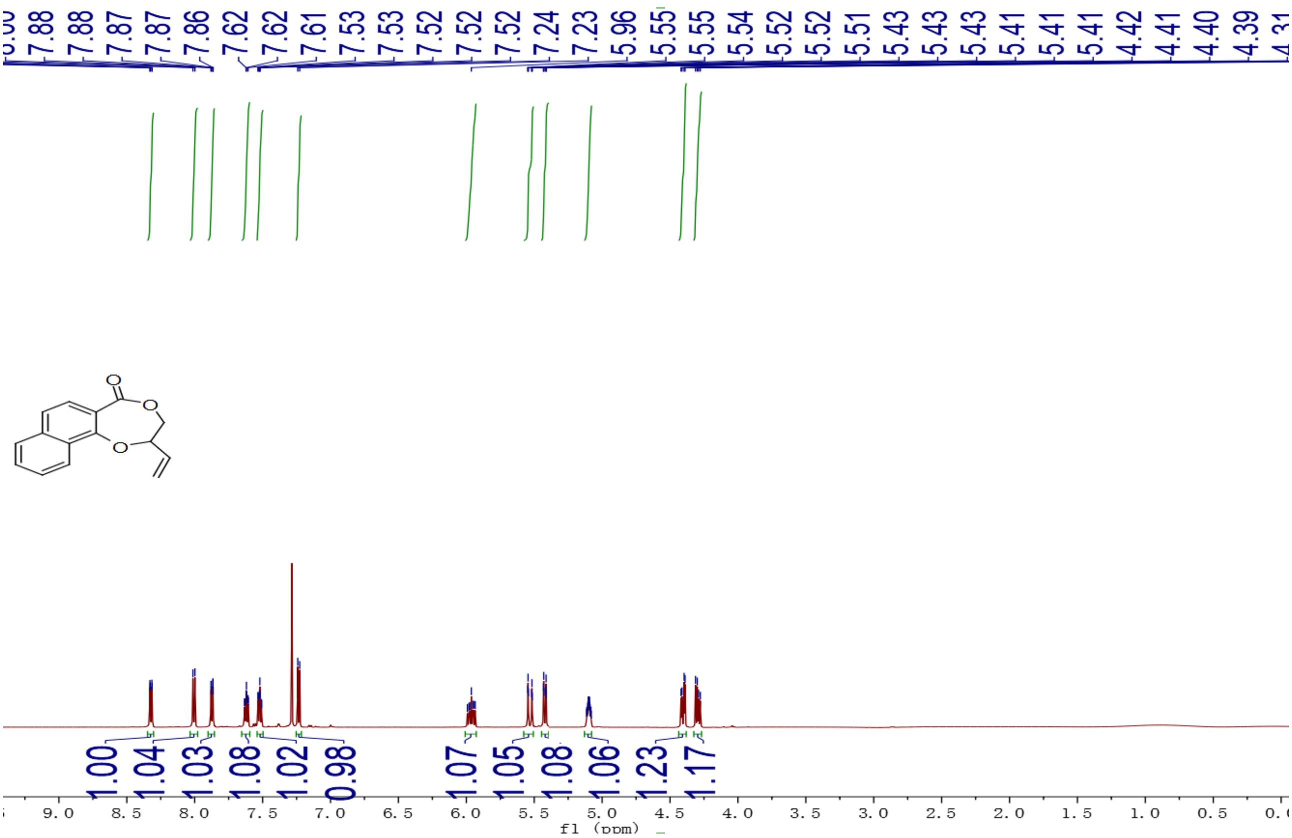


Figure 53. **[13]C NMR (151 MHz, CDCl₃) spectrum of 2v**

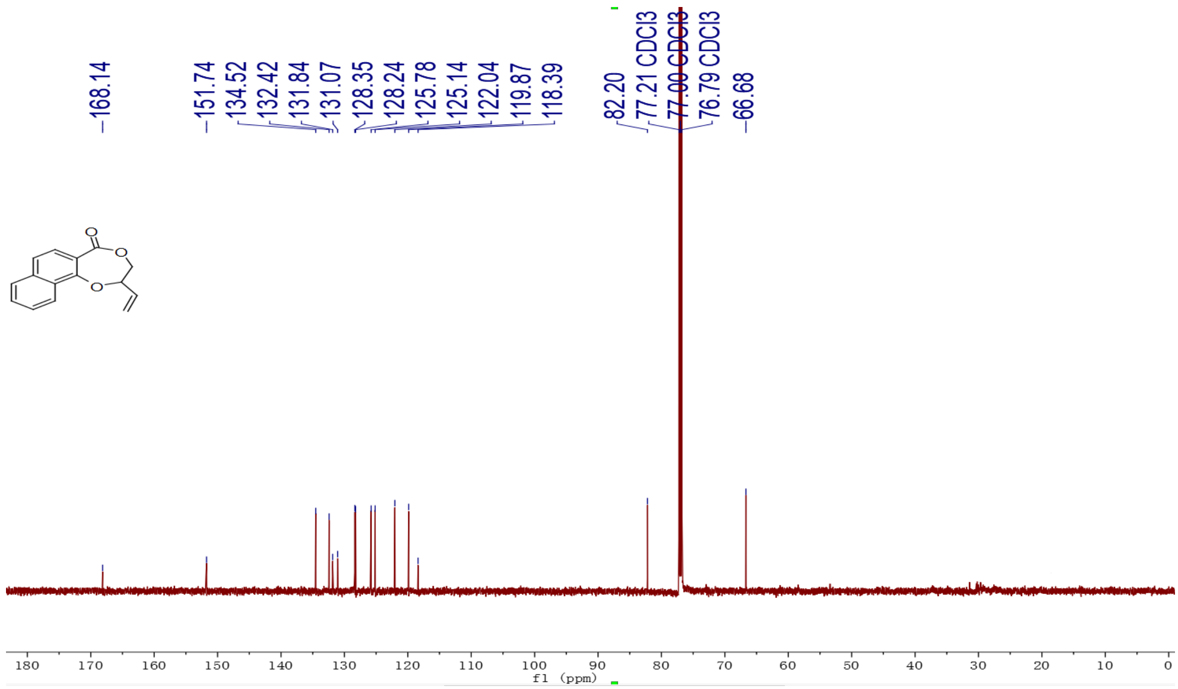


Figure 54. **[1]H NMR (600 MHz, CDCl3) spectrum of 2w**

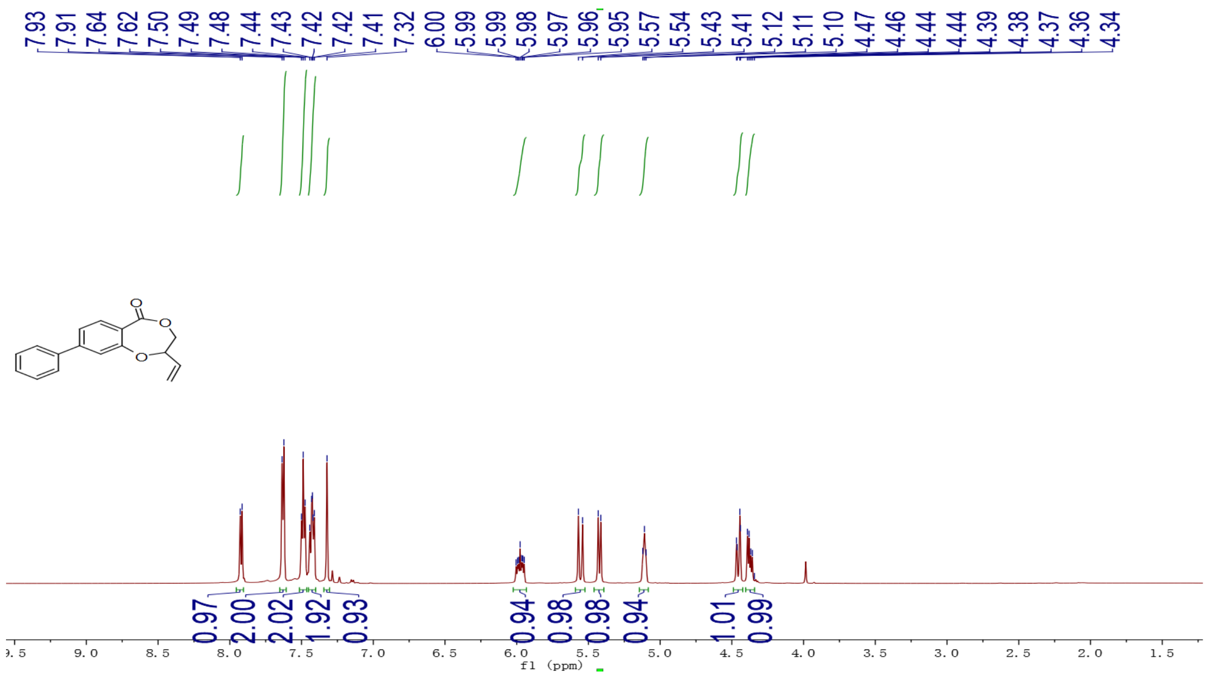


Figure 55. ^{13}C **NMR (151 MHz, CDCl3) spectrum of 2w**

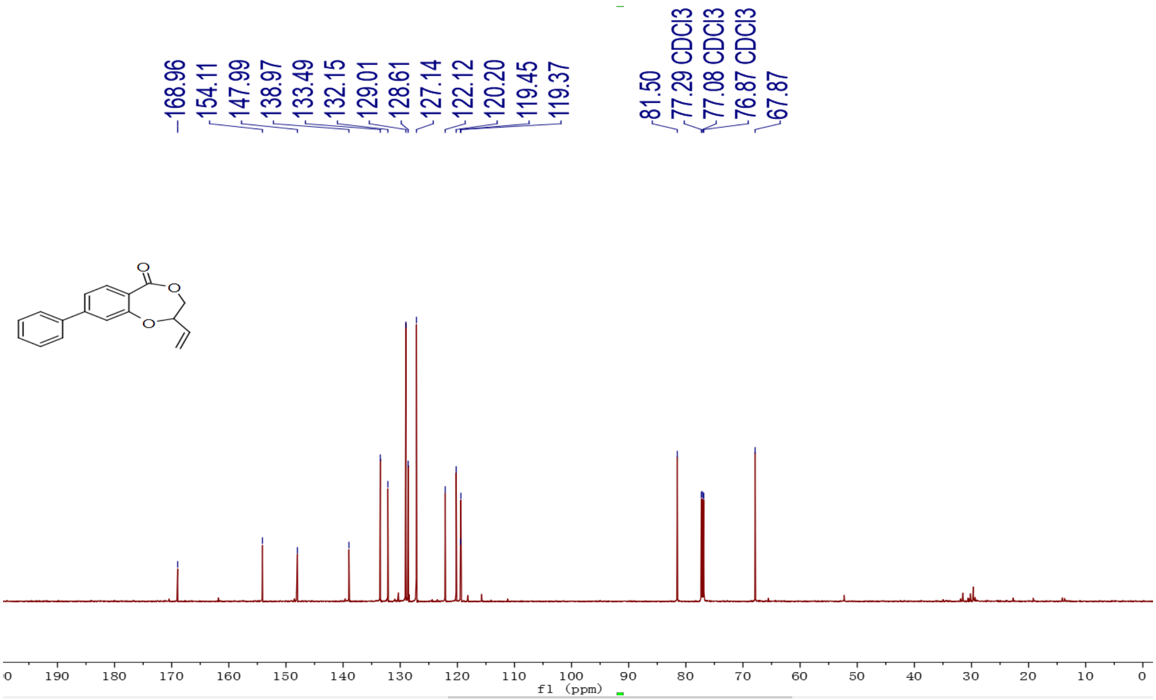


