

Supplementary Methods

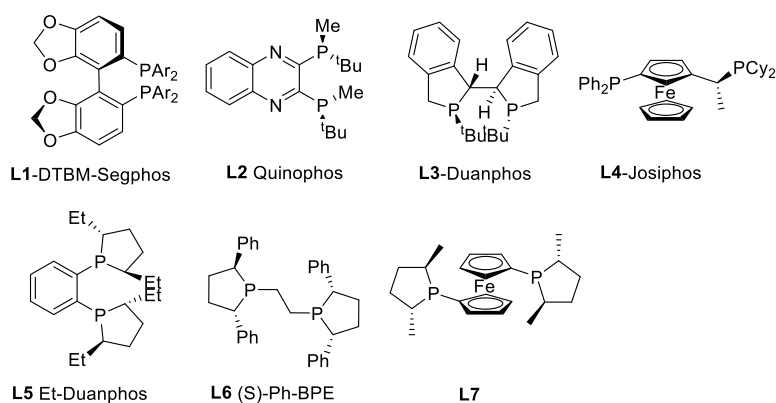
General Remarks

Unless otherwise stated, commercially available reagents were used as received without further purification. All the chiral ligands were purchased from Strem Chemicals Inc., Aion Scientific Pte. Ltd. or Sigma Aldrich. The reactions were performed in an argon-filled glove-box. All the solvents were purified by passing the degassed solvents (N₂) through a column of activated alumina (solvent purification system purchased from Innovative Technologies, Newburyport, MA). ¹H and ¹³C NMR spectra were recorded on Bruker nuclear resonance 300 or 400 MHz spectrometer in the solvents indicated. HPLC analyses were performed on Shimadzu DGU-20A. HR-MS analyses were performed on a Bruker micrOTOFQ II (APCI). The quinoline *N*-oxides¹⁻² and 1,3-enyne derivatives³ were synthesized according to the literatures.

Supplementary Table 1. Reaction Conditions Screening^a

Reaction scheme: Quinoline *N*-oxide **1a** + Enyne **2a** (Ph-C≡C-CH=CH₂) → Product **3a** (2-(1-phenyl-2-methylvinyl)quinoline).
 Reagents: CuOAc, ligand
 Conditions: Silane, Solvent, 5 °C
 Work up: silica gel

Entry	Ligand/mol %	Silane/equiv	solvent	Yield/% ^b	ee/% ^c
1	L1/6	(EtO) ₂ SiHMe/2	Cyclohexane	74	46
2	L2/6	(EtO) ₂ SiHMe/2	Cyclohexane	75	<5
3	L3/6	(EtO) ₂ SiHMe/2	Cyclohexane	78	17
4	L4/6	(EtO) ₂ SiHMe/2	Cyclohexane	46	30
5	L5/6	(EtO) ₂ SiHMe/2	Cyclohexane	73	32
6	L6/6	(EtO) ₂ SiHMe/2	Cyclohexane	90	95
7	L7/6	(EtO) ₂ SiHMe/2	Cyclohexane	77	11
8	L6/6	(EtO) ₂ SiHMe/2	PhMe	87	94
9	L6/6	(EtO) ₂ SiHMe/2	dioxane	84	91
10	L6/6	(EtO) ₂ SiHMe/2	Et ₂ O	80	95
11	L6/6	(EtO) ₂ SiHMe/2	Hexane	16	-
12	L6/6	(EtO) ₂ SiHMe/2	THF	82	89
13	L6/6	(MeO) ₂ SiHMe/2	Cyclohexane	87	94
14	L6/6	(EtO) ₃ SiH/2	Cyclohexane	83	95
15	L6/6	Ph ₂ SiH/2	Cyclohexane	81	94



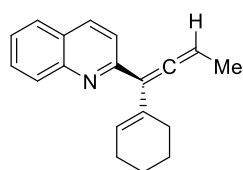
^aConditions: quinoline oxide (0.4 mmol), phenylacetylene (0.2 mmol), Cu(OAc) (4 mol%), ligand (6 mol%), solvent (1 mL), 20 h; ^bisolated yields; ^c*ee* was determined by chiral HPLC analysis.

General procedure for the synthesis of achiral allenes

CuOAc (4mol %, 0.9 mg) and dcpe (6mol %, 5.1 mg) were dissolved in cyclohexane (1 mL) in a screw-capped vial under argon atmosphere. The resulting mixture was stirred for 5 min, to which was added (EtO)₂SiHMe (0.4 mmol, 65 μ L), 1,3-enynes (0.2 mmol), and quinoline *N*-oxide (0.4 mmol) successively. The vial was stirred at 5 $^{\circ}$ C for 20 hours. The mixture was concentrated under vacuum and the crude product was purified by flash chromatography on silica with a mixture of ethyl acetate/hexane (1:100 to 1:50).

General procedure for the synthesis of chiral allenes

CuOAc (4mol %, 0.9 mg) and (*S,S*)-Ph-BPE (6mol %, 6.1 mg) were dissolved in cyclohexane (1 mL) in a screw-capped vial under argon atmosphere. The resulting mixture was stirred for 5 min, to which was added (EtO)₂SiHMe (0.4 mmol, 65 μ L), 1,3-enynes (0.2 mmol), and quinoline *N*-oxide (0.4 mmol) successively. The vial was stirred at 5 $^{\circ}$ C for 20 hours. The mixture was concentrated under vacuum and the crude product was purified by flash chromatography on silica with a mixture of ethyl acetate/hexane (1:100 to 1:50). The *ee* values were determined by HPLC (*Note: The allene products are unstable and prone to racemization in acidic solvent such as CHCl₃. The ee values and optical rotation should be determined immediately after isolation*).

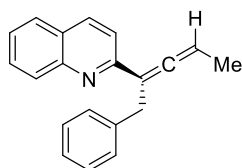
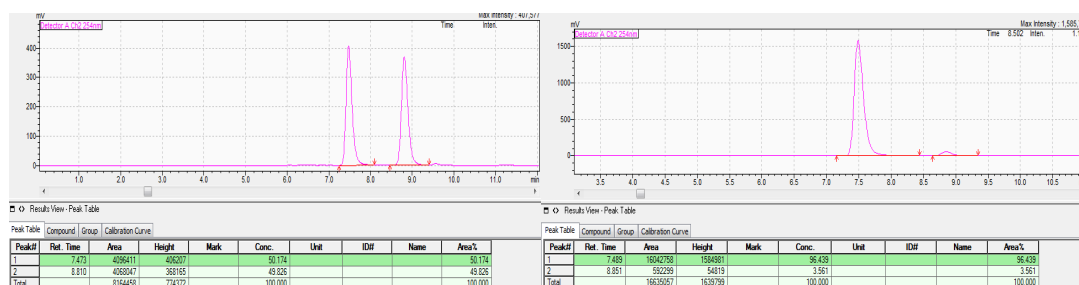


(*S*)-2-(1-(cyclohex-1-en-1-yl)buta-1,2-dien-1-yl)quinoline **3b** (colorless oil, 45.9 mg, 88% yield, 93% *ee*). ¹H NMR (400 MHz, CDCl₃) δ 8.13 (d, *J* = 8.5 Hz, 1H), 8.07 (d, *J* = 8.5 Hz, 1H), 7.77

(dd, $J = 8.0, 1.4$ Hz, 1H), 7.67 (ddd, $J = 8.4, 6.9, 1.5$ Hz, 1H), 7.52 – 7.44 (m, 2H), 5.80 – 5.73 (m, 1H), 5.63 (qd, $J = 7.1, 1.5$ Hz, 1H), 2.39 – 2.19 (m, 2H), 2.16 – 2.08 (m, 2H), 1.80 (d, $J = 7.1$ Hz, 3H), 1.78 – 1.70 (m, 2H), 1.68 – 1.59 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3) δ 206.9, 157.0, 147.8, 136.0, 132.4, 129.6, 129.2, 127.3, 127.0, 126.8, 126.1, 122.9, 111.8, 89.8, 27.4, 26.0, 22.9, 22.3, 14.5. GC-MS (EI): calculated for $\text{C}_{19}\text{H}_{19}\text{N}$: 261.2, found: 261.2.

Optical rotation: $[\alpha]_{\text{D}}^{20} = +60.0$ ($c = 1$, CH_2Cl_2).

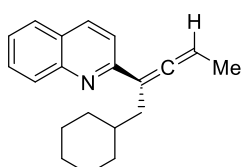
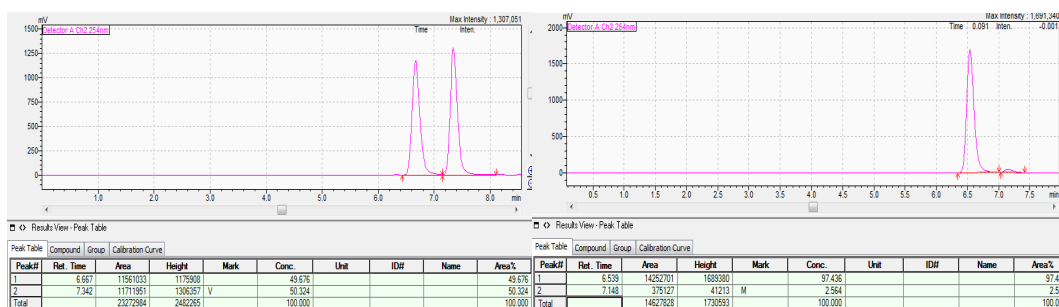
HPLC condition: Chiral column IB, n -hexane/ i -PrOH = 97: 3, flow rate = 0.6 mL/min, wavelength = 254 nm, $t_{\text{R}} = 7.5$ min for the major enantiomer, $t_{\text{R}} = 8.9$ min for the minor enantiomer.



(S)-2-(1-phenylpenta-2,3-dien-2-yl)quinoline 3c (yellow oil, 47.2 mg, 87% yield, 95% ee). ^1H NMR (400 MHz, CDCl_3) δ 8.12 (d, $J = 8.5$ Hz, 1H), 7.98 (dd, $J = 8.7, 0.8$ Hz, 1H), 7.75 (dd, $J = 8.1, 1.4$ Hz, 1H), 7.71 – 7.63 (m, 2H), 7.48 (ddd, $J = 8.1, 6.9, 1.2$ Hz, 1H), 7.45 – 7.39 (m, 2H), 7.33 – 7.27 (m, 2H), 7.24 – 7.16 (m, 1H), 5.63–5.51 (m, 1H), 4.26 – 4.06 (m, 2H), 1.77 (d, $J = 7.1$ Hz, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 209.1, 155.9, 147.9, 141.0, 135.3, 129.5, 129.4, 129.1, 128.0, 127.4, 126.7, 125.9, 125.8, 120.6, 108.3, 90.6, 35.3, 13.9. HR-MS (APCI $^+$): m/z calculated for $\text{C}_{20}\text{H}_{18}\text{N}$ ($\text{M}+\text{H}^+$): 272.1434, found: 272.1436.

Optical rotation: $[\alpha]_{\text{D}}^{20} = +65.2$ ($c = 1$, CH_2Cl_2).

HPLC condition: Chiral column IB, n -hexane/ i -PrOH = 99: 1, flow rate = 0.7 mL/min, wavelength = 254 nm, $t_{\text{R}} = 6.5$ min for the major enantiomer, $t_{\text{R}} = 7.1$ min for the minor enantiomer.

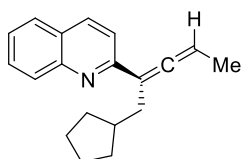
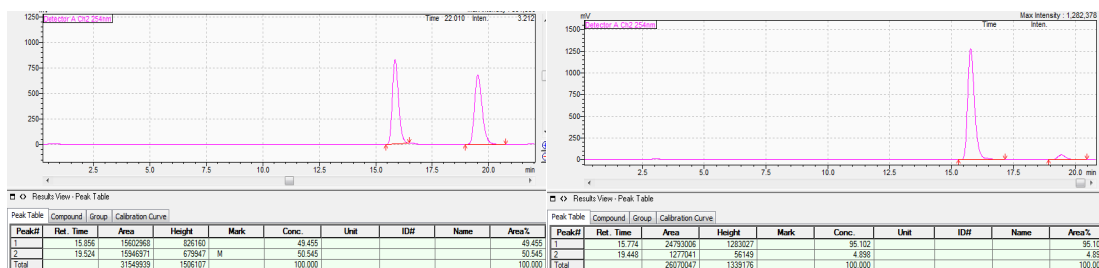


(S)-2-(1-cyclohexylpenta-2,3-dien-2-yl)quinoline 3d (yellow oil, 46.5 mg, 84% yield, 90% *ee*).

^1H NMR (400 MHz, Chloroform-*d*) δ 8.05 (dq, J = 8.4, 0.9 Hz, 1H), 7.96 (dd, J = 8.7, 0.8 Hz, 1H), 7.73 (dd, J = 8.0, 1.4 Hz, 1H), 7.68 – 7.62 (m, 2H), 7.45 (ddd, J = 8.1, 6.9, 1.2 Hz, 1H), 5.64 – 5.53 (m, 1H), 2.71 (ddd, J = 14.3, 7.0, 2.5 Hz, 1H), 2.58 (ddd, J = 14.3, 6.7, 2.5 Hz, 1H), 1.90 – 1.81 (m, 4H), 1.77 – 1.59 (m, 4H), 1.31 – 1.15 (m, 4H), 1.09 – 1.01 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3) δ 208.6, 156.8, 148.0, 135.1, 129.5, 129.0, 127.3, 126.6, 125.7, 120.6, 106.4, 89.2, 36.6, 36.4, 33.50, 33.46, 26.8, 26.5, 26.4, 14.1. HR-MS (APCI $^+$): m/z calculated for $\text{C}_{20}\text{H}_{18}\text{N}$ ($\text{M}+\text{H}^+$): 278.1903, found: 278.1904.

Optical rotation: $[\alpha]_{\text{D}}^{20} = +36.9$ ($c=1$, CH_2Cl_2).

HPLC condition: Chiral column IB, *n*-hexane/*i*-PrOH = 99.8: 0.2, flow rate = 0.3 mL/min, wavelength = 254 nm, t_{R} = 15.8 min for the major enantiomer, t_{R} = 19.5 min for the minor enantiomer.



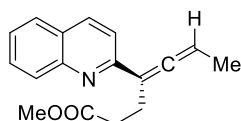
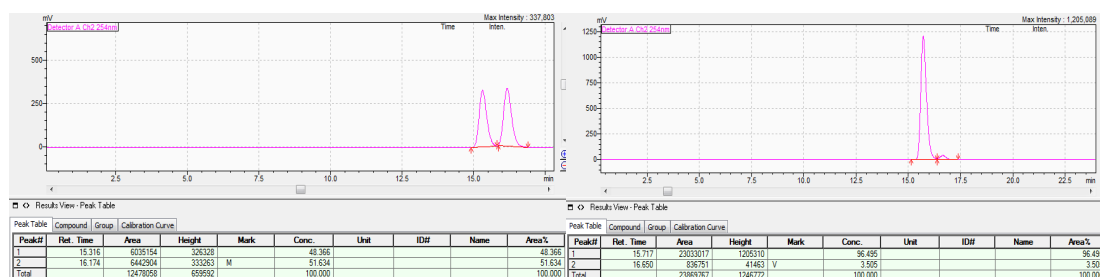
(S)-2-(1-cyclopentylpenta-2,3-dien-2-yl)quinoline 3e (yellow oil, 41.6 mg, 79% yield, 93% *ee*).

^1H NMR (400 MHz, Chloroform-*d*) δ 8.05 (d, J = 8.4 Hz, 1H), 7.97 (dd, J = 8.7, 0.9 Hz, 1H), 7.73

(dd, $J = 8.0, 1.4$ Hz, 1H), 7.68 – 7.60 (m, 2H), 7.45 (ddd, $J = 8.1, 6.9, 1.2$ Hz, 1H), 5.65 (qd, $J = 7.0, 2.4$ Hz, 1H), 3.59 (pd, $J = 7.8, 2.4$ Hz, 1H), 2.19 – 2.03 (m, 2H), 1.84 (d, $J = 7.1$ Hz, 3H), 1.80 – 1.64 (m, 4H), 1.59 – 1.45 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3) δ 206.9, 156.8, 148.1, 135.0, 129.5, 129.0, 127.3, 126.7, 125.7, 121.0, 113.3, 90.9, 38.1, 32.8, 32.5, 25.3, 25.2, 14.2. HR-MS (APCI $^+$): m/z calculated for $\text{C}_{18}\text{H}_{20}\text{N}$ ($\text{M}+\text{H}^+$): 250.1090, found: 250.1096.

Optical rotation: $[\alpha]_{\text{D}}^{20} = +19.2$ ($c = 1$, CH_2Cl_2).

HPLC condition: Chiral column IB, n -hexane/ i -PrOH = 99.9: 0.1, flow rate = 0.3 mL/min, wavelength = 254 nm, $t_{\text{R}} = 15.7$ min for the major enantiomer, $t_{\text{R}} = 16.7$ min for the minor enantiomer.

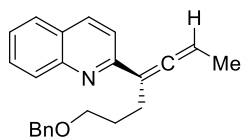
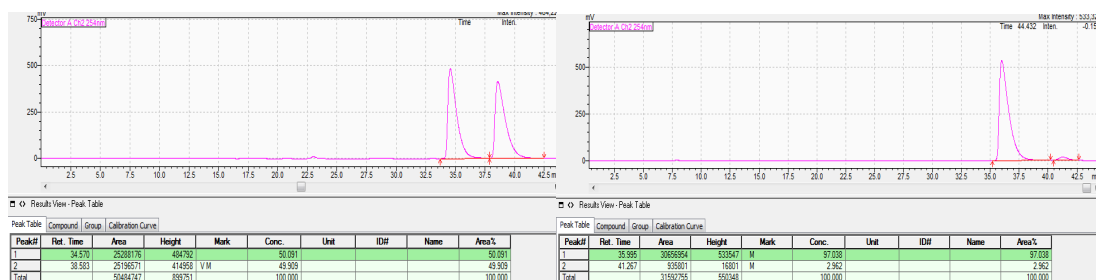


Methyl (*S*)-5-(quinolin-2-yl)hepta-5,6-dienoate 3f (colorless oil, 47.3 mg, 83% yield, 94% *ee*).

^1H NMR (400 MHz, CDCl_3) δ 8.04 (d, $J = 8.4$ Hz, 1H), 7.97 (d, $J = 8.7$ Hz, 1H), 7.73 (dd, $J = 8.0, 1.4$ Hz, 1H), 7.65 (ddd, $J = 8.4, 6.9, 1.5$ Hz, 1H), 7.61 (d, $J = 8.7$ Hz, 1H), 7.46 (ddd, $J = 8.1, 6.9, 1.2$ Hz, 1H), 5.72–5.61 (m, 1H), 3.70 (s, 3H), 3.19 – 3.00 (m, 2H), 2.72 – 2.64 (m, 2H), 1.82 (d, $J = 7.1$ Hz, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 207.5, 173.9, 155.8, 148.0, 135.2, 129.5, 129.1, 127.3, 126.7, 125.9, 120.3, 107.0, 91.4, 51.5, 32.9, 24.1, 14.1. GC-MS (EI): calculated for $\text{C}_{17}\text{H}_{17}\text{NO}_2$: 267.1, found: 267.2.

Optical rotation: $[\alpha]_{\text{D}}^{20} = +47.3$ ($c = 1$, CH_2Cl_2).

HPLC condition: Chiral column IB, n -hexane/ i -PrOH = 99.9: 0.1, flow rate = 0.7 mL/min, wavelength = 254 nm, $t_{\text{R}} = 36.0$ min for the major enantiomer, $t_{\text{R}} = 41.3$ min for the minor enantiomer.

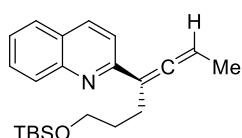
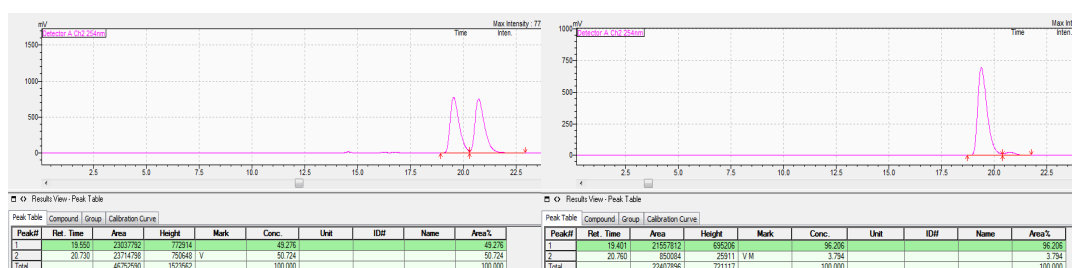


(S)-2-(7-(benzyloxy)hepta-2,3-dien-4-yl)quinoline 3g (colorless oil, 50.2 mg, 76% yield, 92% *ee*).

^1H NMR (400 MHz, CDCl_3) δ 8.05 (d, J = 8.4 Hz, 1H), 7.98 (d, J = 8.7 Hz, 1H), 7.74 (dd, J = 8.0, 1.4 Hz, 1H), 7.69 – 7.62 (m, 2H), 7.47 (ddd, J = 8.1, 6.9, 1.2 Hz, 1H), 7.41 – 7.32 (m, 4H), 7.31 – 7.26 (m, 1H), 5.69 – 5.56 (m, 1H), 4.56 (s, 2H), 3.64 (t, J = 6.7 Hz, 2H), 2.96 – 2.74 (m, 2H), 2.04 – 1.94 (m, 2H), 1.83 (d, J = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 208.0, 156.4, 148.0, 138.8, 135.2, 129.4, 129.1, 128.3, 127.7, 127.5, 127.3, 126.7, 125.8, 120.5, 107.7, 90.5, 72.9, 70.3, 28.4, 25.2, 14.2. GC-MS (EI): calculated for $\text{C}_{23}\text{H}_{23}\text{NO}$: 329.2, found: 329.2.

Optical rotation: $[\alpha]_D^{20}$ = +49.2 (c = 1, CH_2Cl_2).

HPLC condition: Chiral column IE, n -hexane/ i -PrOH = 99.3: 0.7, flow rate = 0.5 mL/min, wavelength = 254 nm, t_R = 19.4 min for the major enantiomer, t_R = 20.8 min for the minor enantiomer.

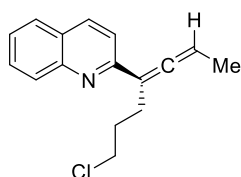
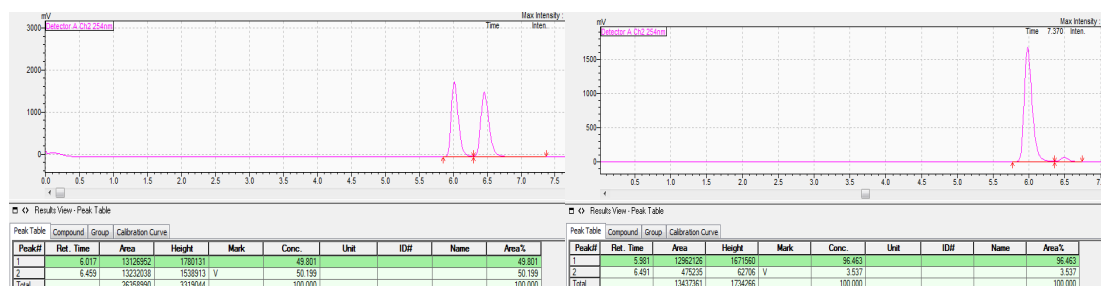


(S)-2-(7-((tert-butyldimethylsilyl)oxy)hepta-2,3-dien-4-yl)quinoline 3h (colorless oil, 63.1 mg, 89% yield, 93% *ee*). ^1H NMR (400 MHz, CDCl_3) δ 8.05 (d, J = 7.8 Hz, 1H), 7.97 (d, J = 8.6 Hz, 1H), 7.73 (dd, J = 8.0, 1.4 Hz, 1H), 7.69 – 7.61 (m, 2H), 7.46 (ddd, J = 8.1, 6.9, 1.2 Hz, 1H), 5.71

– 5.57 (m, 1H), 3.77 (t, $J = 6.8$ Hz, 2H), 2.90 – 2.70 (m, 2H), 1.92 – 1.82 (m, 5H), 0.92 (s, 9H), 0.08 (s, 6H). ^{13}C NMR (100 MHz, CDCl_3) δ 208.0, 156.5, 148.0, 135.1, 129.4, 129.0, 127.3, 126.6, 125.8, 120.5, 107.8, 90.3, 63.2, 31.5, 26.1, 24.9, 18.4, 14.2, -5.2. GC-MS (EI): calculated for $\text{C}_{22}\text{H}_{31}\text{NOSi}$: 353.2, found: 353.2.

Optical rotation: $[\alpha]_{\text{D}}^{20} = +44.8$ ($c=1$, CH_2Cl_2).

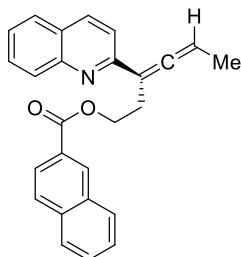
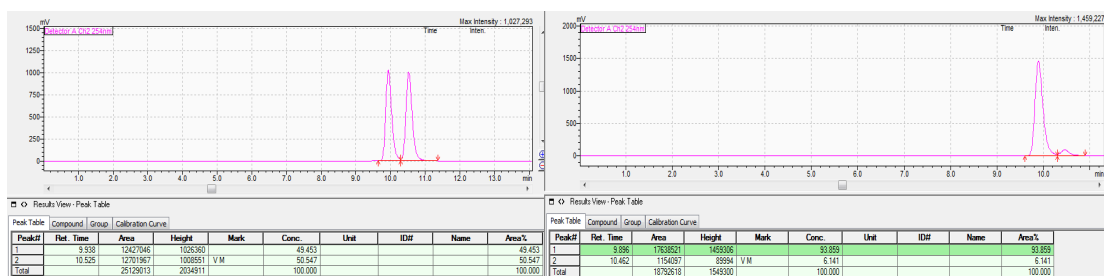
HPLC condition: Chiral column IB, n -hexane/ i -PrOH = 99.5: 0.5, flow rate = 0.7 mL/min, wavelength = 254 nm, $t_{\text{R}} = 6.0$ min for the major enantiomer, $t_{\text{R}} = 6.5$ min for the minor enantiomer.



(S)-2-(7-chlorohepta-2,3-dien-4-yl)quinoline 3i (yellow oil, 43.2 mg, 84% yield, 88% *ee*). ^1H NMR (400 MHz, CDCl_3) δ 8.05 (d, $J = 8.5$ Hz, 1H), 7.98 (dd, $J = 8.7$, 0.9 Hz, 1H), 7.74 (dd, $J = 8.0$, 1.4 Hz, 1H), 7.69 – 7.60 (m, 2H), 7.47 (ddd, $J = 8.1$, 6.9, 1.2 Hz, 1H), 5.80 – 5.52 (m, 1H), 3.68 (t, $J = 6.8$ Hz, 2H), 3.02 – 2.77 (m, 2H), 2.21–2.09 (m, 2H), 1.86 (d, $J = 7.1$ Hz, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 207.9, 156.0, 147.9, 135.3, 129.4, 129.2, 127.4, 126.7, 125.9, 120.4, 106.7, 90.7, 44.9, 31.4, 26.2, 14.1. HR-MS (APCI $^+$): m/z calculated for $\text{C}_{16}\text{H}_{17}\text{NCl}$ ($\text{M}+\text{H}^+$): 258.1044, found: 258.1050.

Optical rotation: $[\alpha]_{\text{D}}^{20} = +42.2$ ($c=1$, CH_2Cl_2).

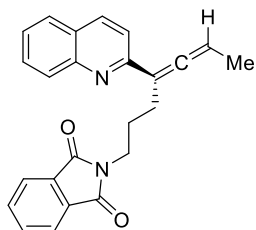
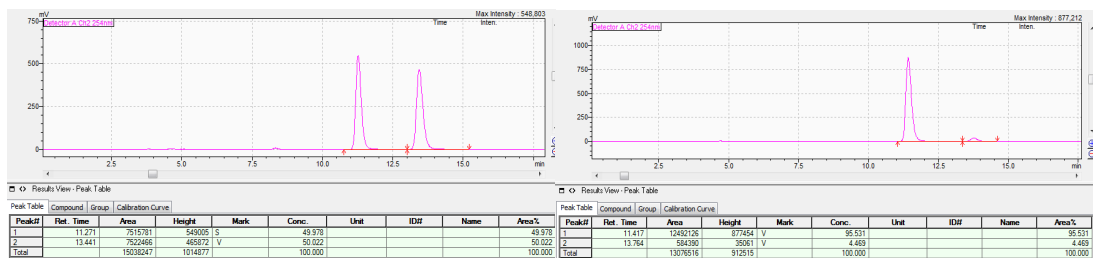
HPLC condition: Chiral column IB, n -hexane/ i -PrOH = 99: 1, flow rate = 0.5 mL/min, wavelength = 254 nm, $t_{\text{R}} = 10.0$ min for the major enantiomer, $t_{\text{R}} = 10.7$ min for the minor enantiomer.



(S)-3-(quinolin-2-yl)hexa-3,4-dien-1-yl-2-naphthoate 3j (yellow oil, 60.6 mg, 80% yield, 91% *ee*). ^1H NMR (400 MHz, CDCl_3) δ 8.62 – 8.54 (m, 1H), 8.11 – 8.05 (m, 2H), 8.00 (dd, $J = 8.7, 0.8$ Hz, 1H), 7.93 – 7.81 (m, 3H), 7.75 (dd, $J = 8.0, 1.4$ Hz, 1H), 7.72 – 7.64 (m, 2H), 7.63 – 7.42 (m, 3H), 5.78 – 5.60 (m, 1H), 4.73 (t, $J = 6.6$ Hz, 2H), 3.43 – 3.22 (m, 2H), 1.81 (d, $J = 7.1$ Hz, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 208.3, 166.8, 155.7, 148.0, 135.5, 135.4, 132.5, 131.0, 129.5, 129.3, 129.2, 128.1, 128.0, 127.8, 127.7, 127.4, 126.7, 126.5, 126.0, 125.4, 120.3, 104.3, 90.9, 64.2, 28.4, 14.1. HR-MS (APCI $^+$): m/z calculated for $\text{C}_{26}\text{H}_{22}\text{NO}_2$ ($\text{M}+\text{H}^+$): 380.1645, found: 380.1649.

Optical rotation: $[\alpha]_{\text{D}}^{20} = +16.4$ ($c = 1$, CH_2Cl_2).

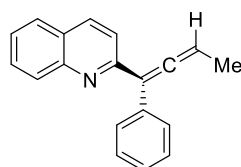
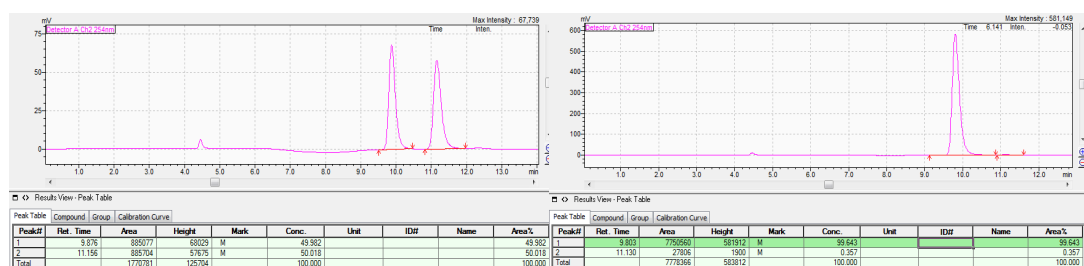
HPLC condition: Chiral column IB, *n*-hexane/*i*-PrOH = 97: 3, flow rate = 0.9 mL/min, wavelength = 254 nm, $t_{\text{R}} = 11.4$ min for the major enantiomer, $t_{\text{R}} = 13.8$ min for the minor enantiomer.



(S)-2-(4-(quinolin-2-yl)hepta-4,5-dien-1-yl)isoindoline-1,3-dione 3k (white solid, 44.9 mg, 61% yield, 99% *ee*). ¹H NMR (400 MHz, CDCl₃) δ 8.01 – 7.96 (m, 2H), 7.88 – 7.82 (m, 2H), 7.77 – 7.70 (m, 3H), 7.68 – 7.62 (m, 2H), 7.47 (ddd, *J* = 8.0, 6.9, 1.2 Hz, 1H), 5.78 – 5.66 (m, 1H), 3.93 – 3.81 (m, 2H), 2.95 – 2.75 (m, 2H), 2.11 – 1.99 (m, 2H), 1.88 (d, *J* = 7.1 Hz, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 207.8, 168.4, 156.1, 135.2, 133.8, 132.3, 129.4, 129.0, 127.3, 126.6, 125.8, 123.1, 120.4, 107.1, 91.0, 38.0, 27.2, 25.8, 14.2. HR-MS (APCI⁺): *m/z* calculated for C₂₄H₂₁N₂O₂ (M+H⁺): 369.1598, found: 369.1598.

Optical rotation: [α]_D²⁰ = +14.5 (c = 1, CH₂Cl₂). The absolute configuration was assigned by X-ray crystallography.

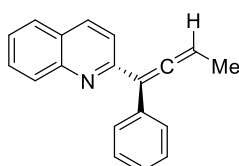
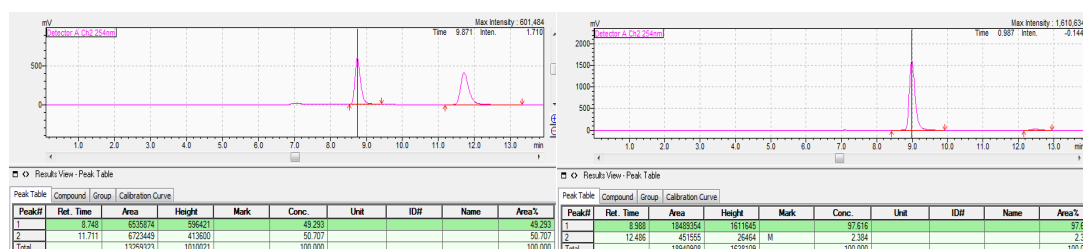
HPLC condition: Chiral column IB, *n*-hexane/*i*-PrOH = 95: 5, flow rate = 0.9 mL/min, wavelength = 254 nm, *t*_R = 9.8 min for the major enantiomer, *t*_R = 11.1 min for the minor enantiomer.



(S)-2-(1-phenylbuta-1,2-dien-1-yl)quinoline 3a (yellow oil, 46.3 mg, 90% yield, 95% *ee*). ¹H NMR (400 MHz, CDCl₃) δ 8.13-8.07 (m, 2H), 7.80 (dd, *J* = 8.1, 1.4 Hz, 1H), 7.68 (ddd, *J* = 8.4, 6.9, 1.5 Hz, 1H), 7.61 (d, *J* = 8.5 Hz, 1H), 7.58 – 7.54 (m, 2H), 7.51 (ddd, *J* = 8.1, 6.9, 1.2 Hz, 1H), 7.41 – 7.36 (m, 2H), 7.34 – 7.28 (m, 1H), 5.89 (q, *J* = 7.2 Hz, 1H), 1.94 (d, *J* = 7.2 Hz, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 209.4, 156.3, 148.0, 136.1, 135.8, 129.7, 129.3, 128.9, 128.2, 127.3, 127.2, 126.9, 126.2, 122.0, 110.4, 90.5, 14.0. ¹³C NMR (DEPT135, 100 MHz, CDCl₃) δ 136.1, 129.7, 129.3, 128.9, 128.2, 127.3, 127.2, 126.2, 122.0, 90.5, 14.0. HR-MS (APCI⁺): *m/z* calculated for C₁₉H₁₆N (M+H⁺): 258.1277, found: 258.1273.

Optical rotation: [α]_D²⁰ = +37.1 (c = 1, CH₂Cl₂).

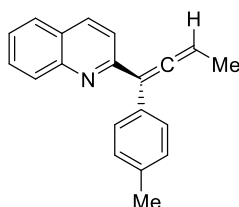
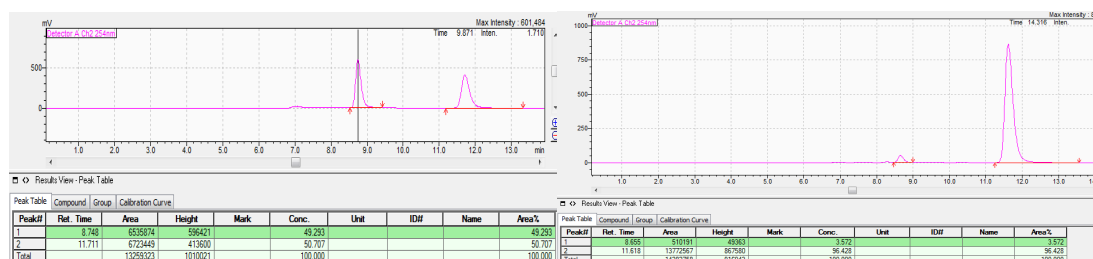
HPLC condition: Chiral column IB, *n*-hexane/*i*-PrOH = 97: 3, flow rate = 0.6 mL/min, wavelength = 254 nm, t_R = 9.0 min for the major enantiomer, t_R = 12.5 min for the minor enantiomer.



(*R*)-2-(1-phenylbuta-1,2-dien-1-yl)quinoline 3a' (yellow oil, 48.4 mg, 94% yield, 93% *ee* with (*R,R*)-Ph-BPE ligand).

Optical rotation: $[\alpha]_D^{20}$ = -35.6 (*c* = 1, CH₂Cl₂).

HPLC condition: Chiral column IB, *n*-hexane/*i*-PrOH = 97: 3, flow rate = 0.6 mL/min, wavelength = 254 nm, t_R = 8.7 min for the minor enantiomer, t_R = 11.6 min for the major enantiomer.

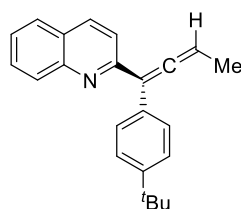
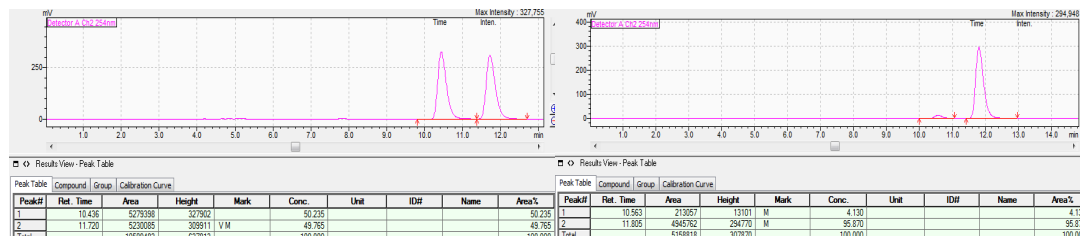


(*S*)-2-(1-(p-tolyl)buta-1,2-dien-1-yl)quinoline 3l (yellow oil, 45.0 mg, 83% yield, 92% *ee*). ¹H NMR (400 MHz, C₆D₆) δ 7.98 – 7.90 (m, 1H), 7.46 – 7.41 (m, 2H), 7.38 (dd, *J* = 8.6, 0.8 Hz, 1H), 7.31 (d, *J* = 8.6 Hz, 1H), 7.16 (dd, *J* = 8.2, 1.4 Hz, 1H), 7.05 (ddd, *J* = 8.5, 6.9, 1.5 Hz, 1H), 6.92 – 6.84 (m, 3H), 5.26 (q, *J* = 7.1 Hz, 1H), 1.91 (s, 3H), 1.32 (d, *J* = 7.1 Hz, 3H). ¹³C NMR (100 MHz, C₆D₆) δ 209.6, 156.4, 148.4, 136.5, 135.5, 133.5, 129.9, 129.3, 129.1, 128.8, 127.2, 126.8, 125.9,

121.6, 111.0, 89.8, 20.9, 13.6. HR-MS (APCI⁺): m/z calculated for C₂₀H₁₈N (M+H⁺): 272.1434, found: 272.1434.

Optical rotation: $[\alpha]_D^{20} = +32.0$ ($c=1$, CH₂Cl₂).

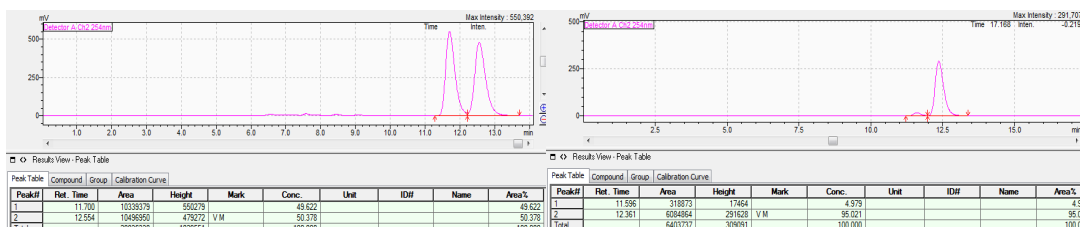
HPLC condition: Chiral column IE, *n*-hexane/*i*-PrOH = 97: 3, flow rate = 0.9 mL/min, wavelength = 254 nm, t_R = 10.6 min for the minor enantiomer, t_R = 11.8 min for the major enantiomer.

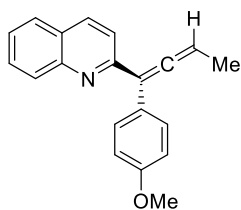


(S)-2-(1-(4-(tert-butyl)phenyl)buta-1,2-dien-1-yl)quinoline 3m (yellow oil, 55.7 mg, 89% yield, 90% *ee*). ¹H NMR (400 MHz, C₆D₆) δ 8.23-8.14 (m, 1H), 7.79 – 7.71 (m, 2H), 7.64 (dd, J = 8.7, 0.9 Hz, 1H), 7.58 (d, J = 8.6 Hz, 1H), 7.42 – 7.35 (m, 3H), 7.28 (ddd, J = 8.4, 6.9, 1.5 Hz, 1H), 7.16 – 7.11 (m, 1H), 5.53 (q, J = 7.1 Hz, 1H), 1.59 (d, J = 7.2 Hz, 3H), 1.25 (s, 9H). ¹³C NMR (100 MHz, C₆D₆) δ 209.8, 156.4, 149.7, 148.5, 135.5, 133.4, 129.9, 129.2, 129.1, 127.2, 126.8, 125.9, 125.0, 121.6, 111.0, 89.8, 34.2, 31.1, 13.6. HR-MS (APCI⁺): m/z calculated for C₂₃H₂₄N (M+H⁺): 314.1903, found: 314.1900.

Optical rotation: $[\alpha]_D^{20} = +18.1$ ($c=1$, CH₂Cl₂).

HPLC condition: Chiral column IE, *n*-hexane/*i*-PrOH = 97: 3, flow rate = 0.6 mL/min, wavelength = 254 nm, t_R = 11.6 min for the minor enantiomer, t_R = 12.4 min for the major enantiomer.

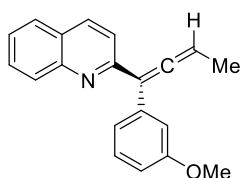
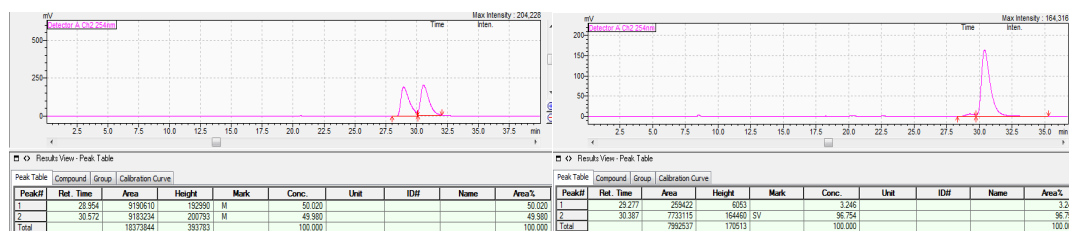




(S)-2-(1-(4-methoxyphenyl)buta-1,2-dien-1-yl)quinoline 3n (yellow oil, 42.5 mg, 74% yield, 94% *ee*). ^1H NMR (400 MHz, Acetone- d_6) δ 8.15 (dd, J = 8.7, 0.8 Hz, 1H), 7.87 – 7.78 (m, 2H), 7.64 – 7.55 (m, 2H), 7.47 – 7.36 (m, 3H), 6.87–6.80 (m, 2H), 5.78 (q, J = 7.1 Hz, 1H), 3.71 (s, 3H), 1.79 (d, J = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, Acetone- d_6) δ 209.2, 159.0, 156.2, 147.9, 136.0, 130.2, 129.3, 129.2, 128.0, 127.6, 126.8, 126.2, 121.7, 113.4, 109.9, 90.0, 54.7, 13.3. HR-MS (APCI $^+$): m/z calculated for $\text{C}_{20}\text{H}_{18}\text{NO}$ ($\text{M}+\text{H}^+$): 288.1383, found: 288.1383.

Optical rotation: $[\alpha]_{\text{D}}^{20}$ = +21.3 (c = 1, CH_2Cl_2).

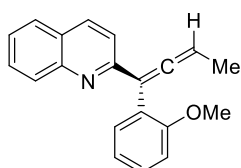
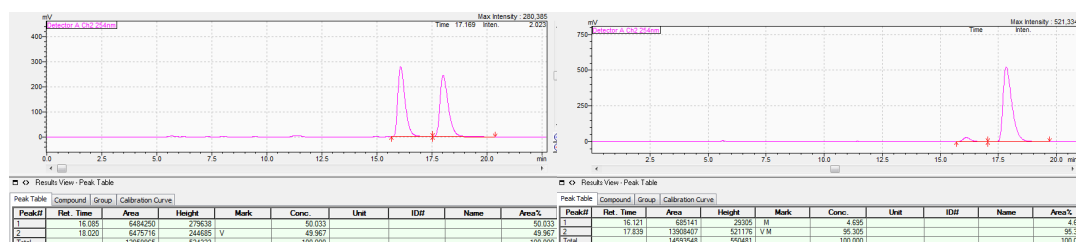
HPLC condition: Chiral column IE, *n*-hexane/*i*-PrOH = 97: 3, flow rate = 0.9 mL/min, wavelength = 254 nm, t_{R} = 29.3 min for the minor enantiomer, t_{R} = 30.4 min for the major enantiomer.



(S)-2-(1-(3-methoxyphenyl)buta-1,2-dien-1-yl)quinoline 3o (yellow oil, 94% yield, 91% *ee*). ^1H NMR (400 MHz, CDCl_3) δ 7.98 – 7.89 (m, 2H), 7.63 (dd, J = 8.1, 1.5 Hz, 1H), 7.52 (ddd, J = 8.4, 6.9, 1.5 Hz, 1H), 7.43 (d, J = 8.6 Hz, 1H), 7.35 (ddd, J = 8.1, 6.9, 1.2 Hz, 1H), 7.17 – 7.09 (m, 1H), 7.00 – 6.92 (m, 2H), 6.70 (ddd, J = 8.2, 2.6, 1.0 Hz, 1H), 5.71 (q, J = 7.2 Hz, 1H), 3.65 (s, 3H), 1.77 (d, J = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 209.3, 159.5, 156.2, 148.0, 137.3, 136.1, 129.7, 129.3, 129.1, 127.3, 126.9, 126.3, 122.0, 121.5, 114.6, 112.8, 110.2, 90.5, 55.3, 14.0. HR-MS (APCI $^+$): m/z calculated for $\text{C}_{20}\text{H}_{18}\text{NO}$ ($\text{M}+\text{H}^+$): 288.1383, found: 288.1381.

Optical rotation: $[\alpha]_{\text{D}}^{20}$ = +25.3 (c = 1, CH_2Cl_2).

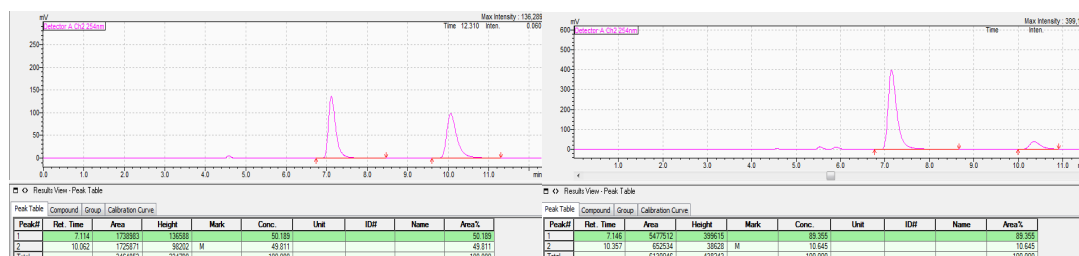
HPLC condition: Chiral column IE, *n*-hexane/*i*-PrOH = 97: 3, flow rate = 0.9 mL/min, wavelength = 254 nm, t_R = 16.1 min for the minor enantiomer, t_R = 17.8 min for the major enantiomer.

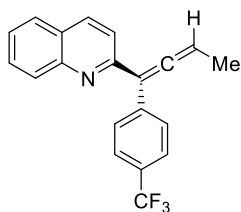


(*S*)-2-(1-(2-methoxyphenyl)buta-1,2-dien-1-yl)quinoline **3p** (yellow oil, 41.9 mg, 73% yield, 80% *ee*). ^1H NMR (400 MHz, CDCl_3) δ 8.05 (d, J = 8.6 Hz, 1H), 8.01 (d, J = 8.5 Hz, 1H), 7.77 (dd, J = 8.2, 1.5 Hz, 1H), 7.64 (ddd, J = 8.4, 6.9, 1.5 Hz, 1H), 7.53 (d, J = 8.6 Hz, 1H), 7.48 (ddd, J = 8.1, 6.9, 1.2 Hz, 1H), 7.42 (dd, J = 7.4, 1.7 Hz, 1H), 7.38 (ddd, J = 8.2, 7.5, 1.8 Hz, 1H), 7.06 (td, J = 7.5, 1.1 Hz, 1H), 6.99 (dd, J = 8.2, 1.1 Hz, 1H), 5.80 (q, J = 7.2 Hz, 1H), 3.65 (s, 3H), 1.94 (d, J = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 209.4, 157.5, 156.8, 148.1, 135.5, 131.6, 129.7, 128.9, 127.2, 126.7, 125.9, 125.7, 120.7, 120.6, 111.7, 107.4, 89.1, 55.8, 14.0. HR-MS (APCI $^+$): m/z calculated for $\text{C}_{20}\text{H}_{18}\text{NO}$ ($\text{M}+\text{H}^+$): 288.1383, found: 288.1386.

Optical rotation: $[\alpha]_D^{20}$ = +36.2 (c = 1, CH_2Cl_2).

HPLC condition: Chiral column IB, *n*-hexane/*i*-PrOH = 97: 3, flow rate = 0.9 mL/min, wavelength = 254 nm, t_R = 7.1 min for the major enantiomer, t_R = 10.4 min for the minor enantiomer.

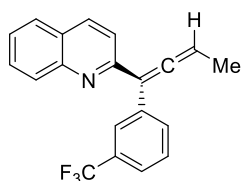
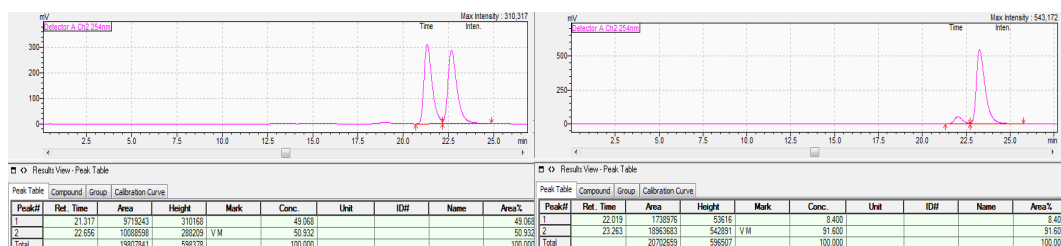




(S)-2-(1-(4-(trifluoromethyl)phenyl)buta-1,2-dien-1-yl)quinoline 3q (yellow oil, 89% yield, 83% *ee*). ^1H NMR (300 MHz, C_6D_6) δ 8.10 (dd, $J = 8.5, 0.8$ Hz, 1H), 7.64 (dd, $J = 8.6, 0.8$ Hz, 1H), 7.61-7.56 (m, 2H), 7.52 – 7.36 (m, 4H), 7.29 (ddd, $J = 8.4, 6.9, 1.5$ Hz, 1H), 7.20 – 7.09 (m, 1H), 5.44 (q, $J = 7.2$ Hz, 1H), 1.50 (d, $J = 7.2$ Hz, 3H). ^{13}C NMR (75 MHz, C_6D_6) δ 209.8, 155.0, 148.1, 140.0, 135.6, 135.61, 129.7, 129.6, 129.2, 127.0, 126.6 (q, $J = 278.9$ Hz), 126.1, 124.7 (q, $J = 3.8$ Hz), 121.1, 110.0, 90.6, 13.1. ^{19}F NMR (377 MHz, CDCl_3) δ -62.4 (s). HR-MS (APCI $^+$): m/z calculated for $\text{C}_{20}\text{H}_{15}\text{NF}_3$ ($\text{M}+\text{H}^+$): 326.1151, found: 326.1158.

Optical rotation: $[\alpha]_{\text{D}}^{20} = +26.2$ ($c = 1$, CH_2Cl_2).

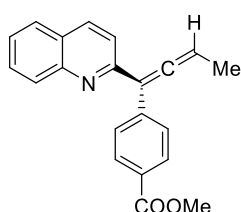
HPLC condition: Chiral column IE, *n*-hexane/*i*-PrOH = 99: 1, flow rate = 0.3 mL/min, wavelength = 254 nm, $t_{\text{R}} = 22.0$ min for the minor enantiomer, $t_{\text{R}} = 23.3$ min for the major enantiomer.



(S)-2-(1-(3-(trifluoromethyl)phenyl)buta-1,2-dien-1-yl)quinoline 3r (yellow oil, 58.5 mg, 90% yield, 80% *ee*). ^1H NMR (400 MHz, CDCl_3) δ 8.03 (dd, $J = 8.5, 0.8$ Hz, 1H), 7.94 (dq, $J = 8.5, 0.9$ Hz, 1H), 7.82-7.78 (m, 1H), 7.70 (dd, $J = 8.0, 1.4$ Hz, 1H), 7.68 – 7.63 (m, 1H), 7.58 (ddd, $J = 8.4, 6.9, 1.5$ Hz, 1H), 7.54 (d, $J = 8.6$ Hz, 1H), 7.47 – 7.35 (m, 3H), 5.84 (q, $J = 7.2$ Hz, 1H), 1.86 (d, $J = 7.3$ Hz, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 209.8, 155.3, 147.8, 136.6, 136.3, 132.4 (q, $J = 1.5$ Hz), 130.4 (q, $J = 31.9$ Hz), 129.6, 129.5, 128.4, 127.4, 126.9, 126.5, 126.0 (q, $J = 4.0$ Hz), 124.3 (q, $J = 270.6$ Hz), 123.8 (q, $J = 3.8$ Hz), 121.7, 109.5, 91.5, 13.9. ^{19}F NMR (377 MHz, CDCl_3) δ -62.5 (s). HR-MS (APCI $^+$): m/z calculated for $\text{C}_{20}\text{H}_{15}\text{NF}_3$ ($\text{M}+\text{H}^+$): 326.1151, found: 326.1154.

Optical rotation: $[\alpha]_D^{20} = +26.5$ ($c=1$, CHCl_3).

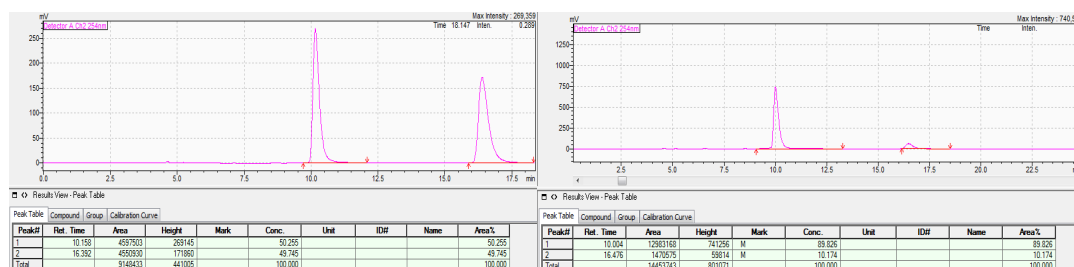
HPLC condition: Chiral column IB, n -hexane/ i -PrOH = 97: 3, flow rate = 0.6 mL/min, wavelength = 254 nm, t_R = 7.7 min for the major enantiomer, t_R = 9.5 min for the minor enantiomer.

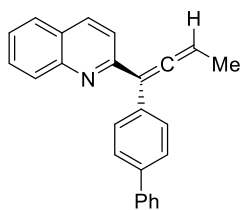


Methyl (*S*)-4-(1-(quinolin-2-yl)buta-1,2-dien-1-yl)benzoate 3s (yellow oil, 50.0 mg, 79% yield, 80% *ee*). ^1H NMR (400 MHz, CDCl_3) δ 8.13 (d, J = 8.6 Hz, 1H), 8.07 – 8.01 (m, 3H), 7.80 (dd, J = 8.0, 1.4 Hz, 1H), 7.68 (ddd, J = 8.4, 6.9, 1.5 Hz, 1H), 7.64 – 7.58 (m, 3H), 7.52 (ddd, J = 8.1, 6.9, 1.2 Hz, 1H), 5.92 (q, J = 7.2 Hz, 1H), 3.93 (s, 3H), 1.94 (d, J = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 209.9, 167.1, 155.6, 147.86, 140.8, 136.3, 129.6, 129.5, 129.4, 128.8, 128.6, 127.4, 126.9, 126.4, 121.9, 109.9, 91.2, 52.0, 13.8. GC-MS (EI): calculated for $\text{C}_{21}\text{H}_{17}\text{NO}_2$: 315.1, found: 315.2.

Optical rotation: $[\alpha]_D^{20} = +11.7$ ($c=1$, CH_2Cl_2).

HPLC condition: Chiral column IB, n -hexane/ i -PrOH = 97: 3, flow rate = 0.9 mL/min, wavelength = 254 nm, t_R = 10.0 min for the major enantiomer, t_R = 16.5 min for the minor enantiomer.

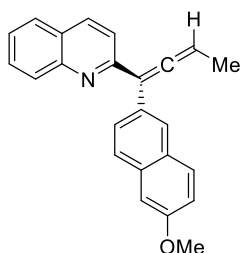
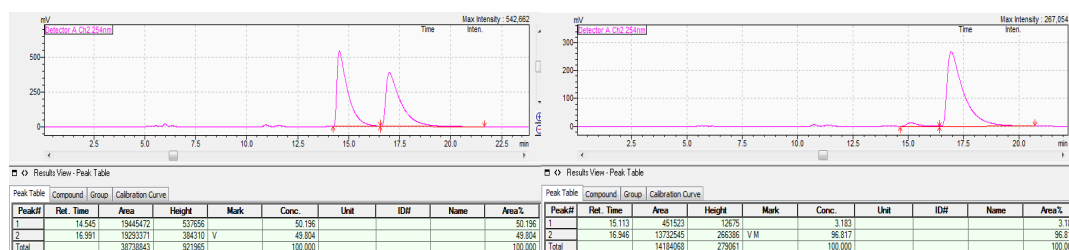




(S)-2-(1-([1,1'-biphenyl]-4-yl)buta-1,2-dien-1-yl)quinoline 3t (yellow oil, 59.4 mg, 91% yield, 94% *ee*). ¹H NMR (400 MHz, C₆D₆) δ 7.96 (dd, *J* = 8.5, 1.1 Hz, 1H), 7.60 – 7.52 (m, 2H), 7.41 (dd, *J* = 8.6, 0.8 Hz, 1H), 7.35 – 7.31 (m, 3H), 7.29 – 7.25 (m, 2H), 7.17 (dd, *J* = 8.0, 1.4 Hz, 1H), 7.06 (ddd, *J* = 8.4, 6.9, 1.5 Hz, 1H), 7.00 – 6.95 (m, 2H), 6.93 – 6.86 (m, 2H), 5.29 (q, *J* = 7.1 Hz, 1H), 1.33 (d, *J* = 7.2 Hz, 3H). ¹³C NMR (100 MHz, C₆D₆) δ 209.8, 156.2, 148.4, 141.2, 140.1, 135.6, 135.4, 129.9, 129.9, 129.2, 128.7, 127.2, 127.1, 127.0, 126.9, 126.8, 126.0, 121.6, 110.8, 90.2, 13.6. HR-MS (APCI⁺): *m/z* calculated for C₂₅H₂₀N (M+H⁺): 334.1590, found: 334.1588.

Optical rotation: $[\alpha]_D^{20}$ = +11.8 (*c* = 1, CH₂Cl₂).

HPLC condition: Chiral column IE, *n*-hexane/*i*-PrOH = 97: 3, flow rate = 0.9 mL/min, wavelength = 254 nm, *t*_R = 15.1 min for the minor enantiomer, *t*_R = 16.9 min for the major enantiomer.

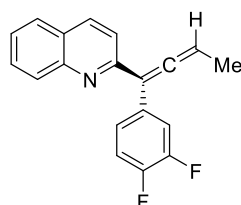
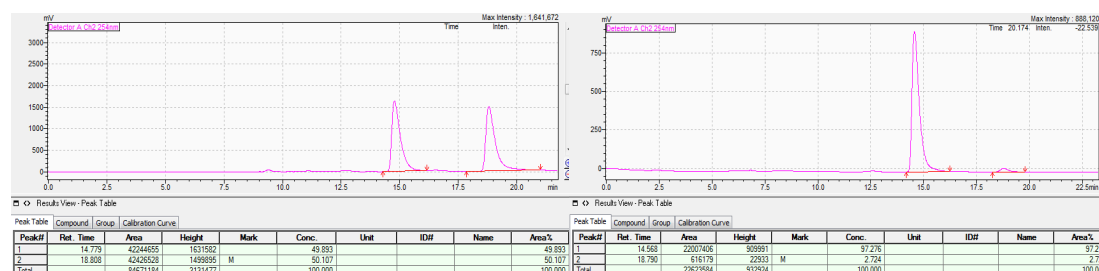


(S)-2-(1-(6-methoxynaphthalen-2-yl)buta-1,2-dien-1-yl)quinoline 3u (yellow oil, 53.2 mg, 79% yield, 95% *ee*). ¹H NMR (400 MHz, CDCl₃) δ 8.14 (dd, *J* = 8.5, 0.9 Hz, 1H), 8.11 – 8.08 (m, 1H), 7.90 (d, *J* = 1.7 Hz, 1H), 7.82 (dd, *J* = 8.0, 1.5 Hz, 1H), 7.7 (d, *J* = 8.5 Hz, 1H), 7.72 – 7.62 (m, 4H), 7.53 (ddd, *J* = 8.1, 6.9, 1.2 Hz, 1H), 7.17 – 7.11 (m, 2H), 5.92 (q, *J* = 7.2 Hz, 1H), 3.93 (s, 3H), 1.97 (d, *J* = 7.1 Hz, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 209.4, 157.7, 156.5, 148.0, 136.1, 133.9, 131.0, 129.7, 129.7, 129.3, 129.0, 127.7, 127.4, 127.4, 126.9, 126.5, 126.3, 122.2, 118.6,

110.4, 105.7, 90.6, 55.3, 14.2. HR-MS (APCI⁺): m/z calculated for C₂₄H₂₀NO (M+H⁺): 338.1539, found: 338.1544.

Optical rotation: $[\alpha]_D^{20} = +147.1$ ($c=1$, CHCl₃).

HPLC condition: Chiral column IB, *n*-hexane/*i*-PrOH = 97: 3, flow rate = 0.6 mL/min, wavelength = 254 nm, t_R = 25.0 min for the major enantiomer, t_R = 26.5 min for the minor enantiomer.

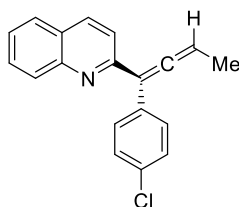
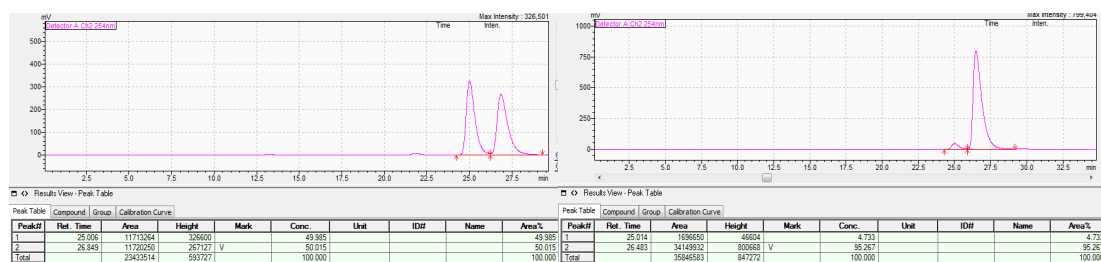


(S)-2-(1-(3,4-difluorophenyl)buta-1,2-dien-1-yl)quinoline 3v (yellow oil, 93% yield, 92% *ee*).

