Supporting Information

Enantioselective synthesis of 3-amino-hydrobenzofuran-2,5-diones *via* Cu(I)-catalyzed intramolecular conjugate addition of imino esters

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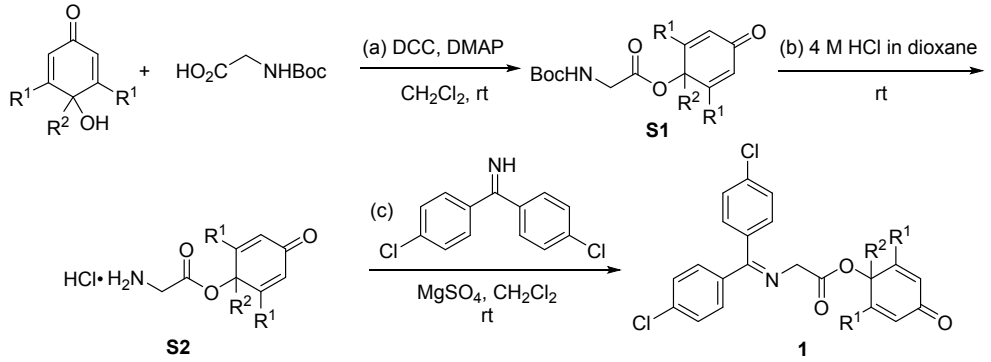
Contents

1. General information

^{1}H NMR spectrum were recorded on a Bruker DPX 400 MHz spectrometer in $CDCl_3$. Chemical shifts were reported in ppm with the internal TMS signal at 0.0 ppm as a standard. The spectra are interpreted as: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, dd = doublet of doublets, ddd = doublet of doublet of doublets, ddt = doublet of doublet of triplets, coupling constant(s) *J* are reported in Hz and relative integrations are reported. ^{13}C NMR (100 MHz) spectrum were recorded on a Bruker DPX 400 MHz spectrometer in $CDCl_3$. Chemical shifts were reported in ppm with the internal chloroform signal at 77.16 ppm as a standard. Optical rotations were measured on an AUTOPOL V. Diastereomeric ratios were determined by analysis of ^{1}H NMR spectroscopy. Enantiomeric excesses were determined by analysis of HPLC traces, obtained by using Chiralpak IA and IB columns with hexane and *i*-propanol or ethanol as solvents. (Chiralpak IA and IB columns were purchased from Daicel Chemical Industries, LTD.) Melting points were obtained in open capillary tubes using SGW X-4 micro melting point apparatus which were uncorrected. Mass spectrum were recorded on TOF mass spectrometer. Commercially available materials purchased from Adamas-beta, TCI or Energy Chemical and were used as received.

2. Preparation and characterization data of substrate imine esters

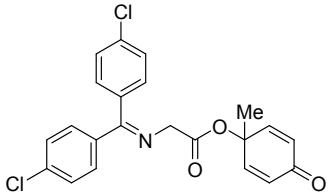
2.1 General procedure A for the synthesis of ketimine esters 1



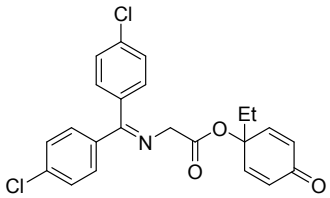
(a) DCC (2.1 g, 10 mmol, 2.0 equiv) was added to a solution of the appropriate *p*-quinol (5 mmol, 1.0 equiv), Boc-glycine (1.7 g, 10 mmol, 2.0 equiv), and DMAP (61 mg, 0.5 mmol, 10 mol%) in anhydrous CH_2Cl_2 (15 mL). The mixture was stirred at ambient temperature until consumption of the starting material (usually between 1 and 3 h), then filtered. The filtrate was concentrated and purified by flash column chromatography (petroleum ether/ethyl acetate = 5:1) to afford **S1**.

(b) **S1** was treated with 4 M HCl in dioxane (10 mL) at 0 °C. The mixture was stirred at ambient temperature until consumption of the starting material, then was concentrated to provide HCl salt **S2**. This material was carried forward without purification.

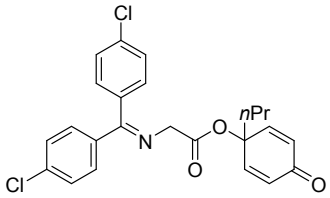
(c) Bis(4-chlorophenyl)methanimine (1.0 equiv) was added to a suspension of HCl salt **S2** (1.5 equiv) and anhydrous $MgSO_4$ (2.0 equiv) in anhydrous CH_2Cl_2 (1.0 M in substrate). The mixture was stirred at ambient temperature for 12 h, then filtered. The filtrate was washed with water and brine. The organic phase was dried over Na_2SO_4, filtered and concentrated. The residue was purified by flash column chromatography (petroleum ether/ethyl acetate = 15:1), followed by recrystallization from isopropyl ether gave the ketimine esters **1**.



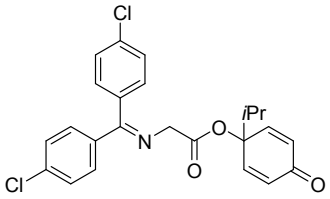
1-Methyl-4-oxocyclohexa-2,5-dien-1-yl 2-((bis(4-chlorophenyl)methylene)amino)acetate (1a): Following the general procedure **A**, compound **1a** was obtained as a white solid in 45% overall yield (621 mg); mp = 124–126 ºC; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.56 (d, *J* = 8.6 Hz, 2H), 7.48 (d, *J* = 8.4 Hz, 2H), 7.31 (d, *J* = 8.6 Hz, 2H), 7.11 (d, *J* = 8.3 Hz, 2H), 6.88 (d, *J* = 10.1 Hz, 2H), 6.24 (d, *J* = 10.1 Hz, 2H), 4.18 (s, 2H), 1.57 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 185.0, 170.2, 168.9, 148.6 (2C), 137.3, 137.2, 135.6, 133.7, 130.1 (2C), 129.4 (2C), 129.2 (2C), 128.6 (2C), 128.5 (2C), 75.0, 55.5, 26.3; **HRMS** (EI, m/z): calcd for $C_{22}H_{17}Cl_2NO_3$ $[M]^+$: 413.0580, found: 413.0584.



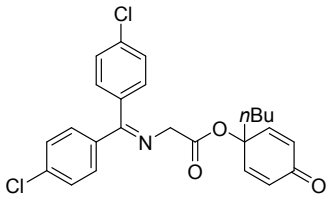
1-Ethyl-4-oxocyclohexa-2,5-dien-1-yl 2-((bis(4-chlorophenyl)methylene)amino)acetate (1b): Following the general procedure **A**, compound **1b** was obtained as a white solid in 50% overall yield (713 mg); mp = 142–144 ºC; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.56 (d, *J* = 8.6 Hz, 2H), 7.48 (d, *J* = 8.4 Hz, 2H), 7.31 (d, *J* = 8.6 Hz, 2H), 7.11 (d, *J* = 8.4 Hz, 2H), 6.80 (d, *J* = 10.2 Hz, 2H), 6.31 (d, *J* = 10.2 Hz, 2H), 4.19 (s, 2H), 1.89 (q, *J* = 7.5 Hz, 2H), 0.89 (t, *J* = 7.5 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 185.3, 170.1, 168.9, 147.7 (2C), 137.3, 137.2, 135.5, 133.7, 130.1 (2C), 129.6 (2C), 129.4 (2C), 129.2 (2C), 128.6 (2C), 78.2, 55.5, 32.2, 7.8; **HRMS** (EI, m/z): calcd for $C_{23}H_{19}Cl_2NO_3$ $[M]^+$: 427.0737, found: 427.0735.



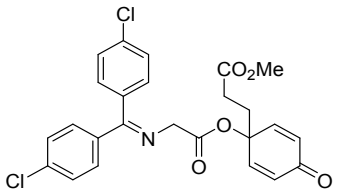
4-Oxo-1-propylcyclohexa-2,5-dien-1-yl 2-((bis(4-chlorophenyl)methylene)amino)acetate (1c): Following the general procedure **A**, compound **1c** was obtained as a white solid in 43% overall yield (634 mg); mp = 142–144 ºC; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.56 (d, *J* = 8.3 Hz, 2H), 7.48 (d, *J* = 7.9 Hz, 2H), 7.31 (d, *J* = 8.2 Hz, 2H), 7.11 (d, *J* = 8.0 Hz, 2H), 6.82 (d, *J* = 9.8 Hz, 2H), 6.28 (d, *J* = 9.9 Hz, 2H), 4.18 (s, 2H), 1.85 – 1.77 (m, 2H), 1.40 – 1.25 (m, 2H), 0.90 (d, *J* = 7.3 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 185.3, 170.1, 168.9, 148.0 (2C), 137.2(8), 137.2(5), 135.6, 133.7, 130.1 (2C), 129.4 (2C), 129.3 (2C), 129.2 (2C), 128.6 (2C), 77.8, 55.5, 41.3, 16.9, 14.2; **HRMS** (EI, m/z): calcd for $C_{24}H_{21}Cl_2NO_3$ $[M]^+$: 441.0893, found: 441.0895.



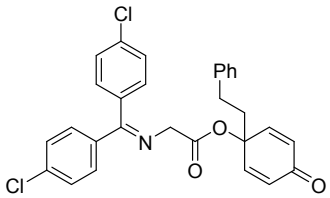
1-Isopropyl-4-oxocyclohexa-2,5-dien-1-yl 2-((bis(4-chlorophenyl)methylene)amino) acetate (1d): Following the general procedure **A**, compound **1d** was obtained as a white solid in 35% overall yield (516 mg); mp = 124–125 ºC; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.56 (d, *J* = 8.5 Hz, 2H), 7.48 (d, *J* = 8.2 Hz, 2H), 7.31 (d, *J* = 8.5 Hz, 2H), 7.11 (d, *J* = 8.2 Hz, 2H), 6.77 (d, *J* = 10.2 Hz, 2H), 6.34 (d, *J* = 10.2 Hz, 2H), 4.20 (s, 2H), 2.16 (p, *J* = 6.9 Hz, 1H), 0.96 (d, *J* = 6.9 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 185.4, 170.0, 168.8, 146.7 (2C), 137.2(8), 137.2(5), 135.6, 133.7, 130.3 (2C), 130.1 (2C), 129.4 (2C), 129.2 (2C), 128.6 (2C), 80.3, 55.6, 36.4, 17.0 (2C); **HRMS** (EI, m/z): calcd for $C_{24}H_{21}Cl_2NO_3$ $[M]^+$: 441.0893, found: 441.0897.



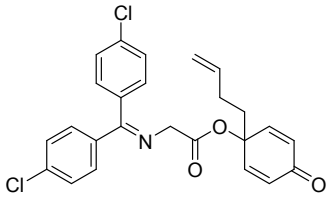
1-Butyl-4-oxocyclohexa-2,5-dien-1-yl 2-((bis(4-chlorophenyl)methylene)amino)acetate (1e): Following the general procedure **A**, compound **1e** was obtained as a white solid in 46% overall yield (700 mg); mp = 94–96 ºC; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.56 (d, *J* = 8.3 Hz, 2H), 7.48 (d, *J* = 8.1 Hz, 2H), 7.30 (d, *J* = 8.4 Hz, 2H), 7.11 (d, *J* = 8.1 Hz, 2H), 6.82 (d, *J* = 9.8 Hz, 2H), 6.28 (d, *J* = 9.8 Hz, 2H), 4.18 (s, 2H), 1.87 – 1.80 (m, 2H), 1.35 – 1.21 (m, 4H), 0.87 (t, *J* = 6.7 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 185.3, 170.1, 168.9, 148.0 (2C), 137.3, 137.2, 135.5, 133.7, 130.1 (2C), 129.4 (2C), 129.3 (2C), 129.2 (2C), 128.6 (2C), 77.8, 55.5, 39.0, 25.5, 22.8, 13.9; **HRMS** (EI, m/z): calcd for $C_{25}H_{23}Cl_2NO_3$ $[M]^+$: 455.1050, found: 455.1057.



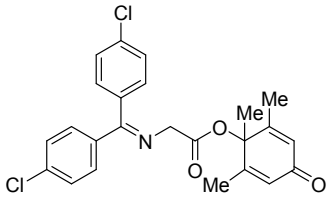
Methyl 3-(1-(2-((bis(4-chlorophenyl)methylene)amino)acetoxy)-4-oxocyclohexa-2,5-dien-1-yl)propanoate (1f): Following the general procedure **A**, compound **1f** was obtained as a white solid in 53% overall yield (859 mg); mp = 162–164 ºC; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.56 (d, *J* = 8.6 Hz, 2H), 7.48 (d, *J* = 8.4 Hz, 2H), 7.31 (d, *J* = 8.7 Hz, 2H), 7.11 (d, *J* = 8.4 Hz, 2H), 6.78 (d, *J* = 10.2 Hz, 2H), 6.31 (d, *J* = 10.2 Hz, 2H), 4.18 (s, 2H), 3.64 (s, 3H), 2.36 – 2.28 (m, 2H), 2.26 – 2.18 (m, 2H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 184.8, 172.6, 170.2, 168.7, 146.8 (2C), 137.3, 137.2, 135.6, 133.6, 130.1 (2C), 129.9 (2C), 129.4 (2C), 129.2 (2C), 128.6 (2C), 76.8, 55.4, 52.0, 33.8, 28.2; **HRMS** (EI, m/z): calcd for $C_{25}H_{21}Cl_2NO_5$ $[M]^+$: 485.0791, found: 485.0793.



4-Oxo-1-phenethylcyclohexa-2,5-dien-1-yl 2-((bis(4-chlorophenyl)methylene)amino) acetate (1g): Following the general procedure **A**, compound **1g** was obtained as a white solid in 40% overall yield (673 mg); mp = 139–140 ºC; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.57 (d, *J* = 8.6 Hz, 2H), 7.48 (d, *J* = 8.3 Hz, 2H), 7.34 – 7.23 (m, 4H), 7.22 – 7.16 (m, 1H), 7.14 – 7.06 (m, 4H), 6.88 (d, *J* = 10.2 Hz, 2H), 6.32 (d, *J* = 10.2 Hz, 2H), 4.19 (s, 2H), 2.74 – 2.58 (m, 2H), 2.20 – 2.09 (m, 2H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 185.1, 170.2, 168.9, 147.6 (2C), 140.4, 137.3, 137.2, 135.6, 133.7, 130.1 (2C), 129.5 (2C), 129.4 (2C), 129.2 (2C), 128.8 (2C), 128.6 (2C), 128.4 (2C), 126.6, 77.4, 55.5, 41.0, 29.9; **HRMS** (EI, m/z): calcd for $C_{29}H_{23}Cl_2NO_3$ $[M]^+$: 503.1050, found: 503.1048.

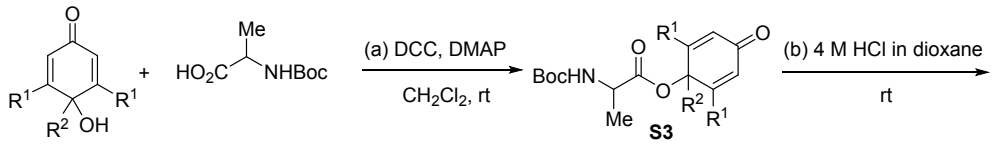


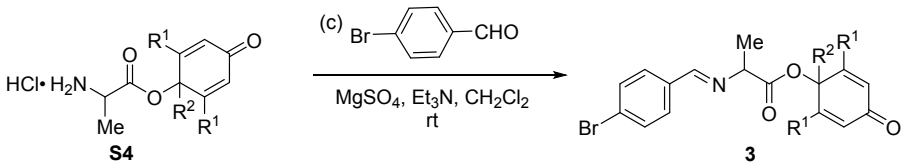
1-(But-3-en-1-yl)-4-oxocyclohexa-2,5-dien-1-yl 2-((bis(4-chlorophenyl)methylene)amino) acetate (1h): Following the general procedure **A**, compound **1h** was obtained as a white solid in 50% overall yield (757 mg); mp = 146–147 ºC; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.56 (d, *J* = 8.5 Hz, 2H), 7.48 (d, *J* = 8.3 Hz, 2H), 7.31 (d, *J* = 8.5 Hz, 2H), 7.11 (d, *J* = 8.3 Hz, 2H), 6.84 (d, *J* = 10.2 Hz, 2H), 6.30 (d, *J* = 10.2 Hz, 2H), 5.80 – 5.66 (m, 1H), 5.08 – 4.93 (m, 2H), 4.19 (s, 2H), 2.13 – 2.04 (m, 2H), 1.98 – 1.88 (m, 2H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 185.1, 170.1, 168.8, 147.6 (2C), 137.3, 137.2, 136.7, 135.6, 133.7, 130.1 (2C), 129.5 (2C), 129.4 (2C), 129.2 (2C), 128.6 (2C), 115.9, 77.4, 55.5, 38.4, 27.7; **HRMS** (EI, m/z): calcd for $C_{25}H_{21}Cl_2NO_3$ $[M]^+$: 453.0893, found: 453.0890.



1,2,6-Trimethyl-4-oxocyclohexa-2,5-dien-1-yl 2-((bis(4-chlorophenyl)methylene)amino) acetate (1i): Following the general procedure **A**, compound **1i** was obtained as a white solid in 40% overall yield (295 mg); mp = 140–141 ºC; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.55 (d, *J* = 8.5 Hz, 2H), 7.48 (d, *J* = 8.2 Hz, 2H), 7.31 (d, *J* = 8.5 Hz, 2H), 7.12 (d, *J* = 8.2 Hz, 2H), 6.09 (s, 2H), 4.23 (s, 2H), 1.91 (s, 6H), 1.50 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 185.1, 170.3, 168.1, 158.9 (2C), 137.2, 137.0, 135.4, 133.5, 129.9 (2C), 129.3 (2C), 129.0 (2C), 128.5 (2C), 126.9 (2C), 79.3, 55.1, 26.2, 17.7 (2C); **HRMS** (EI, m/z): calcd for $C_{24}H_{21}Cl_2NO_3$ $[M]^+$: 441.0893, found: 441.0896.

2.2 General procedure B for the synthesis of aldimine esters 3

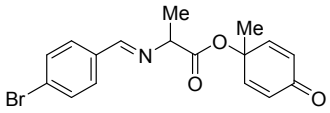




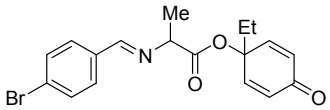
(a-b) Same methods as General procedure A.

(c) A suspension of HCl salt **S4** (1.5 equiv), 4-bromobenzaldehyde (1.0 equiv) and anhydrous $MgSO_4$ (2.0 equiv) in anhydrous CH_2Cl_2 (1.0 M in substrate) was stirred at 0 ºC.

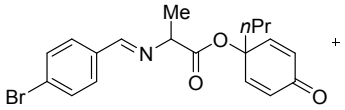
Et_3N (1.5 equiv) was added dropwise. The mixture was stirred at ambient temperature for 12 h, then filtered. The filtrate was washed with water and brine. The organic phase was dried over Na_2SO_4, filtered and concentrated. The residue was purified by flash column chromatography (petroleum ether/ethyl acetate = 15:1 + 0.5% Et_3N), followed by recrystallization from isopropyl ether gave the aldimine esters **3**.



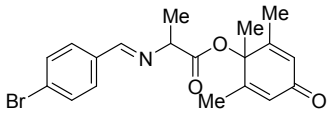
1-Methyl-4-oxocyclohexa-2,5-dien-1-yl (*E*)-2-((4-bromobenzylidene)amino)propanoate (3a): Following the general procedure **B**, compound **3a** was obtained as a white solid in 30% overall yield (362 mg); mp = 101–103 ºC; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.26 (s, 1H), 7.64 (d, *J* = 8.3 Hz, 2H), 7.56 (d, *J* = 8.3 Hz, 2H), 6.89 (d, *J* = 9.6 Hz, 2H), 6.24 (d, *J* = 9.6 Hz, 2H), 4.14 (q, *J* = 6.8 Hz, 1H), 1.58 (s, 3H), 1.52 (d, *J* = 6.8 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 185.0, 171.0, 162.1, 148.7 (2C), 134.6, 132.0 (2C), 130.0 (2C), 128.5 (2C), 125.9, 75.0, 67.8, 26.3, 19.3; **HRMS** (EI, m/z): calcd for $C_{17}H_{16}BrNO_3$ $[M]^+$: 361.0308, found: 361.0305.



1-Ethyl-4-oxocyclohexa-2,5-dien-1-yl (*E*)-2-((4-bromobenzylidene)amino)propanoate (3b): Following the general procedure **B**, compound **3b** was obtained as a white solid in 35% overall yield (439 mg); mp = 100–102 ºC; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.26 (s, 1H), 7.64 (d, *J* = 8.3 Hz, 2H), 7.56 (d, *J* = 8.4 Hz, 2H), 6.81 (d, *J* = 9.5 Hz, 2H), 6.30 (d, *J* = 9.7 Hz, 2H), 4.15 (q, *J* = 6.8 Hz, 1H), 1.90 (q, *J* = 7.5 Hz, 2H), 1.53 (d, *J* = 6.8 Hz, 3H), 0.90 (t, *J* = 7.5 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 185.3, 170.9, 162.1, 147.8 (2C), 134.7, 132.1 (2C), 130.0 (2C), 129.5 (2C), 125.9, 78.0, 67.9, 32.3, 19.3, 7.8; **HRMS** (EI, m/z): calcd for $C_{18}H_{18}BrNO_3$ $[M]^+$: 375.0465, found: 375.0468.

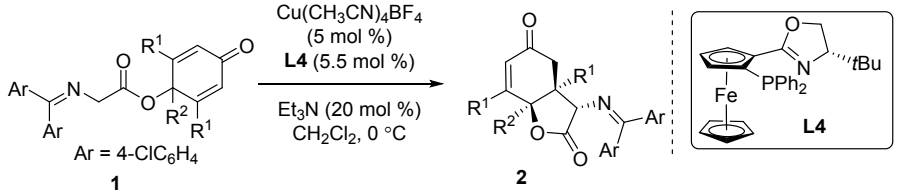


4-Oxo-1-propylcyclohexa-2,5-dien-1-yl (*E*)-2-((4-bromobenzylidene)amino)propanoate (3c): Following the general procedure **B**, compound **3c** was obtained as a white solid in 36% overall yield (468 mg); mp = 115–117 ºC; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.26 (s, 1H), 7.64 (d, *J* = 8.3 Hz, 2H), 7.56 (d, *J* = 8.4 Hz, 2H), 6.83 (d, *J* = 9.4 Hz, 2H), 6.28 (d, *J* = 9.5 Hz, 2H), 4.14 (q, *J* = 6.8 Hz, 1H), 1.88 – 1.76 (m, 2H), 1.52 (d, *J* = 6.8 Hz, 3H), 1.41 – 1.28 (m, 2H), 0.90 (t, *J* = 7.3 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 185.3, 170.9, 162.1, 148.1 (2C), 134.7, 132.0 (2C), 130.0 (2C), 129.2 (2C), 125.9, 77.7, 67.9, 41.4, 19.3, 16.9, 14.2; **HRMS** (EI, m/z): calcd for $C_{19}H_{20}BrNO_3$ $[M]^+$: 389.0621, found: 389.0625.

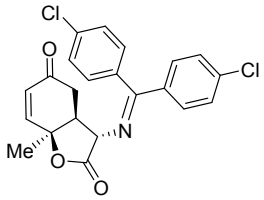


1,2,6-Trimethyl-4-oxocyclohexa-2,5-dien-1-yl (*E*)-2-((4-bromobenzylidene)amino) propanoate (3d): Following the general procedure **B**, compound **3d** was obtained as a white solid in 45% overall yield (585 mg); mp = 86–88 ºC; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.30 (s, 1H), 7.64 (d, *J* = 8.4 Hz, 2H), 7.56 (d, *J* = 8.4 Hz, 2H), 6.08 (s, 2H), 4.18 (q, *J* = 6.8 Hz, 1H), 1.93 (s, 3H), 1.91 (s, 3H), 1.54 (d, *J* = 6.7 Hz, 3H), 1.51 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 185.3, 170.3, 162.2, 159.2, 159.1, 134.6, 132.1 (2C), 130.0 (2C), 127.1, 127.0, 126.0, 79.3, 67.7, 26.3, 19.0, 17.8 (2C); **HRMS** (EI, m/z): calcd for $C_{19}H_{20}BrNO_3$ $[M]^+$: 389.0621, found: 389.0626.

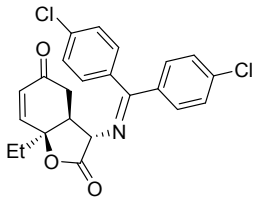
3. Preparation and characterization data of conjugate adducts



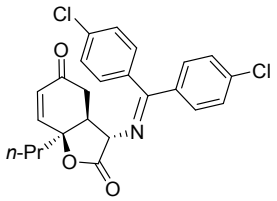
General procedure C: Under a nitrogen atmosphere, $Cu(CH_3CN)_4BF_4$ (3.1 mg, 0.01 mmol) and ligand **L4** (5.4 mg, 0.011 mmol) were dissolved in anhydrous CH_2Cl_2 (2.0 mL), and stirred at room temperature for approximately 1 h. Then, the mixture was cooled to 0 °C, ketimine esters **1** (0.2 mmol) and Et_3N (5.6 μL, 0.04 mmol) were added sequentially, the reaction mixture was stirred at 0 °C. Once starting material was consumed (monitored by TLC), the mixture was concentrated and purified by column chromatography (petroleum ether/ethyl acetate = 20:1) to give the corresponding conjugate adducts.



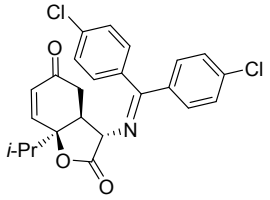
(3*S*,3a*S*,7a*S*)-3-((Bis(4-chlorophenyl)methylene)amino)-7a-methyl-3a,7a-dihydrobenzofuran-2,5(3*H*,4*H*)-dione (2a): Following the general procedure **C**, compound **2a** was obtained as a white solid in 85% yield (70.4 mg); mp = 75–77 ºC; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.55 (d, *J* = 8.3 Hz, 2H), 7.42 (d, *J* = 8.0 Hz, 2H), 7.32 (d, *J* = 8.3 Hz, 2H), 7.15 (d, *J* = 8.0 Hz, 2H), 6.62 (dd, *J* = 10.3, 2.0 Hz, 1H), 5.91 (d, *J* = 10.3 Hz, 1H), 4.08 (d, *J* = 10.9 Hz, 1H), 3.42 – 3.29 (m, 1H), 2.71 (dd, *J* = 17.6, 5.6 Hz, 1H), 2.48 (dd, *J* = 17.7, 2.2 Hz, 1H), 1.75 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 194.2, 173.1, 171.6, 147.0, 137.6, 136.8, 135.7, 133.0, 130.2 (2C), 129.4, 129.4 (2C), 129.2 (2C), 128.6 (2C), 79.9, 65.5, 49.2, 35.5, 24.4; **HPLC** (Chiralpak IA, hexane/*i*-PrOH = 80/20, 0.8 mL/min, 220 nm) t_R = 15.04 min (minor), 16.50 min (major); $[\alpha]_D^{25}$ = -41.6 (*c* 1.00, CH_2Cl_2); **HRMS** (EI, m/z): calcd for $C_{22}H_{17}Cl_2NO_3$ $[M]^+$: 413.0580, found: 413.0581.



(3*S*,3a*S*,7a*S*)-3-((Bis(4-chlorophenyl)methylene)amino)-7a-ethyl-3a,7a-dihydrobenzofuran-2,5(3*H*,4*H*)-dione (2b): Following the general procedure **C**, compound **2b** was obtained as a white solid in 87% yield (74.5 mg); mp = 175–177 ºC; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.55 (d, *J* = 8.6 Hz, 2H), 7.42 (d, *J* = 8.3 Hz, 2H), 7.32 (d, *J* = 8.7 Hz, 2H), 7.15 (d, *J* = 8.3 Hz, 2H), 6.65 (dd, *J* = 10.4, 2.0 Hz, 1H), 5.97 (d, *J* = 10.4 Hz, 1H), 4.08 (d, *J* = 10.8 Hz, 1H), 3.51 – 3.27 (m, 1H), 2.66 (dd, *J* = 17.8, 5.7 Hz, 1H), 2.46 (d, *J* = 17.8 Hz, 1H), 2.16 – 1.92 (m, 3H), 1.15 (t, *J* = 7.5 Hz, 2H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 194.5, 173.2, 171.7, 146.4, 137.6, 136.8, 135.8, 133.1, 130.3 (3C), 129.5 (2C), 129.3 (2C), 128.6 (2C), 82.3, 65.8, 46.8, 35.9, 31.0, 8.0; **HPLC** (Chiralpak IA, hexane/*i*-PrOH = 80/20, 0.8 mL/min, 220 nm) t_R = 11.37 min (minor), 13.21 min (major); $[\alpha]_D^{25}$ = -53.5 (*c* 1.00, CH_2Cl_2); **HRMS** (EI, m/z): calcd for $C_{23}H_{19}Cl_2NO_3$ $[M]^+$: 427.0737, found: 427.0739.

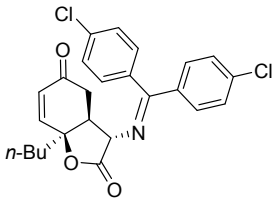


(3*S*,3a*S*,7a*S*)-3-((Bis(4-chlorophenyl)methylene)amino)-7a-propyl-3a,7a-dihydrobenzofuran-2,5(3*H*,4*H*)-dione (2c): Following the general procedure **C**, compound **2c** was obtained as a colorless oil in 87% yield (79.6 mg); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.55 (d, *J* = 8.6 Hz, 2H), 7.42 (d, *J* = 8.6 Hz, 2H), 7.32 (d, *J* = 8.6 Hz, 2H), 7.15 (d, *J* = 8.4 Hz, 2H), 6.65 (dd, *J* = 10.4, 2.0 Hz, 1H), 5.95 (d, *J* = 10.4 Hz, 1H), 4.07 (d, *J* = 10.9 Hz, 1H), 3.52 – 3.27 (m, 1H), 2.67 (dd, *J* = 17.8, 5.7 Hz, 1H), 2.46 (d, *J* = 16.8 Hz, 1H), 2.03 (ddd, *J* = 14.3, 10.5, 6.4 Hz, 1H), 1.91 (ddd, *J* = 14.3, 10.8, 5.8 Hz, 1H), 1.68 – 1.50 (m, 2H), 1.03 (t, *J* = 7.3 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 194.6, 173.2, 171.8, 146.6, 137.7, 136.9, 135.8, 133.1, 130.3 (2C), 130.1, 129.5 (2C), 129.3 (2C), 128.7 (2C), 82.2, 65.7, 47.4, 40.3, 35.9, 17.1, 14.4; **HPLC** (Chiralpak IA, hexane/*i*-PrOH = 90/10, 1.0 mL/min, 220 nm) t_R = 12.98 min (minor), 15.99 min (major); $[\alpha]_D^{25}$ = -51.2 (*c* 1.00, CH_2Cl_2); **HRMS** (EI, m/z): calcd for $C_{24}H_{21}Cl_2NO_3$ $[M]^+$: 441.0893, found: 441.0899.