Figure 56. ^{1}H **NMR (600 MHz, CDCl3) spectrum of 2x**

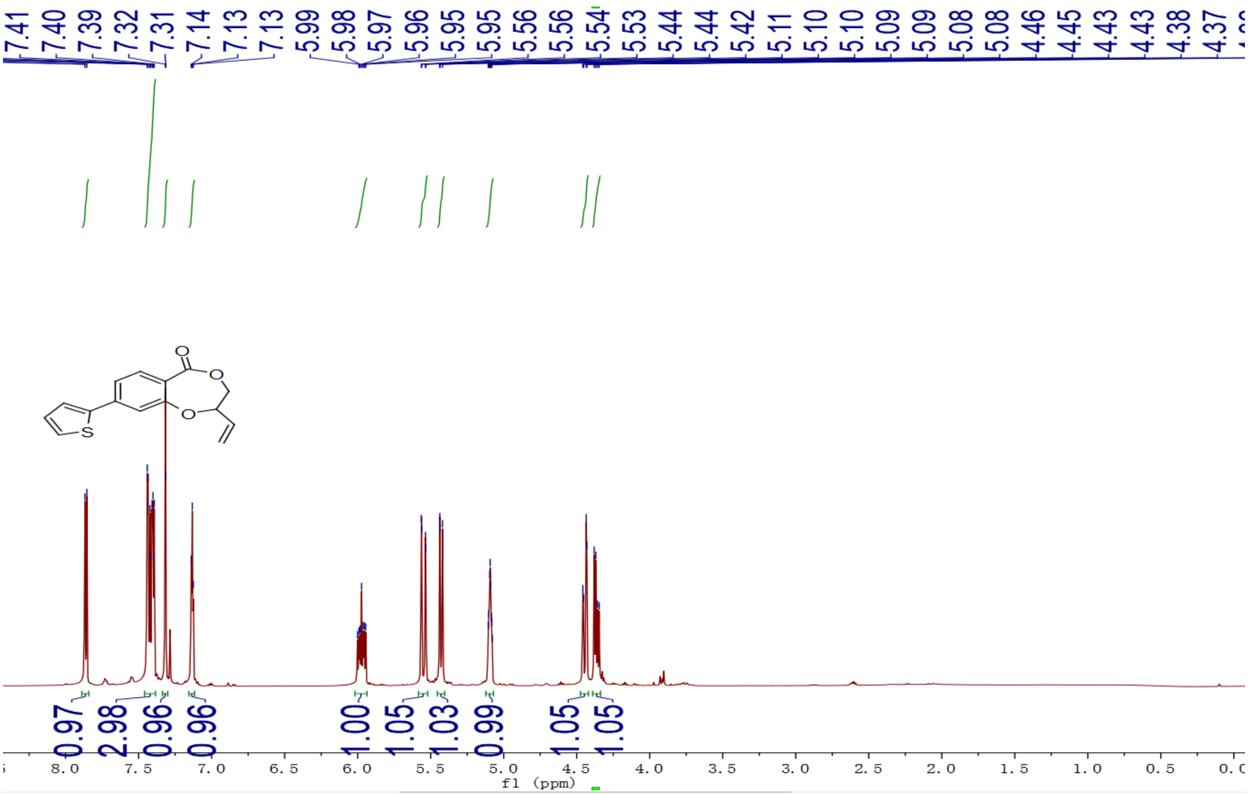


Figure 57. ^{13}C NMR (151 MHz, CDCl3) spectrum of 2x

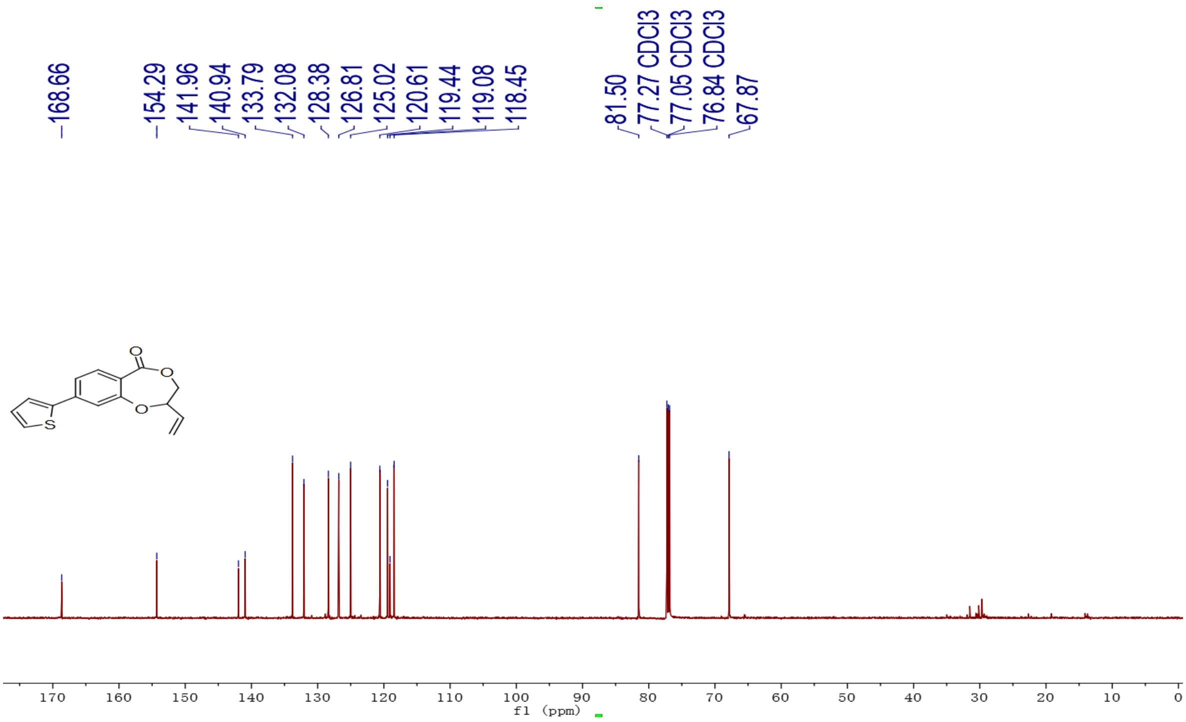


Figure 58. ^{1}H NMR (600 MHz, CDCl$_3$) spectrum of 2a'

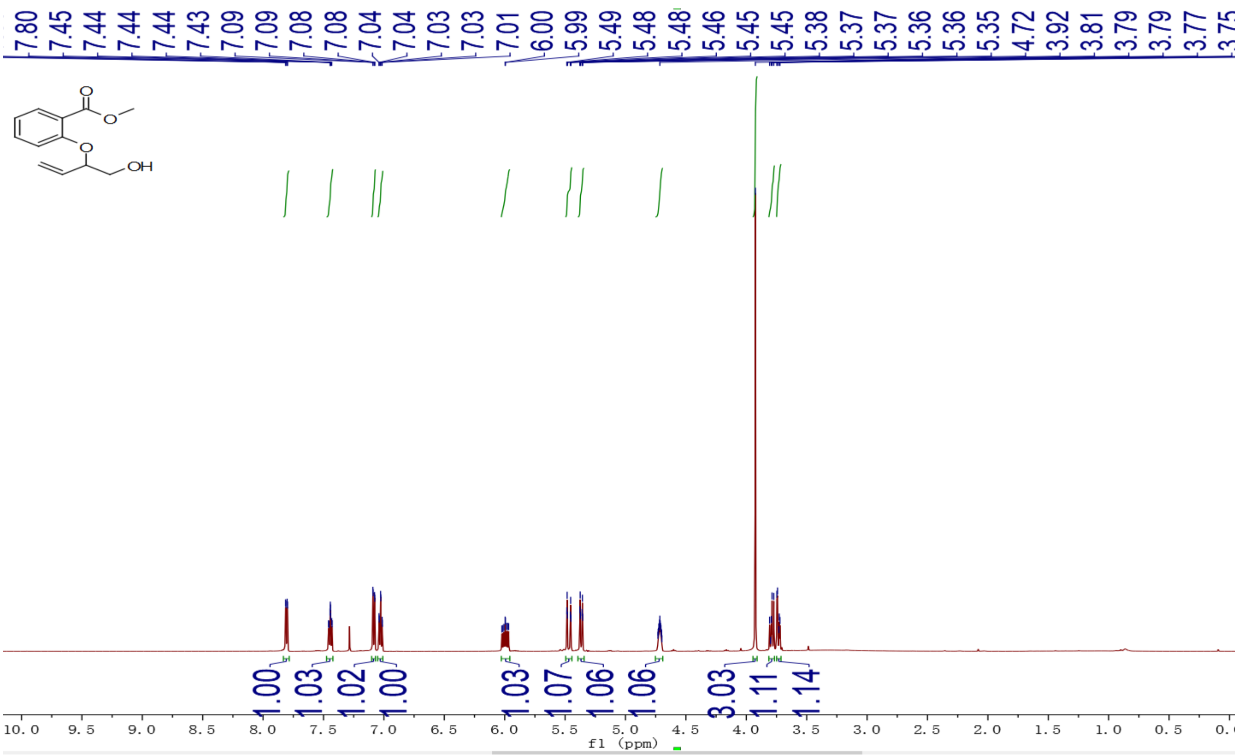
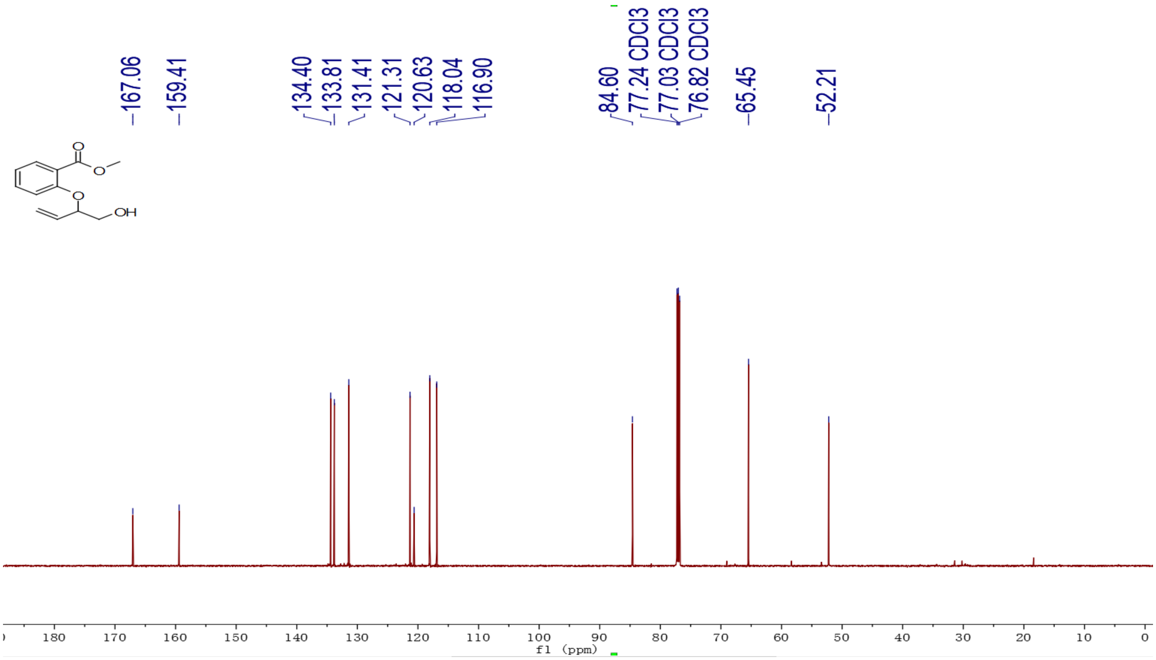