¹H NMR (400 MHz, CDCl₃) δ 7.97 (dd, J = 8.7, 0.9 Hz, 1H), 7.91 (dq, J = 8.6, 0.9 Hz, 1H), 7.65 (dd, J = 8.0, 1.3 Hz, 1H), 7.54 (ddd, J = 8.4, 6.9, 1.5 Hz, 1H), 7.46 (d, J = 8.6 Hz, 1H), 7.37 (ddd, J = 8.1, 6.9, 1.2 Hz, 1H), 7.31 (ddd, J = 12.0, 7.8, 2.2 Hz, 1H), 7.15 (dddd, J = 6.7, 5.9, 2.3, 1.5 Hz, 1H), 6.99 (dt, J = 10.2, 8.4 Hz, 1H), 5.76 (q, J = 7.2 Hz, 1H), 1.79 (d, J = 7.3 Hz, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 209.4 (d, J = 1.5 Hz), 155.3, 151.0 (dd, J = 46.6, 12.6 Hz), 148.6 (dd, J = 48.3, 12.7 Hz), 147.8, 136.3, 132.6 (dd, J = 6.0, 4.0 Hz), 129.58, 129.50, 127.4, 126.8, 126.5, 125.0 (dd, J = 6.0, 3.4 Hz), 121.8, 118.0 (d, J = 18.3 Hz), 116.7 (d, J = 17.2 Hz), 108.9, 91.4, 13.88. ¹⁹F NMR (377 MHz, CDCl₃) δ -138.6 (d, J = 21.4 Hz), -140.1 (d, J = 21.3 Hz). HR-MS (APCI⁺): m/z calculated for C₁₉H₁₄NF₂ (M+H⁺): 294.1089, found: 294.1088.

Optical rotation: $[\alpha]_D^{20} = +68.1$ ($c=1$, CHCl₃).

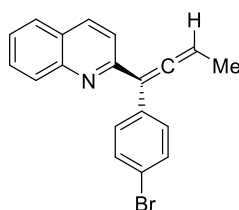
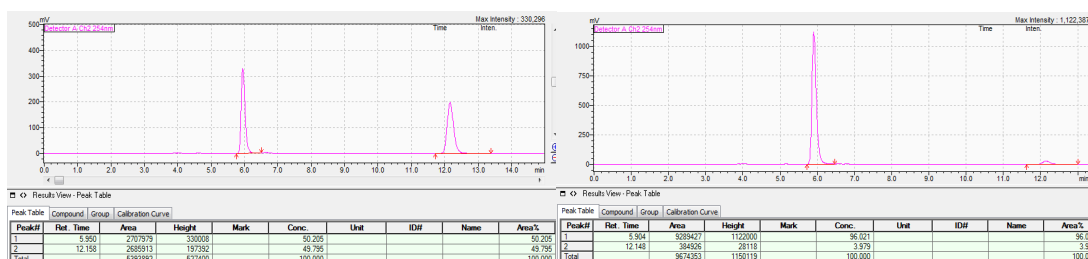
HPLC condition: Chiral column IE, *n*-hexane/*i*-PrOH = 99: 1, flow rate = 0.3 mL/min, wavelength = 254 nm, t_R = 25.0 min for the minor enantiomer, t_R = 26.5 min for the major enantiomer.



(S)-2-(1-(4-chlorophenyl)buta-1,2-dien-1-yl)quinoline 3w (yellow oil, 55.5 mg, 95% yield, 92% *ee*). ^1H NMR (400 MHz, CDCl_3) δ 8.11 (dd, $J = 8.5, 0.9$ Hz, 1H), 8.05 (dd, $J = 8.5, 1.1$ Hz, 1H), 7.80 (dd, $J = 8.1, 1.4$ Hz, 1H), 7.68 (ddd, $J = 8.4, 6.9, 1.5$ Hz, 1H), 7.61 (d, $J = 8.6$ Hz, 1H), 7.56 – 7.47 (m, 3H), 7.37 – 7.31 (m, 2H), 5.89 (q, $J = 7.2$ Hz, 1H), 1.93 (d, $J = 7.2$ Hz, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 209.4, 155.7, 147.9, 136.2, 134.3, 132.9, 130.3, 129.6, 129.4, 128.3, 127.4, 126.8, 126.4, 121.8, 109.5, 91.0, 13.9. HR-MS (APCI $^+$): m/z calculated for $\text{C}_{19}\text{H}_{15}\text{N Cl}$ ($\text{M}+\text{H}^+$): 292.0888, found: 292.0889.

Optical rotation: $[\alpha]_{\text{D}}^{20} = +31.9$ ($c = 1$, CH_2Cl_2).

HPLC condition: Chiral column IB, *n*-hexane/*i*-PrOH = 97: 3, flow rate = 0.9 mL/min, wavelength = 254 nm, $t_{\text{R}} = 5.9$ min for the major enantiomer, $t_{\text{R}} = 12.1$ min for the minor enantiomer.

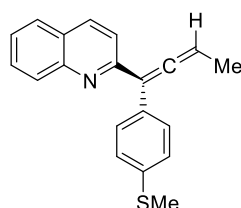
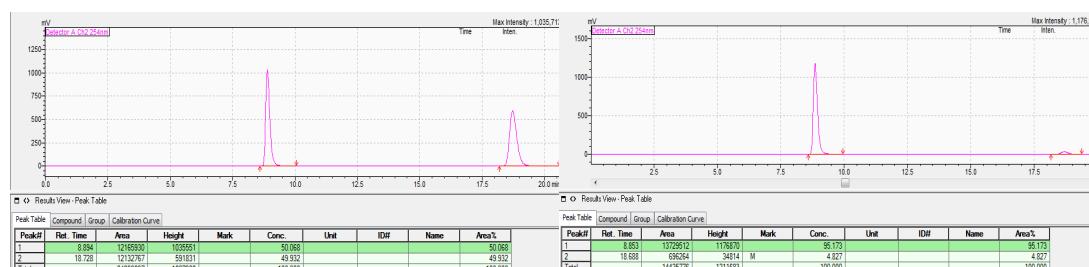


(S)-2-(1-(4-bromophenyl)buta-1,2-dien-1-yl)quinoline 3x (yellow oil, 57.1 mg, 85% yield, 90% *ee*). ^1H NMR (400 MHz, CDCl_3) δ 8.11 (dd, $J = 8.6, 0.8$ Hz, 1H), 8.05 (dq, $J = 8.5, 0.8$ Hz, 1H),

7.79 (dd, $J = 8.1, 1.3$ Hz, 1H), 7.68 (ddd, $J = 8.4, 6.9, 1.5$ Hz, 1H), 7.61 (d, $J = 8.6$ Hz, 1H), 7.55 – 7.40 (m, 5H), 5.88 (q, $J = 7.2$ Hz, 1H), 1.93 (d, $J = 7.2$ Hz, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 209.4, 155.6, 147.9, 136.2, 134.8, 131.2, 130.7, 129.6, 129.4, 127.4, 126.8, 126.4, 121.8, 121.1, 109.6, 91.0, 13.9. HR-MS (APCI $^+$): m/z calculated for $\text{C}_{19}\text{H}_{15}\text{N Br (M+H}^+)$: 336.0382, found: 336.0380.

Optical rotation: $[\alpha]_{\text{D}}^{20} = +14.3$ ($c = 1$, CH_2Cl_2).

HPLC condition: Chiral column IB, n -hexane/ i -PrOH = 97: 3, flow rate = 0.6 mL/min, wavelength = 254 nm, $t_{\text{R}} = 8.8$ min for the major enantiomer, $t_{\text{R}} = 18.7$ min for the minor enantiomer.

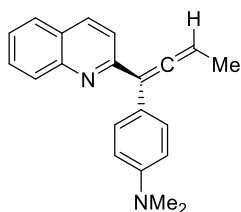
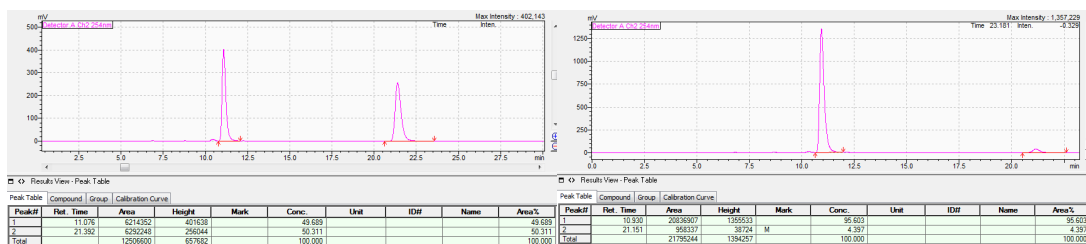


(S)-2-(1-(4-(methylthio)phenyl)buta-1,2-dien-1-yl)quinoline 3y (yellow oil, 75% yield, 91% *ee*).

^1H NMR (400 MHz, CDCl_3) δ 7.93 (dd, $J = 8.5, 0.8$ Hz, 1H), 7.90 (dq, $J = 8.5, 1.0$ Hz, 1H), 7.62 (dd, $J = 8.0, 1.4$ Hz, 1H), 7.50 (ddd, $J = 8.5, 6.9, 1.5$ Hz, 1H), 7.43 (d, $J = 8.5$ Hz, 1H), 7.36 – 7.29 (m, 3H), 7.13 – 7.08 (m, 2H), 5.70 (q, $J = 7.2$ Hz, 1H), 2.33 (s, 3H), 1.75 (d, $J = 7.1$ Hz, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 209.3, 156.1, 147.9, 137.2, 136.1, 132.7, 129.7, 129.4, 129.3, 127.4, 126.9, 126.5, 126.3, 122.0, 109.9, 90.7, 16.1, 14.0. HR-MS (APCI $^+$): m/z calculated for $\text{C}_{20}\text{H}_{18}\text{NS (M+H}^+)$: 304.1154, found: 304.1147.

Optical rotation: $[\alpha]_{\text{D}}^{20} = +42.3$ ($c = 1$, CHCl_3).

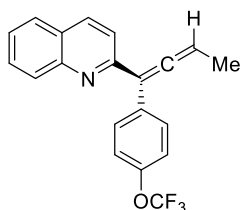
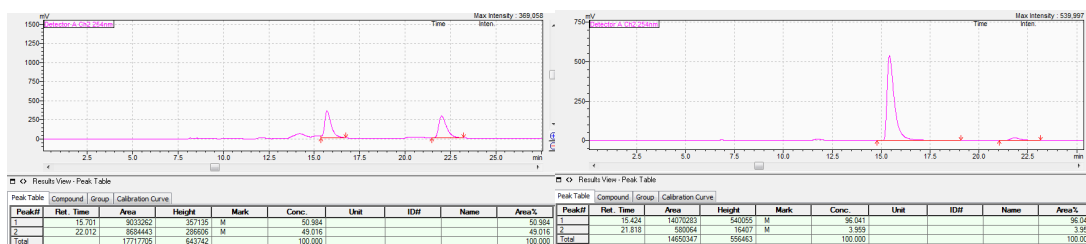
HPLC condition: Chiral column IB, n -hexane/ i -PrOH = 97: 3, flow rate = 0.6 mL/min, wavelength = 254 nm, $t_{\text{R}} = 10.9$ min for the major enantiomer, $t_{\text{R}} = 21.2$ min for the minor enantiomer.



(S)-N,N-dimethyl-4-(1-(quinolin-2-yl)buta-1,2-dien-1-yl)aniline 3z (yellow oil, 44.4 mg, 74% yield, 92% *ee*). ^1H NMR (400 MHz, CD_2Cl_2) δ 8.16 (d, $J = 8.7$ Hz, 1H), 8.08 – 8.00 (m, 1H), 7.86 (dd, $J = 8.1, 1.4$ Hz, 1H), 7.75 – 7.65 (m, 2H), 7.58 – 7.52 (m, 1H), 7.43 – 7.37 (m, 2H), 6.81–6.77 (m, 2H), 5.87 (q, $J = 7.1$ Hz, 1H), 3.02 (s, 6H), 1.96 (d, $J = 7.1$ Hz, 3H). ^{13}C NMR (100 MHz, CD_2Cl_2) δ 208.9, 156.9, 150.0, 147.9, 135.7, 129.7, 129.3, 129.2, 127.4, 126.8, 126.0, 123.5, 122.0, 112.1, 110.3, 89.9, 40.4, 14.0. HR-MS (APCI $^+$): m/z calculated for $\text{C}_{21}\text{H}_{21}\text{N}_2$ ($\text{M}+\text{H}^+$): 301.1699, found: 301.1696.

Optical rotation: $[\alpha]_{\text{D}}^{20} = +30.1$ ($c = 1$, CH_2Cl_2).

HPLC condition: Chiral column IB, *n*-hexane/*i*-PrOH = 97: 3, flow rate = 0.6 mL/min, wavelength = 254 nm, $t_{\text{R}} = 15.4$ min for the minor enantiomer, $t_{\text{R}} = 21.8$ min for the major enantiomer.

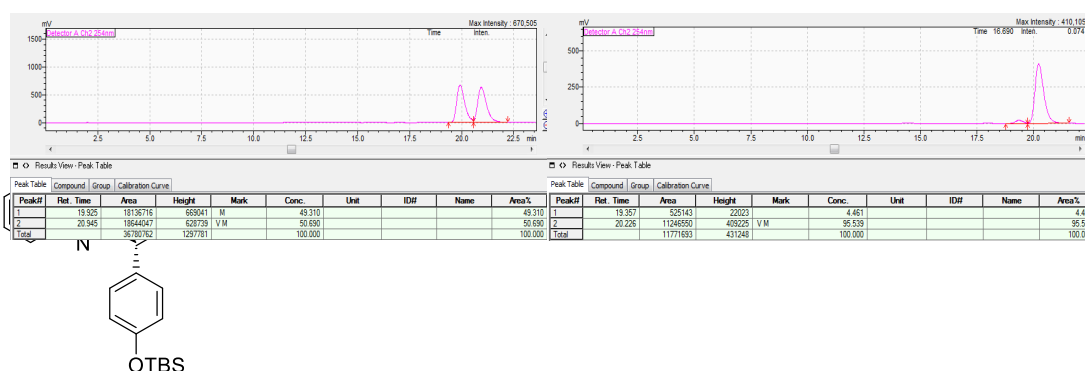


(S)-2-(1-(4-(trifluoromethoxy)phenyl)buta-1,2-dien-1-yl)quinoline 3aa (yellow oil, 62.7 mg, 92% yield, 91% *ee*). ^1H NMR (300 MHz, C_6D_6) δ 8.10 (dd, $J = 8.5, 0.7$ Hz, 1H), 7.63 (dd, $J = 8.6, 0.8$ Hz, 1H), 7.58 – 7.51 (m, 2H), 7.49 (d, $J = 8.6$ Hz, 1H), 7.40 (dd, $J = 8.1, 1.4$ Hz, 1H), 7.29 (ddd, J

= 8.4, 6.9, 1.5 Hz, 1H), 7.18 – 7.10 (m, 2H), 7.07 – 7.01 (m, 2H), 5.44 (q, $J = 7.2$ Hz, 1H), 1.50 (d, $J = 7.2$ Hz, 3H). ^{13}C NMR (100 MHz, C_6D_6) δ 209.7, 155.4, 148.3 (q, $J = 1.7$ Hz), 148.2, 135.7, 135.0, 130.8, 129.8, 129.3, 127.2, 126.7, 126.1, 121.3, 121.0 (q, $J = 255.0$ Hz), 120.4, 109.8, 90.5, 13.3. HR-MS (APCI $^+$): m/z calculated for $\text{C}_{20}\text{H}_{15}\text{NFO}_3$ ($\text{M}+\text{H}^+$): 342.1100, found: 342.1100.

Optical rotation: $[\alpha]_{\text{D}}^{20} = +21.8$ ($c = 1$, CH_2Cl_2).

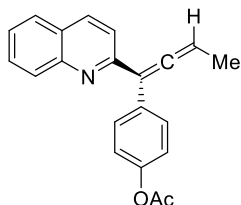
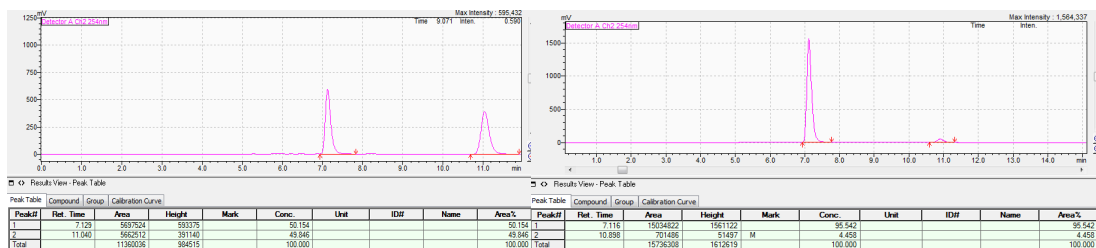
HPLC condition: Chiral column IE, n -hexane/ i -PrOH = 99: 1, flow rate = 0.3 mL/min, wavelength = 254 nm, $t_{\text{R}} = 15.1$ min for the minor enantiomer, $t_{\text{R}} = 16.9$ min for the major enantiomer.



(S)-2-(1-(4-((tert-butyldimethylsilyl)oxy)phenyl)buta-1,2-dien-1-yl)quinoline 3a (yellow oil, 66.8 mg, 85% yield, 91% ee). ^1H NMR (400 MHz, CDCl_3) δ 7.90 – 7.83 (m, 2H), 7.57 (dd, $J = 8.1, 1.5$ Hz, 1H), 7.45 (ddd, $J = 8.5, 6.9, 1.6$ Hz, 1H), 7.37 (d, $J = 8.6$ Hz, 1H), 7.28 (ddd, $J = 8.1, 6.9, 1.2$ Hz, 1H), 7.21 – 7.17 (m, 2H), 6.65 – 6.60 (m, 2H), 5.62 (q, $J = 7.1$ Hz, 1H), 1.69 (d, $J = 7.1$ Hz, 3H), 0.79 (s, 9H), 0.01 (s, 6H). ^{13}C NMR (100 MHz, CDCl_3) δ 208.9, 156.6, 155.0, 147.9, 136.0, 129.9, 129.7, 129.3, 128.4, 127.3, 126.8, 126.2, 122.1, 119.8, 109.9, 90.4, 25.7, 25.7, 18.3, 14.1, -4.3. HR-MS (APCI $^+$): m/z calculated for $\text{C}_{25}\text{H}_{30}\text{NOSi}$ ($\text{M}+\text{H}^+$): 388.2091, found: 388.2088.

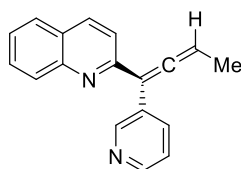
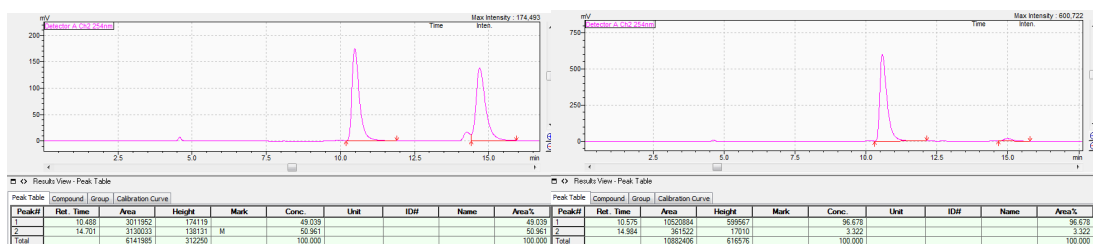
Optical rotation: $[\alpha]_{\text{D}}^{20} = +20.8$ ($c = 1$, CH_2Cl_2).

HPLC condition: Chiral column IB, n -hexane/ i -PrOH = 97: 3, flow rate = 0.6 mL/min, wavelength = 254 nm, $t_{\text{R}} = 7.1$ min for the major enantiomer, $t_{\text{R}} = 10.9$ min for the minor enantiomer.



(S)-4-(1-(quinolin-2-yl)buta-1,2-dien-1-yl)phenyl acetate 3ac (yellow oil, 58.0 mg, 92% yield, 93% *ee*). ^1H NMR (400 MHz, CDCl_3) δ 8.13 (dd, J = 8.6, 0.8 Hz, 1H), 8.09 (dq, J = 8.4, 0.9 Hz, 1H), 7.81 (dd, J = 8.0, 1.4 Hz, 1H), 7.70 (ddd, J = 8.4, 6.9, 1.5 Hz, 1H), 7.63 (d, J = 8.5 Hz, 1H), 7.62 – 7.58 (m, 2H), 7.53 (ddd, J = 8.1, 6.9, 1.2 Hz, 1H), 7.16 – 7.10 (m, 2H), 5.90 (q, J = 7.2 Hz, 1H), 2.34 (s, 3H), 1.95 (d, J = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 209.5, 169.5, 156.0, 149.8, 147.9, 136.1, 133.4, 130.0, 129.6, 129.4, 127.4, 126.8, 126.3, 121.9, 121.2, 109.7, 90.8, 21.2, 14.0. HR-MS (APCI $^+$): m/z calculated for $\text{C}_{21}\text{H}_{18}\text{NO}_2$ ($\text{M}+\text{H}^+$): 316.1332, found: 316.1333. Optical rotation: $[\alpha]_{\text{D}}^{20}$ = +23.3 (c = 1, CH_2Cl_2).

HPLC condition: Chiral column IB, *n*-hexane/*i*-PrOH = 97: 3, flow rate = 0.9 mL/min, wavelength = 254 nm, t_{R} = 10.6 min for the minor enantiomer, t_{R} = 15.0 min for the major enantiomer.

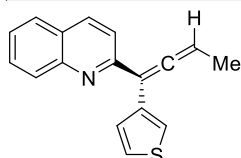
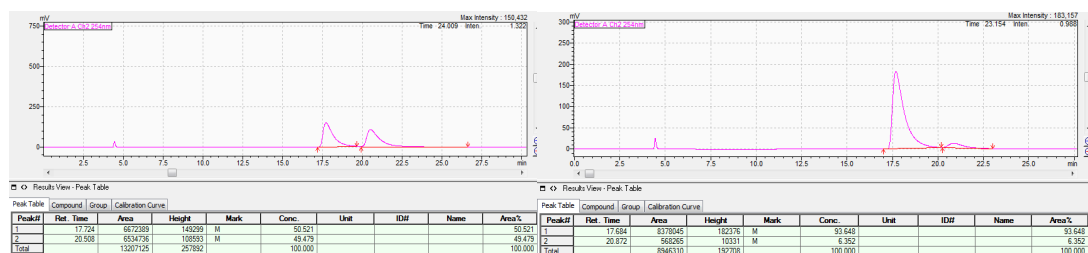


(S)-2-(1-(pyridin-3-yl)buta-1,2-dien-1-yl)quinoline 3ad (yellow oil, 44.9 mg, 81% yield, 87% *ee*). ^1H NMR (300 MHz, CD_2Cl_2) δ 8.82 (d, J = 2.4 Hz, 1H), 8.59 – 8.49 (m, 1H), 8.19 (dd, J = 8.6, 0.8 Hz, 1H), 8.07 – 7.92 (m, 2H), 7.86 (dd, J = 8.0, 1.6 Hz, 1H), 7.80 – 7.67 (m, 2H), 7.56

(ddd, $J = 8.1, 6.9, 1.3$ Hz, 1H), 7.35 (ddd, $J = 7.9, 4.8, 0.9$ Hz, 1H), 6.00 (q, $J = 7.2$ Hz, 1H), 1.98 (d, $J = 7.2$ Hz, 3H). ^{13}C NMR (75 MHz, CD_2Cl_2) δ 209.8, 155.0, 150.2, 147.9, 147.6, 136.3, 136.0, 131.8, 129.3, 129.2, 127.3, 126.7, 126.2, 122.6, 121.1, 104.9, 91.4, 13.5. HR-MS (APCI $^+$): m/z calculated for $\text{C}_{18}\text{H}_{15}\text{N}_2$ ($\text{M}+\text{H}^+$): 259.1230, found: 259.1230.

Optical rotation: $[\alpha]_{\text{D}}^{20} = +24.7$ ($c=1$, CH_2Cl_2).

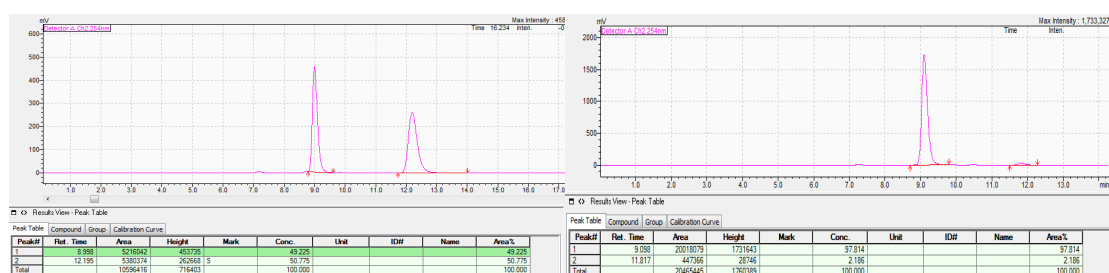
HPLC condition: Chiral column IB, n -hexane/ i -PrOH = 95: 5, flow rate = 0.9 mL/min, wavelength = 254 nm, $t_{\text{R}} = 17.7$ min for the major enantiomer, $t_{\text{R}} = 20.9$ min for the minor enantiomer.

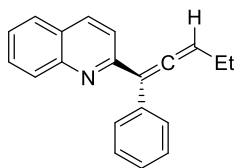


(*S*)-2-(1-(thiophen-3-yl)buta-1,2-dien-1-yl)quinoline **3ae** (yellow oil, 47.9 mg, 91% yield, 96% *ee*). ^1H NMR (400 MHz, CD_2Cl_2) δ 8.01 (d, $J = 8.6$ Hz, 1H), 7.96 (dq, $J = 8.3, 0.9$ Hz, 1H), 7.87 (ddd, $J = 2.8, 1.5, 0.7$ Hz, 1H), 7.72 (dd, $J = 8.1, 1.4$ Hz, 1H), 7.63 – 7.57 (m, 2H), 7.43 (ddd, $J = 8.2, 6.9, 1.3$ Hz, 1H), 7.26 – 7.22 (m, 2H), 5.81 (q, $J = 7.2$ Hz, 1H), 1.83 (d, $J = 7.2$ Hz, 3H). ^{13}C NMR (100 MHz, CD_2Cl_2) δ 210.0, 155.8, 147.8, 135.8, 135.4, 129.33, 129.31, 128.8, 127.4, 126.8, 126.2, 124.2, 123.5, 121.4, 105.8, 91.1, 13.7.

Optical rotation: $[\alpha]_{\text{D}}^{20} = +12.3$ ($c=1$, Et_2O).

HPLC condition: Chiral column IB, n -hexane/ i -PrOH = 97: 3, flow rate = 0.6 mL/min, wavelength = 254 nm, $t_{\text{R}} = 9.1$ min for the major enantiomer, $t_{\text{R}} = 11.8$ min for the minor enantiomer.

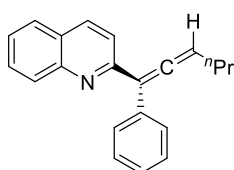
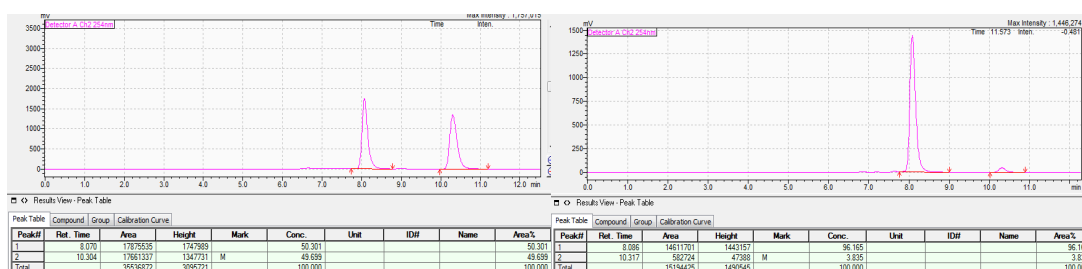




(S)-2-(1-phenylpenta-1,2-dien-1-yl)quinoline 3af (yellow oil, 47.2 mg, 87% yield, 92% *ee*). ^1H NMR (400 MHz, CDCl_3) δ 8.13–8.06 (m, 2H), 7.80 (dd, J = 8.1, 1.4 Hz, 1H), 7.68 (ddd, J = 8.4, 6.9, 1.5 Hz, 1H), 7.64 (d, J = 8.5 Hz, 1H), 7.59 – 7.55 (m, 2H), 7.51 (ddd, J = 8.1, 6.9, 1.2 Hz, 1H), 7.41 – 7.35 (m, 2H), 7.33 – 7.27 (m, 1H), 5.96 (t, J = 6.3 Hz, 1H), 2.39 – 2.23 (m, 2H), 1.19 (t, J = 7.4 Hz, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 208.2, 156.3, 148.0, 136.0, 135.9, 129.7, 129.3, 128.8, 128.1, 127.3, 127.1, 126.8, 126.2, 121.9, 111.5, 97.6, 22.2, 13.6. HR-MS (APCI $^+$): m/z calculated for $\text{C}_{20}\text{H}_{18}\text{N}$ ($\text{M}+\text{H}^+$): 272.1434, found: 272.1439.

Optical rotation: $[\alpha]_{\text{D}}^{20}$ = +34.7 (c = 1, CH_2Cl_2).

HPLC condition: Chiral column IB, *n*-hexane/*i*-PrOH = 97: 3, flow rate = 0.6 mL/min, wavelength = 254 nm, t_{R} = 8.1 min for the major enantiomer, t_{R} = 10.3 min for the minor enantiomer.

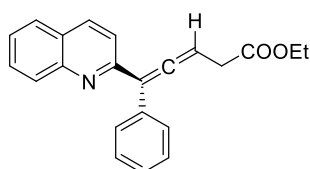
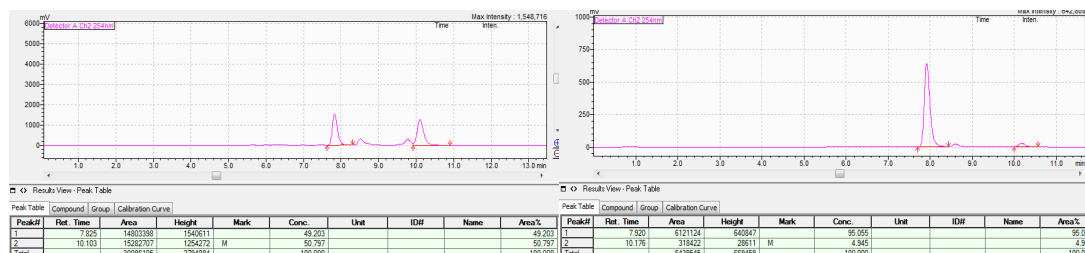


(S)-2-(1-phenylhexa-1,2-dien-1-yl)quinoline 3ag (yellow oil, 39.9 mg, 70% yield, 90% *ee*). ^1H NMR (400 MHz, CDCl_3) δ 8.11 (dd, J = 8.6, 0.8 Hz, 1H), 8.07 (d, J = 8.5 Hz, 1H), 7.79 (dd, J = 8.0, 1.4 Hz, 1H), 7.67 (ddd, J = 8.4, 6.9, 1.5 Hz, 1H), 7.62 (d, J = 8.6 Hz, 1H), 7.57 – 7.53 (m, 2H), 7.51 (ddd, J = 8.1, 6.9, 1.2 Hz, 1H), 7.40 – 7.34 (m, 2H), 7.33 – 7.26 (m, 1H), 5.90 (t, J = 6.9 Hz, 1H), 2.31 – 2.21 (m, 2H), 1.61 (h, J = 7.3 Hz, 2H), 0.99 (t, J = 7.4 Hz, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 208.6, 156.3, 148.0, 136.0, 135.8, 129.7, 129.3, 128.8, 128.1, 127.3, 127.1, 126.8, 126.2,

121.9, 110.8, 95.8, 30.9, 22.5, 13.8. HR-MS (APCI⁺): m/z calculated for C₂₀H₁₈N (M+H⁺): 272.1434, found: 272.1434.

Optical rotation: $[\alpha]_D^{20} = +28.6$ (c=0.5, CH₂Cl₂).

HPLC condition: Chiral column IB, *n*-hexane/*i*-PrOH = 97: 3, flow rate = 0.6 mL/min, wavelength = 254 nm, t_R = 7.9 min for the major enantiomer, t_R = 10.2 min for the minor enantiomer.

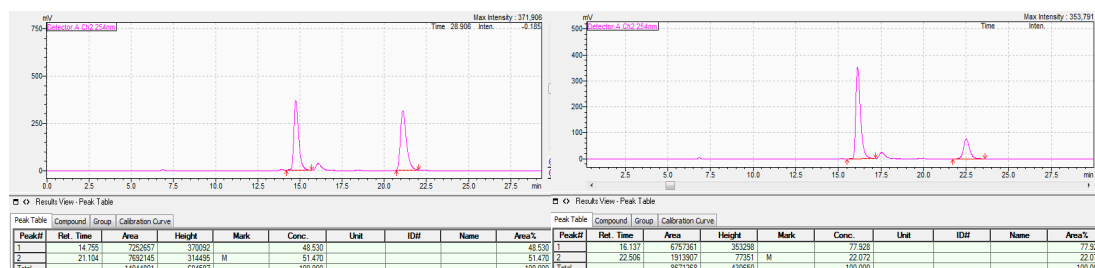


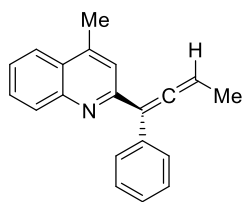
(S)-5-phenyl-5-(quinolin-2-yl)penta-3,4-dienoate 3ah (yellow oil, 46.7 mg, 71% yield, 56% ee).

¹H NMR (400 MHz, CDCl₃) δ 8.13 (dd, *J* = 8.6, 0.8 Hz, 1H), 8.06 (dq, *J* = 8.5, 0.8 Hz, 1H), 7.80 (dd, *J* = 8.0, 1.5 Hz, 1H), 7.70 – 7.63 (m, 2H), 7.57 – 7.49 (m, 3H), 7.40 – 7.35 (m, 2H), 7.33 – 7.29 (m, 1H), 6.04 (t, *J* = 7.3 Hz, 1H), 4.19 (q, *J* = 7.2 Hz, 2H), 3.30 (d, *J* = 7.4 Hz, 2H), 1.26 (t, *J* = 7.1 Hz, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 209.4, 170.9, 155.43, 148.0, 136.2, 134.9, 129.7, 129.4, 129.0, 128.2, 127.5, 127.4, 126.9, 126.4, 122.0, 111.9, 89.1, 61.0, 34.5, 14.2. HR-MS (APCI⁺): m/z calculated for C₂₂H₂₀NO₂ (M+H⁺): 330.1489, found: 330.1490.

Optical rotation: $[\alpha]_D^{20} = +11.6$ (c=1, CHCl₃).

HPLC condition: Chiral column IB, *n*-hexane/*i*-PrOH = 97: 3, flow rate = 0.6 mL/min, wavelength = 254 nm, t_R = 16.1 min for the major enantiomer, t_R = 22.5 min for the minor enantiomer.

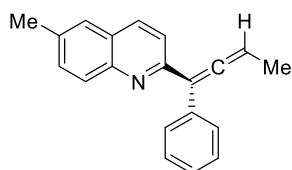
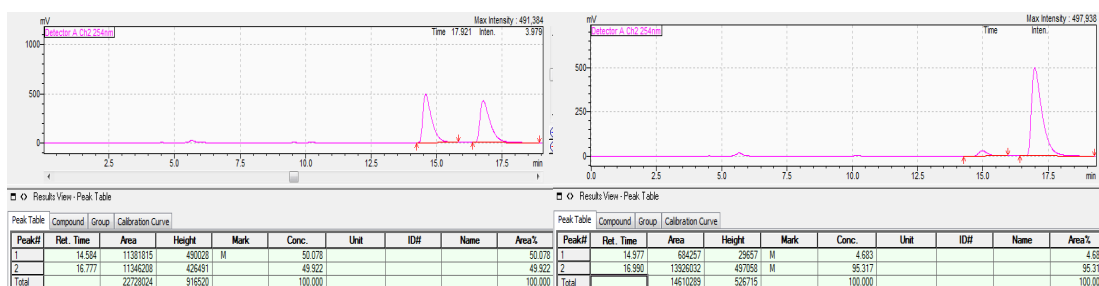




(S)-4-methyl-2-(1-phenylbuta-1,2-dien-1-yl)quinoline 3ai (yellow oil, 50.4 mg, 93% yield, 91% *ee*). ^1H NMR (400 MHz, CDCl_3) δ 7.95 – 7.87 (m, 1H), 7.79 (ddd, J = 8.4, 1.5, 0.6 Hz, 1H), 7.49 (ddd, J = 8.4, 6.8, 1.5 Hz, 1H), 7.38 – 7.31 (m, 3H), 7.25 (d, J = 1.1 Hz, 1H), 7.22 – 7.16 (m, 2H), 7.14 – 7.08 (m, 1H), 5.69 (q, J = 7.2 Hz, 1H), 2.52 (d, J = 1.1 Hz, 3H), 1.76 (d, J = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 209.1, 156.0, 147.8, 144.1, 136.0, 130.3, 129.0, 128.9, 128.2, 127.1, 127.0, 126.0, 123.5, 122.6, 110.3, 90.4, 18.8, 14.1. HR-MS (APCI $^+$): m/z calculated for $\text{C}_{20}\text{H}_{18}\text{N}$ ($\text{M}+\text{H}^+$): 272.1434, found: 272.1432.

Optical rotation: $[\alpha]_{\text{D}}^{20} = +33.0$ ($c=1$, CH_2Cl_2).

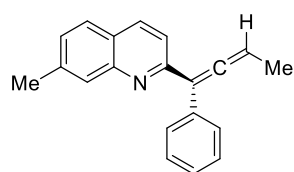
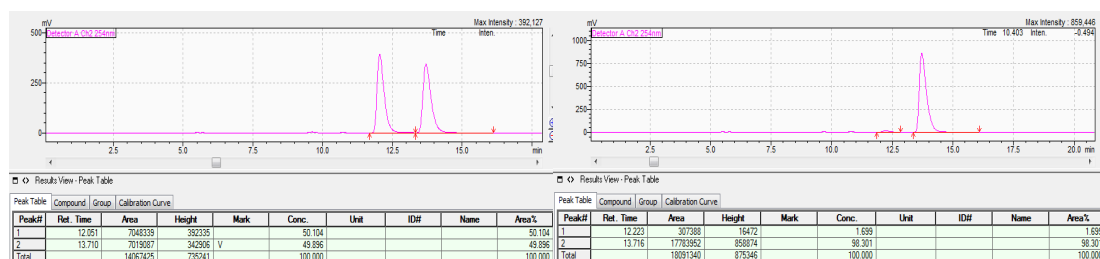
HPLC condition: Chiral column IE, *n*-hexane/*i*-PrOH = 98: 2, flow rate = 0.9 mL/min, wavelength = 254 nm, t_{R} = 15.0 min for the minor enantiomer, t_{R} = 17.0 min for the major enantiomer.



(S)-6-methyl-2-(1-phenylbuta-1,2-dien-1-yl)quinoline 3aj (yellow oil, 51.5 mg, 95% yield, 97% *ee*). ^1H NMR (400 MHz, Acetone- d_6) δ 8.05 (dd, J = 8.5, 0.8 Hz, 1H), 7.71 (d, J = 8.6 Hz, 1H), 7.57 – 7.52 (m, 2H), 7.47 – 7.41 (m, 3H), 7.29 – 7.24 (m, 2H), 7.22 – 7.15 (m, 1H), 5.80 (q, J = 7.2 Hz, 1H), 2.40 (d, J = 0.9 Hz, 3H), 1.80 (d, J = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, Acetone- d_6) δ 209.3, 155.0, 146.5, 136.2, 136.0, 135.4, 131.5, 129.1, 129.0, 127.9, 126.9, 126.9, 126.4, 121.6, 110.4, 90.2, 20.6, 13.3. HR-MS (APCI $^+$): m/z calculated for $\text{C}_{20}\text{H}_{18}\text{N}$ ($\text{M}+\text{H}^+$): 272.1434, found: 272.1432.

Optical rotation: $[\alpha]_{\text{D}}^{20} = +36.6$ ($c=1$, CH_2Cl_2).

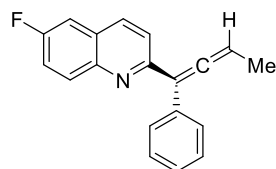
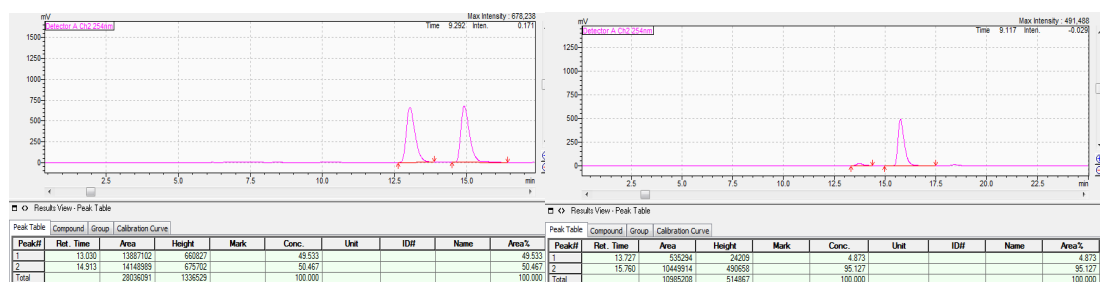
HPLC condition: Chiral column IE, *n*-hexane/*i*-PrOH = 97: 3, flow rate = 0.9 mL/min, wavelength = 254 nm, t_R = 12.2 min for the minor enantiomer, t_R = 13.7 min for the major enantiomer.



(*S*)-7-methyl-2-(1-phenylbuta-1,2-dien-1-yl)quinoline **3ak** (yellow oil, 49.3 mg, 91% yield, 90% *ee*). ^1H NMR (300 MHz, CDCl_3) δ 8.06 (dd, J = 8.5, 0.8 Hz, 1H), 7.88 (d, J = 1.8 Hz, 1H), 7.69 (d, J = 8.3 Hz, 1H), 7.59 – 7.49 (m, 3H), 7.44 – 7.27 (m, 4H), 5.87 (q, J = 7.2 Hz, 1H), 2.54 (s, 3H), 1.94 (d, J = 7.2 Hz, 3H). ^{13}C NMR (75 MHz, CDCl_3) δ 209.1, 156.1, 148.1, 139.4, 135.9, 135.6, 128.8, 128.7, 128.3, 128.0, 127.0, 126.9, 124.8, 121.1, 110.3, 90.2, 21.7, 13.9. HR-MS (APCI $^+$): m/z calculated for $\text{C}_{20}\text{H}_{18}\text{N}$ ($\text{M}+\text{H}^+$): 272.1434, found: 272.1430.

Optical rotation: $[\alpha]_D^{20}$ = +22.3 (c = 1, CH_2Cl_2).

HPLC condition: Chiral column IE, *n*-hexane/*i*-PrOH = 97: 3, flow rate = 0.6 mL/min, wavelength = 254 nm, t_R = 13.7 min for the minor enantiomer, t_R = 15.7 min for the major enantiomer.

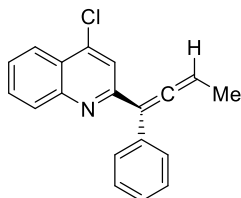
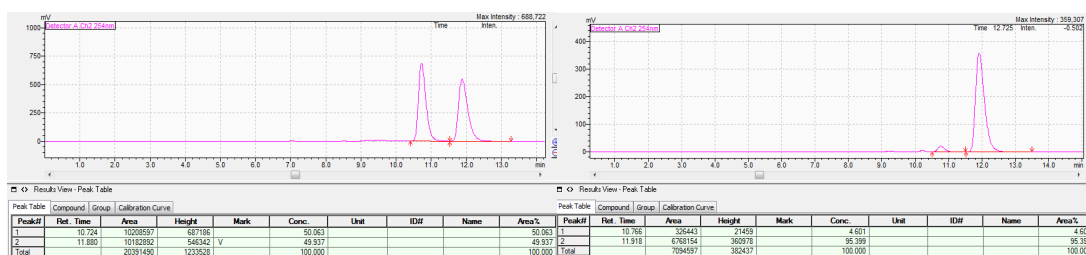


(*S*)-6-fluoro-2-(1-phenylbuta-1,2-dien-1-yl)quinoline **3al** (yellow, 49.5 mg, 90% yield, 91% *ee*). ^1H NMR (300 MHz, CDCl_3) δ 8.16 – 8.00 (m, 2H), 7.67 (d, J = 8.6 Hz, 1H), 7.63 – 7.54 (m, 2H), 7.54 – 7.30 (m, 5H), 5.92 (q, J = 7.2 Hz, 1H), 1.98 (dd, J = 7.2, 0.9 Hz, 3H). ^{13}C NMR (75 MHz,

CDCl₃) δ 209.26, 160.3 (d, J = 246.0 Hz), 155.6 (d, J = 2.7 Hz), 144.9, 135.6, 135.3 (d, J = 5.3 Hz), 132.0 (d, J = 9.1 Hz), 128.8, 128.1, 127.3 (d, J = 10.0 Hz), 127.1, 122.6, 119.2 (d, J = 25.5 Hz), 110.3 (d, J = 21.6 Hz), 110.1, 90.5, 13.9. ¹⁹F NMR (377 MHz, CDCl₃) δ -119.8 (s). HR-MS (APCI⁺): m/z calculated for C₁₉H₁₅NF (M+H⁺): 276.1183, found: 276.1178.

Optical rotation: $[\alpha]_D^{20}$ = +50.2 (c = 1, CH₂Cl₂).

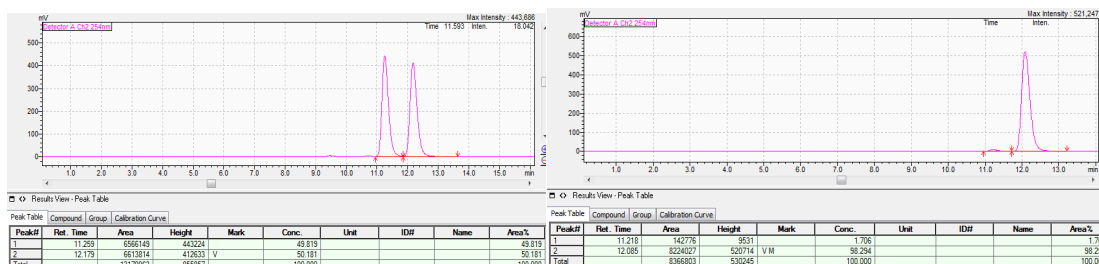
HPLC condition: Chiral column IE, *n*-hexane/*i*-PrOH = 97: 3, flow rate = 0.6 mL/min, wavelength = 254 nm, t_R = 10.8 min for the minor enantiomer, t_R = 11.9 min for the major enantiomer.

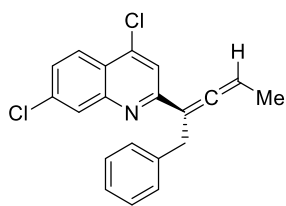


(*S*)-4-chloro-2-(1-phenylbuta-1,2-dien-1-yl)quinoline **3am** (yellow oil, 35.5 mg, 61% yield, 97% *ee*). ¹H NMR (400 MHz, CDCl₃) δ 8.12 (ddd, J = 8.5, 1.6, 0.7 Hz, 1H), 7.99 (d, J = 8.5 Hz, 1H), 7.66 – 7.60 (m, 2H), 7.52 (ddd, J = 8.2, 6.9, 1.2 Hz, 1H), 7.46 – 7.42 (m, 2H), 7.32 – 7.27 (m, 2H), 7.25 – 7.20 (m, 1H), 5.82 (q, J = 7.2 Hz, 1H), 1.86 (d, J = 7.2 Hz, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 209.5, 156.2, 148.7, 142.4, 135.3, 130.2, 130.1, 129.0, 128.2, 127.3, 127.2, 125.0, 123.8, 121.7, 109.8, 91.0, 14.0. HR-MS (APCI⁺): m/z calculated for C₁₉H₁₅NCl (M+H⁺): 292.0888, found: 292.0886.

Optical rotation: $[\alpha]_D^{20}$ = +61.4 (c = 1, CH₂Cl₂).

HPLC condition: Chiral column IE, *n*-hexane/*i*-PrOH = 98: 2, flow rate = 0.5mL/min, wavelength = 254 nm, t_R = 12.1 min for the minor enantiomer, t_R = 17.0 min for the major enantiomer.

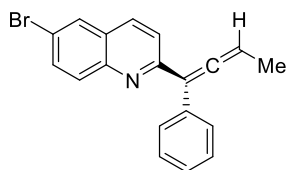
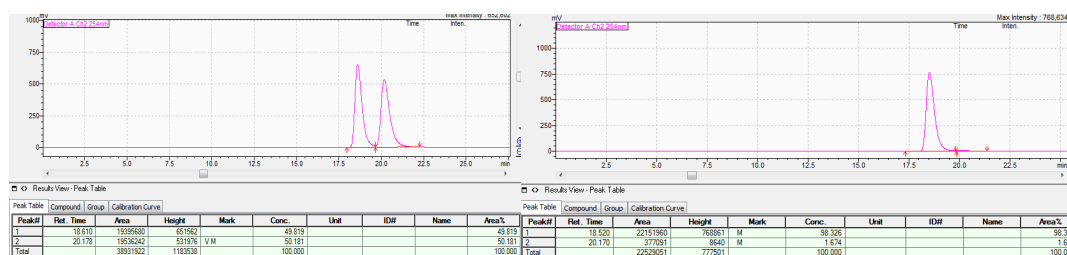




(S)-4,7-dichloro-2-(1-phenylbuta-1,2-dien-1-yl)quinoline 3an (white solid, 49.5 mg, 73% yield, 97% *ee*). ^1H NMR (400 MHz, CDCl_3) δ 7.97 (d, $J = 2.0$ Hz, 1H), 7.93 (d, $J = 8.9$ Hz, 1H), 7.58 (s, 1H), 7.37 (dd, $J = 8.9, 2.1$ Hz, 1H), 7.30 – 7.24 (m, 2H), 7.21 – 7.14 (m, 2H), 7.11 – 7.05 (m, 1H), 5.59 – 5.47 (m, 1H), 4.04 – 3.84 (m, 2H), 1.68 (d, $J = 7.2$ Hz, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 209.2, 157.1, 149.1, 141.6, 140.5, 136.1, 129.3, 128.7, 128.0, 127.6, 126.0, 125.2, 123.3, 120.5, 107.6, 91.3, 35.1, 13.8. HR-MS (APCI $^+$): m/z calculated for $\text{C}_{20}\text{H}_{16}\text{NCl}_2$ ($\text{M}+\text{H}^+$): 340.0654, found: 340.0658.

Optical rotation: $[\alpha]_{\text{D}}^{20} = +50.5$ ($c=1$, EA).

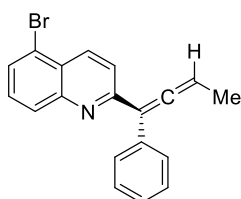
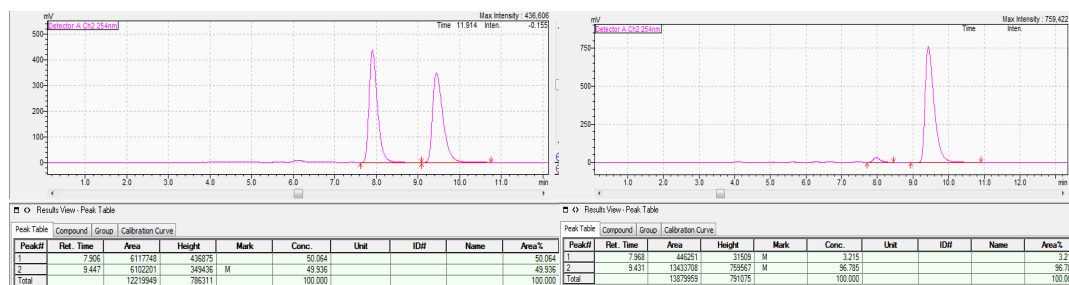
HPLC condition: Chiral column IB, *n*-hexane/*i*-PrOH = 99.9: 0.1, flow rate = 0.3 mL/min, wavelength = 254 nm, $t_{\text{R}} = 18.5$ min for the major enantiomer, $t_{\text{R}} = 20.2$ min for the minor enantiomer.



(S)-6-bromo-2-(1-phenylbuta-1,2-dien-1-yl)quinoline 3ao (yellow oil, 65.0 mg, 97% yield, 94% *ee*). ^1H NMR (300 MHz, CDCl_3) δ 8.04 (d, $J = 8.6$ Hz, 1H), 8.01 – 7.94 (m, 2H), 7.77 (dd, $J = 9.0, 2.2$ Hz, 1H), 7.67 (d, $J = 8.7$ Hz, 1H), 7.61 – 7.55 (m, 2H), 7.46 – 7.31 (m, 3H), 5.92 (q, $J = 7.2$ Hz, 1H), 1.98 (dd, $J = 7.2, 0.7$ Hz, 3H). ^{13}C NMR (75 MHz, CDCl_3) δ 209.5, 156.6, 146.5, 135.5, 134.9, 132.6, 131.3, 129.3, 128.9, 128.1, 127.8, 127.2, 122.6, 119.9, 110.2, 90.6, 13.8. HR-MS (APCI $^+$): m/z calculated for $\text{C}_{19}\text{H}_{15}\text{NBr}$ ($\text{M}+\text{H}^+$): 336.0382, found: 336.0384.

Optical rotation: $[\alpha]_{\text{D}}^{20} = +42.7$ ($c=1$, CH_2Cl_2).

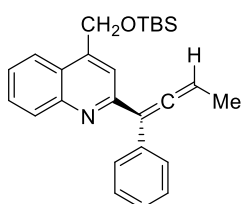
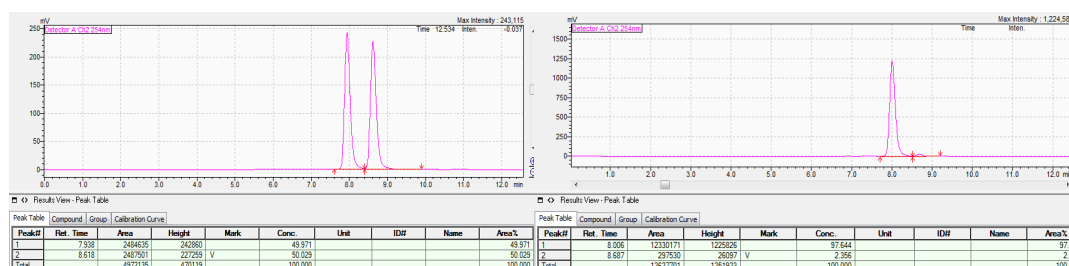
HPLC condition: Chiral column IE, *n*-hexane/*i*-PrOH = 97: 3, flow rate = 0.9 mL/min, wavelength = 254 nm, t_R = 8.0 min for the minor enantiomer, t_R = 9.4 min for the major enantiomer.



(S)-5-bromo-2-(1-phenylbuta-1,2-dien-1-yl)quinoline 3ap (yellow oil, 51.6 mg, 77% yield, 95% *ee*). ^1H NMR (300 MHz, CDCl_3) δ 8.51 (d, J = 8.8 Hz, 1H), 8.06 (dd, J = 8.5, 1.0 Hz, 1H), 7.81 (dd, J = 7.5, 1.1 Hz, 1H), 7.74 (d, J = 8.8 Hz, 1H), 7.59 – 7.51 (m, 3H), 7.46 – 7.33 (m, 3H), 5.94 (q, J = 7.2 Hz, 1H), 1.98 (d, J = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 209.8, 157.1, 148.7, 135.5, 135.4, 129.9, 129.6, 129.5, 129.0, 128.2, 127.3, 126.3, 123.1, 121.6, 110.0, 90.8, 14.0. HR-MS (APCI $^+$): m/z calculated for $\text{C}_{19}\text{H}_{15}\text{NBr}$ ($\text{M}+\text{H}^+$): 336.0382, found: 336.0383.

Optical rotation: $[\alpha]_D^{20}$ = +59.4 (c = 1, CH_2Cl_2).

HPLC condition: Chiral column IB, *n*-hexane/*i*-PrOH = 97: 3, flow rate = 0.6 mL/min, wavelength = 254 nm, t_R = 8.0 min for the major enantiomer, t_R = 8.7 min for the minor enantiomer.

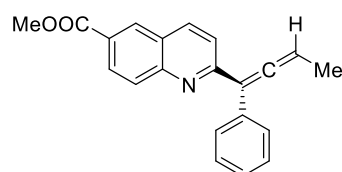
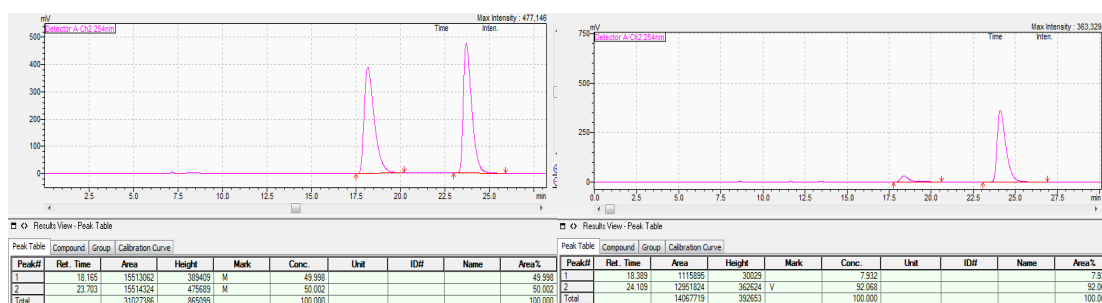


(S)-4-(((tert-butyldimethylsilyl)oxy)methyl)-2-(1-phenylbuta-1,2-dien-1-yl)quinoline 3aq (yellow oil, 69.0 mg, 86% yield, 84% *ee*). ^1H NMR (400 MHz, CDCl_3) δ 7.92 (d, J = 8.3 Hz, 1H),

7.67 (t, $J = 1.2$ Hz, 1H), 7.64 (dd, $J = 8.3, 0.8$ Hz, 1H), 7.48 (ddd, $J = 8.4, 6.9, 1.4$ Hz, 1H), 7.43 – 7.39 (m, 2H), 7.33 (ddd, $J = 8.3, 6.9, 1.3$ Hz, 1H), 7.24 – 7.17 (m, 2H), 7.16 – 7.10 (m, 1H), 5.69 (t, $J = 7.2$ Hz, 1H), 5.07 (d, $J = 1.3$ Hz, 2H), 1.77 (d, $J = 7.2$ Hz, 3H), 0.82 (s, 9H), 0.00 (d, $J = 0.7$ Hz, 6H). ^{13}C NMR (100 MHz, CDCl_3) δ 209.6, 156.3, 147.6, 146.4, 135.9, 130.4, 129.1, 128.9, 128.1, 127.1, 126.0, 124.2, 122.0, 118.5, 110.7, 90.4, 61.7, 25.9, 18.4, 14.1, -5.28, -5.29. HR-MS (APCI $^+$): m/z calculated for $\text{C}_{26}\text{H}_{32}\text{NSiO}$ ($\text{M}+\text{H}^+$): 402.2248, found: 402.2252.

Optical rotation: $[\alpha]_{\text{D}}^{20} = +19.0$ ($c = 1$, CH_2Cl_2).

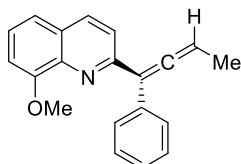
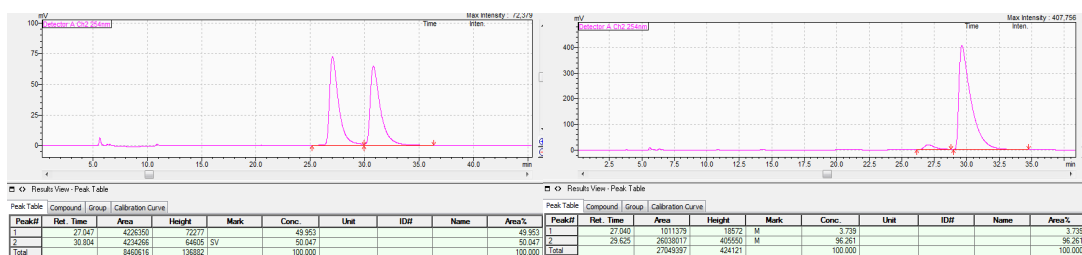
HPLC condition: Chiral column IE, n -hexane/ i -PrOH = 99: 1, flow rate = 0.5 mL/min, wavelength = 254 nm, $t_{\text{R}} = 18.4$ min for the minor enantiomer, $t_{\text{R}} = 24.1$ min for the major enantiomer.



(S)-2-(1-phenylbuta-1,2-dien-1-yl)quinoline-6-carboxylate 3ar (yellow oil, 54.2 mg, 86% yield, 93% *ee*). ^1H NMR (400 MHz, CDCl_3) δ 8.34 (d, $J = 1.9$ Hz, 1H), 8.04 (dd, $J = 8.9, 2.0$ Hz, 1H), 7.97 (dd, $J = 8.7, 0.8$ Hz, 1H), 7.86 (dt, $J = 8.8, 0.7$ Hz, 1H), 7.46 (d, $J = 8.6$ Hz, 1H), 7.37 – 7.31 (m, 2H), 7.20 – 7.15 (m, 2H), 7.13 – 7.08 (m, 1H), 5.69 (q, $J = 7.2$ Hz, 1H), 3.78 (s, 3H), 1.73 (d, $J = 7.2$ Hz, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 210.0, 166.8, 158.5, 149.9, 137.1, 135.4, 130.5, 129.9, 129.1, 128.9, 128.2, 127.6, 127.3, 125.9, 122.6, 110.4, 90.8, 52.3, 13.9. HR-MS (APCI $^+$): m/z calculated for $\text{C}_{21}\text{H}_{18}\text{NO}_2$ ($\text{M}+\text{H}^+$): 316.1332, found: 316.1329.

Optical rotation: $[\alpha]_{\text{D}}^{20} = +162.4$ ($c = 1$, CH_2Cl_2).

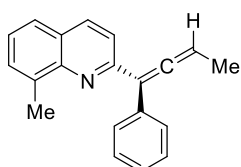
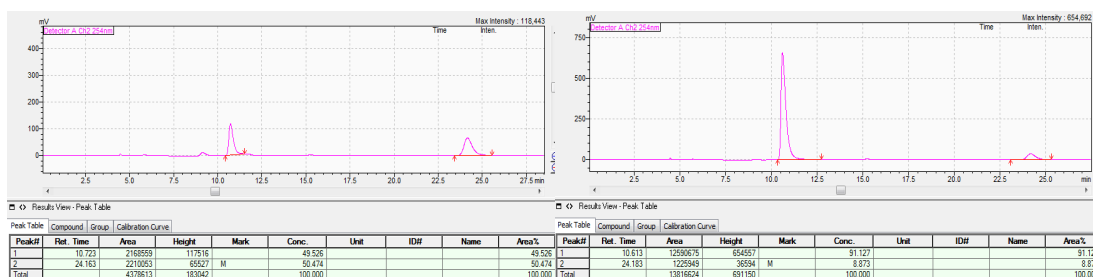
HPLC condition: Chiral column IE, n -hexane/ i -PrOH = 97: 3, flow rate = 0.9 mL/min, wavelength = 254 nm, $t_{\text{R}} = 27.0$ min for the minor enantiomer, $t_{\text{R}} = 29.6$ min for the major enantiomer.



(S)-8-methoxy-2-(1-phenylbuta-1,2-dien-1-yl)quinoline 3as (yellow oil, 40.2 mg, 70% yield, 82% *ee*). ^1H NMR (400 MHz, Chloroform- d) δ 8.01 (d, J = 8.5 Hz, 1H), 7.54 – 7.48 (m, 3H), 7.38 (dd, J = 8.2, 7.6 Hz, 1H), 7.33 – 7.28 (m, 3H), 7.25 – 7.19 (m, 1H), 6.99 (dd, J = 7.6, 1.4 Hz, 1H), 5.82 (q, J = 7.2 Hz, 1H), 3.97 (s, 3H), 1.87 (d, J = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 209.3, 155.6, 155.3, 140.0, 136.1, 136.0, 128.8, 128.1, 128.0, 127.0, 126.4, 122.5, 119.3, 110.4, 108.3, 90.4, 56.2, 14.0. HR-MS (APCI $^+$): m/z calculated for $\text{C}_{20}\text{H}_{18}\text{NO}$ ($\text{M}+\text{H}^+$): 288.1383, found: 288.1372.