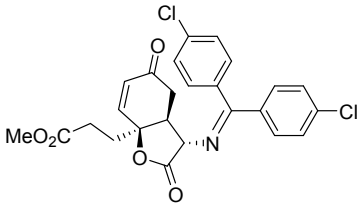


(3*S*,3a*S*,7a*S*)-3-((Bis(4-chlorophenyl)methylene)amino)-7a-isopropyl-3a,7a-dihydrobenzofuran-2,5(3*H*,4*H*)-dione (2d): Following the general procedure **C**, compound **2d** was obtained as a white solid in 75% yield (66.4 mg); mp = 160–162 ºC; **^{1}H NMR** (400

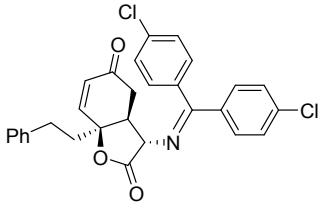
MHz, $CDCl_3$) δ 7.56 (d, *J* = 8.7 Hz, 2H), 7.42 (d, *J* = 8.4 Hz, 2H), 7.32 (d, *J* = 8.6 Hz, 2H), 7.16 (d, *J* = 8.1 Hz, 2H), 6.65 (dd, *J* = 10.5, 2.0 Hz, 1H), 6.05 (d, *J* = 10.5 Hz, 1H), 4.05 (d, *J* = 10.7 Hz, 1H), 3.48 – 3.38 (m, 1H), 2.68 (dd, *J* = 18.1, 6.0 Hz, 1H), 2.42 (d, *J* = 18.1 Hz, 1H), 2.34 – 2.23 (m, 1H), 1.14 (dd, *J* = 6.9, 4.1 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 194.7, 173.2, 171.6, 145.6, 137.7, 136.8, 135.8, 133.1, 131.3, 130.3 (2C), 129.5 (2C), 129.3 (2C), 128.6 (2C), 84.4, 66.6, 44.9, 36.8, 36.4, 17.7, 16.9; **HPLC** (Chiralpak IA, hexane/*i*-PrOH = 90/10, 1.0 mL/min, 220 nm) t_R = 12.11 min (minor), 14.26 min (major); $[\alpha]_D^{25}$ = -59.0 (*c* 1.00, CH_2Cl_2); **HRMS** (EI, m/z): calcd for $C_{24}H_{21}Cl_2NO_3$ $[M]^+$: 441.0893, found: 441.0890.



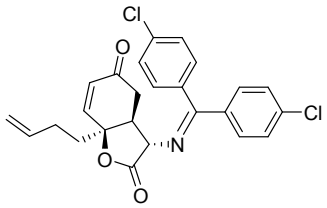
(3*S*,3a*S*,7a*S*)-3-((Bis(4-chlorophenyl)methylene)amino)-7a-butyl-3a,7a-dihydrobenzofuran-2,5(3*H*,4*H*)-dione (2e): Following the general procedure **C**, compound **2e** was obtained as a white solid in 82% yield (74.8 mg); mp = 60–63 ºC; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.55 (d, *J* = 8.6 Hz, 2H), 7.42 (d, *J* = 8.5 Hz, 2H), 7.32 (d, *J* = 8.6 Hz, 2H), 7.15 (d, *J* = 8.3 Hz, 2H), 6.65 (dd, *J* = 10.4, 2.0 Hz, 1H), 5.95 (d, *J* = 10.4 Hz, 1H), 4.07 (d, *J* = 10.9 Hz, 1H), 3.49 – 3.31 (m, 1H), 2.67 (dd, *J* = 17.7, 5.7 Hz, 1H), 2.46 (d, *J* = 17.4 Hz, 1H), 2.11 – 1.99 (m, 1H), 1.99 – 1.87 (m, 1H), 1.58 – 1.47 (m, 2H), 1.48 – 1.35 (m, 2H), 0.96 (t, *J* = 7.2 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 194.6, 173.2, 171.8, 146.7, 137.7, 136.9, 135.8, 133.1, 130.3 (2C), 130.1, 129.5 (2C), 129.3 (2C), 128.7 (2C), 82.2, 65.8, 47.4, 37.9, 35.9, 25.7, 23.0, 14.0; **HPLC** (Chiralpak IA, hexane/*i*-PrOH = 90/10, 1.0 mL/min, 220 nm) t_R = 10.75 min (minor), 12.69 min (major); $[\alpha]_D^{25}$ = -58.6 (*c* 1.00, CH_2Cl_2); **HRMS** (EI, m/z): calcd for $C_{25}H_{23}Cl_2NO_3$ $[M]^+$: 455.1050, found: 455.1055.



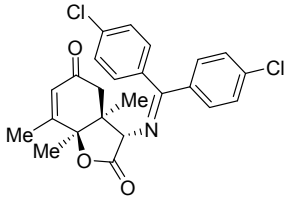
Methyl 3-((3*S*,3a*S*,7a*S*)-3-((bis(4-chlorophenyl)methylene)amino)-2,5-dioxo-3,3a,4,5-tetrahydrobenzofuran-7a(2*H*)-yl)propanoate (2f): Following the general procedure **C**, compound **2f** was obtained as a white solid in 88% yield (85.6 mg); mp = 57–59 ºC; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.55 (d, *J* = 8.7 Hz, 2H), 7.42 (d, *J* = 8.2 Hz, 2H), 7.32 (d, *J* = 8.6 Hz, 2H), 7.14 (d, *J* = 8.0 Hz, 2H), 6.62 (dd, *J* = 10.4, 2.1 Hz, 1H), 5.96 (d, *J* = 10.4 Hz, 1H), 4.08 (d, *J* = 10.9 Hz, 1H), 3.72 (s, 3H), 3.43 – 3.30 (m, 1H), 2.72 (dd, *J* = 17.8, 5.6 Hz, 1H), 2.68 – 2.55 (m, 2H), 2.47 (d, *J* = 18.4 Hz, 1H), 2.42 – 2.26 (m, 2H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 194.1, 173.3, 172.7, 171.3, 145.4, 137.7, 136.7, 135.7, 132.9, 130.5, 130.3 (2C), 129.4 (2C), 129.2 (2C), 128.6 (2C), 80.9, 65.4, 52.2, 47.1, 35.5, 32.2, 28.1; **HPLC** (Chiralpak IA, hexane/*i*-PrOH = 80/20, 0.8 mL/min, 220 nm) t_R = 16.32 min (minor), 20.63 min (major); $[\alpha]_D^{25}$ = -61.7 (*c* 1.00, CH_2Cl_2); **HRMS** (EI, m/z): calcd for $C_{25}H_{21}Cl_2NO_5$ $[M]^+$: 485.0791, found: 485.0797.



(3*S*,3a*S*,7a*S*)-3-((Bis(4-chlorophenyl)methylene)amino)-7a-phenethyl-3a,7a-dihydrobenzofuran-2,5(3*H*,4*H*)-dione (2g): Following the general procedure **C**, compound **2g** was obtained as a white solid in 85% yield (85.7 mg); mp = 84–86 ºC; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.56 (d, *J* = 8.7 Hz, 2H), 7.43 (d, *J* = 8.5 Hz, 2H), 7.37 – 7.29 (m, 4H), 7.26 – 7.18 (m, 3H), 7.15 (d, *J* = 8.4 Hz, 2H), 6.70 (dd, *J* = 10.4, 2.0 Hz, 1H), 5.98 (d, *J* = 10.4 Hz, 1H), 4.10 (d, *J* = 10.9 Hz, 1H), 3.52 – 3.36 (m, 1H), 3.04 – 2.80 (m, 2H), 2.68 (dd, *J* = 17.8, 5.7 Hz, 1H), 2.48 (d, *J* = 17.9 Hz, 1H), 2.36 (ddd, *J* = 14.4, 11.7, 5.6 Hz, 1H), 2.24 (ddd, *J* = 14.4, 11.7, 5.4 Hz, 1H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 194.3, 173.3, 171.7, 146.1, 140.3, 137.7, 136.8, 135.8, 133.0, 130.3 (2C), 130.3, 129.5 (2C), 129.3 (2C), 128.9 (2C), 128.6 (2C), 128.4 (2C), 126.7, 81.7, 65.6, 47.5, 39.9, 35.7, 29.9. **HPLC** (Chiralpak IA, hexane/*i*-PrOH = 90/10, 1.0 mL/min, 220 nm) t_R = 15.85 min (minor), 36.05 min (major). $[\alpha]_D^{25}$ = -87.8 (*c* 1.00, CH_2Cl_2); **HRMS** (EI, m/z): calcd for $C_{29}H_{23}Cl_2NO_3$ $[M]^+$: 503.1050, found: 503.1053.

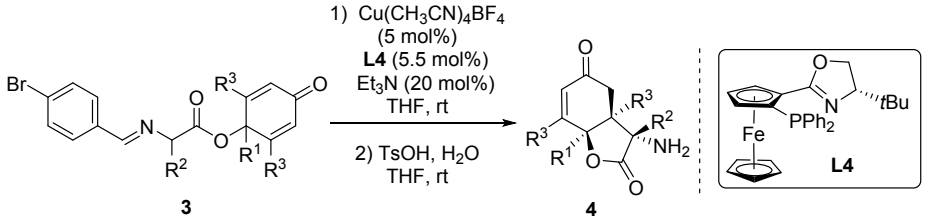


(3*S*,3a*S*,7a*S*)-3-((bis(4-chlorophenyl)methylene)amino)-7a-(but-3-en-1-yl)-3a,7a-dihydrobenzofuran-2,5(3*H*,4*H*)-dione (2h): Following the general procedure **C**, compound **2h** was obtained as a white solid in 85% yield (78.1 mg); mp = 63–65 ºC; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.55 (d, *J* = 8.7 Hz, 2H), 7.42 (d, *J* = 8.4 Hz, 2H), 7.32 (d, *J* = 8.6 Hz, 2H), 7.15 (d, *J* = 8.4 Hz, 2H), 6.66 (dd, *J* = 10.4, 2.0 Hz, 1H), 5.97 (d, *J* = 10.4 Hz, 1H), 5.84 (ddt, *J* = 16.7, 10.2, 6.4 Hz, 1H), 5.12 (dd, *J* = 17.1, 1.6 Hz, 1H), 5.06 (dd, *J* = 10.2, 1.5 Hz, 1H), 4.08 (d, *J* = 10.9 Hz, 1H), 3.47 – 3.35 (m, 1H), 2.69 (dd, *J* = 17.8, 5.7 Hz, 1H), 2.47 (d, *J* = 18.4 Hz, 1H), 2.40 – 2.26 (m, 2H), 2.15 (ddd, *J* = 14.3, 10.6, 5.8 Hz, 1H), 2.04 (ddd, *J* = 14.3, 10.4, 6.1 Hz, 1H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 194.4, 173.3, 171.7, 146.2, 137.7, 136.8, 136.6, 135.8, 133.0, 130.3 (2C), 130.2, 129.5 (2C), 129.3 (2C), 128.6 (2C), 116.2, 81.8, 65.6, 47.4, 37.1, 35.8, 27.8; **HPLC** (Chiralpak IA, hexane/*i*-PrOH = 90/10, 1.0 mL/min, 220 nm) t_R = 12.16 min (minor), 16.73 min (major); $[\alpha]_D^{25}$ = -77.0 (*c* 1.00, CH_2Cl_2); **HRMS** (EI, m/z): calcd for $C_{25}H_{21}Cl_2NO_3$ $[M]^+$: 453.0893, found: 453.0898.

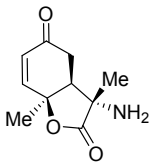


(3*S*,3a*S*,7a*S*)-3-((bis(4-chlorophenyl)methylene)amino)-3a,7,7a-trimethyl-3a,7a-dihydrobenzofuran-2,5(3*H*,4*H*)-dione (2i): Following the general procedure **C**, compound **2i**

was obtained as a colorless oil in 80% yield (70.8 mg); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.55 (d, *J* = 8.6 Hz, 2H), 7.41 (d, *J* = 8.2 Hz, 2H), 7.31 (d, *J* = 8.7 Hz, 2H), 7.08 (d, *J* = 7.9 Hz, 2H), 5.76 (s, 1H), 4.25 (s, 1H), 2.38 (s, 2H), 1.98 (s, 3H), 1.61 (s, 3H), 1.47 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 194.5, 172.9, 171.9, 158.5, 137.6, 137.0, 135.6, 133.1, 130.3 (2C), 129.4 (2C), 129.2 (2C), 128.6 (2C), 127.8, 84.9, 66.9, 49.7, 43.0, 19.5, 19.0, 18.7; **HPLC** (Chiralpak IB, hexane/*i*-PrOH = 100/5, 1.0 mL/min, 220 nm) t_R = 11.62 min (minor), 12.39 min (major); $[\alpha]_D^{25}$ = -29.3 (*c* 1.00, CH_2Cl_2); **HRMS** (EI, m/z): calcd for $C_{24}H_{21}Cl_2NO_3$ $[M]^+$: 441.0893, found: 441.0895.

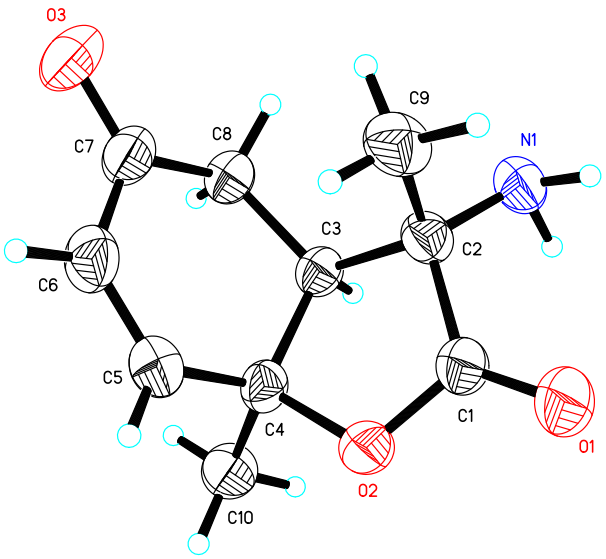


General procedure D: Under a nitrogen atmosphere, $Cu(CH_3CN)_4BF_4$ (3.1 mg, 0.01 mmol) and ligand **L4** (5.4 mg, 0.011 mmol) were dissolved in anhydrous THF (2.0 mL), and stirred at room temperature for approximately 1 h. Then, aldimine esters **3** (0.2 mmol) and Et_3N (5.6 μL, 0.04 mmol) were added sequentially, the reaction mixture was stirred at room temperature. Once starting material was consumed (monitored by TLC), the mixture was concentrated and purified by column chromatography (petroleum ether/ethyl acetate = 20:1 + 0.5% Et_3N) to give the corresponding conjugate adducts, which was dissolved in THF (2.0 mL) at room temperature. *p*-Toluenesulfonic acid (41.3 mg, 0.2 mmol) and water (3 drops) was then added and the mixture was stirred for 2 h at room temperature. The mixture was rendered alkaline by addition of saturated aq. $NaHCO_3$ and then extracted with EtOAc. The organic layer was dried over Na_2SO_4, concentrated and purified by column chromatography (petroleum ether/ethyl acetate = 1:1) to give the desired compound **4**.



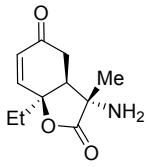
(3*S*,3a*S*,7a*S*)-3-amino-3,7a-dimethyl-3a,7a-dihydrobenzofuran-2,5(3*H*,4*H*)-dione (4a): Following the general procedure **D**, compound **4a** was obtained as a white solid in 80% yield (30.5 mg); mp = 129–131 ºC; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 6.74 (dd, *J* = 10.4, 1.6 Hz, 1H), 6.08 (d, *J* = 10.4 Hz, 1H), 2.81 (d, *J* = 18.0 Hz, 1H), 2.76 – 2.62 (m, 2H), 1.70 (s, 3H), 1.66 (br, 2H), 1.18 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 195.3, 180.0, 147.3, 129.6, 78.3, 59.2, 51.0, 33.7, 27.0, 21.2. **HPLC** (Chiralpak IA, hexane/EtOH = 2/1, 1.0 mL/min, 220 nm) t_R = 17.47 min (minor), 33.74 min (major). $[\alpha]_D^{25}$ = +67.8 (*c* 1.00, CH_2Cl_2); **HRMS** (EI, m/z): calcd for $C_{10}H_{13}NO_3$ $[M]^+$: 195.0890, found: 195.0896.

(CCDC 1883504 (**4a**) contains the supplementary crystallographic data for this paper. These data can be obtained free of charge via www.ccdc.cam.ac.uk/conts/retrieving.html.)



Identification code	cu_d8v18549_0m	
Empirical formula	C10 H13 N O3	
Formula weight	195.21	
Temperature	293(2) K	
Wavelength	1.54178 Å	
Crystal system	Triclinic	
Space group	P 1	
Unit cell dimensions	a = 6.9308(8) Å	α= 84.194(6)°.
	b = 6.9507(8) Å	β= 79.023(6)°.
	c = 11.8464(14) Å	γ = 64.094(6)°.
Volume	503.84(10) $Å^3$	
Z	2	
Density (calculated)	1.287 Mg/m^3	
Absorption coefficient	0.791 mm^{-1}	
F(000)	208	
Crystal size	0.160 x 0.130 x 0.080 mm^3	
Theta range for data collection	3.802 to 70.153°.	
Index ranges	-8<=h<=8, -8<=k<=8, -14<=l<=14	
Reflections collected	12059	
Independent reflections	3664 [R(int) = 0.0668]	
Completeness to theta = 67.679°	99.0 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	0.7456 and 0.5832	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	3664 / 3 / 274	
Goodness-of-fit on F^2	1.068	

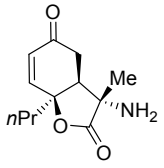
Final R indices [I>2sigma(I)]	R1 = 0.0514, wR2 = 0.1367
R indices (all data)	R1 = 0.0598, wR2 = 0.1453
Absolute structure parameter	0.24(17)
Largest diff. peak and hole	0.207 and -0.189 e.Å^{-3}



(3*S*,3a*S*,7a*S*)-3-Amino-7a-ethyl-3-methyl-3a,7a-dihydrobenzofuran-2,5(3*H*,4*H*)-dione

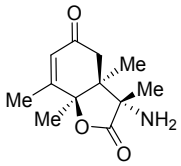
(4b): Following the general procedure **D**, compound **4a** was obtained as a white solid in 73% yield (30.6 mg); mp = 58–60 ºC; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 6.74 (dd, *J* = 10.5, 1.4 Hz, 1H), 6.15 (d, *J* = 10.5 Hz, 1H), 2.84 – 2.75 (m, 1H), 2.71 – 2.61 (m, 2H), 2.09 – 1.86 (m, 2H), 1.65 (br, 2H), 1.19 (s, 3H), 1.09 (t, *J* = 7.5 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 195.5, 180.1, 146.5, 130.6, 80.6, 59.3, 48.6, 34.2, 33.3, 21.4, 7.9. **HPLC** (Chiralpak IA, hexane/EtOH = 2/1, 1.0 mL/min, 220 nm) t_R = 20.87 min (minor), 44.09 min (major). $[\alpha]_D^{25}$ = +65.0 (*c* 1.00, CH_2Cl_2);

HRMS (EI, m/z): calcd for $C_{11}H_{15}NO_3$ $[M]^+$: 209.1046, found: 209.1050.



(3*S*,3a*S*,7a*S*)-3-Amino-3-methyl-7a-propyl-3a,7a-dihydrobenzofuran-2,5(3*H*,4*H*)-dione

(4c): Following the general procedure **D**, compound **4a** was obtained as a white solid in 73% yield (33.5 mg); mp = 96–98 ºC; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 6.75 (dd, *J* = 10.5, 1.1 Hz, 1H), 6.13 (d, *J* = 10.5 Hz, 1H), 2.83 – 2.74 (m, 1H), 2.72 – 2.62 (m, 2H), 2.02 – 1.90 (m, 1H), 1.89 – 1.80 (m, 1H), 1.69 (br, 2H), 1.59 – 1.46 (m, 2H), 1.18 (s, 3H), 1.00 (t, *J* = 7.3 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 195.5, 180.1, 146.7, 130.4, 80.4, 59.2, 49.2, 42.6, 34.1, 21.4, 17.0, 14.3; **HPLC** (Chiralpak IA, hexane/EtOH = 2/1, 1.0 mL/min, 220 nm) t_R = 14.88 min (minor), 37.24 min (major); $[\alpha]_D^{25}$ = +27.2 (*c* 1.00, CH_2Cl_2); **HRMS** (EI, m/z): calcd for $C_{12}H_{17}NO_3$ $[M]^+$: 223.1203, found: 223.1206.

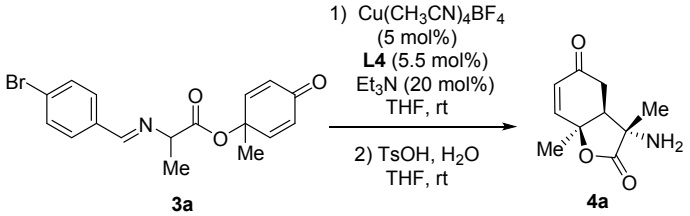


(3*S*,3a*S*,7a*S*)-3-Amino-3,3a,7,7a-tetramethyl-3a,7a-dihydrobenzofuran-2,5(3*H*,4*H*)-dione

(4d): Following the general procedure **D**, compound **4d** was obtained as a white solid in 73% yield (34.4 mg); mp = 134–136 ºC; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 5.96 (s, 1H), 2.74 (d, *J* = 18.5 Hz, 1H), 2.26 (d, *J* = 18.6 Hz, 1H), 2.10 (d, *J* = 1.3 Hz, 3H), 1.59 (s, 3H), 1.24 (s, 3H), 1.18 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 195.4, 180.2, 160.2, 128.2, 83.8, 61.3, 47.6, 41.7,

23.5, 22.2, 21.1, 18.9; **HPLC** (Chiralpak IA, hexane/EtOH = 2/1, 1.0 mL/min, 220 nm) t_R = 11.04 min (minor), 12.75 min (major); $[\alpha]_D^{25}$ = +103.5 (*c* 1.00, CH_2Cl_2); **HRMS** (EI, m/z): calcd for $C_{12}H_{17}NO_3$ $[M]^+$: 223.1203, found: 223.1205.

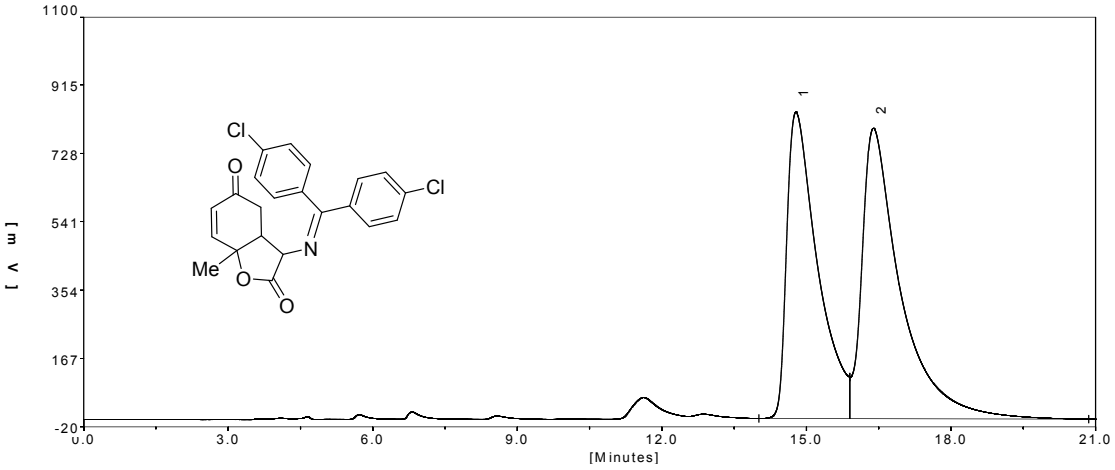
4. Gram-scale experiment



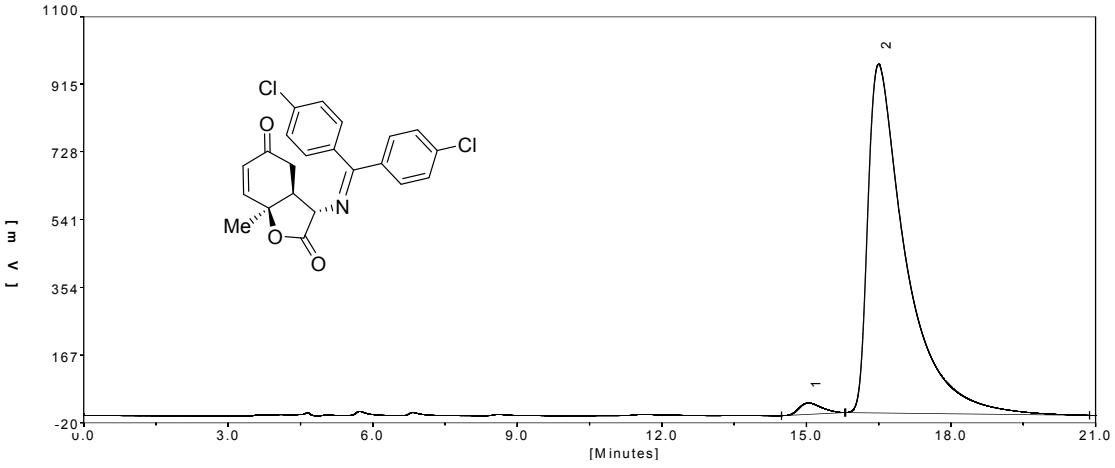
Under a nitrogen atmosphere, $Cu(CH_3CN)_4BF_4$ (55.0 mg, 0.175 mmol) and ligand **L4** (95.6 mg, 0.193 mmol) were dissolved in anhydrous THF (20 mL), and stirred at room temperature for approximately 1 h. Then, aldimine esters **3a** (1.27 g, 3.5 mmol) and Et_3N (167.3 μL, 0.7 mmol) were added sequentially, the reaction mixture was stirred at room temperature for 20 h. Then, the mixture was concentrated and purified by column chromatography (petroleum ether/ethyl acetate = 20:1 + 0.5% Et_3N) to give the corresponding conjugate adducts, which was dissolved in THF (20 mL) at room temperature. *p*-Toluenesulfonic acid (602.7 mg, 3.5 mmol) and water (1.0 mL) was then added and the mixture was stirred for 2 h at room temperature. The mixture was rendered alkaline by addition of saturated aq. $NaHCO_3$ and then extracted with EtOAc. The organic layer was dried over Na_2SO_4, concentrated and purified by column chromatography (petroleum ether/ethyl acetate = 1:1) to give the desired compound **4a**.

5. HPLC chromatograms

HPLC chromatogram of compound **2a** (96% ee).

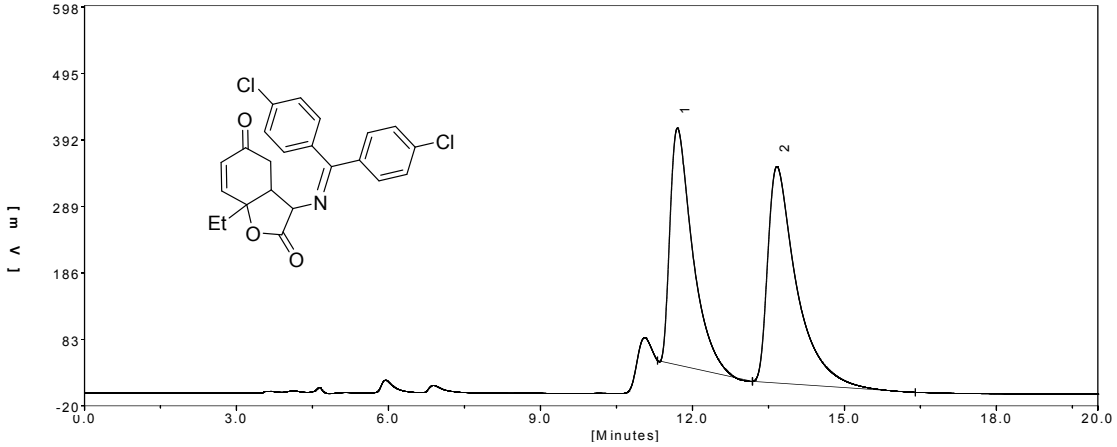


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	14.78333	838.03	37240.22	45.7682
2	16.39333	794.18	44126.84	54.2318

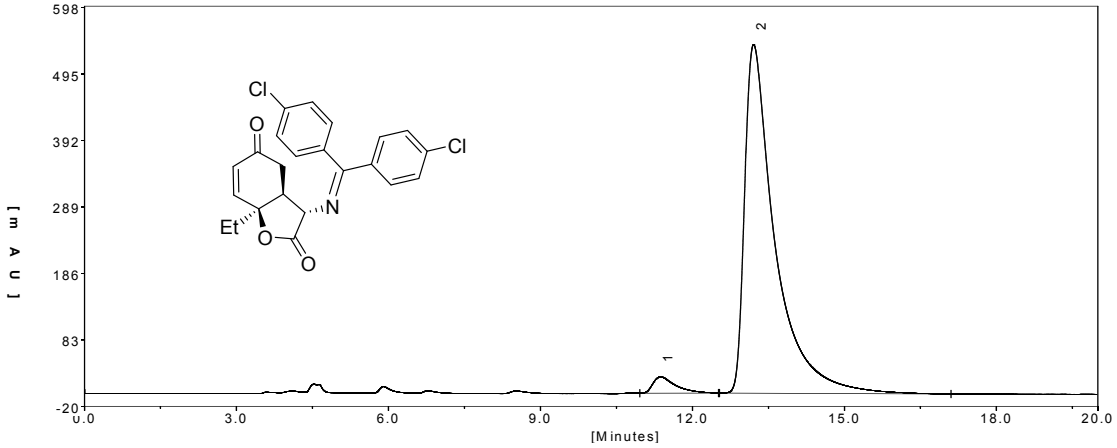


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	15.04083	31.67	1017.89	1.9050
2	16.49833	962.45	52414.64	98.0950

HPLC chromatogram of compound **2b** (93% ee).