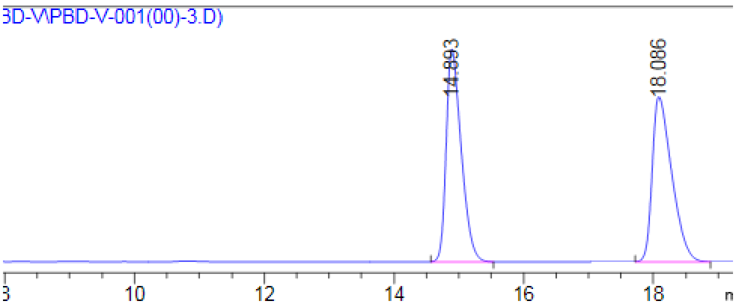
Figure 59. ^{13}C NMR (151 MHz, CDCl$_3$) spectrum of 2a'



5. Copies of HPLC Chromatograms

Figure 60. HPLC spectra of 2a

2a (The top one is racemic, and the bottom one is chiral)



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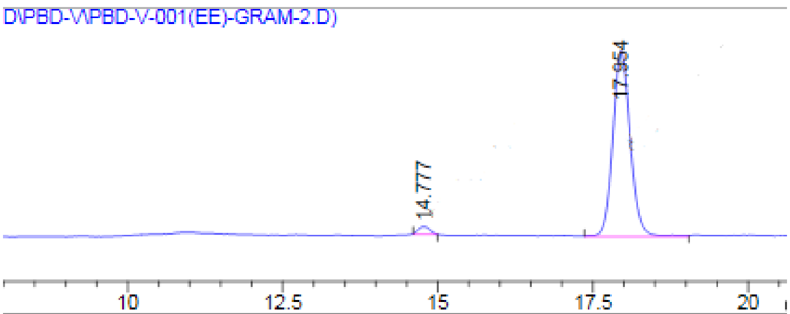
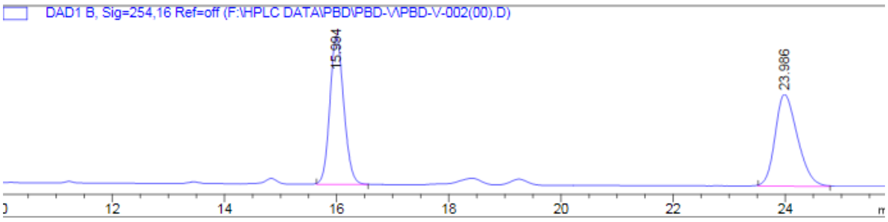
2	18.086	BB	0.3119	4276.48145	206.26509	49.9222



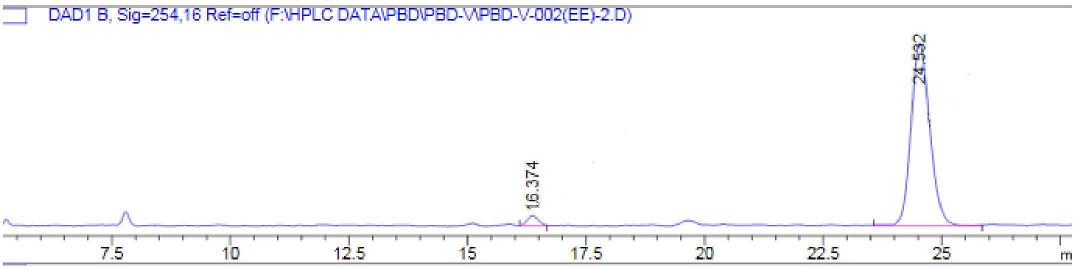
#	[min]		[min]	[mAU*s]	[mAU]	%
1	14.777	MM	0.2130	9.74528	7.62612e-1	2.6905
2	17.954	MM	0.3235	352.46518	18.15662	97.3095

Figure 61. HPLC spectra of 2b

2b (The top one is racemic, and the bottom one is chiral)



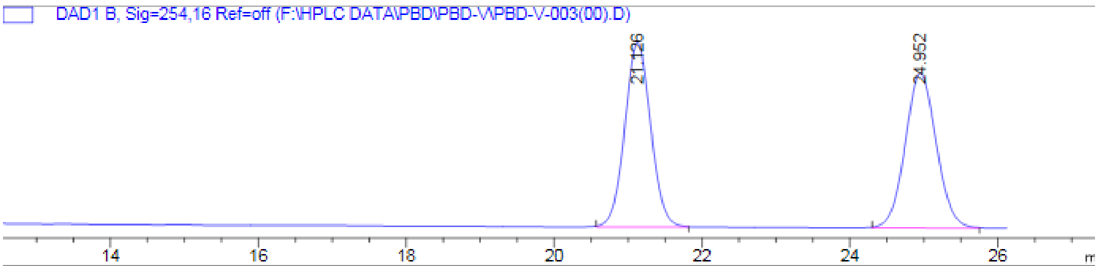
#	[min]		[min]	[mAU*s]	[mAU]	%
1	15.994	BB	0.2655	1160.20203	67.16561	50.0835
2	23.986	BB	0.4248	1156.33496	41.53177	49.9165



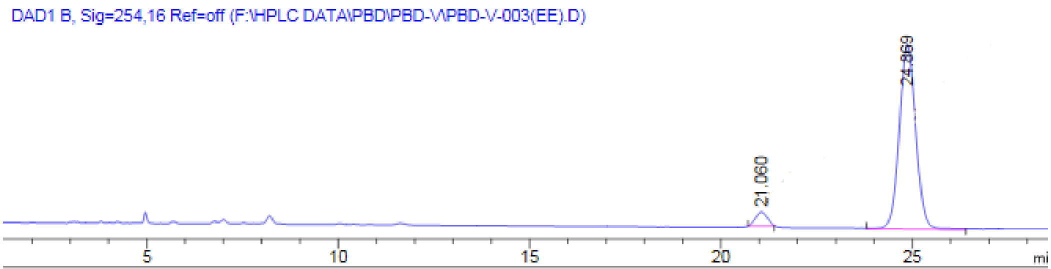
#	[min]		[min]	[mAU*s]	[mAU]	%
1	16.374	MM	0.2784	18.75078	1.12272	3.1310
2	24.532	MM	0.4591	580.12152	21.05964	96.8690

Figure 62. HPLC spectra of 2c

2c (The top one is racemic, and the bottom one is chiral)



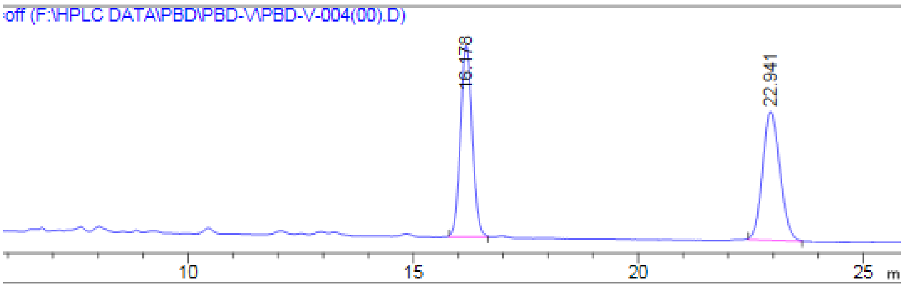
#	[min]		[min]	[mAU*s]	[mAU]	%
1	21.126	BB	0.3759	2451.13477	100.71136	49.8423
2	24.952	BB	0.4531	2466.64502	84.36039	50.1577



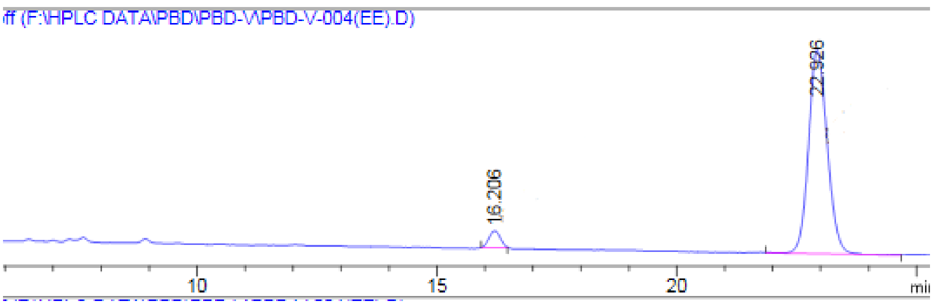
#	[min]		[min]	[mAU*s]	[mAU]	%
1	21.060	MM	0.3580	134.32198	6.25385	5.2232
2	24.869	MM	0.4955	2437.30396	81.98064	94.7768

Figure 63. HPLC spectra of 2d

2d (The top one is racemic, and the bottom one is chiral)



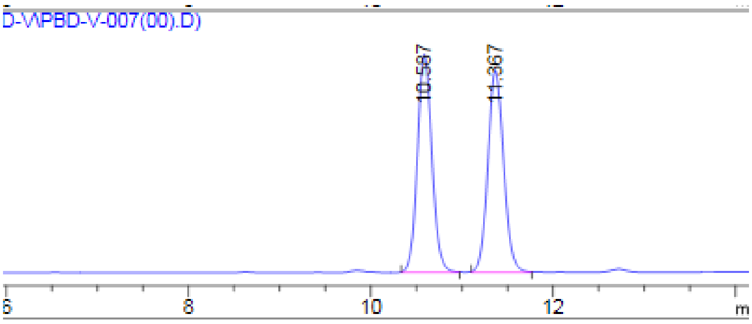
#	[min]		[min]	[mAU*s]	[mAU]	%
1	16.178	BB	0.2824	592.14886	32.52798	50.3690
2	22.941	BB	0.4117	583.47375	21.83762	49.6310