Optical rotation: $[\alpha]_D^{20} = +12.7$ ($c=0.5$, CH_2Cl_2).

HPLC condition: Chiral column IB, *n*-hexane/*i*-PrOH = 99.5: 0.5, flow rate = 0.9 mL/min, wavelength = 254 nm, t_R = 10.6 min for the major enantiomer, t_R = 21.2 min for the minor enantiomer.

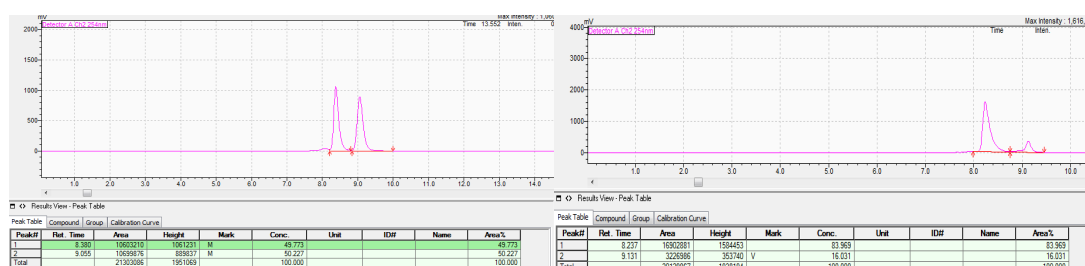


(R)-8-methyl-2-(1-phenylbuta-1,2-dien-1-yl)quinoline 3at (yellow oil, 40.1 mg, 74% yield, 68% *ee*). ^1H NMR (400 MHz, CDCl_3) δ 8.07 (d, J = 8.6 Hz, 1H), 7.75 – 7.69 (m, 2H), 7.67 (d, J = 8.6 Hz, 1H), 7.63 (d, J = 7.9 Hz, 1H), 7.53 (d, J = 6.6 Hz, 1H), 7.44 – 7.38 (m, 3H), 7.35 – 7.30 (m,

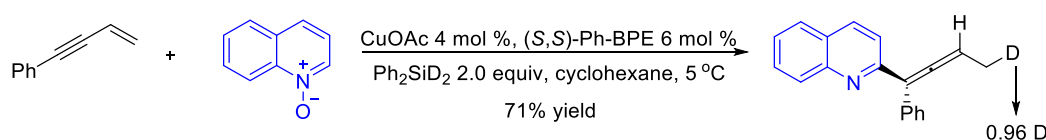
1H), 5.89 (q, $J = 7.2$ Hz, 1H), 2.72 (s, 3H), 1.96 (d, $J = 7.2$ Hz, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 209.9, 154.6, 146.8, 137.6, 136.1, 135.9, 129.4, 127.8, 127.0, 126.6, 125.9, 125.2, 121.3, 110.6, 90.4, 17.8, 14.0. HR-MS (APCI $^+$): m/z calculated for $\text{C}_{20}\text{H}_{18}\text{N}$ ($\text{M}+\text{H}^+$): 272.1434, found: 272.1433.

Optical rotation: $[\alpha]_{\text{D}}^{20} = +15.0$ ($c=1$, CH_2Cl_2).

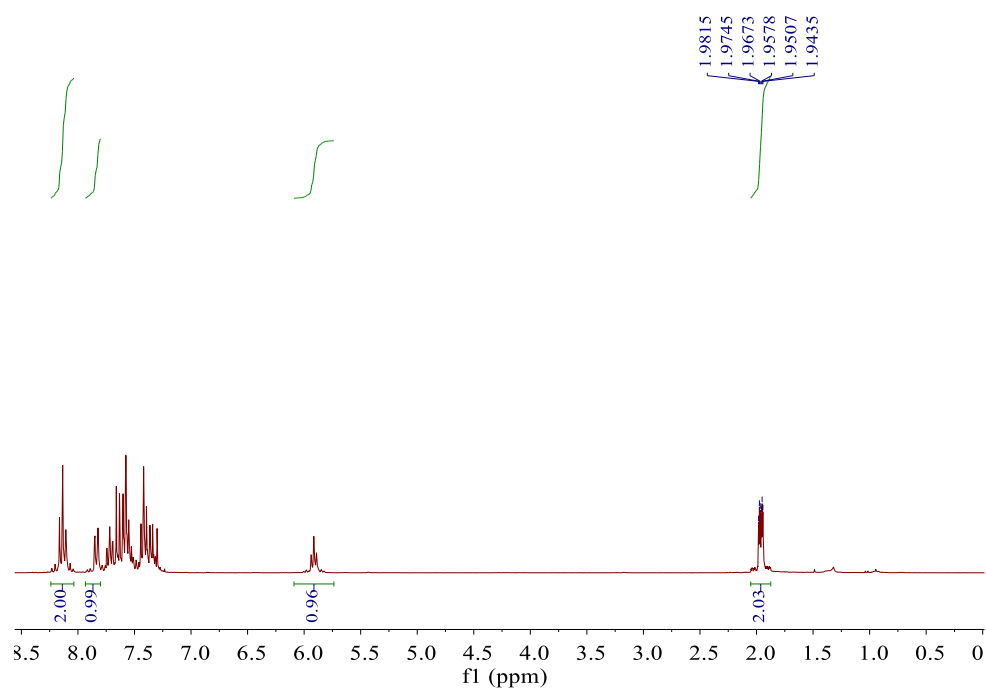
HPLC condition: Chiral column IB, n -hexane/ i -PrOH = 99: 1, flow rate = 0.5 mL/min, wavelength = 254 nm, $t_{\text{R}} = 8.2$ min for the major enantiomer, $t_{\text{R}} = 9.1$ min for the minor enantiomer.



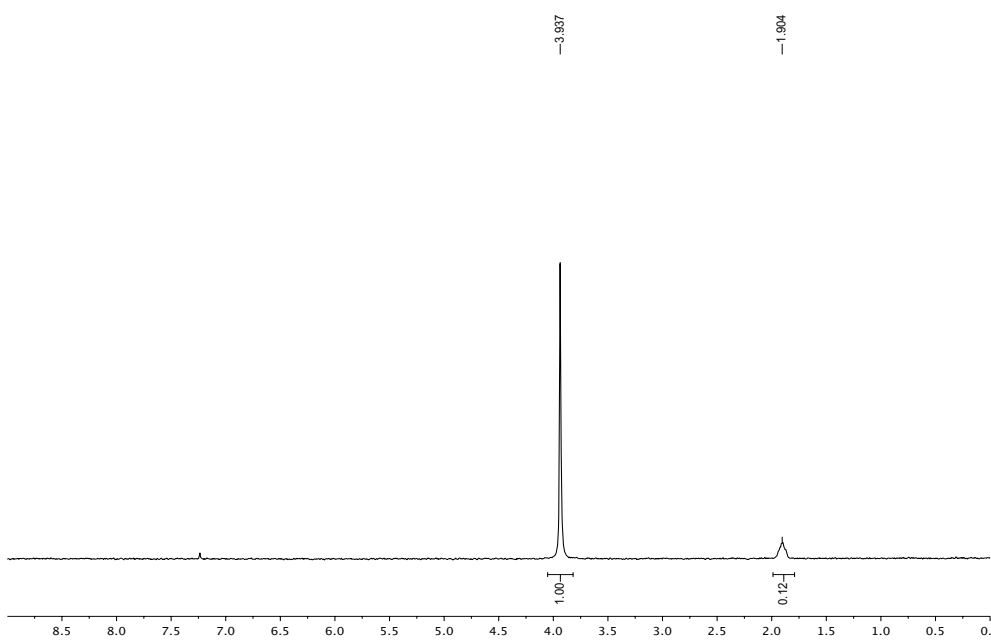
Deuterium Experiments



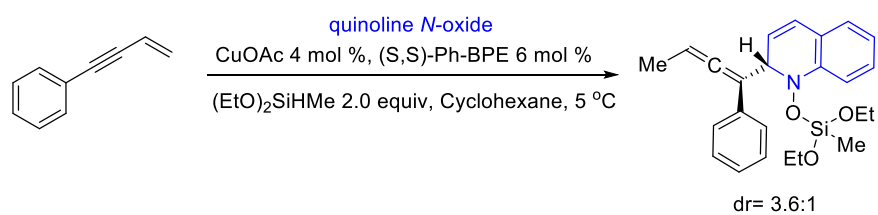
CuOAc (4 mol %, 0.9 mg) and (S,S)-Ph-BPE (6 mol %, 6.1 mg) were dissolved in cyclohexane (1 mL) in a screw-capped vial under argon atmosphere. The resulting mixture was stirred for 5 min, to which was added Ph_2SiD_2 (2.0 equiv), enynes derived from natural products (0.2 mmol), and quinoline N -oxide (2.0 equiv, 0.4 mmol) successively. The vial was stirred at 5°C for 20 hours. The mixture was concentrated under vacuum and the crude product was purified by flash chromatography on silica with a mixture of ethyl acetate/hexane (1:100 to 1:50). The deuterium ratio was determined by ^2H NMR.



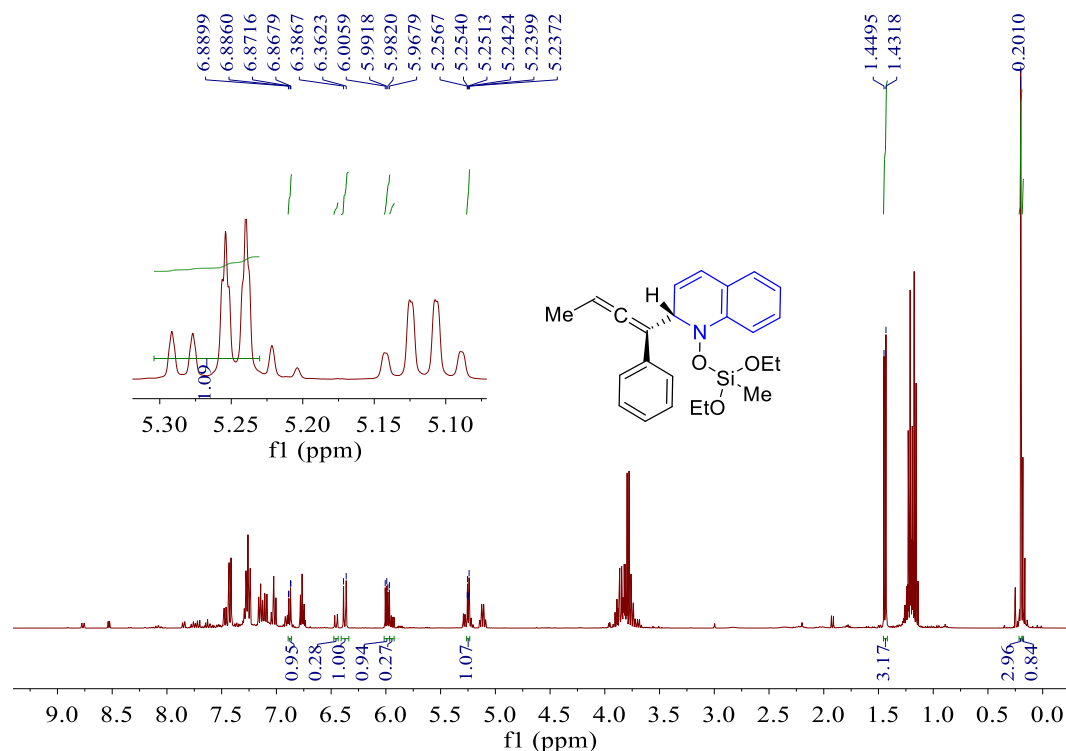
Supplementary Figure 1



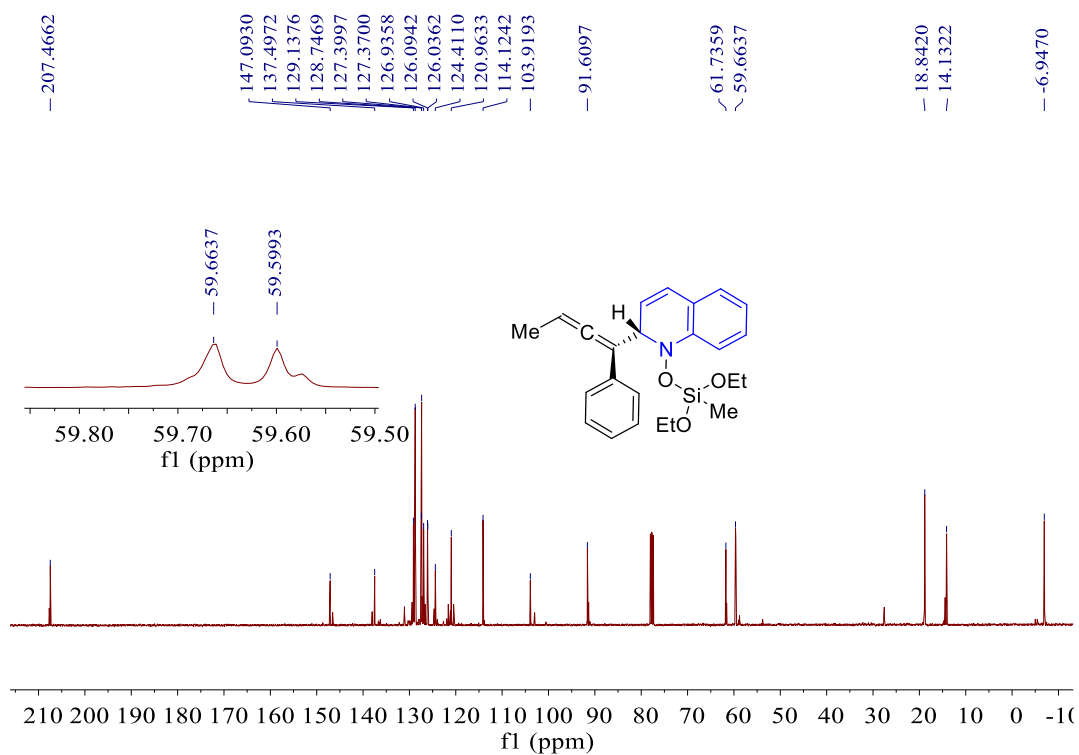
Supplementary Figure 2



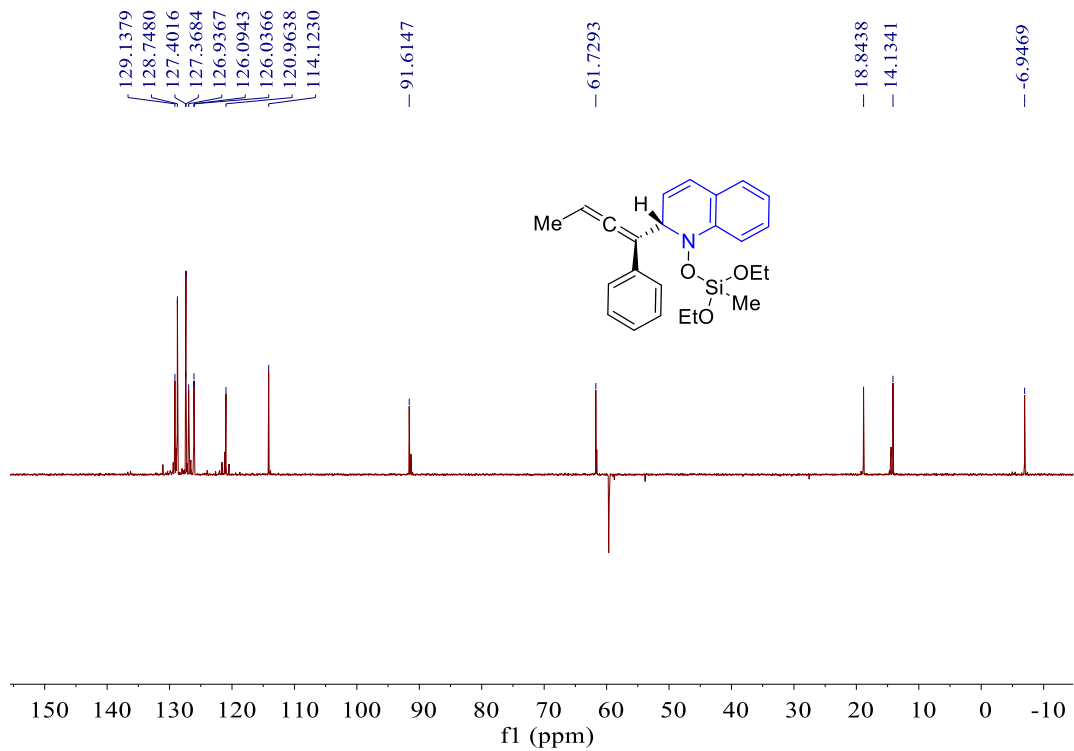
CuOAc (4 mol %, 0.9 mg) and (*S,S*)-Ph-BPE (6 mol %, 6.1 mg) were dissolved in cyclohexane (1 mL) in a screw-capped vial under argon atmosphere. The resulting mixture was stirred for 5 min, to which was added (EtO)₂SiHMe (0.4 mmol, 65 μ L), enyne (0.2 mmol), and quinoline *N*-oxide (0.4 mmol) successively. The vial was stirred at 5 $^{\circ}$ C for 20 hours. The mixture was filtered and concentrated under vacuum. The siloxane was determined by NMR of crude product (**Note: the pure compound cannot be isolated because the compound is unstable when working up with silica gel or neutral aluminium oxide**). The siloxane intermediate was detected by HRMS and GC/MS(HRMS (APCI⁺): calculated for C₂₄H₃₀NO₃Si: 408.1989, found: 408.1995. GC-MS (EI⁺): calculated for C₂₄H₂₉NO₃Si (M⁺): 407.19, found: 407.20. Major diastereoisomer: ¹H NMR (400 MHz, CDCl₃) selected signals δ 6.88 (dd, *J* = 7.3, 1.5 Hz, 1H), 6.37 (d, *J* = 9.8 Hz, 1H), 5.99 (dd, *J* = 9.6, 5.6 Hz, 1H), 5.25 (dt, *J* = 5.6, 1.1 Hz, 1H), 1.44 (d, *J* = 7.1 Hz, 3H), 0.20 (s, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 207.5, 147.1, 137.5, 129.1, 128.8, 127.40, 127.37, 126.9, 126.1, 126.0, 124.4, 121.0, 114.1, 103.9, 91.6, 61.7, 59.7, 18.8, 14.1, -7.0. ¹³C (DEPT 135) NMR (100 MHz, CDCl₃) δ 129.1, 128.8, 127.4, 127.4, 126.9, 126.09, 126.0, 121.0, 114.1, 91.6, 61.7, 18.9, 18.8, 14.1, -7.0.



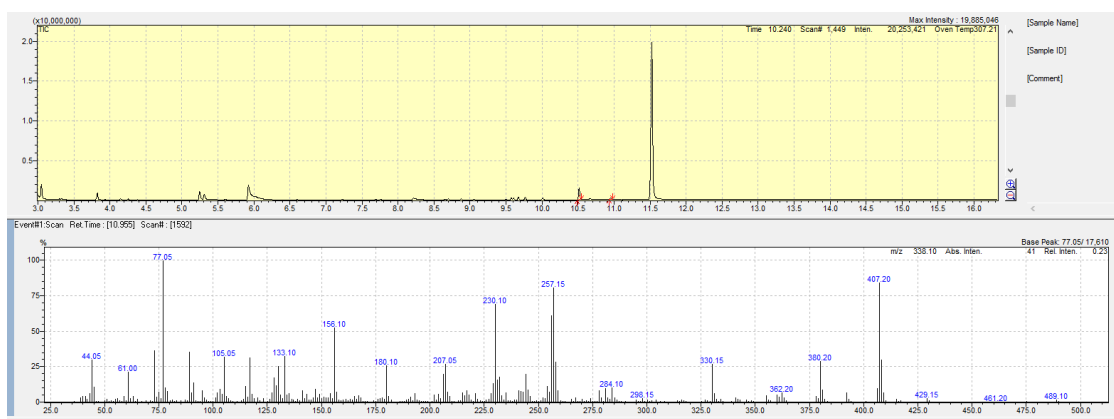
Supplementary Figure 3



Supplementary Figure 4

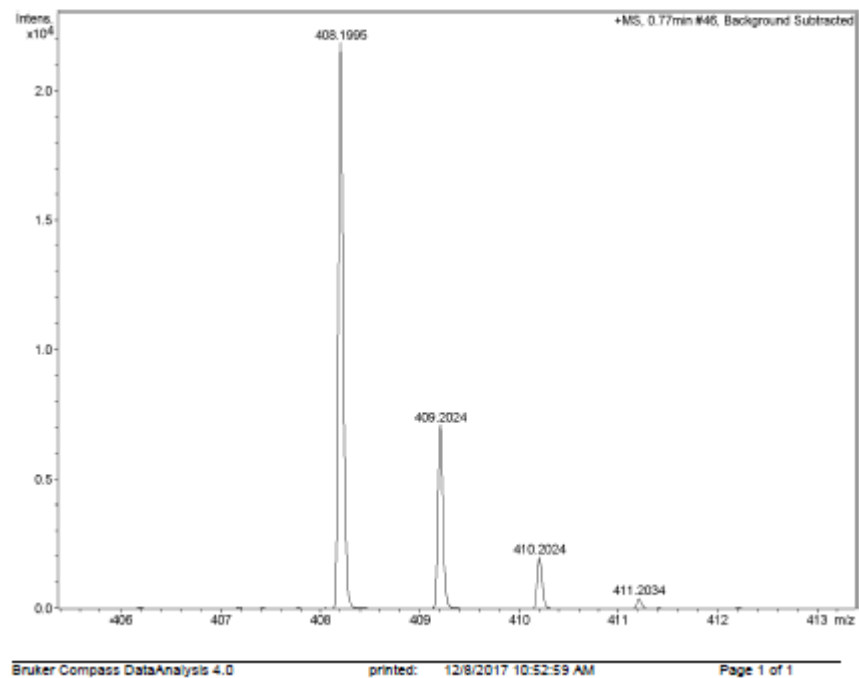


Supplementary Figure 5

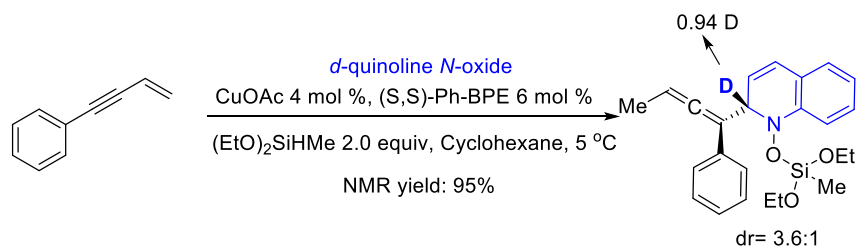


Supplementary Figure 6

Mass Spectrum SmartFormula Report							
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Analysis Name D:\Data\Chem\2017 Samples\201712\1208\1698.d				Operator default user			
Method YCH_Pos-150-1800-APCI.m				Instrument / Ser# microTOF-Q II 10269			
Sample Name 1698							
Comment Dr Ge Shaozhong							
Acquisition Parameter							
Source Type APCI		Ion Polarity Positive		Set Nebulizer 3.0 Bar			
Focus Not active		Set Capillary 4500 V		Set Dry Heater 200 °C			
Scan Begin 50 m/z		Set End Plate Offset -500 V		Set Dry Gas 4.0 l/min			
Scan End 1000 m/z		Set Collision Cell RF 50.0 Vpp		Set Divert Valve Waste			
Mass, m/z		#	Formula	m/z	err [ppm]	rdb	e⁻ Conf N-Rule
408.1995		1	C ₂₄ H ₃₀ N ₃ O ₃ Si	408.1989	-1.4	11.5	even ok

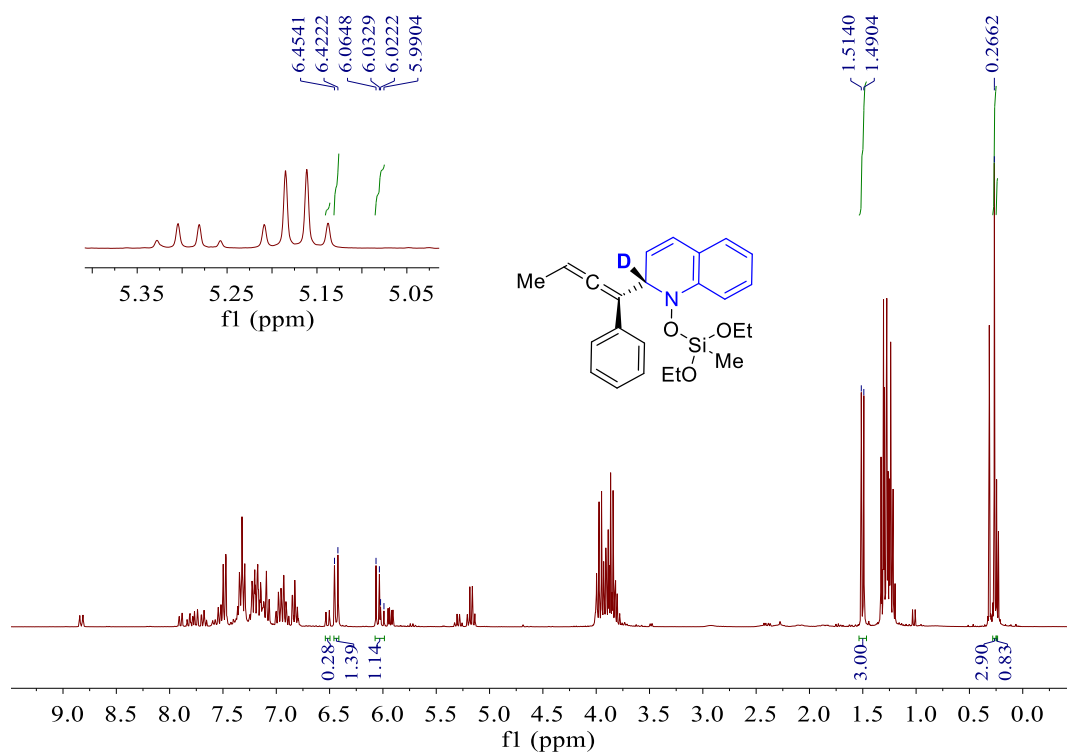


Supplementary Figure 7

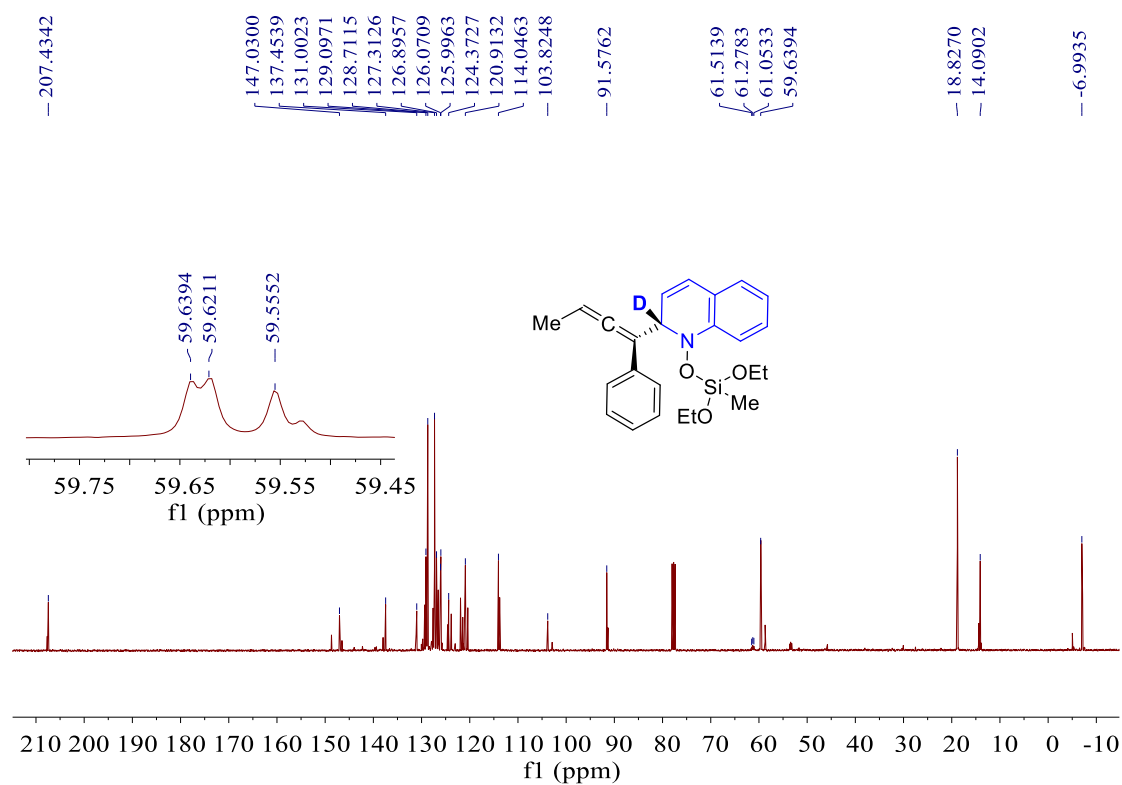


CuOAc (4 mol %, 0.9 mg) and (*S,S*)-Ph-BPE (6 mol %, 6.1 mg) were dissolved in cyclohexane (1 mL) in screw-capped vial under argon atmosphere. The resulting mixture was stirred for 5 min, to which was added (EtO)₂SiHMe (0.4 mmol, 65 μ L), enyne (0.2 mmol), and *d*-quinoline *N*-oxide (0.4 mmol) successively. The vial was stirred at 5 °C for 20 hours. The mixture was filtered and concentrated under vacuum. The deuterated siloxane was determined by NMR of crude product. The yield and deuterium ratio were determined by ¹H NMR and ²H NMR with benzaldehyde and CDCl₃ as internal standards. The siloxane intermediate was detected by HRMS (HRMS (APCI⁺): calculated for C₂₄H₂₉DNO₃Si: 409.2052, found: 409.2049 (**Note:** *The pure compound cannot be isolated because the compound is unstable when working up with silica gel or neutral aluminium oxide*).

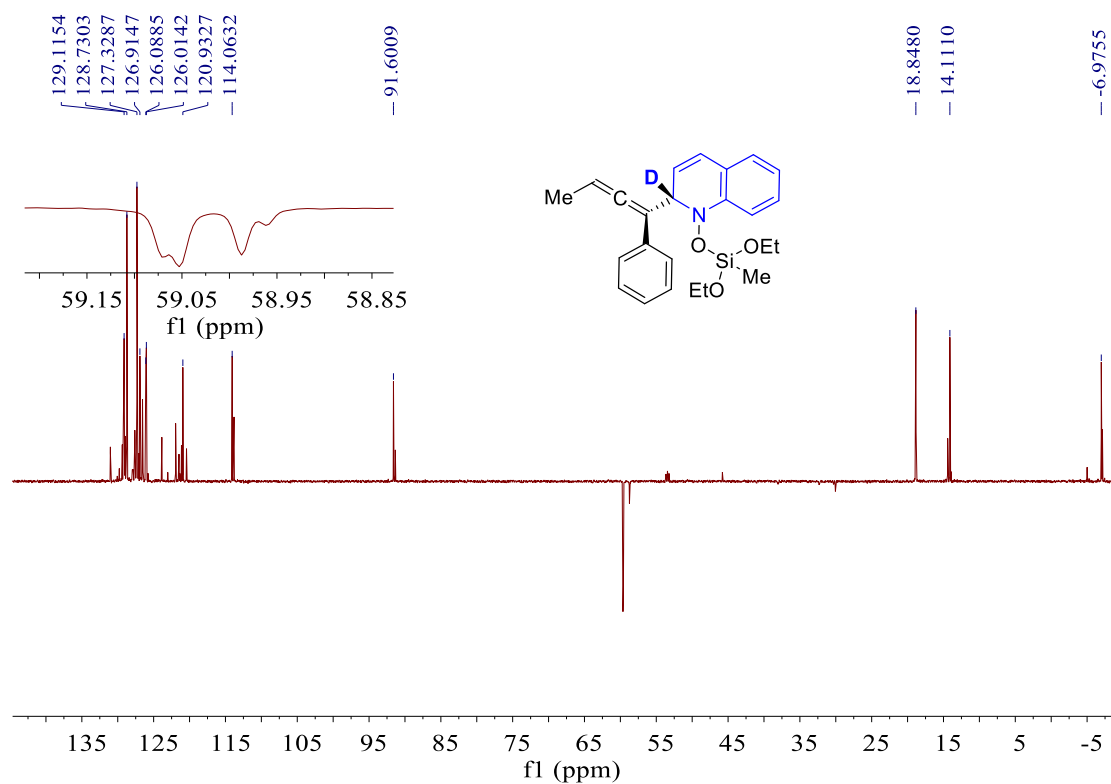
Major diastereoisomer: ¹H NMR (400 MHz, CDCl₃) selected signals ¹H NMR (300 MHz, Chloroform-d) δ 6.52 (d, *J* = 9.6 Hz, 0H), 6.44 (d, *J* = 9.6 Hz, 1H), 6.03 (dd, *J* = 12.8, 9.6 Hz, 1H), 1.50 (d, *J* = 7.1 Hz, 3H), 0.27 (s, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 207.4, 147.0, 137.5, 131.0, 129.1, 128.7, 127.3, 126.9, 126.1, 126.0, 124.4, 120.9, 114.1, 103.8, 91.6, 61.3, 59.6, 18.8, 14.1, -7.0. ¹³C (DEPT 135) NMR (100 MHz, CDCl₃) δ 129.1, 128.7, 127.3, 126.9, 126.1, 126.0, 120.9, 114.1, 91.6, 18.9, 14.1, -7.0.



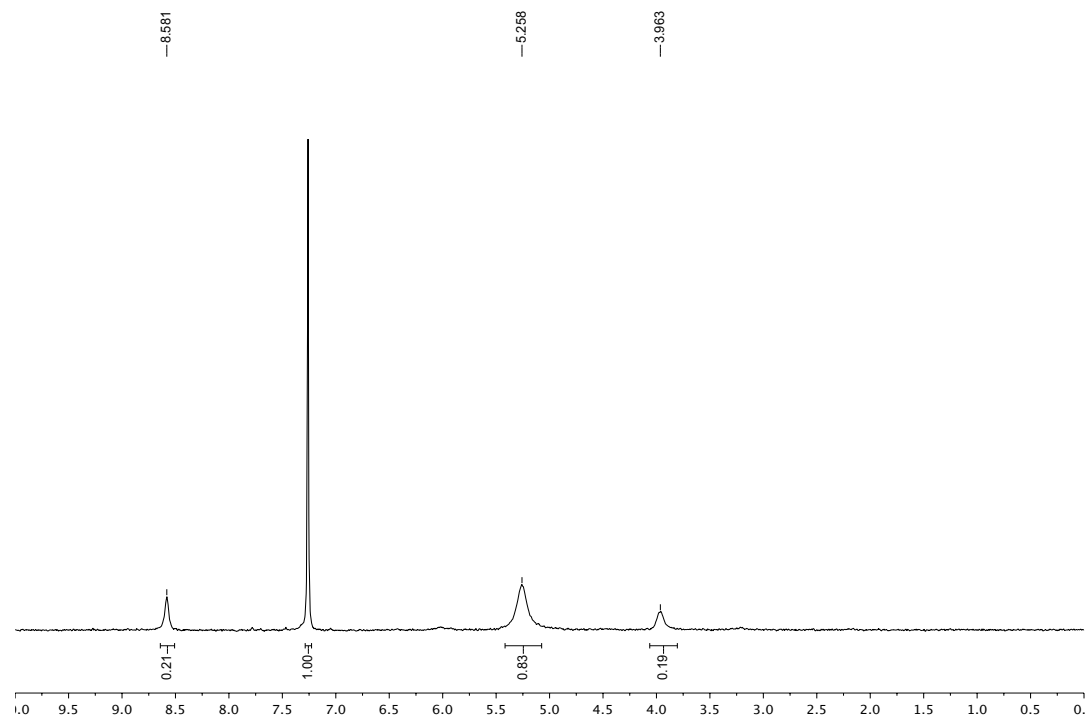
Supplementary Figure 8



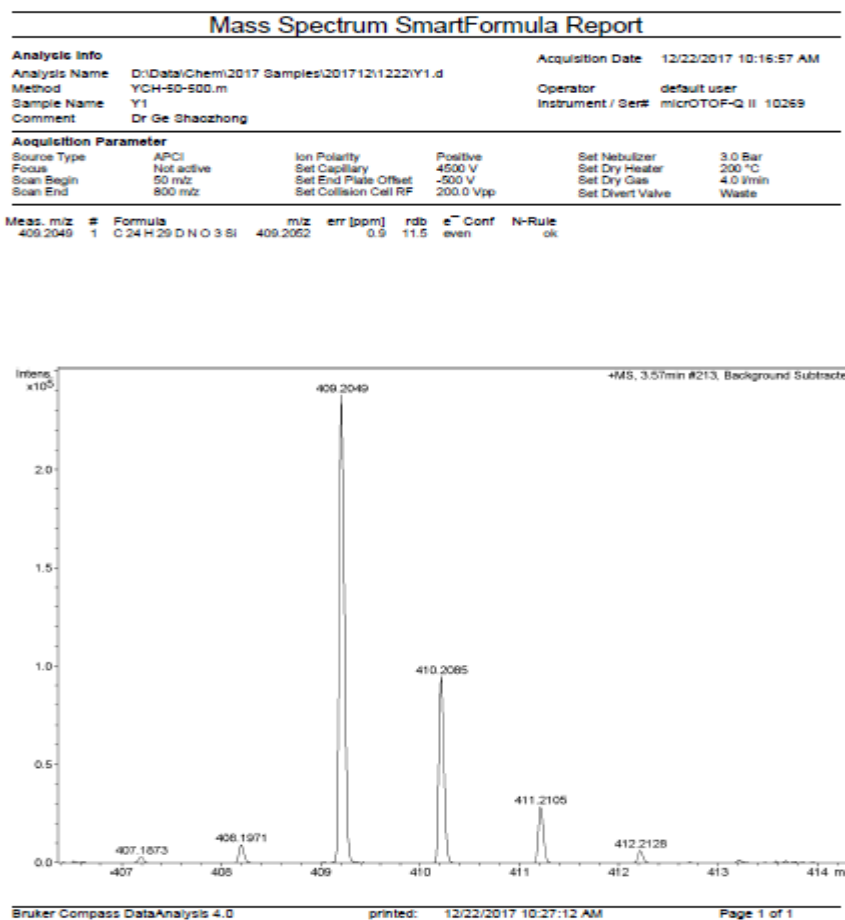
Supplementary Figure 9



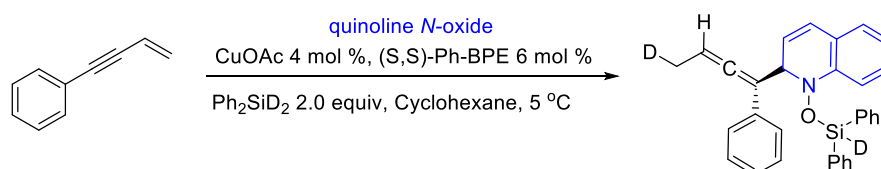
Supplementary Figure 10



Supplementary Figure 11

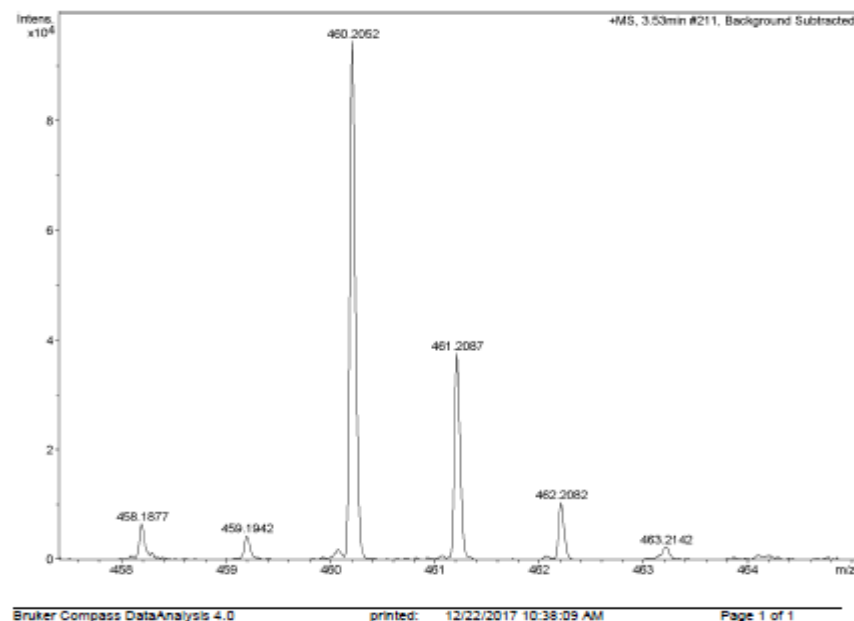


Supplementary Figure 12



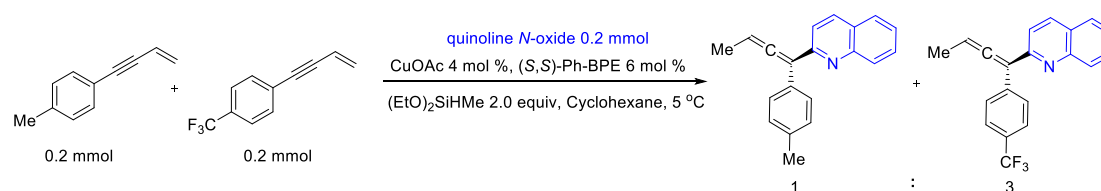
CuOAc (4 mol %, 0.9 mg) and (*S,S*)-Ph-BPE (6 mol %, 6.1 mg) were dissolved in cyclohexane (1 mL) in a screw-capped vial under argon atmosphere. The resulting mixture was stirred for 5 min, to which was added Ph₂SiD₂ (0.4 mmol), enyne (0.2 mmol), and quinoline *N*-oxide (0.4 mmol) successively. The vial was stirred at 5 °C for 20 hours. The mixture was filtered and concentrated under vacuum. The siloxane intermediate was detected by HRMS (HRMS (APCI⁺): calculated for C₃₁H₂₆D₂NOSi: 460.2060, found: 4460.2052 (**Note:** the pure compound cannot be isolated because the compound is unstable when working up with silica gel or neutral aluminium oxide).

Mass Spectrum SmartFormula Report							
Analysis Info				Acquisition Date 12/22/2017 10:28:27 AM			
Analysis Name D:\Data\Chem\2017 Samples\201712\1222\Y2.d				Operator default user			
Method YCH-50-500.m				Instrument / Ser# microTOF-Q II 10269			
Sample Name Y2							
Comment Dr Ge Shaozhong							
Acquisition Parameter							
Source Type APCI		Ion Polarity Positive		Set Nebulizer 3.0 Bar			
Focus Not active		Set Capillary 4500 V		Set Dry Heater 200 °C			
Scan Begin 50 m/z		Set End Plate Offset -500 V		Set Dry Gas 4.0 l/min			
Scan End 800 m/z		Set Collision Cell RF 200.0 Vpp		Set Divert Valve Waste			
Meas. m/z	#	Formula	m/z	err [ppm]	rd	e ⁻ Conf	N-Rule
460.2052	1	C ₃₁ H ₂₆ D ₂ N ₂ O ₂ Si	460.2060	1.8	19.5	even	ok

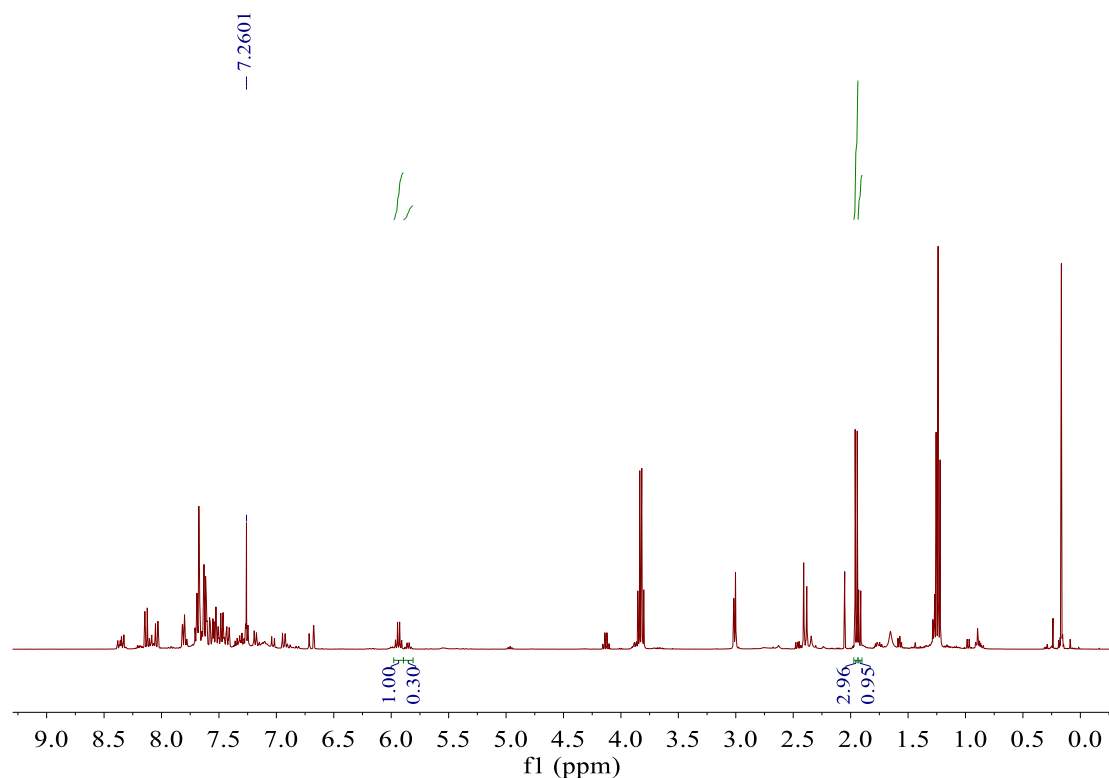


Supplementary Figure 13

Competition Reaction



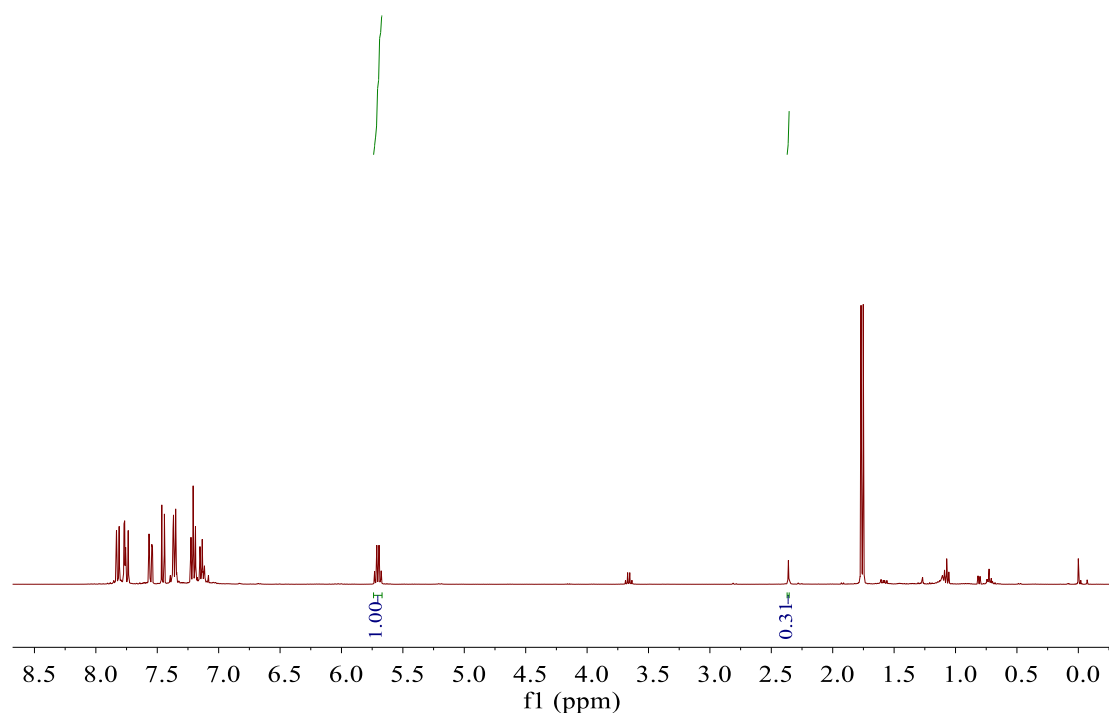
CuOAc (4 mol %, 0.9 mg) and (*S,S*)-Ph-BPE (6 mol %, 6.1 mg) were dissolved in cyclohexane (1 mL) in a screw-capped vial under argon atmosphere. The resulting mixture was stirred for 5 min, to which was added (EtO)₂SiHMe (0.4 mmol, 65 μ L), 1-(but-3-en-1-yn-1-yl)-4-methylbenzene (0.2 mmol), 1-(but-3-en-1-yn-1-yl)-4-(trifluoromethyl)- benzene (0.2 mmol), and quinoline *N*-oxide (0.2 mmol). The vial was stirred at 5 °C for 20 hours. The mixture was purified by flash chromatography on silica. The ratio of products was determined by ¹HMR.



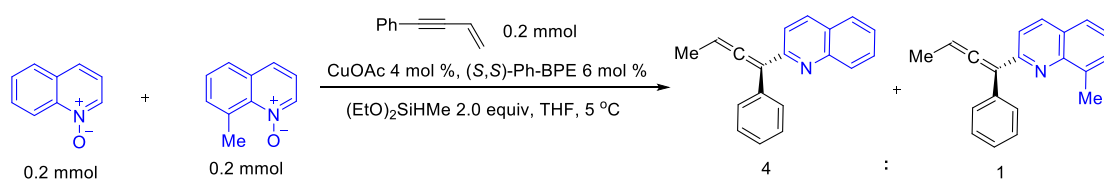
Supplementary Figure 14



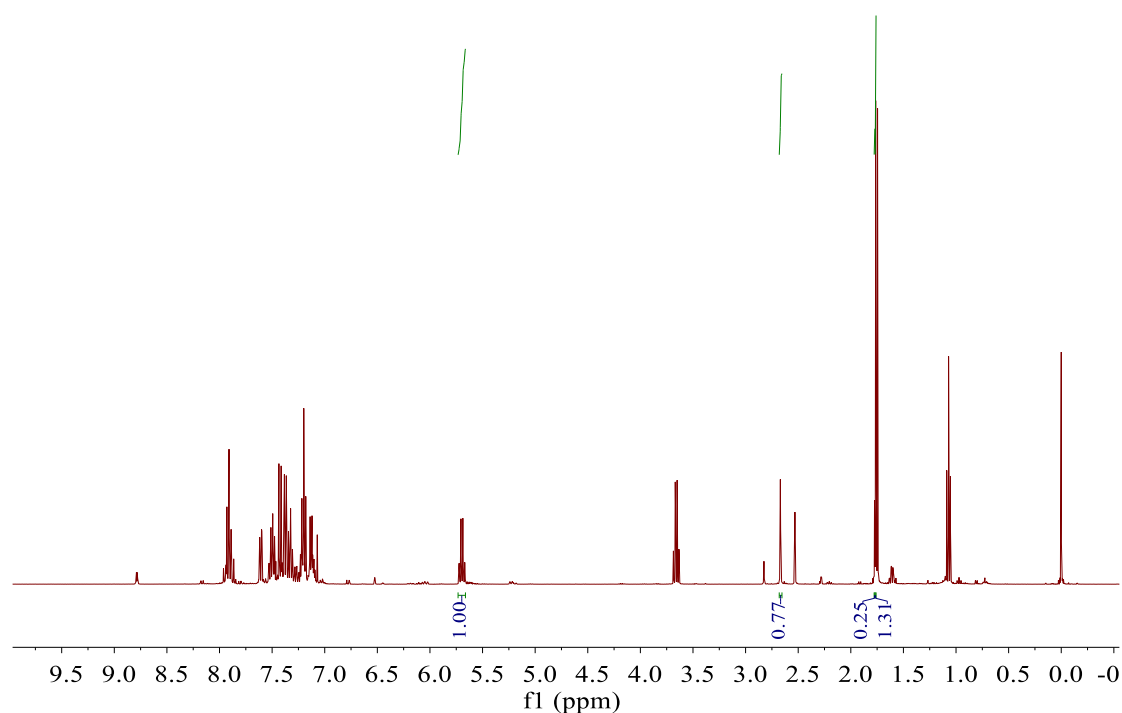
CuOAc (4 mol %, 0.9 mg) and (*S,S*)-Ph-BPE (6 mol %, 6.1 mg) were dissolved in THF (1 mL) in a screw-capped vial under argon atmosphere. The resulting mixture was stirred for 5 min, to which was added (EtO)₂SiHMe (0.4 mmol, 65 μ L), enyne (0.2 mmol), 6-methylquinoline 1-oxide (0.2 mmol), and 6-bromoquinoline *N*-oxide (0.2 mmol). The vial was stirred at 5 $^{\circ}$ C for 20 hours. The mixture was purified by flash chromatography on silica. The ratio of products was determined by ¹HMR (**Note:** *The solubility of quinoline N-oxide is bad in cyclohexane, but good in THF*).



Supplementary Figure 15



CuOAc (4 mol %, 0.9 mg) and (*S,S*)-Ph-BPE (6 mol %, 6.1 mg) were dissolved in THF (1 mL) in a screw-capped vial under argon atmosphere. The resulting mixture was stirred for 5 min, to which was added (EtO)₂SiHMe (0.4 mmol, 65 μ L), enyne (0.2 mmol), 8-methylquinoline 1-oxide (0.2 mmol), and quinoline *N*-oxide (0.2 mmol). The vial was stirred at 5 $^\circ$ C for 20 hours. The mixture was purified by flash chromatography on silica. The ratio of products was determined by ¹HMR (**Note:** *The solubility of quinoline N-oxide is bad in cyclohexane, but good in THF*).

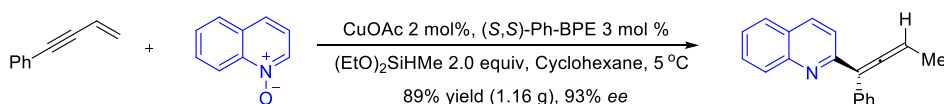


Supplementary Figure 16

Applications:

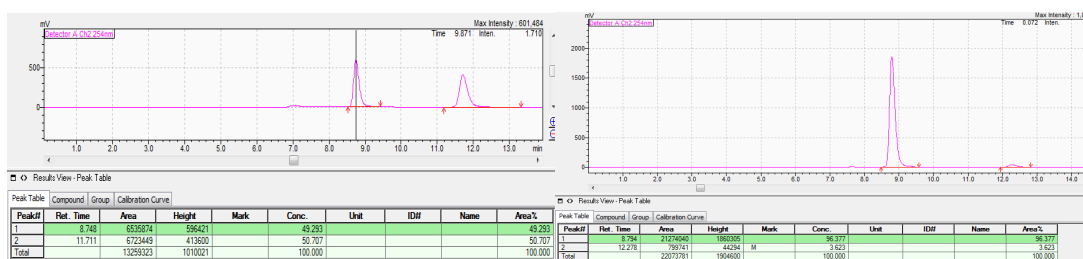
Gram-scale reaction

Gram-scale reaction

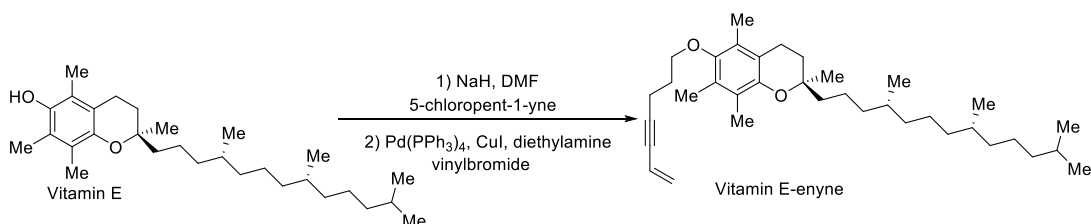


CuOAc (2 mol %, 12 mg) and (*S,S*)-Ph-BPE (3 mol %, 76 mg) were dissolved in cyclohexane (20 mL) under argon atmosphere. The resulting mixture was stirred for 5 min, to which was added (EtO)₂SiHMe (10 mmol), enynes (5 mmol), and quinoline *N*-oxide (10 mmol) successively. The vial was stirred at 5 °C for 24 hours. The mixture was filtered with cotton to remove the excess quinoline *N*-oxide. Silica gel was added into the filtrate at 0 °C and stirred for 20 min. The resulted mixture was concentrated under vacuum and the crude product was purified by flash chromatography on silica with a mixture of ethyl acetate/hexane (1:100 to 1:50).

HPLC condition: Chiral column IB, *n*-hexane/*i*-PrOH = 97: 3, flow rate = 0.6 mL/min, wavelength = 254 nm, *t*_R = 8.8 min for the major enantiomer, *t*_R = 12.3 min for the minor enantiomer.



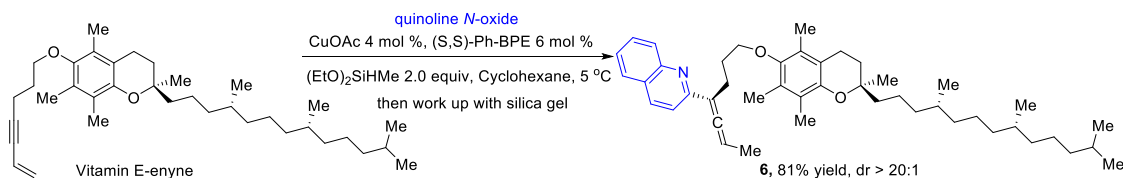
Modification of drugs and natural products



Vitamin E (10 mmol) was dissolved in 20 mL DMF under argon atmosphere, to which was added NaH (30 mmol) slowly at 0 °C. The resulting mixture was stirred at rt for 30 min. Then 15 mmol 5-chloropent-1-yne was added dropwise and the mixture was stirred at rt overnight. After that, the mixture was quenched with water and extracted with EA. The combined organic phase washed with water and dried with sodium sulfate. The mixture was concentrated under vacuum and the crude product was purified by flash chromatography on silica with a mixture of ethyl acetate/hexane (1:100). The resulting compound was added into a solution of Pd(PPh₃)₄ (5 mol %) and CuI (10 mol %) in 5 mL diethylamine. Then 15 mmol vinylbromide was added at 0 °C. The resulting mixture was stirred at rt overnight. After that, the mixture was quenched with saturated NH₄Cl and extracted with ether. The combined organic phase was washed with HCl (2M). The solvent was removed under vacuum and the crude product was purified by flash chromatography on silica with a mixture of ethyl acetate/hexane (1:100).

¹H NMR (400 MHz, CDCl₃) δ 5.79 (ddt, J = 17.5, 11.0, 2.1 Hz, 1H), 5.56 (dd, J = 17.5, 2.3 Hz, 1H), 5.39 (dd, J = 11.0, 2.3 Hz, 1H), 3.75 (t, J = 6.1 Hz, 2H), 2.66 – 2.54 (m, 4H), 2.18 (s, 3H), 2.14 (s, 3H), 2.09 (s, 3H), 2.04 – 1.97 (m, 2H), 1.86-1.72 (m, 2H), 1.58 – 1.51 (m, 3H), 1.45 – 1.25 (m, 12H), 1.24 (s, 3H), 1.17 – 1.03 (m, 6H), 0.88 (s, 3H), 0.87 – 0.84 (m, 9H). ¹³C NMR (100 MHz, CDCl₃) δ 148.1, 147.8, 127.9, 125.8, 125.6, 122.8, 117.6, 117.5, 90.3, 79.9, 74.8, 71.0, 40.1, 39.4, 37.5, 37.5, 37.5, 37.3, 32.8, 32.7, 31.4, 29.3, 28.0, 24.9, 24.5, 23.9, 22.8, 22.7, 21.1, 20.7, 19.8, 19.7, 16.3, 12.7, 11.83, 11.81. HR-MS (APCI⁺): m/z calculated for C₃₆H₅₉NO₂ (M+H⁺): 523.4510, found: 523.4515.

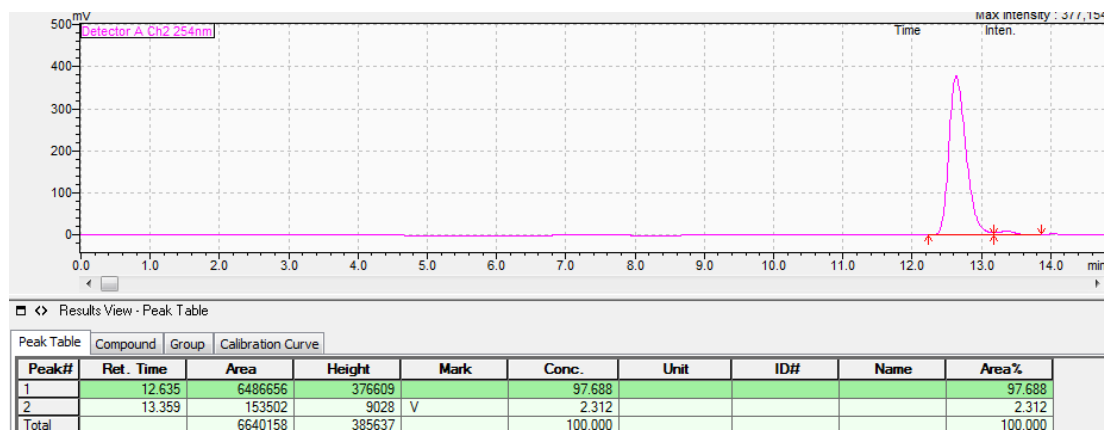
Late-stage modification of a drug (Vitamin E)



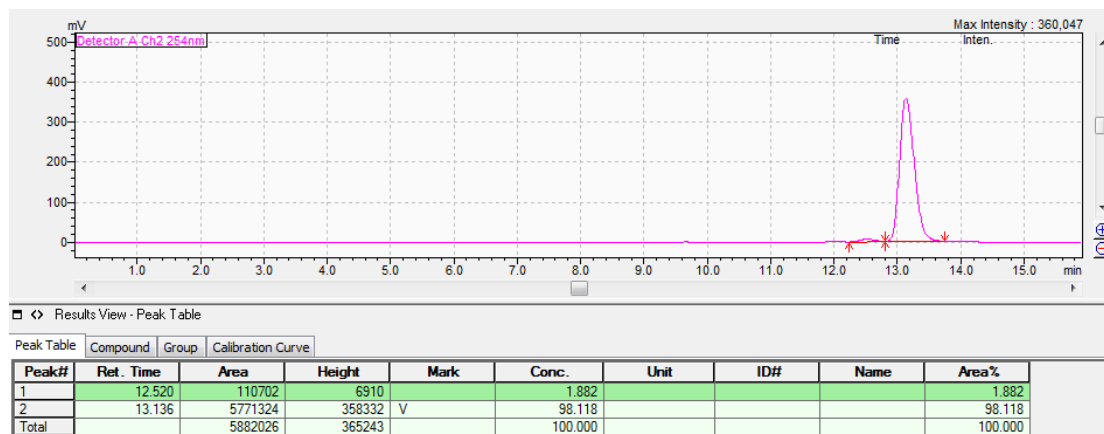
CuOAc (4 mol %, 0.9 mg) and $(S,S)\text{-Ph-BPE}$ (6 mol %, 6.1 mg) were dissolved in cyclohexane (1 mL) in a screw-capped vial under argon atmosphere. The resulting mixture was stirred for 5 min, to which was added $(\text{EtO})_2\text{SiHMe}$ (0.4 mmol, 65 μL), enynes derived from natural products (0.2 mmol), and quinoline *N*-oxide (0.4 mmol) successively. The vial was stirred at 5 °C for 20 hours. The mixture was stirred with silica gel for 30 min. Then the mixture was filtered and concentrated under vacuum. The pure product was obtained by flash chromatography on silica with a mixture of ethyl acetate/hexane (1:100 to 1:50). The *dr* value of allene product was determined by HPLC.

^1H NMR (400 MHz, CDCl_3) δ 8.08 (d, J = 8.4 Hz, 1H), 8.00 (d, J = 8.6 Hz, 1H), 7.76 (dd, J = 8.2, 1.4 Hz, 1H), 7.70 – 7.65 (m, 2H), 7.48 (ddd, J = 8.1, 6.9, 1.2 Hz, 1H), 5.76–5.64 (m, 1H), 3.85 (t, J = 6.8 Hz, 2H), 3.08 – 2.91 (m, 2H), 2.61 (t, J = 6.8 Hz, 2H), 2.25 (s, 3H), 2.20 (s, 3H), 2.14 (s, 3H), 1.89 (d, J = 7.1 Hz, 3H), 1.86 – 1.75 (m, 2H), 1.61 – 1.54 (m, 2H), 1.51 – 1.05 (m, 24H), 0.92 (s, 3H), 0.92 – 0.88 (m, 9H). ^{13}C NMR (100 MHz, CDCl_3) δ 208.0, 156.4, 148.6, 148.1, 147.7, 135.2, 129.5, 129.1, 128.0, 127.3, 126.7, 125.9, 125.8, 122.7, 120.5, 117.4, 107.9, 90.7, 74.7, 73.0, 40.2, 39.4, 37.6, 37.5, 37.5, 37.4, 32.9, 32.8, 31.4, 28.9, 28.0, 25.1, 24.9, 24.5, 24.0, 22.8, 22.7, 21.1, 20.7, 19.8, 19.7, 14.3, 12.9, 12.0, 11.9. HR-MS (APCI $^+$): *m/z* calculated for $\text{C}_{45}\text{H}_{66}\text{NO}_2$ ($\text{M}+\text{H}^+$): 652.5088, found: 652.5082.