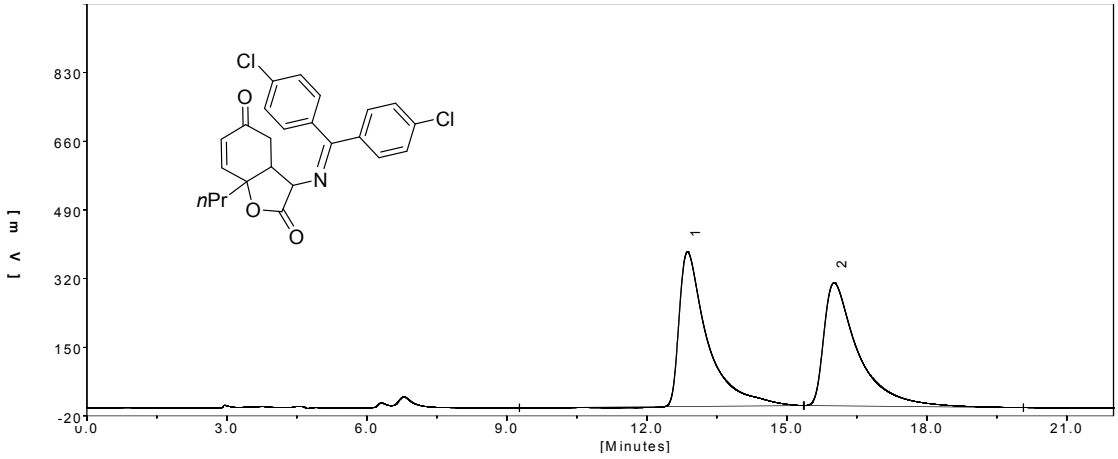


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	11.70333	366.99	11352.20	46.3359
2	13.66667	335.59	13147.58	53.6641

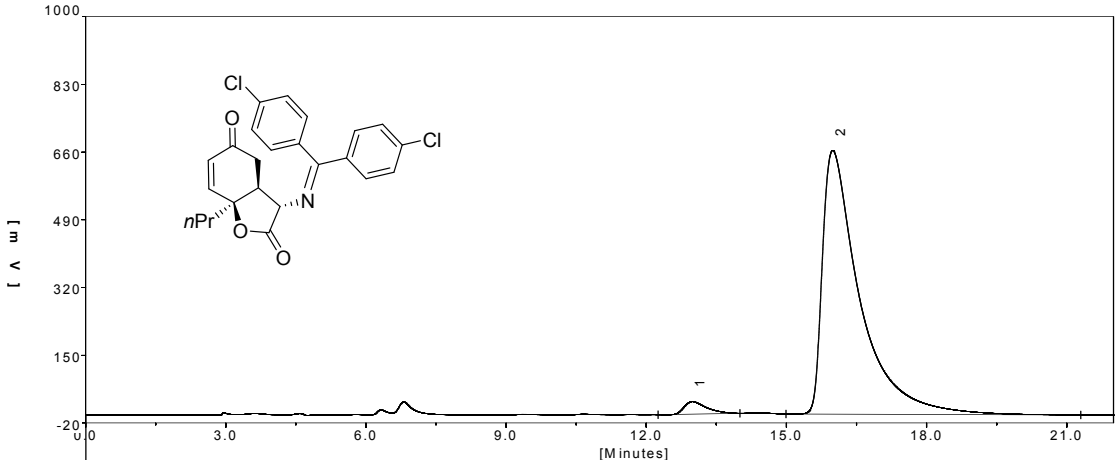


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	11.36583	25.39	778.25	3.3498
2	13.20750	540.38	22454.56	96.6502

HPLC chromatogram of compound **2c** (95% ee).

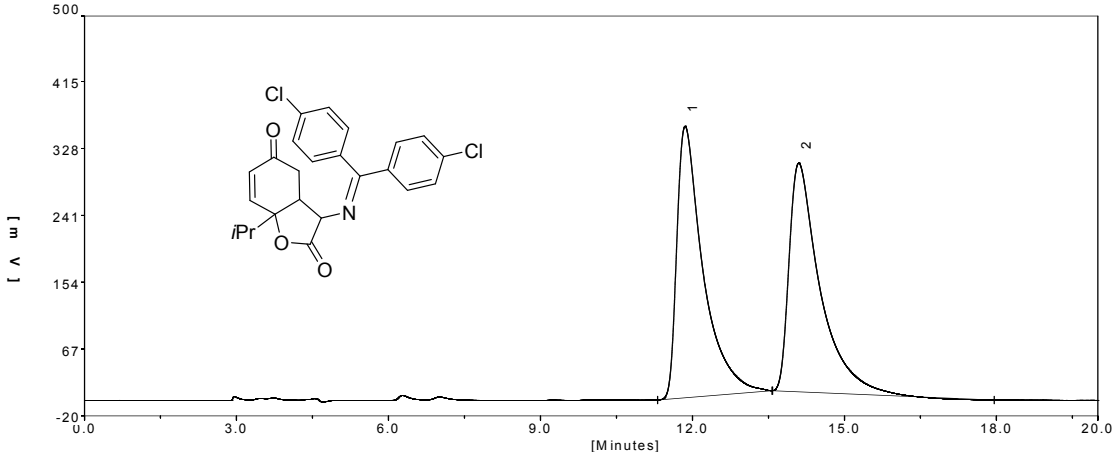


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	12.87333	382.87	15927.42	50.7211
2	16.01500	304.73	15474.52	49.2789

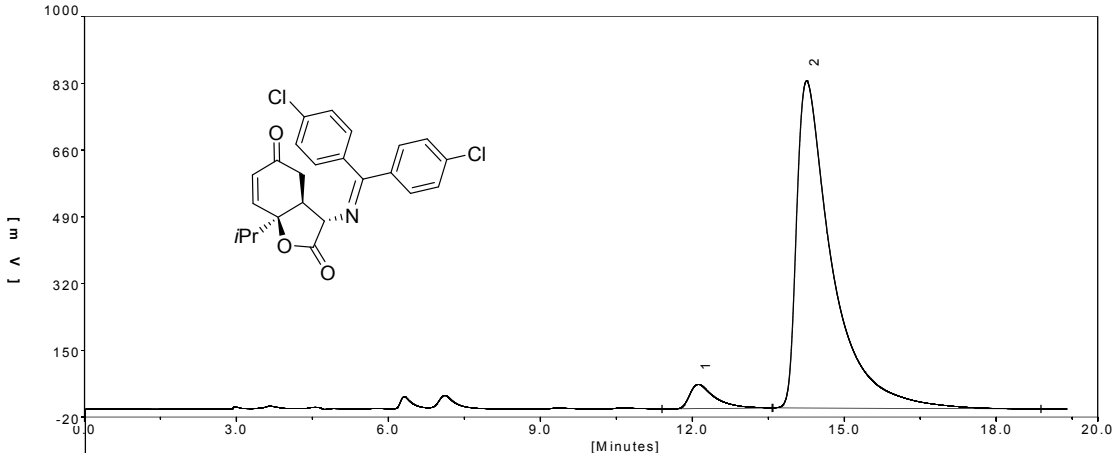


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	12.98167	31.44	1031.16	2.7347
2	15.99250	662.31	36675.84	97.2653

HPLC chromatogram of compound **2d** (90% ee).

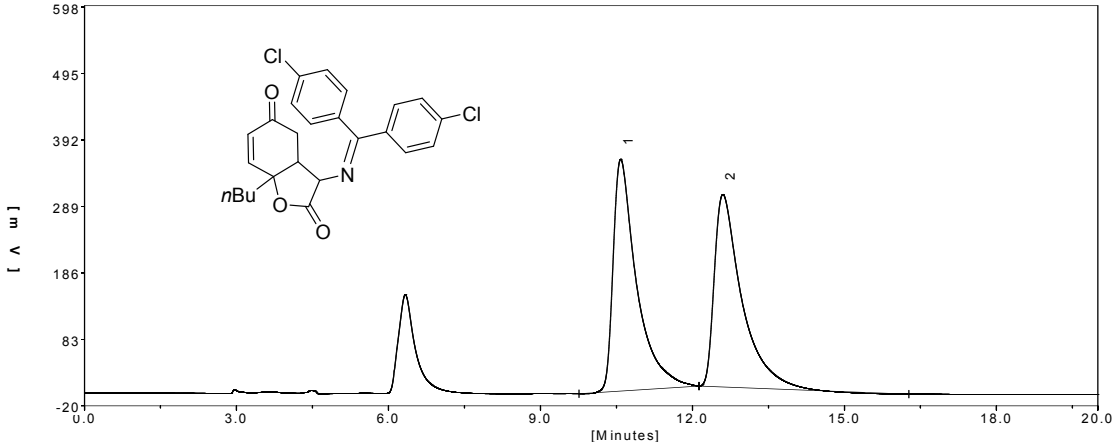


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	11.85583	353.26	12675.97	50.2399
2	14.09833	297.56	12554.89	49.7601

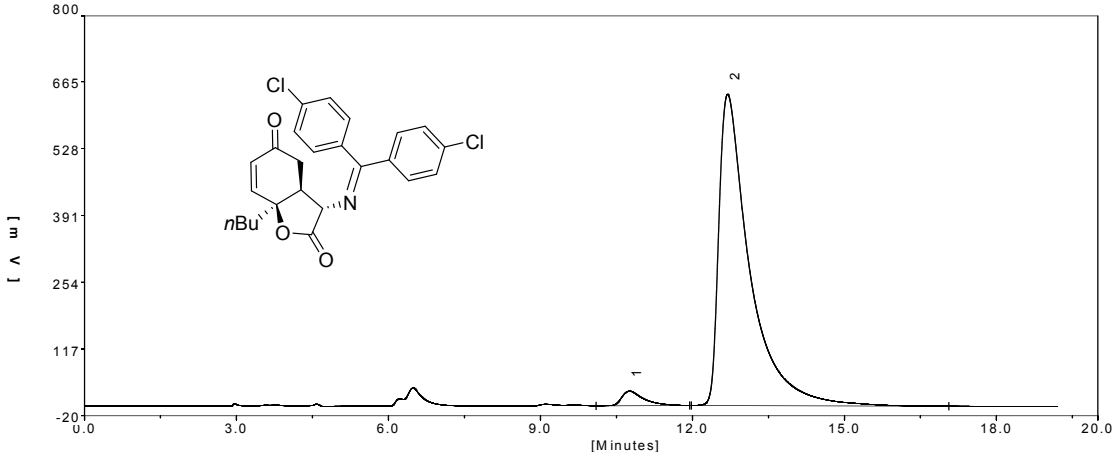


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	12.11333	61.84	2096.34	4.9293
2	14.25583	833.18	40431.94	95.0707

HPLC chromatogram of compound **2e** (94% ee).

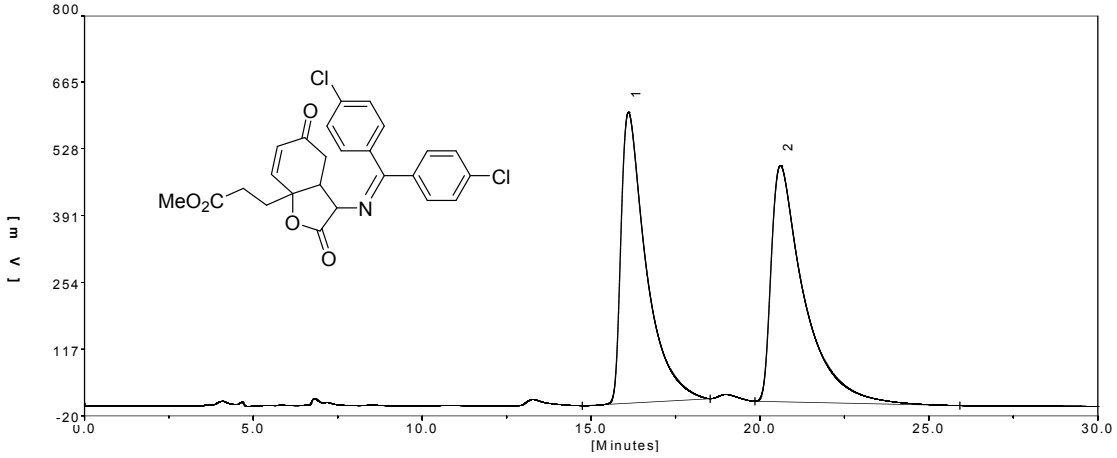


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	10.58333	359.25	11557.08	50.8360
2	12.60167	298.49	11176.97	49.1640

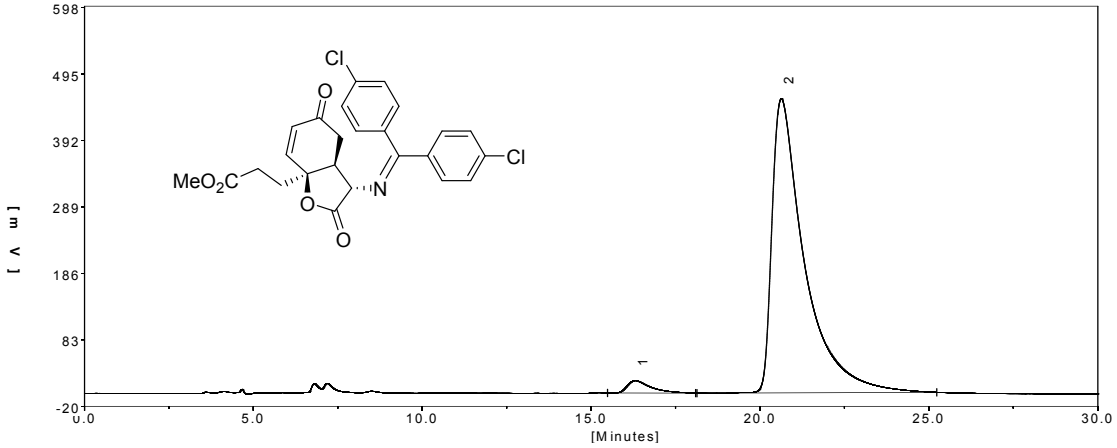


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	10.75083	30.10	899.48	3.2144
2	12.69417	638.61	27083.61	96.7856

HPLC chromatogram of compound **2f** (94% ee).

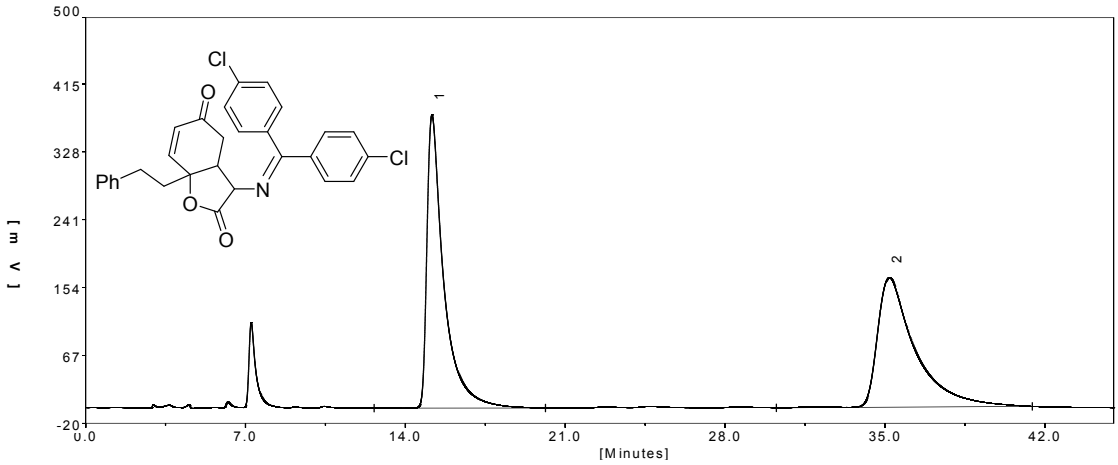


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	16.10500	596.89	30804.72	48.5928
2	20.60417	484.92	32588.92	51.4072

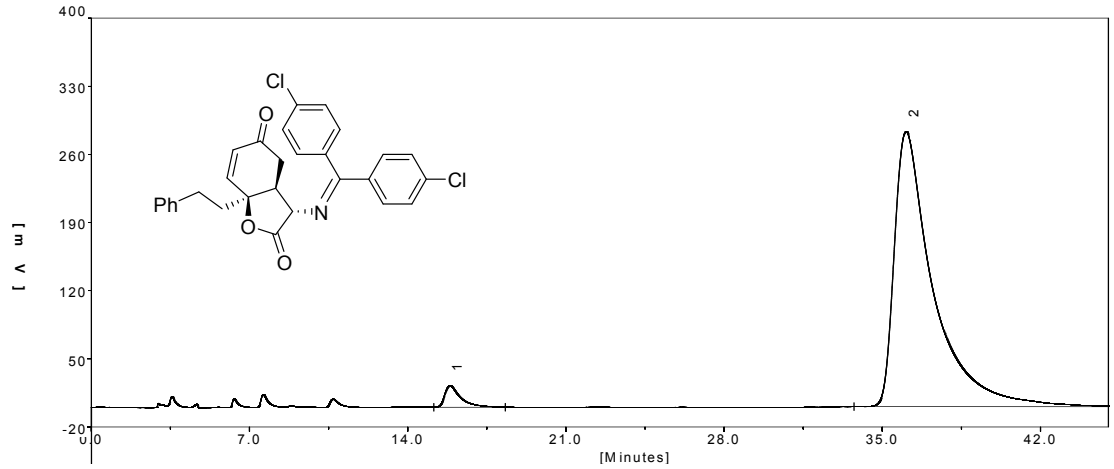


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	16.31500	19.11	920.76	2.9374
2	20.63250	455.79	30425.13	97.0626

HPLC chromatogram of compound **2g** (94% ee).

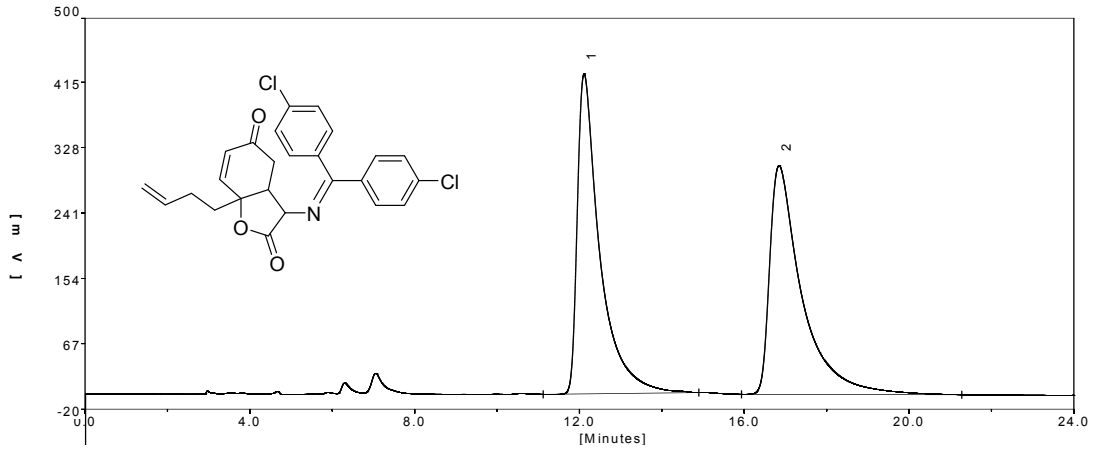


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	15.16167	376.01	19253.99	50.3992
2	35.18667	166.13	18948.99	49.6008

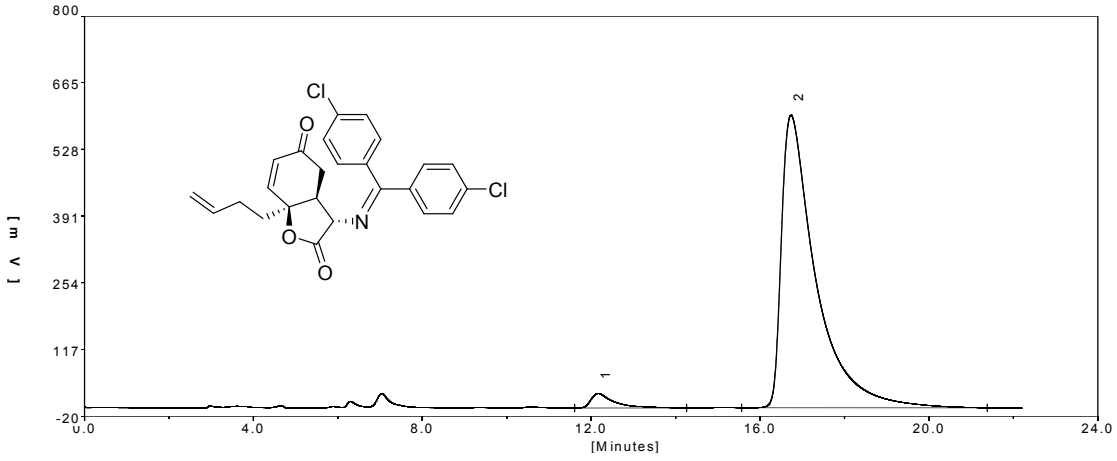


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	15.85417	22.28	1080.32	3.1095
2	36.05417	282.61	33662.45	96.8905

HPLC chromatogram of compound **2h** (94% ee).

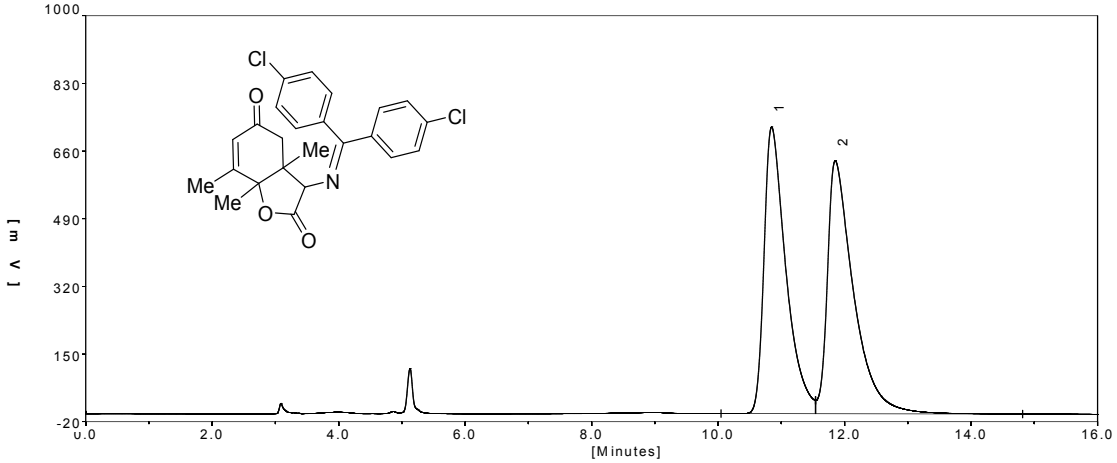


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	12.11500	425.73	16129.63	49.5135
2	16.84750	304.38	16446.57	50.4865

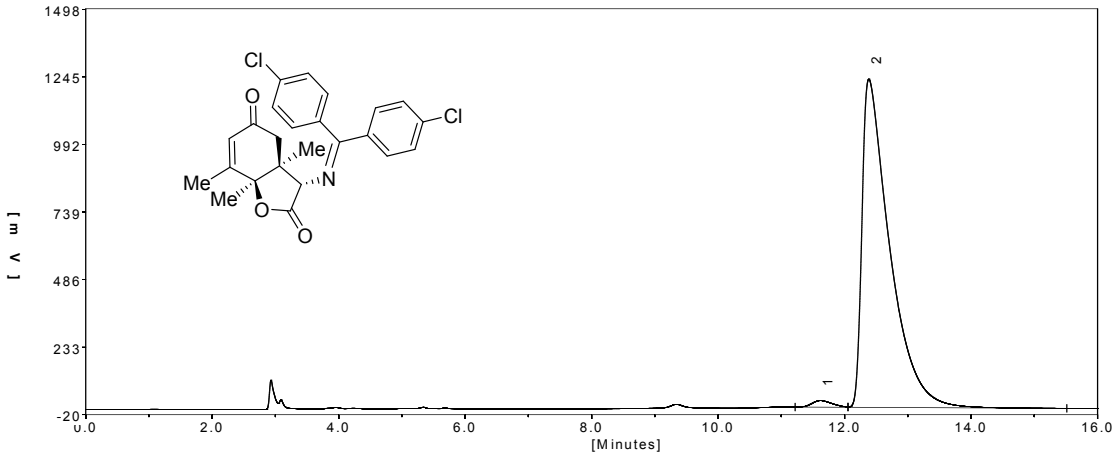


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	12.16417	29.69	1124.71	3.2088
2	16.73417	600.19	33926.16	96.7912

HPLC chromatogram of compound **2i** (97% ee).

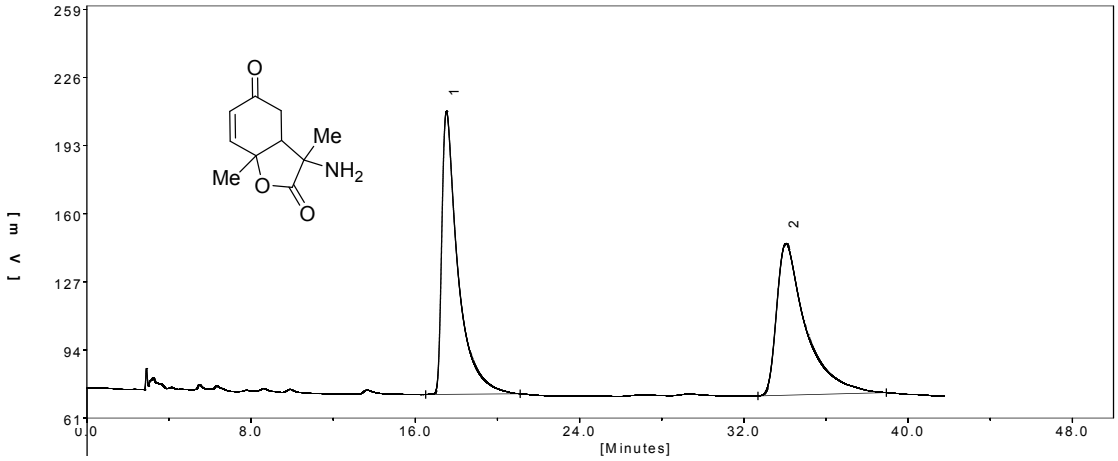


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	10.84750	720.44	17315.17	48.6516
2	11.85333	635.65	18274.98	51.3484

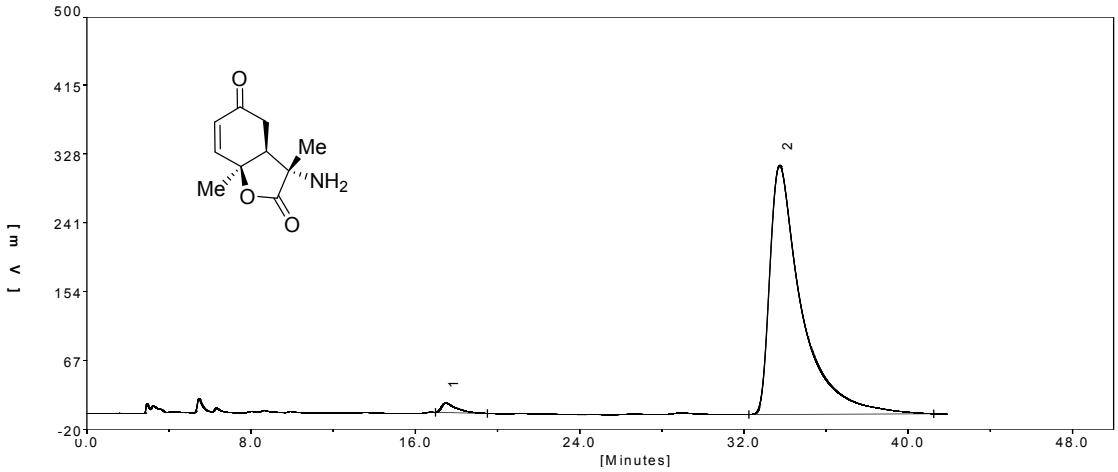


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	11.61667	24.50	537.77	1.4208
2	12.38500	1229.33	37311.42	98.5792

HPLC chromatogram of compound **4a** (96% ee).

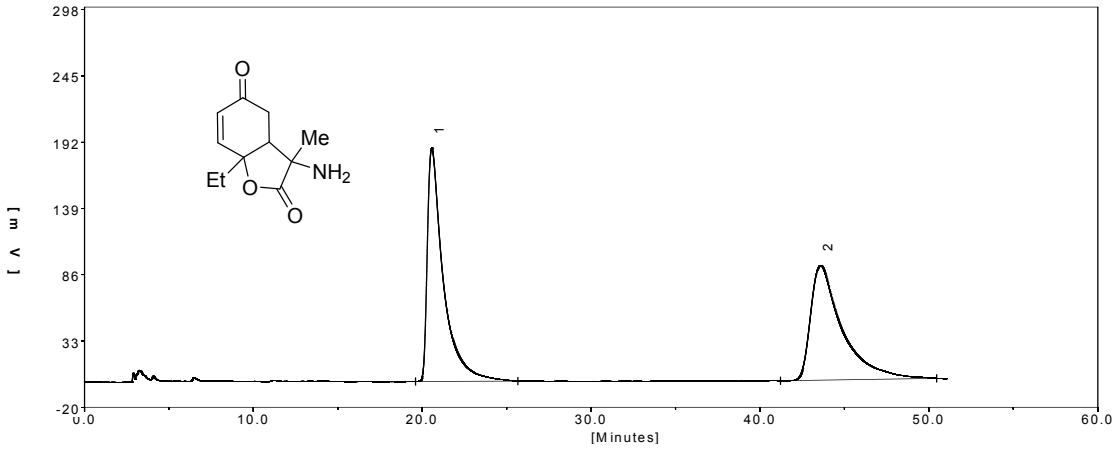


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	17.51583	137.24	7440.68	50.7744
2	34.04750	73.60	7213.70	49.2256

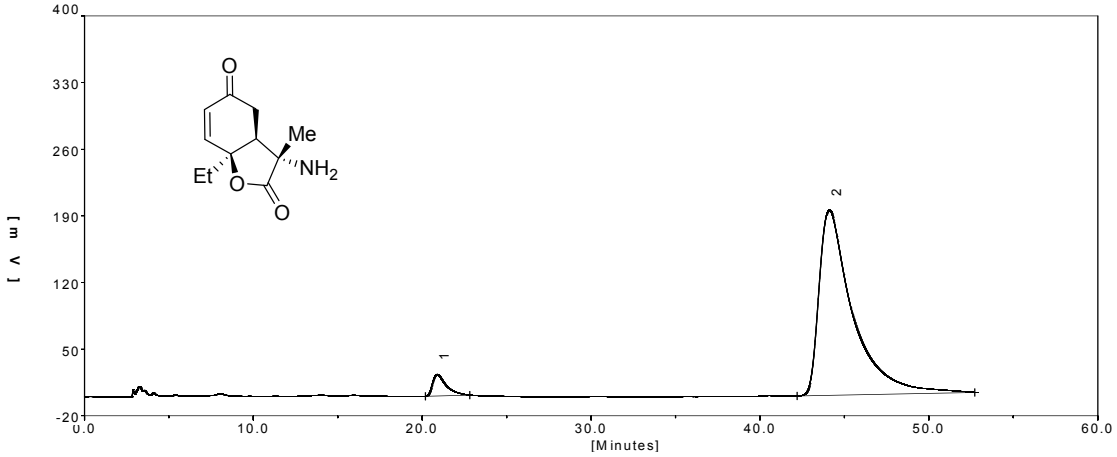


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	17.47250	12.15	602.77	1.7575
2	33.73833	314.56	33693.91	98.2425

HPLC chromatogram of compound **4b** (91% ee).