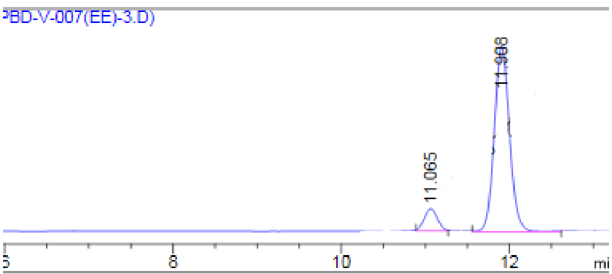
#	[min]		[min]	[mAU*s]	[mAU]	%
1	16.206	MM	0.2698	31.37724	1.93810	4.6396
2	22.926	MM	0.4534	644.91638	23.70427	95.3604

Figure 64. HPLC spectra of 2e

2e (The top one is racemic, and the bottom one is chiral)



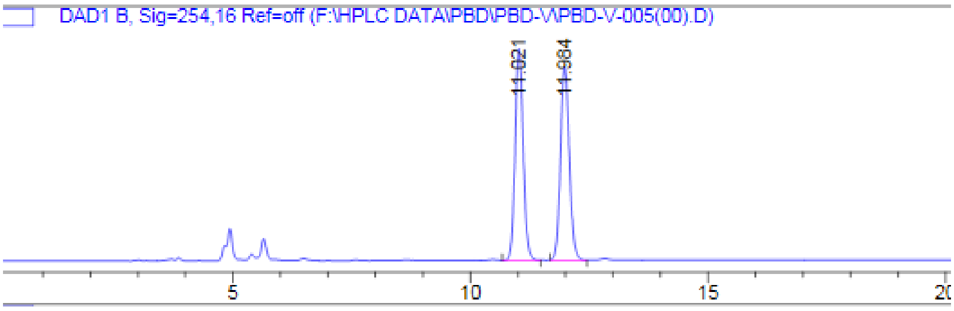
#	[min]		[min]	[mAU*s]	[mAU]	%
1	10.587	BB	0.1711	801.53479	72.42214	49.9858
2	11.367	BB	0.1857	801.99152	66.97631	50.0142



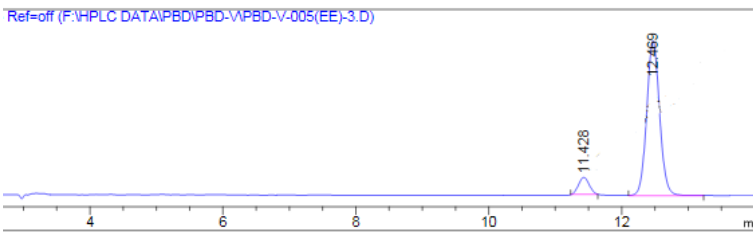
#	[min]		[min]	[mAU*s]	[mAU]	%
1	11.065	MM	0.1813	46.79551	4.30297	9.2101
2	11.908	MM	0.2097	461.29376	36.66157	90.7899

Figure 65. HPLC spectra of 2f

2f (The top one is racemic, and the bottom one is chiral)



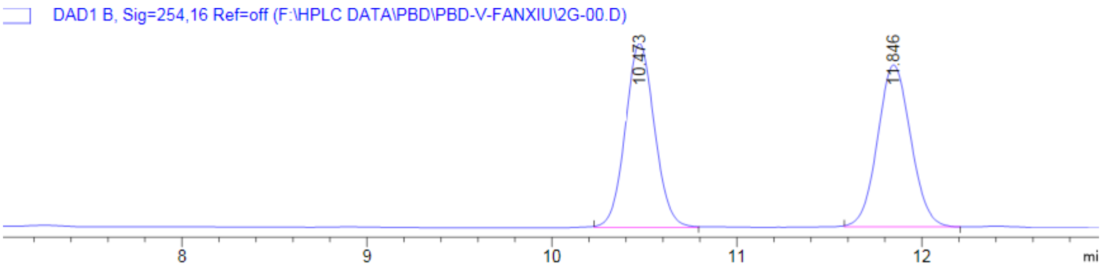
#	[min]		[min]	[mAU*s]	[mAU]	%
1	11.021	VB	0.1837	2236.04858	189.44183	49.9272
2	11.984	BB	0.2009	2242.56616	173.43178	50.0728



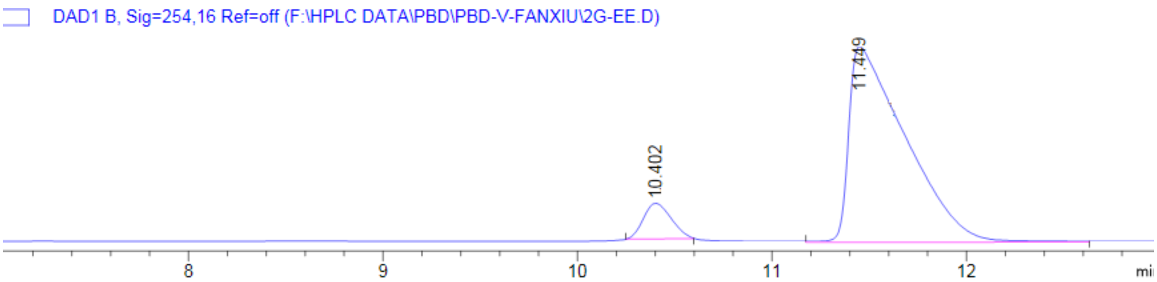
#	[min]		[min]	[mAU*s]	[mAU]	%
1	11.428	MM	0.1867	69.30746	6.18712	8.4048
2	12.469	MM	0.2245	755.30829	56.07504	91.5952

Figure 66. HPLC spectra of 2g

2g (The top one is racemic, and the bottom one is chiral)



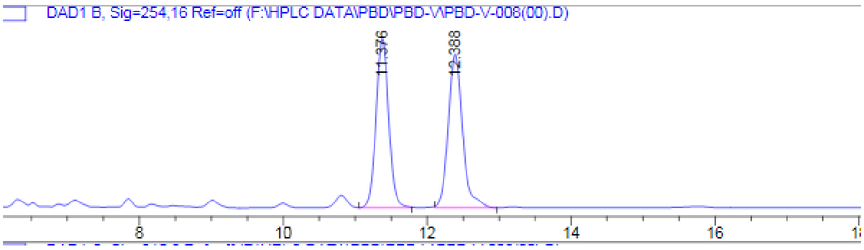
#	[min]		[min]	[mAU*s]	[mAU]	%
1	10.473	BB	0.1699	374.46851	34.16391	49.9258
2	11.846	BB	0.1936	375.58224	30.09640	50.0742



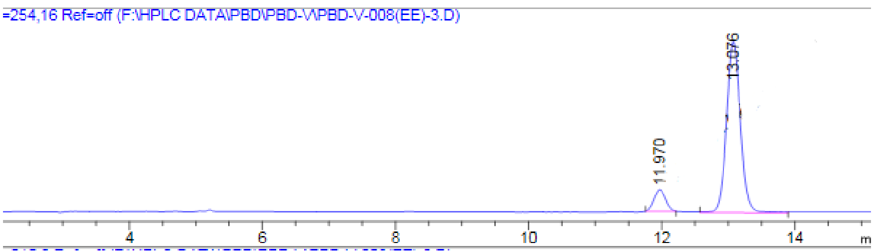
#	[min]		[min]	[mAU*s]	[mAU]	%
1	10.402	MM	0.1653	2279.11499	229.81543	8.1399
2	11.449	MM	0.3385	2.57201e4	1266.47034	91.8601

Figure 67. HPLC spectra of 2h

2h (The top one is racemic, and the bottom one is chiral)



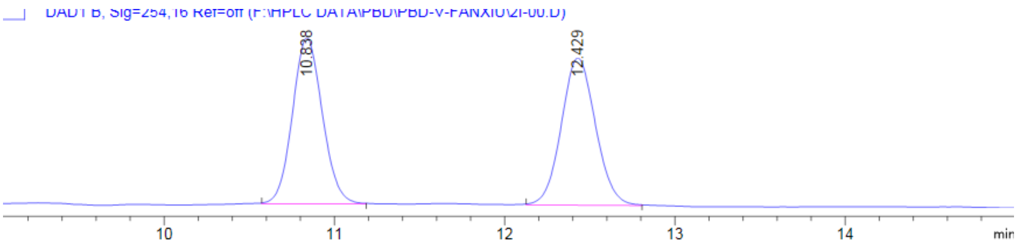
#	[min]		[min]	[mAU*s]	[mAU]	%
1	11.376	VB	0.1881	701.94580	57.61454	49.1906
2	12.388	BB	0.2115	725.04706	52.37590	50.8094



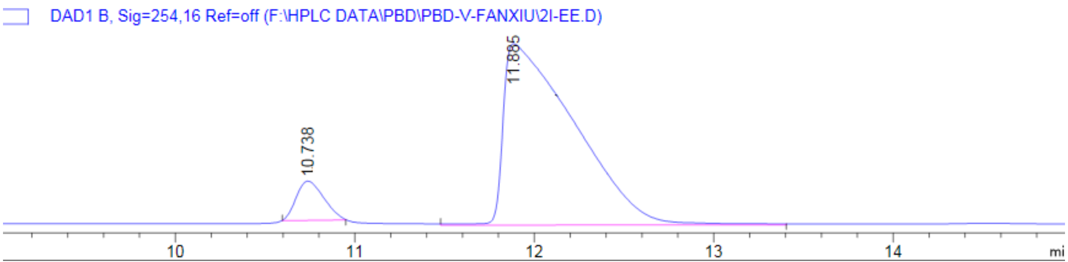
#	[min]		[min]	[mAU*s]	[mAU]	%
1	11.970	MM	0.2003	132.74246	11.04334	9.4410
2	13.076	MM	0.2403	1273.28162	88.32760	90.5590

Figure 68. HPLC spectra of 2i

2i (The top one is racemic, and the bottom one is chiral)



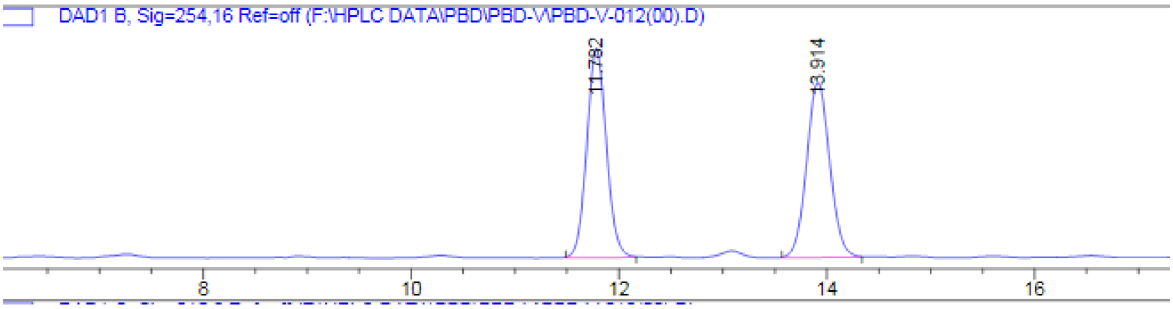
#	[min]		[min]	[mAU*s]	[mAU]	%
1	10.838	BB	0.1906	520.55609	42.59544	49.7299
2	12.429	BB	0.2146	526.21051	37.76420	50.2701