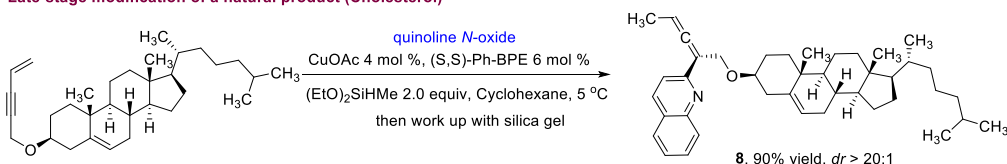
HPLC condition ($(S,S)\text{-Ph-BPE}$ ligand): Chiral column IB, *n*-hexane/*i*-PrOH = 99.7: 0.3, flow rate = 0.5 mL/min, wavelength = 254 nm, t_{R} = 12.6 min for the major enantiomer, t_{R} = 13.4 min for the minor enantiomer.



HPLC condition ((*R,R*)-Ph-BPE ligand, 77% yield): Chiral column IB, *n*-hexane/*i*-PrOH = 99.7: 0.3, flow rate = 0.5 mL/min, wavelength = 254 nm, t_R = 12.5 min for the minor enantiomer, t_R = 13.1 min for the major enantiomer.

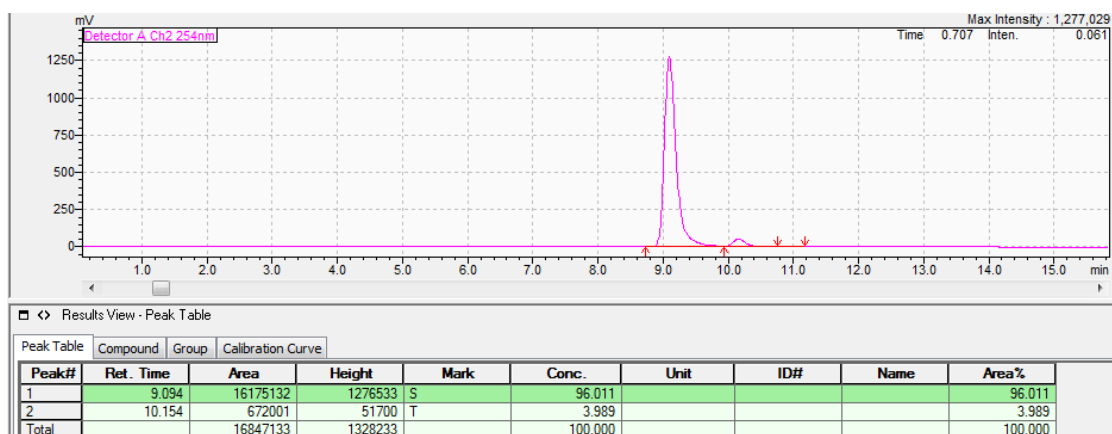


Late-stage modification of a natural product (Cholesterol)

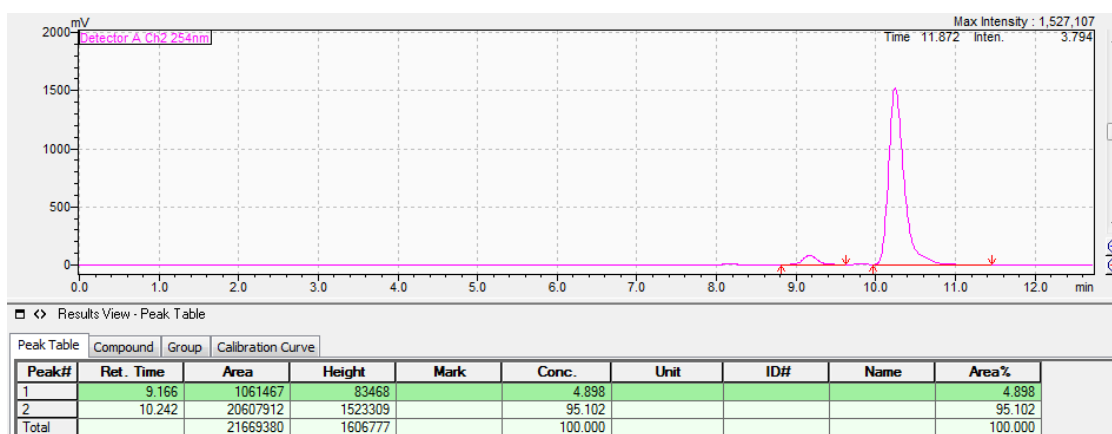


¹H NMR (400 MHz, CDCl₃) δ 8.06 – 8.01 (m, 1H), 7.99 (dd, *J* = 8.7, 0.8 Hz, 1H), 7.73 (dd, *J* = 8.0, 1.4 Hz, 1H), 7.68 – 7.60 (m, 2H), 7.46 (ddd, *J* = 8.1, 6.9, 1.2 Hz, 1H), 5.84 – 5.66 (m, 1H), 5.35 (dd, *J* = 5.1, 2.3 Hz, 1H), 4.82 (q, *J* = 2.2 Hz, 2H), 3.44 (ddd, *J* = 11.2, 6.8, 4.5 Hz, 1H), 2.56 – 2.42 (m, 1H), 2.36 – 2.23 (m, 1H), 2.09 – 1.94 (m, 3H), 1.92 – 1.78 (m, 5H), 1.64 – 0.96 (m, 24H), 0.94 – 0.86 (m, 9H), 0.68 (s, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 208.2, 155.3, 148.0, 141.3, 135.4, 129.5, 129.1, 127.4, 126.7, 125.9, 121.4, 120.4, 106.3, 91.2, 78.8, 65.6, 56.8, 56.2, 50.3, 42.4, 39.9, 39.6, 39.3, 37.5, 37.0, 36.2, 35.8, 32.00, 31.95, 28.5, 28.3, 28.0, 24.3, 23.9, 22.9, 22.6, 21.1, 19.5, 18.8, 13.9, 11.9. HR-MS (APCI⁺): *m/z* calculated for C₄₁H₅₈NO (*M*+H⁺): 580.4513, found: 580.4523.

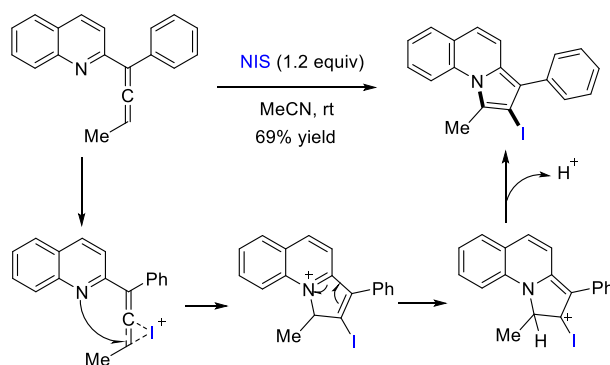
HPLC condition ((*S,S*)-Ph-BPE ligand): Chiral column IB, *n*-hexane/*i*-PrOH = 98: 2, flow rate = 0.5 mL/min, wavelength = 254 nm, t_R = 9.1 min for the major enantiomer, t_R = 10.1 min for the minor enantiomer.



HPLC condition ((*R,R*)-Ph-BPE ligand, 88% yield): Chiral column IB, *n*-hexane/*i*-PrOH = 98: 2, flow rate = 0.5 mL/min, wavelength = 254 nm, t_R = 9.2 min for the major enantiomer, t_R = 10.2 min for the minor enantiomer.

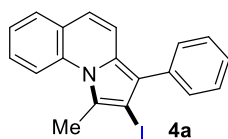


NIS-mediated cyclization of allene

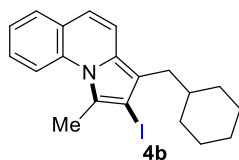


Allene product (0.2 mmol) was dissolved in 2 mL MeCN, to which was added NIS (0.24 mmol). The resulting mixture was stirred at rt for 5 min. After that, the reaction was quenched with

Na₂SO₃ and extracted with EA. The pure product was obtained after flash chromatography on silica as a light yellow solid in 69% yield.

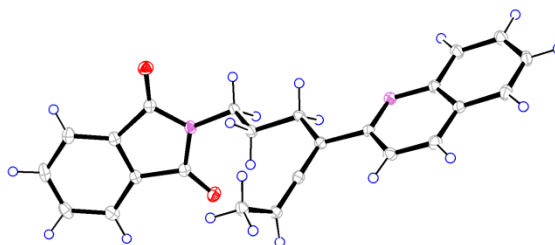


¹H NMR (400 MHz, CDCl₃) δ 8.35 (d, J = 8.5 Hz, 1H), 7.62 (dd, J = 7.7, 1.6 Hz, 1H), 7.55 – 7.43 (m, 5H), 7.41 – 7.36 (m, 1H), 7.33 (ddd, J = 8.0, 7.3, 1.0 Hz, 1H), 7.28 (d, J = 9.4 Hz, 1H), 6.91 (d, J = 9.3 Hz, 1H), 3.11 (s, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 135.3, 135.1, 130.6, 129.5, 128.4, 128.2, 127.0, 126.9, 126.8, 125.5, 123.8, 120.6, 119.3, 117.6, 116.5, 78.8, 19.8. ¹³C (DEPT 135) NMR (100 MHz, CDCl₃) δ 130.6, 128.4, 128.2, 127.00, 126.9, 123.8, 119.3, 117.6, 116.5, 19.9. GC-MS (EI): calculated for C₁₉H₁₄NI: 383.0, found: 383.1.



Colorless oil, 58.1 mg, 72% yield. ¹H NMR (400 MHz, CDCl₃) δ 8.27 (d, J = 8.6 Hz, 1H), 7.59 (dd, J = 7.7, 1.7 Hz, 1H), 7.42 (ddd, J = 8.7, 7.2, 1.7 Hz, 1H), 7.28 (ddd, J = 8.0, 7.2, 1.0 Hz, 1H), 7.21 (d, J = 9.3 Hz, 1H), 6.85 (d, J = 9.3 Hz, 1H), 3.02 (s, 3H), 2.61 (d, J = 7.1 Hz, 2H), 1.77 – 1.56 (m, 6H), 1.23 – 1.13 (m, 3H), 1.12-1.01 (m, 2H). ¹³C NMR (100 MHz, CDCl₃) δ 135.3, 129.2, 128.3, 126.7, 125.6, 125.3, 123.3, 117.7, 117.4, 117.3, 116.3, 81.1, 39.5, 35.2, 33.5, 26.6, 26.4, 19.6. GC-MS (EI): calculated for C₂₀H₂₂NI: 403.1, found: 403.2.

X-Ray Crystallographic Structure (3k)

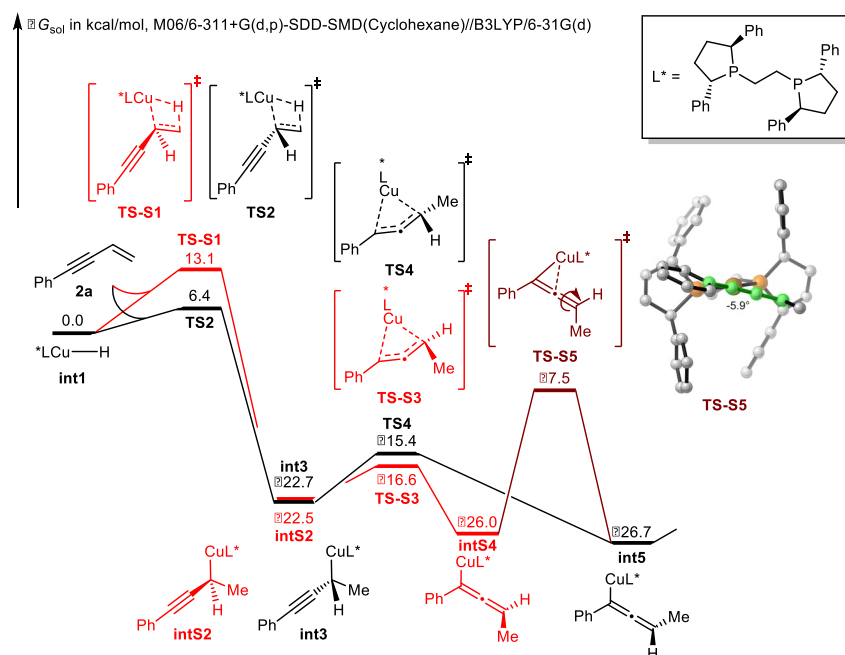


Supplementary Figure 17

DFT Calculations

Computational Methods

All DFT calculations were performed with the Gaussian 09 software package⁴. Geometry optimizations of all the minima and transition states were carried out at the M06^{5,6} level of theory with the LANL2DZ⁷⁻⁹ basis set for copper and the 6-31G(d) basis set for the other atoms. Vibrational frequencies were computed at the same level to evaluate its zero-point vibrational energy (ZPVE) and thermal corrections at 298 K, and to check whether each optimized structure is a transition state or not. The single-point energies and solvent effects in cyclohexane were computed at the M06 level of theory with the SDD¹⁰⁻¹² basis set for copper and the 6-311+G(d,p) basis set for the other atoms, using the gas-phase optimized structures. Solvation energies were evaluated by a self-consistent reaction field (SCRF) using the SMD model¹³. The 3D diagrams of molecules were generated using CYLView¹⁴. In addition, to correct the Gibbs free energies under pressure of 1 atm to the standard state in solution (1 mol/L), a correction of $RT\ln(c_s/c_g)$ (about 1.9 kcal/mol) is added to energies of all species except carbon dioxide. c_s is the standard molar concentration in solution (1 mol/L), c_g is the standard molar concentration in gas phase (0.0446 mol/L), and R is the gas constant.



Supplementary Figure 18. DFT-computed free energy changes of epimerization of allenyl copper intermediate **int5**.

The enantioselective hydrocupration generates the enantiomeric propargyl copper intermediates **int3** and **intS2**. Both intermediates can undergo the stereospecific isomerization to the corresponding allenyl copper species (**int3** to **int5**, **intS2** to **intS4**). However, the enantiomeric allenyl copper intermediates **intS4** and **int5** can epimerize through **TS-S5**. **TS-S5** is the transition state of the rotation of allenyl moiety. **TS-S5** is about 20 kcal/mol higher than the two allenyl copper intermediates, which is higher in free energy as compared to the subsequent C-C bond formation step via **TS7**. However, if the subsequent transformation requires a barrier competitive or higher than 20 kcal/mol, **intS4** and **int5** can epimerize, and the enantioselectivity is affected by the C-C bond formation steps.

Supplementary Table 2. Zero-point correction (*ZPE*), thermal correction to enthalpy (*TCH*), thermal correction to Gibbs free energy (*TCG*), energies (*E*), enthalpies (*H*), and Gibbs free energies (*G*) (in Hartree) of the structures calculated at the M06/6-311+G(d,p)-SDD-SMD(Cyclohexane)//B3LYP/6-31G(d)-LANL2DZ level of theory

Structure s	<i>ZPE</i>	<i>TCH</i>	<i>TCG</i>	<i>E</i>	<i>H</i>	<i>G</i>	Imaginary Frequency
int1	0.6169	0.6531	0.5446	-2197.331	-2196.678	-2196.787	
	84	49	59	75	601	091	
1a	0.1404	0.1488	0.1081	-476.8809	-476.7320	-476.7728	
	18	66	6	63	97	03	
2a	0.1437	0.1535	0.1087	-385.5938	-385.4402	-385.4850	
	58	73	27	05	32	78	
(EtO) ₂ Me	0.1867	0.1998	0.1469	-638.8527	-638.6528	-638.7058	
SiH	77	82	08	68	86	6	
TS2	0.7620	0.8075	0.6777	-2582.936	-2582.129	-2582.259	739.3i
	87	04	74	798	294	024	
int3	0.7671	0.8132	0.6801	-2582.985	-2582.172	-2582.305	
	94	63	79	532	269	353	
TS4	0.7666	0.8119	0.6830	-2582.976	-2582.164	-2582.293	79.8i
	51	78	58	794	816	736	
int5	0.7668	0.8130	0.6793	-2582.991	-2582.178	-2582.311	
	48	27	87	066	039	679	
int6	0.9093	0.9646	0.8131	-3059.884	-3058.920	-3059.071	
	08	55	3	897	242	767	
TS7	0.9093	0.9635	0.8168	-3059.873	-3058.909	-3059.056	204.7i
	44	7	01	247	677	446	
int8	0.9103	0.9649	0.8139	-3059.890	-3058.925	-3059.076	
	52	59	49	339	38	39	
TS9	1.1015	1.1684	0.9913	-3698.747	-3697.579	-3697.756	55.2i
	74	83	97	921	438	524	
int10	0.4808	0.5122	0.4158	-1501.412	-1500.899	-1500.996	
	45	95	96	031	736	135	
TS11	0.9082	0.9627	0.8126	-3059.863	-3058.900	-3059.050	370.1i
	09	92	27	534	742	907	
TS12	0.9082	0.9627	0.8142	-3059.856	-3058.894	-3059.042	249.0i
	63	36	67	991	255	724	
TS13	0.9069	0.9619	0.8098	-3059.851	-3058.889	-3059.041	111.0i
	64	53	93	537	584	644	
TS-S1	0.7625	0.8077	0.6789	-2582.927	-2582.119	-2582.248	708.4i
	39	81	18	205	424	287	
intS2	0.7672	0.8132	0.6806	-2582.985	-2582.172	-2582.304	
	5	62	82	627	365	945	
TS-S3	0.7665	0.8118	0.6831	-2582.978	-2582.166	-2582.295	73.1i
	9	83	85	825	942	64	

intS4	0.7668 27	0.813	0.6797 24	-2582.990 354	-2582.177 354	-2582.310 63	
TS-S5	0.7652 51	0.8110 49	0.6806 09	-2582.961 644	-2582.150 595	-2582.281 035	240.5i

Supplementary Table 3. Cartesian coordinates of the structures

int1

P	0.93713005	1.34764433	0.04380109
C	0.16160037	3.07989948	-0.16621621
C	1.30713517	3.98061855	-0.67139665
C	2.58837390	3.51450235	0.03063886
C	2.70807744	1.98609133	-0.19435170
H	1.08853853	5.03787422	-0.47663494
H	1.43720505	3.87428124	-1.75563363
H	3.47999784	4.02880991	-0.34713721
H	2.52802704	3.72529957	1.10628725
P	-0.93709247	-1.34766043	0.04386489
C	-0.16161007	-3.07992898	-0.16615181
C	-1.30715890	-3.98062439	-0.67134039
C	-2.58839691	-3.51448318	0.03068212
C	-2.70805536	-1.98606558	-0.19429033
H	-1.08858554	-5.03788613	-0.47658209
H	-1.43721269	-3.87427743	-1.75557844
H	-3.48002786	-4.02876160	-0.34711982
H	-2.52808045	-3.72530608	1.10632776
H	-0.05334055	3.37098901	0.86971817
H	2.94903468	1.82792196	-1.25423879
C	-0.64590495	-0.42162754	-1.56304141
H	-0.64515867	-1.10568318	-2.42060005
H	-1.51620651	0.23650283	-1.67080040
C	0.64591506	0.42157259	-1.56307165
H	0.05332083	-3.37101800	0.86978584
H	-2.94899156	-1.82788406	-1.25418028
C	1.14924481	-3.08725673	-0.92202498
C	3.63411327	-2.98889633	-2.25993937
C	2.33267849	-2.76748403	-0.23315974
C	1.24007961	-3.36433320	-2.29428540
C	2.47052425	-3.31830349	-2.95554132
C	3.56050155	-2.71280750	-0.89186011
H	2.28646338	-2.55246813	0.83237665
H	0.35111389	-3.63015883	-2.85856276
H	2.51597708	-3.54430451	-4.01793177
H	4.45577866	-2.45047963	-0.33535626
H	4.58963546	-2.95322846	-2.77628615

C	-3.77314883	-1.30328332	0.63974918
C	-5.82097363	-0.09835833	2.15580963
C	-3.61234618	-1.08599406	2.01766515
C	-4.97474671	-0.90295331	0.03769561
C	-5.99234322	-0.30725288	0.78624839
C	-4.62683592	-0.48878384	2.76676561
H	-2.67935763	-1.35424304	2.50636988
H	-5.11577184	-1.06142865	-1.02963901
H	-6.91697725	-0.00857966	0.29852519
H	-4.47629273	-0.32154272	3.82985652
H	-6.60899627	0.36753981	2.74156961
C	3.77316687	1.30332314	0.63970382
C	5.82096363	0.09839719	2.15579941
C	4.97471722	0.90285991	0.03764439
C	3.61239644	1.08616383	2.01764486
C	4.62687380	0.48895502	2.76676342
C	5.99229933	0.30715769	0.78621363
H	5.11571435	1.06123170	-1.02971000
H	2.67944299	1.35451845	2.50635913
H	4.47635844	0.32181998	3.82987553
H	6.91689630	0.00838018	0.29848483
H	6.60897843	-0.36749854	2.74157245
C	-1.14925735	3.08720443	-0.92208906
C	-3.63414071	2.98883308	-2.25998070
C	-1.24011045	3.36428595	-2.29434868
C	-2.33268377	2.76742416	-0.23321428
C	-3.56051389	2.71274773	-0.89190092
C	-2.47056122	3.31824546	-2.95559278
H	-0.35115506	3.63011864	-2.85863734
H	-2.28645850	2.55240414	0.83232137
H	-4.45578298	2.45041810	-0.33538676
H	-2.51602507	3.54424568	-4.01798436
H	-4.58966832	2.95316200	-2.77631695
H	0.64513790	1.10560887	-2.42064504
H	1.51621435	-0.23655840	-1.67084066
Cu	0.00001572	0.00004455	1.84106151
H	-0.00000410	0.00005890	3.41923953

1a

C	2.69705700	0.37903900	-0.00013000
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C	0.33155900	0.95922300	-0.00003800
C	0.03310600	-0.43217000	0.00005800
C	1.05191400	-1.40339100	0.00004200

C	2.37058600	-0.99774500	-0.00004800
H	-0.51118100	2.96355900	-0.00013000
H	3.73974800	0.68418900	-0.00020000
H	1.95077100	2.39090800	-0.00019800
C	-0.73043200	1.90057700	-0.00005300
H	0.75896600	-2.44568200	0.00012300
H	3.16386000	-1.73956000	-0.00005500
C	-2.29573500	0.05876500	0.00007500
C	-2.02578100	1.43398100	-0.00002700
H	-3.29061500	-0.36592800	0.00007500
H	-2.87000100	2.11614600	-0.00008800
N	-1.30897700	-0.86702900	0.00018700
O	-1.57342700	-2.11509900	0.00008300

2a

C	0.48616700	-0.08303500	-0.00002600
C	1.30734500	-1.22928900	-0.00000300
C	1.09465100	1.18902700	-0.00000900
C	2.69392900	-1.10251400	0.00003400
H	0.84377400	-2.21099600	-0.00001500
C	-0.93300700	-0.20777700	-0.00006500
C	2.48204800	1.30615500	0.00002800
H	0.46649400	2.07446600	-0.00002600
C	3.28645100	0.16324600	0.00004900
H	3.31492500	-1.99426500	0.00005200
C	-2.14699800	-0.29619100	-0.00008700
H	2.93788000	2.29260300	0.00003900
H	4.36880900	0.25844500	0.00007900
C	-3.55781800	-0.45167700	-0.00009200
C	-4.44163600	0.56077300	0.00012600
H	-3.92684000	-1.47760200	-0.00029500
H	-4.12220300	1.59850300	0.00033100
H	-5.50963500	0.36653600	0.00010100

(EtO)₂MeSiH

Si	-0.12081000	1.25992800	-0.14799000
O	-0.08191000	-0.08618200	0.84401100
O	-0.29941000	0.73809300	-1.71060300
C	0.40113300	-0.15123200	2.17211700
H	1.18555900	1.97313400	0.02367700
C	0.58705000	-0.10191300	-2.43277900
C	0.62970600	-1.60044600	2.56764900
H	1.34530700	0.42125000	2.27207800
H	-0.32746400	0.31398200	2.86527100

C	0.17001300	-1.56354200	-2.35018900
H	1.62681400	0.01857400	-2.06895900
H	0.57808500	0.23792100	-3.48321100
H	0.98167100	-1.66856100	3.60967400
H	1.38309400	-2.06733500	1.91387100
H	-0.30502200	-2.17533300	2.47641400
H	-0.85487400	-1.69267800	-2.73239900
H	0.19274900	-1.91228000	-1.30661700
H	0.84649600	-2.19441600	-2.95019000
C	-1.57565300	2.36869300	0.21932800
H	-1.53613100	2.74734800	1.25392600
H	-1.58961500	3.23567900	-0.46056500
H	-2.52022800	1.81627400	0.09073400

TS2

P	2.40835898	-0.43926186	0.20561900
C	2.03757896	-0.17210188	-1.61383900
C	3.94156294	0.64153820	0.55576099
C	1.02462991	0.95836908	-1.88432799
H	1.63254000	-1.12438689	-1.97442899
H	2.96306595	0.02119616	-2.17103400
C	3.43366505	-2.05044282	0.14696099
Cu	0.38245997	0.17282605	1.28573701
C	5.14631898	-0.24041575	0.18216598
C	3.87061088	2.03645620	-0.02888601
H	3.92581094	0.73953720	1.64918299
P	-0.49067708	0.89113602	-0.78098998
H	1.49125887	1.93022210	-1.68784699
H	0.73464091	0.94472007	-2.94257199
C	4.83223304	-1.65307976	0.68509099
C	2.81443510	-3.23981585	0.84751000
H	3.53995905	-2.29488482	-0.91748601
H	5.28249097	-0.27022874	-0.90645702
H	6.07571996	0.15434629	0.61144898
C	3.07294284	3.00297816	0.60978000
C	4.55202086	2.40809323	-1.19744601
C	-1.76884304	-0.14649803	-1.73836997
C	-1.35181215	2.53865798	-1.20104697
H	5.58519907	-2.38485573	0.36926698
H	4.82177504	-1.66121576	1.78245199
C	2.48988611	-3.19978286	2.21300400
C	2.57986715	-4.43026486	0.14659100
C	2.95244279	4.29177816	0.09156700
H	2.52495386	2.72882614	1.50808100

C	4.43714580	3.70195722	-1.71419501
H	5.19087188	1.69496325	-1.70970301
C	-2.49746009	0.86061394	-2.64659497
C	-1.20841099	-1.40251101	-2.36627798
H	-2.46708802	-0.45337206	-0.95010297
C	-2.71682013	2.12596793	-1.81127197
C	-1.45475818	3.53022598	-0.06341597
H	-0.74861117	2.99028001	-1.99916598
C	1.95282116	-4.31484988	2.85602500
H	2.65129808	-2.28446386	2.77759100
C	2.04167620	-5.54965188	0.78637700
H	2.82182814	-4.48140984	-0.91259700
C	3.63545677	4.64775619	-1.07502500
H	2.31982476	5.01421913	0.59974001
H	4.98087879	3.96812825	-2.61718801
H	-3.44258107	0.44320890	-3.01467196
H	-1.88866810	1.10899396	-3.52594897
C	-1.03646494	-2.54341600	-1.56222698
C	-0.83015200	-1.48099999	-3.71516198
H	-3.13263417	2.94964691	-2.40367096
H	-3.43321912	1.91569490	-1.00761696
C	-2.10046516	3.20171395	1.13907703
C	-0.93239724	4.82268600	-0.20577297
C	1.72635320	-5.49607389	2.14429500
H	1.70867216	-4.26085589	3.91368800
H	1.87286223	-6.46349689	0.22239500
H	3.54863272	5.65374619	-1.47716100
C	-0.49495489	-3.71706098	-2.08580398
H	-1.33604694	-2.50025202	-0.51811398
C	-0.29119095	-2.65791297	-4.24224198
H	-0.96567504	-0.62596100	-4.37069898
C	-2.22703319	4.14204094	2.16081003
H	-2.49510412	2.19877793	1.28291503
C	-1.05439427	5.76606599	0.81733803
H	-0.42729225	5.09445602	-1.13029898
H	1.30717024	-6.36443791	2.64505600
C	-0.11731690	-3.77926796	-3.43012999
H	-0.36935186	-4.58238998	-1.44085899
H	-0.01251996	-2.69664696	-5.29241799
C	-1.70494625	5.42870797	2.00463403
H	-2.73040918	3.86752792	3.08424304
H	-0.64598731	6.76456101	0.68228503
H	0.29835913	-4.69508395	-3.84234099
H	-1.80380427	6.15999596	2.80241903

C	-0.37685401	-0.14574298	3.30674502
C	-0.89484797	-1.21158100	2.51499902
H	0.43536800	-0.37365195	3.98925701
H	-1.06588004	0.61160199	3.66521302
C	-2.19196697	-1.18578005	1.96755503
H	-0.33418693	-2.14132198	2.45940102
C	-3.32855998	-1.17600410	1.50732004
C	-4.64399198	-1.15288215	0.97488104
C	-5.15088894	-2.24673017	0.23477505
C	-5.48640103	-0.03144219	1.16220605
C	-6.43943695	-2.21474823	-0.29040995
H	-4.51780691	-3.11562815	0.08107804
C	-6.77233503	-0.00942124	0.62940206
H	-5.11719406	0.81396983	1.73584505
C	-7.25932199	-1.09836426	-0.09960094
H	-6.80687291	-3.06852724	-0.85461995
H	-7.40084207	0.86366373	0.78760006
H	-8.26439099	-1.07804630	-0.51184893
H	0.57868293	1.14618006	2.59693501

int3

P	2.41946700	0.34260713	0.25221402
C	3.34677394	1.94561014	0.71818913
C	4.84284095	1.60040519	0.57490317
C	5.02021198	0.15986317	1.06710110
C	3.99373004	-0.72061882	0.31087502
H	5.46311891	2.31029318	1.13576023
H	5.15653299	1.65938326	-0.47475381
H	6.03782700	-0.21342779	0.90282012
H	4.83027594	0.10527611	2.14691509
P	-0.68729696	0.53442710	-0.88438509
C	-1.48733388	-0.93668988	-1.79015920
C	-2.52454986	-0.30883687	-2.74062620
C	-3.18622493	0.83859607	-1.96906317
C	-2.05859598	1.74489608	-1.40817008
H	-3.25602483	-1.05749987	-3.06817027
H	-2.04139884	0.09050320	-3.64213816
H	-3.86618792	1.42514308	-2.59842416
H	-3.78195495	0.43199801	-1.14307821
H	3.13478789	2.04765108	1.79021913
H	4.33442208	-0.80620776	-0.72935597
C	0.74559406	1.09111320	-1.96362201
H	0.53462811	0.91627325	-3.02592402
H	0.81374202	2.17587319	-1.82113295

C	2.09099107	0.43298222	-1.59291699
H	-2.03880089	-1.43619694	-0.98424124
H	-1.64619196	2.32505514	-2.24403303
C	-0.49444583	-1.92705382	-2.35479721
C	1.42963327	-3.76916571	-3.29144624
C	0.06072017	-2.89443985	-1.49824924
C	-0.07267478	-1.91030074	-3.69270319
C	0.87821627	-2.82374469	-4.15679121
C	1.01488322	-3.80196380	-1.95688225
H	-0.26510887	-2.93103991	-0.46096225
H	-0.49392477	-1.19049572	-4.38826417
H	1.18326431	-2.79609262	-5.19995619
H	1.43385121	-4.53241782	-1.27061427
H	2.16800430	-4.47931867	-3.65423124
C	-2.50937205	2.71162801	-0.33305104
C	-3.41164518	4.53481388	1.61811302
C	-2.91828208	2.26223193	0.93362492
C	-2.55824008	4.08655302	-0.60050198
C	-3.00634415	4.99303696	0.36401906
C	-3.36536015	3.16614187	1.89778595
H	-2.87603506	1.20251892	1.17512286
H	-2.24560606	4.45154108	-1.57676594
H	-3.04163617	6.05467397	0.13185711
H	-3.67573217	2.79779481	2.87213892
H	-3.76089023	5.23616283	2.37129604
C	3.82612406	-2.11786585	0.86940094
C	3.60116010	-4.73139492	1.90088680
C	4.26965712	-3.22376580	0.13128890
C	3.26354802	-2.34489994	2.13559591
C	3.15230904	-3.63804897	2.64625484
C	4.16101014	-4.52005783	0.64024883
H	4.70667315	-3.06806674	-0.85278008
H	2.89037897	-1.50755798	2.71908394
H	2.70842701	-3.79148303	3.62620481
H	4.51569919	-5.36207379	0.05129180
H	3.51300912	-5.73832394	2.29971174
C	2.83114092	3.19166016	0.03157818
C	1.74981890	5.47922119	-1.22097374
C	3.40398795	3.71011824	-1.13943677
C	1.71003988	3.84986509	0.56575817
C	1.17005087	4.97667411	-0.05294779
C	2.86996494	4.84385325	-1.75783873
H	4.28000398	3.23888029	-1.57483276
H	1.25246086	3.46834703	1.47602313

H	0.29490284	5.45562106	0.37636020
H	3.33564696	5.23051431	-2.66073570
H	1.33601489	6.36049920	-1.70353271
H	2.91288207	0.94727827	-2.10667493
H	2.09838312	-0.60963876	-1.93273905
Cu	0.33985498	-0.09007499	1.29141292
H	-1.39010615	1.07691384	3.68024891
C	-2.95537899	-1.64465311	1.73748371
C	-1.91234902	-1.29374111	2.28165077
C	-0.69037706	-0.84184910	2.87446984
H	-0.09844204	-1.69993910	3.22007782
C	-0.87990513	0.16889283	4.02313888
H	0.09185684	0.47534984	4.43039994
H	-1.47277115	-0.24347923	4.85549584
C	-4.15111495	-2.06487412	1.09616564
C	-5.30206498	-1.24067615	1.07446564
C	-4.23097289	-3.32121509	0.44883858
C	-6.46744494	-1.65505216	0.43444658
H	-5.26593903	-0.27556518	1.57171270
C	-5.40104685	-3.72552509	-0.18835949
H	-3.36164987	-3.97256406	0.46078658
C	-6.52795488	-2.89812912	-0.20238849
H	-7.33716296	-1.00206618	0.43515158
H	-5.43422180	-4.69681607	-0.67654554
H	-7.43972285	-3.21817713	-0.69935154

TS4

P	0.14791999	1.96352391	0.30754500
C	-0.34469097	1.95505093	-1.50198701
C	-1.04311003	3.19525391	1.14971999
C	-1.37956597	0.87530494	-1.87588404
H	0.58663704	1.77782293	-2.05150299
H	-0.71882996	2.94111594	-1.80515801
C	1.58815900	3.21526390	0.28777105
Cu	-0.10060804	-0.29969309	0.97705398
C	-0.37540901	4.57414191	0.99573001
C	-2.48905902	3.05047992	0.72712995
H	-0.97596105	2.91009090	2.20776198
P	-1.06990099	-0.80447807	-1.10231605
H	-2.37216997	1.17179294	-1.51746706
H	-1.44120794	0.79060095	-2.96811205
C	1.12493798	4.36441490	1.22029105
C	2.95779498	2.66995789	0.63032107
H	1.62158302	3.60970791	-0.73609195

H	-0.80211303	5.30084590	1.69835101
H	-0.53356399	4.97300092	-0.01430899
C	-3.25750503	2.00460992	1.26891792
C	-3.09777199	3.90218994	-0.20662606
C	-2.61606399	-1.75877905	-1.68218710
C	0.08736903	-1.74900606	-2.29724603
H	1.70749299	5.27250090	1.02470707
H	1.31054595	4.08603889	2.26577805
C	3.18739795	1.93580988	1.80411107
C	4.04961901	2.94607689	-0.20470690
C	-4.58226503	1.80839593	0.88076989
H	-2.80144206	1.33029191	1.99027193
C	-4.42812698	3.71187095	-0.59136509
H	-2.54213697	4.73109094	-0.63428704
C	-2.04495998	-2.99805905	-2.41405709
C	-3.64711401	-2.07930306	-0.62342012
H	-3.08856797	-1.11772104	-2.43821410
C	-0.84550795	-2.52986705	-3.24342606
C	1.17621405	-0.90515006	-2.92370900
H	0.57365301	-2.47134707	-1.63042403
C	4.47099794	1.50205987	2.13655610
H	2.35547094	1.68601088	2.45750605
C	5.33589800	2.51185288	0.12335813
H	3.89059503	3.51185790	-1.12026990
C	-5.17423400	2.66327095	-0.05342912
H	-5.14941904	0.98500093	1.30523387
H	-4.87958196	4.38995296	-1.31128509
H	-2.82029396	-3.46704404	-3.03151412
H	-1.72459000	-3.74782506	-1.67932409
C	-3.32202904	-2.82838407	0.51835188
C	-4.97603001	-1.66586205	-0.79002215
H	-0.31288795	-3.36711505	-3.71074006
H	-1.20543093	-1.88603704	-4.05562306
C	2.38766503	-0.73074708	-2.23244497
C	1.02309108	-0.26193005	-4.16216600
C	5.55133696	1.78969887	1.29786013
H	4.62463292	0.93068586	3.04789810
H	6.16788501	2.74146989	-0.53756785
H	-6.20847399	2.51638595	-0.35314714
C	-4.29899907	-3.16098107	1.45632685
H	-2.29457205	-3.14407508	0.68117590
C	-5.95674503	-1.99470805	0.14873282
H	-5.24687598	-1.08333604	-1.66802515
C	3.40329605	0.07163192	-2.75277494

H	2.53396201	-1.23012709	-1.27794497
C	2.04194910	0.53680195	-4.68749297
H	0.10843209	-0.38579204	-4.73470402
H	6.55044996	1.45048886	1.55768415
C	-5.62111606	-2.74613706	1.27553882
H	-4.02604209	-3.74182008	2.33318185
H	-6.98195203	-1.66743504	-0.00506420
C	3.23414508	0.71146593	-3.98331994
H	4.32614104	0.19467991	-2.19317392
H	1.90212012	1.01857896	-5.65203897
H	-6.38100308	-3.00682607	2.00730280
H	4.02697109	1.33135593	-4.39372891
C	0.62263491	-1.38616911	2.64356298
C	-0.39476910	-0.67386011	3.24865597
C	1.44027693	-1.86387411	1.80719800
C	-1.63795311	-1.34976511	3.79828793
H	-0.10441110	0.24966688	3.75501598
C	2.53844493	-2.73564511	1.50672302
H	-2.49373311	-0.66224510	3.80450292
H	-1.50330714	-1.70309512	4.83313593
H	-1.91812010	-2.21549510	3.18991192
C	3.80767694	-2.22996812	1.14203405
C	2.37399092	-4.14077611	1.52929500
C	4.85846995	-3.09028712	0.83120807
H	3.95661695	-1.15433312	1.11660006
C	3.42853293	-4.99152011	1.20833402
H	1.40745392	-4.55061311	1.81027597
C	4.68025694	-4.47641612	0.85778205
H	5.82659996	-2.67250612	0.56361109
H	3.27316392	-6.06776711	1.23885200
H	5.50084694	-5.14352412	0.60814006

int5

Cu	0.28367100	0.78562400	-0.04397300
P	0.45057300	-1.18210000	-1.35626300
C	1.11949400	2.51468800	0.43626000
C	-0.47113100	-2.51549100	-0.40988500
C	2.04306400	-2.08789200	-1.85556100
C	-0.24943900	-1.18809500	-3.13319700
C	2.10259800	3.24324400	-0.40205800
C	0.79989200	2.92428000	1.63965200
C	-1.72932900	-2.00583900	0.32399800
H	0.25303000	-2.89787700	0.31949200
H	-0.73691000	-3.34895600	-1.07176300

C	2.09104400	-1.94306000	-3.39717900
C	3.29927400	-1.64900800	-1.13220800
H	1.86864800	-3.14833800	-1.62958400
C	0.66500000	-2.14750300	-3.92193000
C	-1.74650700	-1.39185200	-3.21509000
H	-0.03515700	-0.16989200	-3.48232200
C	2.02190200	3.19006000	-1.80682400
C	3.15844400	3.99467200	0.15429900
C	0.41886700	3.29703500	2.85083400
P	-1.45885600	-0.37772600	1.21651300
H	-2.52684100	-1.81003400	-0.40241300
H	-2.09497500	-2.78013300	1.00950600
H	2.79839100	-2.66230100	-3.82638500
H	2.45178900	-0.94127200	-3.66383000
C	3.69457100	-0.30272800	-1.08913700
C	4.11338400	-2.60308900	-0.50562200
H	0.58822700	-1.96202300	-5.00036700
H	0.37056000	-3.19092400	-3.75350000
C	-2.59587400	-0.28792000	-3.02514500
C	-2.33542200	-2.64496300	-3.44140600
C	2.93724600	3.86214800	-2.61837300
H	1.21424700	2.61399600	-2.25425400
C	4.08236900	4.65672900	-0.65274600
H	3.24284200	4.05049800	1.23652900
C	1.11399500	2.90168000	4.13721200
H	-0.43806900	3.96798200	2.95485600
C	-3.22954000	0.12273100	1.68652900
C	-0.98205100	-0.81105800	3.01114500
C	4.86885000	0.07613900	-0.43824700
H	3.07681300	0.46553900	-1.54525500
C	5.29205600	-2.22773600	0.14333900
H	3.82254200	-3.65146900	-0.52813100
C	-3.98279800	-0.43021400	-3.04708300
H	-2.16162700	0.69434800	-2.85164800
C	-3.72509200	-2.78957100	-3.47171100
H	-1.71340500	-3.51938700	-3.60755500
C	3.97798700	4.59662000	-2.04603500
H	2.83957600	3.80927700	-3.70068600
H	4.88816700	5.22507800	-0.19292000
H	1.50820800	3.77784400	4.67215100
H	0.43016500	2.39332800	4.83386500
H	1.95409200	2.22778500	3.93790700
C	-3.18102400	0.28724700	3.22729000
C	-3.78015300	1.32059400	0.94060300

H	-3.86405400	-0.74541900	1.46401600
C	-2.31419900	-0.84780400	3.78532200
C	-0.04058800	-1.98852200	3.13330000
H	-0.43849100	0.08694500	3.33074100
C	5.67265700	-0.88515900	0.17976400
H	5.14323500	1.12685900	-0.40814500
H	5.91117900	-2.98513500	0.61781600
C	-4.55438100	-1.68566800	-3.27111000
H	-4.61248800	0.43978800	-2.88471800
H	-4.15731100	-3.76981400	-3.65600900
H	4.69902900	5.11261900	-2.67494700
H	-4.19499000	0.28127700	3.64448100
H	-2.73404200	1.25741800	3.47834600
C	-3.06869200	2.52905600	0.86213900
C	-5.04201000	1.24790700	0.33434600
H	-2.14384800	-0.74643200	4.86434800
H	-2.83125200	-1.80326600	3.62906300
C	1.33437500	-1.78381600	2.92084700
C	-0.47770000	-3.29124500	3.41589500
H	6.58692500	-0.58925200	0.68739400
H	-5.63470100	-1.80033500	-3.29513700
C	-3.61003600	3.62984700	0.19742200
H	-2.08003200	2.60899700	1.30750500
C	-5.58620700	2.34992100	-0.32988700
H	-5.60623600	0.31884200	0.38577400
C	2.23893400	-2.84365800	2.97536700
H	1.69480500	-0.78031100	2.70530400
C	0.42802300	-4.35394100	3.47935400
H	-1.52981700	-3.48604800	3.60164900
C	-4.87009300	3.54574300	-0.40085700
H	-3.04040100	4.55372100	0.14319300
H	-6.56922100	2.27274800	-0.78799900
C	1.78783600	-4.13664400	3.25552600
H	3.29375100	-2.65664200	2.79532500
H	0.06596400	-5.35319800	3.70795300
H	-5.28854700	4.40486700	-0.91845800
H	2.49044800	-4.96419800	3.30537000

int6

C	1.92806643	-4.32472187	-0.61110693
C	1.49099242	-5.53537047	0.18583526
C	1.15735719	-3.29362555	-0.91735340
H	2.95543874	-4.34269107	-0.98276851
H	0.43433527	-5.45835835	0.46420106

H	2.07914876	-5.66130533	1.10784411
H	1.61091809	-6.46354368	-0.39139699
C	0.37805479	-2.28069234	-1.19866045
C	-0.41460023	-2.30513597	-2.45707713
C	0.14584184	-2.71468116	-3.68462997
C	-1.76302240	-1.89551075	-2.46785091
C	-0.60389076	-2.71793400	-4.86141595
H	1.18333339	-3.03849614	-3.69975686
C	-2.52060701	-1.91981321	-3.64053089
H	-2.20942509	-1.55994852	-1.53519395
C	-1.94430330	-2.32380568	-4.84828032
H	-0.13998763	-3.03560208	-5.79286804
H	-3.56644405	-1.61991716	-3.61269012
H	-2.53070979	-2.33130561	-5.76351497
C	-6.35193055	-2.19265937	1.63084626
C	-5.60022379	-3.31368132	1.90715955
C	-4.18136598	-3.26640102	1.87177370
C	-3.56816017	-2.02202344	1.54929319
C	-4.34122388	-0.88067297	1.25833614
C	-5.71768733	-0.97254623	1.29974696
H	-3.82323622	-5.34769028	2.37958659
H	-7.43648626	-2.24520480	1.66100535
H	-6.08062156	-4.25678107	2.15350181
C	-3.36334000	-4.39535676	2.13439708
H	-3.83468583	0.03736476	0.99161804
H	-6.31762552	-0.09651055	1.07163433
C	-1.41717812	-3.01991351	1.75028175
C	-1.99658229	-4.25957630	2.06069915
H	-0.35297310	-2.86139062	1.64862465
H	-1.33261129	-5.09899613	2.23607668
N	-2.17023566	-1.92960650	1.52092851
O	-1.62223259	-0.77652194	1.26217587
Cu	0.28187826	-0.63176468	-0.02958951
P	1.52131579	0.67576689	1.53818326
P	0.09518500	1.53047262	-1.35008457
C	0.46867616	1.10888087	3.08239192
C	3.06063153	0.31755579	2.58267468
C	2.02161325	2.26147278	0.68091177
C	1.17487597	1.26868993	-2.91317581
C	-1.12433841	2.67266919	-2.28494922
C	0.98230817	2.81829857	-0.30943750
C	1.38239096	0.85983973	4.30838263
H	-0.29830628	0.32856126	3.05372975
C	-0.24657972	2.44193390	3.03648091

C	2.45562732	-0.16491508	3.92074356
H	3.52052464	1.29735165	2.77625631
C	4.12896018	-0.58315508	2.00296570
H	2.27713232	3.03189494	1.41847964
H	2.94311800	2.00323696	0.14571614
C	0.60073434	2.21126796	-3.99113436
H	0.92256606	0.24146224	-3.20159969
C	2.66712993	1.31979757	-2.65938020
C	-0.91277611	2.29774389	-3.76960934
H	-0.73184442	3.68922009	-2.14691932
C	-2.56043145	2.66774840	-1.81434721
H	1.45773789	3.57301669	-0.94851809
H	0.18102769	3.32143801	0.24556060
H	0.78636014	0.52951138	5.16778291
H	1.88081038	1.78829840	4.61016678
C	0.36809546	3.65098657	3.40154350
C	-1.57796912	2.48808214	2.58981165
H	3.23405141	-0.25650247	4.68768607
H	2.01380646	-1.16223765	3.79119836
C	5.47253139	-0.18604350	2.08578066
C	3.83836319	-1.83158121	1.43284343
H	0.85138823	1.84799863	-4.99530105
H	1.02665040	3.21807082	-3.89971847
C	3.31664029	0.16836262	-2.17883671
C	3.43494359	2.47933528	-2.84812955
H	-1.38494303	3.04037538	-4.42456554
H	-1.37913973	1.32904951	-3.98833337
C	-3.38419975	1.53981307	-1.95720935
C	-3.11843244	3.82546690	-1.25227786
C	-0.32342030	4.86169850	3.32374587
H	1.39517836	3.65601850	3.75627071
C	-2.26990918	3.69696332	2.50816156
H	-2.06210470	1.56025841	2.29636358
C	6.50059126	-1.01100158	1.62759080
H	5.71543540	0.78179830	2.52002608
C	4.86532978	-2.65919803	0.97595704
H	2.80874388	-2.15682552	1.31416517
C	4.67999045	0.18071361	-1.88443763
H	2.73743912	-0.73777705	-2.01644245
C	4.80318531	2.49064344	-2.56261388
H	2.97373118	3.38547991	-3.22961157
C	-4.72189803	1.57578516	-1.56207401
H	-2.97586167	0.62826061	-2.38238945
C	-4.45587236	3.86412482	-0.85161090

H	-2.49888311	4.71158230	-1.13337161
C	-1.64545916	4.89088398	2.87624979
H	0.17363409	5.78323047	3.61653094
H	-3.29581202	3.70383738	2.15062461
C	6.19939332	-2.25622976	1.07350168
H	7.53342689	-0.68065321	1.70511107
H	4.61295639	-3.61947993	0.53639837
C	5.43068558	1.34387923	-2.07555175
H	5.15277617	-0.71729284	-1.49729186
H	5.37644430	3.40055801	-2.72338601
C	-5.26547266	2.73819017	-1.00757736
H	-5.34158976	0.69189901	-1.69068480
H	-4.86539663	4.77783424	-0.42792291
H	-2.18331423	5.83354602	2.81812636
H	6.99534636	-2.90521061	0.71737587
H	6.49355142	1.35367024	-1.84890914
H	-6.31029421	2.76841314	-0.70888382

TS7

C	2.48779490	-2.94217704	-0.72380344
C	2.92688783	-4.39154506	-0.71837768
C	1.21731491	-2.56741097	-0.77690538
H	3.27967493	-2.19568909	-0.69320631
H	2.06696479	-5.06859002	-0.74786180
H	3.51824681	-4.62245124	0.17748529
H	3.56336982	-4.61857695	-1.58537671
C	-0.08229708	-2.38984492	-0.71084836
C	-0.98737407	-2.46701368	-1.88130138
C	-0.53179309	-2.88524449	-3.14994445
C	-2.35518206	-2.16665863	-1.75026934
C	-1.39843408	-2.97718326	-4.23696447
H	0.51835690	-3.13999952	-3.26940148
C	-3.22773706	-2.26501841	-2.83649436
H	-2.73415305	-1.86438178	-0.77993229
C	-2.75397807	-2.66571522	-4.08706242
H	-1.01768209	-3.29856412	-5.20384452
H	-4.28043505	-2.02867438	-2.70223133
H	-3.43221907	-2.74334805	-4.93285544
C	-5.73230511	-2.64065213	2.14446156
C	-4.94976316	-3.70893310	1.73776039
C	-3.55391315	-3.57670214	1.58726442
C	-2.95597809	-2.31288221	1.86912363
C	-3.75694504	-1.22756924	2.27976581
C	-5.12588905	-1.39855020	2.41367877

H	-3.14473525	-5.62548005	0.97079107
H	-6.80605611	-2.75985709	2.25689653
H	-5.40380120	-4.67360604	1.52283822
C	-2.70517220	-4.64997211	1.16171324
H	-3.27759600	-0.28135230	2.49095097
H	-5.73675501	-0.55938623	2.73690091
C	-0.78234313	-3.15334821	1.24463351
C	-1.36623319	-4.44741315	1.02358428
H	0.25507987	-3.07202331	1.54139053
H	-0.70365623	-5.24832113	0.71147515
N	-1.58297208	-2.17616926	1.77233567
O	-1.01808903	-0.97484132	1.96077587
Cu	0.14652901	-0.45797310	0.27557297
P	1.77793107	0.95395363	1.41532821
P	-0.08389389	1.37136719	-1.35856073
C	1.07637510	1.75957340	2.99709335
C	3.52529506	0.76140142	2.18016319
C	2.09341115	2.38495281	0.24424946
C	0.74473710	0.90529043	-3.02764180
C	-1.48894784	2.31943640	-2.22487658
C	0.88505017	2.79418202	-0.61964448
C	2.30723312	2.20310320	3.80636843
H	0.61650106	0.90597134	3.51245820
C	-0.00925085	2.78995749	2.76703251
C	3.34564606	1.08821017	3.68473625
H	4.11608010	1.56999847	1.73142133
C	4.25758600	-0.53914258	1.93317598
H	2.45726619	3.26011370	0.79794161
H	2.91253014	2.05071088	-0.40427659
C	-0.14568787	1.52111666	-4.13524170
H	0.61140204	-0.18114556	-3.06005898
C	2.22843211	1.18898838	-3.12750874
C	-1.57846986	1.62419964	-3.60309969
H	-1.09405579	3.33059741	-2.39835340
C	-2.81042484	2.45881135	-1.50304656
H	1.21874121	3.48382013	-1.40408936
H	0.15481620	3.33291595	-0.00515439
H	2.03994012	2.40655904	4.85095946
H	2.72769216	3.13046625	3.39671259
C	0.22040822	4.17027346	2.86187375
C	-1.30433687	2.34958961	2.44105543
H	4.30941007	1.36314205	4.12996330
H	2.99195502	0.19752210	4.21788410
C	5.45304700	-0.54416151	1.20015299

C	3.81292993	-1.75193465	2.48294777
H	-0.08745489	0.91467081	-5.04687080
H	0.20735018	2.52527569	-4.39857553
C	3.14684306	0.16139829	-2.85441891
C	2.74030717	2.45168041	-3.47053253
H	-2.22705983	2.19530679	-4.27841860
H	-2.02193191	0.62650564	-3.49456686
C	-3.50268189	1.35009829	-0.99451875
C	-3.40714778	3.72293336	-1.38784735
C	-0.81147874	5.08556655	2.63268689
H	1.20312523	4.54636337	3.12948382
C	-2.33127382	3.26276370	2.20650258
H	-1.49070192	1.28070763	2.35947725
C	6.19378894	-1.71690252	1.03454179
H	5.81480305	0.38492055	0.76482114
C	4.55657688	-2.92164366	2.33183758
H	2.87881693	-1.78329869	3.03796576
C	4.52288007	0.38791423	-2.90884086
H	2.77509801	-0.82612174	-2.59441508
C	4.11652619	2.68065035	-3.52821248
H	2.06370322	3.26902348	-3.70368139
C	-4.75506689	1.49993126	-0.39793773
H	-3.05683594	0.36404829	-1.06608792
C	-4.66174177	3.87770132	-0.79513033
H	-2.88550273	4.59628540	-1.77385820
C	-2.08922176	4.63625967	2.30133881
H	-0.61135468	6.15092553	2.71798408
H	-3.32021584	2.90247379	1.93963951
C	5.75281588	-2.90918959	1.60940659
H	7.12127895	-1.69350047	0.46806180
H	4.19953983	-3.84620371	2.77793842
C	5.01548913	1.65092226	-3.24447565
H	5.20878303	-0.42718284	-2.69292200
H	4.48518924	3.66658938	-3.80005931
C	-5.34196683	2.76459027	-0.29821453
H	-5.26640694	0.62570621	-0.00411289
H	-5.10605173	4.86735233	-0.72360417
H	-2.89116972	5.34638974	2.11851593
H	6.33284884	-3.82089560	1.49455544
H	6.08647014	1.82912922	-3.29284761
H	-6.31962983	2.88035524	0.16253149
int8			
C	-1.16900589	-4.63340343	-0.00650791

C	-1.72772796	-6.03903850	-0.00209181
C	-1.88621532	-3.53852258	-0.04625148
H	-0.08189390	-4.54576805	0.04790729
H	-2.82088260	-6.03507749	-0.03647613
H	-1.41241916	-6.57717852	0.90135205
H	-1.35679644	-6.61211718	-0.86207515
C	-2.62313574	-2.44481943	-0.03720035
C	-3.07705365	-1.80973237	-1.30867641
C	-2.89034433	-2.47365378	-2.53865980
C	-3.71856005	-0.55795050	-1.33487114
C	-3.32290812	-1.91544525	-3.73880688
H	-2.40882124	-3.44747135	-2.54193647
C	-4.15825078	-0.00203798	-2.53943594
H	-3.87741341	-0.01596233	-0.41258660
C	-3.96541153	-0.67312240	-3.74749353
H	-3.17097094	-2.45888927	-4.66828778
H	-4.65787312	0.96341258	-2.52574409
H	-4.31703988	-0.24105640	-4.68077835
C	-4.71897541	2.46475613	3.54248435
C	-5.36720213	1.33544935	3.04014486
C	-4.65695557	0.28930625	2.44299833
C	-3.23841014	0.38339135	2.31584759
C	-2.58458459	1.50905884	2.86031112
C	-3.32354499	2.52882173	3.45773942
H	-6.37735416	-1.00972388	2.06655693
H	-5.28560139	3.26545396	4.00886725
H	-6.44882582	1.24359627	3.12402050
C	-5.29571132	-0.92802132	1.97467377
H	-1.50474402	1.55245072	2.80941742
H	-2.79635430	3.38693657	3.86985177
C	-3.07371074	-1.91179958	1.34934664
C	-4.58049682	-1.94691355	1.47460439
H	-2.62476396	-2.61103725	2.08078548
H	-5.05871971	-2.87357923	1.16770966
N	-2.54081432	-0.57787627	1.61949798
O	-1.16206084	-0.59995050	1.79770589
Cu	0.00406145	0.05958949	0.44437965
P	2.36920047	0.11799965	1.17345707
P	0.65760542	0.82913026	-1.61773178
C	2.98336605	1.54251181	2.29518562
C	3.43190652	-1.18385109	2.05171560
C	3.24821815	0.31608858	-0.46997255
C	0.44693537	-0.34007082	-3.10686018
C	0.02255925	2.34525071	-2.56166819

C	2.48738057	1.21683345	-1.46520079
C	4.16639261	0.95148663	3.08934638
H	2.14924614	1.67255095	2.99630783
C	3.19783259	2.86485343	1.59265682
C	3.82025268	-0.50894402	3.39271143
H	4.35018138	-1.28841077	1.45781030
C	2.81371232	-2.55741125	2.22368314
H	4.26688492	0.69998301	-0.33655187
H	3.33615657	-0.69838674	-0.87828608
C	0.16302662	0.58595832	-4.30824618
H	-0.48679015	-0.86523612	-2.87414836
C	1.53798608	-1.37925437	-3.24068387
C	-0.70196527	1.74168294	-3.79057341
H	0.92321046	2.85440592	-2.93069577
C	-0.78877982	3.34607394	-1.76479979
H	2.97027572	1.17265857	-2.44867336
H	2.53351577	2.25897641	-1.12868677
H	4.35254020	1.53304137	4.00070477
H	5.08774900	0.98266847	2.49457500
C	4.43500550	3.24546061	1.04914413
C	2.11497900	3.74889625	1.44827599
H	4.65249715	-1.04570596	3.86312962
H	2.97142153	-0.56162755	4.08684012
C	3.62081001	-3.69324670	2.05778250
C	1.47649620	-2.73524730	2.61386837
H	-0.33241206	0.02896331	-5.11230141
H	1.09568012	0.99100971	-4.72117510
C	1.41979982	-2.58363984	-2.52505264
C	2.68568692	-1.18785918	-4.02517229
H	-0.86138687	2.51369677	-4.55276215
H	-1.68911930	1.36777958	-3.49425282
C	-1.85289422	2.95401479	-0.93785714
C	-0.50040657	4.71387371	-1.87577528
C	4.58195163	4.46353319	0.38121886
H	5.29980498	2.59675101	1.15216421
C	2.25692724	4.96334386	0.77717718
H	1.14776214	3.47906670	1.86637235
C	3.11879031	-4.97438012	2.29180134
H	4.65746999	-3.57066094	1.74953382
C	0.97606923	-4.01692241	2.85123542
H	0.80280820	-1.88662794	2.70862662
C	2.41876651	-3.55527047	-2.57950751
H	0.53095277	-2.75869640	-1.92325146
C	3.68463255	-2.16301373	-4.08605597

H	2.80443522	-0.27810664	-4.60661000
C	-2.60213766	3.90157379	-0.23860737
H	-2.09206971	1.90023528	-0.82762650
C	-1.25449894	5.66611394	-1.18635619
H	0.32185507	5.03630717	-2.51143019
C	3.49422027	5.32619127	0.23912963
H	5.55230204	4.73819127	-0.02467529
H	1.39828207	5.62014004	0.67349766
C	1.79305609	-5.13952726	2.69665196
H	3.76373585	-5.83968984	2.16042999
H	-0.06322426	-4.13200740	3.14519009
C	3.55880160	-3.34810689	-3.36041175
H	2.30304384	-4.47661471	-2.01489675
H	4.56120090	-1.99412003	-4.70636858
C	-2.30646154	5.26141536	-0.36270199
H	-3.40367685	3.57257419	0.41626862
H	-1.01770465	6.72195733	-1.29288419
H	3.61061528	6.27417841	-0.27920931
H	1.39820651	-6.13475405	2.88452387
H	4.33611987	-4.10586513	-3.40871010
H	-2.89005465	5.99867499	0.18219620

TS9

C	0.60158209	-4.15113126	1.28314418
C	0.68234513	-5.54924437	1.85517692
C	-0.42277395	-3.67103514	0.62299933
H	1.46812110	-3.50975929	1.45644525
H	-0.21657188	-6.12890133	1.62707286
H	0.80125819	-5.51330957	2.94587292
H	1.55280511	-6.08486329	1.45485477
C	-1.48129298	-3.20230802	-0.00949852
C	-1.63592107	-3.37514874	-1.48542354
C	-0.83756510	-4.31064361	-2.17385677
C	-2.57376611	-2.64114061	-2.23535835
C	-0.96178918	-4.50023836	-3.54790379
H	-0.11691807	-4.90017772	-1.61464792
C	-2.70350819	-2.83911935	-3.61247538
H	-3.20593808	-1.91189370	-1.74775818
C	-1.90027522	-3.76544322	-4.27873360
H	-0.33250521	-5.23303526	-4.04662097
H	-3.44627522	-2.26609825	-4.16212323
H	-2.01012728	-3.92200302	-5.34864463
C	-6.59518400	0.58665899	-0.14189452
C	-6.45245599	-0.79697503	-0.05752479

C	-5.21227397	-1.38929907	0.20731203
C	-4.06317797	-0.56821910	0.37314512
C	-4.21303098	0.82867791	0.30090939
C	-5.46625099	1.38796696	0.05395257
H	-5.94848296	-3.44647409	0.30594069
H	-7.56645101	1.03180902	-0.33586438
H	-7.31877600	-1.44494501	-0.17572886
C	-5.06071196	-2.82334711	0.39360775
H	-3.35240797	1.46141988	0.47417746
H	-5.56232899	2.47129596	0.03481078
C	-2.60676093	-2.57250219	0.85802266
C	-3.88020294	-3.37164816	0.70925158
H	-2.25934388	-2.64319338	1.89983263
H	-3.78355493	-4.43867220	0.89083338
N	-2.82437596	-1.16127613	0.54692494
O	-1.80042793	-0.32638121	1.00082504
Cu	-0.30032699	0.44071999	-0.06059590
Si	-1.51767683	0.36614045	2.83064015
O	-3.09922281	-0.15467061	3.10394914
O	-1.57912577	1.62026922	4.01211839
C	-3.84018975	0.04317516	4.29766722
H	-0.69038689	1.26758563	1.84995327
C	-0.55564576	2.55143418	4.23381351
C	-5.18927475	-0.65354181	4.16415717
H	-3.97852874	1.11457013	4.48437043
H	-3.29180670	-0.36144300	5.16292111
C	-1.04384271	3.63847800	5.18721474
H	0.33822727	2.06358611	4.66536836
H	-0.23333981	3.01401336	3.28421358
H	-5.78075670	-0.52236999	5.07922423
H	-5.75331280	-0.24097266	3.32120428
H	-5.05640376	-1.72688378	3.98761396
H	-1.91360973	4.15208108	4.76312888
H	-1.34371465	3.19963382	6.14498667
H	-0.25688670	4.37977497	5.37428083
C	-0.30352579	-0.89768669	3.55055984
H	0.59408923	-0.38610375	3.92292789
H	0.01039717	-1.65623155	2.82759568
H	-0.76321574	-1.41022085	4.40552477
P	0.78278289	0.73221636	-2.03584991
C	1.04950584	-0.88935645	-3.01164123
C	-0.03641919	1.61524864	-3.49939470
C	2.41532590	1.62803735	-1.93287784
C	0.58960376	-0.57822218	-4.45580215