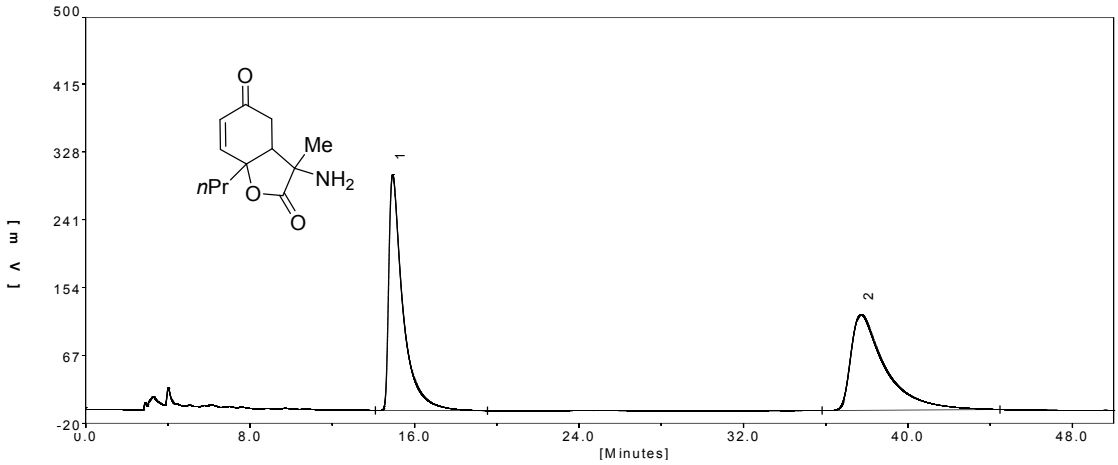


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	20.56583	186.60	12243.52	50.9080
2	43.58250	91.79	11806.78	49.0920

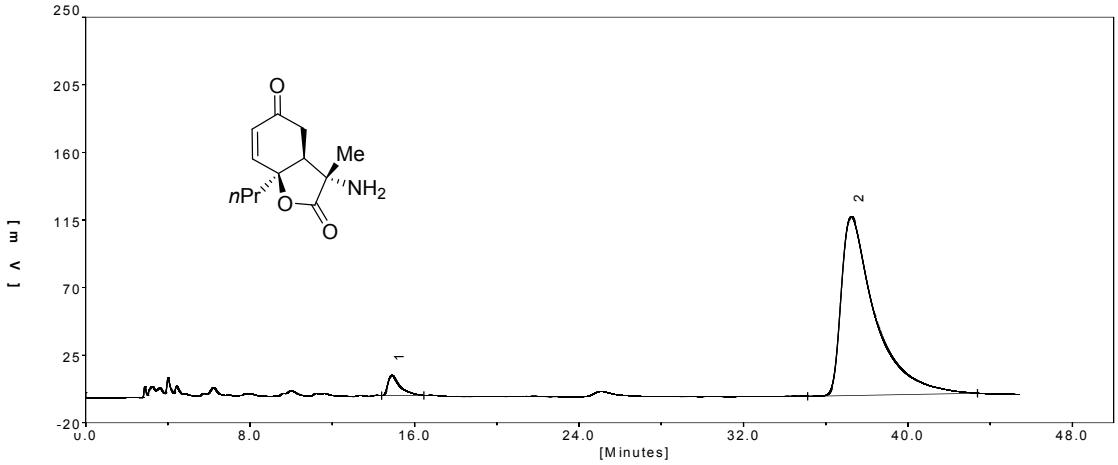


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	20.86500	22.78	1255.87	4.4604
2	44.09333	194.56	26900.02	95.5396

HPLC chromatogram of compound **4c** (92% ee).

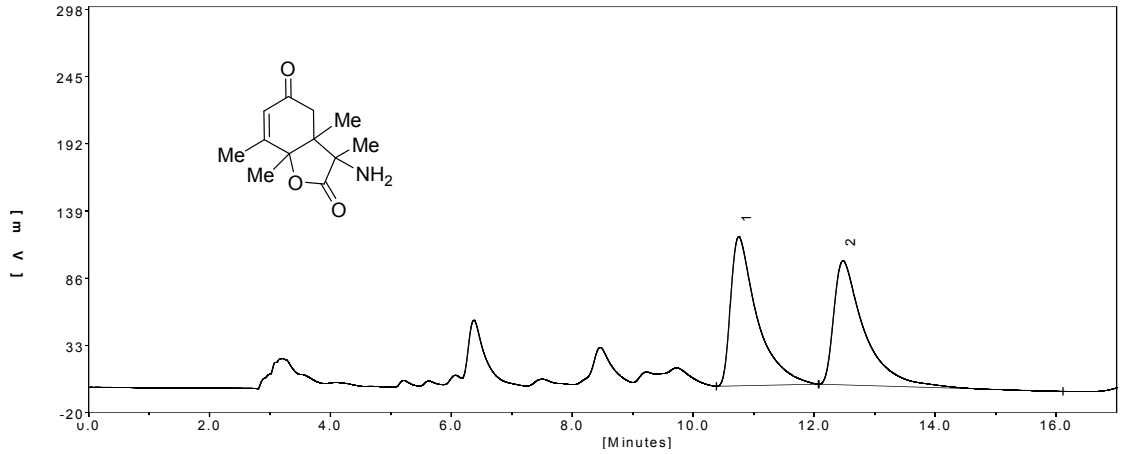


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	14.93750	302.71	14395.61	50.5027
2	37.70583	122.66	14109.02	49.4973

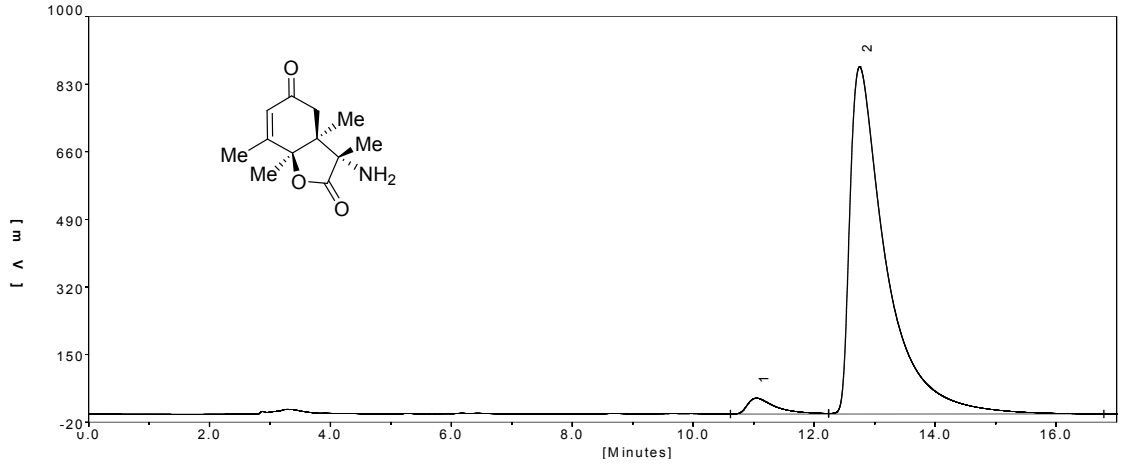


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	14.88333	13.57	542.06	3.8542
2	37.23583	119.10	13522.14	96.1458

HPLC chromatogram of compound **4d** (93% ee).



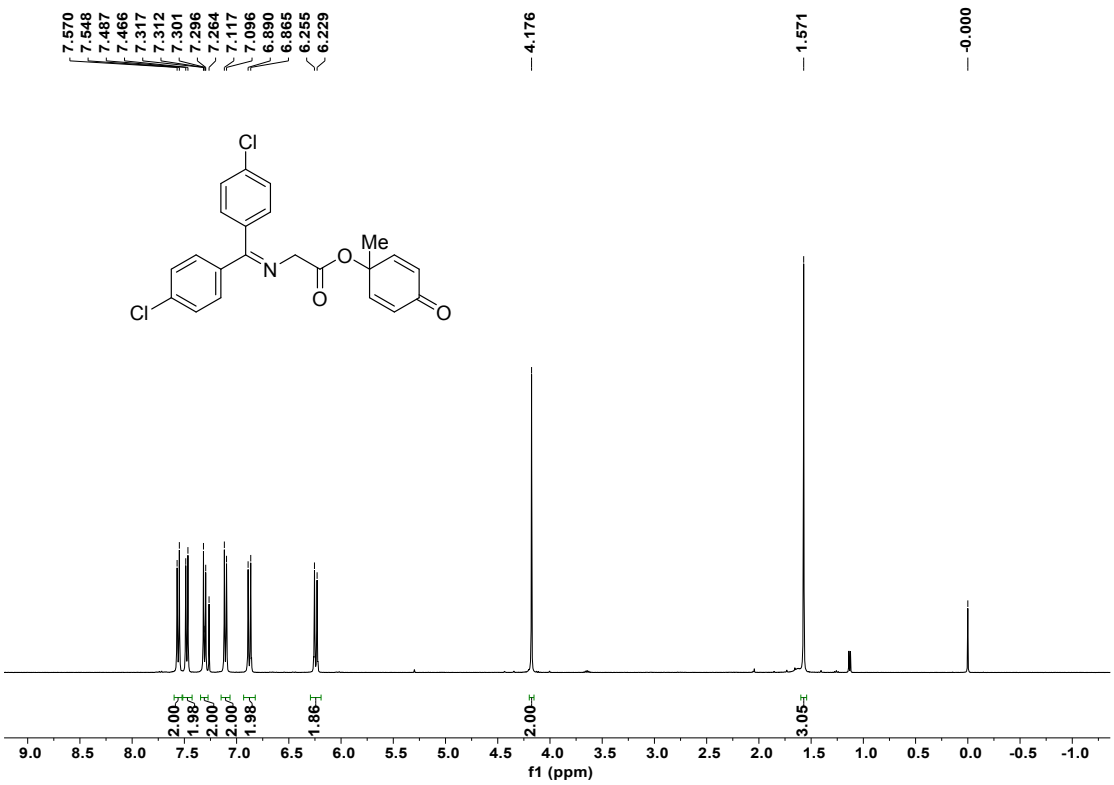
#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	10.75167	117.46	3564.48	51.1512
2	12.47667	97.78	3404.04	48.8488



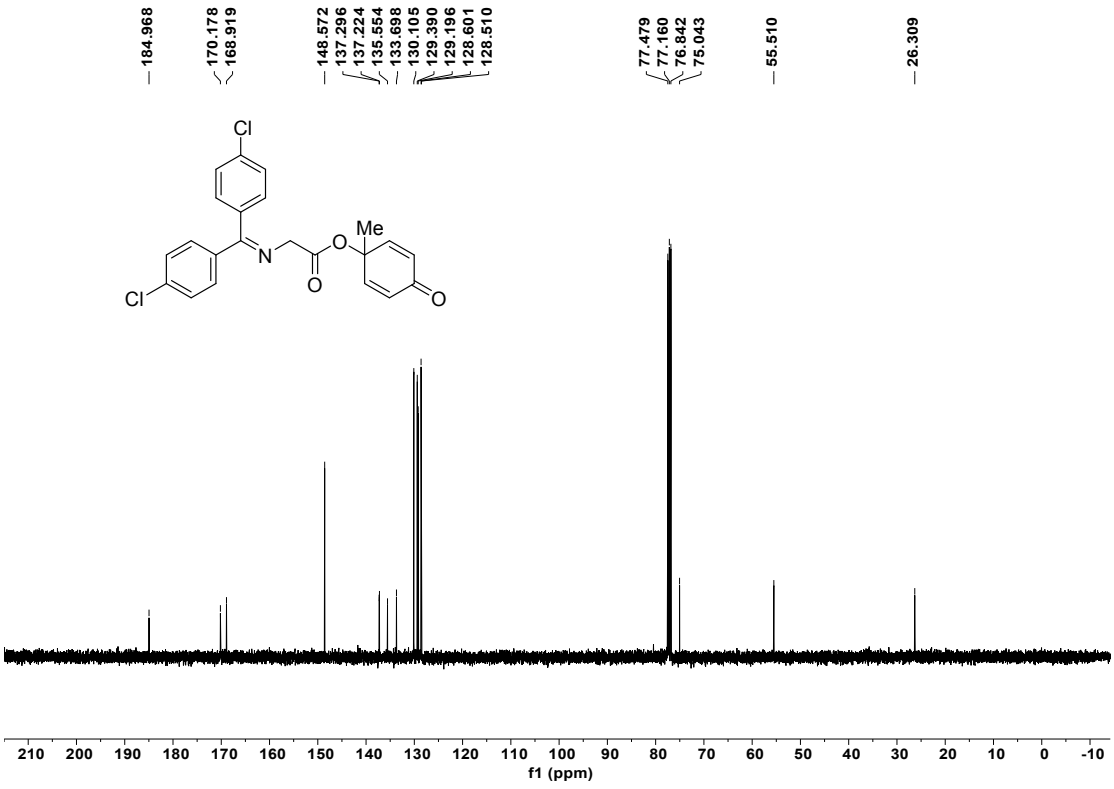
#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	11.03917	40.10	1301.79	3.4767
2	12.75083	873.29	36141.32	96.5233