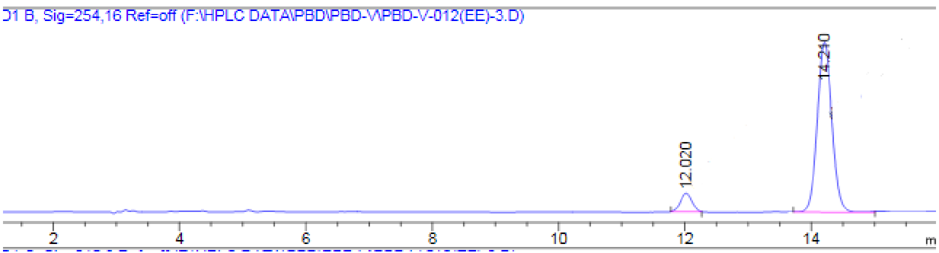
#	[min]		[min]	[mAU*s]	[mAU]	%
1	10.738	MM	0.1772	4356.39648	409.81915	7.7072
2	11.885	MM	0.4593	5.21676e4	1892.87170	92.2928

Figure 69. HPLC spectra of 2j

2j (The top one is racemic, and the bottom one is chiral)



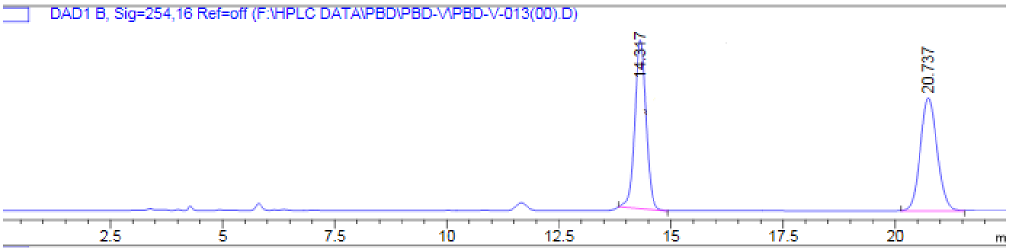
#	[min]		[min]	[mAU*s]	[mAU]	%
1	11.782	BB	0.2025	800.08167	61.19202	50.2849
2	13.914	BB	0.2404	791.01581	51.15328	49.7151



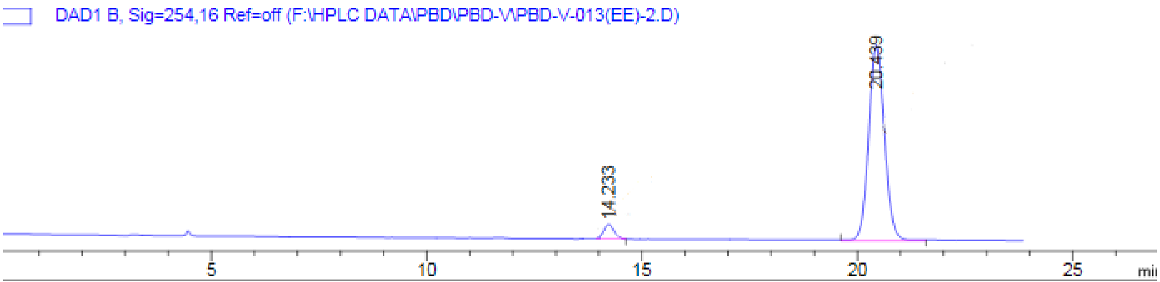
#	[min]		[min]	[mAU*s]	[mAU]	%
1	12.020	MM	0.2138	59.61893	4.64657	7.9371
2	14.210	MM	0.2671	691.52136	43.14197	92.0629

Figure 70. HPLC spectra of 2k

2k (The top one is racemic, and the bottom one is chiral)



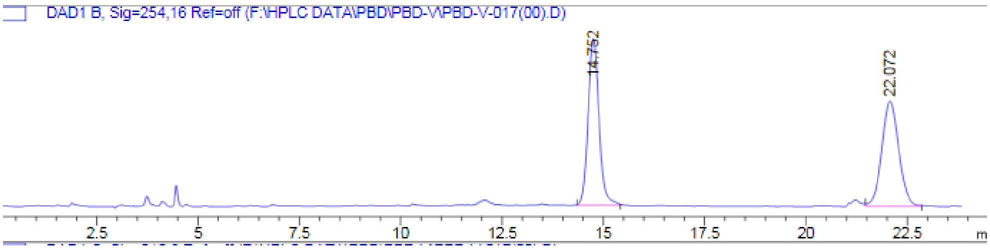
#	[min]		[min]	[mAU*s]	[mAU]	%
1	14.317	MM	0.2910	4864.82471	278.65744	49.8944
2	20.737	BB	0.4078	4885.42285	186.41061	50.1056



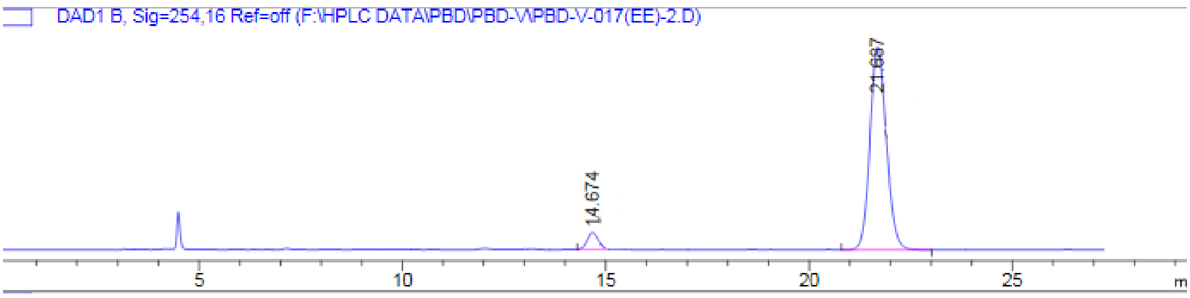
#	[min]		[min]	[mAU*s]	[mAU]	%
1	14.233	MM	0.2544	111.34698	7.29423	3.5031
2	20.439	MM	0.4257	3067.19263	120.08492	96.4969

Figure 71. HPLC spectra of 2l

2l (The top one is racemic, and the bottom one is chiral)



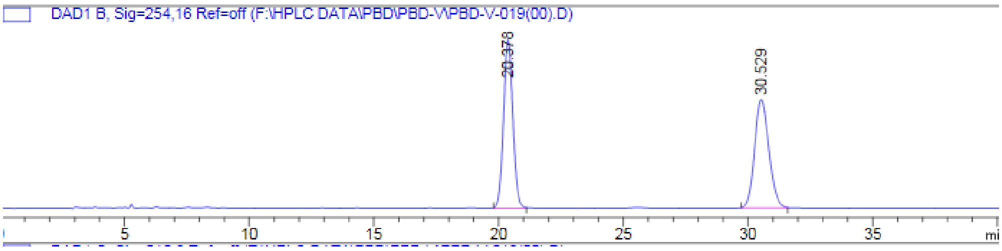
#	[min]		[min]	[mAU*s]	[mAU]	%
1	14.752	BB	0.2895	1038.90234	55.21548	50.6739
2	22.072	VB	0.4470	1011.26923	34.80247	49.3261



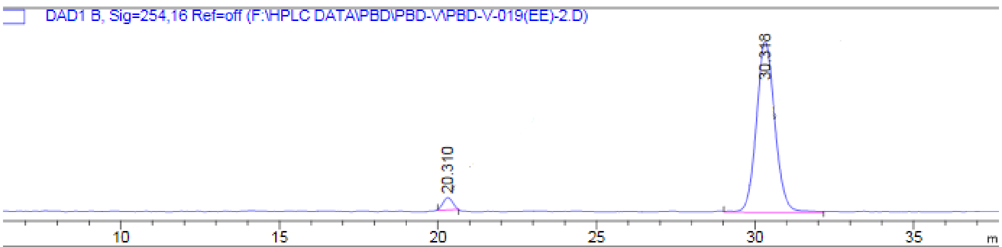
#	[min]		[min]	[mAU*s]	[mAU]	%
1	14.674	MM	0.2525	96.14185	6.34480	3.3978
2	21.687	MM	0.4690	2733.40942	97.12793	96.6022

Figure 72. HPLC spectra of 2m

2m (The top one is racemic, and the bottom one is chiral)



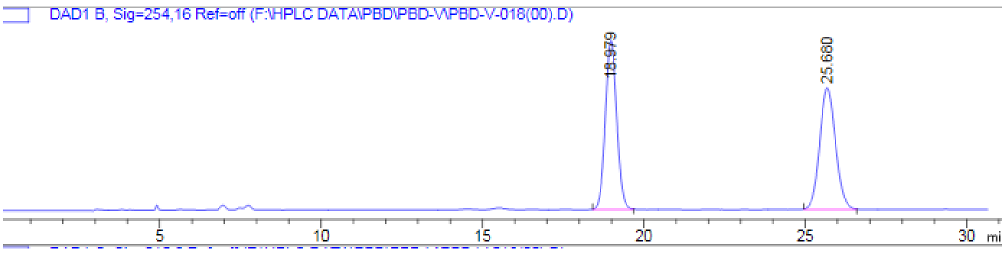
#	[min]		[min]	[mAU*s]	[mAU]	%
1	20.378	BB	0.4017	3131.55273	121.10558	50.1415
2	30.529	BB	0.6182	3113.88086	77.92002	49.8585



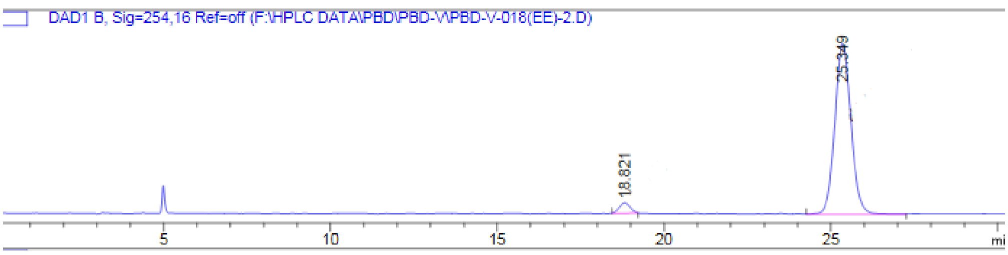
#	[min]		[min]	[mAU*s]	[mAU]	%
1	20.310	MM	0.3547	54.43393	2.55748	3.5295
2	30.318	MM	0.6806	1487.83154	36.43372	96.4705