H	0.31072387	-1.56871354	-2.57494732
C	2.41464985	-1.52490548	-2.84792543
C	-0.54317224	0.44990580	-4.37946989
H	0.79576378	2.09097774	-4.03645066
C	-1.05613318	2.68614558	-3.18648144
H	2.90587484	1.57149054	-2.91304287
H	2.14097890	2.67691532	-1.77246262
C	3.40624196	1.17317115	-0.84621098
H	0.27322273	-1.50313309	-4.94995330
H	1.41232872	-0.15761807	-5.04620911
C	2.61371591	-2.46522967	-1.82318561
C	3.50837080	-1.20020932	-3.66576843
H	-0.83270430	0.82109599	-5.36954580
H	-1.43359621	-0.00602829	-3.93018292
C	-2.25730114	2.39834245	-2.52036143
C	-0.83011521	4.00295866	-3.61199321
P	2.69650406	0.89672082	0.87164701
H	4.22991796	1.89783114	-0.80796889
H	3.84319595	0.20871620	-1.12867018
C	3.86279393	-3.04862771	-1.61131080
H	1.77873195	-2.74296579	-1.18542062
C	4.75856482	-1.78878436	-3.46096861
H	3.39382276	-0.48702517	-4.47687829
C	-3.20407213	3.39775240	-2.29508018
H	-2.46358312	1.38981738	-2.17205060
C	-1.77458020	5.00614561	-3.38542696
H	0.09441176	4.24399876	-4.13231421
C	2.73261310	2.63619067	1.69540934
C	4.30535111	0.36107866	1.76301482
C	4.94291988	-2.71168855	-2.43050779
H	3.99138697	-3.76292086	-0.80325694
H	5.58831278	-1.52436623	-4.11162561
C	-2.96717316	4.70560948	-2.72614795
H	-4.12861010	3.14464731	-1.78577418
H	-1.57919722	6.01852868	-3.72980078
C	4.06776314	2.71896953	2.46351728
H	1.92723014	2.56387653	2.43558137
C	2.39397104	3.78824984	0.77244357
C	4.39288118	1.31440143	2.97764099
H	5.13114307	0.61931179	1.08641582
C	4.42948213	-1.10699040	2.10545654
H	5.91610889	-3.16805158	-2.27093293
H	-3.70828315	5.48120245	-2.55247576
H	4.00532019	3.45533638	3.27429142

H	4.87934810	3.04296166	1.80088529
C	3.36944000	4.55386497	0.11437666
C	1.04343103	4.09994688	0.53266171
H	5.38642720	1.26068735	3.43912893
H	3.66744022	1.01430629	3.74507498
C	5.51335611	-1.85149931	1.61832934
C	3.50963218	-1.75222556	2.94756447
C	3.00848395	5.58776613	-0.75419213
H	4.42424101	4.35732494	0.28040656
C	0.67991998	5.12727405	-0.33740008
H	0.27041606	3.52088279	1.03154764
C	5.68290913	-3.19441337	1.96381707
H	6.23781207	-1.37096318	0.96440839
C	3.67828720	-3.09183663	3.29954421
H	2.65019820	-1.20818464	3.32822062
C	1.66382994	5.87735017	-0.98724699
H	3.78486292	6.16925622	-1.24531306
H	-0.37133603	5.33881308	-0.50985498
C	4.76600518	-3.82021953	2.80920301
H	6.53571411	-3.74699130	1.57746092
H	2.95801924	-3.56584576	3.96134116
H	1.38410790	6.68183330	-1.66204383
H	4.89795420	-4.86245459	3.08729381

int10

C	-1.34277881	0.34411795	-2.81998704
C	-1.57792677	-0.19225113	-4.21273401
C	-1.35942987	-0.36430298	-1.72036200
H	-1.13575579	1.41249995	-2.72990910
H	-0.70254674	-0.01152919	-4.84970499
H	-2.42954674	0.31264486	-4.68684508
H	-1.77723779	-1.26763913	-4.20067396
C	-1.33879293	-1.04158291	-0.58994395
C	-2.58078997	-1.27609884	0.20060001
C	-2.55435803	-1.35803375	1.60475402
C	-3.82151395	-1.41035985	-0.44840103
C	-3.72934506	-1.56551868	2.32924698
H	-1.61518104	-1.22941074	2.13278405
C	-4.99335298	-1.61387978	0.27692394
H	-3.85514990	-1.36161491	-1.53310903
C	-4.95323704	-1.69626369	1.67126994
H	-3.68549210	-1.62000862	3.41403299
H	-5.93900996	-1.71976579	-0.24862610
H	-5.86563606	-1.86319964	2.23739692

C	4.97209199	-1.90066897	0.77766635
C	4.14132502	-2.51870601	-0.15685064
C	2.80718103	-2.12759799	-0.30916472
C	2.30013903	-1.06533393	0.48169419
C	3.13071200	-0.45391089	1.42430119
C	4.45502399	-0.87603791	1.57017027
H	2.30711807	-3.48853408	-1.95882166
H	6.00480698	-2.21807299	0.88848341
H	4.51982302	-3.33007606	-0.77465958
C	1.89490005	-2.79152503	-1.23256372
H	2.74395299	0.33976616	2.04772613
H	5.08283797	-0.39218388	2.31375826
C	-0.01159596	-1.64819891	-0.10927586
C	0.57536406	-2.57870699	-1.15506878
H	-0.12809993	-3.09737402	-1.79819178
N	0.98849705	-0.60217592	0.18939811
O	0.47972402	0.22473516	1.24843604
Si	0.46399307	1.89245514	0.92342994
O	1.80681512	2.34602006	0.09726597
O	-0.83997188	2.37568111	0.02702486
C	2.00520617	2.30598097	-1.32088702
C	-2.18106990	2.49112717	0.51311080
C	3.41948120	2.77132991	-1.62859400
H	1.26731921	2.95815195	-1.80586209
H	1.84474917	1.28411895	-1.68320597
C	-3.02652584	3.21855913	-0.52056628
H	-2.59054693	1.49325519	0.70660084
H	-2.18656992	3.04794423	1.46125476
H	3.59808524	2.75646484	-2.71029299
H	3.57841521	3.79206293	-1.26439005
H	4.15083416	2.11502793	-1.14600693
H	-2.61405081	4.21190811	-0.72747433
H	-3.05690581	2.65279907	-1.45715825
H	-4.05342685	3.33621617	-0.15541533
H	-0.21873001	-2.22612785	0.80844816
C	0.48357902	2.65192924	2.62870889
H	0.31893005	3.73359024	2.57405582
H	1.45221400	2.48377125	3.11128594
H	-0.28883901	2.22028730	3.27461389

TS11

C	1.54342113	-2.48302124	2.92506464
C	2.71456814	-1.92885130	3.71837268
C	0.37335411	-1.75340426	2.82233775

H	1.38985216	-3.55898826	3.04123253
H	3.62542615	-2.49807625	3.49972160
H	2.54243716	-1.98326742	4.80162267
H	2.89388311	-0.88156126	3.45552278
C	-0.65627091	-1.09228625	2.52257684
C	-1.90234591	-0.63887335	3.12285091
C	-3.12026590	-1.29779035	2.85944187
C	-1.92289392	0.47289556	3.99055703
C	-4.30620489	-0.86744645	3.45499094
H	-3.12314789	-2.15416828	2.19111778
C	-3.11425391	0.90196847	4.57584810
H	-0.99006692	0.98472056	4.21143307
C	-4.31458690	0.23658046	4.31221306
H	-5.23124089	-1.39998145	3.24649690
H	-3.10180292	1.75566439	5.24956119
H	-5.24138090	0.57075639	4.77033211
C	7.04368605	-1.08902584	0.47952567
C	6.44970808	-2.33687687	0.58333655
C	5.05031409	-2.47328591	0.66787157
C	4.24433706	-1.29636393	0.63730471
C	4.85382002	-0.02709291	0.53767183
C	6.23401102	0.06302414	0.46149681
H	4.98299014	-4.65008192	0.74227034
H	8.12425804	-0.99957481	0.41644966
H	7.05965010	-3.23743586	0.60278644
C	4.38833312	-3.74029594	0.77193545
H	4.22281000	0.85161008	0.53679694
H	6.69704599	1.04412816	0.39052791
C	2.23011309	-2.59613402	0.95594762
C	3.03395312	-3.79766399	0.87634547
H	1.21215509	-2.61978000	0.57430564
H	2.51635015	-4.74999201	0.94731238
N	2.86715206	-1.41154897	0.66858673
O	2.12973003	-0.28627498	0.59077886
Cu	-0.01413897	-0.27223004	0.60657091
P	-0.52359101	-0.88246180	-1.73732014
P	-0.95964804	1.88636499	0.10574916
C	0.97866798	-1.14181264	-2.89675020
C	-1.52039599	-2.29391674	-2.54279027
C	-1.41877606	0.61930025	-2.41834796
C	-2.73192103	2.30745288	0.71723924
C	-0.28499407	3.59860296	0.55641733
C	-0.99676308	1.94873019	-1.76336183
C	0.50383198	-2.15332954	-3.95922330

H	1.70327200	-1.64841569	-2.24749427
C	1.62739693	0.14043643	-3.38396108
C	-0.44698798	-3.13763563	-3.27044938
H	-2.14450102	-1.82208267	-3.31314821
C	-2.42872295	-3.06919686	-1.61467633
H	-1.27904208	0.68471037	-3.50441096
H	-2.48451005	0.43860720	-2.23598296
C	-2.66224406	3.77168183	1.21791640
H	-2.84889600	1.66145079	1.59230318
C	-3.85396705	1.98316696	-0.24722777
C	-1.23275506	4.05440882	1.69078040
H	-0.47977210	4.24349305	-0.31177060
C	1.18820794	3.69027096	0.88956431
H	-1.65338511	2.75362121	-2.11327973
H	0.02561191	2.20511325	-2.06333383
H	1.35643698	-2.65891547	-4.42927137
H	-0.04690605	-1.64292947	-4.75902923
C	1.47861589	0.62390556	-4.69189003
C	2.40570993	0.88844435	-2.48107402
H	-0.91658798	-3.82781757	-3.98163245
H	0.10473205	-3.75152870	-2.54656846
C	-3.81166595	-3.09669487	-1.84504031
C	-1.92583591	-3.79679496	-0.52458642
H	-3.39955505	3.93344673	2.01320843
H	-2.90988409	4.46851891	0.40860248
C	-4.53074101	0.75739393	-0.12935288
C	-4.24761709	2.85231606	-1.27856067
H	-1.07549308	5.11490980	1.92123251
H	-1.01465002	3.48945173	2.60637833
C	1.78808598	2.85825788	1.84661420
C	1.97916090	4.66775905	0.26771639
C	2.08808885	1.81832262	-5.08896691
H	0.89893289	0.06748663	-5.42209007
C	3.00887589	2.08179441	-2.87736290
H	2.51265796	0.53705625	-1.45506206
C	-4.66736492	-3.82951998	-1.01948337
H	-4.22236699	-2.53898279	-2.68380324
C	-2.77580487	-4.53284107	0.30079452
H	-0.86008390	-3.78216496	-0.31320544
C	-5.55324002	0.40824500	-1.01259690
H	-4.25360098	0.07528585	0.66962904
C	-5.27264510	2.50692813	-2.16163168
H	-3.75913612	3.81538108	-1.39719157
C	3.13343798	3.01264488	2.18140219

H	1.21007101	2.06743381	2.31541813
C	3.32696990	4.82237305	0.59772638
H	1.53116186	5.31981912	-0.47942053
C	2.85376585	2.55302255	-4.18463885
H	1.96374882	2.16858173	-6.11073787
H	3.59845790	2.64491835	-2.15862486
C	-4.15196288	-4.55268508	0.05679455
H	-5.73527292	-3.83923599	-1.22277534
H	-2.36292984	-5.08949615	1.13801645
C	-5.92921407	1.28158710	-2.03541680
H	-6.05719900	-0.54742803	-0.89487399
H	-5.55926114	3.20071120	-2.94796460
C	3.90814094	3.99609896	1.56110728
H	3.58002301	2.35202281	2.91929411
H	3.91889087	5.58974512	0.10517945
H	3.32799482	3.48061859	-4.49485576
H	-4.81351985	-5.12721217	0.69950150
H	-6.72891608	1.01475715	-2.72128281
H	4.95616294	4.11362196	1.82399027

TS12

Cu	-0.03057299	-0.29069297	0.22398905
P	-2.13700998	-0.55283993	-0.95486199
C	0.60635498	-1.05849403	2.23011503
C	-3.15383598	0.97900806	-0.59888796
C	-3.50383598	-1.87884992	-1.06951705
C	-1.83498095	-0.55688288	-2.84574599
P	-0.82112299	2.05395802	0.70775711
C	0.22118997	-2.50234404	2.51526699
C	1.85074398	-0.72727403	1.79517806
H	0.05042097	-0.29931505	2.78141505
C	-2.32471497	2.26111105	-0.39141191
H	-3.88217396	1.14565609	-1.40243196
H	-3.72065699	0.74863904	0.31055703
C	-3.23348296	-2.56825088	-2.42752607
C	-3.64177200	-2.82323596	0.10300292
H	-4.44474698	-1.32074592	-1.16709505
C	-2.93154695	-1.46342385	-3.44344203
C	-1.65435994	0.81015314	-3.47528494
H	-0.87141395	-1.07247288	-2.91938699
C	-0.04457898	3.79220702	0.56747417
C	-1.46316002	2.38457297	2.49051211
H	0.67535297	-3.17929002	1.78344297
H	-0.86353803	-2.63997204	2.47086397

H	0.55696195	-2.82041607	3.51348698
C	3.02557399	-0.48910702	1.35398008
H	-2.97487098	3.05768805	-0.00881390
H	-1.92734496	2.60262508	-1.35343189
H	-4.09318296	-3.18163087	-2.72322410
H	-2.37402697	-3.24540289	-2.34044907
C	-2.63204701	-3.73829697	0.44028291
C	-4.82250101	-2.83299997	0.85964190
H	-2.61241893	-1.86841083	-4.41166904
H	-3.85196294	-0.89536684	-3.62459002
C	-0.37437793	1.39389114	-3.47076491
C	-2.71114693	1.53298216	-4.05089594
C	0.07575600	4.27330797	2.03376418
C	1.24616903	3.89935404	-0.21438581
H	-0.79776497	4.42022603	0.07333418
C	-1.22069601	3.88688696	2.74782515
C	-2.85087702	1.85564496	2.78952807
H	-0.75610603	1.82645494	3.11709710
C	3.31835302	-0.56416395	-0.81102091
C	4.30604598	-0.37484604	2.03985011
C	-2.80463003	-4.63934200	1.49123888
H	-1.69809300	-3.74350896	-0.11563308
C	-4.99712703	-3.73038100	1.91542187
H	-5.61775301	-2.13262796	0.61390891
C	-0.16374492	2.65910815	-4.01981087
H	0.44794806	0.84485812	-3.01596791
C	-2.49864091	2.79891718	-4.60334990
H	-3.71183193	1.11187217	-4.08361296
H	0.26336300	5.35318397	2.06868222
H	0.93323299	3.78484496	2.51467418
C	2.37437902	3.13408302	0.11997118
C	1.36030205	4.82885507	-1.25704378
H	-1.18093803	4.09461492	3.82429716
H	-2.04115301	4.48774797	2.33753016
C	-3.00604203	0.53416795	3.24217203
C	-4.01167302	2.62687797	2.61590708
N	2.28738403	-1.29169494	-1.33371995
C	4.64188402	-1.11744096	-0.93904591
H	3.16054503	0.50234805	-0.89148388
C	4.80392698	0.88015294	2.44986515
C	5.12070597	-1.50670405	2.25387908
C	-3.98830704	-4.64039602	2.23358886
H	-2.00943703	-5.33947101	1.73308087
H	-5.92475904	-3.72203002	2.48224986

C	-1.22495091	3.36846117	-4.58922186
H	0.83275608	3.09158115	-3.99726284
H	-3.33227790	3.33619820	-5.04904089
C	3.58212603	3.30800404	-0.55654179
H	2.30457701	2.38204000	0.90160716
C	2.56590906	4.99994208	-1.94230776
H	0.49640305	5.42991308	-1.53251678
C	-4.26767504	-0.00308205	3.49656200
H	-2.12484904	-0.08356906	3.39333002
C	-5.27684602	2.09456697	2.87533904
H	-3.93871801	3.65761898	2.28292811
C	2.39621502	-2.64437293	-1.57958699
O	1.09402803	-0.68309193	-1.48708595
C	4.81978102	-2.42408895	-1.27353495
H	5.48395202	-0.47518897	-0.70840088
C	6.05330497	0.99436292	3.05759317
H	4.19515099	1.76735495	2.29690417
C	6.36934297	-1.38630007	2.86322111
H	4.75559597	-2.48179104	1.94611305
H	-4.12135805	-5.34417404	3.05079084
H	-1.06000490	4.35187119	-5.02209983
C	3.68350805	4.24238407	-1.59109077
H	4.44592203	2.71386303	-0.26931180
H	2.63062207	5.72994111	-2.74523074
C	-5.41210003	0.77650196	3.31274000
H	-4.35375205	-1.03171006	3.83488596
H	-6.15760902	2.71663398	2.73733705
C	1.25892403	-3.41520991	-1.90117403
C	3.68669302	-3.25241893	-1.55934199
H	5.81686402	-2.85143395	-1.34053995
C	6.84659796	-0.13710009	3.26698915
H	6.40789697	1.97343591	3.37157721
H	6.97220196	-2.27684608	3.02606609
H	4.62480306	4.37685308	-2.11712275
H	-6.39671604	0.36373195	3.51529298
C	1.39993702	-4.76444391	-2.17955006
H	0.29481303	-2.92486091	-1.91839103
C	3.78811702	-4.62720793	-1.85685103
H	7.82079196	-0.04622611	3.73986617
C	2.66625402	-5.38108191	-2.15923907
H	0.51865503	-5.35476590	-2.41804709
H	4.77339202	-5.08767293	-1.84480703
H	2.76127402	-6.43955891	-2.38315610

TS13

Cu	-0.38264796	-0.00412605	0.52652595
C	0.50789709	2.56308002	-0.06614368
P	-2.77692397	-0.48240304	0.71681483
C	0.96835903	2.14972966	2.49837428
C	1.76011910	2.32643908	-0.61983568
P	-0.40198292	-0.89462375	-1.63821717
C	-3.18838394	-1.21700480	-0.96129528
C	-4.41443496	0.40947793	1.13181592
C	-3.10429002	-1.87835921	1.96401763
C	1.91725404	3.15923761	2.78661044
N	1.31864101	0.84948364	2.64194310
C	2.91240011	2.16825712	-1.03568368
C	-1.99696394	-1.87639172	-1.68587634
C	0.80090708	-2.07936165	-2.49900131
C	-0.42629887	0.33381445	-3.10322900
H	-4.00970195	-1.94025780	-0.87884839
H	-3.55952092	-0.37663971	-1.55952217
C	-5.00870400	-0.36778123	2.33838780
C	-4.28822995	1.90143389	1.35567013
H	-5.06607495	0.24595906	0.26472888
C	-4.62338302	-1.84534922	2.20365161
C	-2.45212703	-3.19227516	1.59368747
H	-2.61437403	-1.50987734	2.87573270
C	3.20177303	2.83569055	3.12603842
H	1.59897305	4.19269263	2.70885657
C	2.60132700	0.46017757	2.99022508
O	0.39930000	-0.09297231	2.37271096
C	4.22957112	2.10459817	-1.54356666
H	-2.27896392	-2.09719057	-2.72250338
H	-1.75206996	-2.83174279	-1.20687847
C	1.46783011	-1.19743351	-3.58299817
C	1.76772005	-2.83329878	-1.61344039
H	0.16842208	-2.81352257	-3.01683542
C	0.35843714	-0.36697540	-4.23530908
C	-1.78700886	0.89583552	-3.45656296
H	0.19492113	1.15668139	-2.73112788
H	-6.09441100	-0.22290122	2.38625380
H	-4.59417702	0.03331364	3.27135886
C	-3.49063896	2.42213974	2.38772922
C	-4.99150892	2.80119902	0.54367124
H	-4.89891405	-2.42352434	3.09461352
H	-5.16119301	-2.28730409	1.35492853
C	-1.06424903	-3.33423921	1.77622648

C	-3.16537903	-4.26708008	1.04488730
C	3.57966200	1.46264352	3.25440424
H	3.93860303	3.60810651	3.32648354
C	2.92331997	-0.90436745	3.11977690
C	5.02114914	3.27993417	-1.62836148
C	4.81719811	0.89221323	-1.98425881
H	1.99762612	-1.82477742	-4.30941425
H	2.21132011	-0.53531858	-3.12360207
C	2.60395304	-2.17368392	-0.69908128
C	1.88039003	-4.22528677	-1.73770858
H	0.75800617	0.37595669	-4.93550497
H	-0.29710586	-1.03173531	-4.81142319
C	-2.19876685	2.11262945	-2.88716980
C	-2.67652685	0.24234365	-4.32531107
C	-3.40762195	3.79745071	2.60409841
H	-2.92469999	1.74731665	3.02616914
C	-4.90850590	4.17963499	0.75547943
H	-5.61286691	2.41780714	-0.26263183
C	-0.40975504	-4.50675517	1.40103933
H	-0.49616403	-2.51161028	2.20663460
C	-2.51056204	-5.44716304	0.67874016
H	-4.24044702	-4.19705604	0.90795029
C	4.87244599	1.04995145	3.63978021
C	4.20384596	-1.26731552	3.50805988
H	2.15692497	-1.63896341	2.91297778
C	6.31726315	3.23827222	-2.12906546
H	4.59230114	4.22081613	-1.29562436
C	6.11440812	0.86429728	-2.48787079
H	4.24675810	-0.02883578	-1.91309195
C	3.53586901	-2.88804004	0.05510164
H	2.52482805	-1.09730294	-0.56932314
C	2.80858901	-4.94310088	-0.98078766
H	1.23826304	-4.75205866	-2.44064167
C	-3.45755384	2.64900050	-3.16046175
H	-1.51982586	2.64174235	-2.22387571
C	-3.93526084	0.77924271	-4.60437102
H	-2.38861485	-0.69089529	-4.80065619
C	-4.11743692	4.68300183	1.78813451
H	-2.78815596	4.17855759	3.41177047
H	-5.46646288	4.85792308	0.11504451
C	-1.13162904	-5.56928808	0.84906617
H	0.66539196	-4.58798920	1.53255034
H	-3.08428804	-6.27102897	0.26158803
C	5.18635997	-0.29329357	3.76753603

H	5.62277900	1.81227341	3.83388933
H	4.44839794	-2.32102154	3.61513874
C	6.87769714	2.03283728	-2.56678461
H	6.89739816	4.15705422	-2.18204432
H	6.53587911	-0.08276368	-2.81782391
C	3.64227300	-4.27472702	-0.08282055
H	4.17259800	-2.35581314	0.75503773
H	2.88187299	-6.02146787	-1.09764781
C	-4.33408583	1.98275063	-4.01998086
H	-3.74793784	3.59104545	-2.70338163
H	-4.60251383	0.25611881	-5.28472711
H	-4.05219991	5.75430581	1.95692566
H	-0.62226705	-6.48437505	0.55952305
H	6.18599296	-0.59426763	4.06707701
H	7.89055315	2.00538532	-2.95931459
H	4.37086398	-4.82835511	0.50376639
H	-5.31228182	2.40152768	-4.24095983
H	-0.09149697	2.33578969	2.43629428
C	0.03173411	3.99073800	0.13397151
H	-0.77091391	4.04778191	0.88351850
H	-0.36914887	4.45067213	-0.78575044
H	0.85376911	4.63385894	0.46871962
H	-0.30282591	1.89147708	-0.38311679

TS-S1

P	-0.00702909	-0.93643208	1.26975398
C	1.12669689	-2.15207704	0.40883290
C	-1.46517814	-2.05710606	1.73398485
C	2.35084693	-1.50605802	-0.26624101
H	1.46250184	-2.92306411	1.11225284
H	0.49908089	-2.64608195	-0.34170915
C	0.55832488	-0.76708825	3.09619801
Cu	0.36350301	1.09229401	0.13299517
C	-1.79370115	-1.61068018	3.17688288
C	-2.64630712	-2.11558094	0.79200982
H	-1.03982418	-3.06876009	1.80281777
P	1.94744200	0.00686108	-1.30090589
H	3.04829992	-1.15264912	0.50209603
H	2.87945291	-2.25706499	-0.86719407
C	-0.46147517	-1.57447429	3.93629392
C	2.02447486	-1.04546433	3.35102702
H	0.39022491	0.29802474	3.28462910
H	-2.51181219	-2.29824619	3.63904681
H	-2.26226412	-0.61757716	3.16335096

C	-3.17247516	-3.36635989	0.43447770
C	-3.27603707	-0.96122388	0.30275691
C	1.66112002	-0.68176776	-3.05942296
C	3.70467503	0.63089106	-1.73054580
H	-0.11374121	-2.60398832	4.08121484
H	-0.56578818	-1.13369337	4.93492795
C	2.94034190	0.02081664	3.33638213
C	2.52363181	-2.33720237	3.58653992
C	-4.30259514	-3.46782578	-0.37812333
H	-2.69414220	-4.27142894	0.80365663
C	-4.40630605	-1.05990676	-0.51096513
H	-2.88554804	0.02362109	0.54419000
C	3.06811003	-0.80531475	-3.67002394
C	0.75376198	-1.89125172	-3.11403108
H	1.14806606	0.14442731	-3.57055690
C	3.83925606	0.45417818	-3.26494781
C	4.03935007	2.01833200	-1.22856567
H	4.38746500	-0.07930901	-1.24778784
C	4.30251689	-0.19573643	3.54803814
H	2.57527294	1.02603767	3.14299321
C	3.88620380	-2.55559743	3.80115793
H	1.84742078	-3.18719534	3.61342283
C	-4.92504409	-2.31165072	-0.85266725
H	-4.69595417	-4.44800774	-0.63633543
H	-4.88453301	-0.15273772	-0.86768706
H	3.58505999	-1.68743681	-3.27163700
H	3.01979705	-0.92669466	-4.75950395
C	-0.63192102	-1.71318768	-2.95718510
C	1.23567493	-3.19603172	-3.29449819
H	4.89637907	0.40408017	-3.55163579
H	3.41422510	1.32567524	-3.77824774
C	3.38182312	3.15755207	-1.71911858
C	5.04384806	2.19822688	-0.26843763
C	4.78280784	-1.48617746	3.78275104
H	4.98704792	0.64857955	3.53623423
H	4.24475176	-3.56477946	3.98768385
H	-5.80929408	-2.38383563	-1.48076427
C	-1.50489206	-2.79962465	-2.96472821
H	-1.02671999	-0.71041868	-2.81246602
C	0.36147389	-4.28680569	-3.31152930
H	2.29759493	-3.37278675	-3.43535518
C	3.72076216	4.43271501	-1.26729947
H	2.59184214	3.04925916	-2.45880861
C	5.38440309	3.47271883	0.19006849

H	5.56737102	1.32903983	0.12387630
H	5.84227983	-1.65601352	3.95527605
C	-1.00951210	-4.09448066	-3.14266431
H	-2.56844606	-2.63446563	-2.82150022
H	0.75828886	-5.28801769	-3.46010238
C	4.72453214	4.59586090	-0.30876943
H	3.20013220	5.30041607	-1.66426440
H	6.16844708	3.58591474	0.93435152
H	-1.68801913	-4.94315163	-3.15168440
H	4.98865417	5.58924386	0.04339266
C	0.09658308	3.24592001	0.27109635
C	-0.86193491	2.78818112	-0.67824771
H	-0.26799393	3.63178994	1.21751438
H	0.99853411	3.72060101	-0.09839059
C	-2.23659392	2.69003915	-0.38324275
H	-0.57209089	2.75359121	-1.72662271
C	-3.44034493	2.67263917	-0.15986278
C	-4.83807393	2.69004720	0.08447519
C	-5.76221991	2.60458132	-0.98355984
C	-5.35048896	2.80186010	1.39747419
C	-7.13344092	2.62506635	-0.74234786
H	-5.38467289	2.53032140	-1.99943983
C	-6.72313096	2.82296513	1.62672616
H	-4.65453098	2.87287001	2.22832621
C	-7.62468094	2.73351826	0.56185113
H	-7.82418590	2.55983145	-1.57963689
H	-7.09314198	2.90954806	2.64550016
H	-8.69539695	2.74990028	0.74581211
H	1.12293402	2.11706089	1.17718527

intS2

P	2.39156105	0.34186233	0.24061093
C	2.05907599	0.54181632	-1.59512406
C	3.96246519	-0.72825646	0.22283289
C	0.72278089	1.23611015	-1.92891302
H	2.05371212	-0.48020568	-1.99251707
H	2.88755791	1.07354043	-2.07983106
C	3.32926285	1.90951445	0.79679894
Cu	0.31093312	-0.03814895	1.29798596
C	4.99506709	0.09840966	1.02963088
C	3.79983138	-2.16039849	0.68575687
H	4.29715317	-0.74298540	-0.82281812
P	-0.71403601	0.66244594	-0.86408001
H	0.80979676	2.31287816	-1.74289701

H	0.50215389	1.10851114	-2.99603502
C	4.82310890	1.56725864	0.62748991
C	2.81540668	3.19592739	0.18747697
H	3.12137087	1.94830940	1.87375895
C	-0.77415278	-0.64650112	2.90368697
H	6.01027814	-0.26893620	0.83911286
H	4.80775013	-0.02255338	2.10451289
C	3.23294445	-2.47499058	1.93073188
C	4.25641851	-3.21132442	-0.12156715
C	-2.06889218	1.90609478	-1.35438896
C	-1.53197784	-0.76926515	-1.81627401
H	5.44848682	2.23871672	1.22853991
H	5.13382586	1.68872270	-0.41769909
C	1.69125060	3.81810523	0.75747800
C	3.39159958	3.78675848	-0.94691203
C	-0.06906263	-1.63049704	3.85596495
C	-1.96370872	-1.16573627	2.29725599
H	-1.00578589	0.28821084	3.43491199
C	3.13022063	-3.79993360	2.35432586
H	2.84937535	-1.68194064	2.56667289
C	4.15686769	-4.53917944	0.30024583
H	4.69638146	-2.98741235	-1.09105816
C	-3.20165008	1.03474164	-1.95936096
C	-2.52233729	2.84040670	-0.25182794
H	-1.64219228	2.51112384	-2.16501996
C	-2.54729295	-0.09686327	-2.75950899
C	-0.55188872	-1.76221101	-2.39836405
H	-2.10021776	-1.28105423	-1.02962601
C	1.15138244	4.98018917	0.20781203
H	1.23041968	3.37901816	1.63977900
C	2.85777642	4.95595142	-1.49577300
H	4.26981063	3.34474460	-1.40782305
H	0.83032632	-1.17063893	4.28474894
H	-0.71232257	-1.94282114	4.69430895
H	0.24524448	-2.54076799	3.33182493
C	-2.96419867	-1.60943639	1.74174000
C	3.59278775	-4.83794653	1.54122183
H	2.68214067	-4.02017468	3.31934486
H	4.52140178	-5.33746038	-0.34126219
H	-3.86615817	1.65122156	-2.57655994
H	-3.81258001	0.60858954	-1.15458695
C	-2.92874620	2.35652963	1.00292506
C	-2.57969947	4.22162370	-0.48381592
H	-3.28532186	-0.82338836	-3.12065898

H	-2.04642102	0.32369281	-3.64145599
C	-0.02602658	-2.76478296	-1.56429207
C	-0.11465575	-1.71473493	-3.73051505
C	1.73458635	5.55500226	-0.92474098
H	0.27354139	5.43031105	0.66207305
H	3.32601434	5.39854449	-2.37126101
H	3.51192689	-5.86971355	1.87245982
C	-3.38238330	3.23272855	1.98949008
H	-2.87932706	1.29159563	1.21878004
C	-3.03379757	5.10032362	0.50310910
H	-2.26865654	4.61346575	-1.45013892
C	0.91602253	-3.67682283	-2.03855410
H	-0.36639855	-2.82623802	-0.53284807
C	0.82394736	-2.63271280	-4.21049508
H	-0.51389686	-0.96694198	-4.40936004
H	1.32082022	6.46376122	-1.35335295
C	-3.43718148	4.60761555	1.74483010
H	-3.69108723	2.83756550	2.95378508
H	-3.07498271	6.16733962	0.29829312
C	1.34701250	-3.61315875	-3.36682411
H	1.31340164	-4.43498378	-1.36985012
H	1.14148133	-2.58098975	-5.24901709
H	-3.79118556	5.28733949	2.51541312
H	2.07615159	-4.32656665	-3.74164313
C	-4.12783162	-2.11450453	1.10210701
C	-4.22483844	-3.47525354	0.72641499
C	-5.22993573	-1.27327867	0.81509304
C	-5.36482739	-3.96361968	0.09398700
H	-3.39245335	-4.13852343	0.94347097
C	-6.36411768	-1.77115781	0.17829205
H	-5.18353486	-0.22829167	1.10893806
C	-6.44204551	-3.11793881	-0.18784496
H	-5.41292526	-5.01442168	-0.18216401
H	-7.19670177	-1.10263691	-0.02845992
H	-7.32971347	-3.50347392	-0.68195295

TS-S3

P	0.02808496	1.97924498	0.19108997
C	-0.42184796	1.83367391	-1.62587005
C	-1.20744107	3.24563702	0.90568186
C	-1.42167195	0.70490191	-1.94997005
H	0.52590407	1.64310188	-2.14190599
H	-0.81037593	2.78871990	-2.00156410
C	1.44563297	3.25711696	0.10983499

Cu	-0.12033710	-0.22504499	0.97061805
C	-0.57623404	4.62177200	0.62864984
C	-2.64279805	3.01632002	0.48472980
H	-1.14449012	3.06446206	1.98675187
P	-1.03528501	-0.91286206	-1.08463297
H	-2.42408697	0.98582893	-1.60709311
H	-1.47675190	0.56633287	-3.03711105
C	0.92345495	4.48032000	0.90759192
C	2.80682295	2.76863197	0.55556308
H	1.51607503	3.55040592	-0.94537002
H	-1.03952606	5.40209503	1.24536879
H	-0.72090599	4.91218196	-0.41986118
C	-3.37192709	1.97525405	1.08709481
C	-3.27906999	3.78488699	-0.50091426
C	-2.56366000	-1.96503906	-1.51696700
C	0.10613504	-1.88907812	-2.26381288
H	1.48539897	5.38143598	0.63487491
H	1.08688889	4.31564404	1.98026893
C	3.01174388	2.22754001	1.83422011
C	3.91220299	2.89089292	-0.29777988
C	-4.68555807	1.70320705	0.70727075
H	-2.89386613	1.36407007	1.84924685
C	-4.59859698	3.51830798	-0.87788831
H	-2.75411596	4.60876096	-0.97475927
C	-1.98625398	-3.19968209	-2.25569493
C	-3.47250006	-2.30689001	-0.35609403
H	-3.13945096	-1.37902208	-2.24525005
C	-0.84285793	-2.71491914	-3.15270789
C	1.16958808	-1.05433015	-2.94242686
H	0.61551700	-2.58076109	-1.58104382
C	4.28313685	1.83210402	2.24922418
H	2.16884985	2.10080505	2.50887907
C	5.18712397	2.49488993	0.11304220
H	3.77307004	3.30433289	-1.29431090
C	-5.30552402	2.47524101	-0.27946531
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intS4

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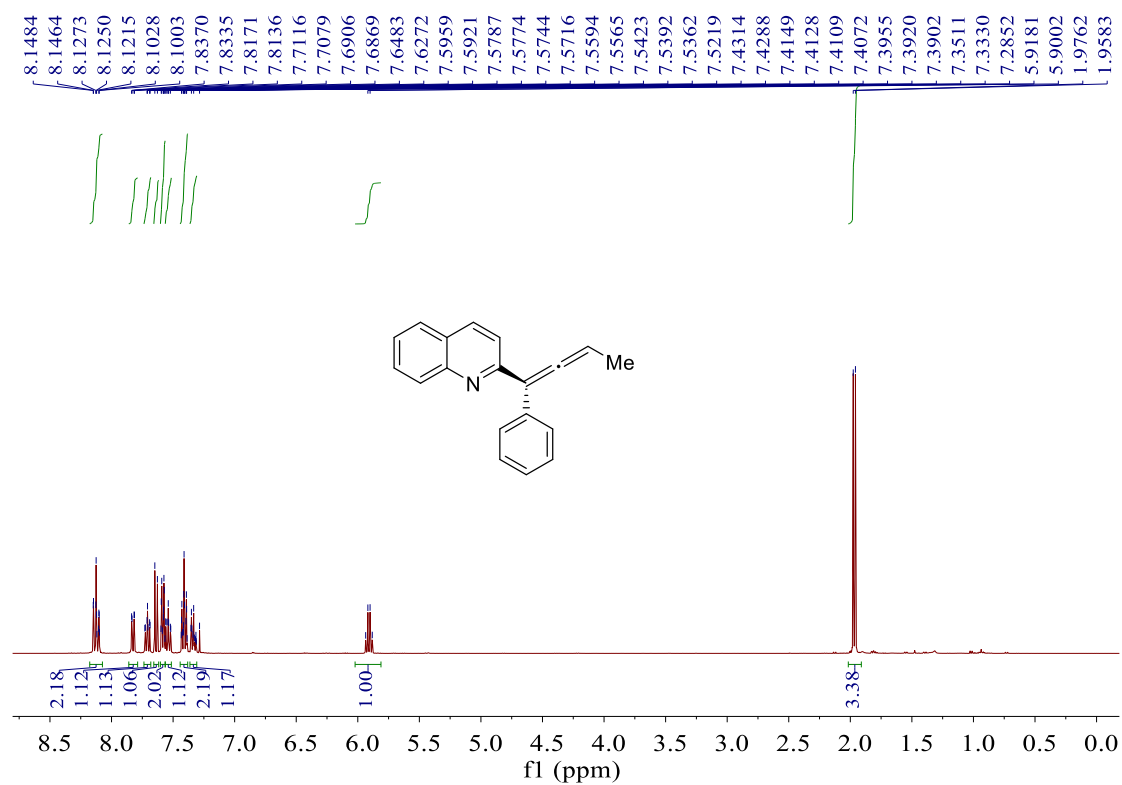
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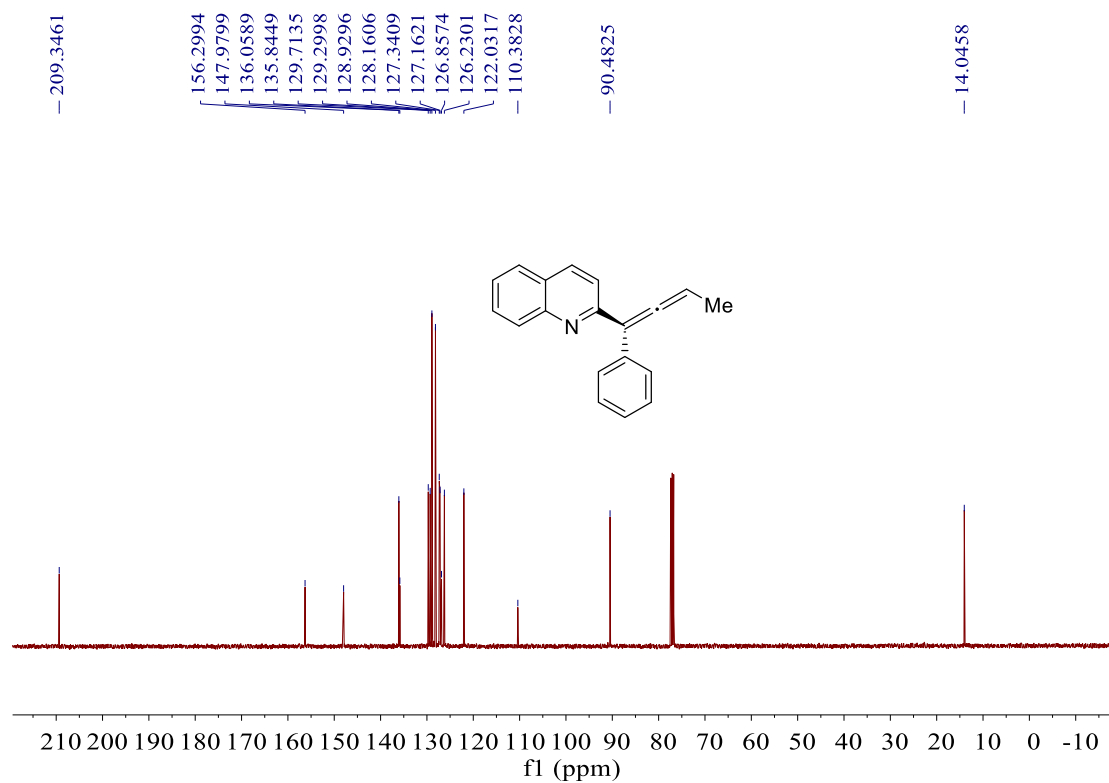
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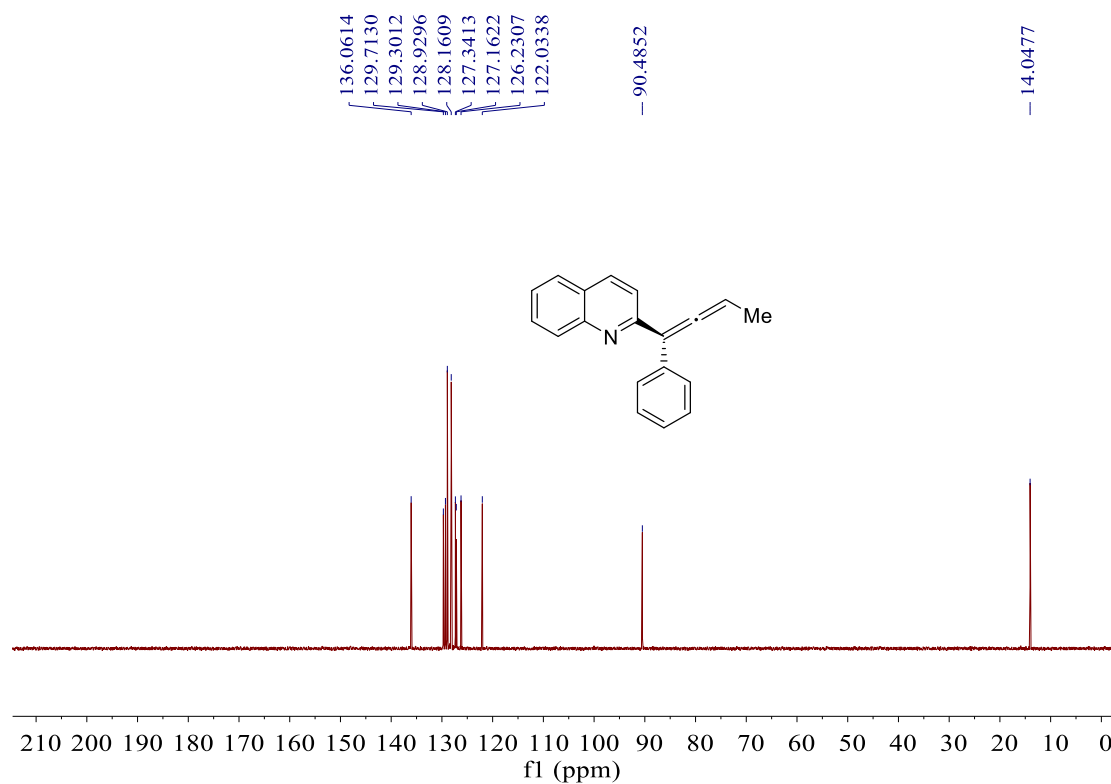
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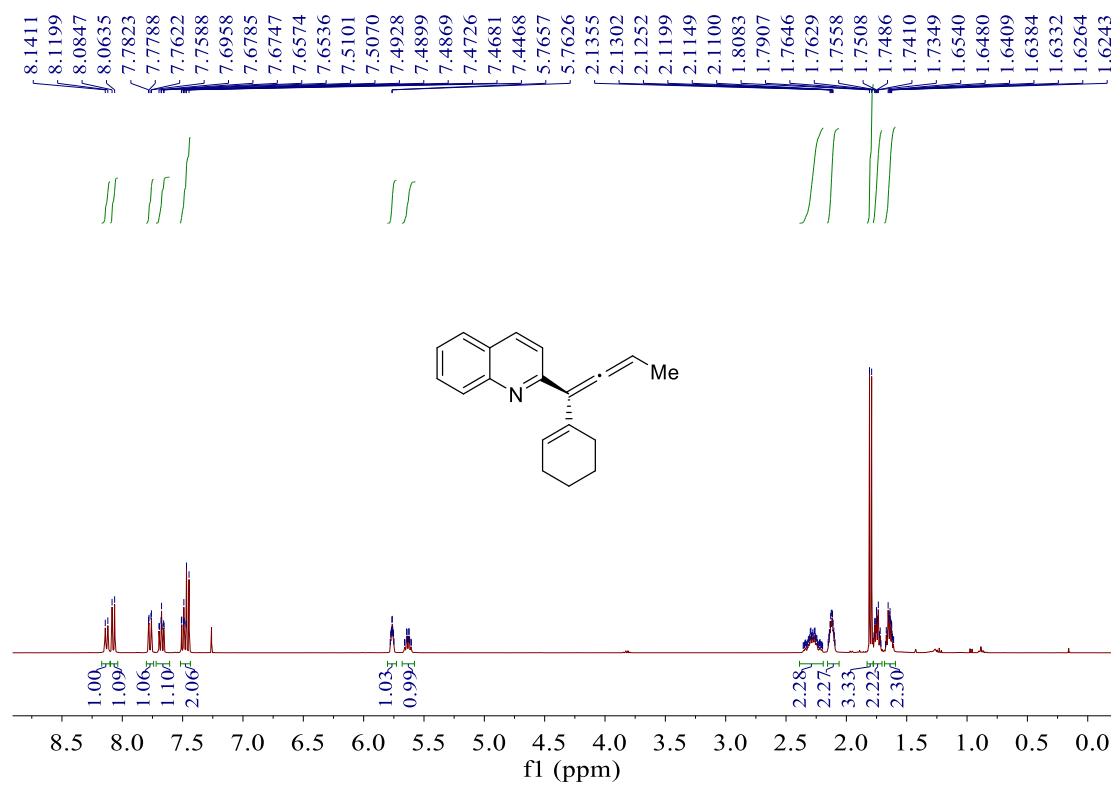
Supplementary Figure 19. ¹H NMR spectra for **3a**



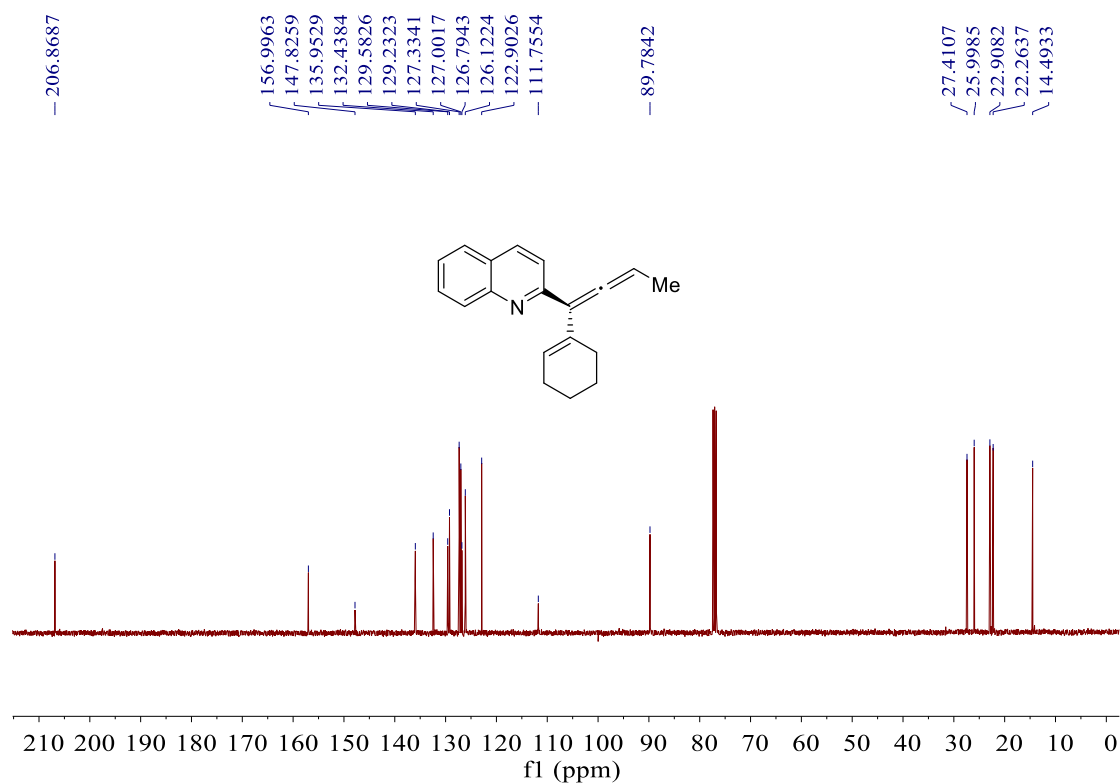
Supplementary Figure 20. ¹³C NMR spectra for **3a**



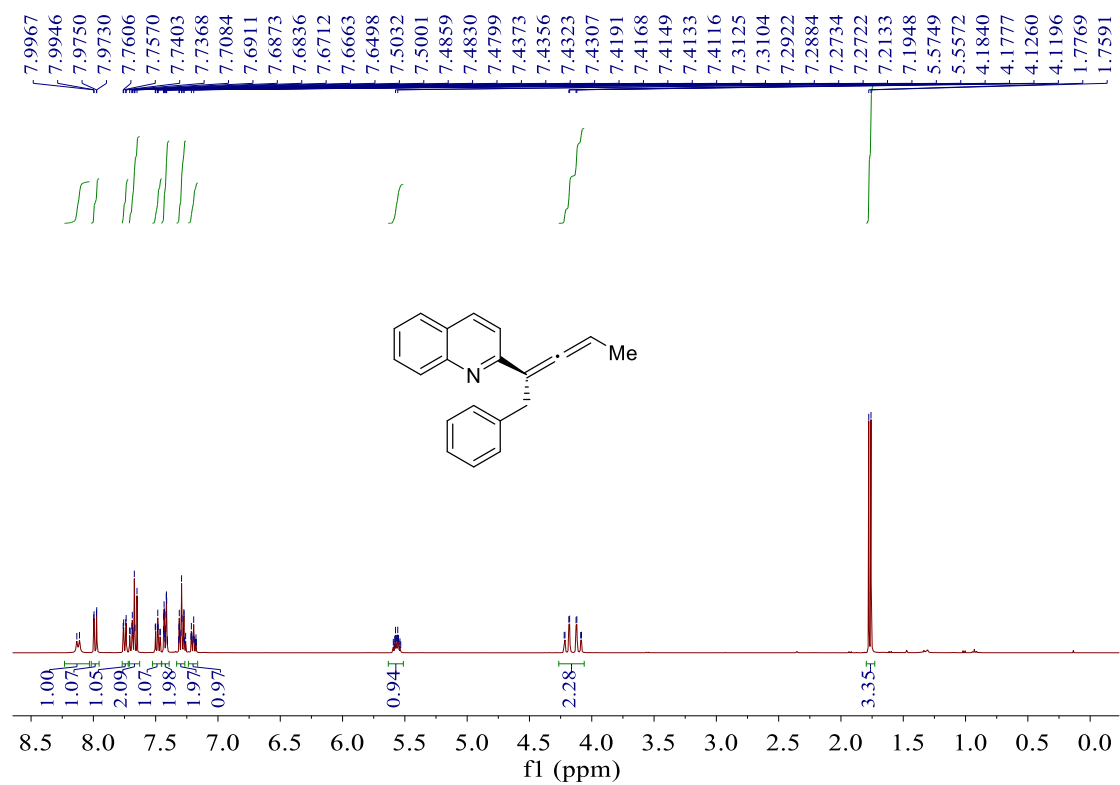
Supplementary Figure 21. ¹³C(DEPT 135) NMR spectra for **3a**



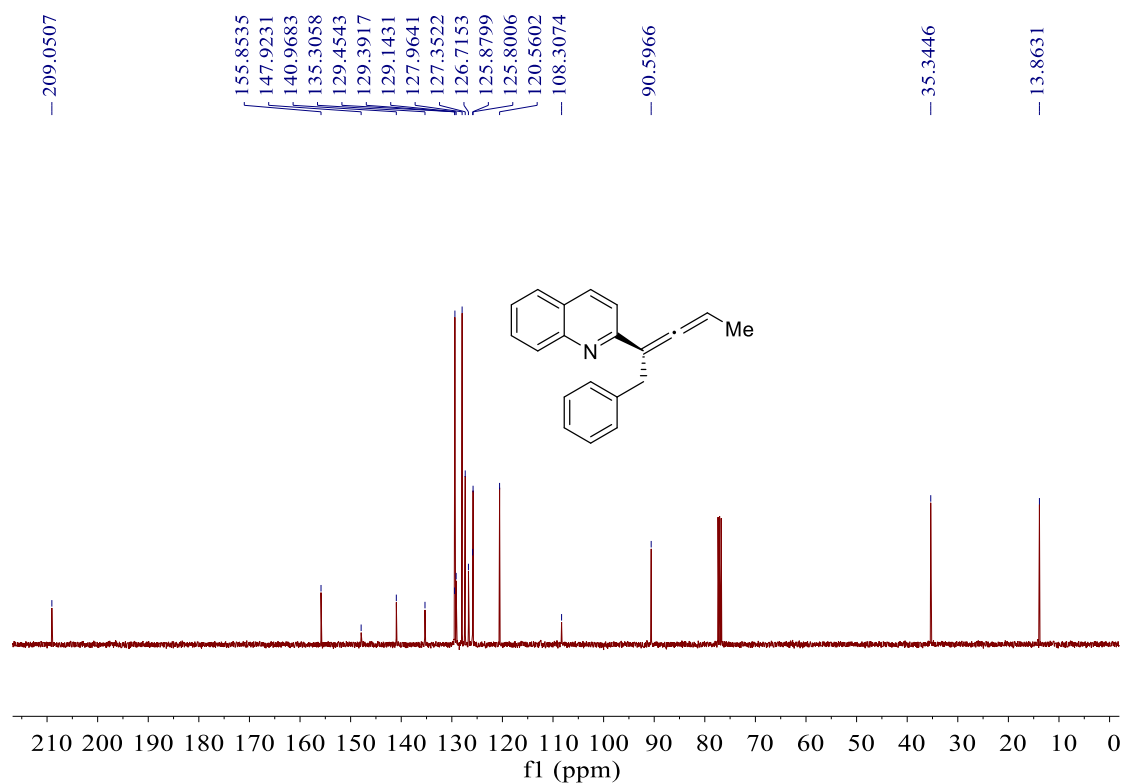
Supplementary Figure 22. ¹H NMR spectra for **3b**



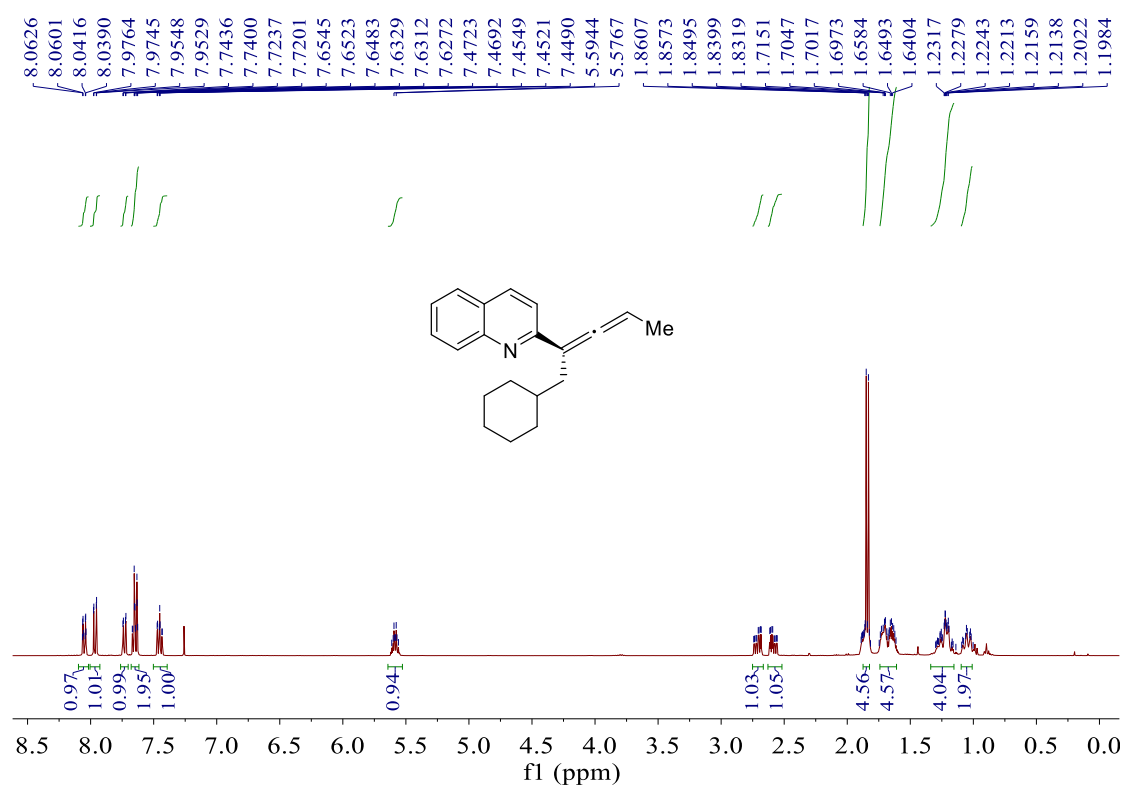
Supplementary Figure 23. ¹³C NMR spectra for **3b**



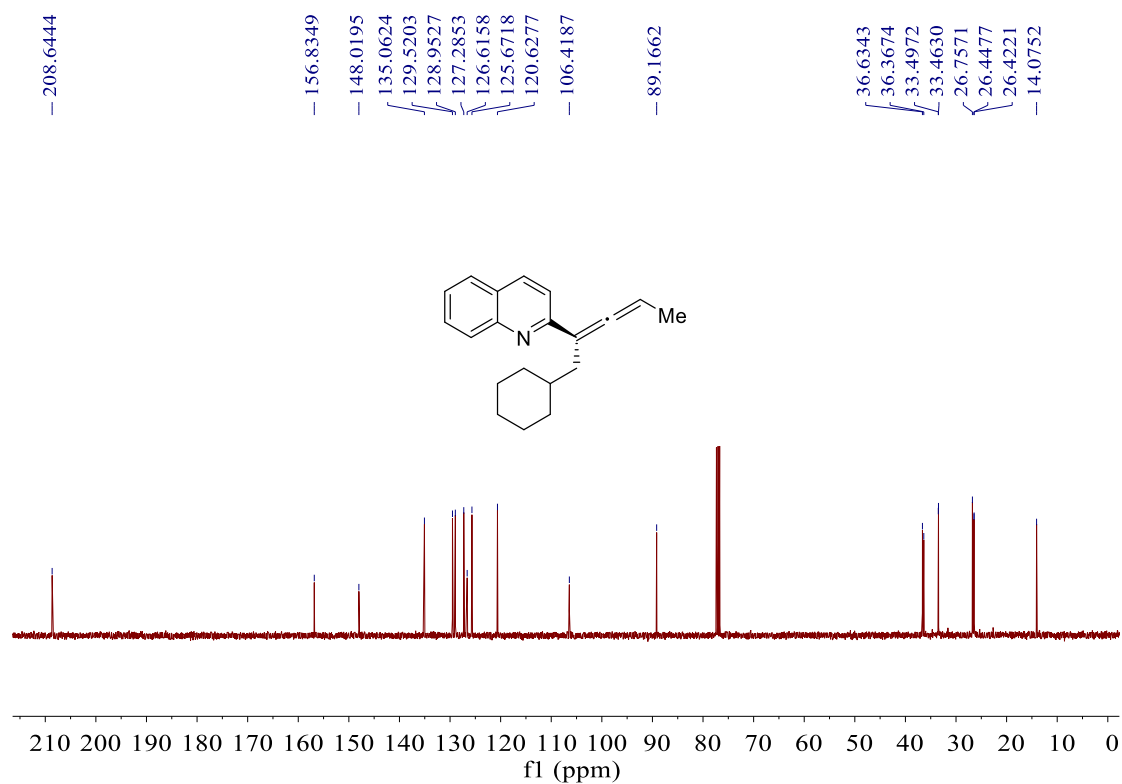
Supplementary Figure 24. ¹H NMR spectra for **3c**



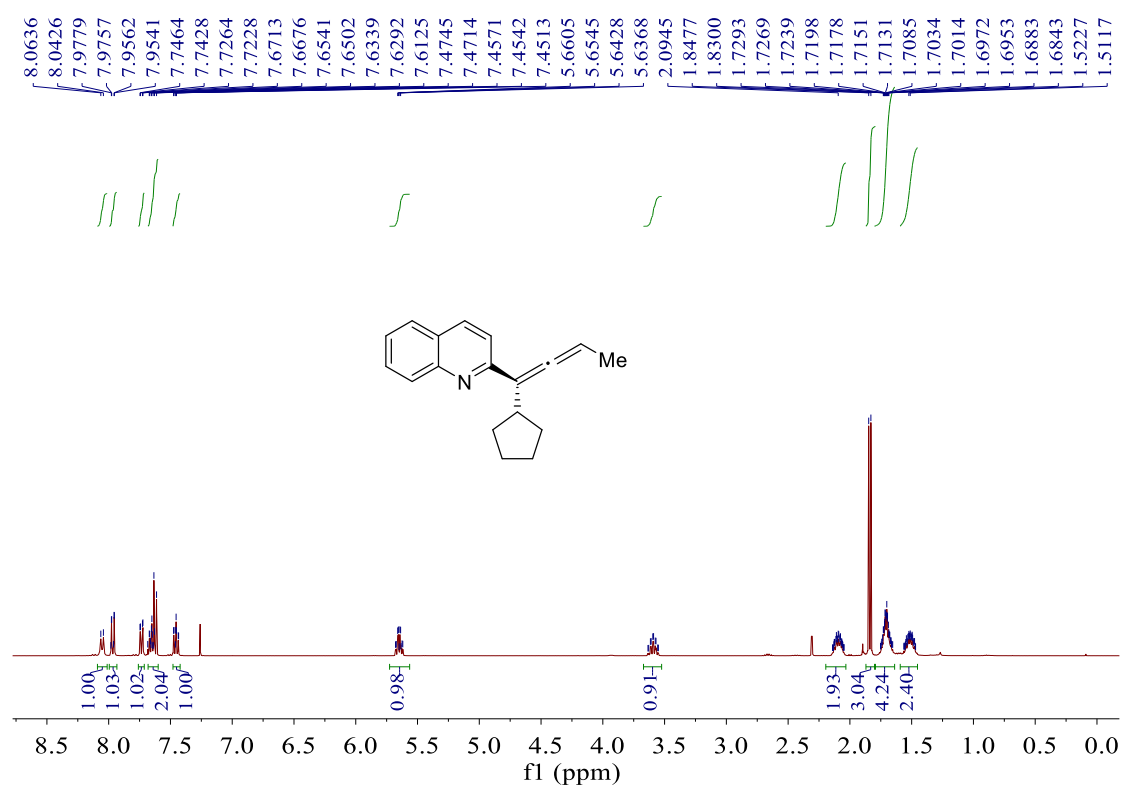
Supplementary Figure 25. ¹³C NMR spectra for **3c**