6. ^{1}H NMR and ^{13}C NMR spectra

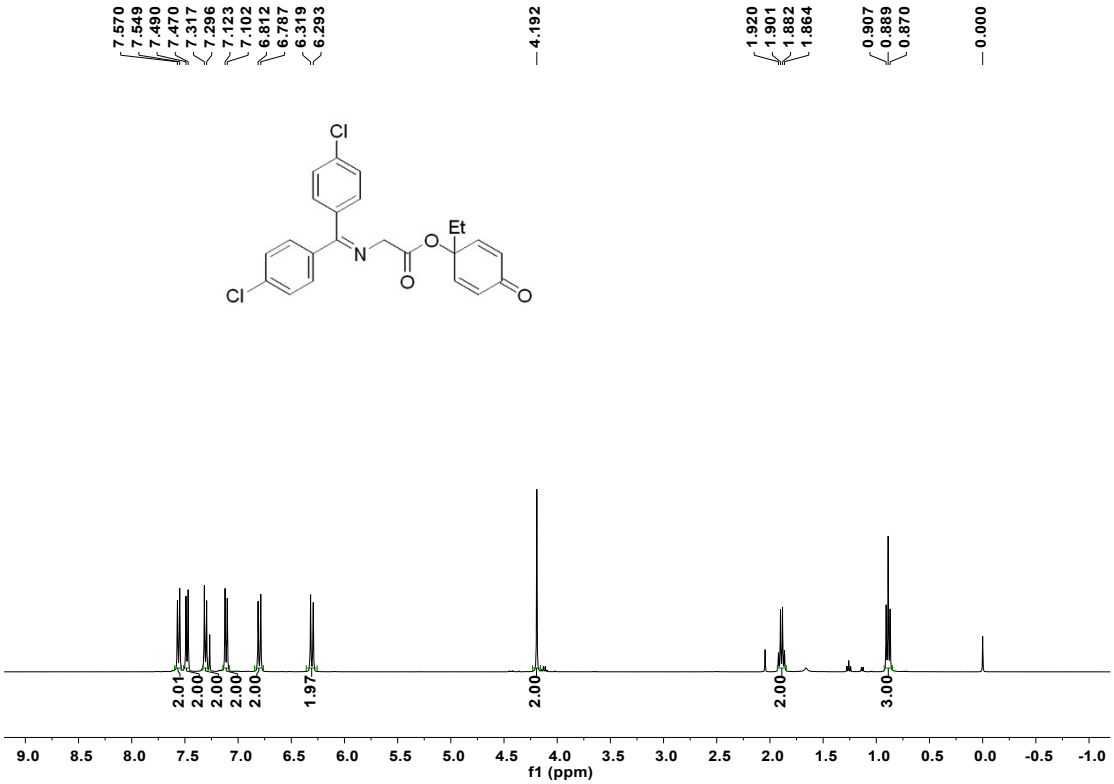
^{1}H NMR of **1a** in $CDCl_3$



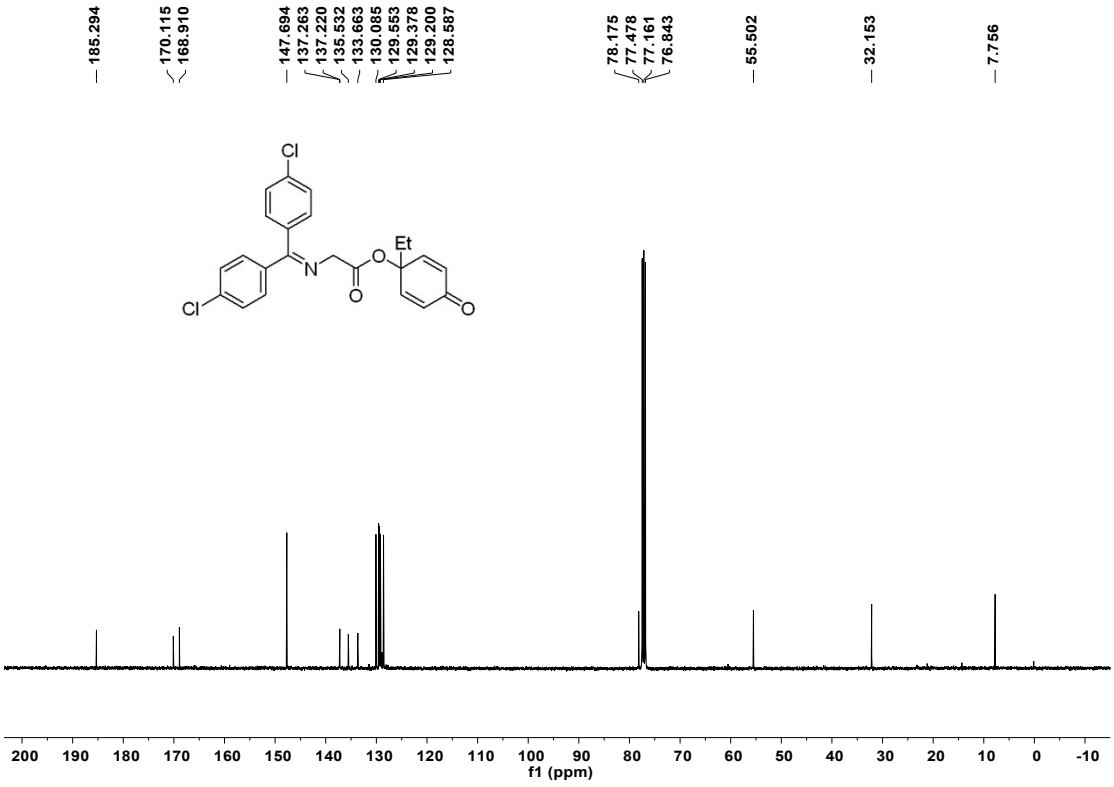
^{13}C NMR of **1a** in $CDCl_3$



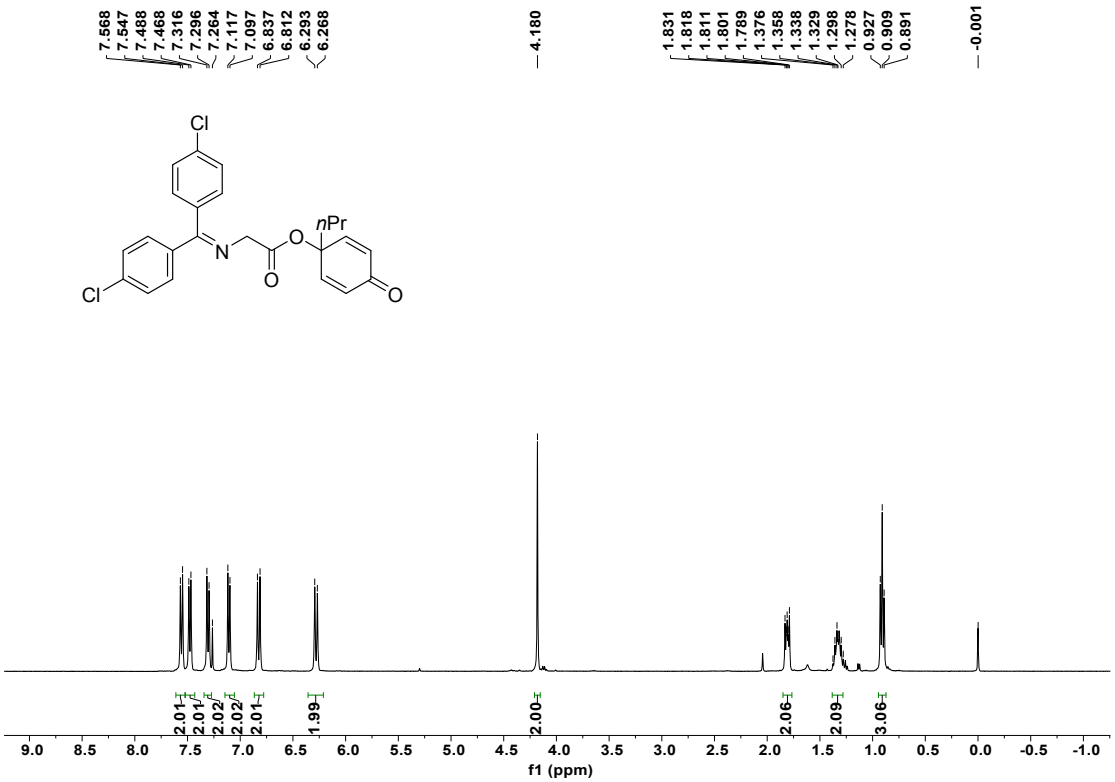
^{1}H NMR of **1b** in $CDCl_3$



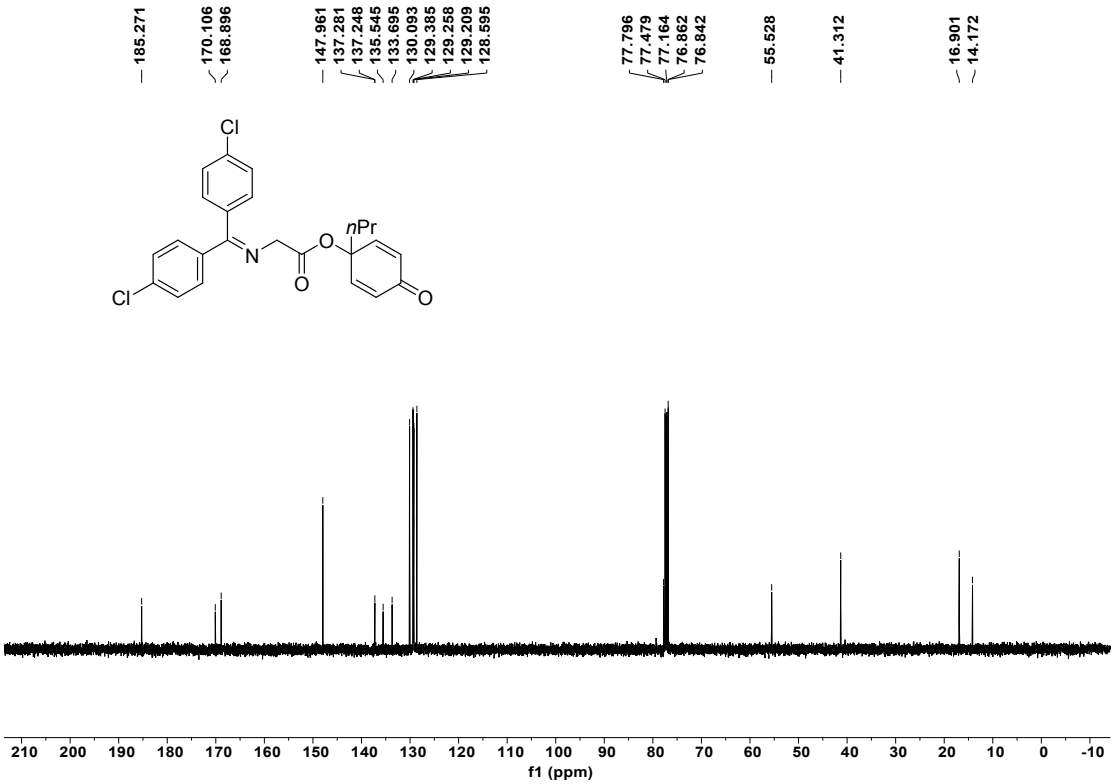
^{13}C NMR of **1b** in $CDCl_3$



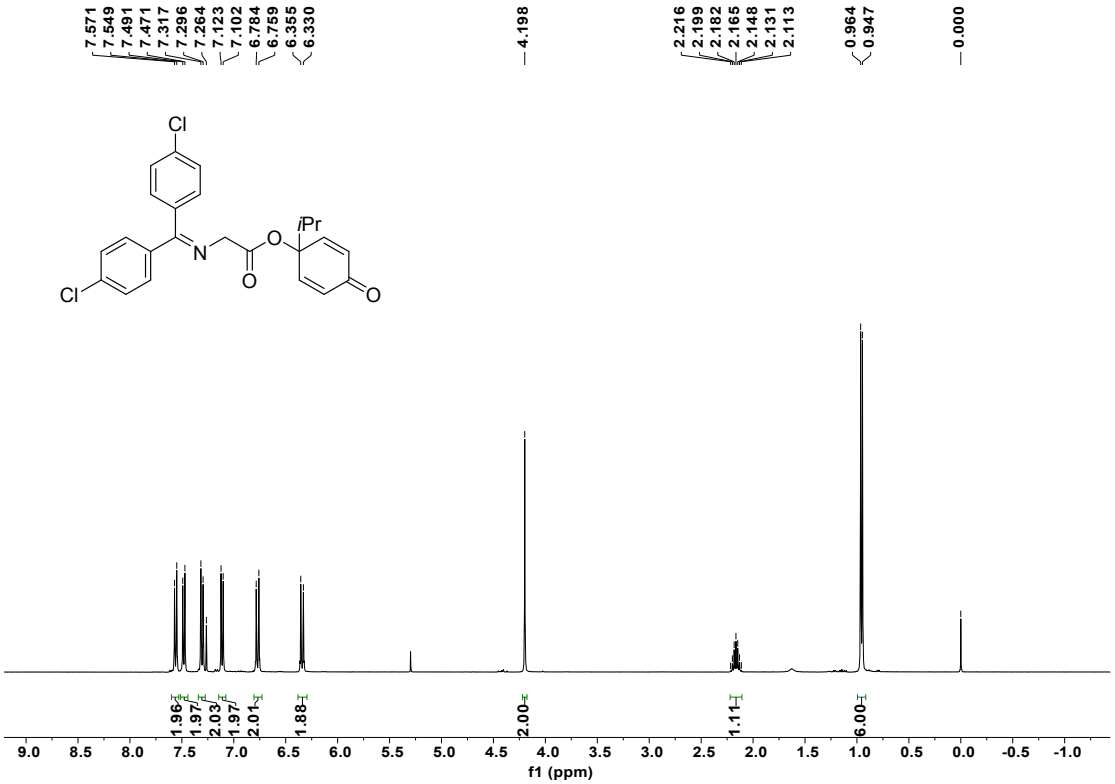
^{1}H NMR of **1c** in $CDCl_3$



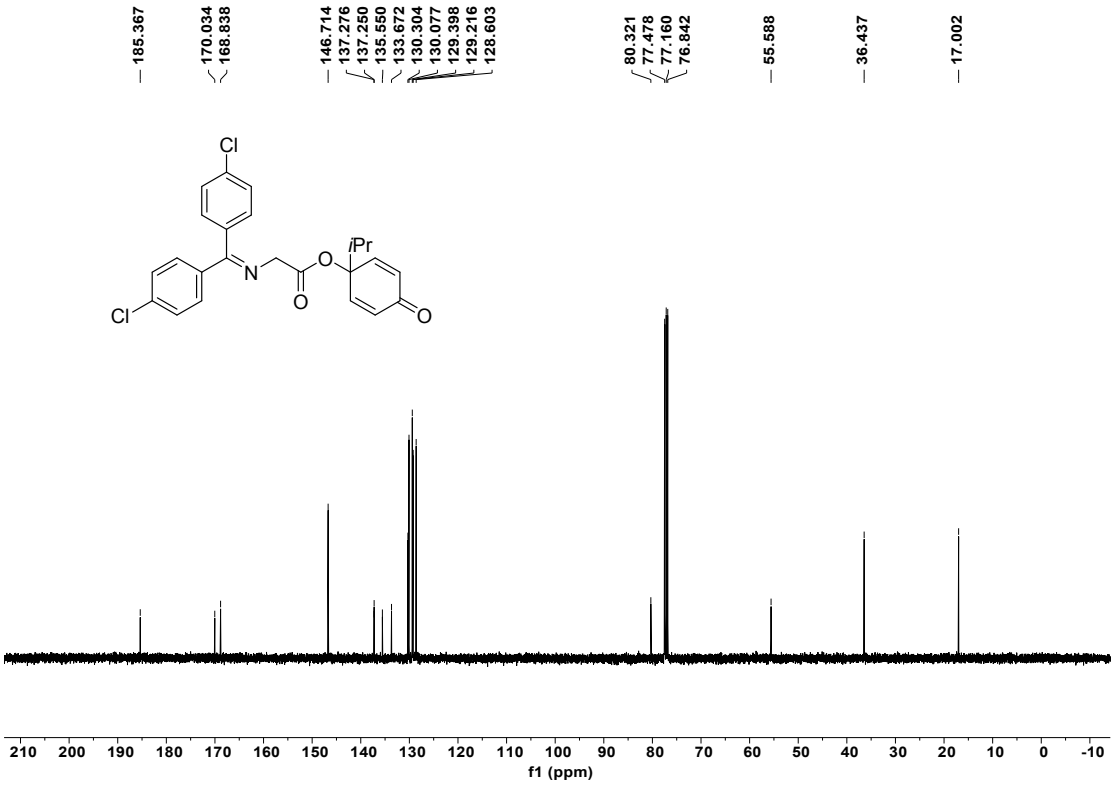
^{13}C NMR of **1c** in $CDCl_3$



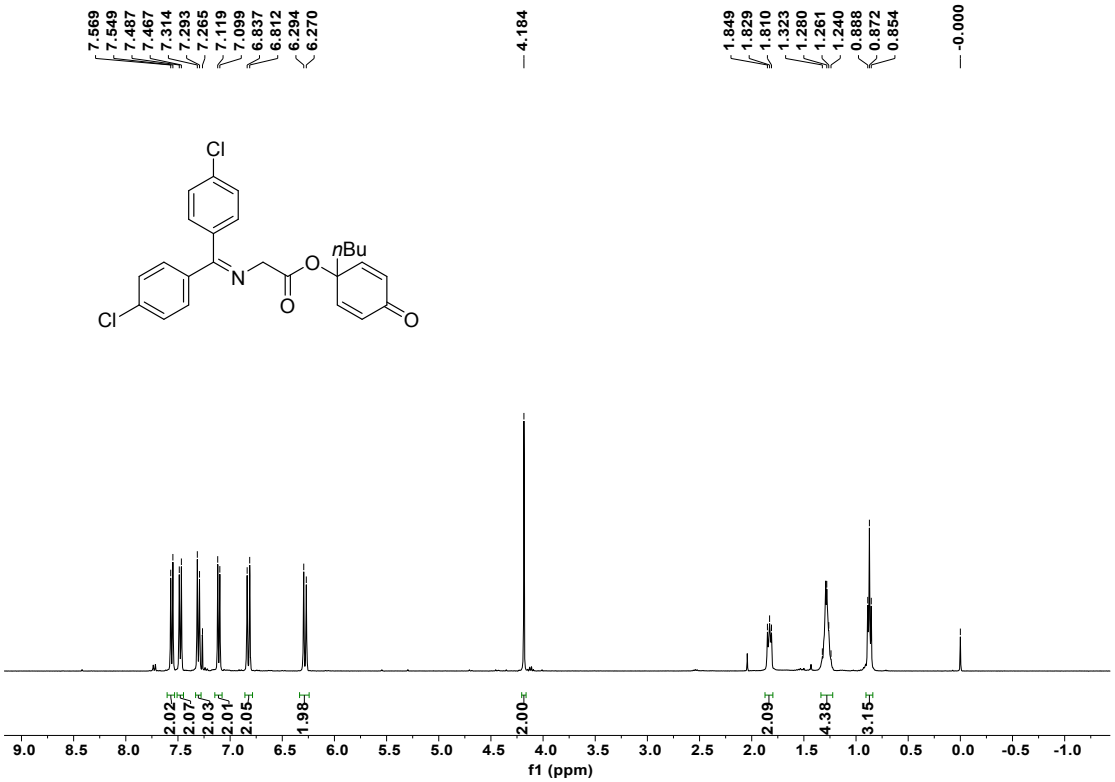
^{1}H NMR of **1d** in $CDCl_3$



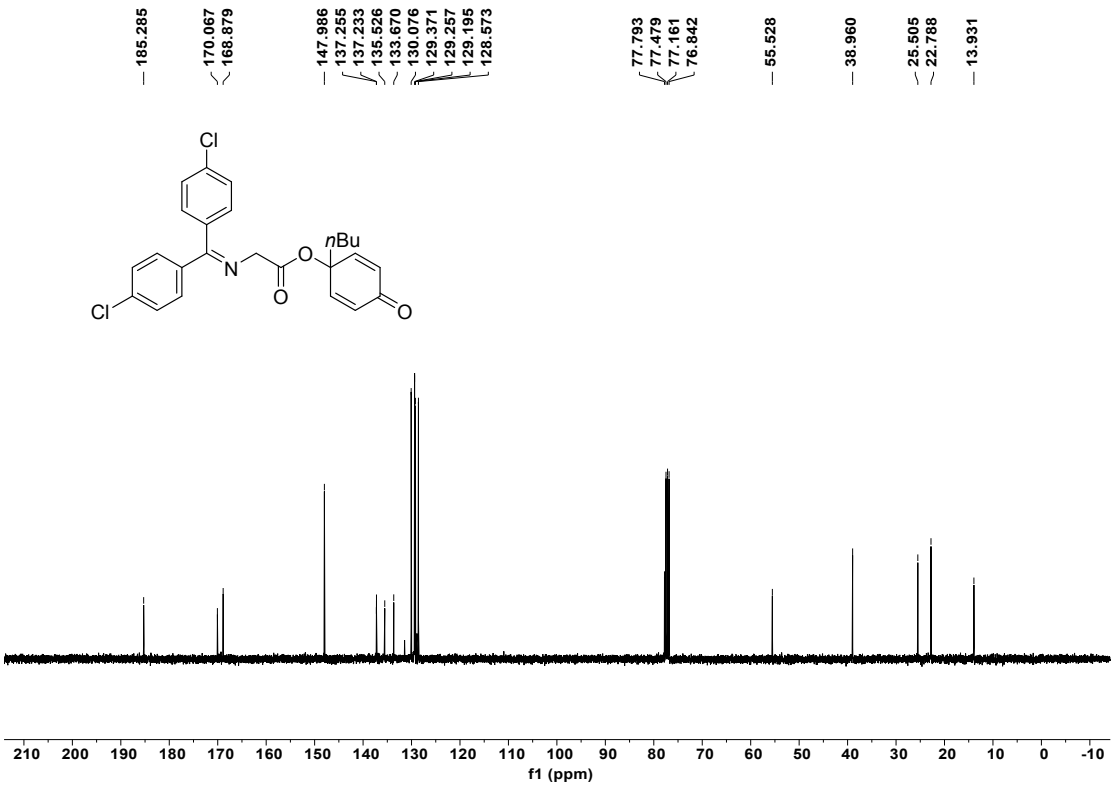
^{13}C NMR of **1d** in $CDCl_3$



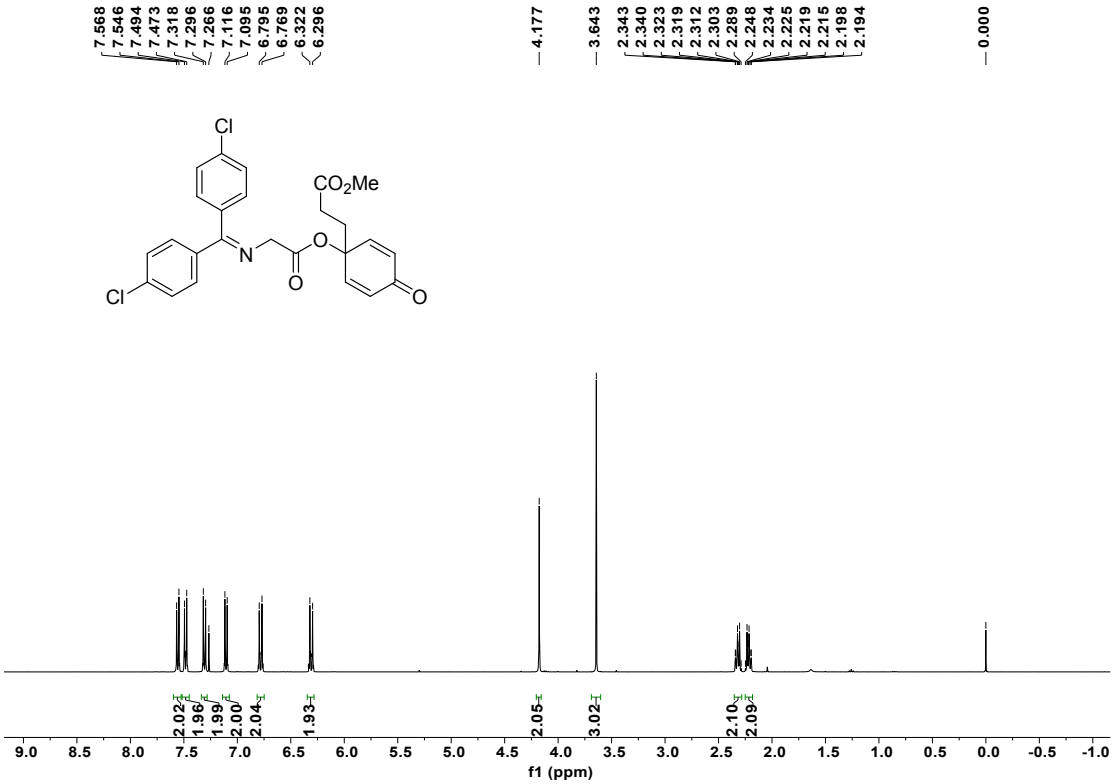
^{1}H NMR of **1e** in $CDCl_3$



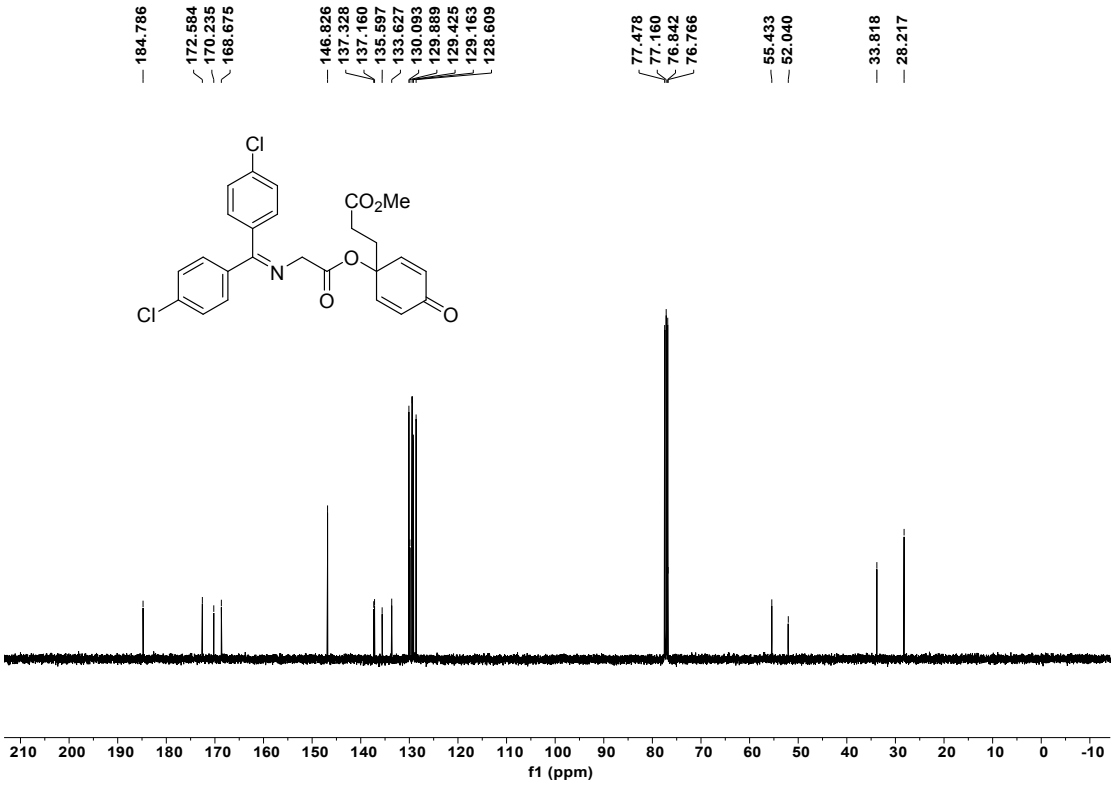
^{13}C NMR of **1e** in $CDCl_3$



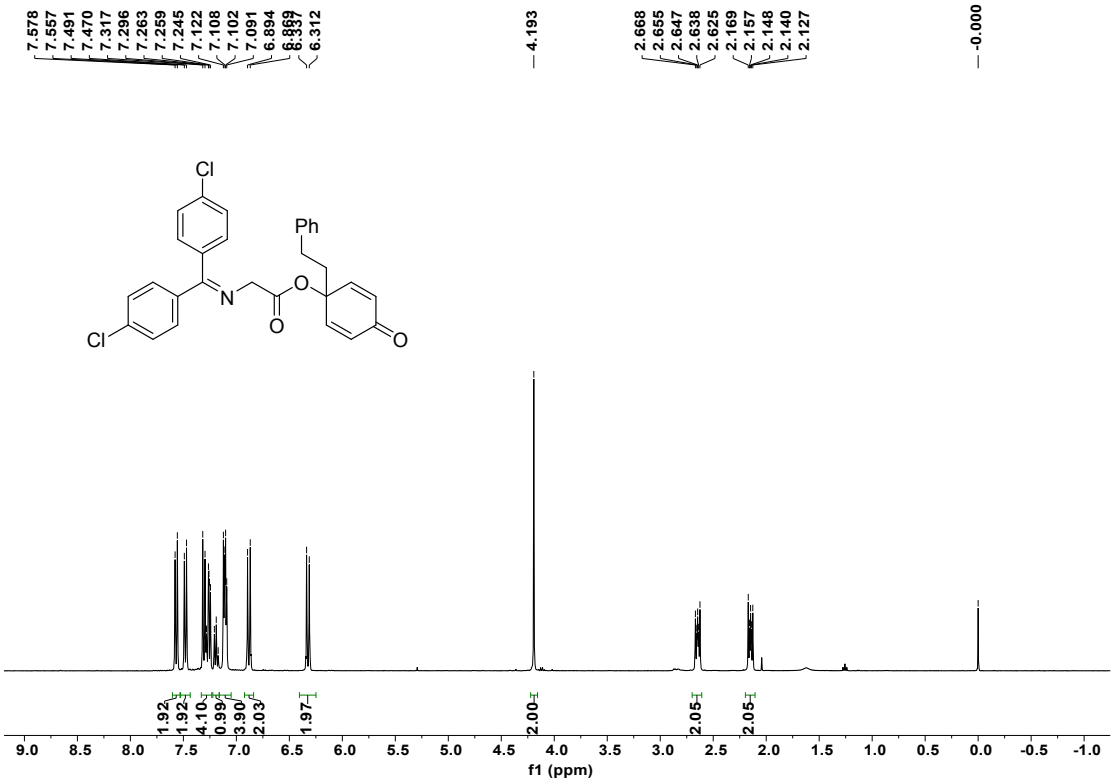
^{1}H NMR of **1f** in $CDCl_3$



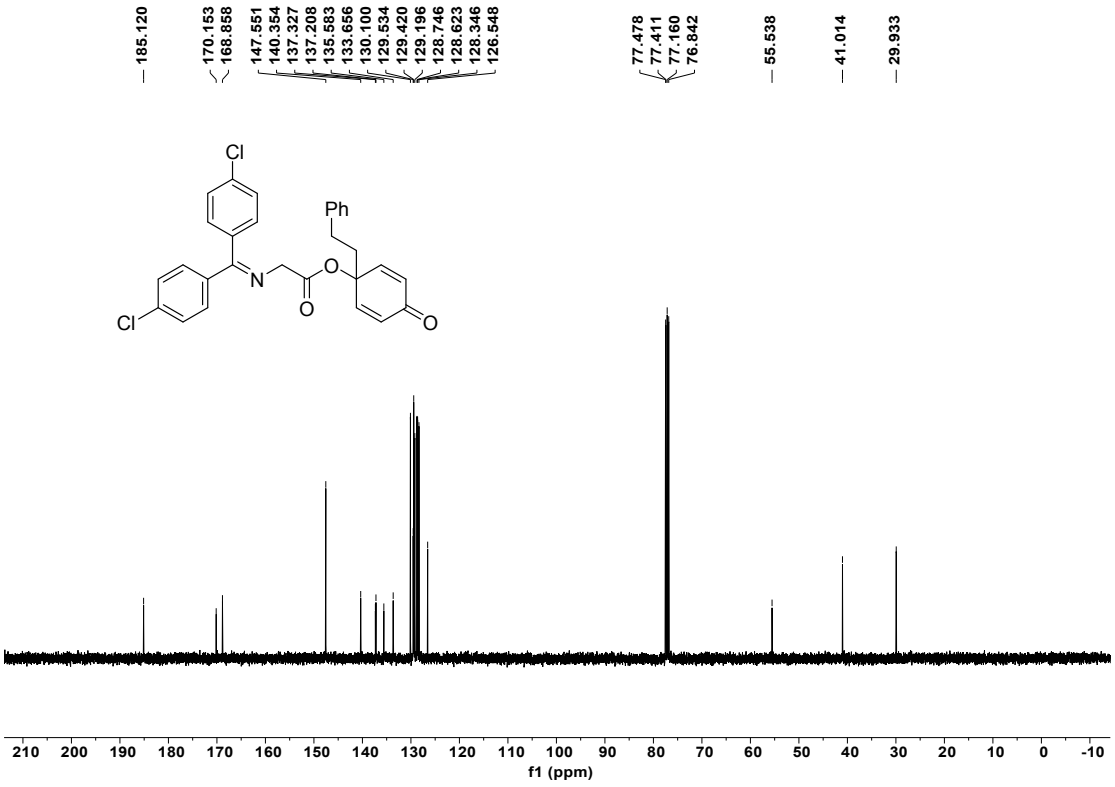
^{13}C NMR of **1f** in $CDCl_3$