Figure 73. HPLC spectra of 2n

2n (The top one is racemic, and the bottom one is chiral)



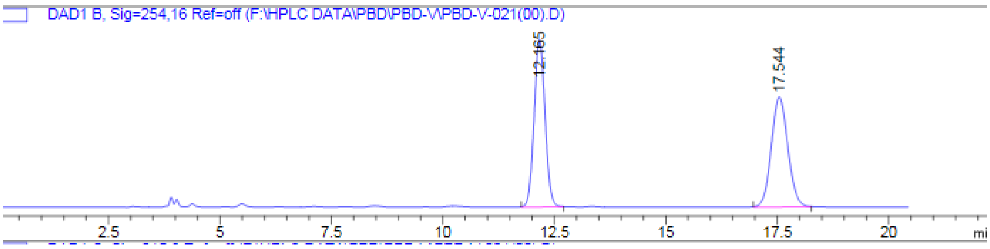
#	[min]		[min]	[mAU*s]	[mAU]	%
1	18.979	BB	0.3796	3344.97437	136.63518	49.9727
2	25.680	BB	0.5270	3348.63257	97.91827	50.0273



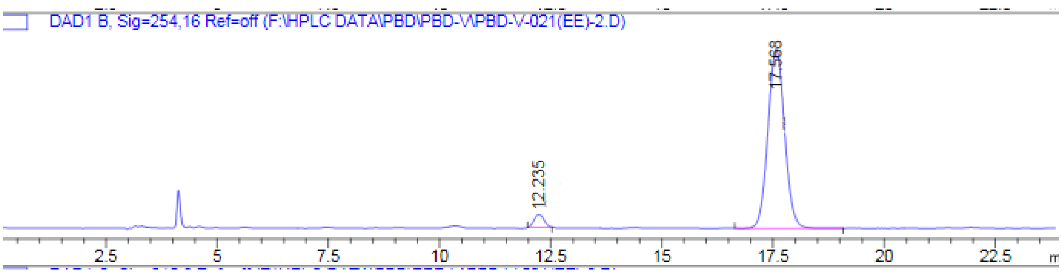
#	[min]		[min]	[mAU*s]	[mAU]	%
1	18.821	MM	0.3843	66.96190	2.90413	3.8897
2	25.349	MM	0.5627	1654.55750	49.00880	96.1103

Figure 74. HPLC spectra of 2o

2o (The top one is racemic, and the bottom one is chiral)



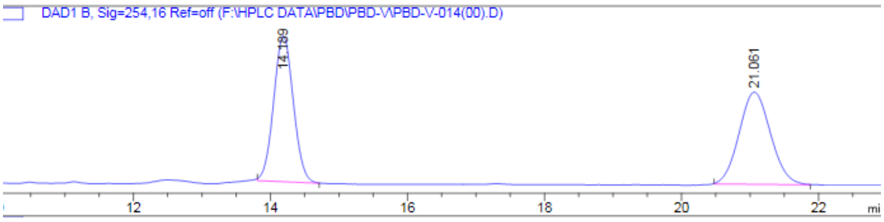
#	[min]		[min]	[mAU*s]	[mAU]	%
1	12.165	BB	0.2635	3287.20532	194.14633	49.9456
2	17.544	BB	0.4014	3294.36108	127.51939	50.0544



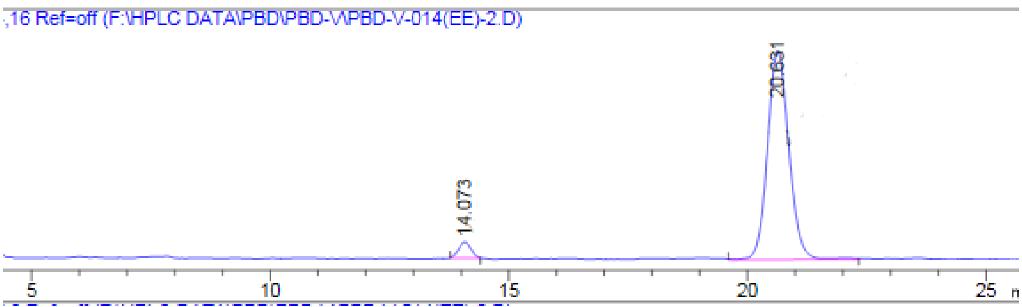
#	[min]		[min]	[mAU*s]	[mAU]	%
1	12.235	MM	0.2641	39.76583	2.50939	4.1176
2	17.568	MM	0.4370	925.99097	35.31615	95.8824

Figure 75. HPLC spectra of 2p

2p (The top one is racemic, and the bottom one is chiral)



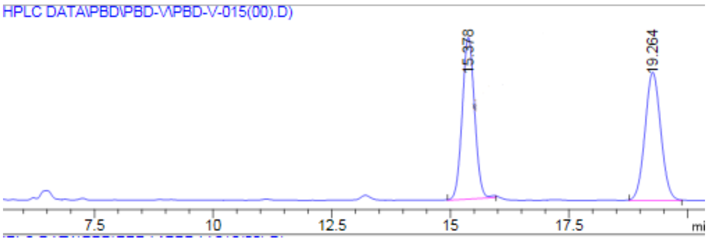
#	[min]		[min]	[mAU*s]	[mAU]	%
1	14.189	BB	0.3082	289.72791	14.55804	49.6491
2	21.061	BB	0.4826	293.82367	9.19985	50.3509



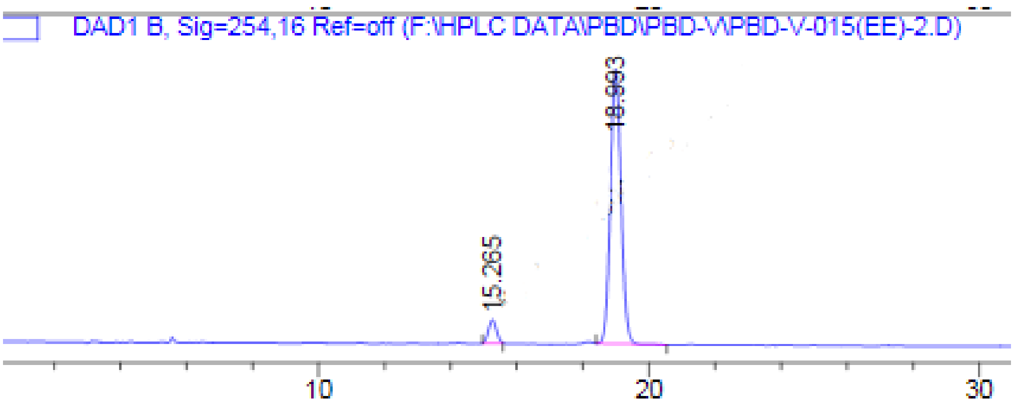
#	[min]		[min]	[mAU*s]	[mAU]	%
1	14.073	MM	0.2982	40.77758	2.27890	4.2069
2	20.631	MM	0.5163	928.51428	29.97207	95.7931

Figure 76. HPLC spectra of 2q

2q (The top one is racemic, and the bottom one is chiral)



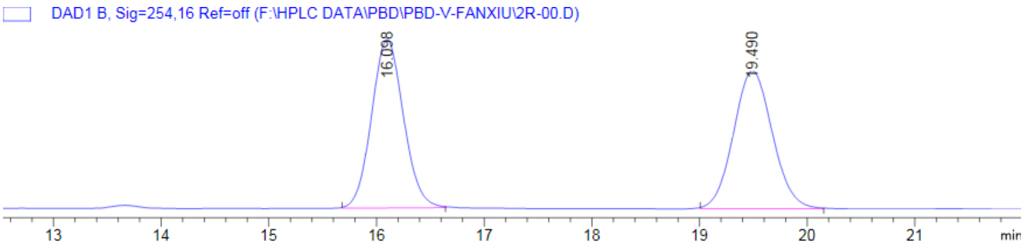
#	[min]		[min]	[mAU*s]	[mAU]	%
1	15.378	MM	0.3016	1150.14673	63.54916	49.6706
2	19.264	BB	0.3582	1165.39954	50.32356	50.3294



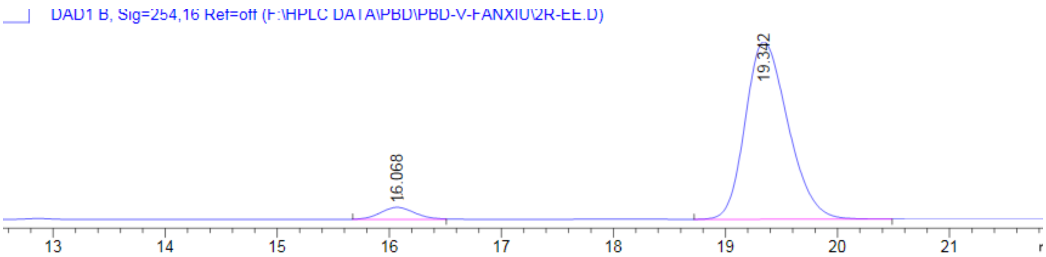
#	[min]		[min]	[mAU*s]	[mAU]	%
1	15.265	MM	0.2789	103.30381	6.17373	5.9838
2	18.993	MM	0.3730	1623.08337	72.52755	94.0162

Figure 77. HPLC spectra of 2r

2r (The top one is racemic, and the bottom one is chiral)



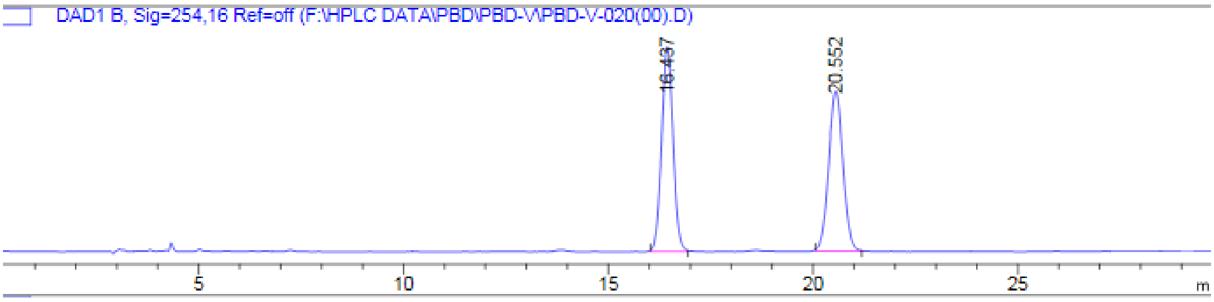
#	[min]		[min]	[mAU*s]	[mAU]	%
1	16.098	BB	0.3203	762.84357	37.04345	50.0638
2	19.490	BB	0.3887	760.89990	30.33063	49.9362