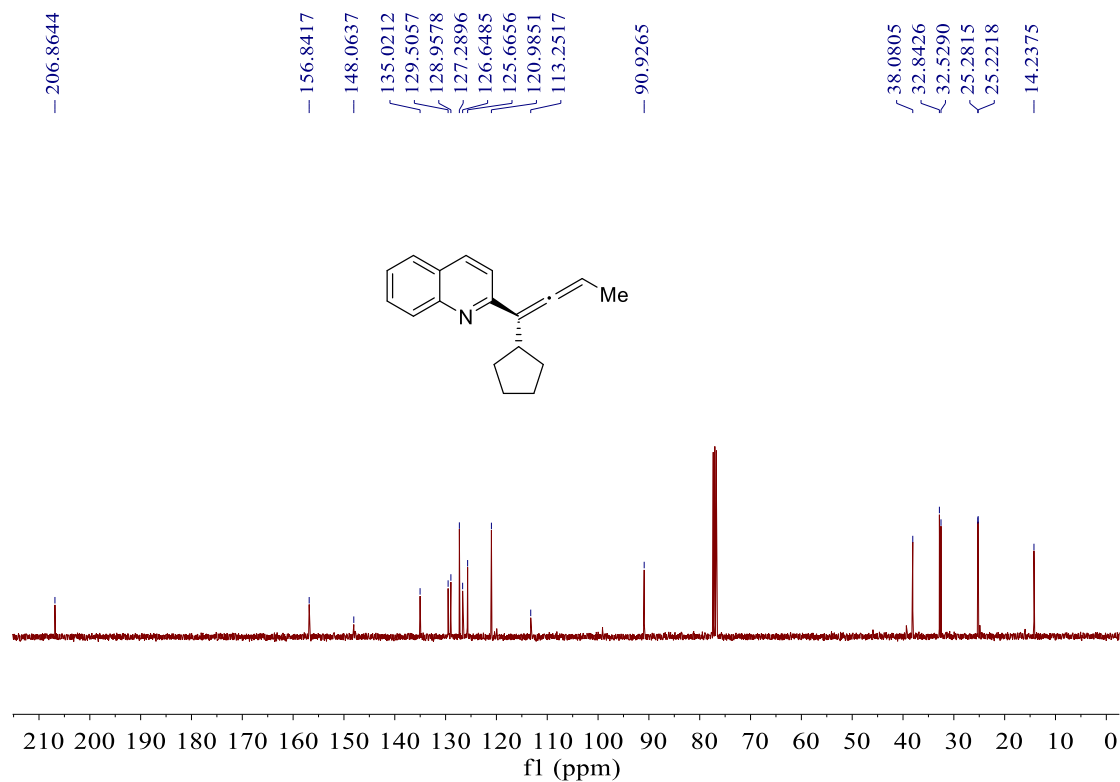
Supplementary Figure 26. ¹H NMR spectra for **3d**



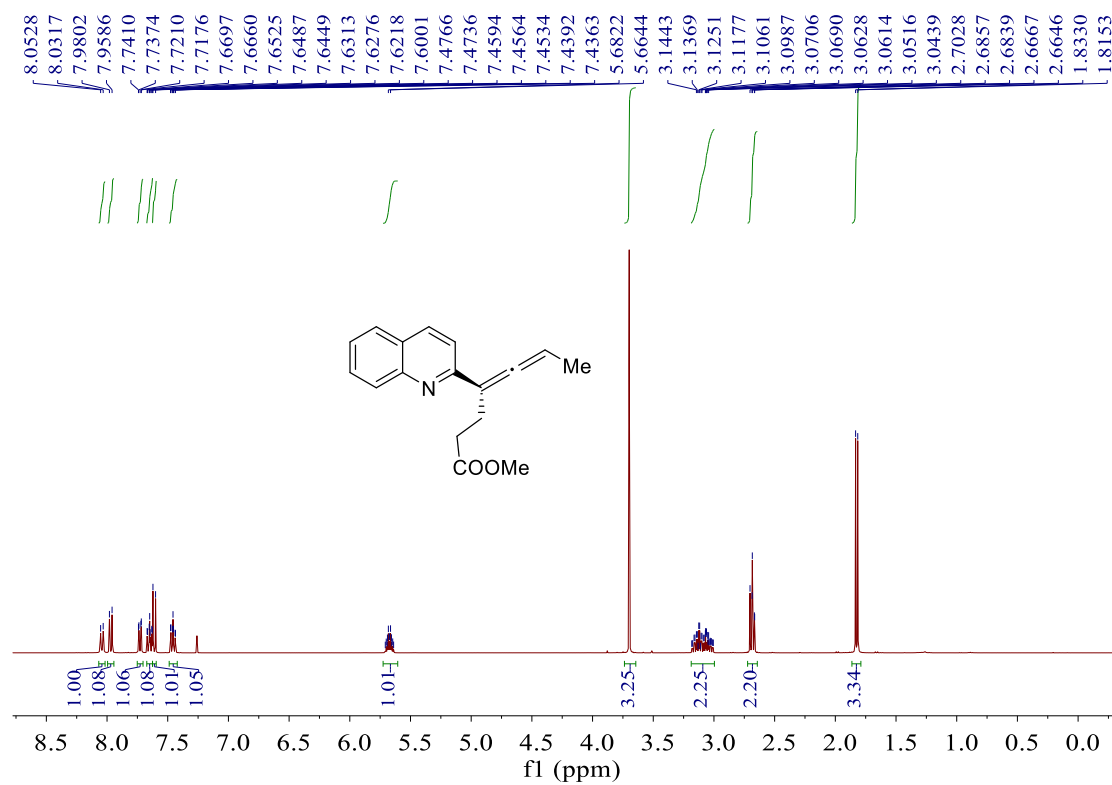
Supplementary Figure 27. ¹³C NMR spectra for **3d**



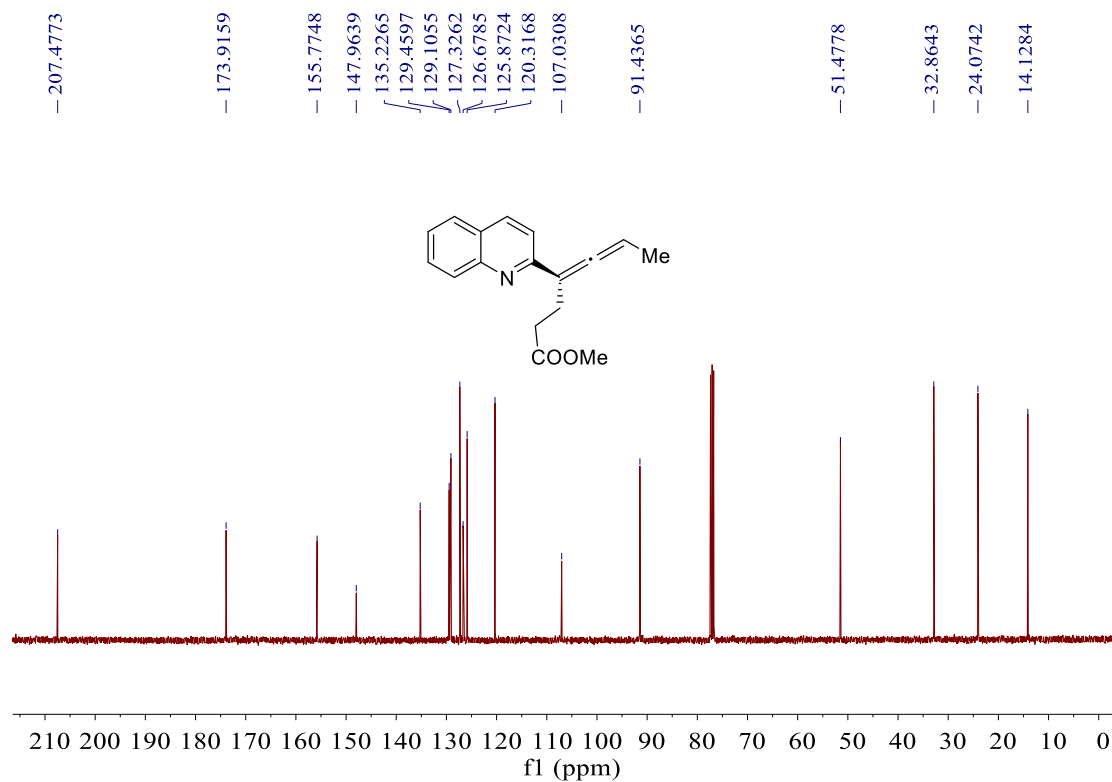
Supplementary Figure 28. ¹H NMR spectra for **3e**



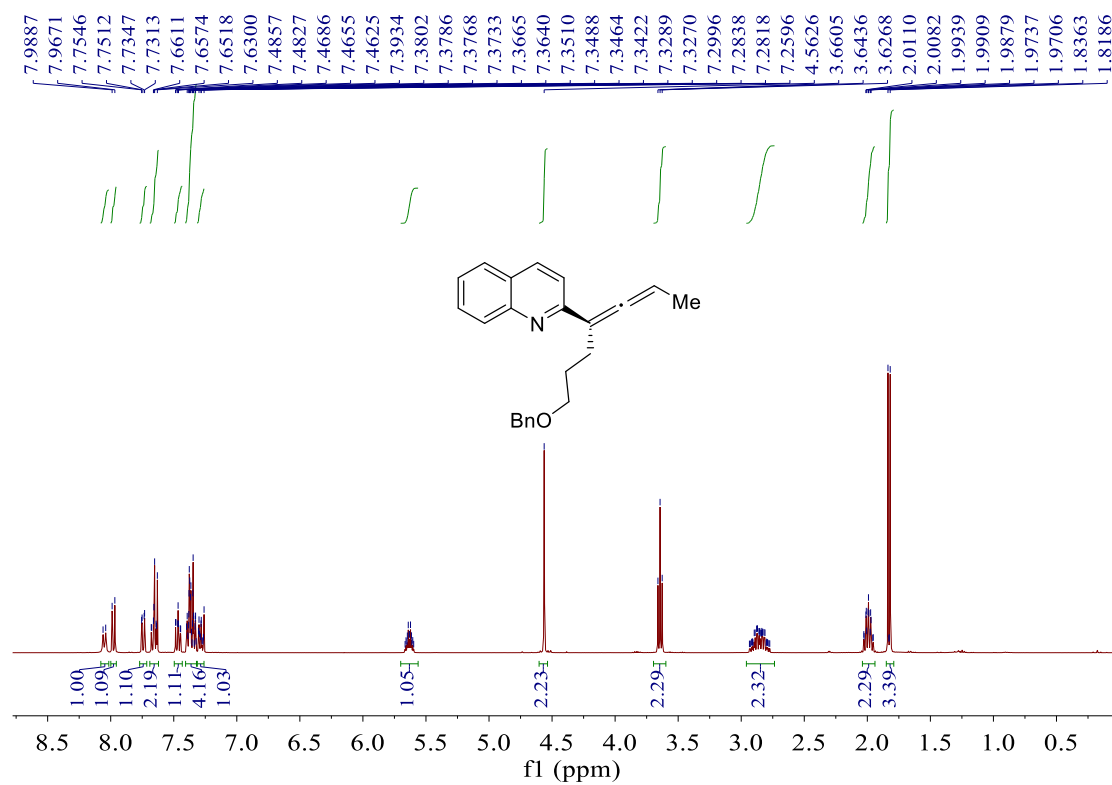
Supplementary Figure 29. ¹³C NMR spectra for **3e**



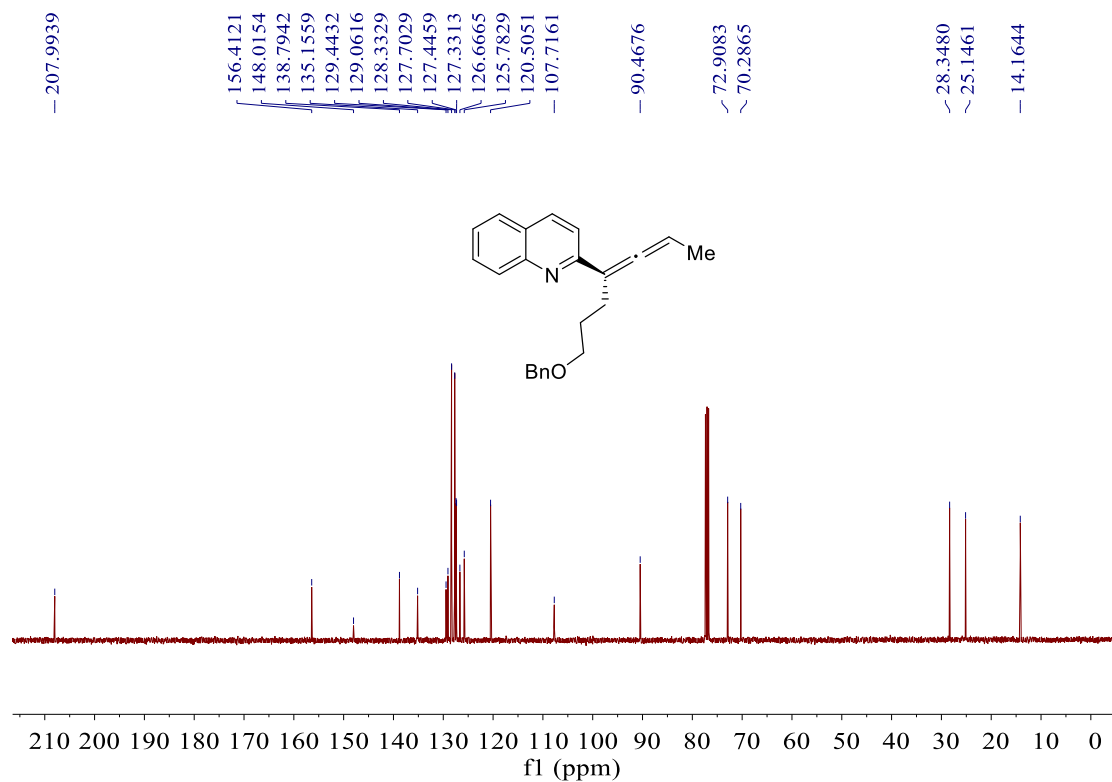
Supplementary Figure 30. ¹H NMR spectra for **3f**



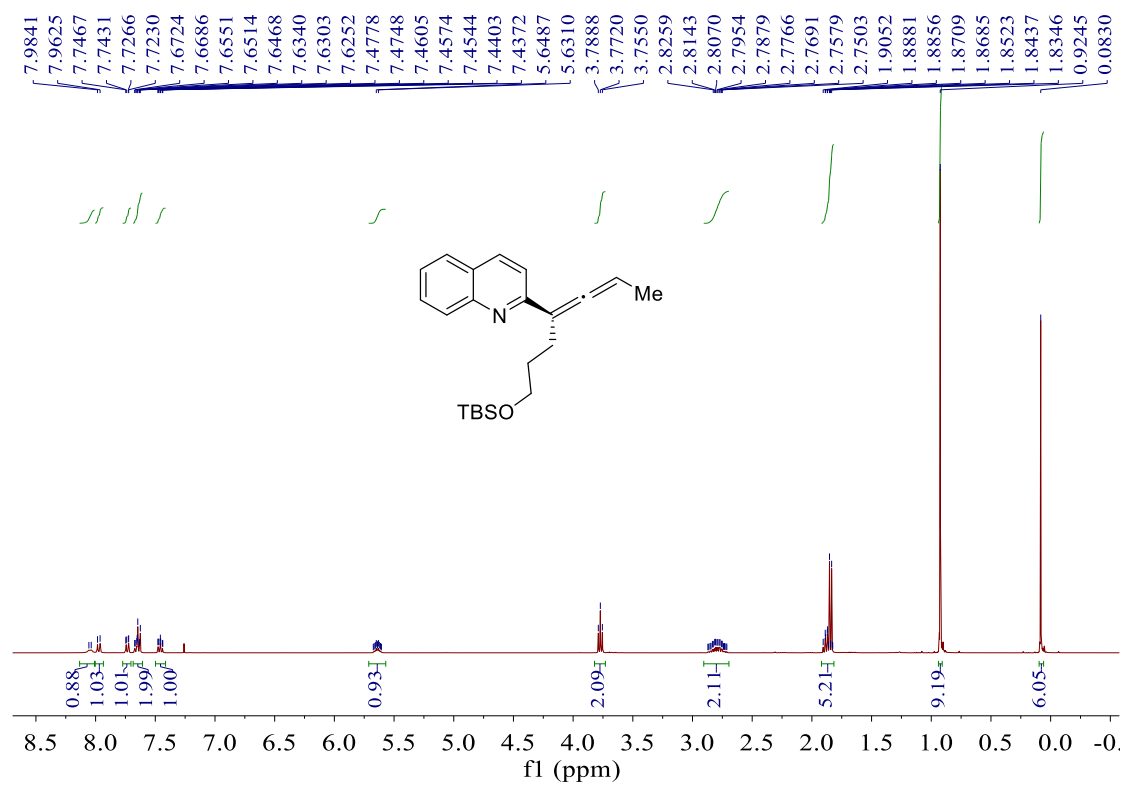
Supplementary Figure 31. ¹³C NMR spectra for **3f**



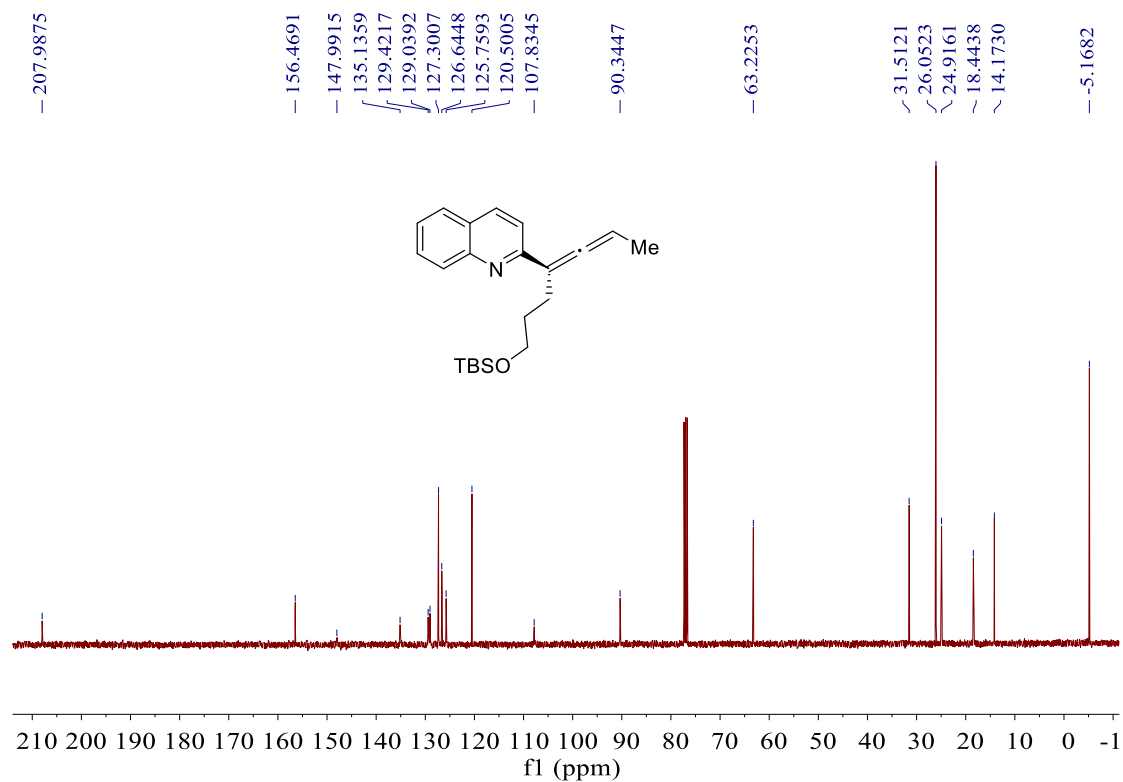
Supplementary Figure 32. ¹H NMR spectra for **3g**



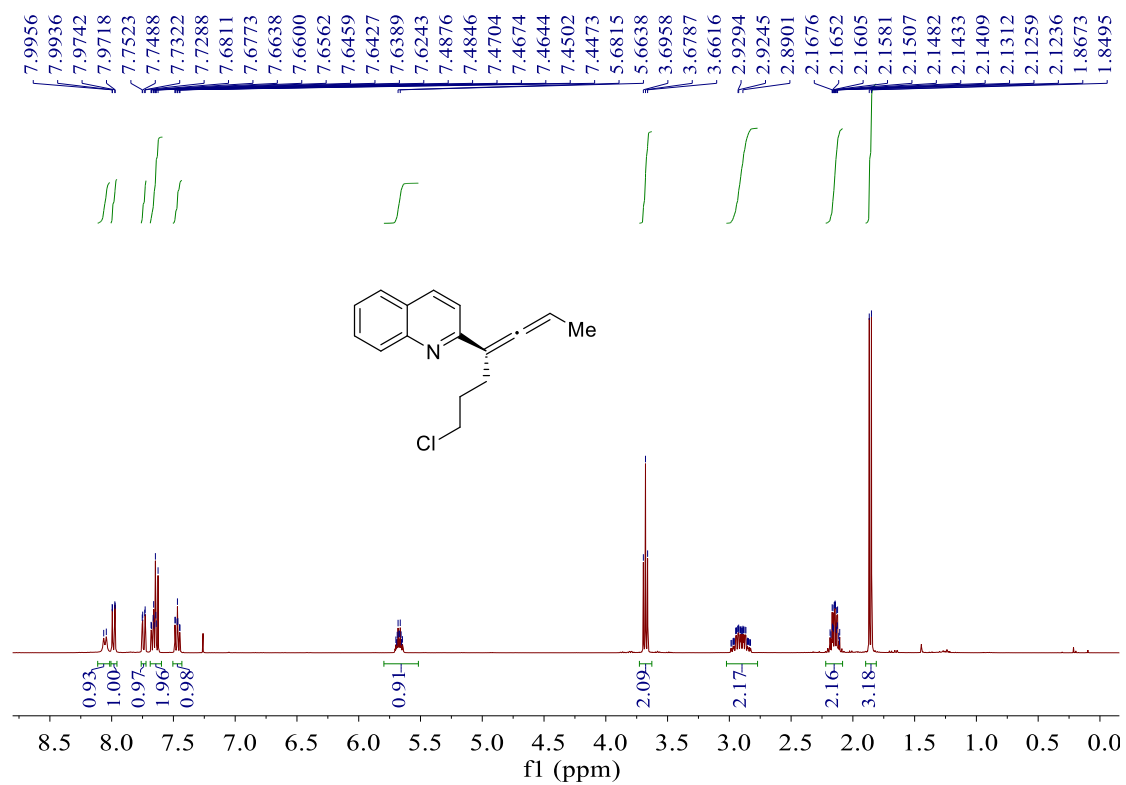
Supplementary Figure 33. ¹³C NMR spectra for **3g**



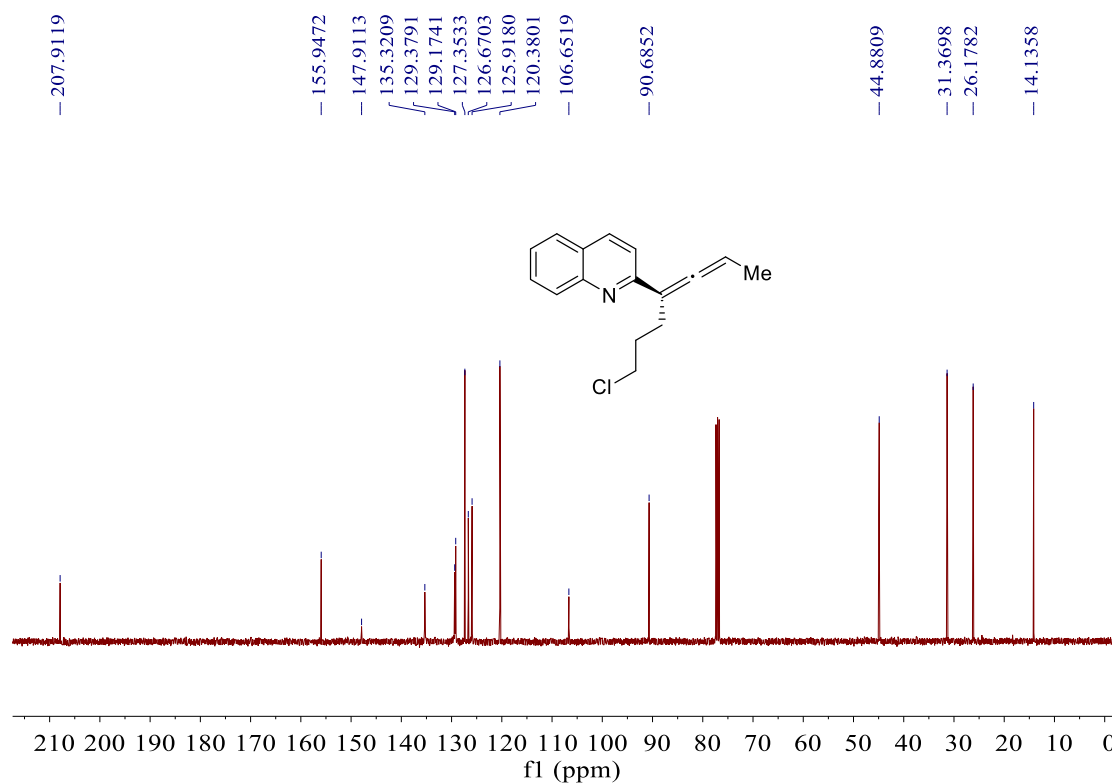
Supplementary Figure 34. ¹H NMR spectra for **3h**



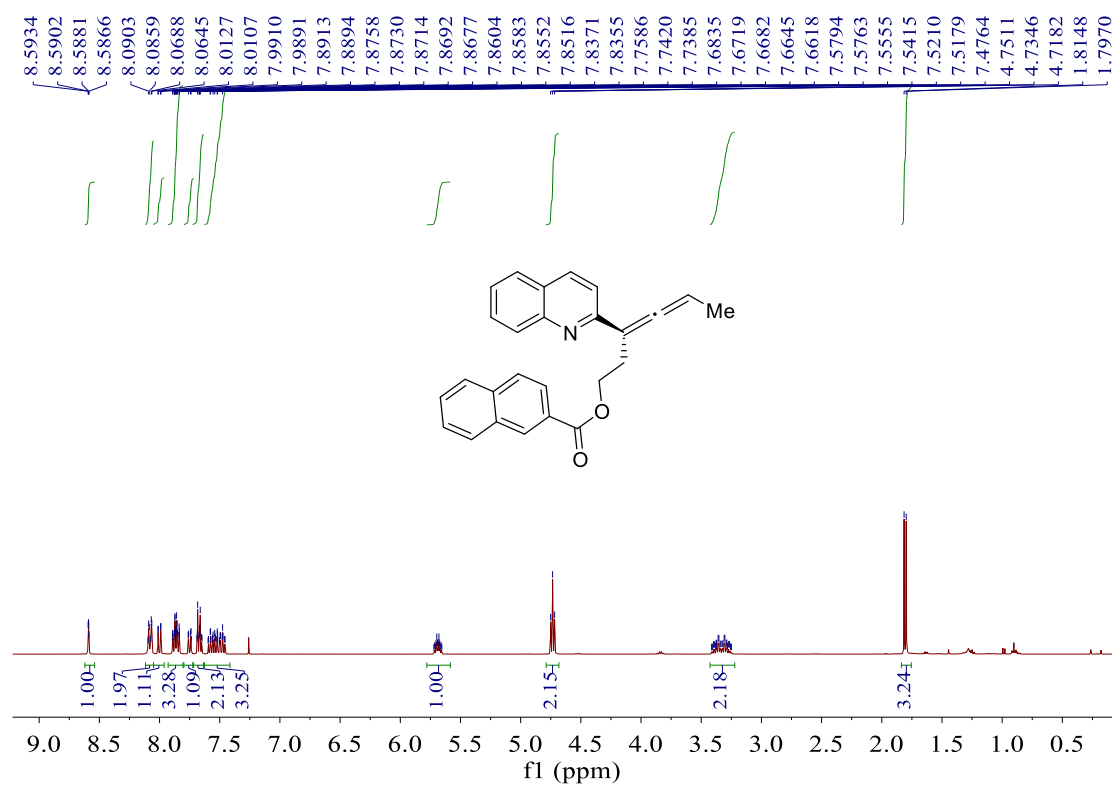
Supplementary Figure 35. ¹³C NMR spectra for **3h**



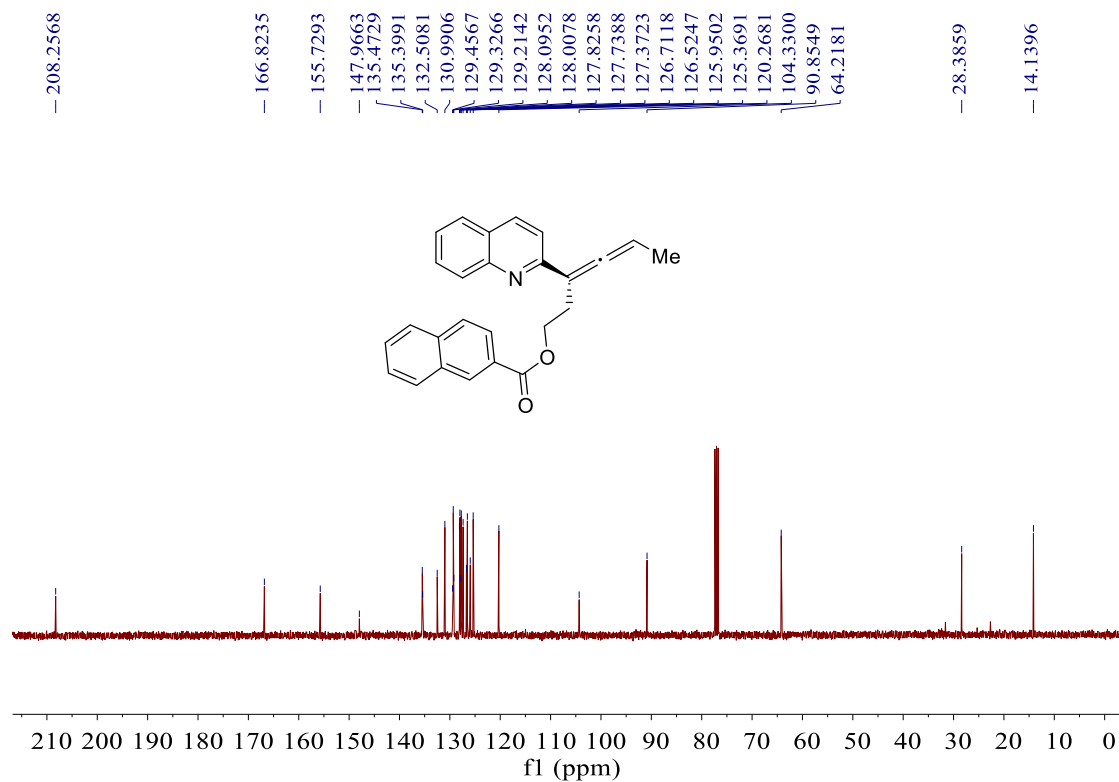
Supplementary Figure 36. ¹H NMR spectra for **3i**



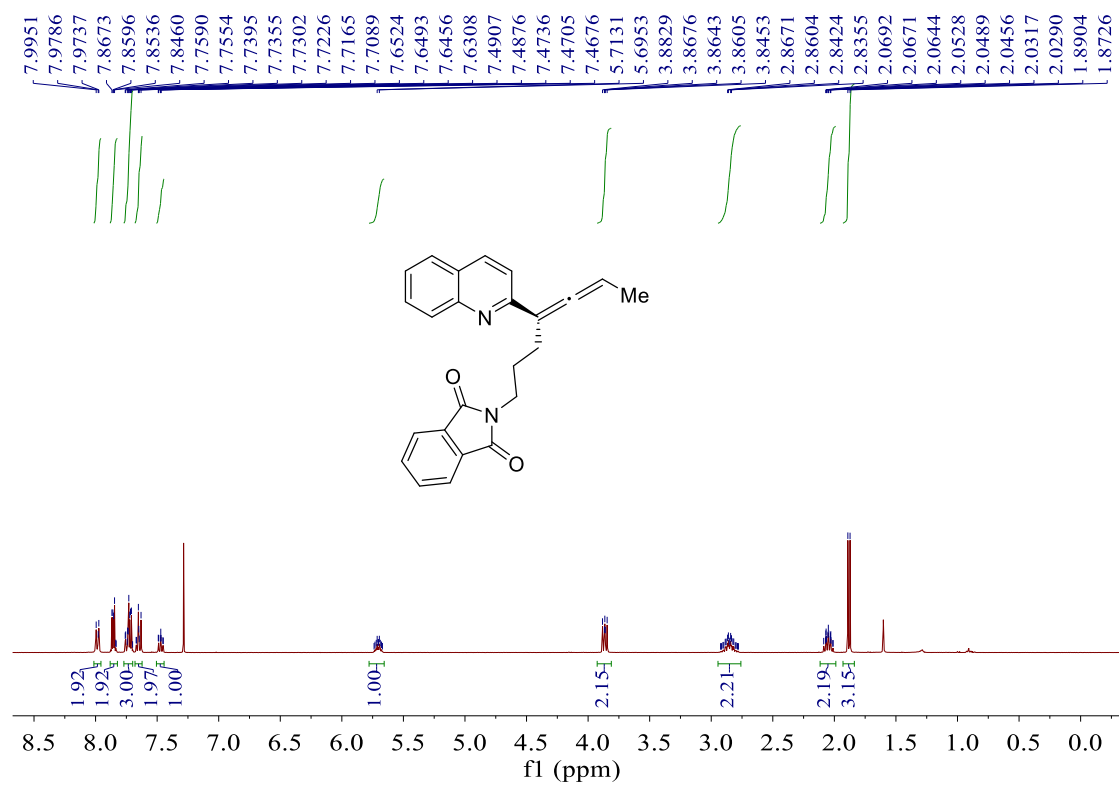
Supplementary Figure 37. ¹³C NMR spectra for **3i**



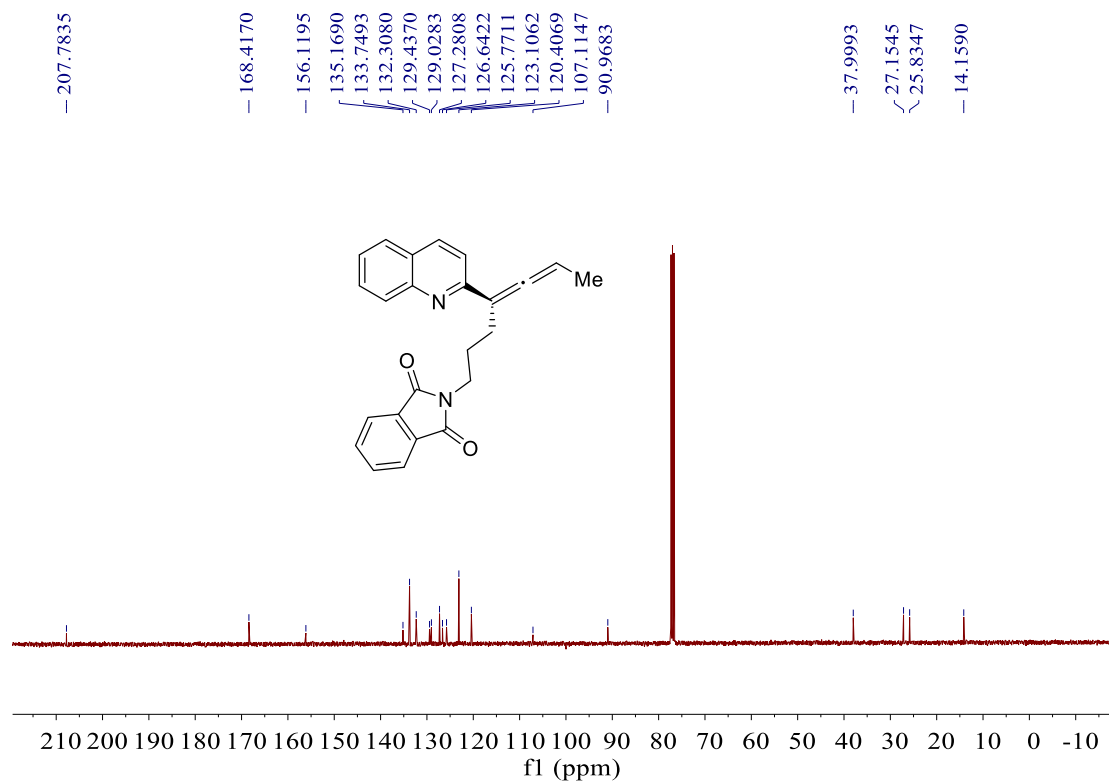
Supplementary Figure 38. ¹H NMR spectra for **3j**



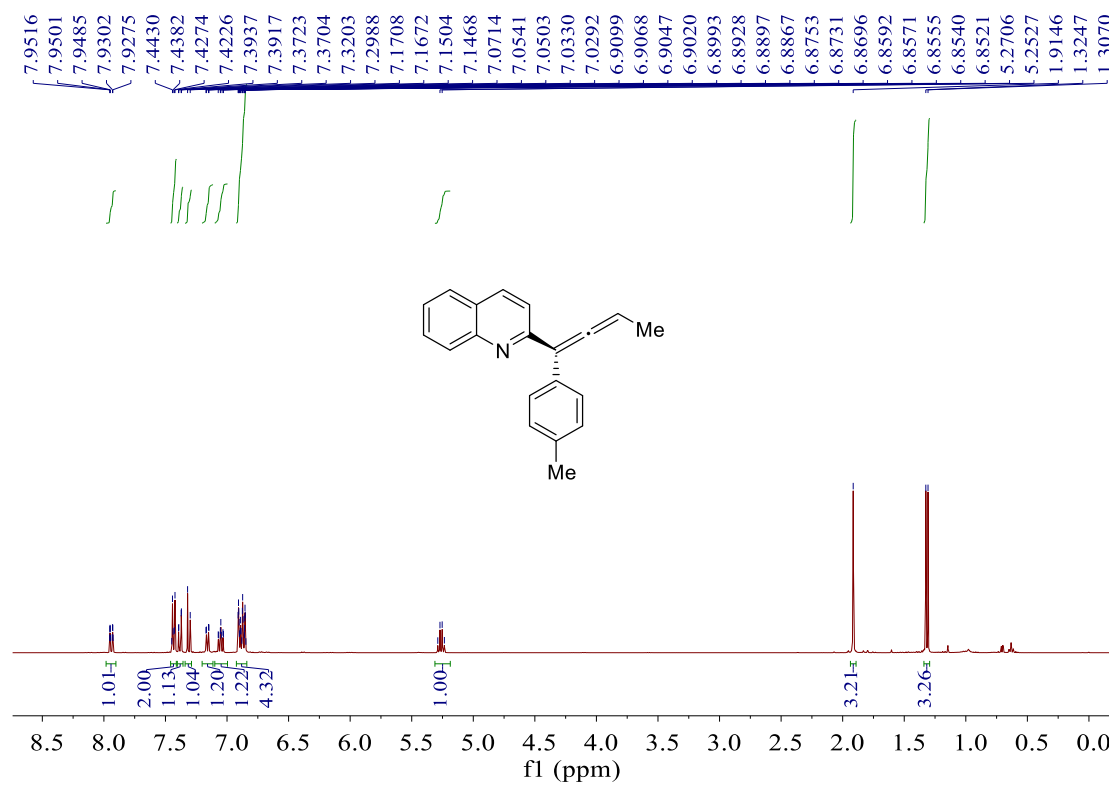
Supplementary Figure 39. ¹³C NMR spectra for **3j**



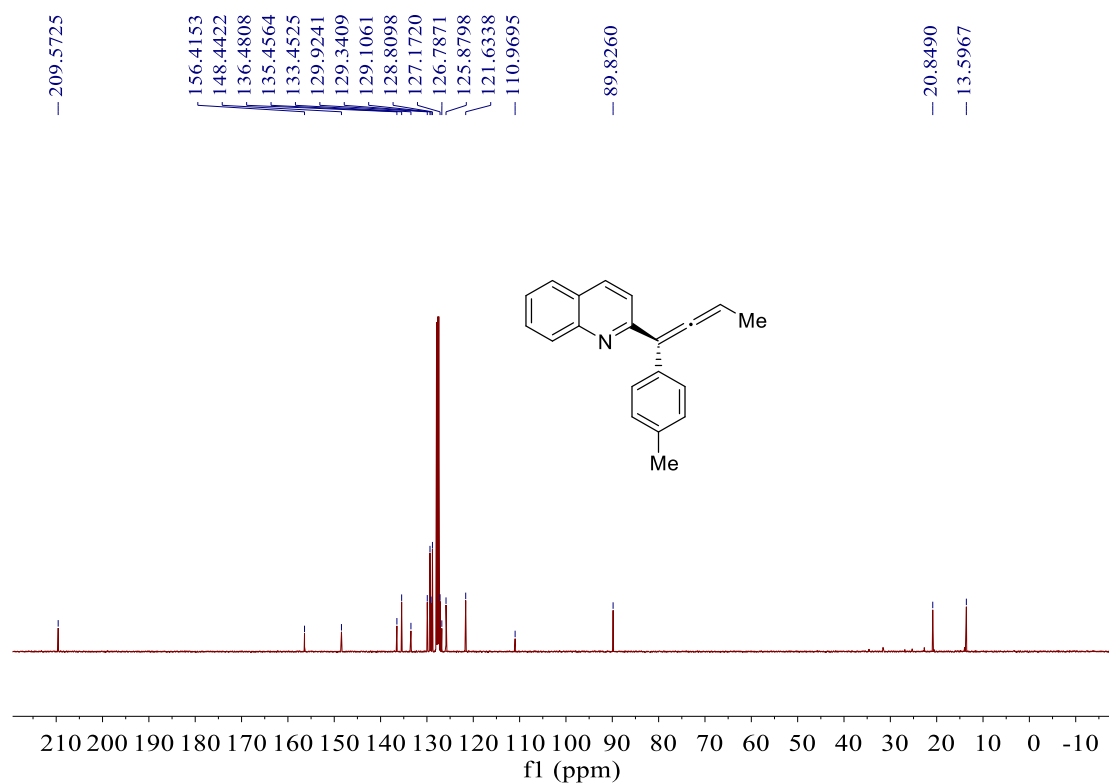
Supplementary Figure 40. ¹H NMR spectra for **3k**



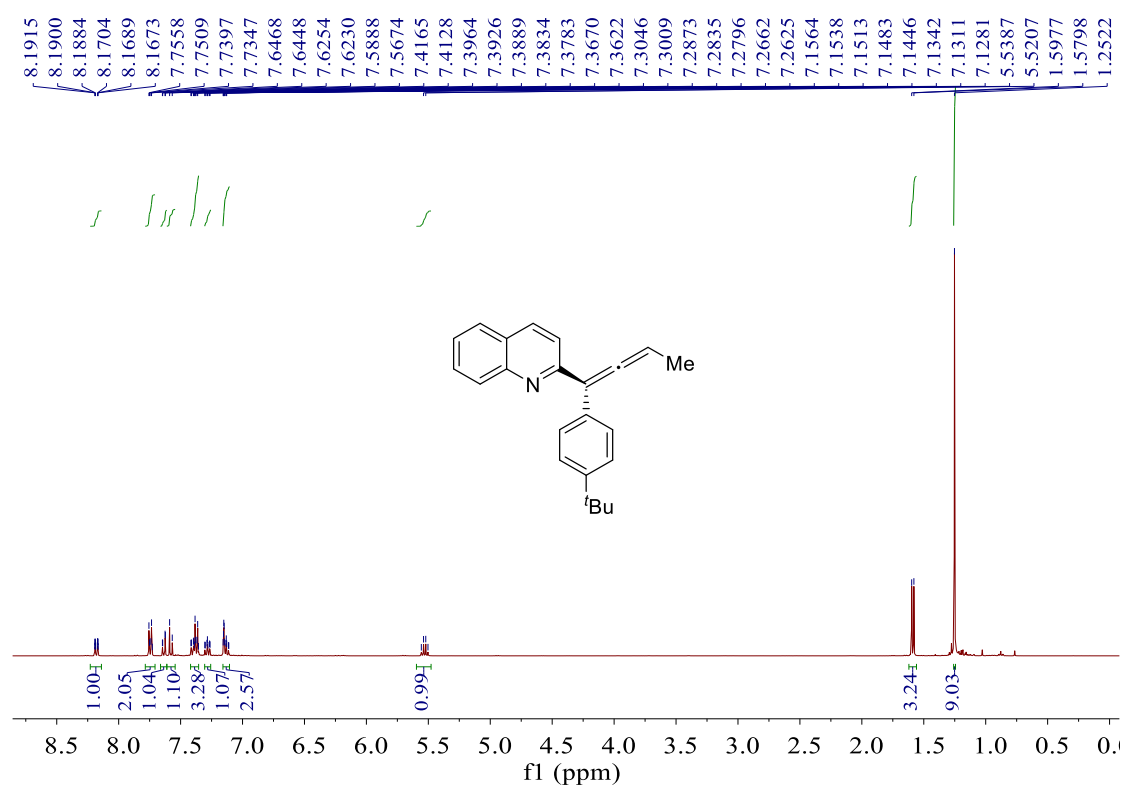
Supplementary Figure 41. ¹³C NMR spectra for **3k**



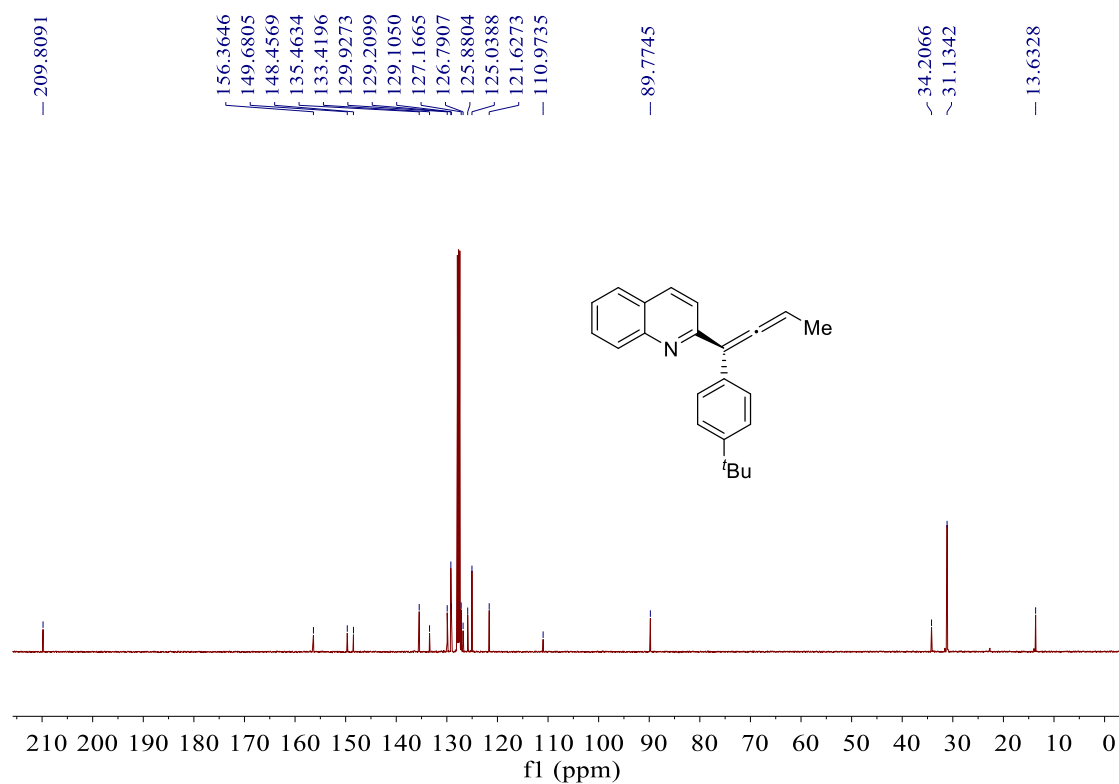
Supplementary Figure 42. ¹H NMR spectra for **3l**



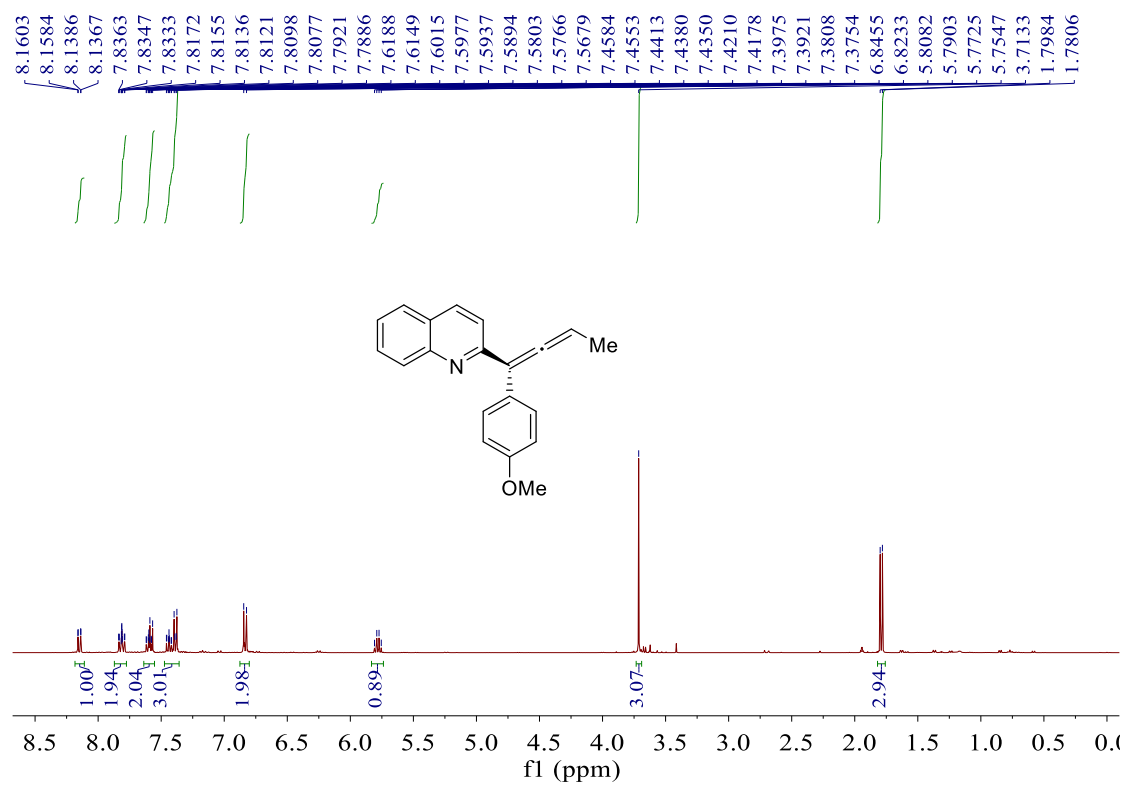
Supplementary Figure 43. ¹³C NMR spectra for **3l**



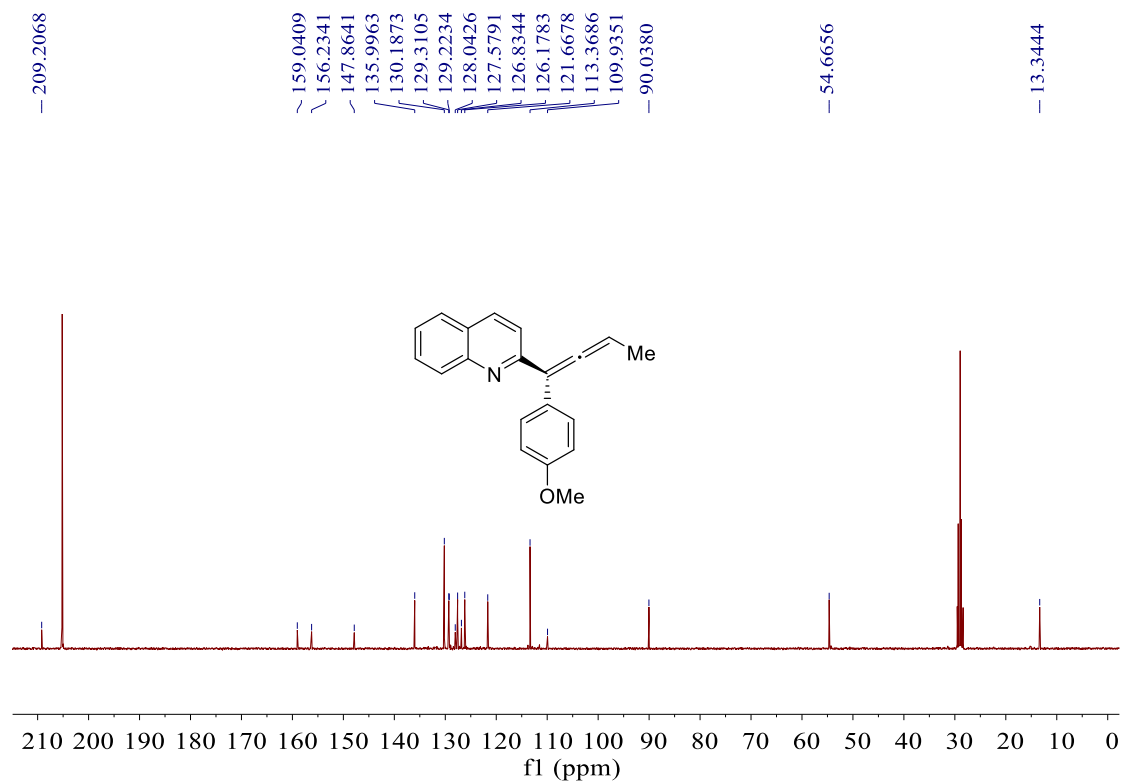
Supplementary Figure 44. ¹H NMR spectra for **3m**



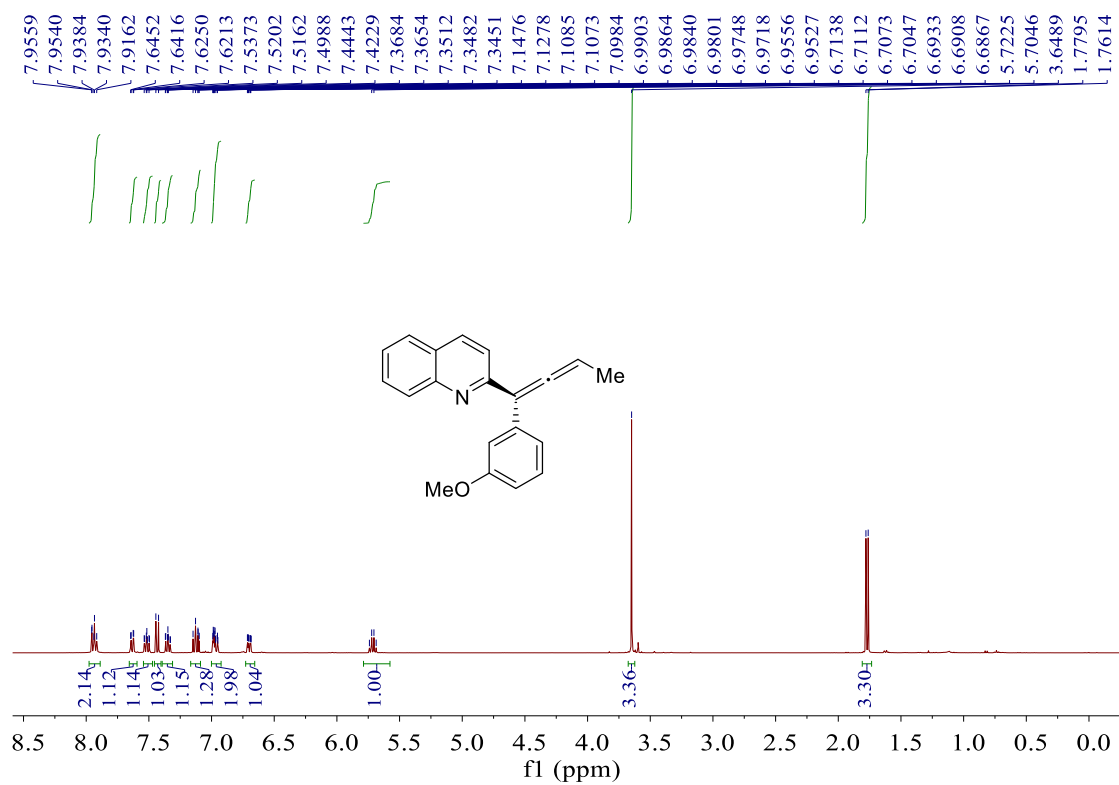
Supplementary Figure 45. ¹³C NMR spectra for **3m**



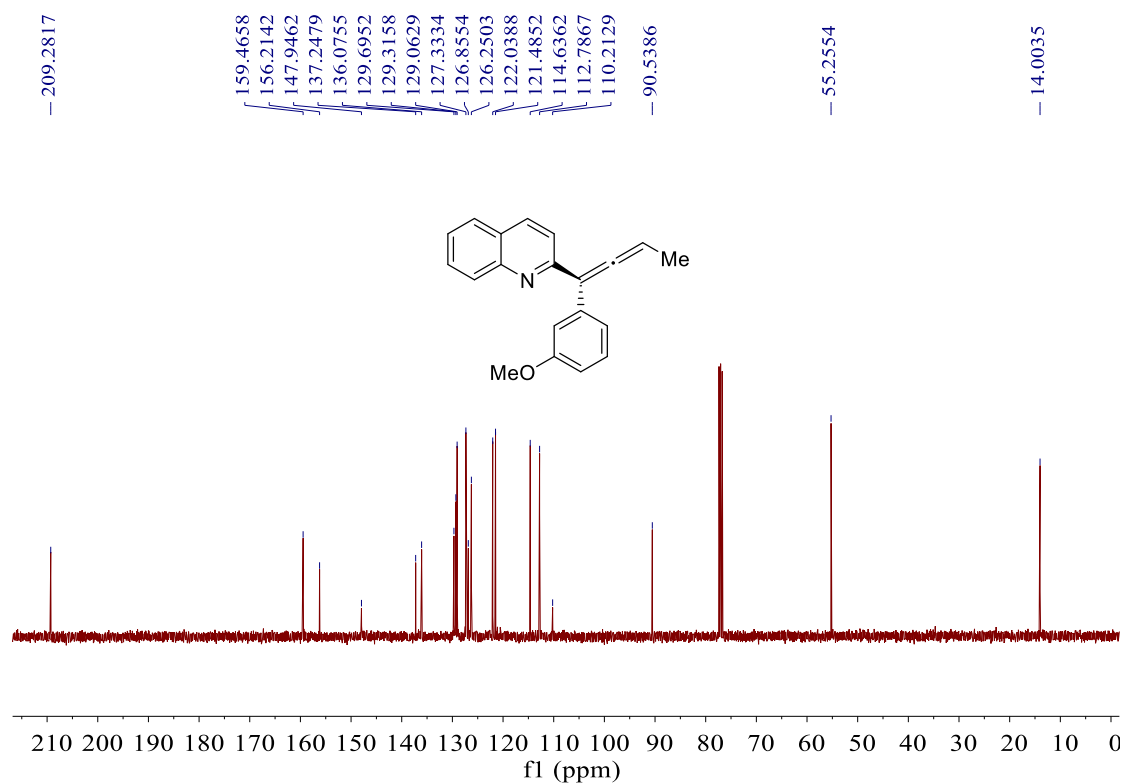
Supplementary Figure 46. ¹H NMR spectra for **3n**



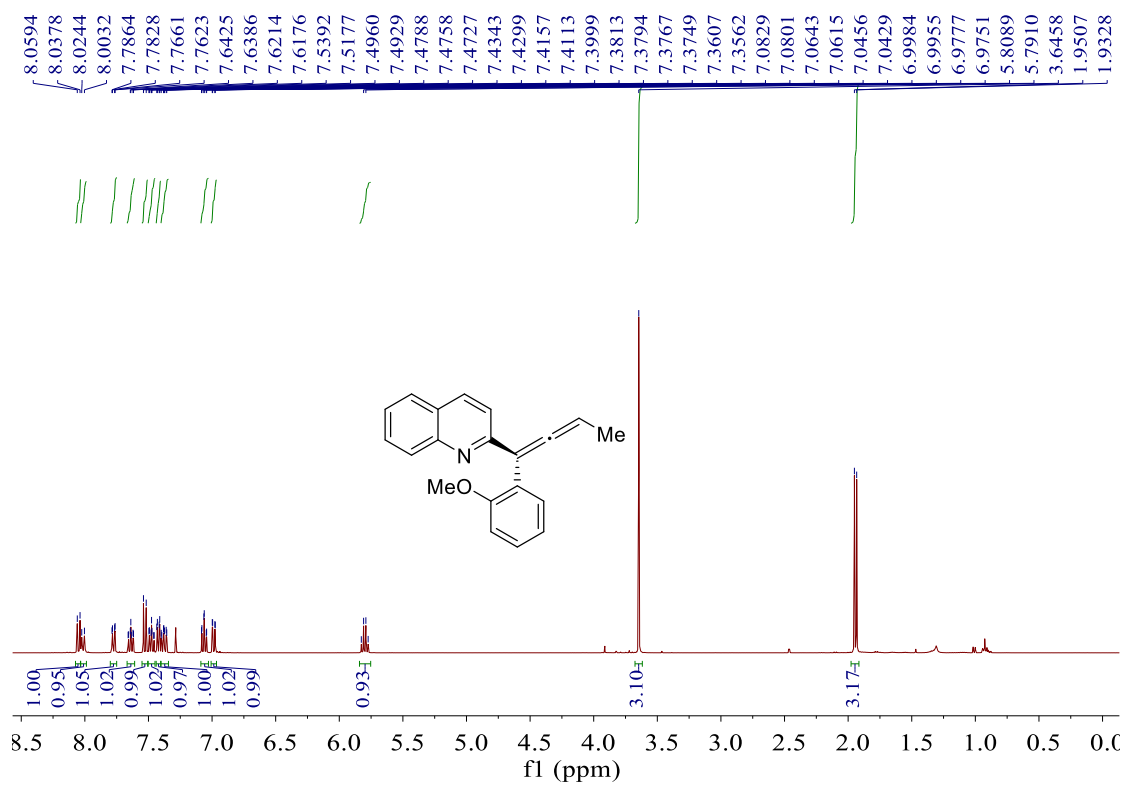
Supplementary Figure 47. ¹³C NMR spectra for **3n**



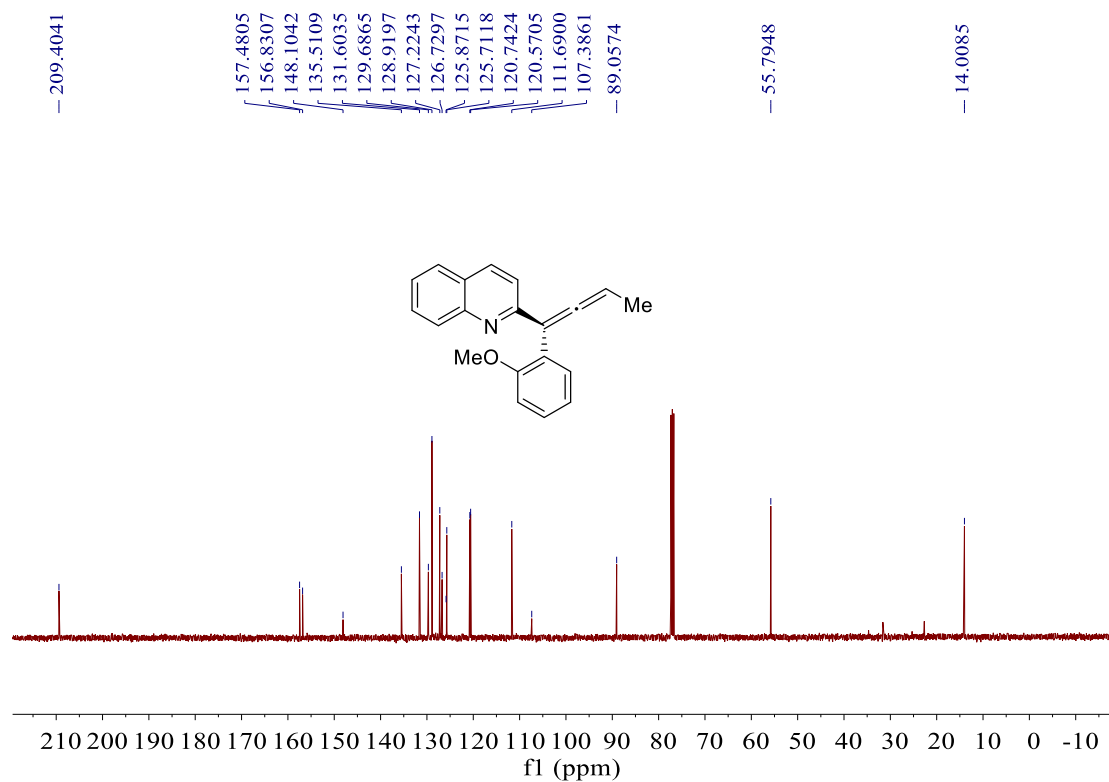
Supplementary Figure 48. ¹H NMR spectra for **3o**