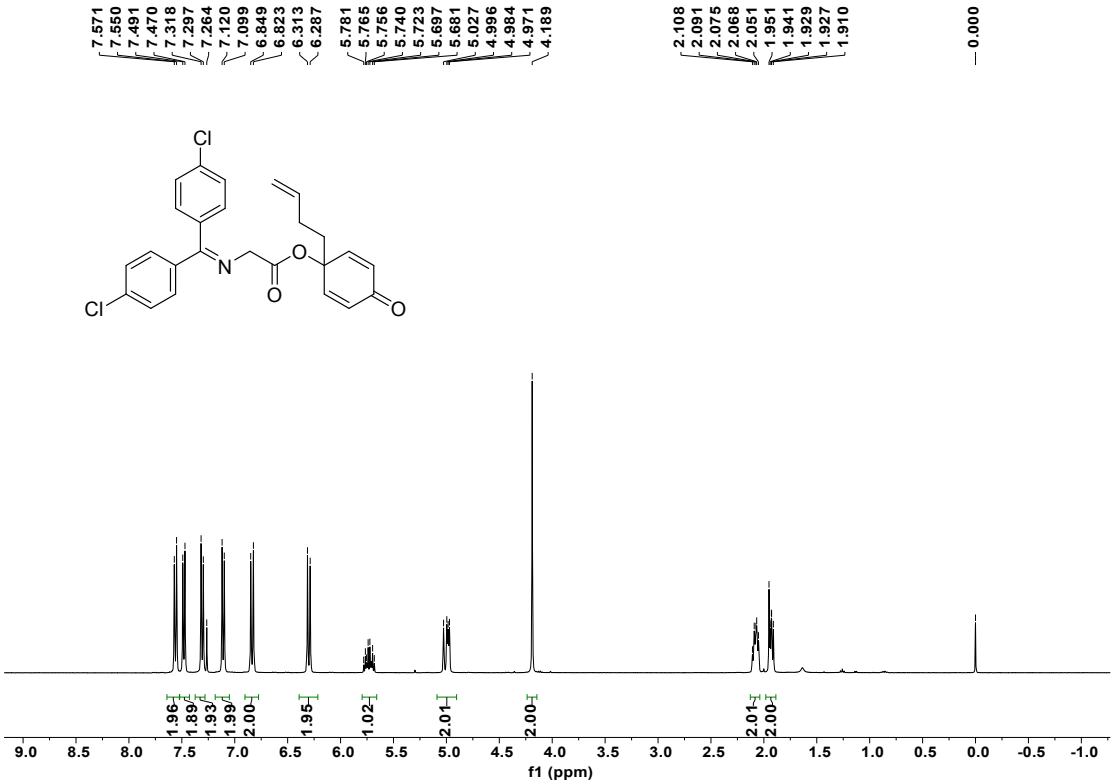
^{1}H NMR of **1g** in $CDCl_3$



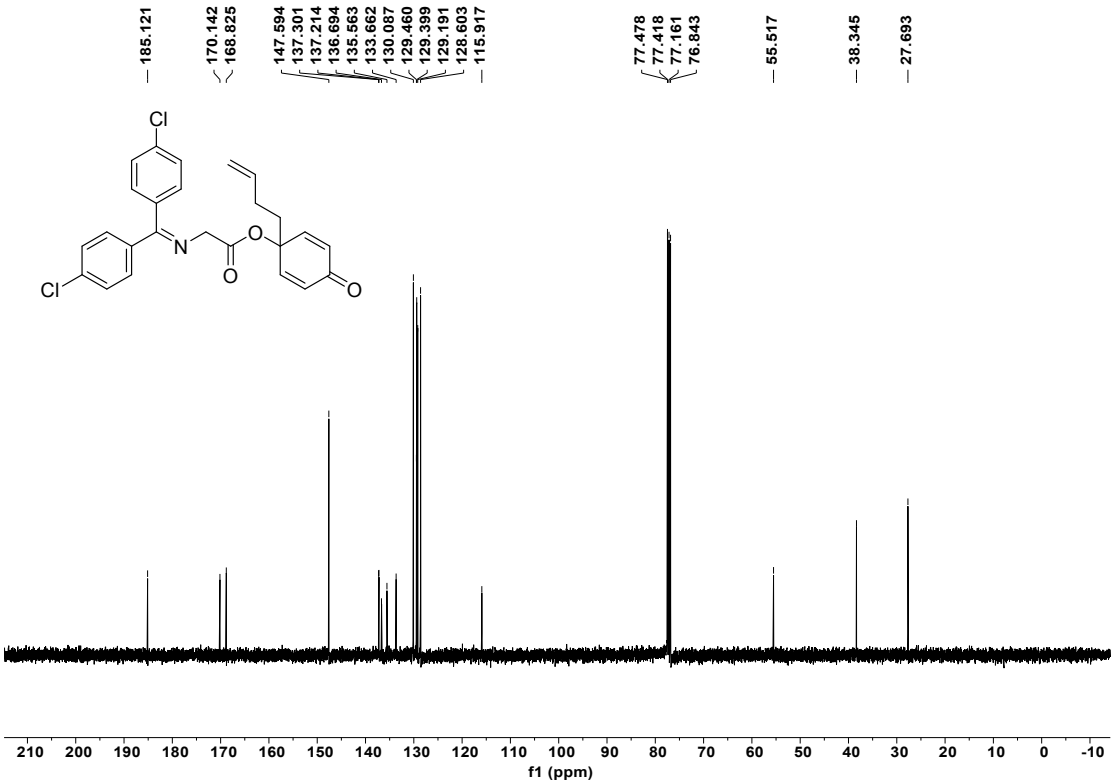
^{13}C NMR of **1g** in $CDCl_3$



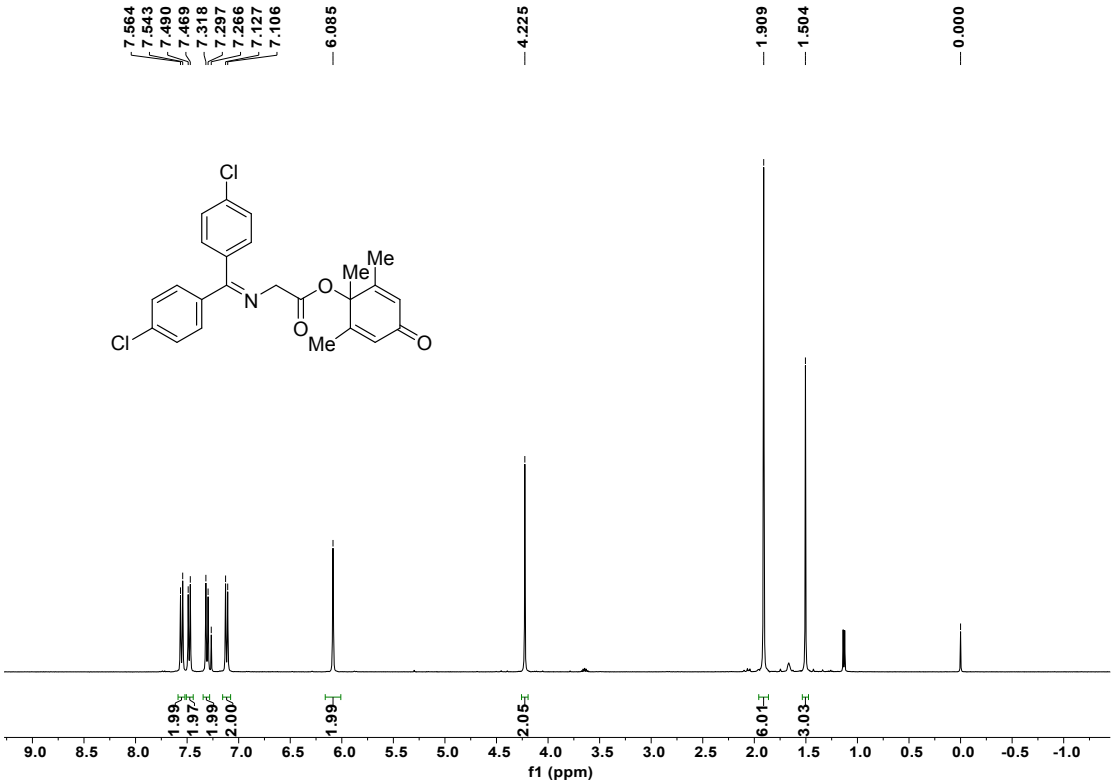
^{1}H NMR of **1h** in $CDCl_3$



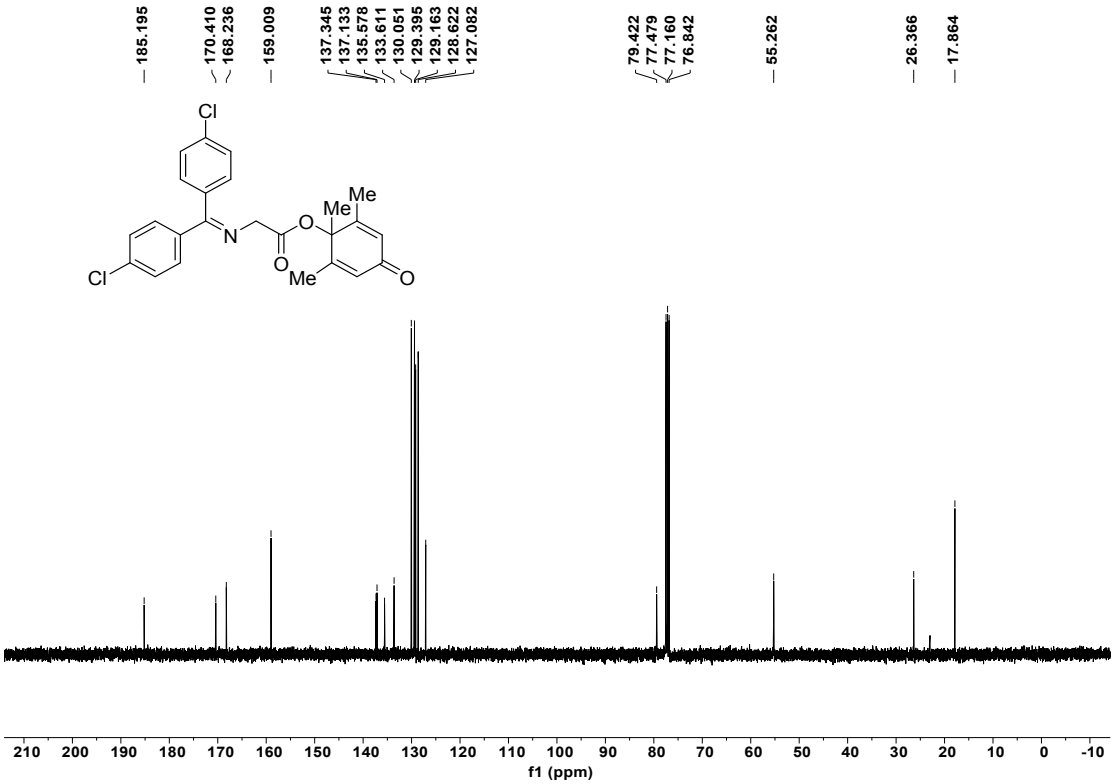
^{13}C NMR of **1h** in $CDCl_3$



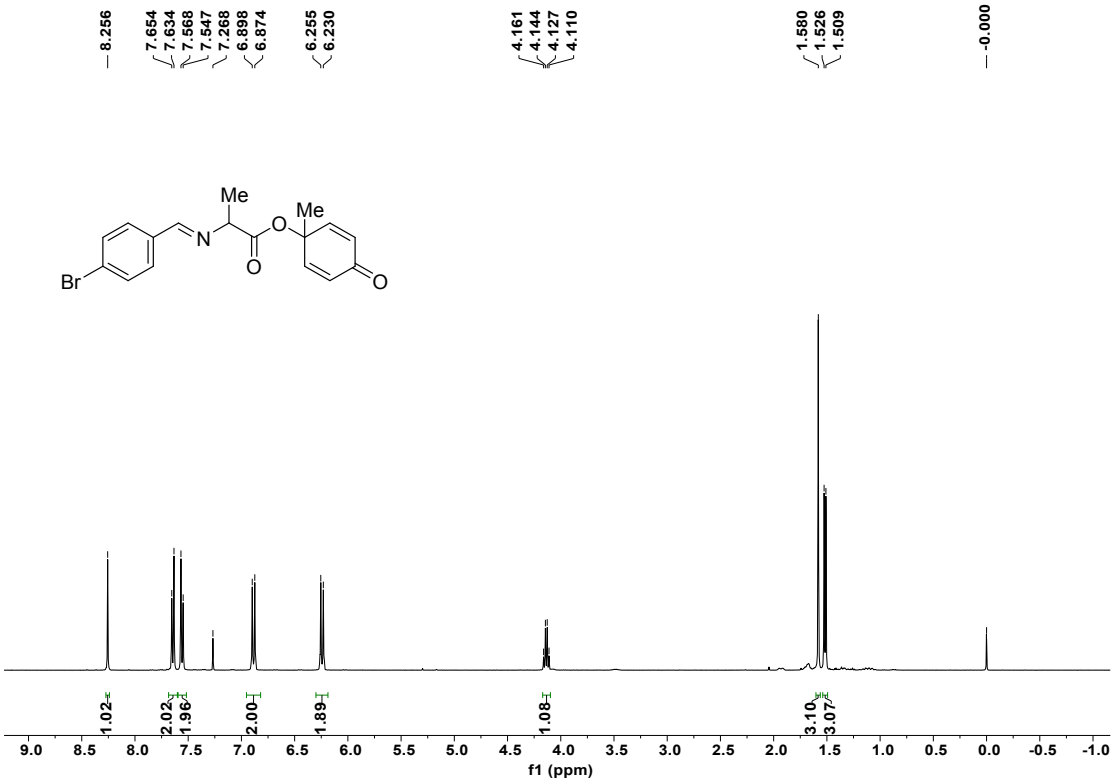
^{1}H NMR of **1i** in $CDCl_3$



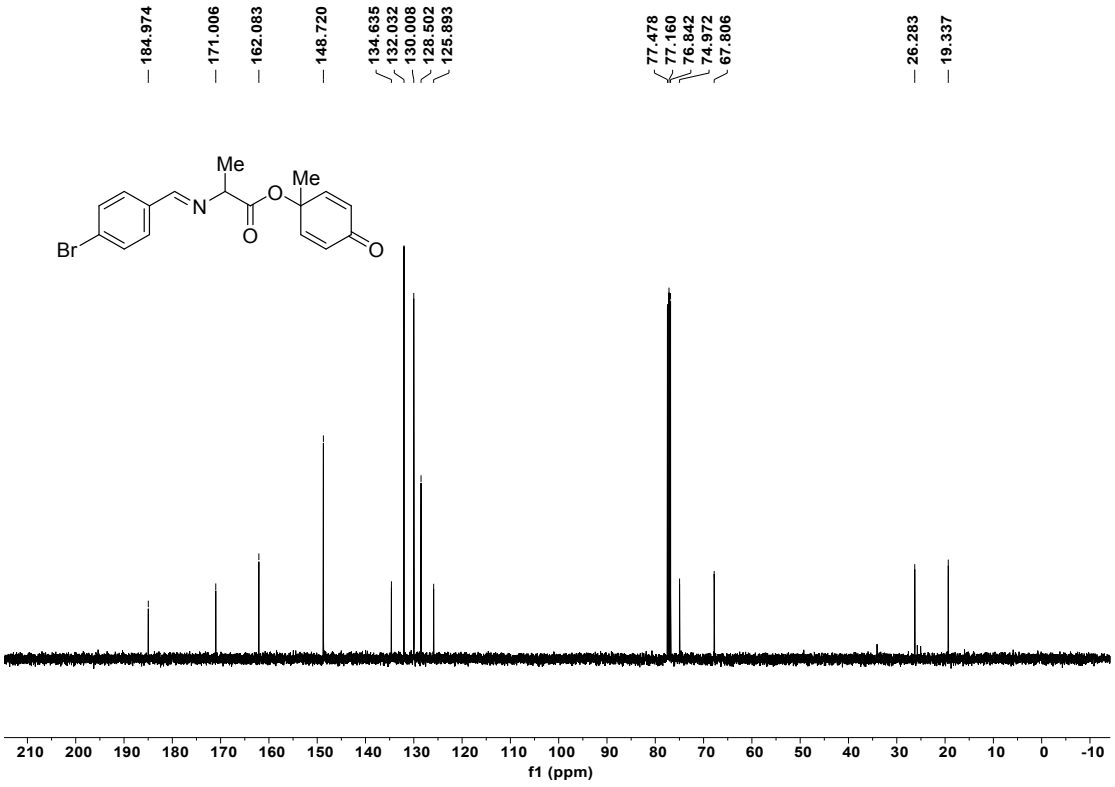
^{13}C NMR of **1i** in $CDCl_3$



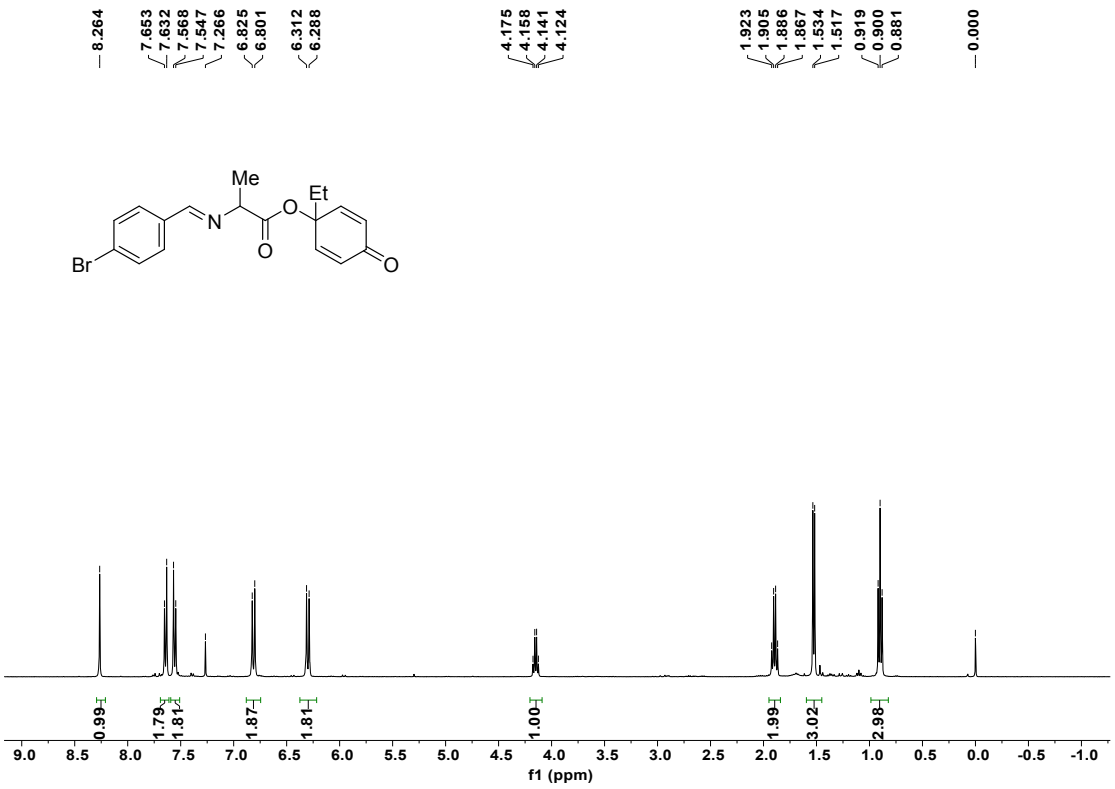
^{1}H NMR of **3a** in $CDCl_3$



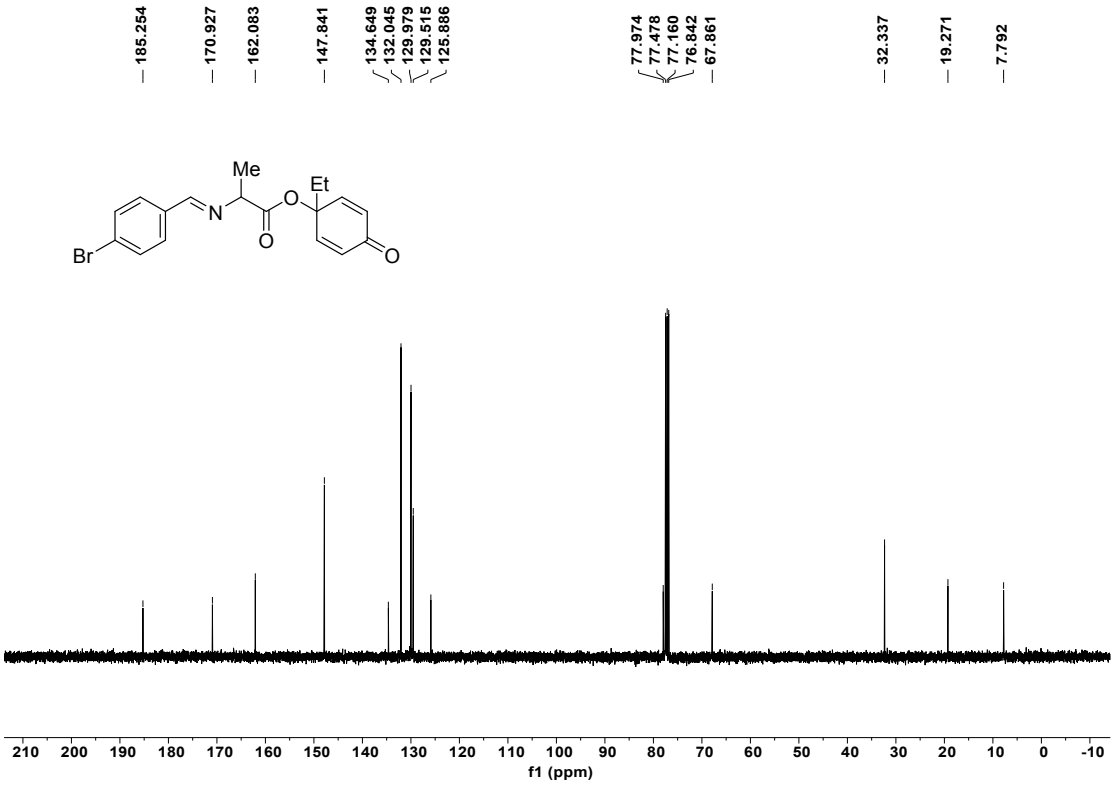
^{13}C NMR of **3a** in $CDCl_3$



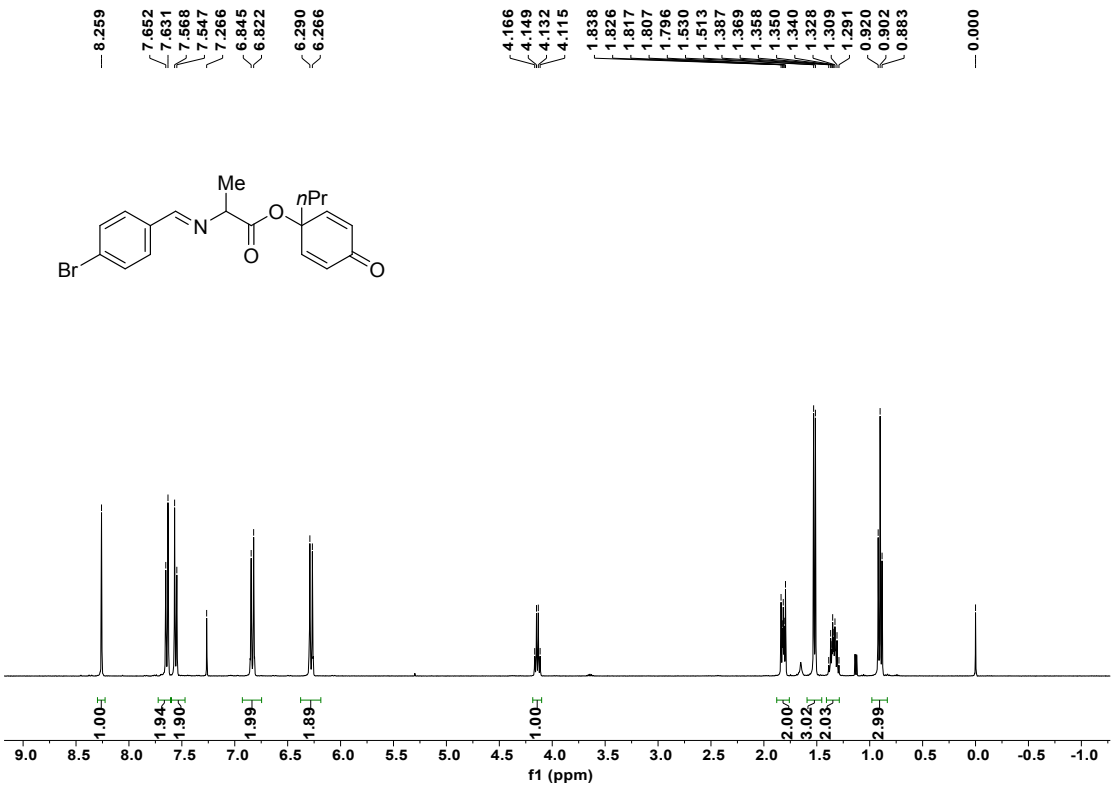
^{1}H NMR of **3b** in $CDCl_3$



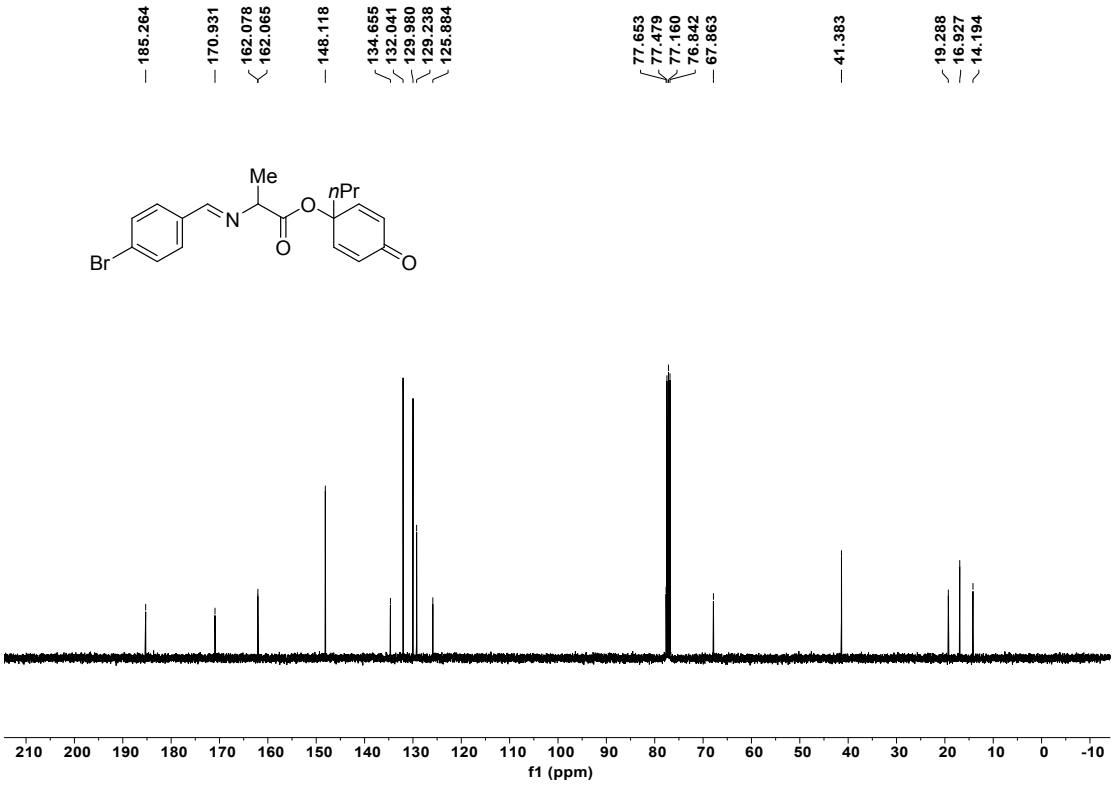
^{13}C NMR of **3b** in $CDCl_3$



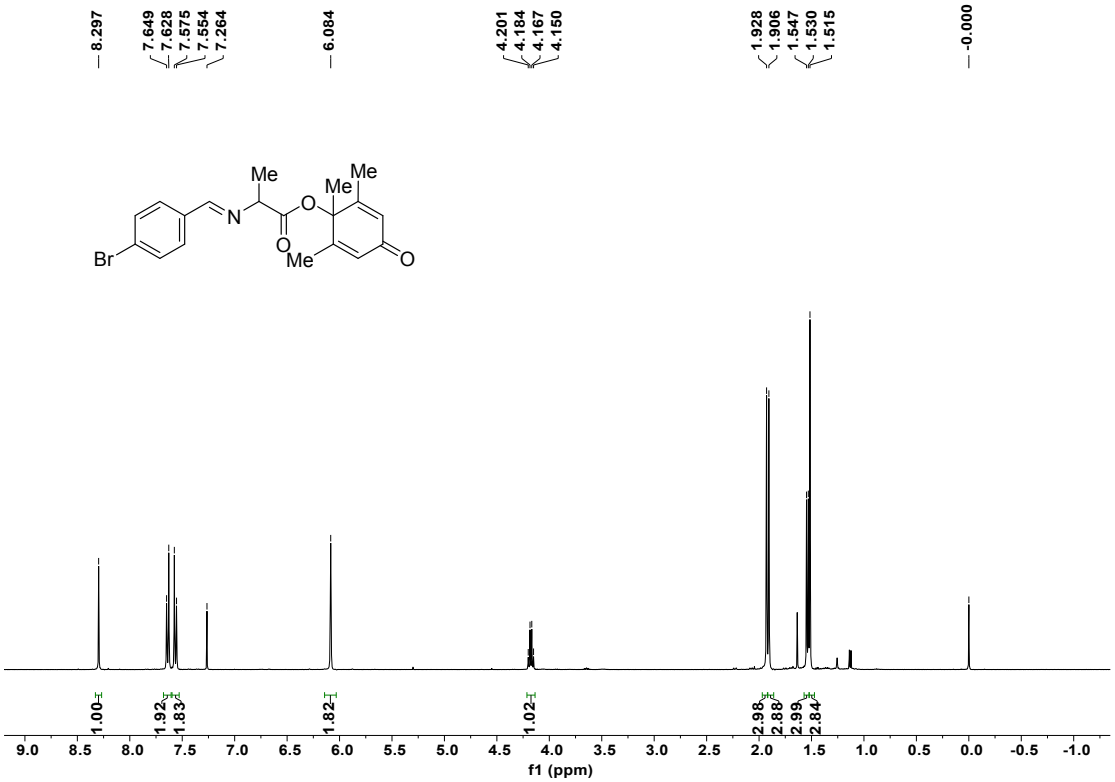
^{1}H NMR of **3c** in $CDCl_3$



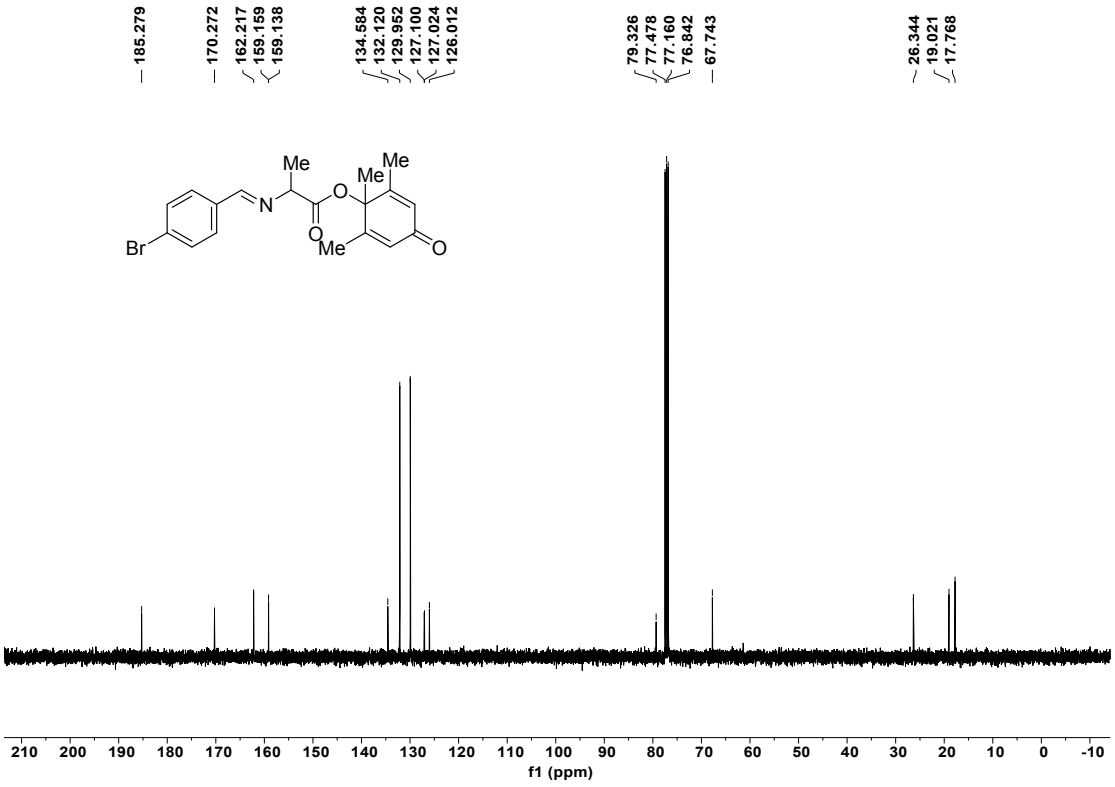
^{13}C NMR of **3c** in $CDCl_3$



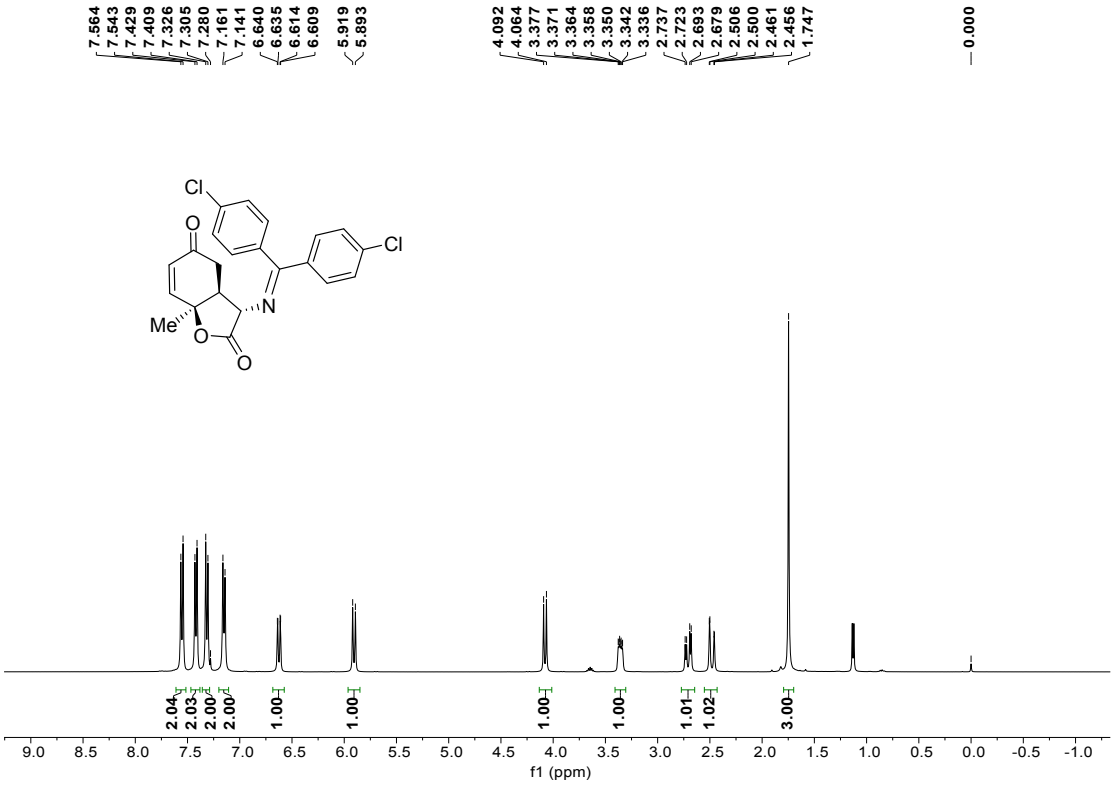
^{1}H NMR of **3d** in $CDCl_3$