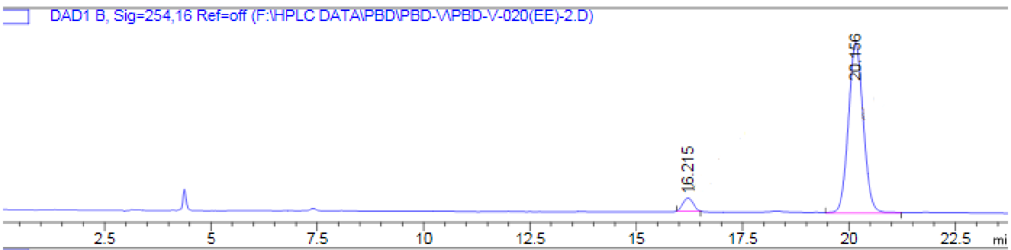
#	[min]		[min]	[mAU*s]	[mAU]	%
1	16.068	MM	0.3650	2246.31104	102.56203	5.3748
2	19.342	BB	0.4108	3.95469e4	1494.13123	94.6252

Figure 78. HPLC spectra of 2s

2s (The top one is racemic, and the bottom one is chiral)



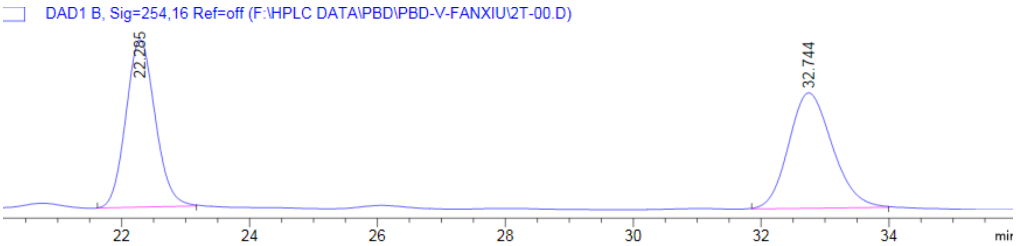
#	[min]		[min]	[mAU*s]	[mAU]	%
1	16.437	BB	0.2955	812.93524	42.42744	50.1218
2	20.552	BB	0.3777	808.98584	33.26333	49.8782



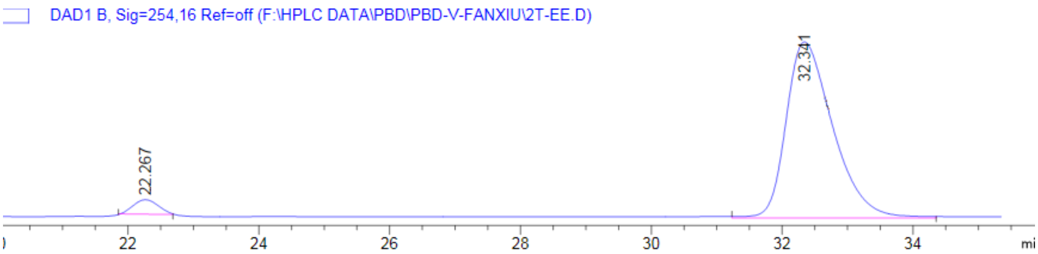
#	[min]		[min]	[mAU*s]	[mAU]	%
1	16.215	MM	0.2826	77.37508	4.56265	5.0062
2	20.156	MM	0.4049	1468.20508	60.44203	94.9938

Figure 79. HPLC spectra of 2t

2t (The top one is racemic, and the bottom one is chiral)



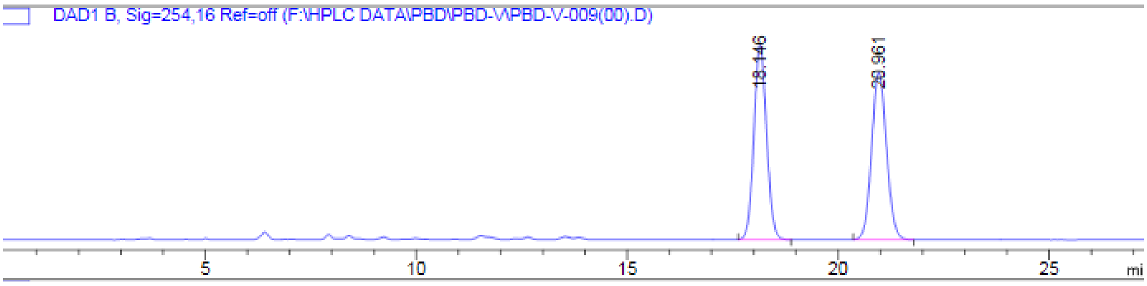
#	[min]		[min]	[mAU*s]	[mAU]	%
1	22.285	BB	0.4945	2965.10474	93.36535	49.2907
2	32.744	BB	0.7282	3050.44336	64.21127	50.7093



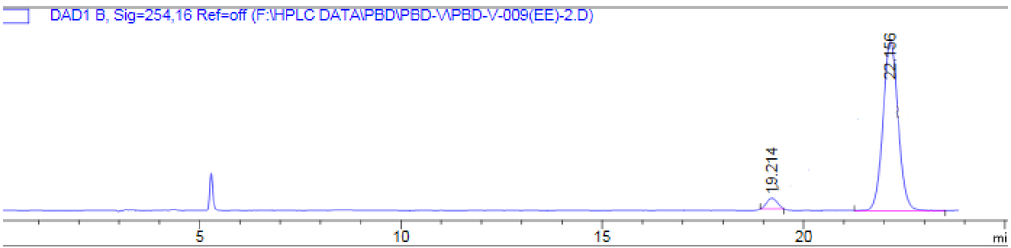
#	[min]		[min]	[mAU*s]	[mAU]	%
1	22.267	MM	0.4424	2599.37524	97.93482	4.1936
2	32.341	MM	0.8295	5.93849e4	1193.21509	95.8064

Figure 80. HPLC spectra of 2u

2u (The top one is racemic, and the bottom one is chiral)



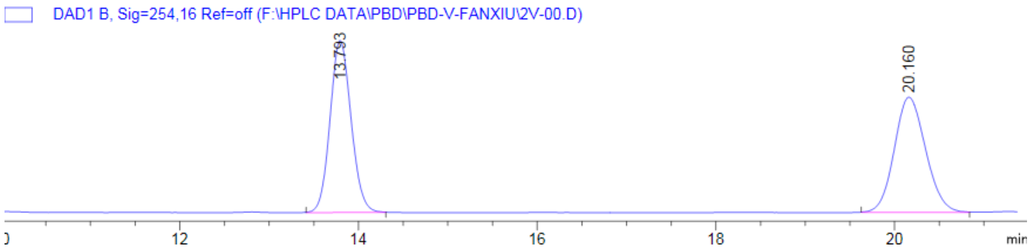
#	[min]		[min]	[mAU*s]	[mAU]	%
1	18.146	BB	0.3239	7036.55176	336.63760	49.7116
2	20.961	BB	0.3807	7118.19531	289.61710	50.2884



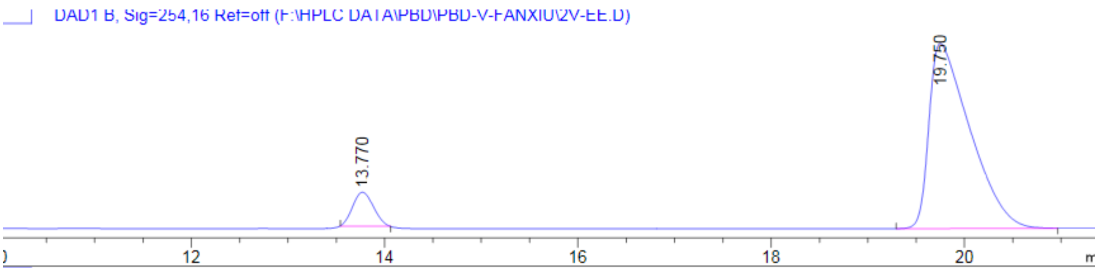
#	[min]		[min]	[mAU*s]	[mAU]	%
1	19.214	MM	0.3107	57.58720	3.08933	4.1928
2	22.156	MM	0.4394	1315.87988	49.91170	95.8072

Figure 81. HPLC spectra of 2v

2v (The top one is racemic, and the bottom one is chiral)



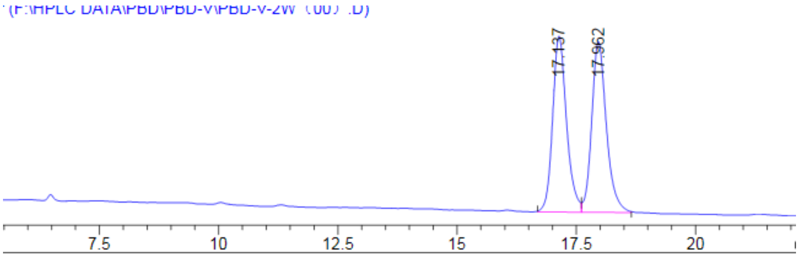
#	[min]		[min]	[mAU*s]	[mAU]	%
1	13.793	BB	0.2526	2081.98267	127.41829	50.0122
2	20.160	BB	0.3785	2080.96680	85.33742	49.9878



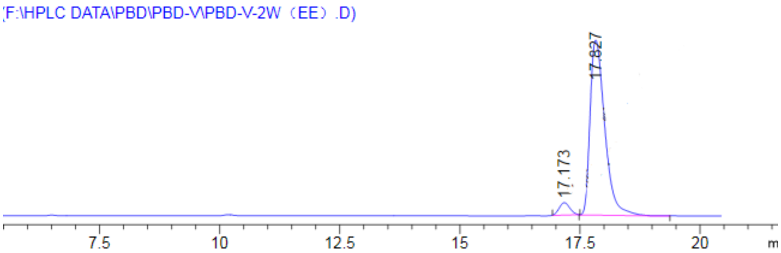
#	[min]		[min]	[mAU*s]	[mAU]	%
1	13.770	MM	0.2493	2628.93848	175.75333	8.5464
2	19.750	BB	0.4379	2.81320e4	954.30780	91.4536

Figure 82. HPLC spectra of 2w

2w (The top one is racemic, and the bottom one is chiral)



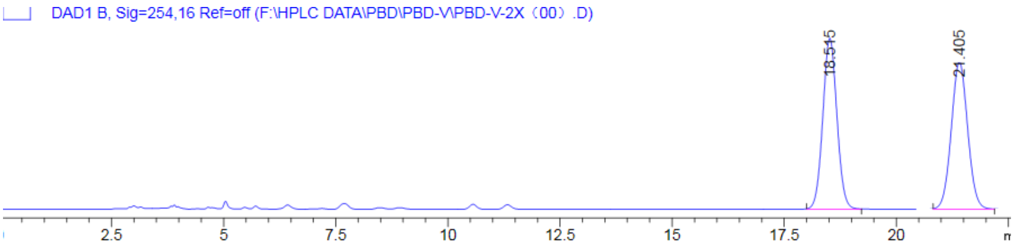
#	[min]		[min]	[mAU*s]	[mAU]	%
1	17.137	BV	0.3069	1122.89185	55.29107	49.4710
2	17.962	VB	0.3256	1146.90820	53.61442	50.5290