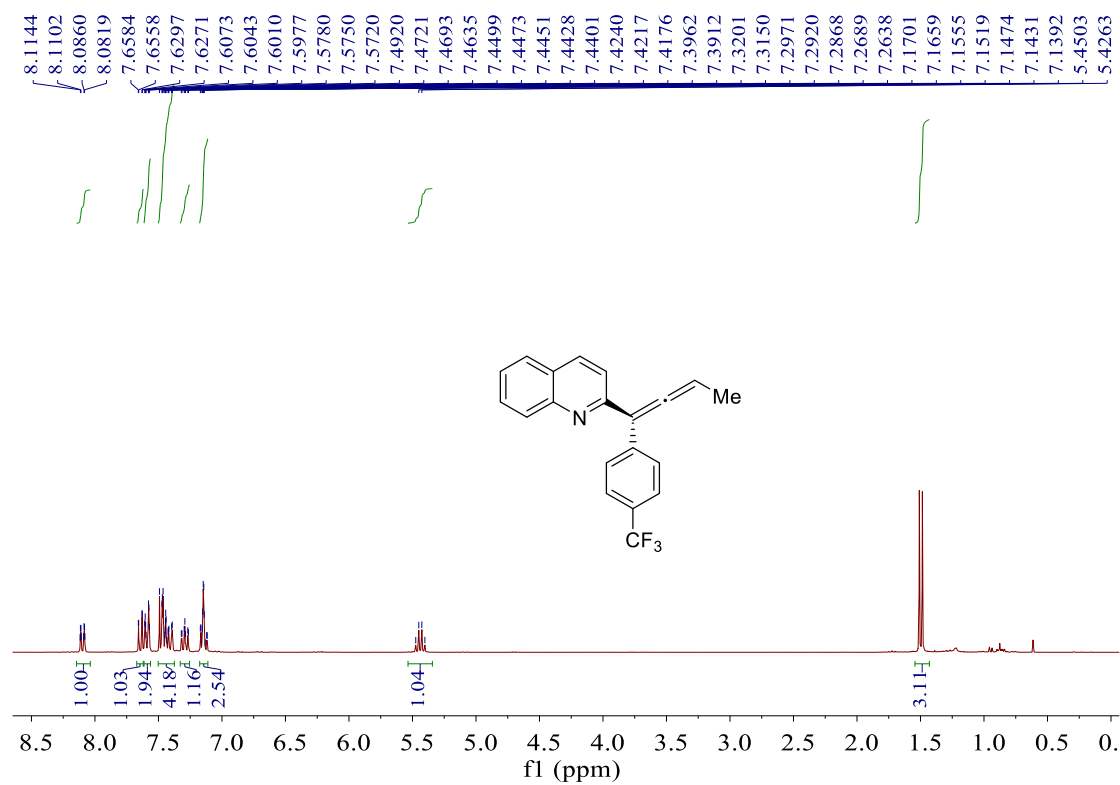
Supplementary Figure 49. ¹³C NMR spectra for **3o**



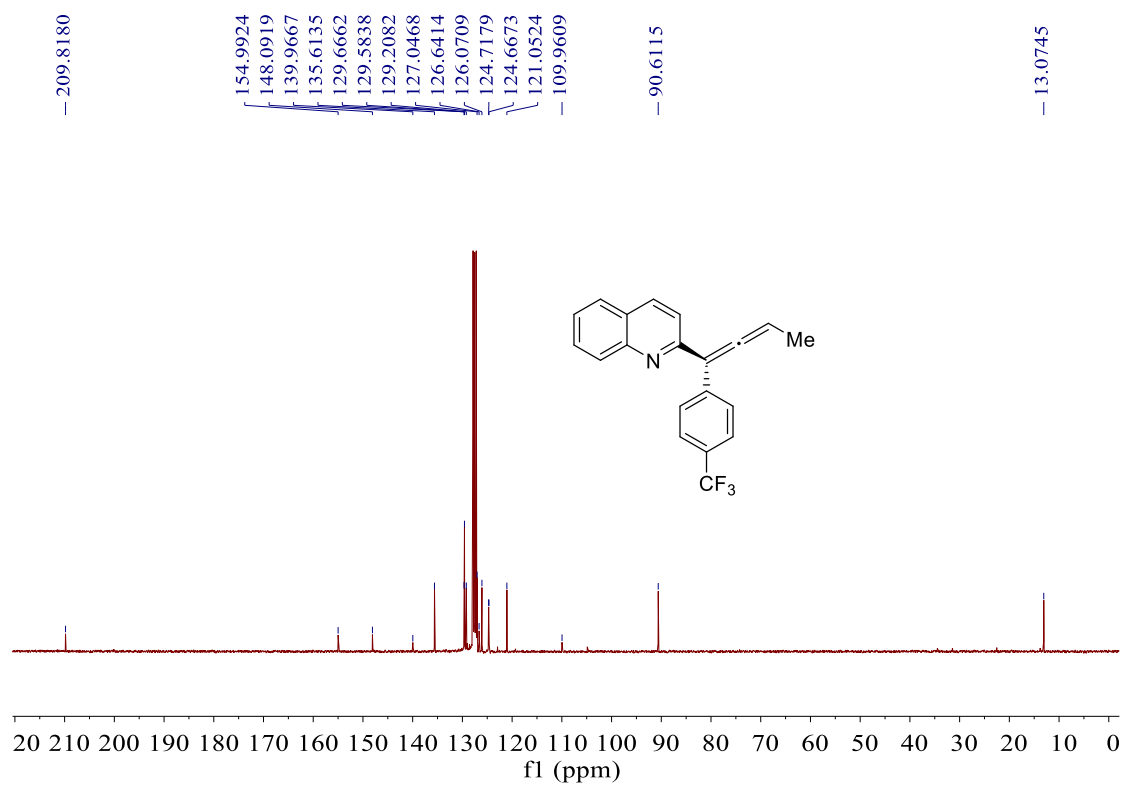
Supplementary Figure 50. ¹H NMR spectra for **3p**



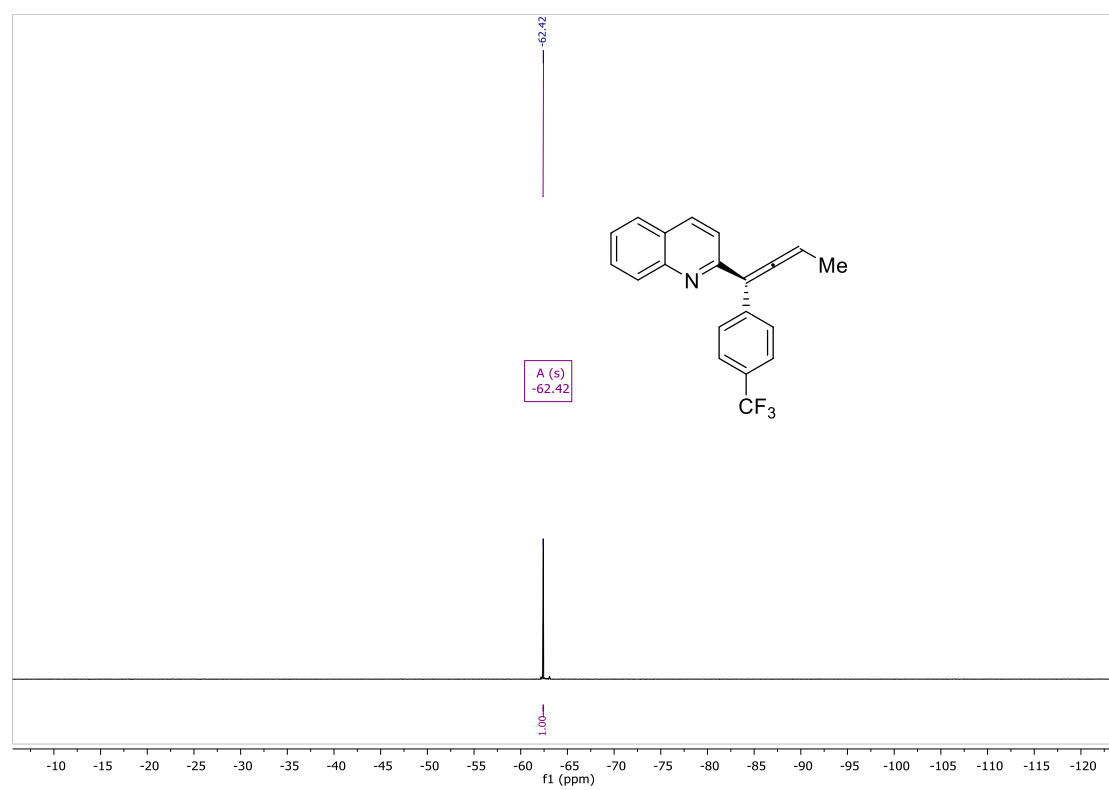
Supplementary Figure 51. ¹³C NMR spectra for **3p**



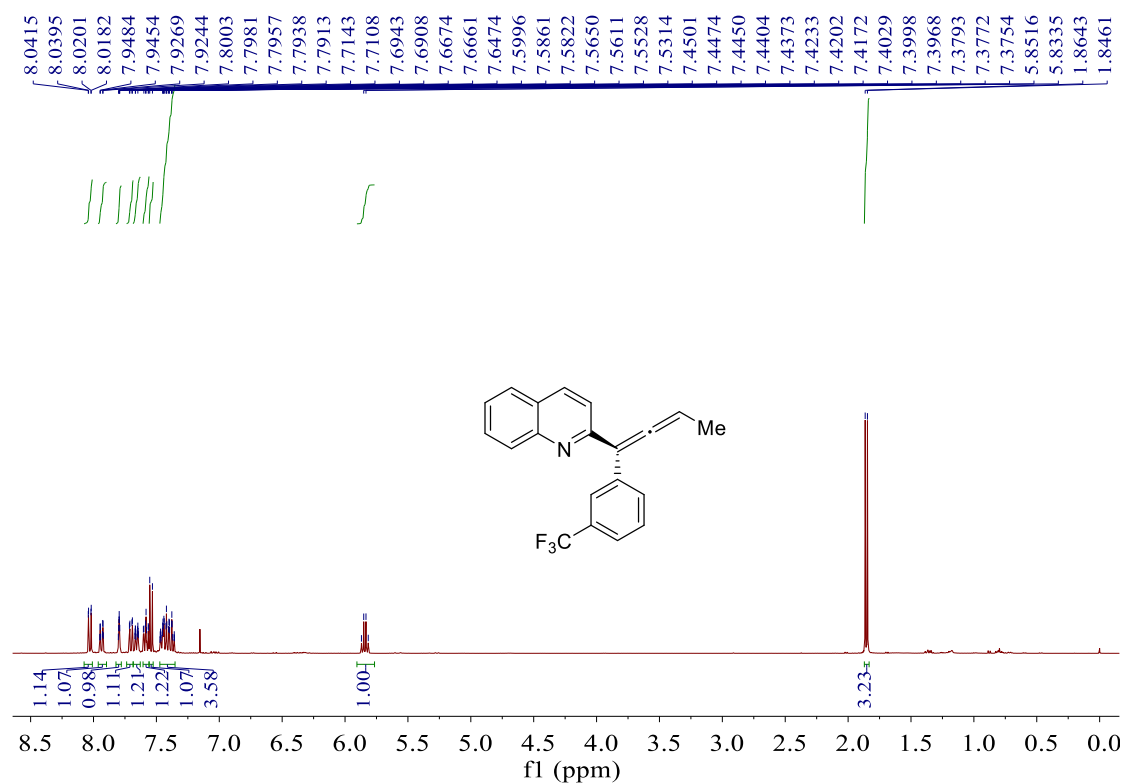
Supplementary Figure 52. ¹H NMR spectra for **3q**



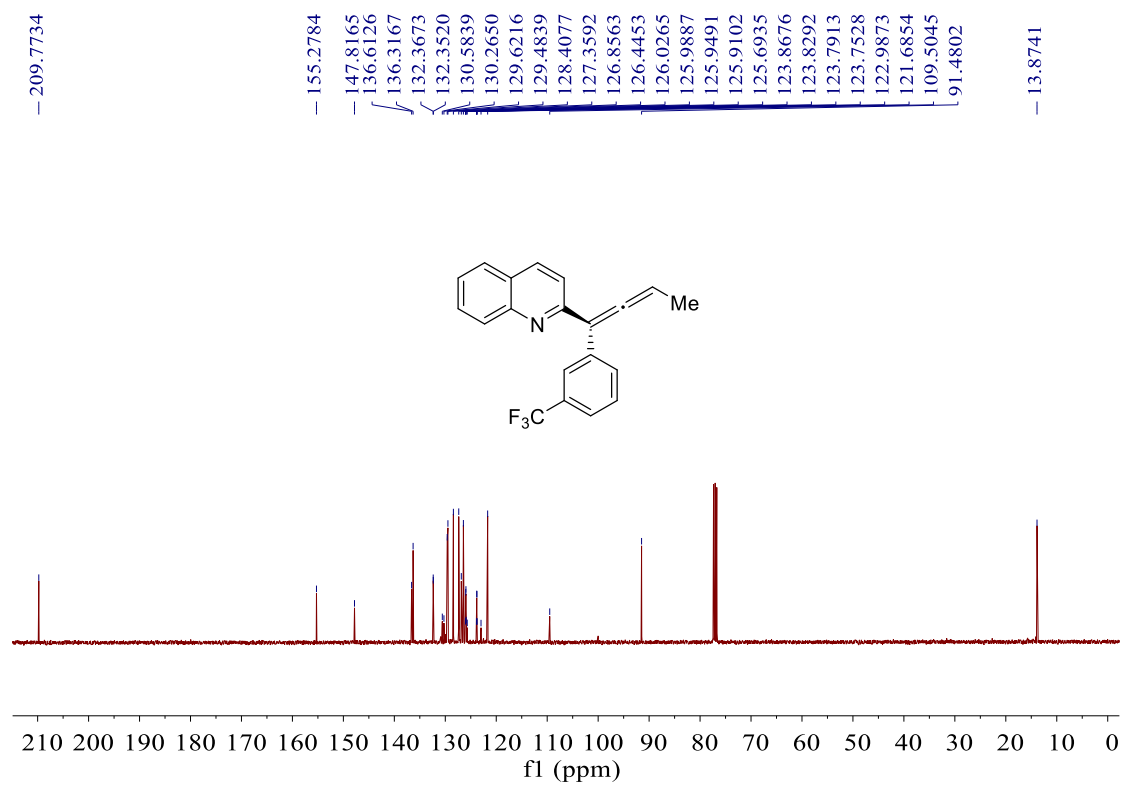
Supplementary Figure 53. ¹³C NMR spectra for **3q**



Supplementary Figure 54. ¹⁹F NMR spectra for **3q**



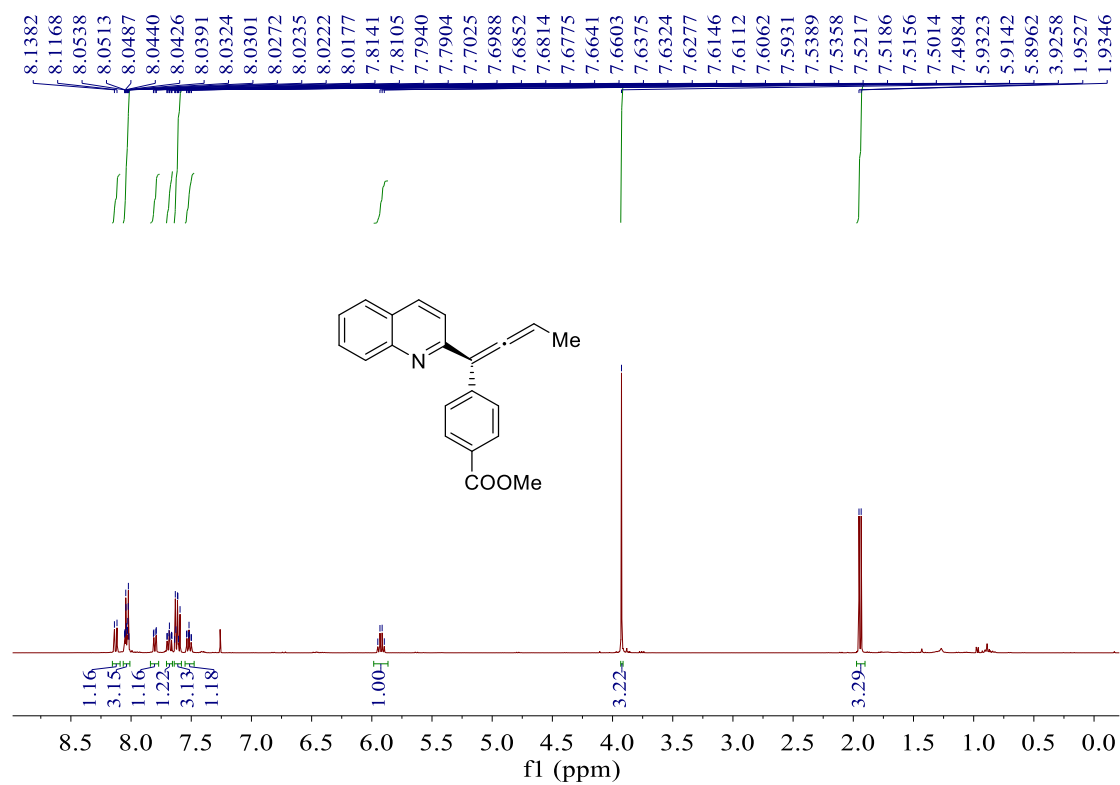
Supplementary Figure 55. ¹H NMR spectra for **3r**



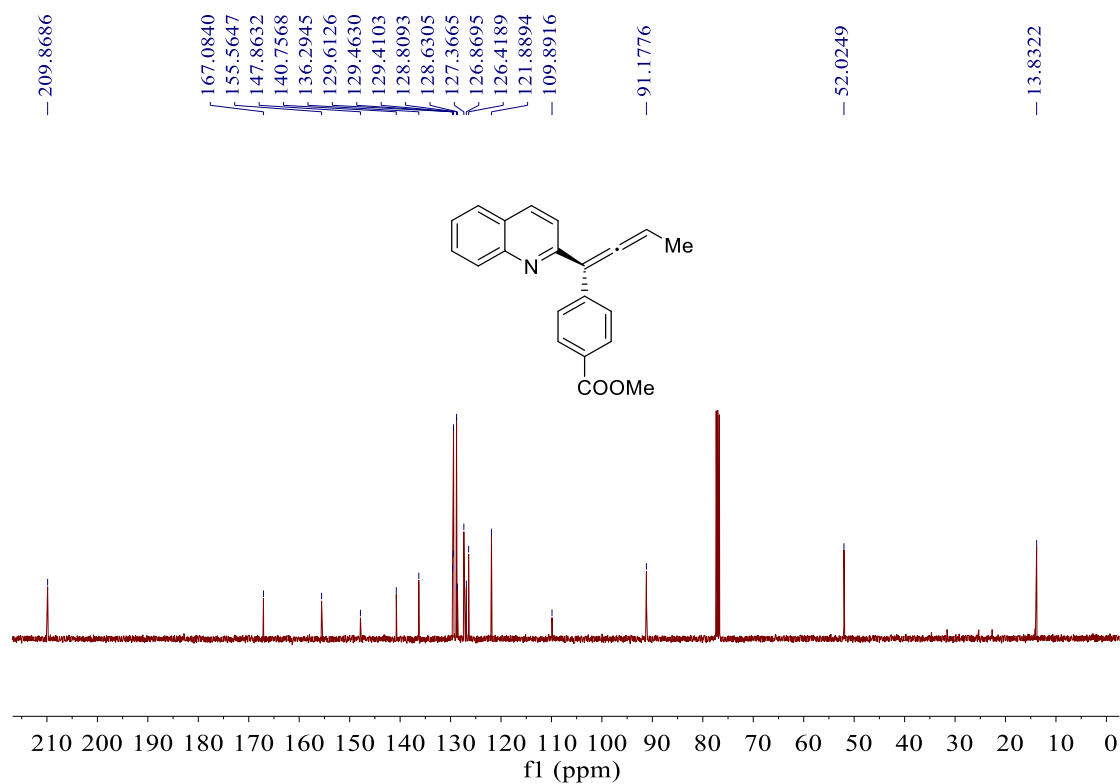
Supplementary Figure 56. ¹³C NMR spectra for **3r**



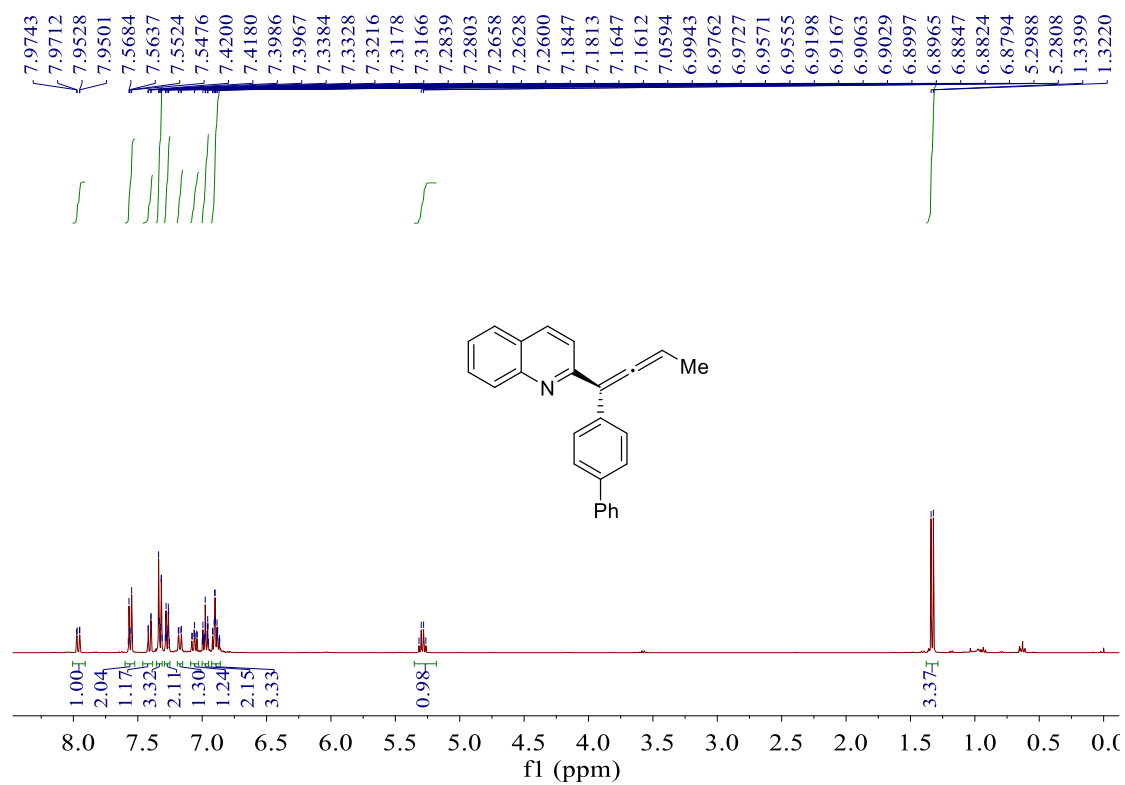
Supplementary Figure 57. ¹⁹F NMR spectra for **3r**



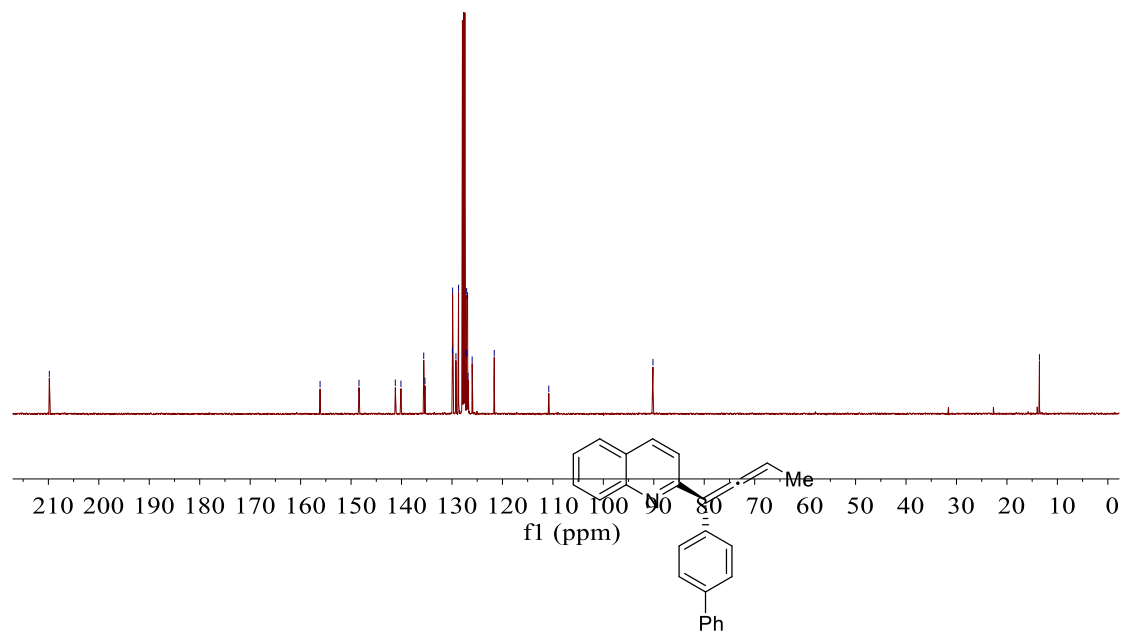
Supplementary Figure 58. ¹H NMR spectra for **3s**



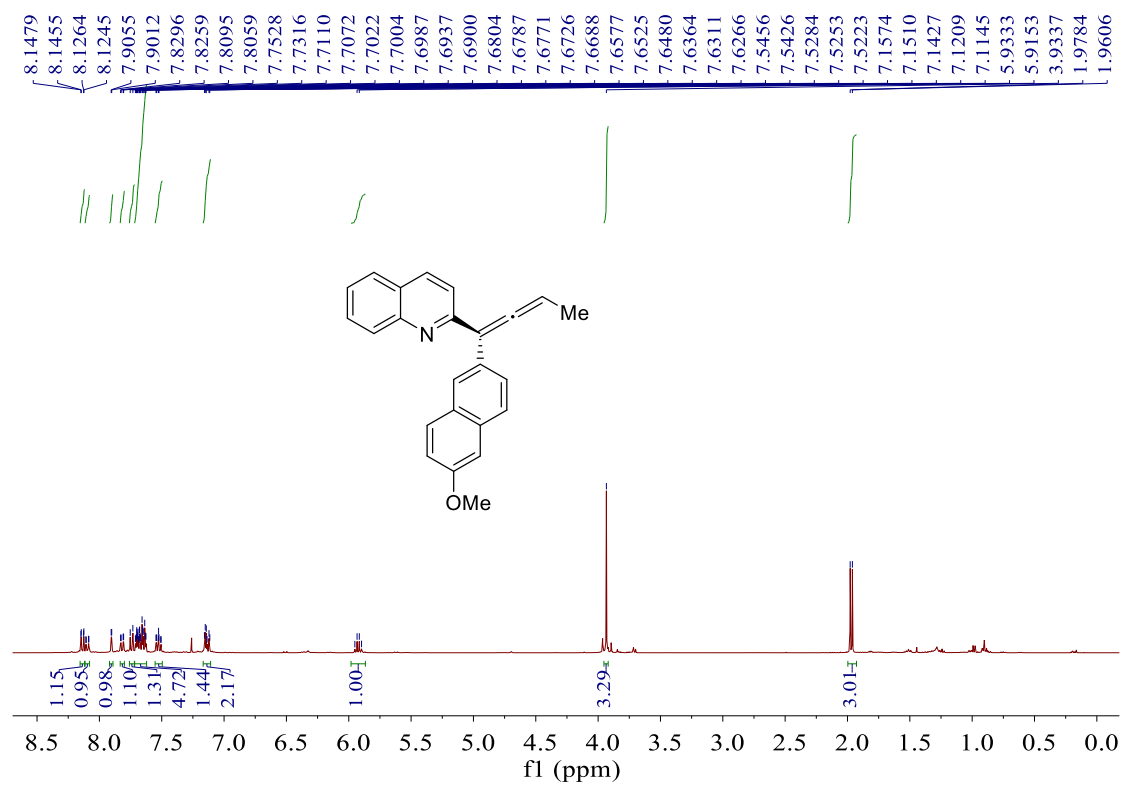
Supplementary Figure 59. ¹³C NMR spectra for **3s**



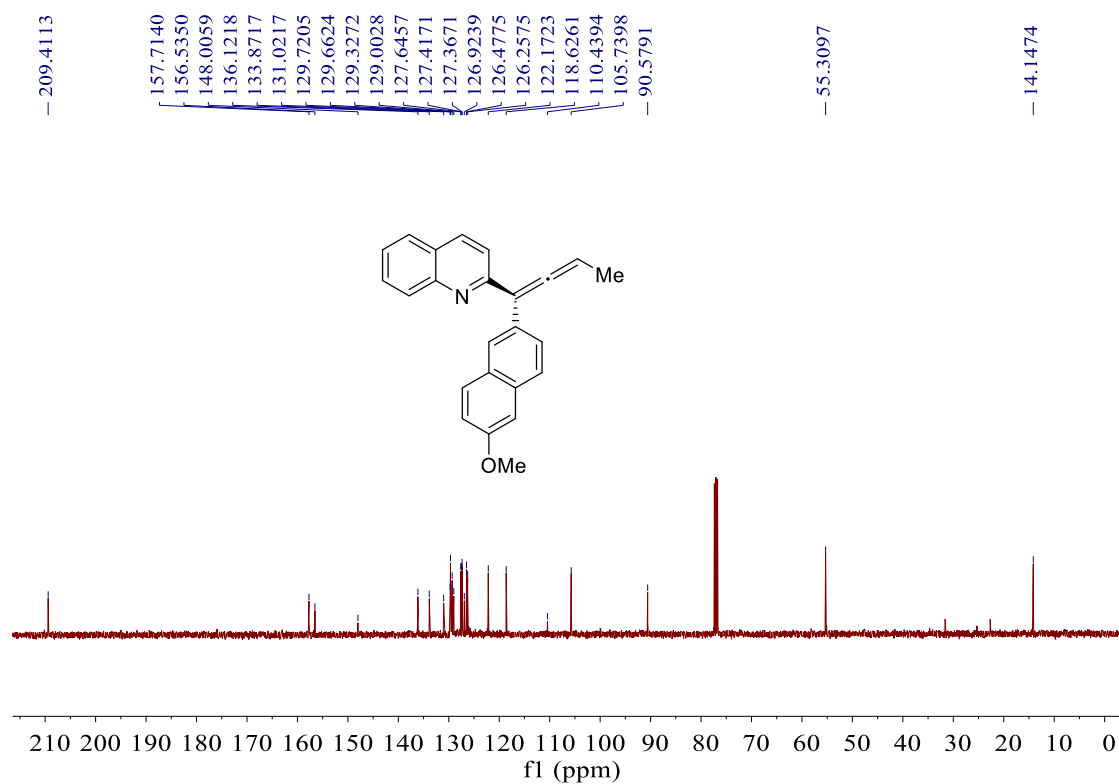
Supplementary Figure 60. ¹H NMR spectra for **3t**



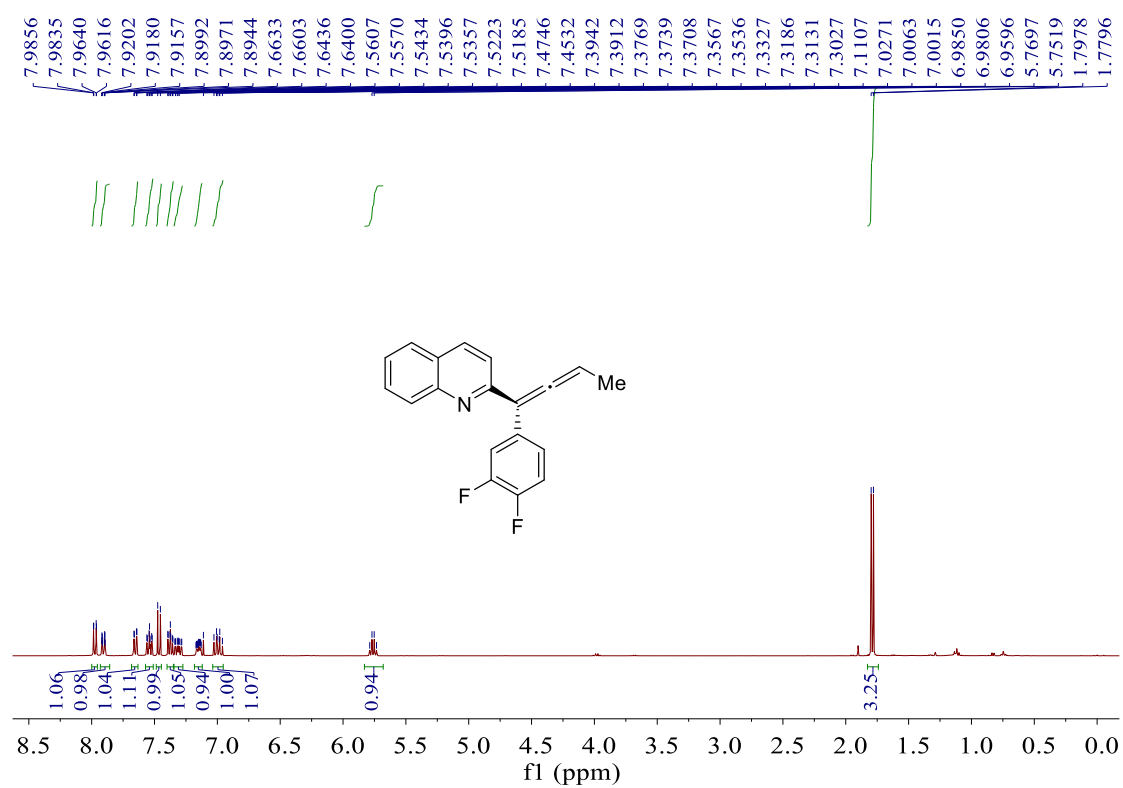
Supplementary Figure 61. ¹³C NMR spectra for **3t**



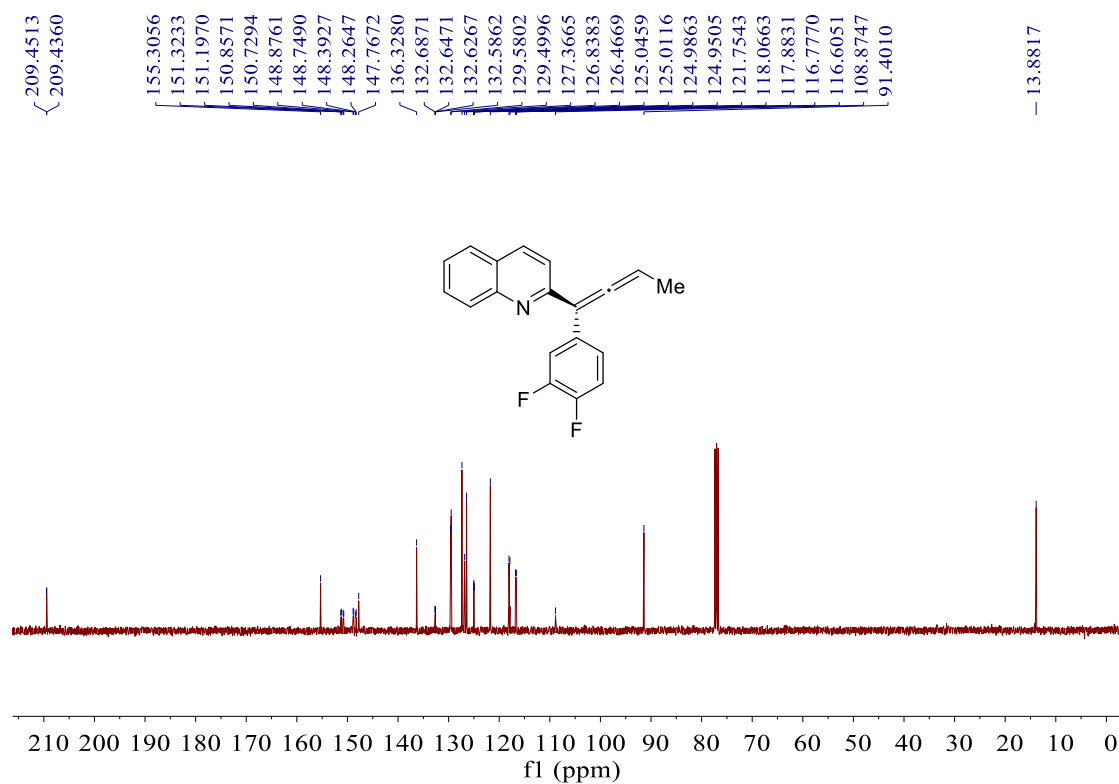
Supplementary Figure 62. ¹H NMR spectra for **3u**



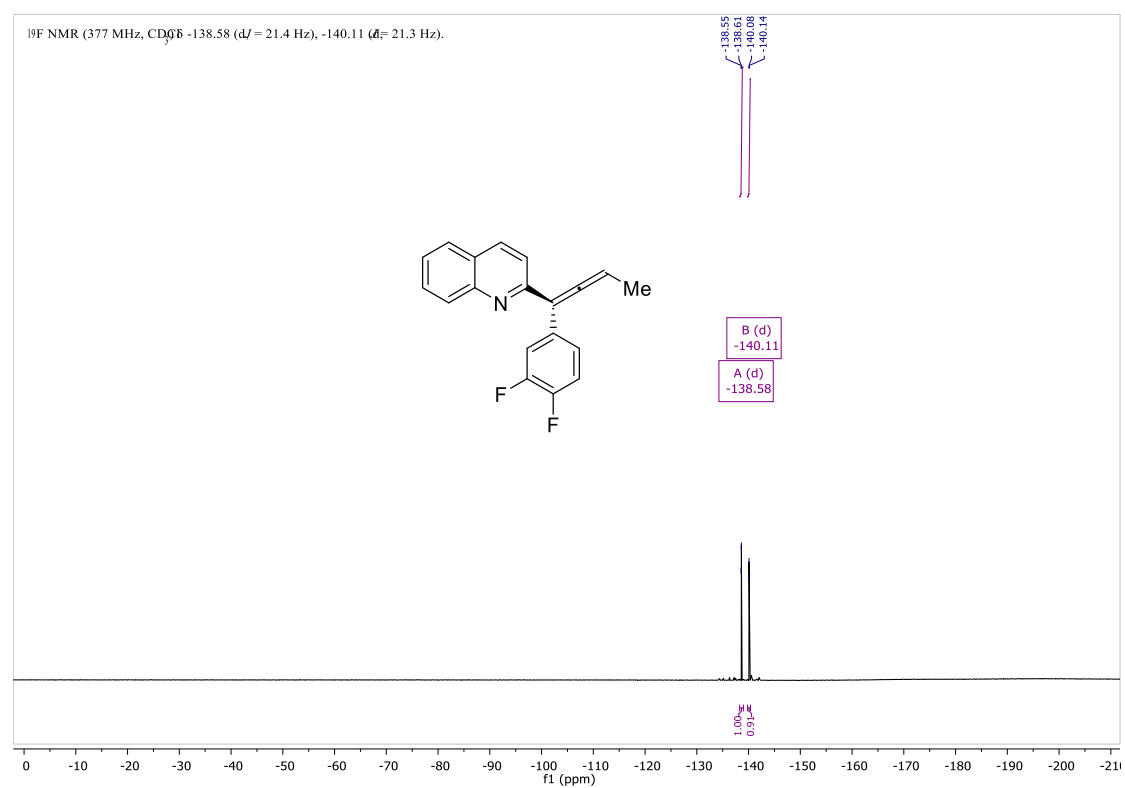
Supplementary Figure 63. ¹³C NMR spectra for **3u**



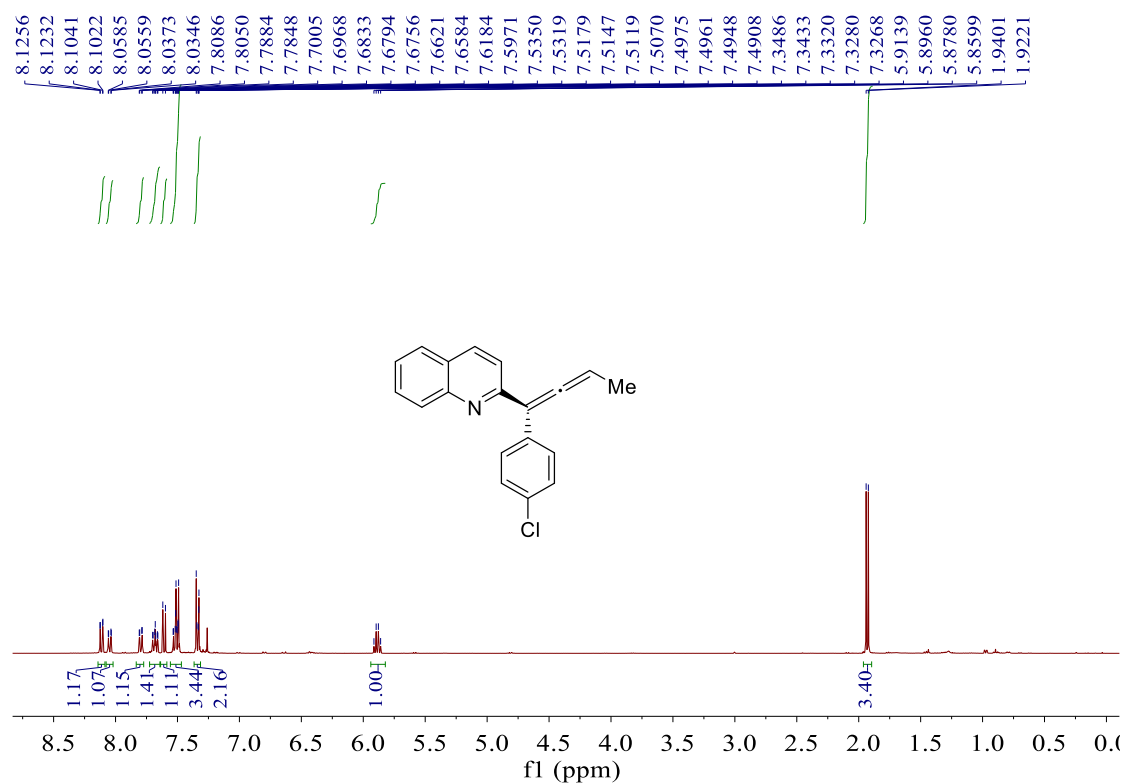
Supplementary Figure 64. ¹H NMR spectra for **3v**



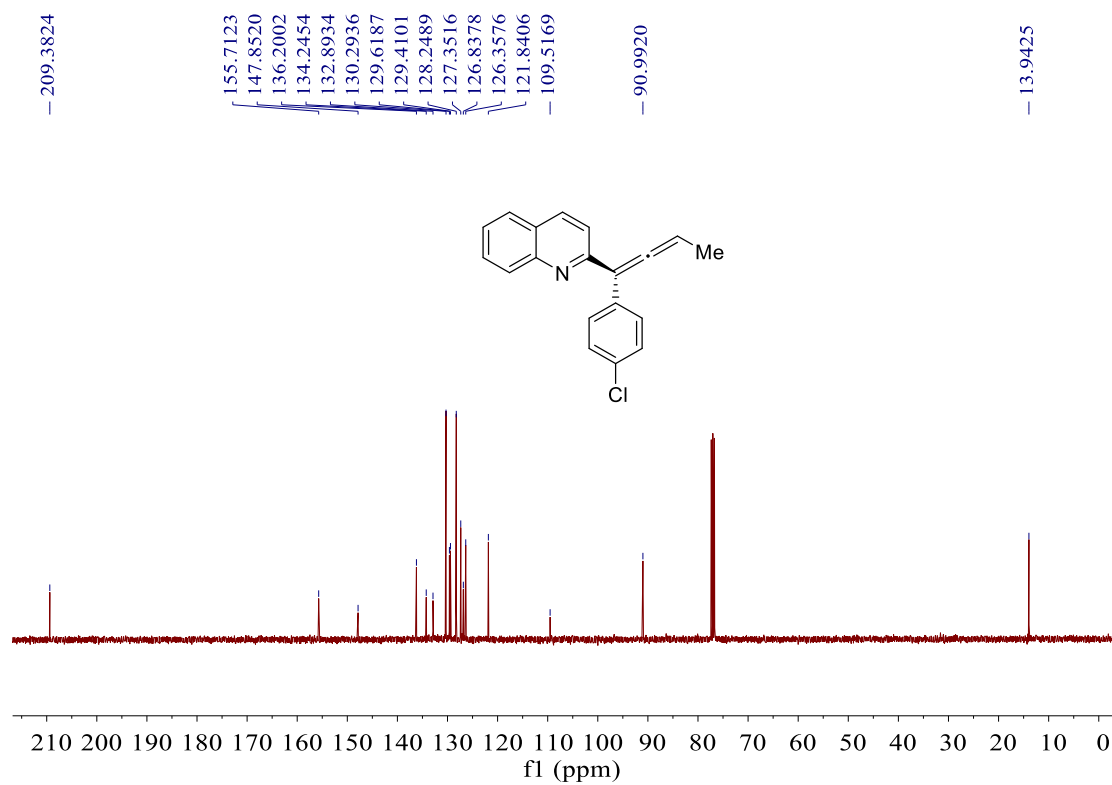
Supplementary Figure 65. ¹³C NMR spectra for **3v**



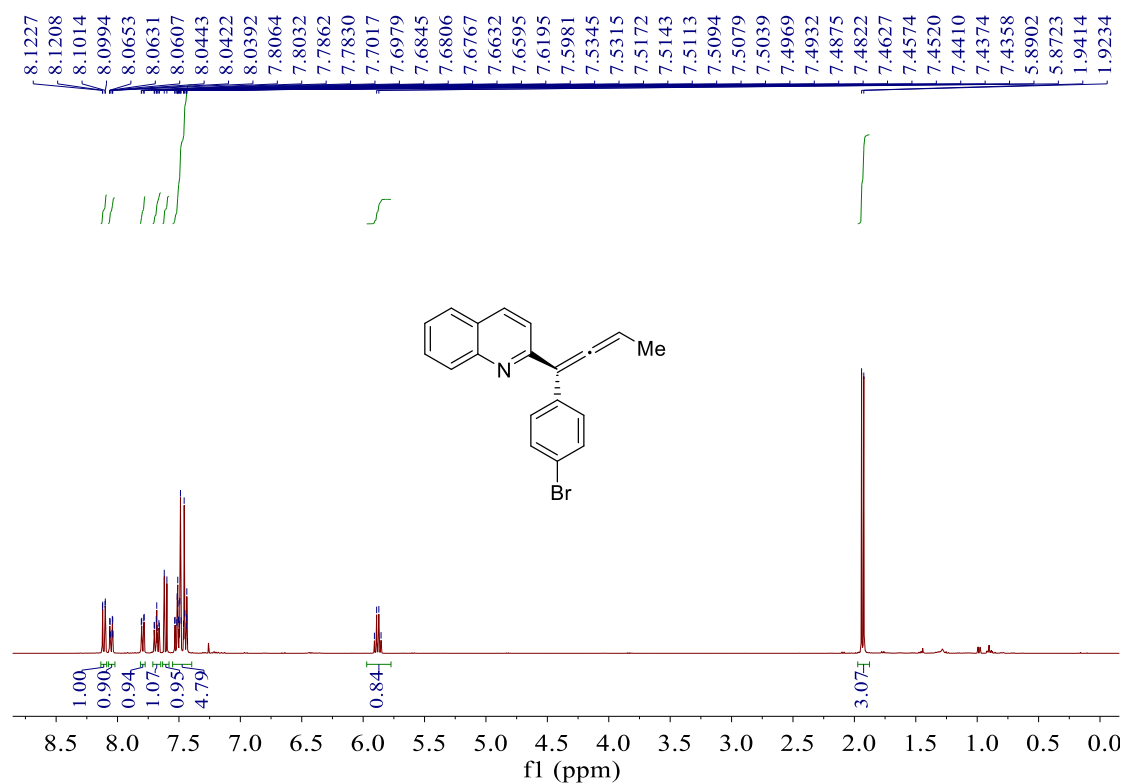
Supplementary Figure 66. ¹⁹F NMR spectra for **3v**



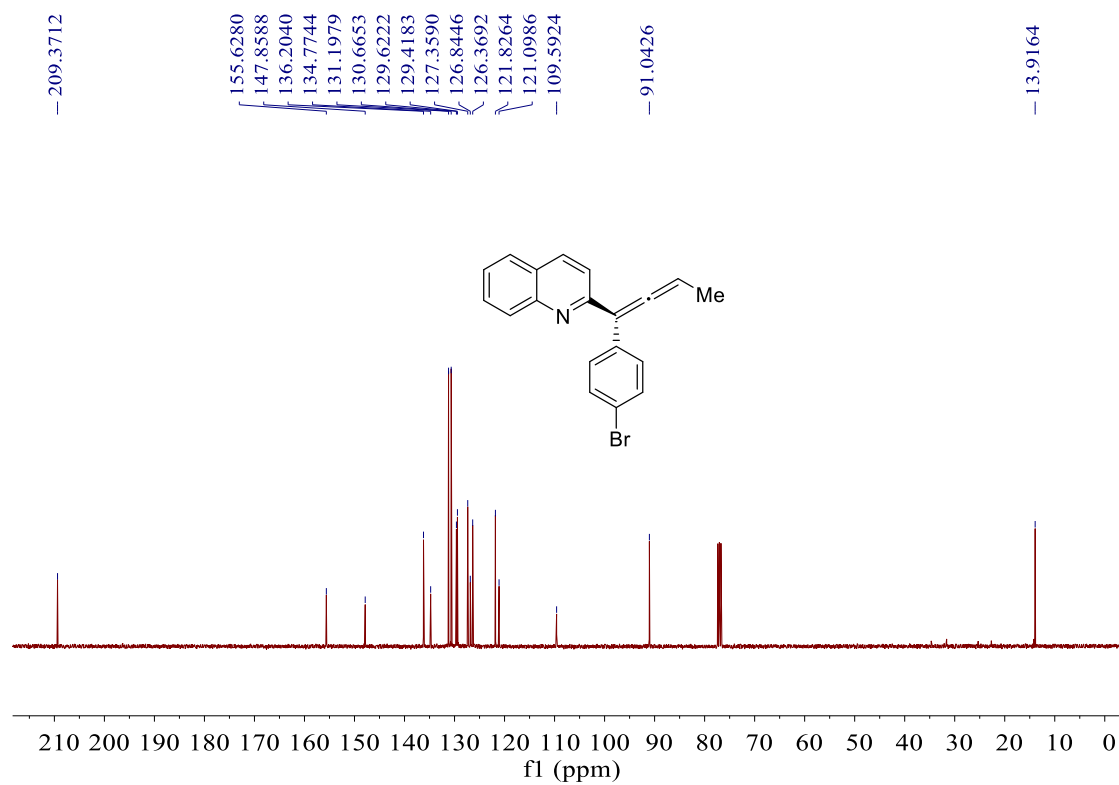
Supplementary Figure 67. ¹H NMR spectra for **3w**



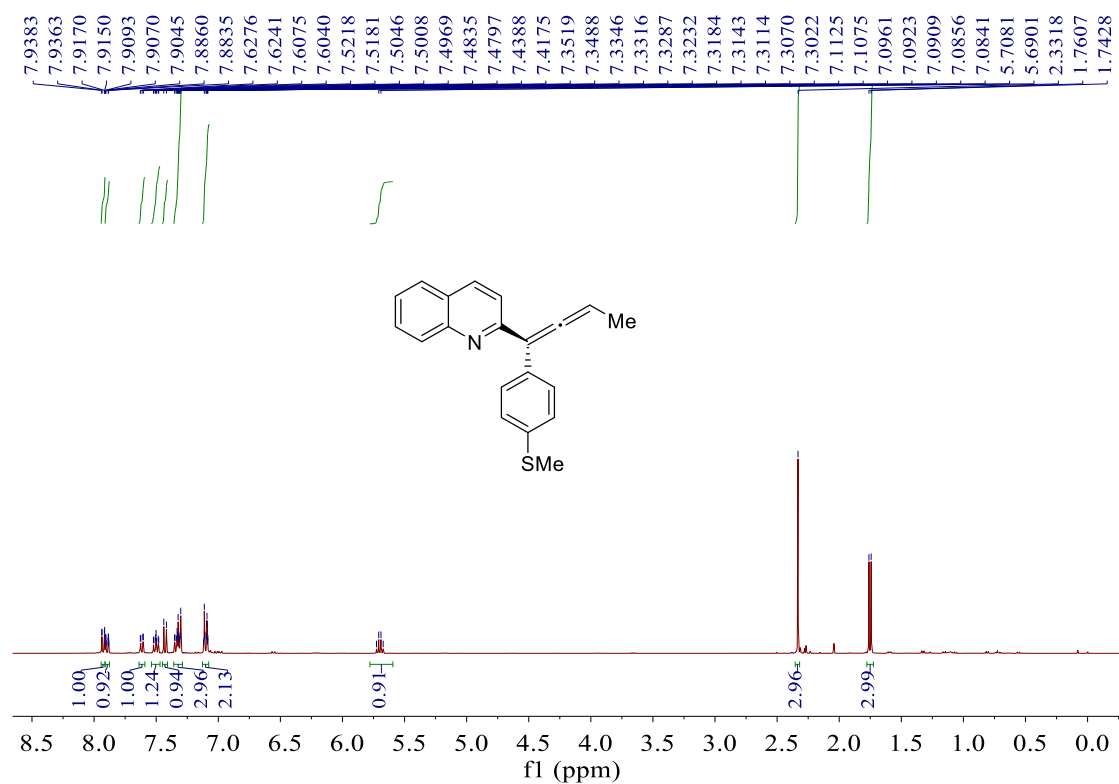
Supplementary Figure 68. ¹³C NMR spectra for **3w**



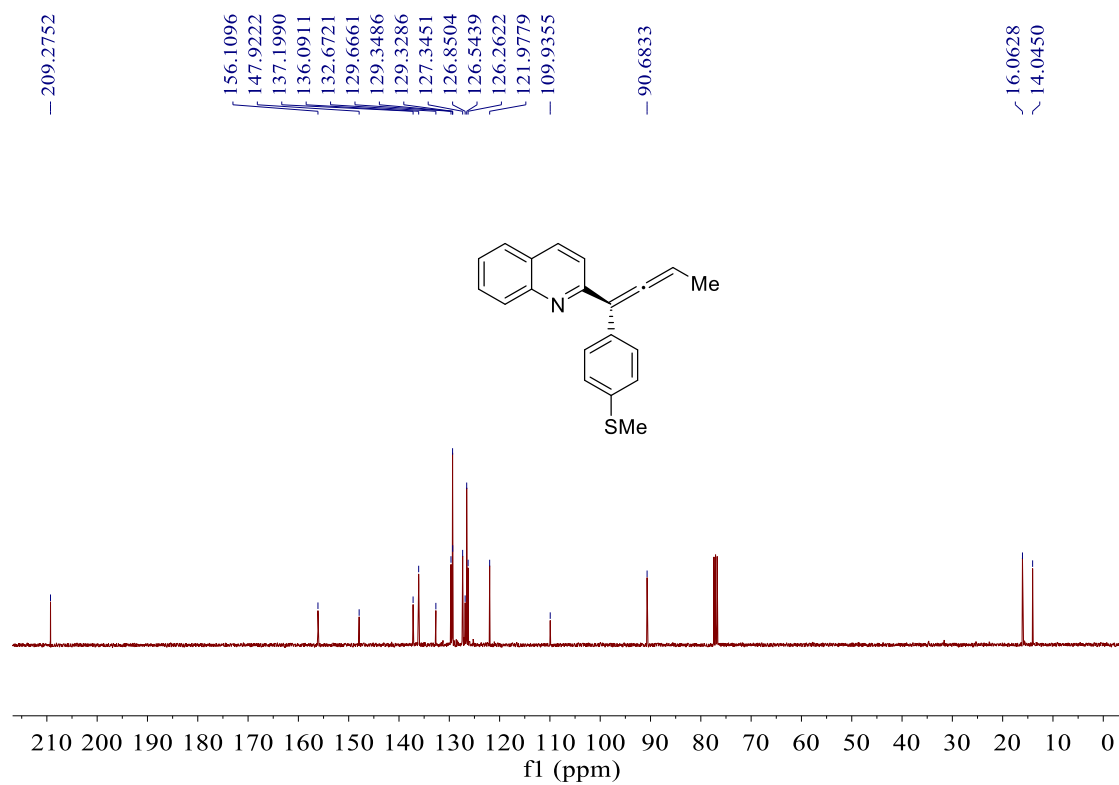
Supplementary Figure 69. ¹H NMR spectra for **3x**



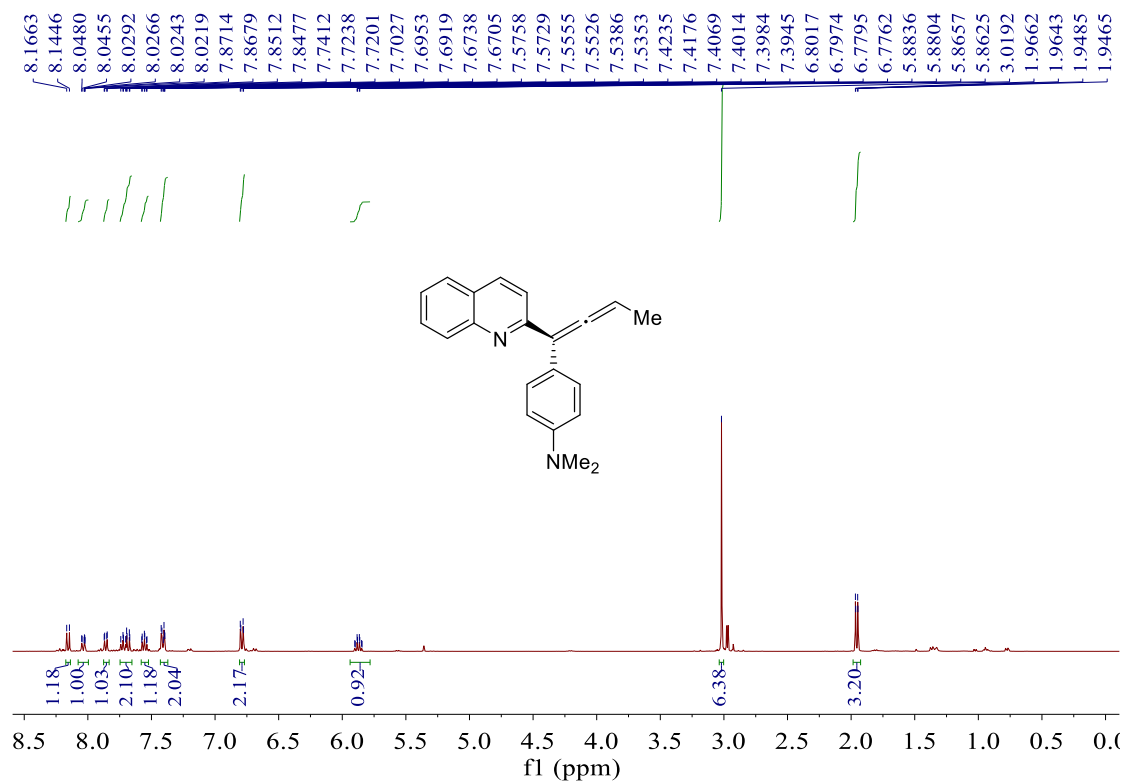
Supplementary Figure 70. ¹³C NMR spectra for **3x**



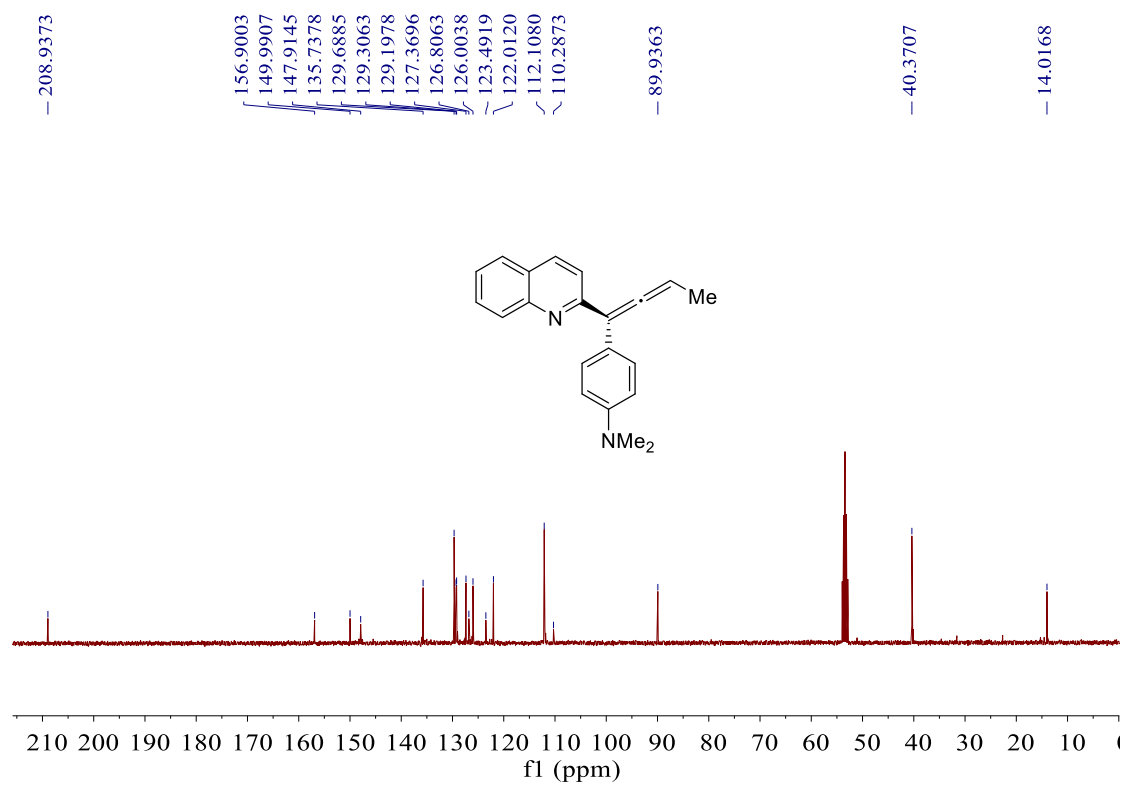
Supplementary Figure 71. ¹H NMR spectra for **3y**



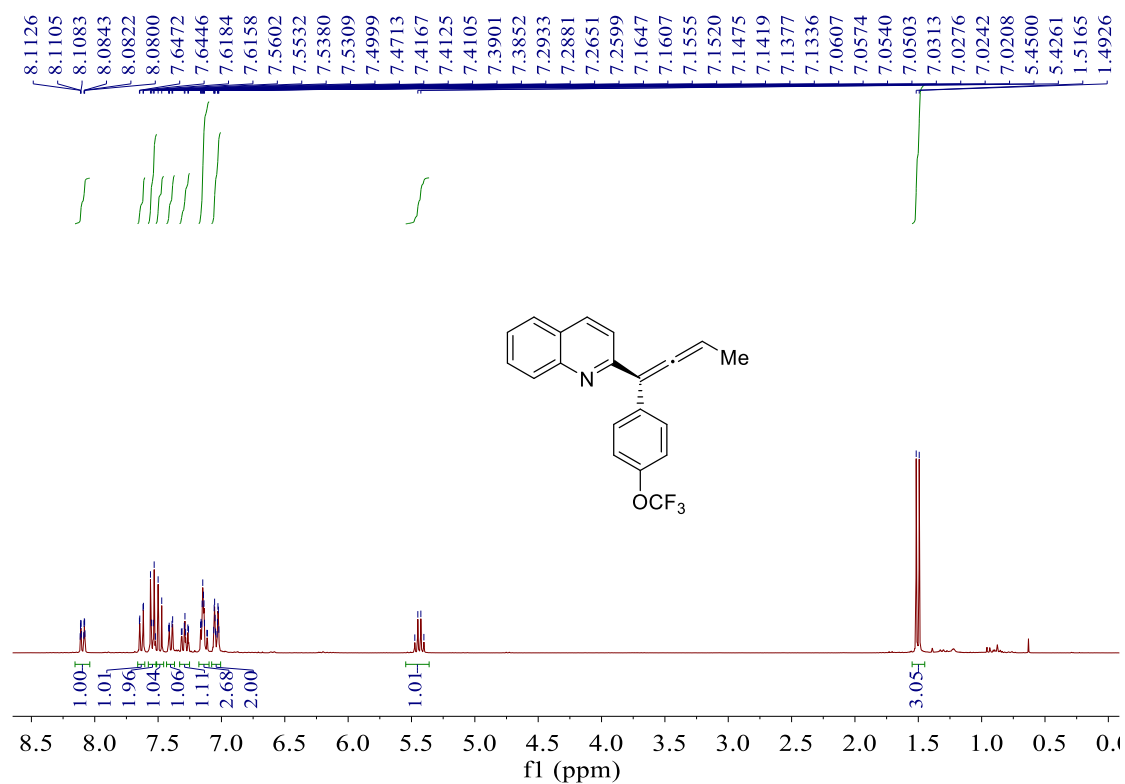
Supplementary Figure 72. ¹³C NMR spectra for **3y**