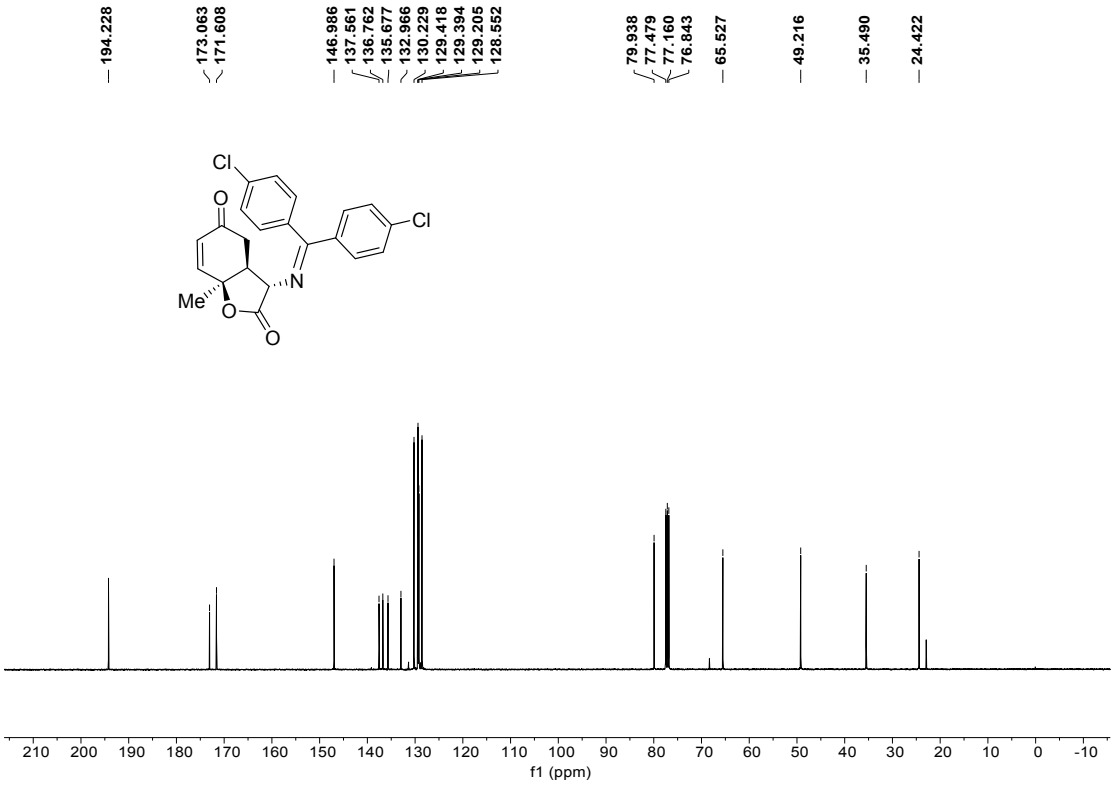
^{13}C NMR of **3d** in $CDCl_3$



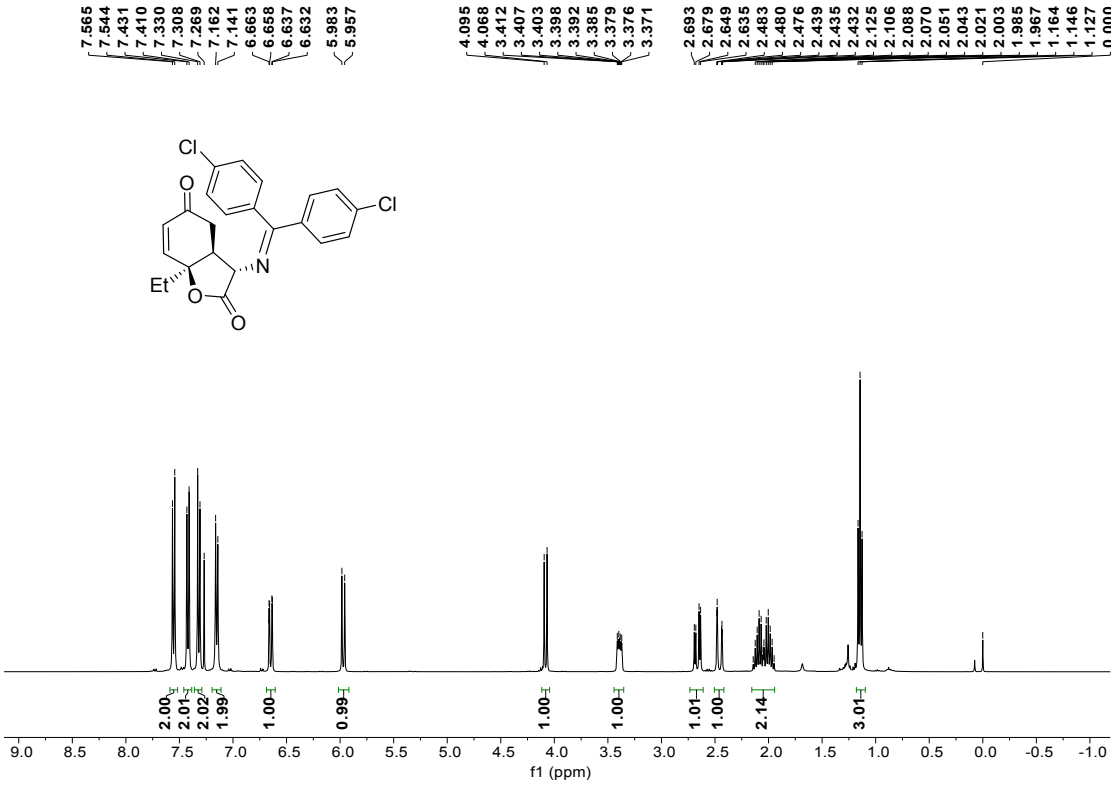
^{1}H NMR of **2a** in $CDCl_3$



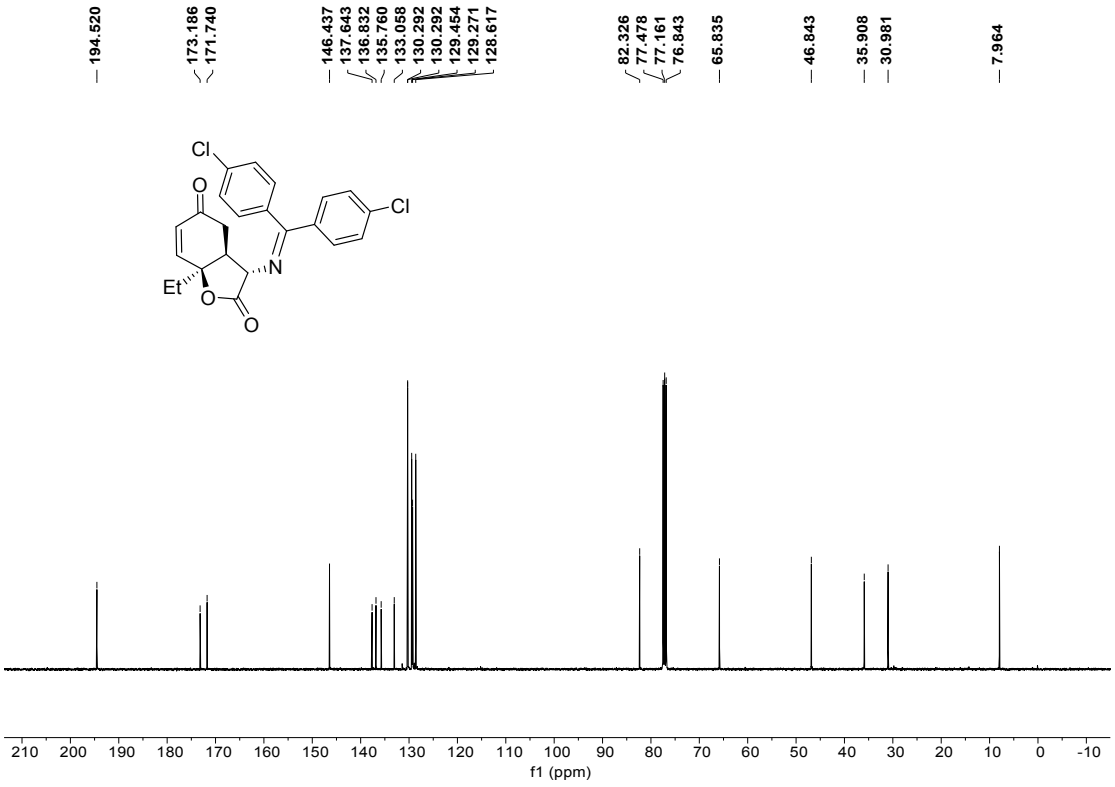
^{13}C NMR of **2a** in $CDCl_3$



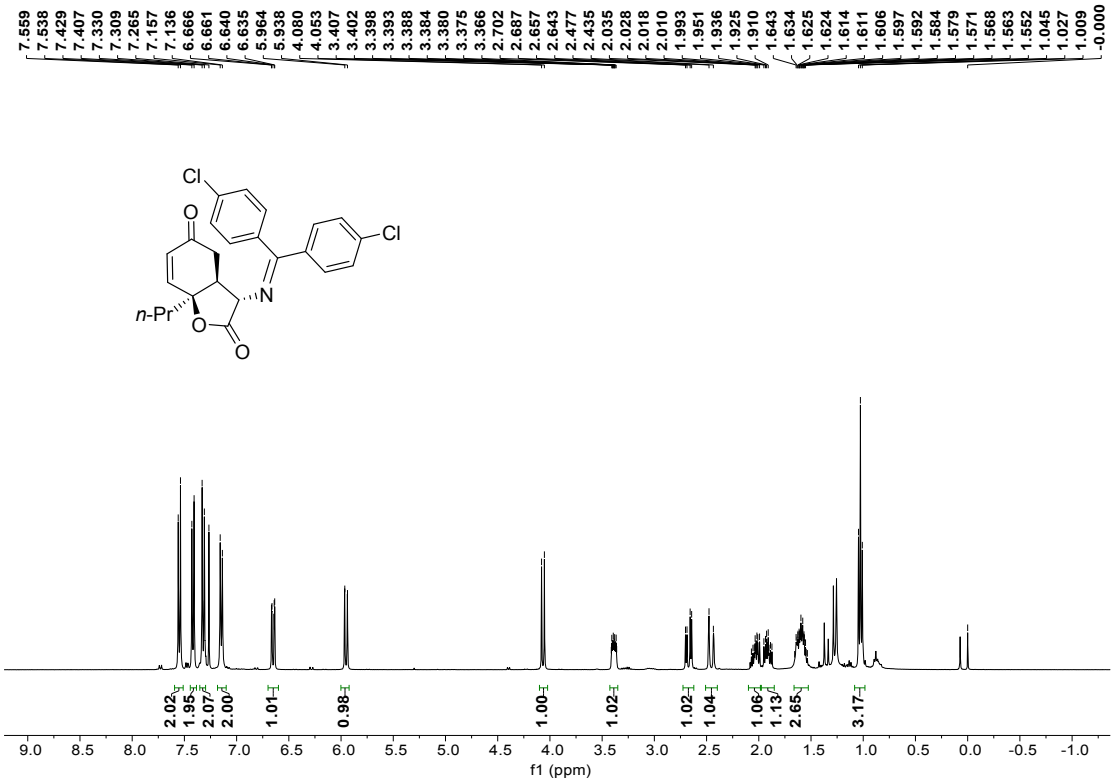
^{1}H NMR of **2b** in $CDCl_3$



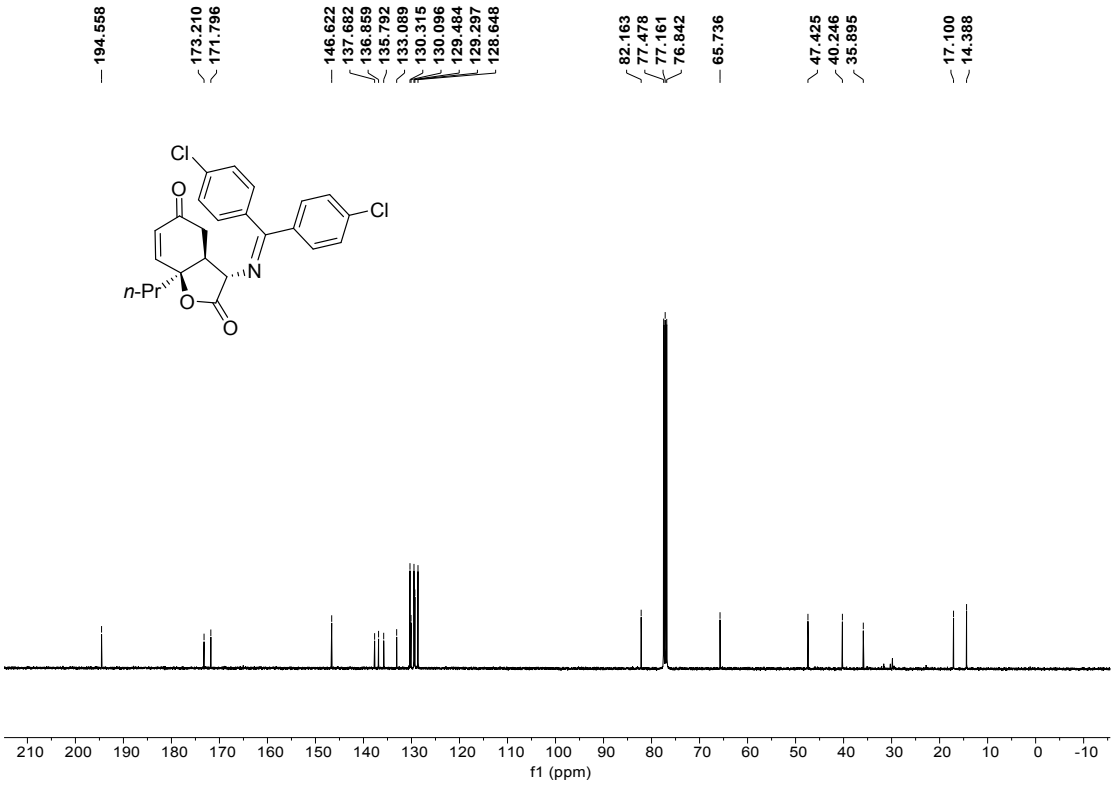
^{13}C NMR of **2b** in $CDCl_3$



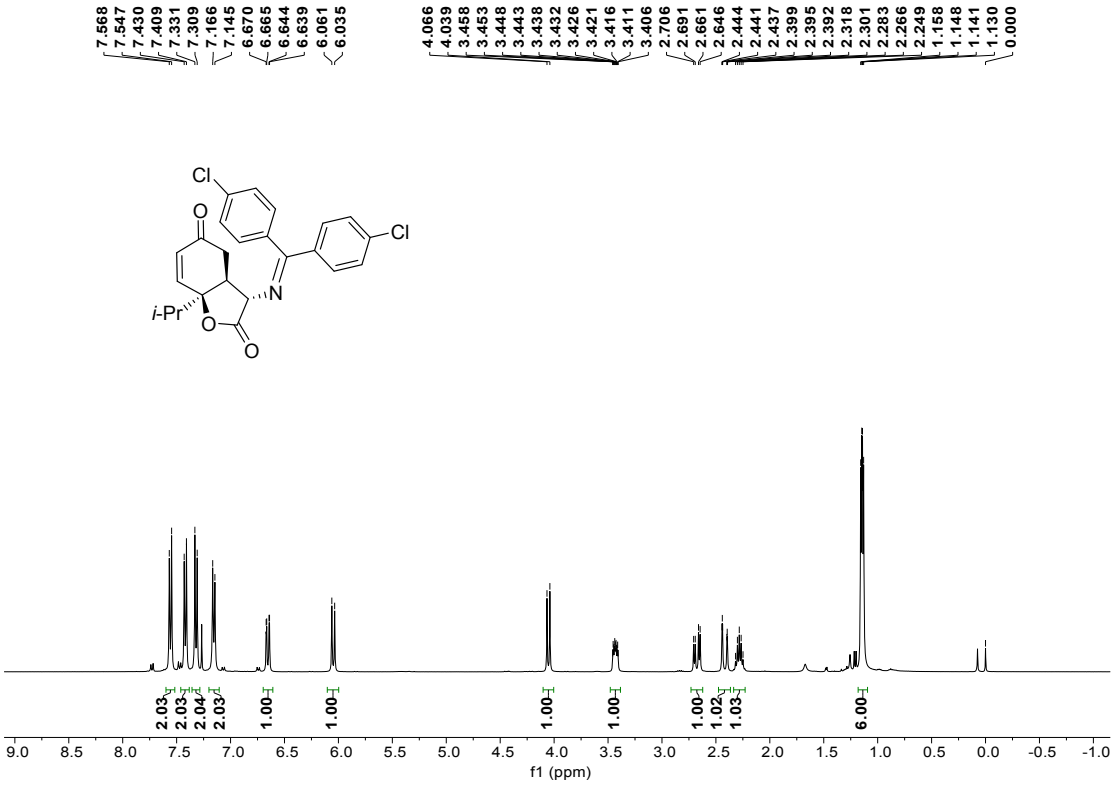
^{1}H NMR of **2c** in $CDCl_3$



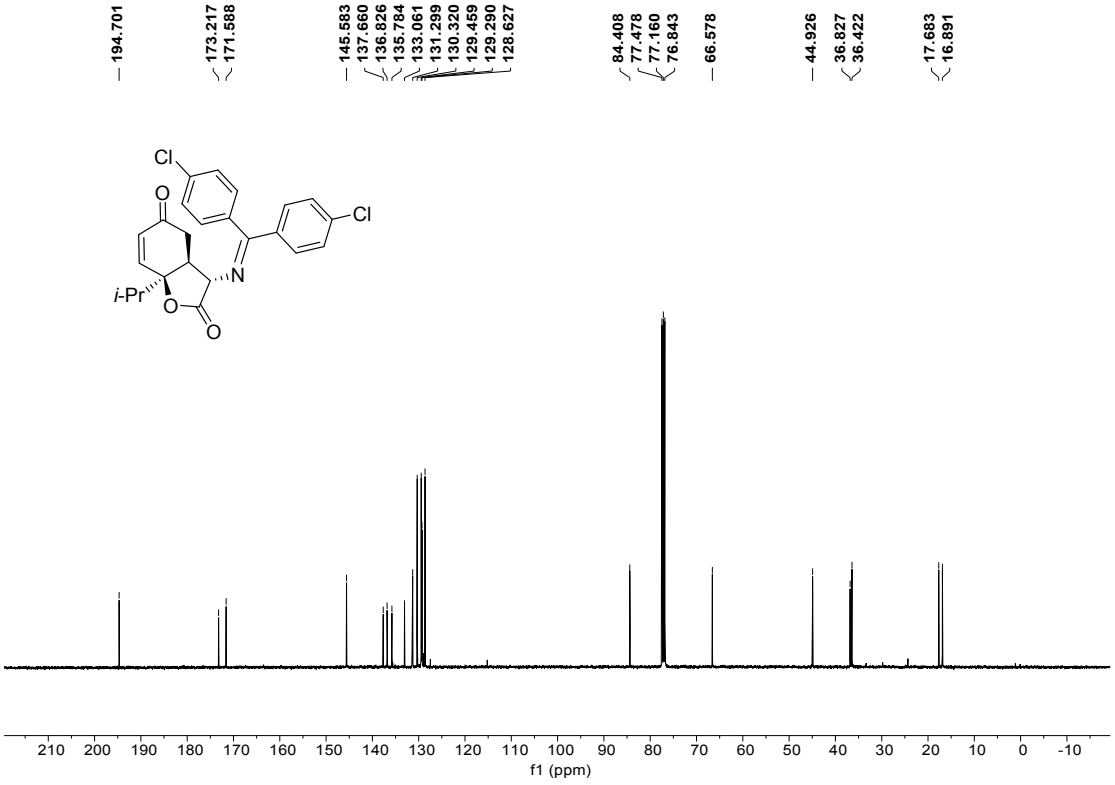
^{13}C NMR of **2c** in $CDCl_3$



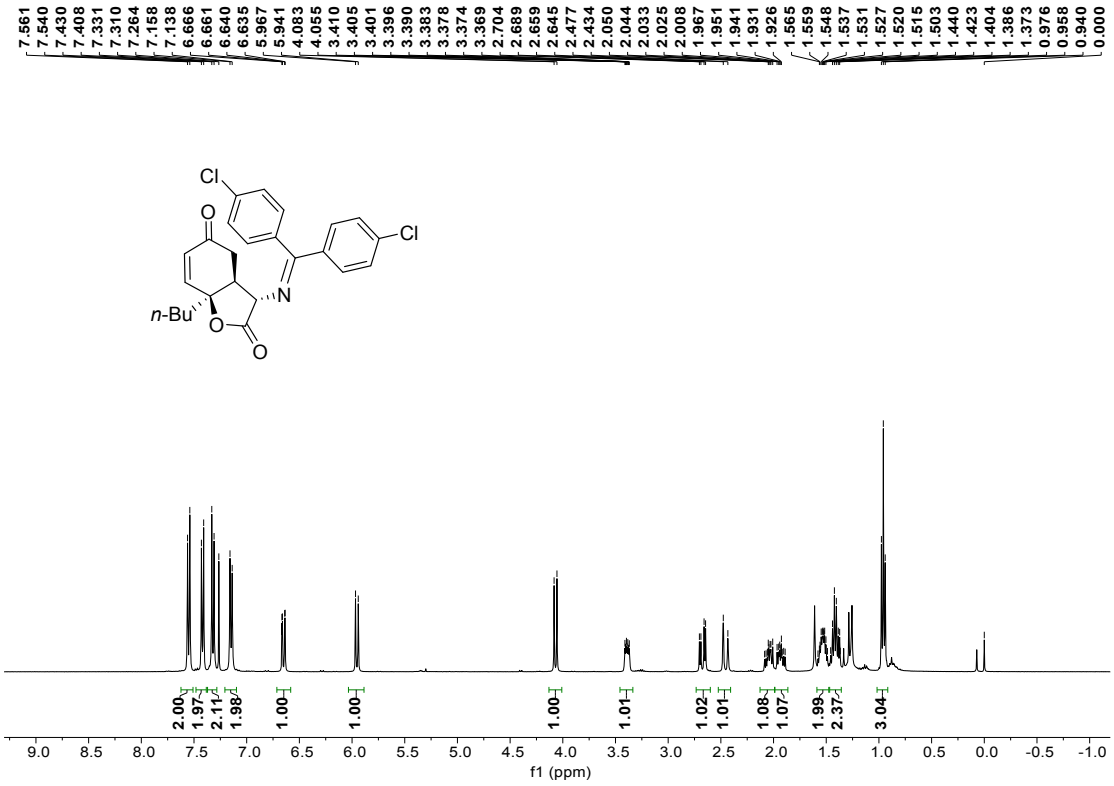
^{1}H NMR of **2d** in $CDCl_3$



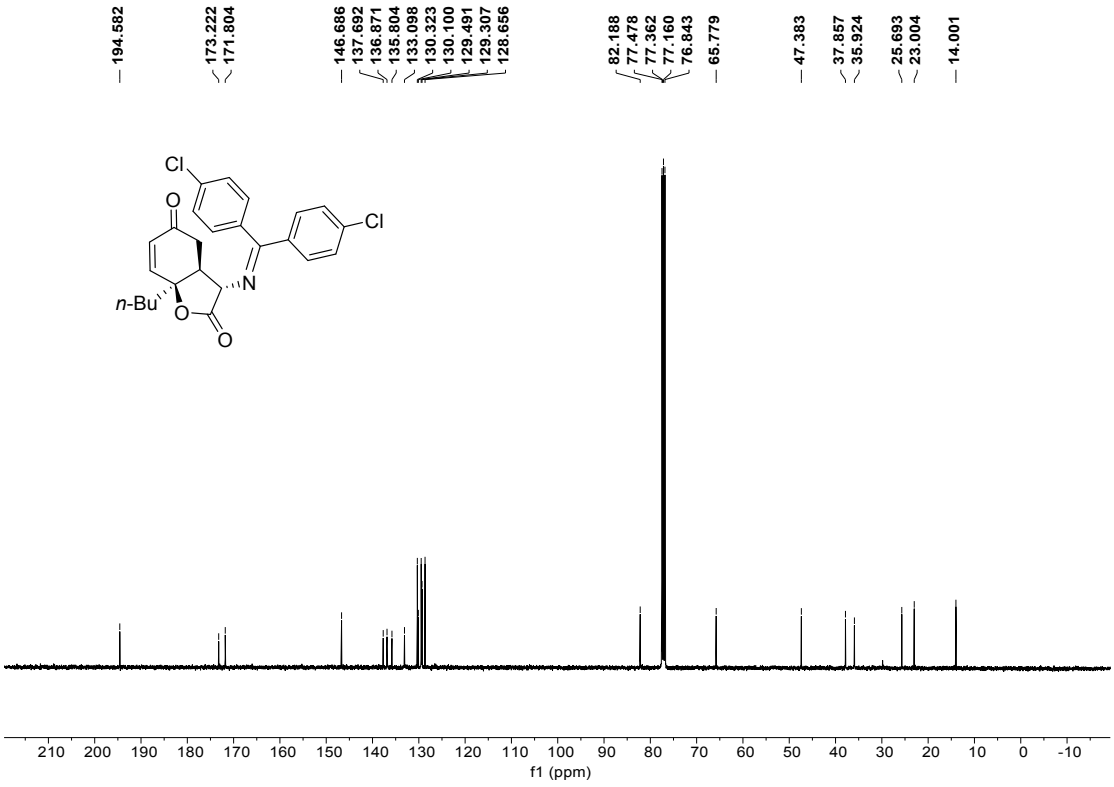
^{13}C NMR of **2d** in $CDCl_3$



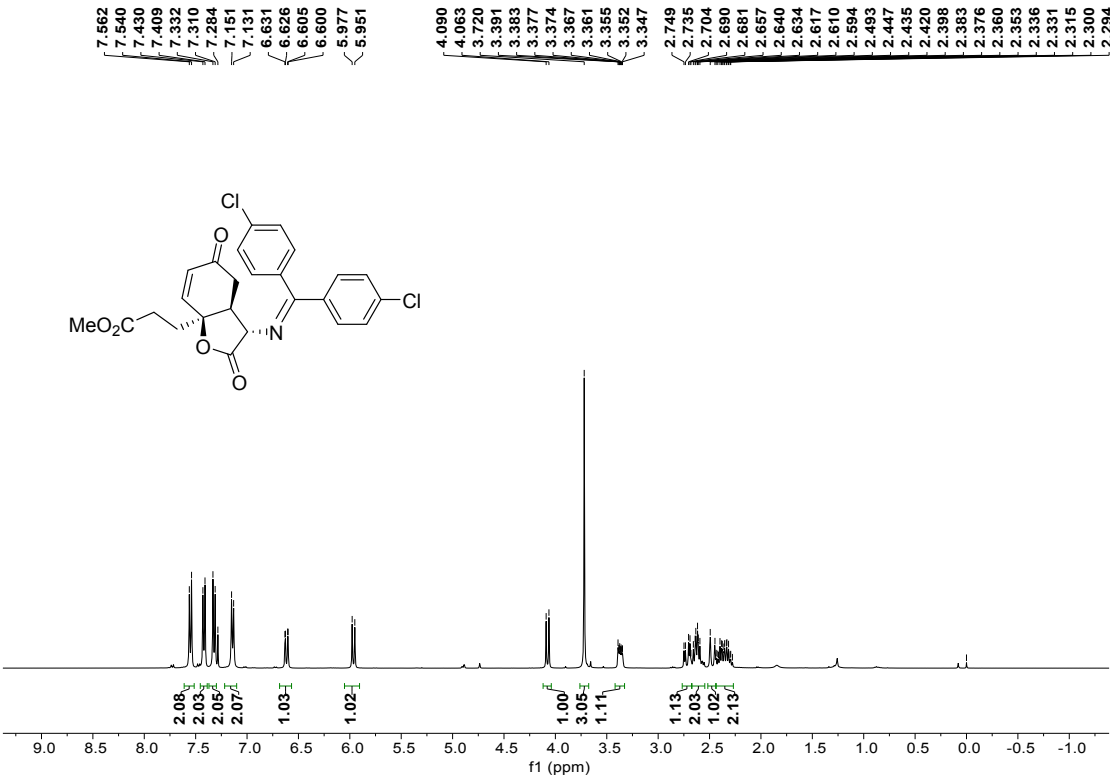
^{1}H NMR of **2e** in $CDCl_3$



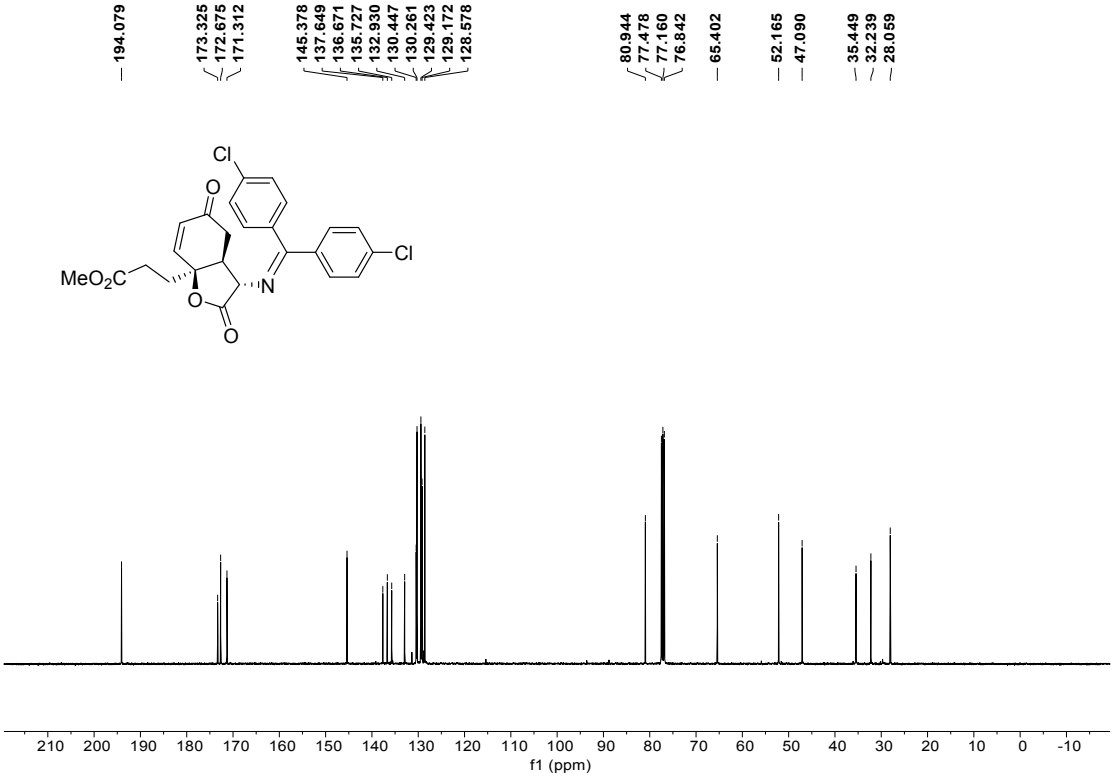
^{13}C NMR of **2e** in $CDCl_3$



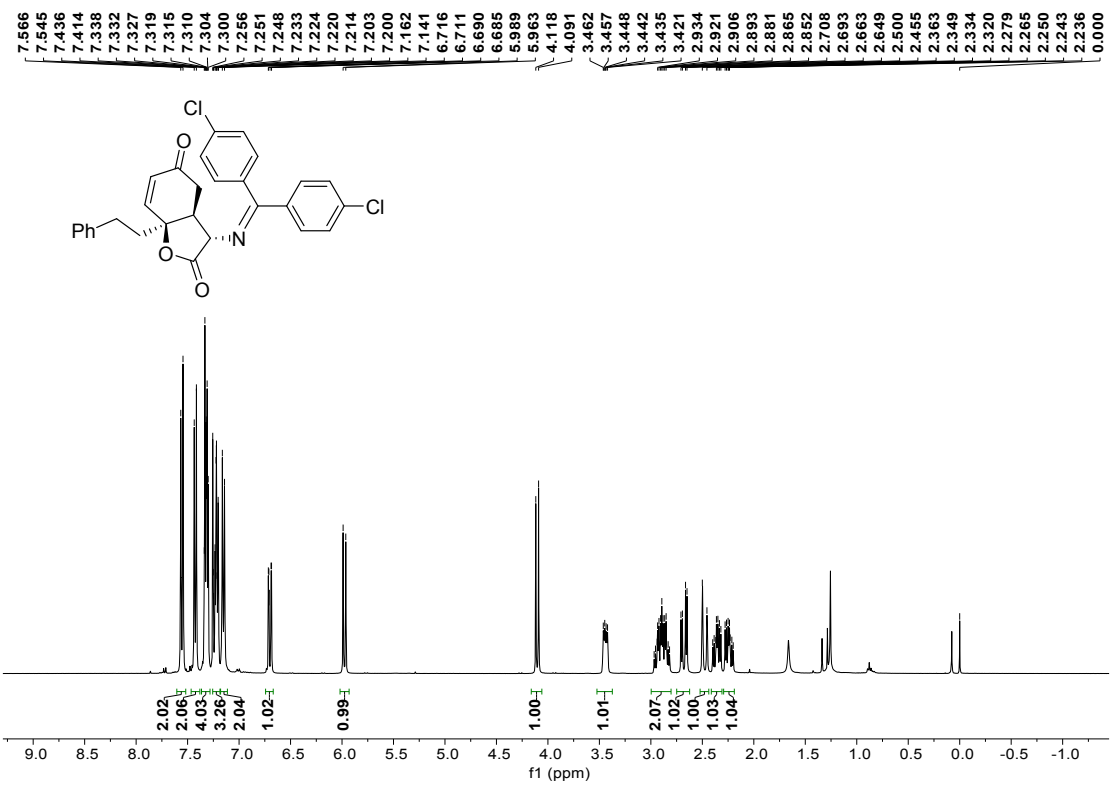
^{1}H NMR of **2f** in $CDCl_3$



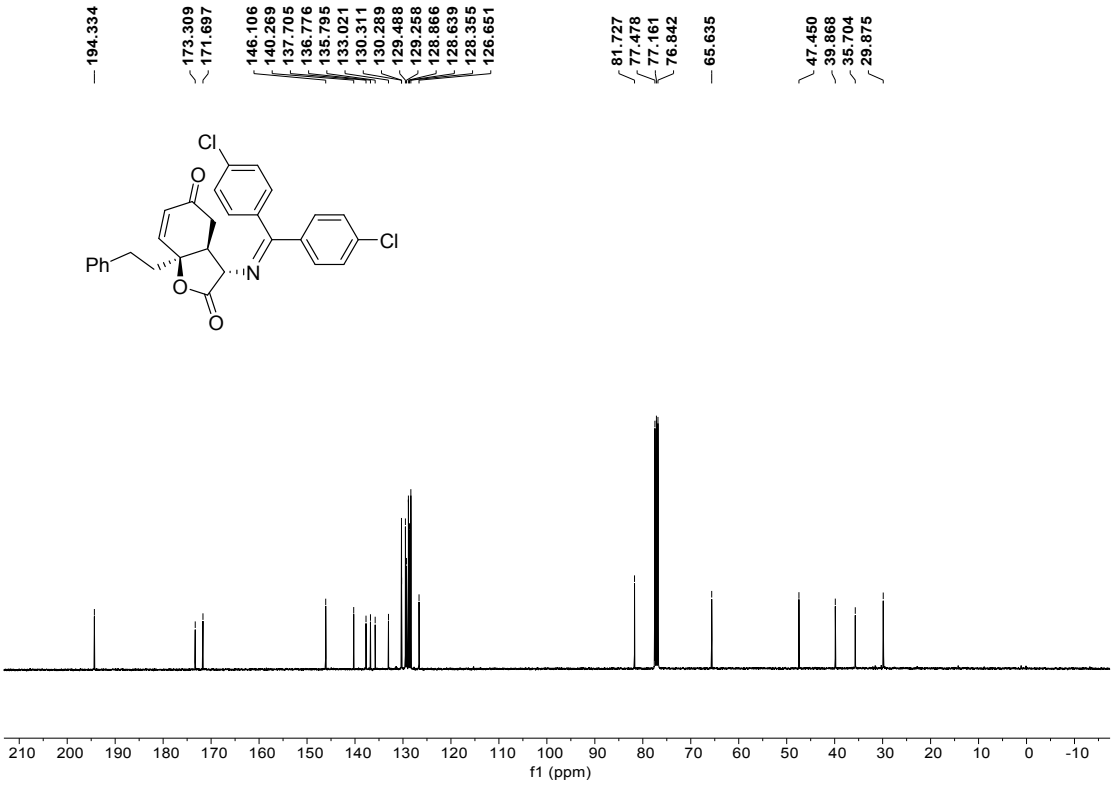