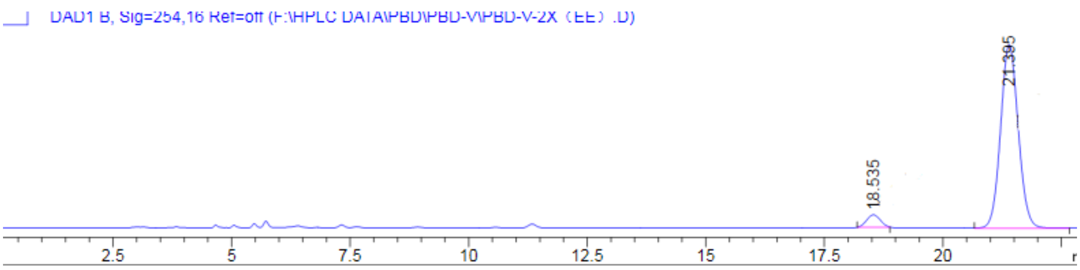
#	[min]		[min]	[mAU*s]	[mAU]	%
1	17.173	MM	0.2566	1855.86609	120.52266	4.8968
2	17.827	MM	0.3562	3.60436e4	1686.44177	95.1032

Figure 83. HPLC spectra of 2x

2x (The top one is racemic, and the bottom one is chiral)



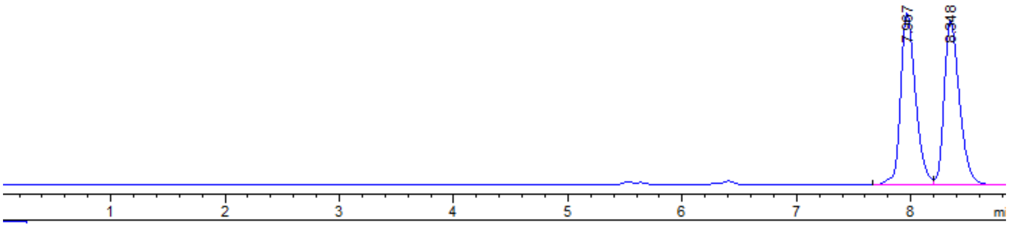
#	[min]		[min]	[mAU*s]	[mAU]	%
1	18.515	BB	0.3391	3857.86328	176.43678	49.9800
2	21.405	BB	0.3943	3860.95459	152.04774	50.0200



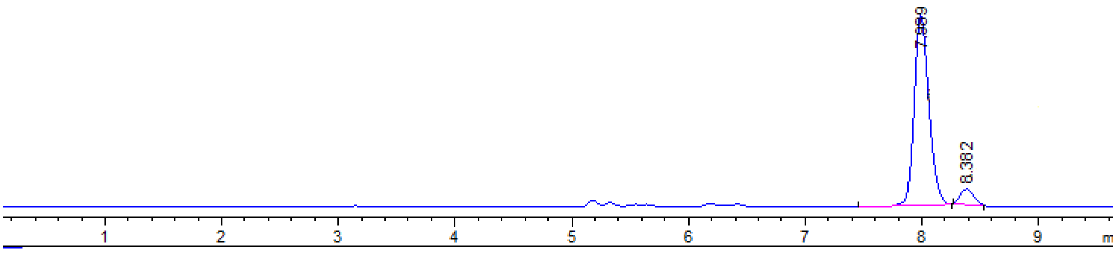
#	[min]		[min]	[mAU*s]	[mAU]	%
1	18.535	MM	0.3277	1198.11206	60.93665	4.8227
2	21.395	MM	0.4330	2.36448e4	910.03833	95.1773

Figure 84. HPLC spectra of 2a’

2a’ (The top one is racemic, and the bottom one is chiral)



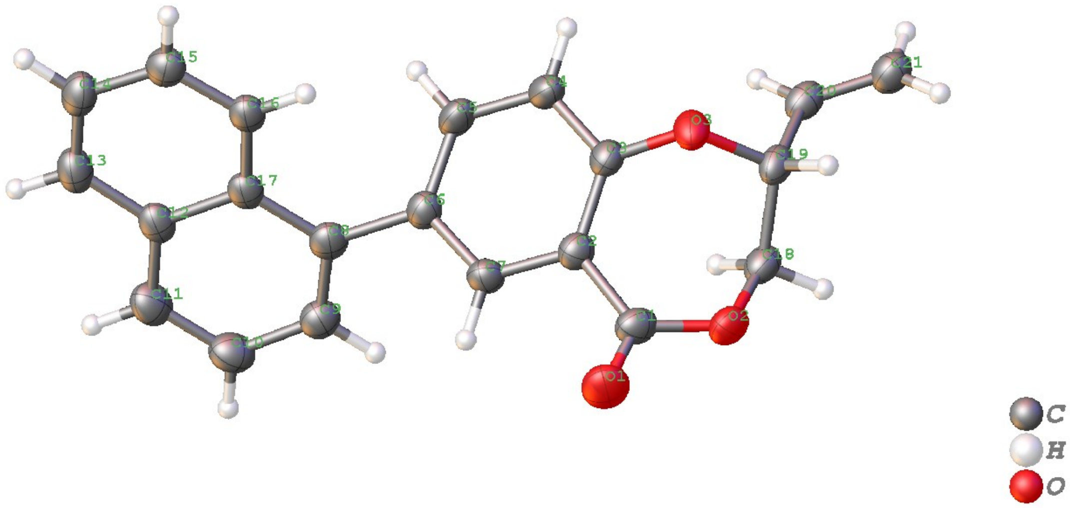
#	[min]		[min]	[mAU*s]	[mAU]	%
1	7.967	BV	0.1383	7161.58398	785.83820	50.4914
2	8.348	VB	0.1453	7022.18359	749.34332	49.5086



#	[min]		[min]	[mAU*s]	[mAU]	%
1	7.989	MM	0.1461	1908.47913	217.69202	93.3738
2	8.382	MM	0.1281	135.43454	17.62702	6.6262

6. X-ray Crystallogaphic Data

Figure 85. X-Ray Crystallographic Data for Compound(*R*)-2p



Prob = 50

Method for preparing single crystal (*R*)-2p: Dissolve 20 mg of **2p** in a sample bottle containing 1 mL of ethyl acetate, and then add 5 mL of n-hexane. The obtained solution is placed in a quiet place at room temperature. Four weeks later, the single crystal of **(*R*)-2p** was obtained.

Structure factors have been supplied for datablock(s) (CCDC: 2294598**)**

checkCIF/PLATON report

Structure factors have been supplied for datablock(s) a23090201aqlq_autored

THIS REPORT IS FOR GUIDANCE ONLY. IF USED AS PART OF A REVIEW PROCEDURE FOR

PUBLICATION, IT SHOULD NOT REPLACE THE EXPERTISE OF AN EXPERIENCED CRYSTALLOGRAPHIC REFEREE.

No syntax errors found. CIF dictionary Interpreting this report

Datablock: a23090201aqlq_autored

Bond precision: C-C = 0.0032 A Wavelength=1.54184

Cell: a=4.5169(1) b=9.4428(2) c=18.5211(3)

alpha=90 beta=95.565(2) gamma=90

Temperature: 150 K

Calculated Reported

Volume 786.24(3) 786.24(3)

Space group P 21 P 1 21 1

Hall group P 2yb P 2yb

Moiety formula C21 H16 O3 C21 H16 O3

Sum formula C21 H16 O3 C21 H16 O3

Mr 316.34 316.34

Dx,g cm-3 1.336 1.336

Z 2 2
Mu (mm-1) 0.715 0.715
F000 332.0 332.0
F000’ 333.02
h,k,lmax 5,11,23 5,11,23
Nref 3303[1755] 3170
Tmin,Tmax 0.926,0.944 0.806,1.000
Tmin’ 0.924
Correction method= # Reported T Limits: Tmin=0.806 Tmax=1.000
AbsCorr = MULTI-SCAN
Data completeness= 1.81/0.96 Theta(max)= 76.123
R(reflections)= 0.0345(3093)
wR2(reflections)=
0.0930(3170)
S = 1.072 Npar= 217
The following ALERTS were generated. Each ALERT has the format
test-name_ALERT_alert-type_alert-level.
Click on the hyperlinks for more details of the test.
Alert level C
PLAT911_ALERT_3_C Missing FCF Refl Between Thmin & STh/L= 0.600 6 Report
Alert level G
PLAT012_ALERT_1_G No _shelx_res_checksum Found in CIF ...... Please Check
PLAT910_ALERT_3_G Missing # of FCF Reflection(s) Below Theta(Min). 1 Note
PLAT912_ALERT_4_G Missing # of FCF Reflections Above STh/L= 0.600 11 Note
PLAT933_ALERT_2_G Number of HKL-OMIT Records in Embedded .res File 7 Note
PLAT978_ALERT_2_G Number C-C Bonds with Positive Residual Density. 3 Info
0 **ALERT level A** = Most likely a serious problem - resolve or explain
0 **ALERT level B** = A potentially serious problem, consider carefully
1 **ALERT level C** = Check. Ensure it is not caused by an omission or oversight
5 **ALERT level G** = General information/check it is not something unexpected
1 ALERT type 1 CIF construction/syntax error, inconsistent or missing data
2 ALERT type 2 Indicator that the structure model may be wrong or deficient
2 ALERT type 3 Indicator that the structure quality may be low
1 ALERT type 4 Improvement, methodology, query or suggestion
0 ALERT type 5 Informative message, check
Validation response form
Please find below a validation response form (VRF) that can be filled in and pasted into your CIF.
start Validation Reply Form
_vrf_PLAT911_a23090201aqlq_autored
;
PROBLEM: Missing FCF Refl Between Thmin & STh/L= 0.600 6 Report
RESPONSE: ...
;
end Validation Reply Form

It is advisable to attempt to resolve as many as possible of the alerts in all categories. Often the minor
alerts point to easily fixed oversights, errors and omissions in your CIF or refinement strategy, so attention to these fine details can be worthwhile. In order to resolve some of the more serious problems
it may be necessary to carry out additional measurements or structure refinements. However, the purpose of your study may justify the reported deviations and the more serious of these should normally be commented upon in the discussion or experimental section of a paper or in the "special_details" fields of the CIF. checkCIF was carefully designed to identify outliers and unusual parameters, but every test has its limitations and alerts that are not important in a particular case may
appear. Conversely, the absence of alerts does not guarantee there are no aspects of the results needing
attention. It is up to the individual to critically assess their own results and, if necessary, seek expert advice.

Publication of your CIF in IUCr journals

A basic structural check has been run on your CIF. These basic checks will be run on all CIFs submitted for publication in IUCr journals (*Acta Crystallographica*, *Journal of Applied Crystallography*, *Journal of Synchrotron Radiation*); however, if you intend to submit to *Acta Crystallographica Section C* or *E* or *IUCrData*, you should make sure that full publication checks are
run on the final version of your CIF prior to submission.

Publication of your CIF in other journals

Please refer to the *Notes for Authors* of the relevant journal for any special instructions relating to CIF
submission.

PLATON version of 06/07/2023; check.def file version of 30/06/2023