^{13}C NMR of **2f** in $CDCl_3$



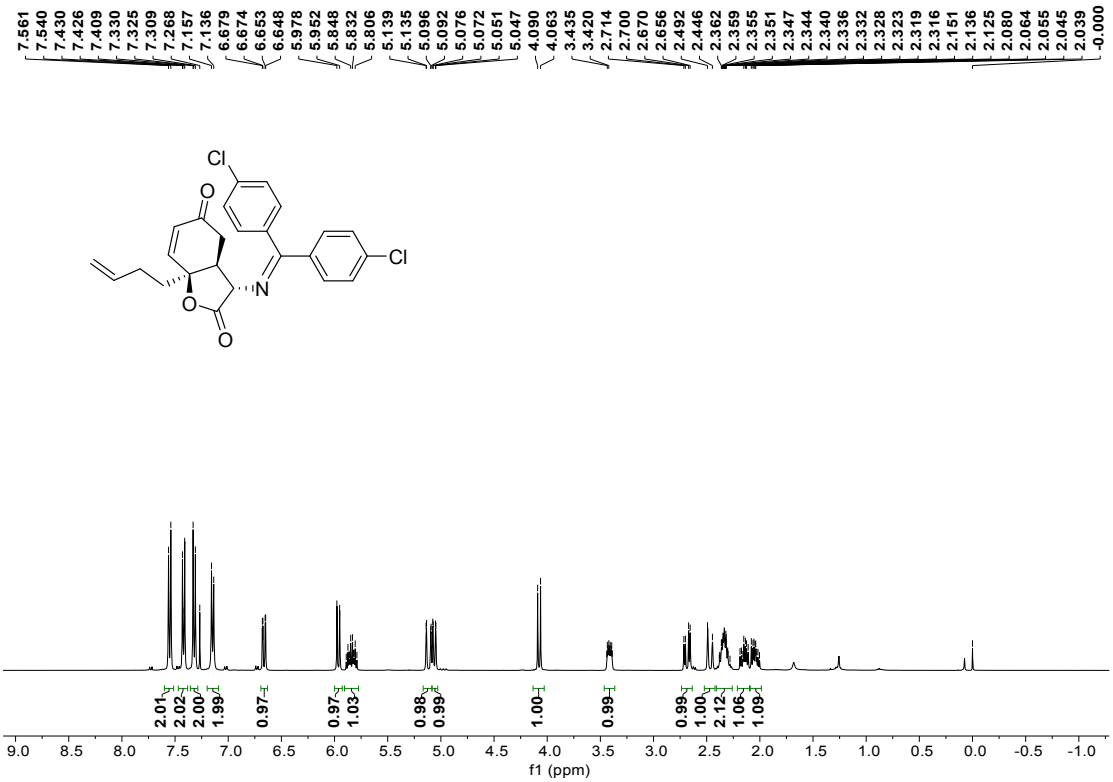
^{1}H NMR of **2g** in $CDCl_3$



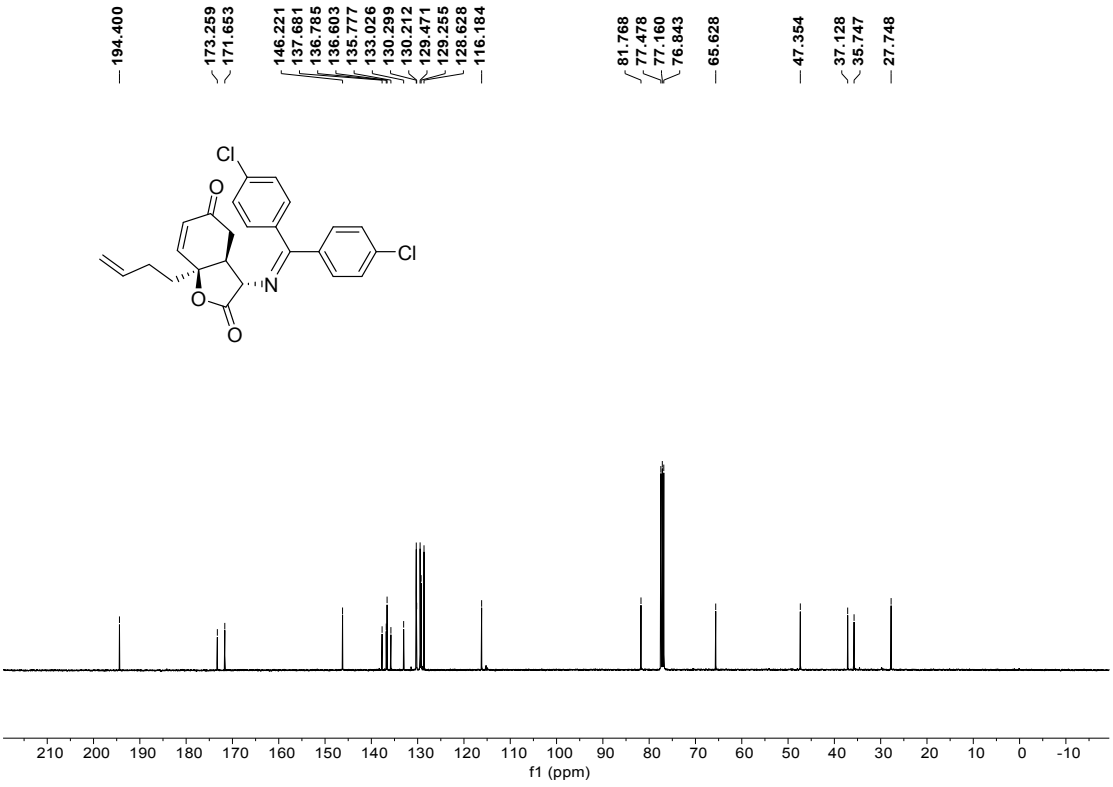
^{13}C NMR of **2g** in $CDCl_3$



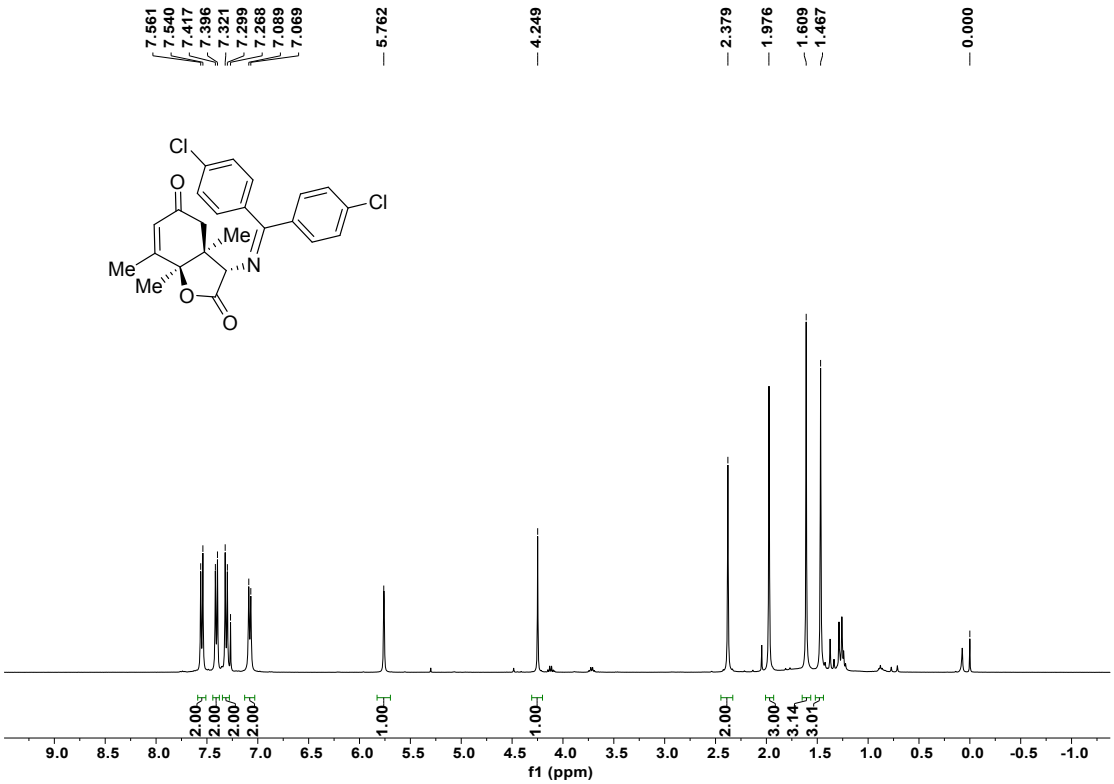
^{1}H NMR of **2h** in $CDCl_3$



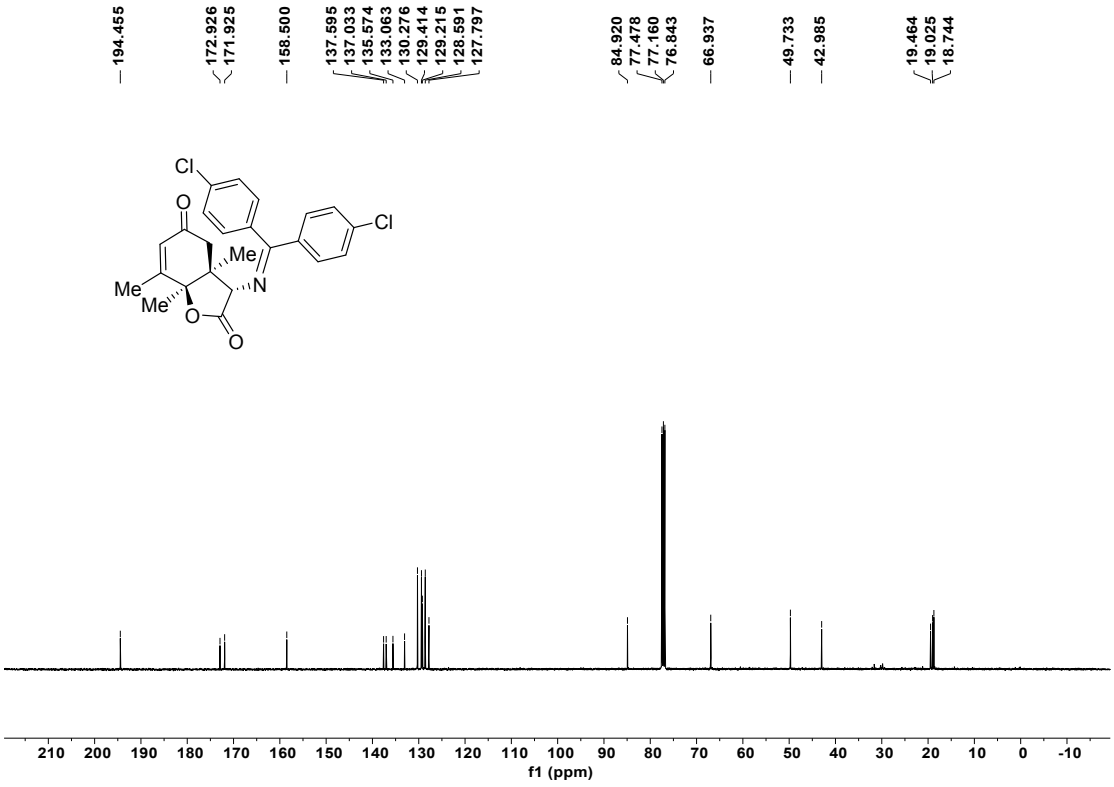
^{13}C NMR of **2h** in $CDCl_3$



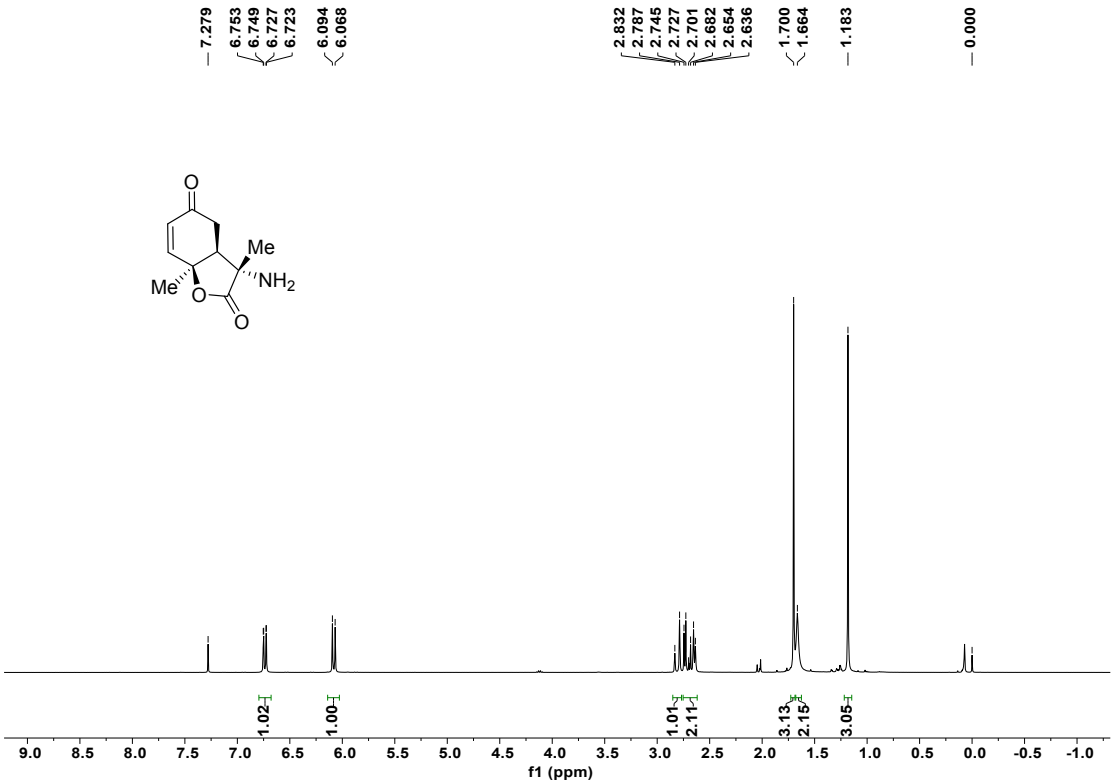
^{1}H NMR of **2i** in $CDCl_3$



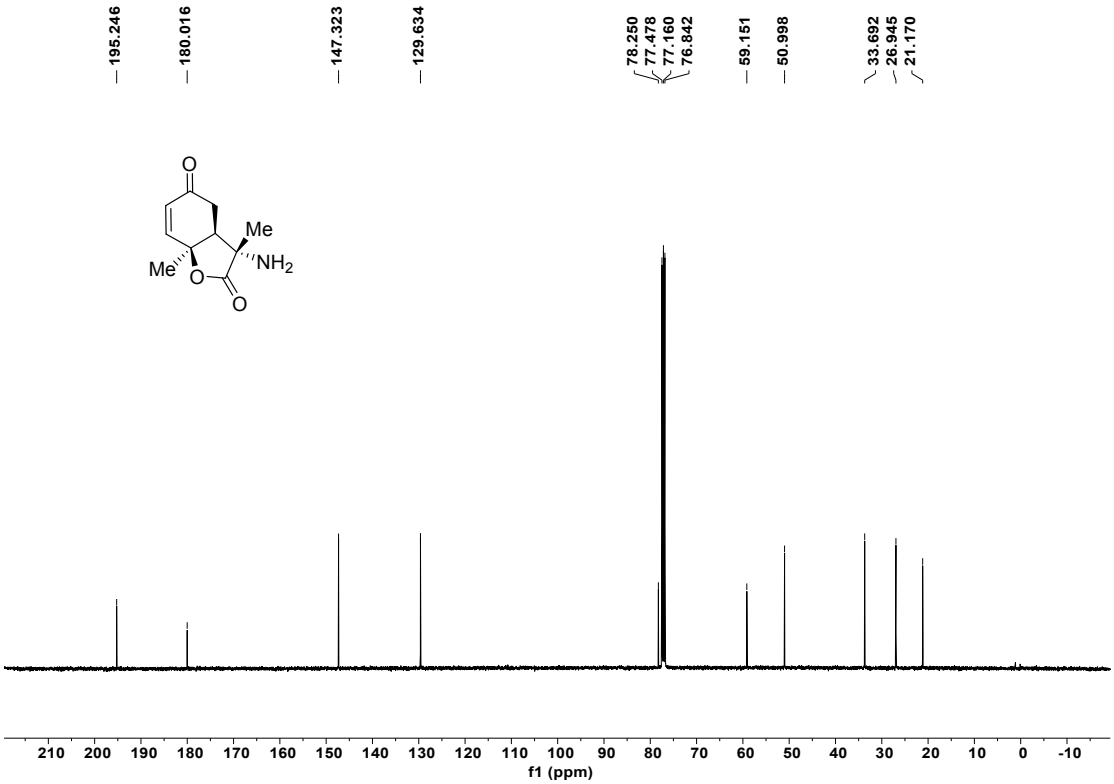
^{13}C NMR of **2i** in $CDCl_3$



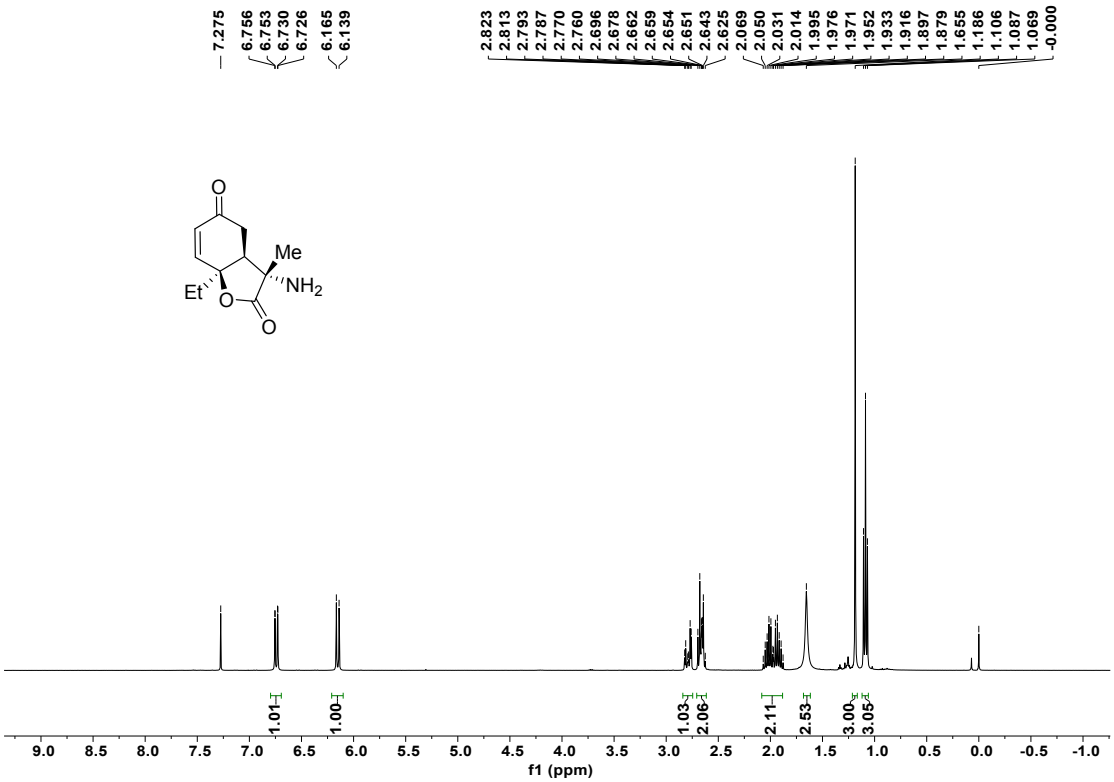
^{1}H NMR of **4a** in $CDCl_3$



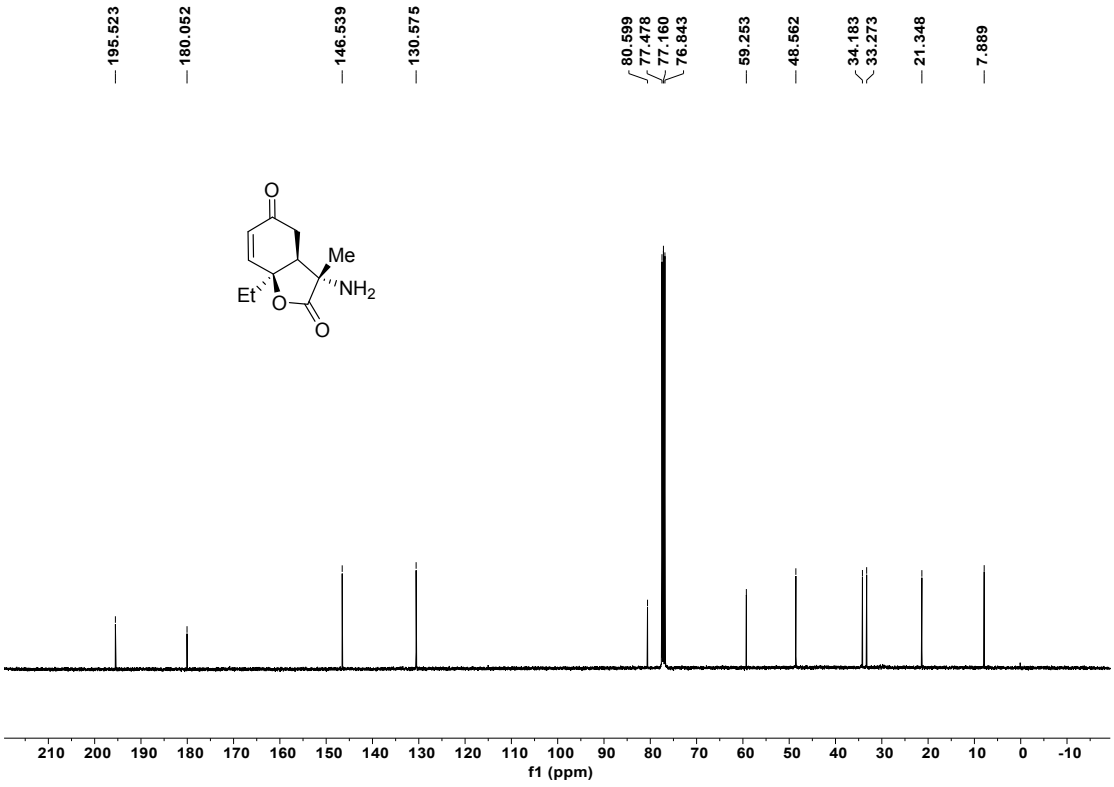
^{13}C NMR of **4a** in $CDCl_3$



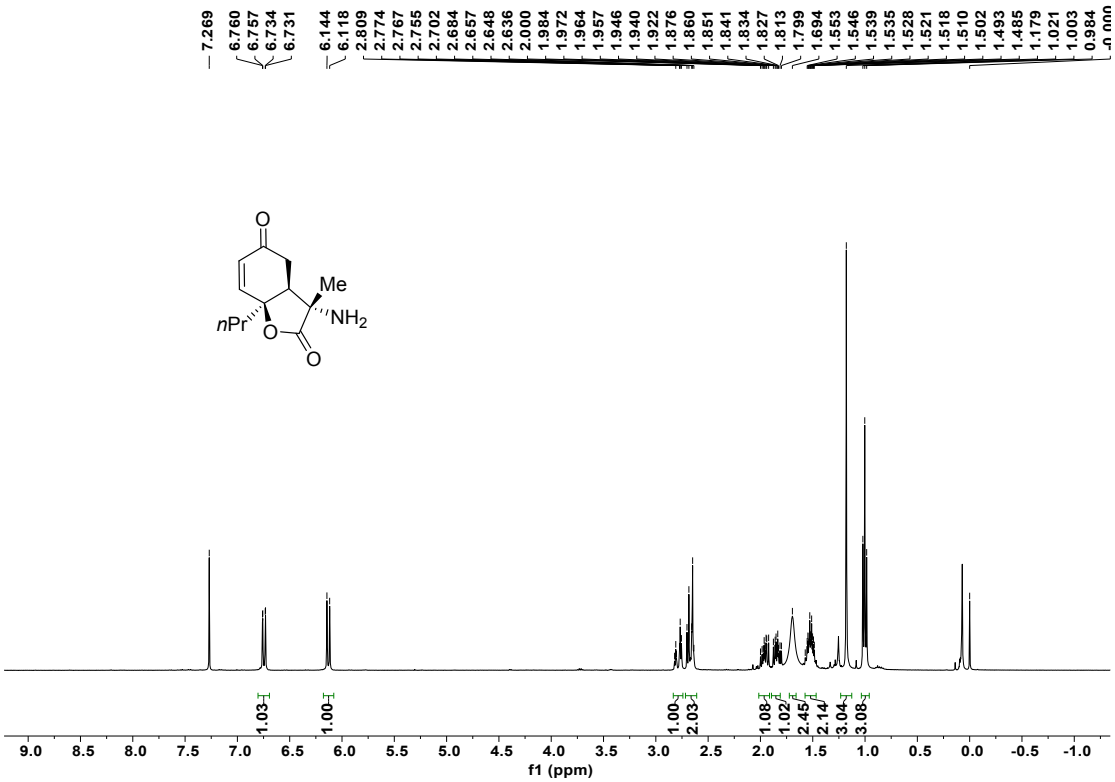
^{1}H NMR of **4b** in $CDCl_3$



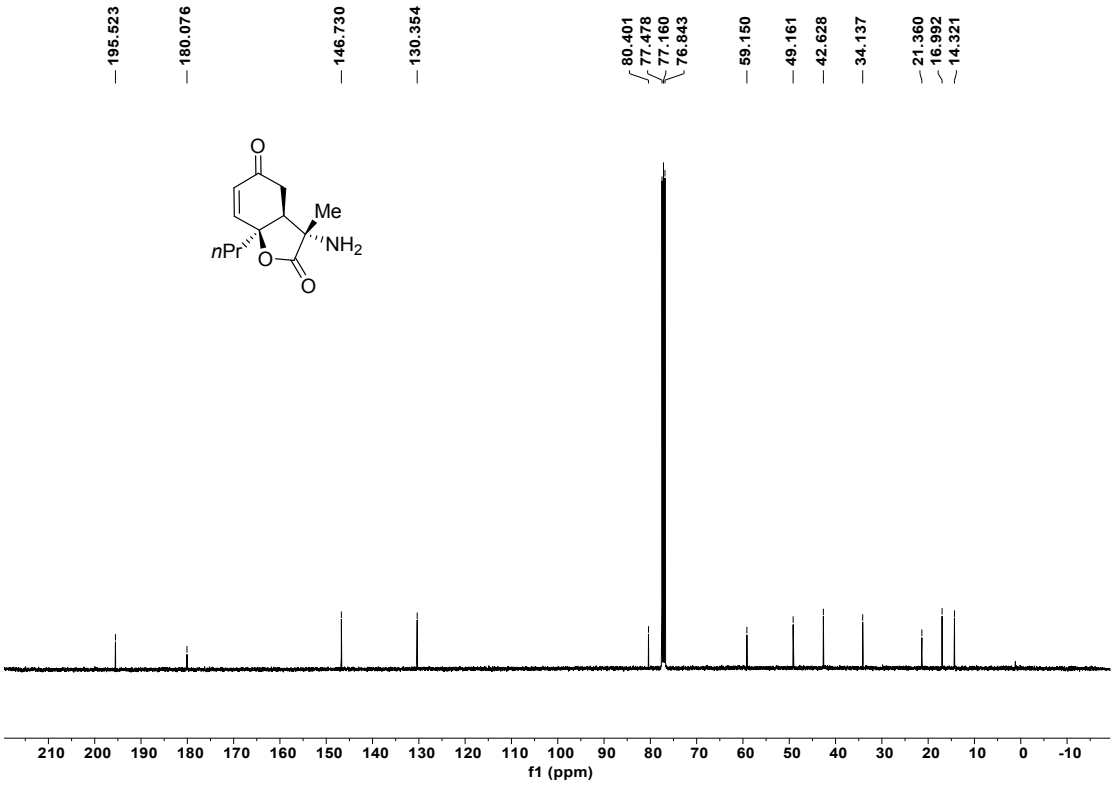
^{13}C NMR of **4b** in $CDCl_3$



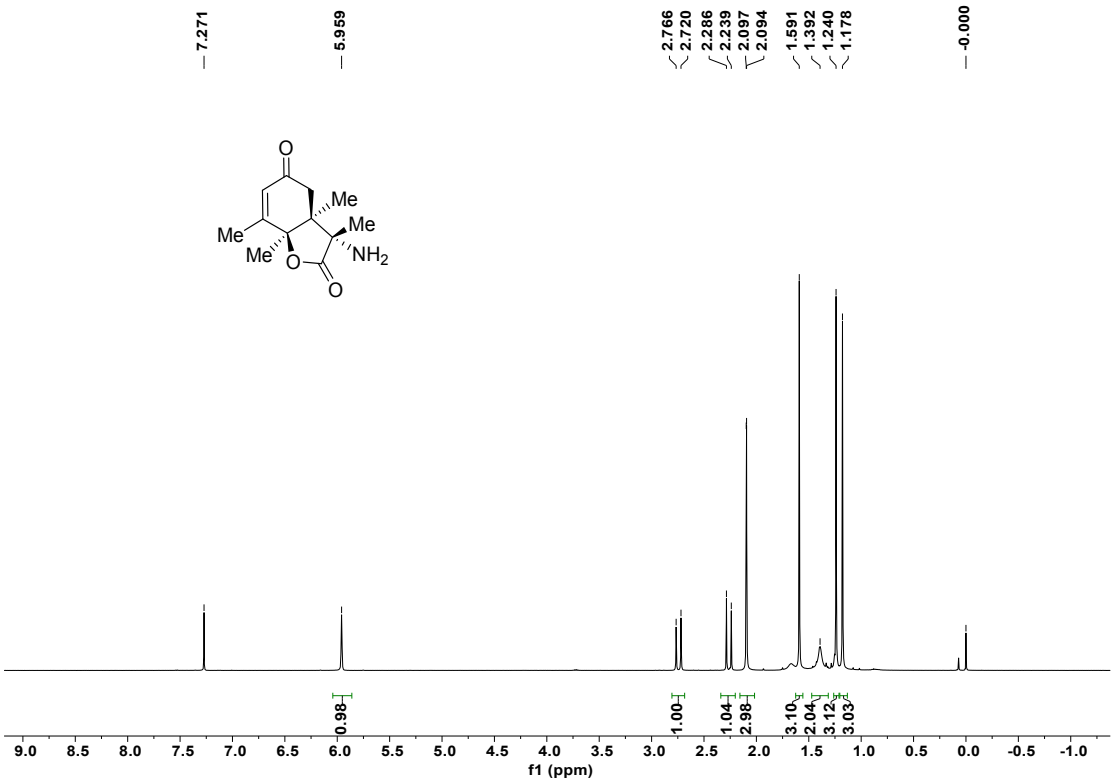
^{1}H NMR of **4c** in $CDCl_3$



^{13}C NMR of **4c** in $CDCl_3$



^{1}H NMR of **4d** in $CDCl_3$



^{13}C NMR of **4d** in $CDCl_3$