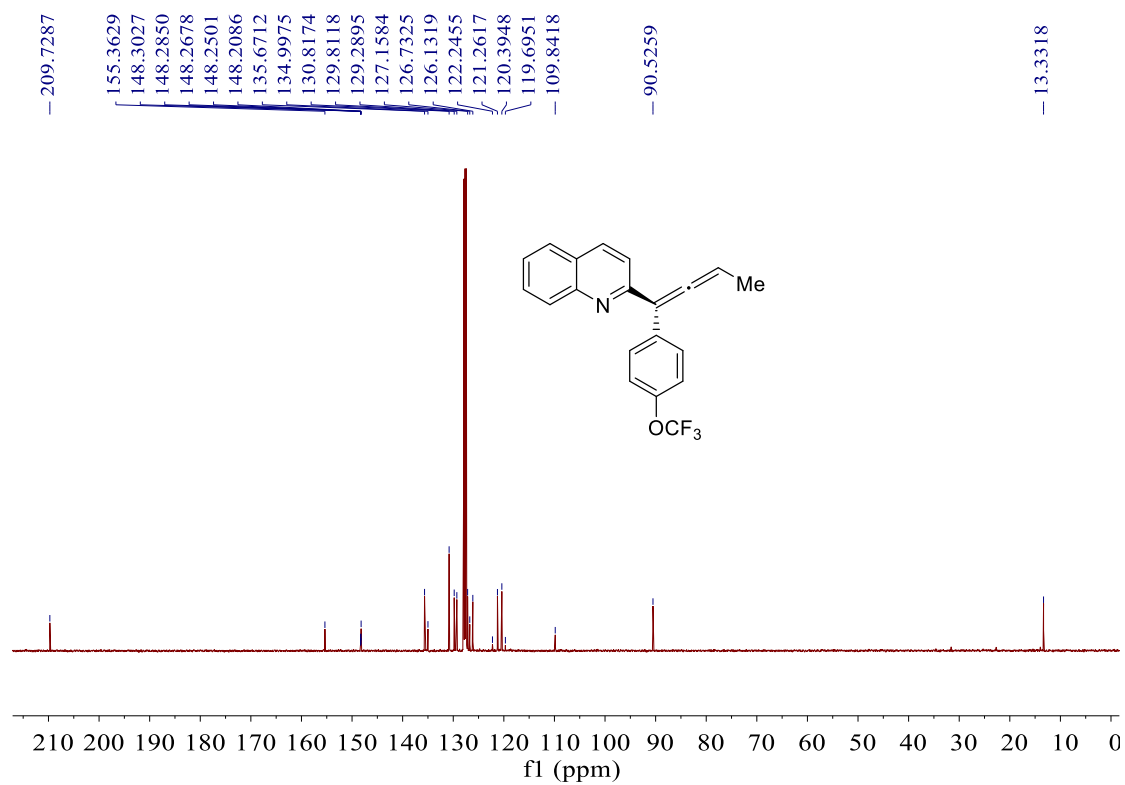
Supplementary Figure 73. ¹H NMR spectra for **3z**



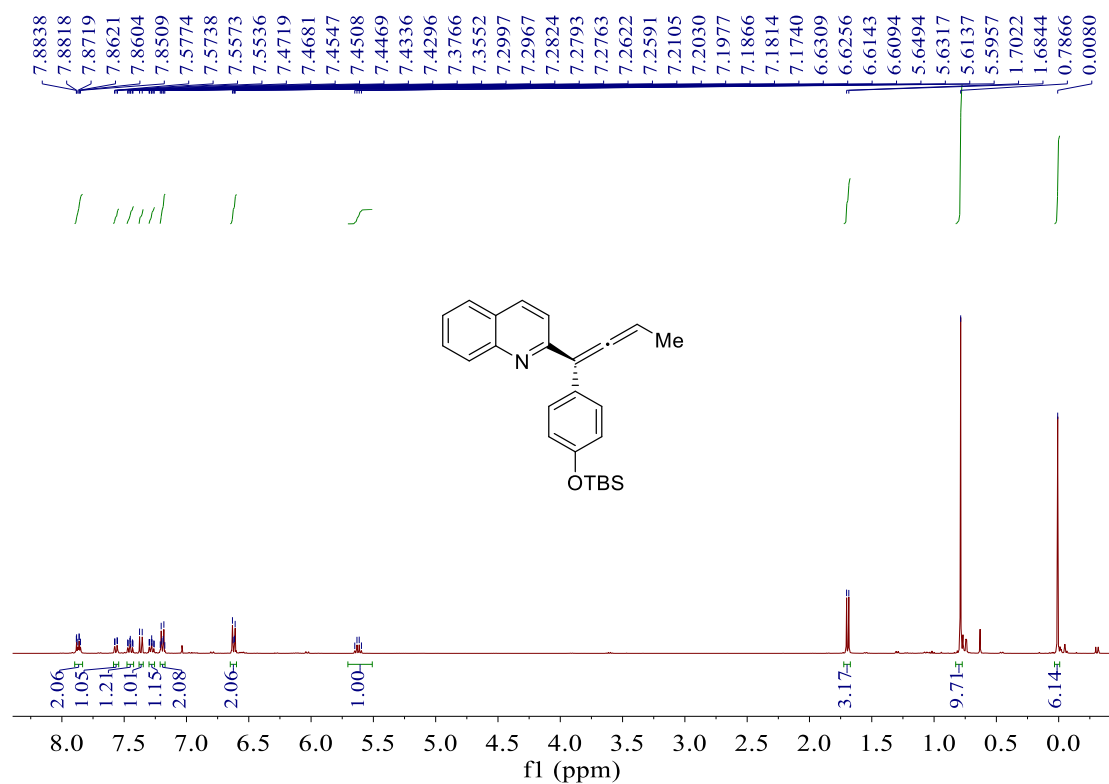
Supplementary Figure 74. ¹³C NMR spectra for **3z**



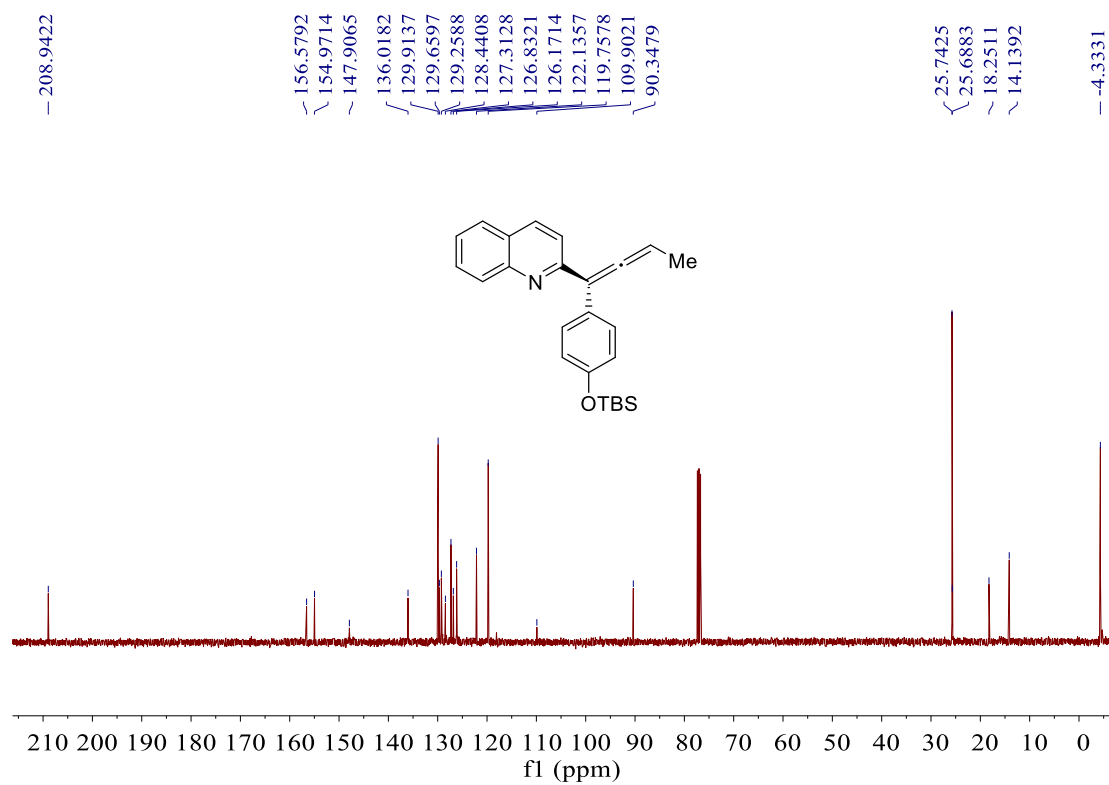
Supplementary Figure 75. ¹H NMR spectra for **3aa**



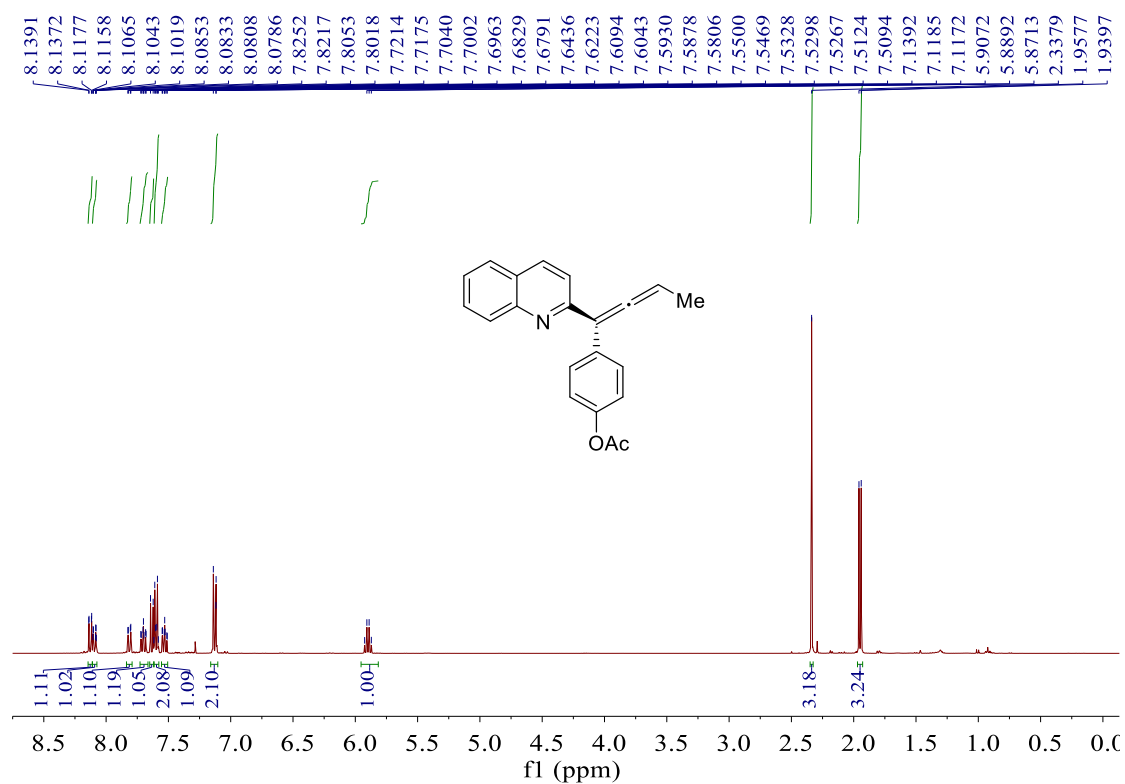
Supplementary Figure 76. ¹³C NMR spectra for **3aa**



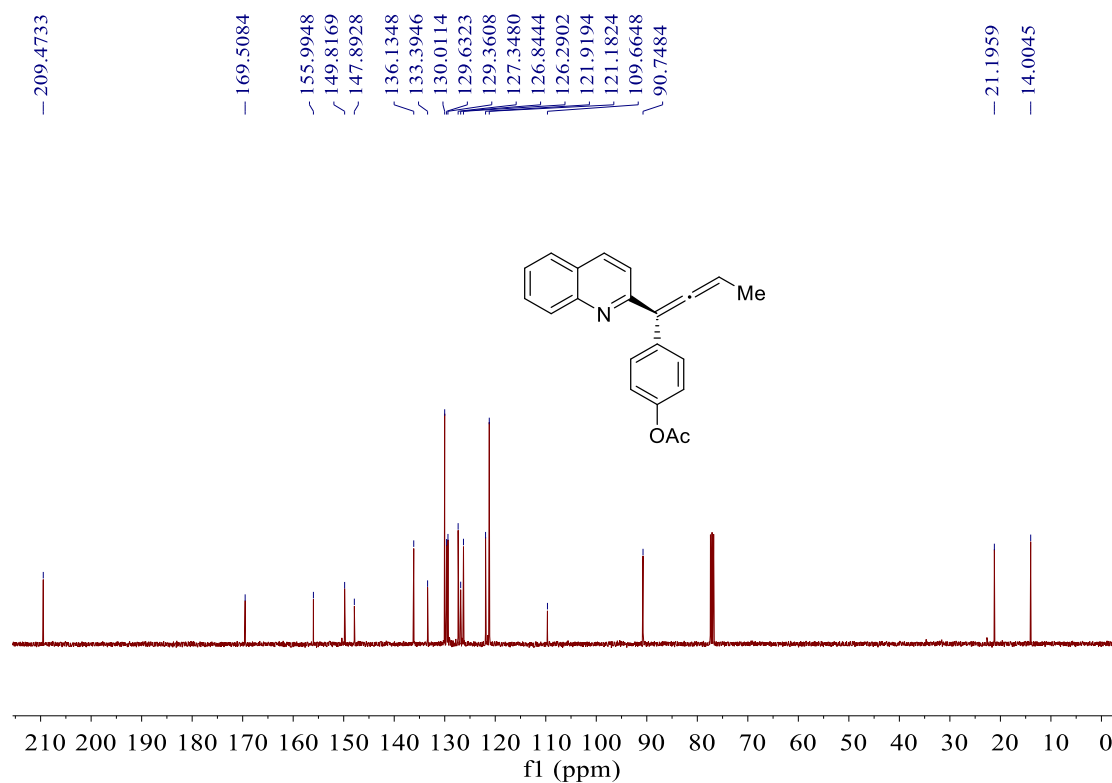
Supplementary Figure 77. ¹H NMR spectra for **3ab**



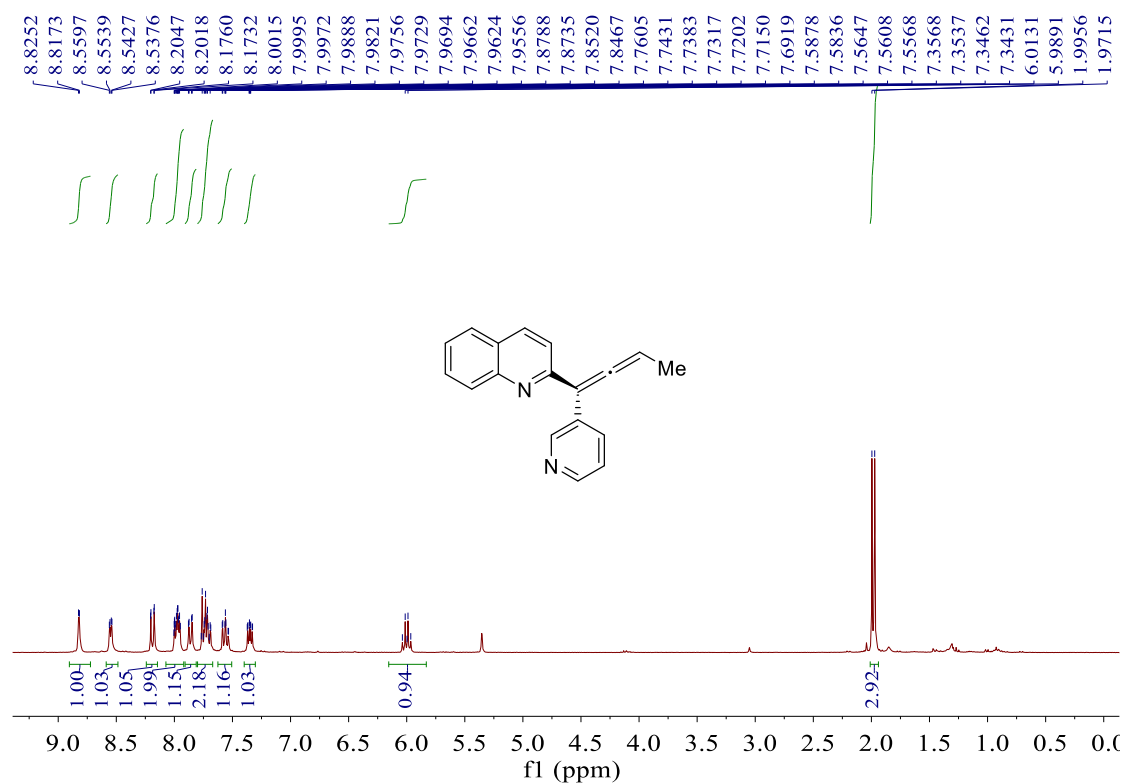
Supplementary Figure 78. ¹³C NMR spectra for **3ab**



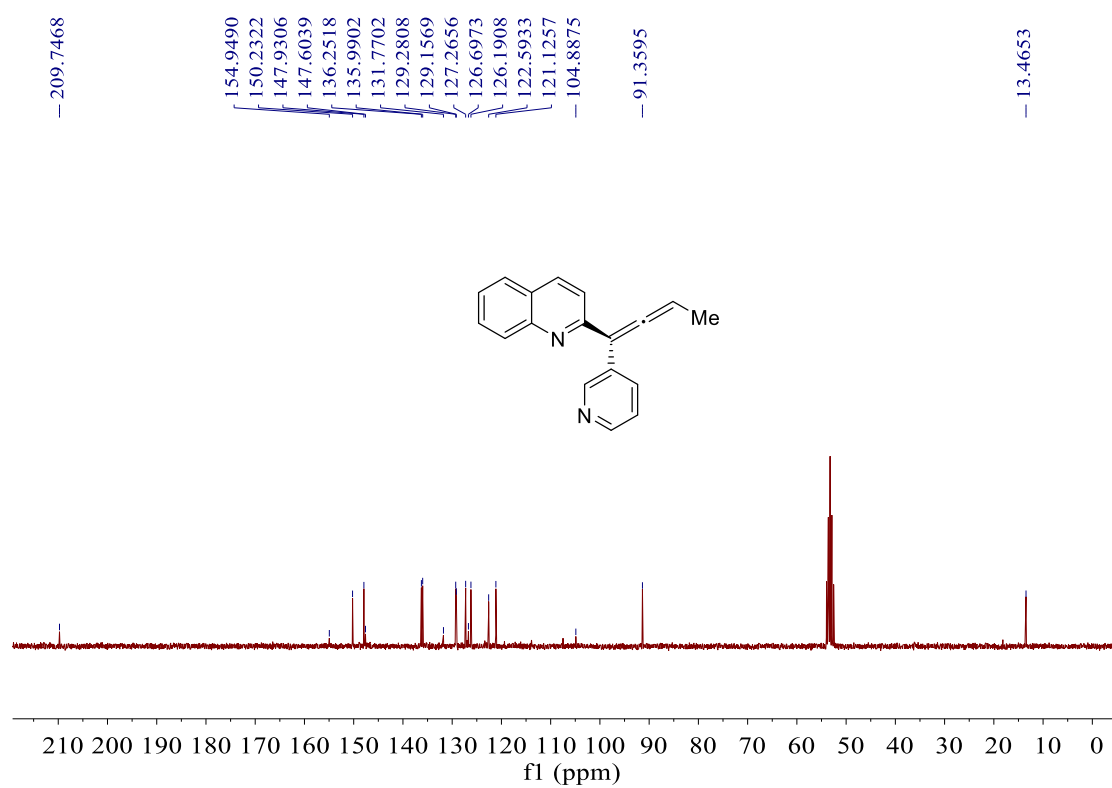
Supplementary Figure 79. ¹H NMR spectra for **3ac**



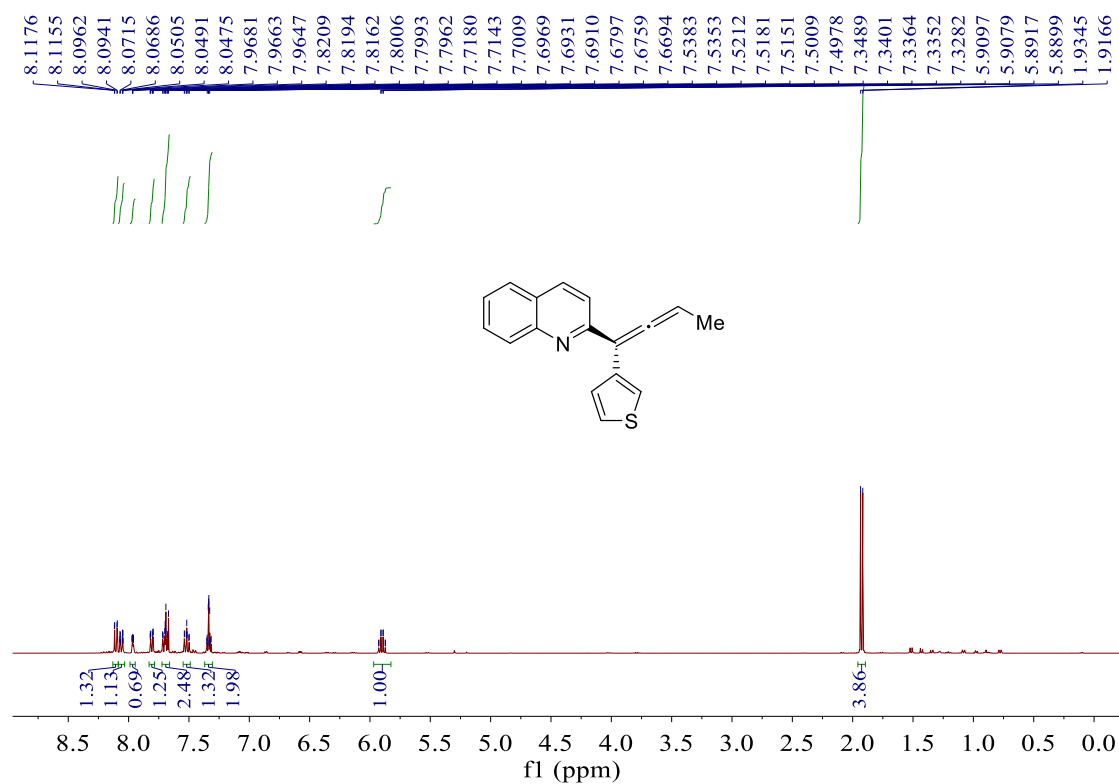
Supplementary Figure 80. ¹³C NMR spectra for **3ac**



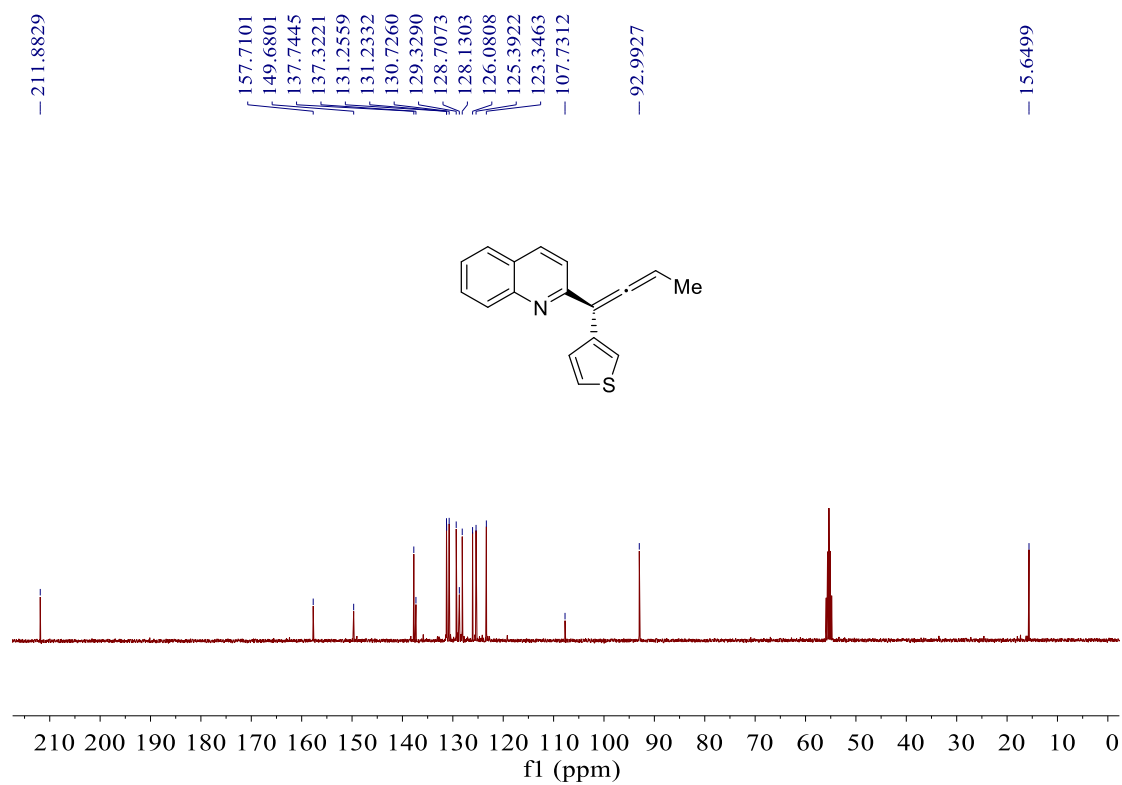
Supplementary Figure 81. ¹H NMR spectra for **3ad**



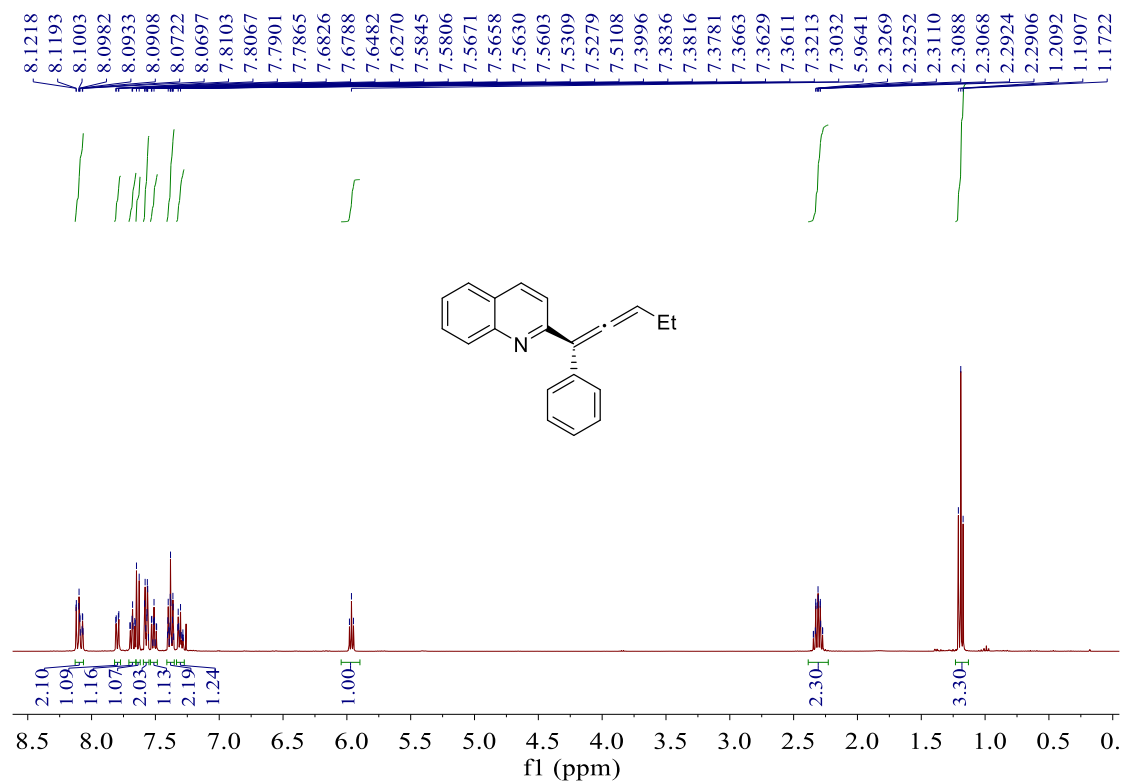
Supplementary Figure 82. ¹³C NMR spectra for **3ad**



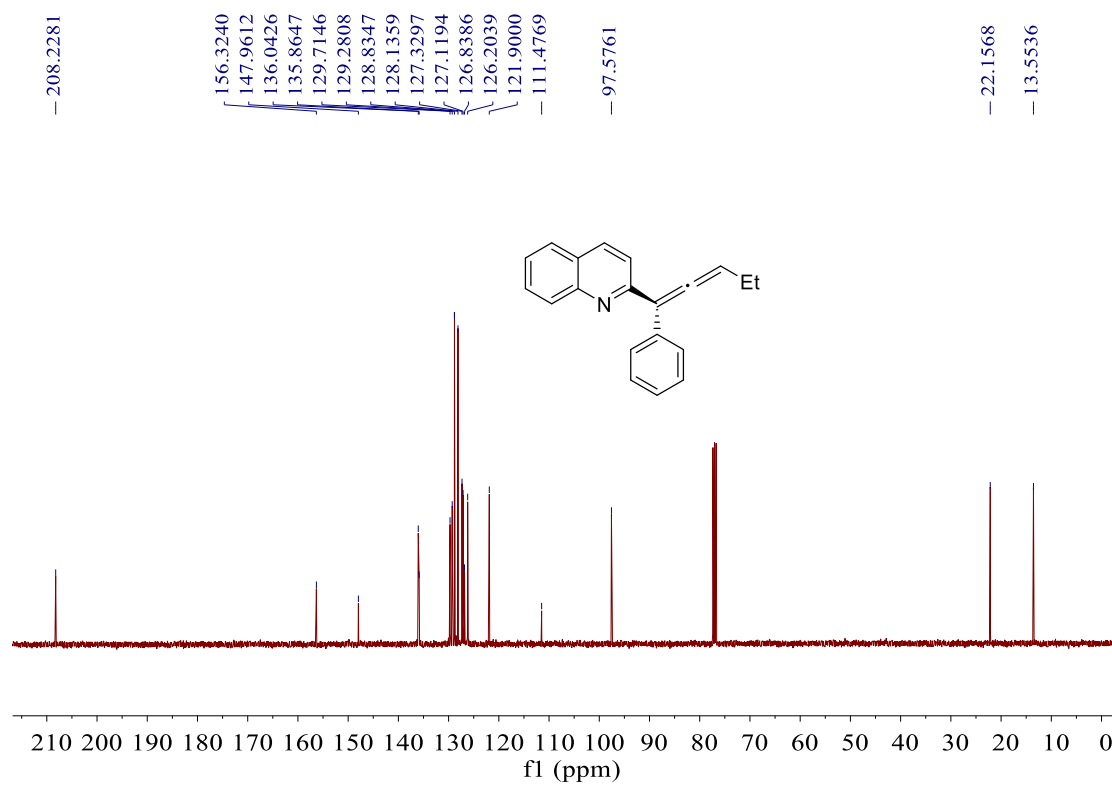
Supplementary Figure 83. ¹H NMR spectra for **3ae**



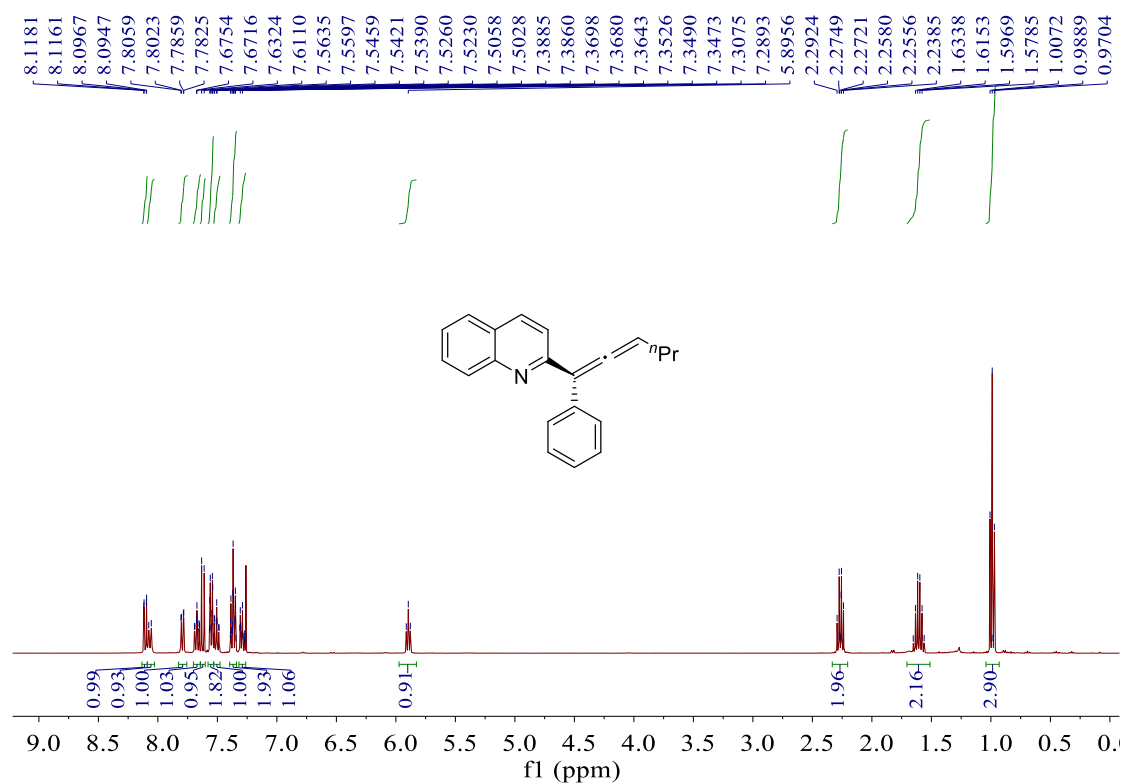
Supplementary Figure 84. ¹³C NMR spectra for **3ae**



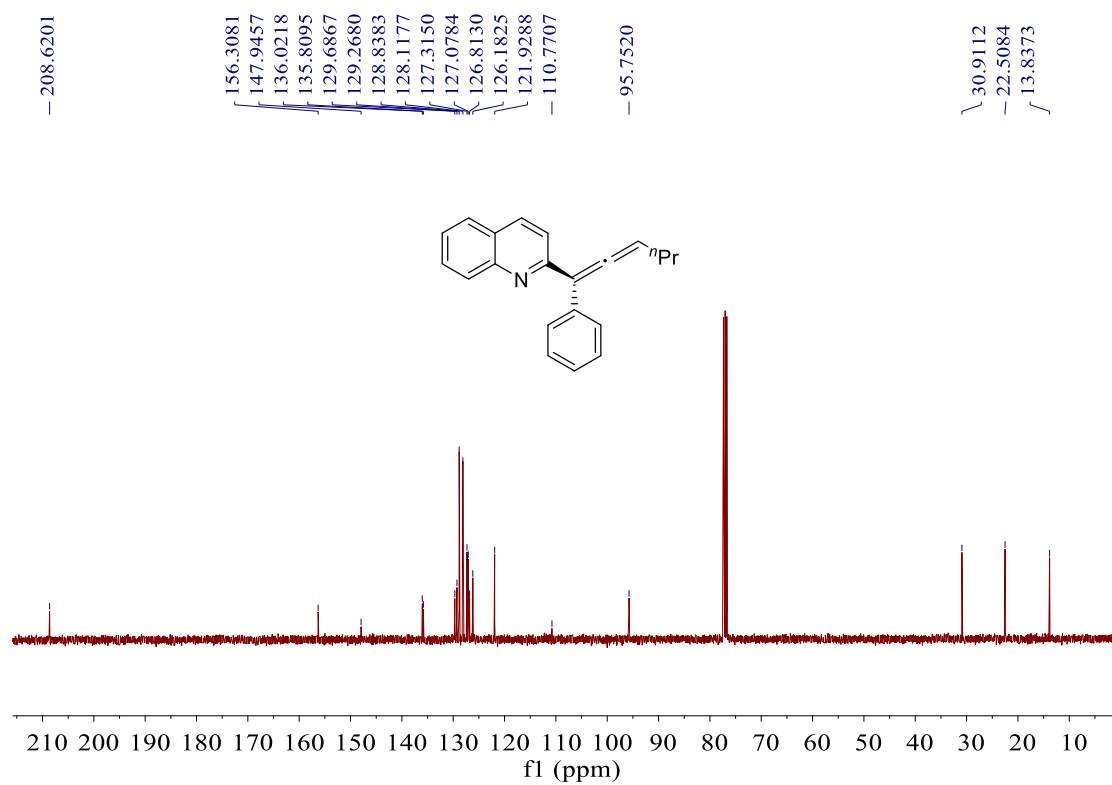
Supplementary Figure 85. ¹H NMR spectra for **3af**



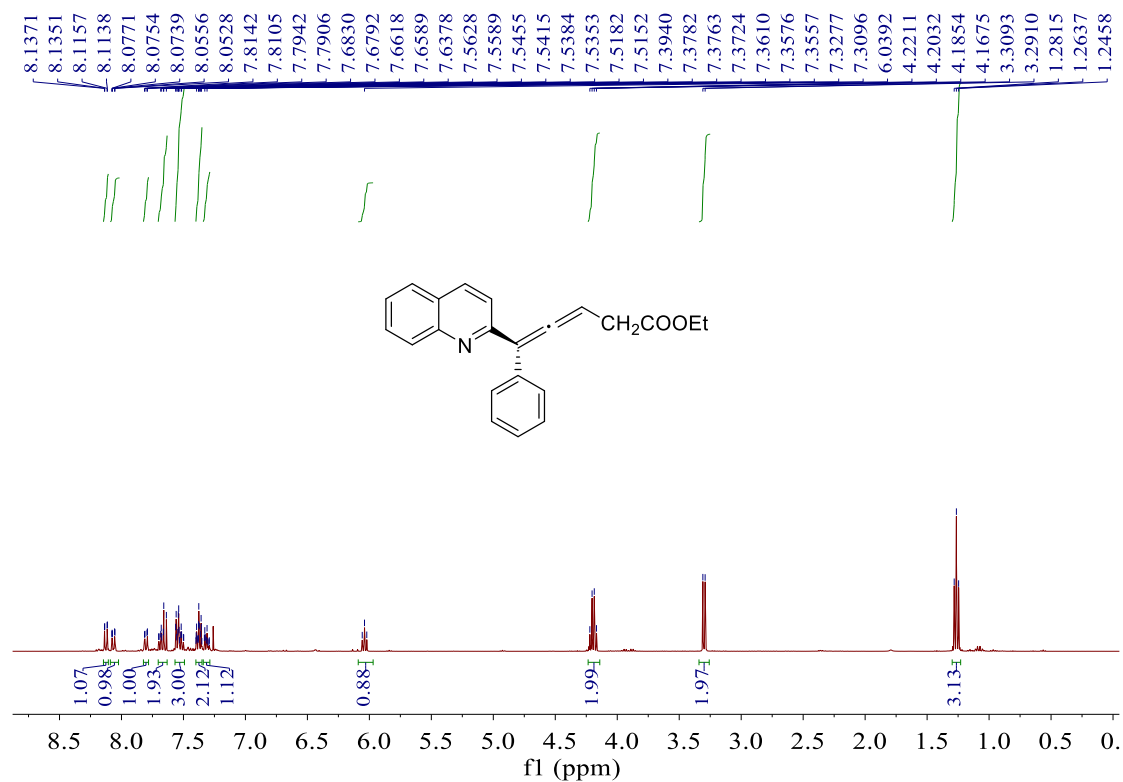
Supplementary Figure 86. ¹³C NMR spectra for **3af**



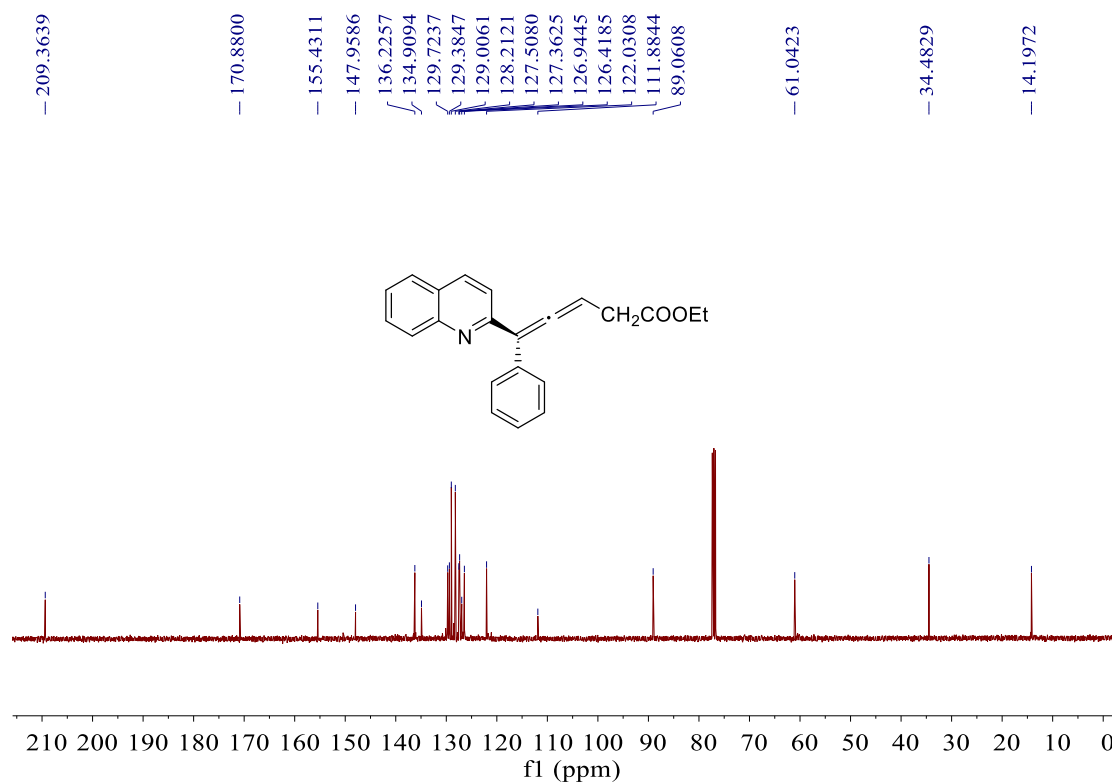
Supplementary Figure 87. ¹H NMR spectra for **3ag**



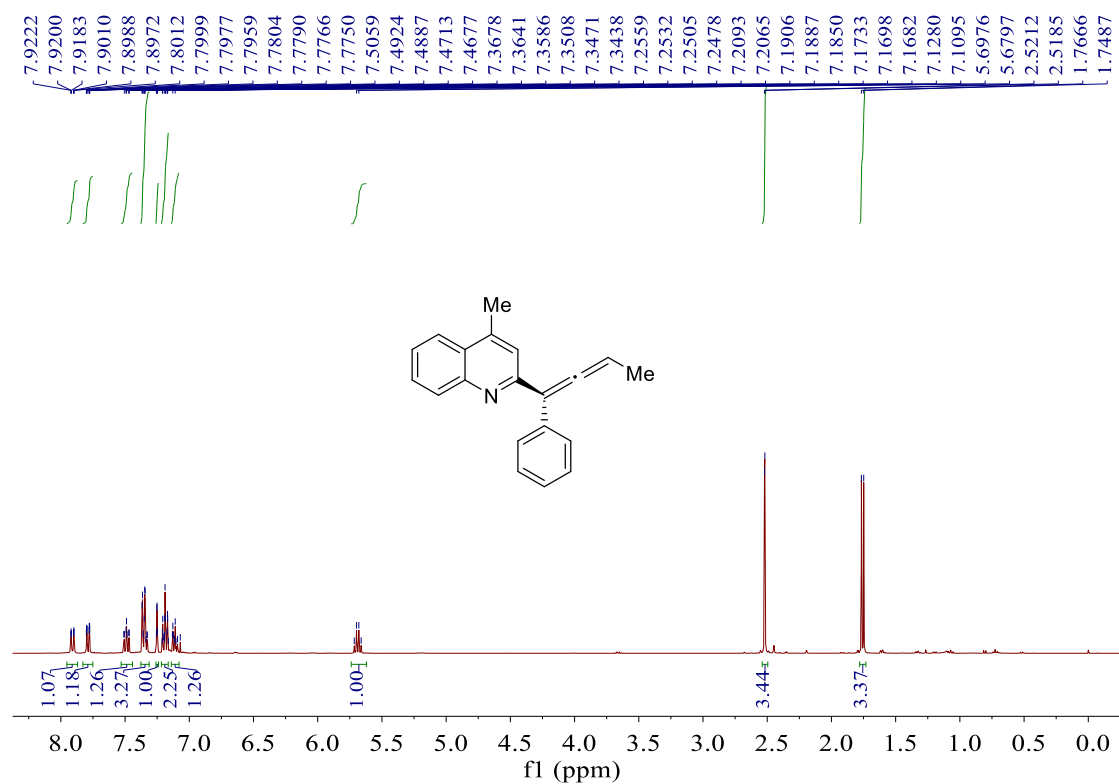
Supplementary Figure 88. ¹³C NMR spectra for **3ag**



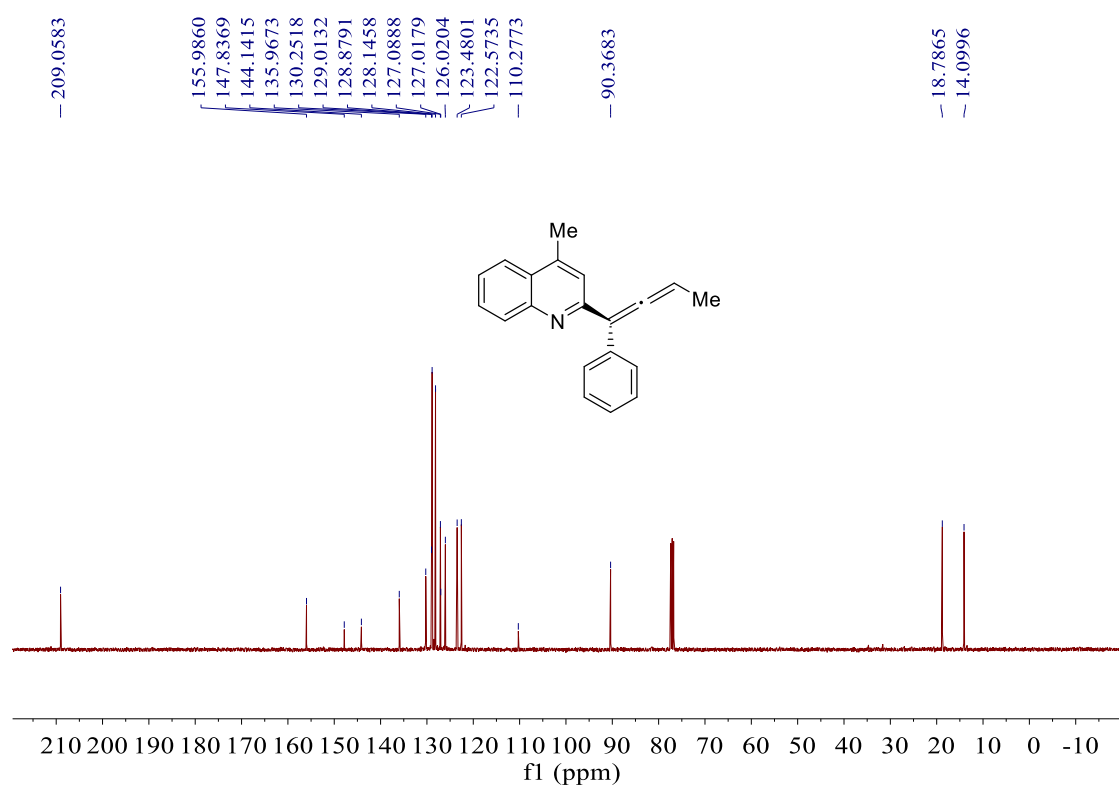
Supplementary Figure 89. ¹H NMR spectra for **3ah**



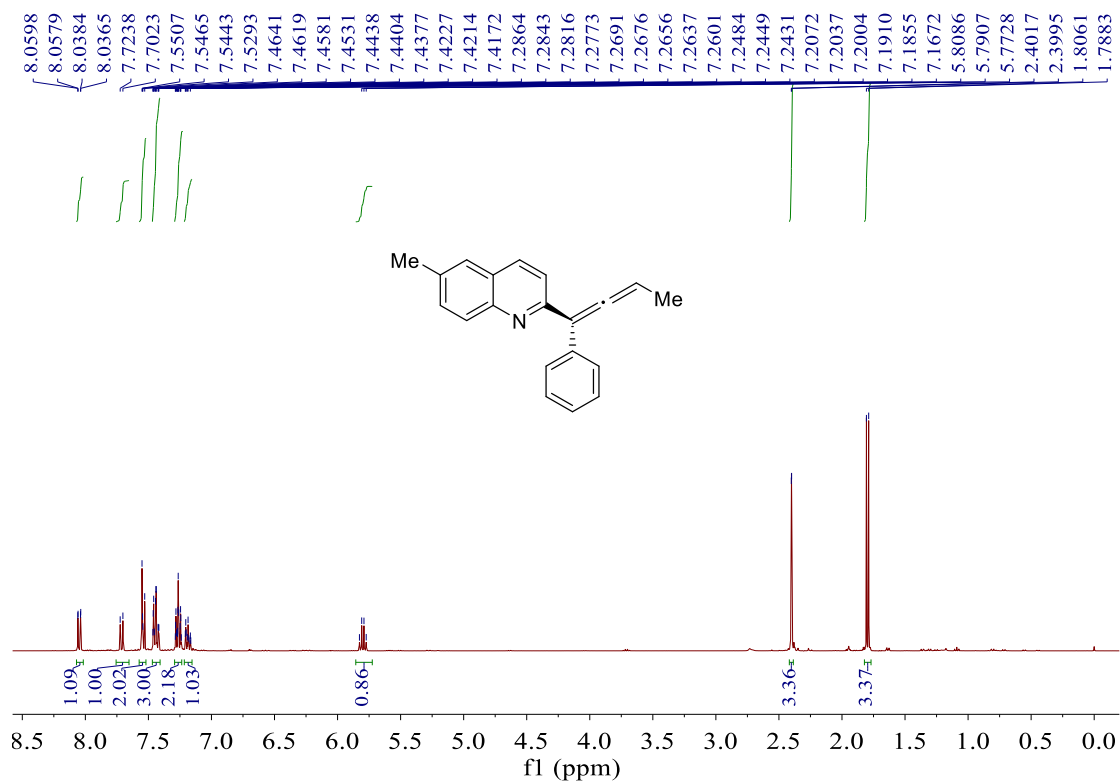
Supplementary Figure 90. ¹³C NMR spectra for **3ah**



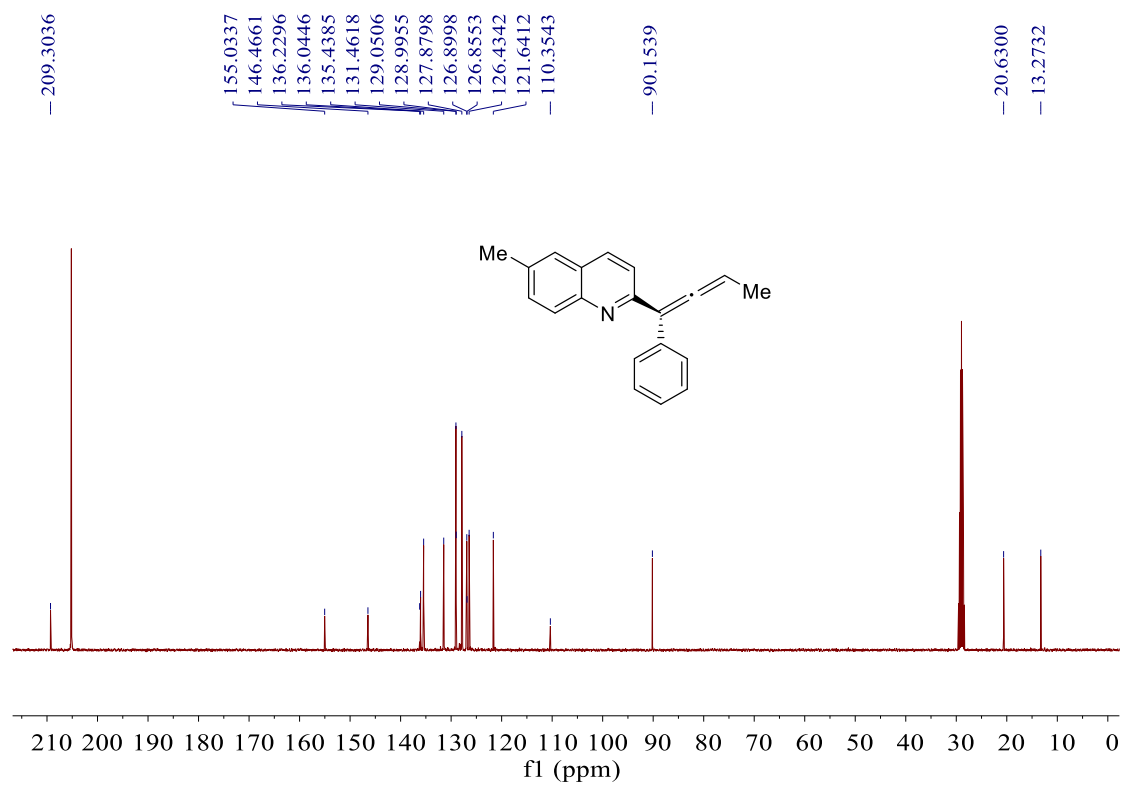
Supplementary Figure 91. ¹H NMR spectra for **3ai**



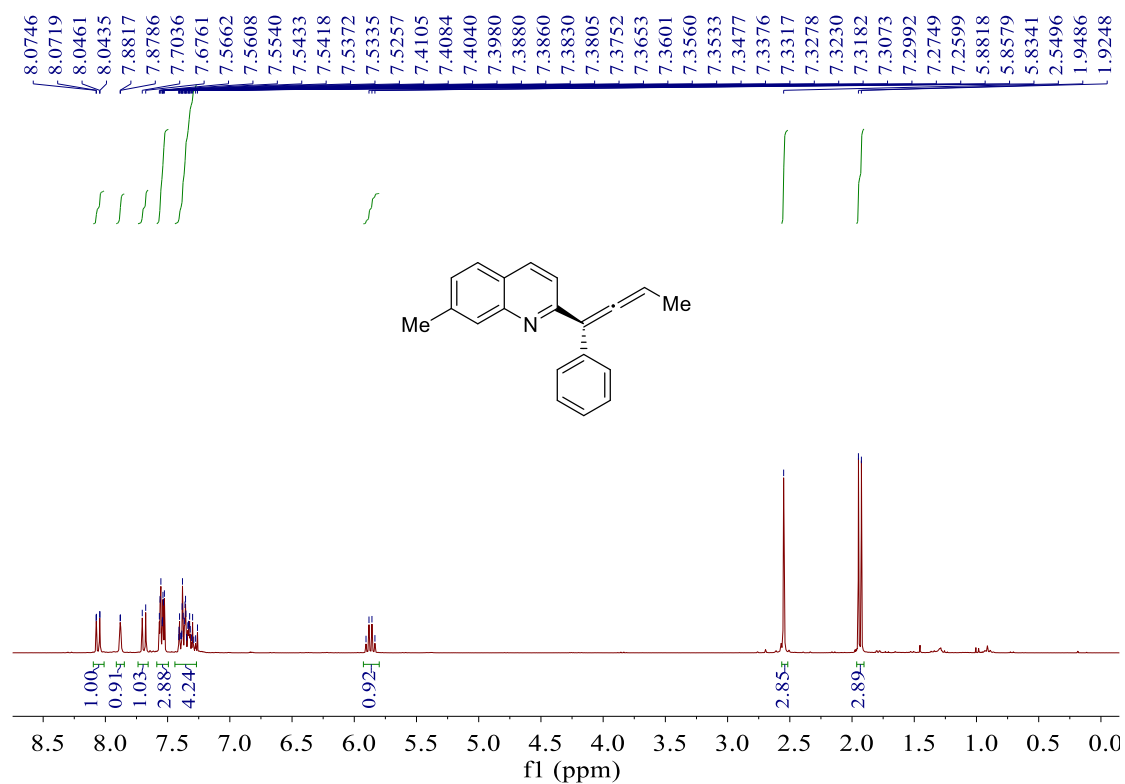
Supplementary Figure 92. ¹³C NMR spectra for **3ai**



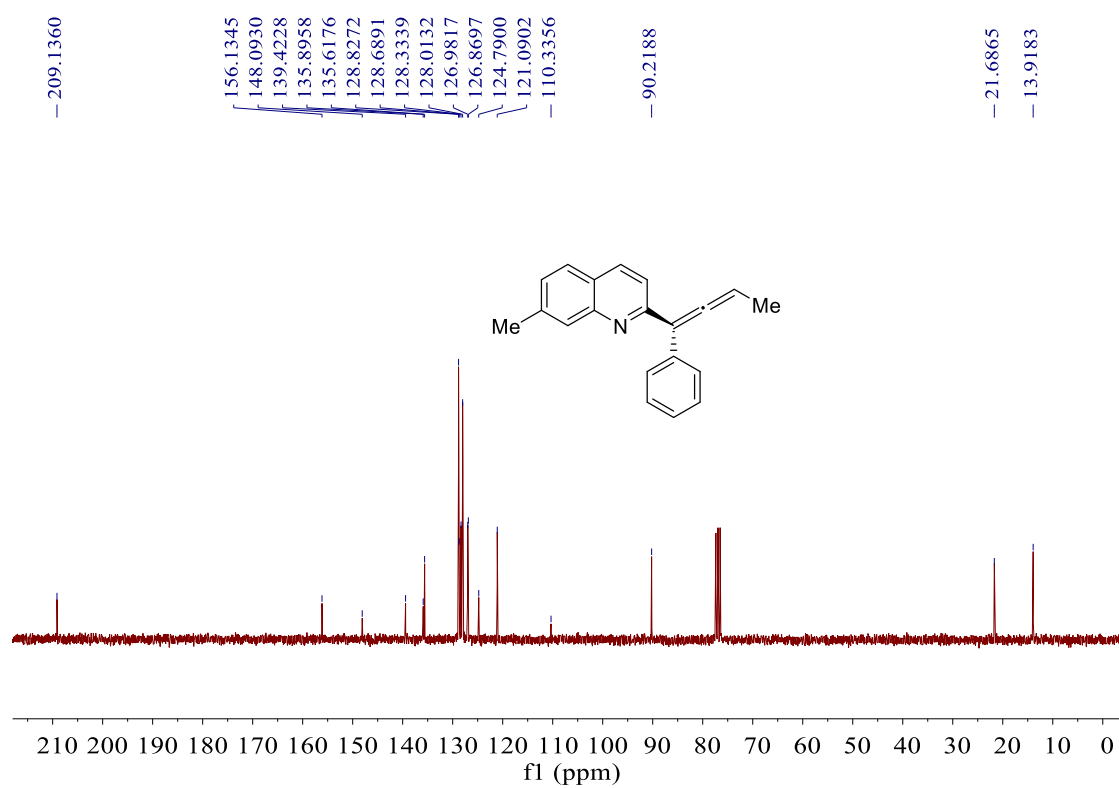
Supplementary Figure 93. ¹H NMR spectra for **3aj**



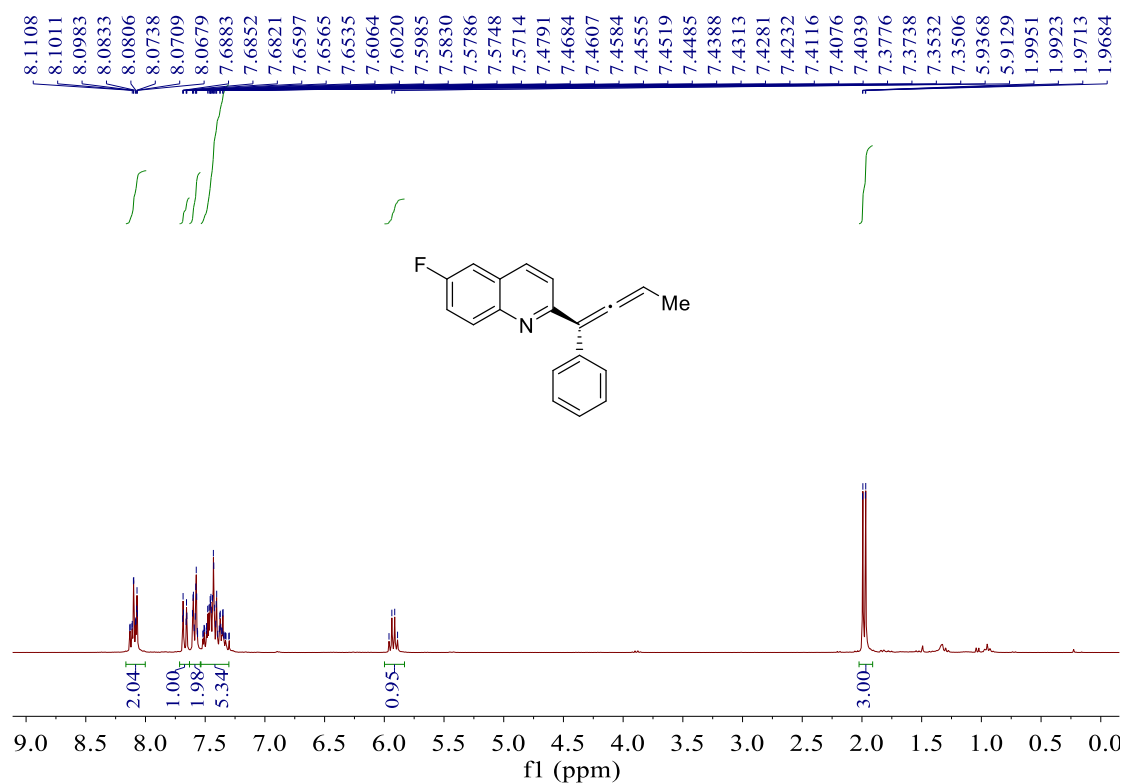
Supplementary Figure 94. ¹³C NMR spectra for **3aj**



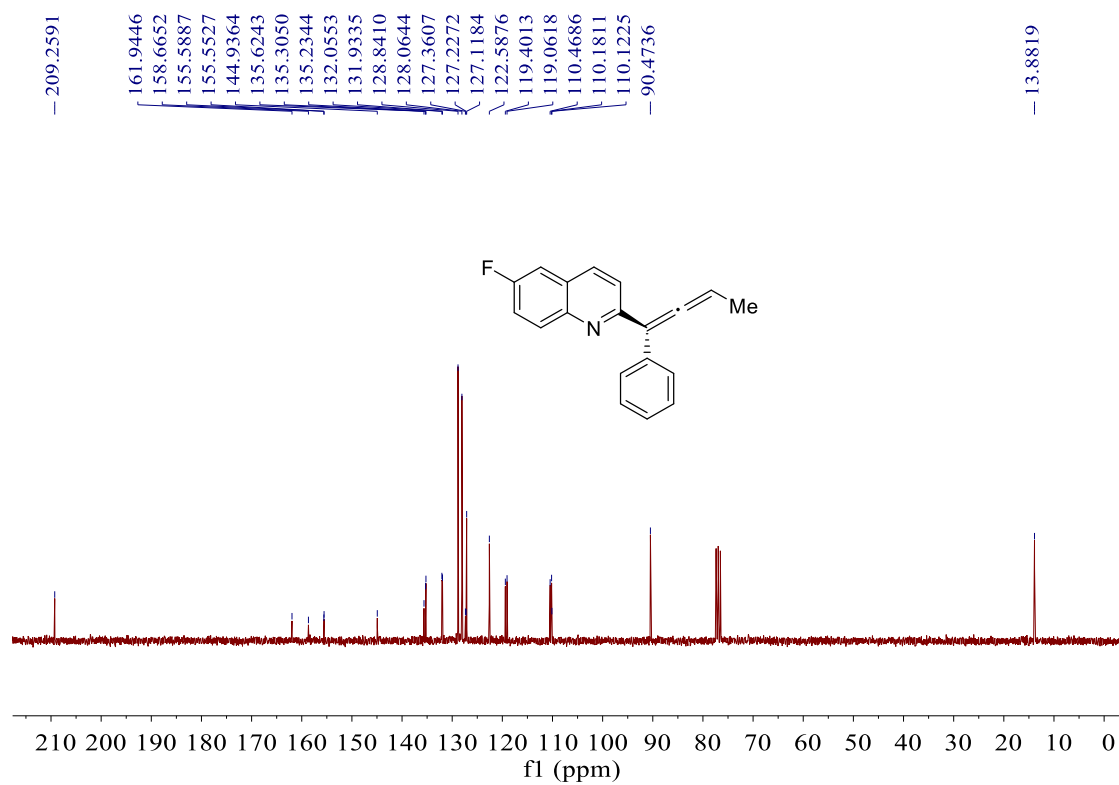
Supplementary Figure 95. ¹H NMR spectra for **3ak**



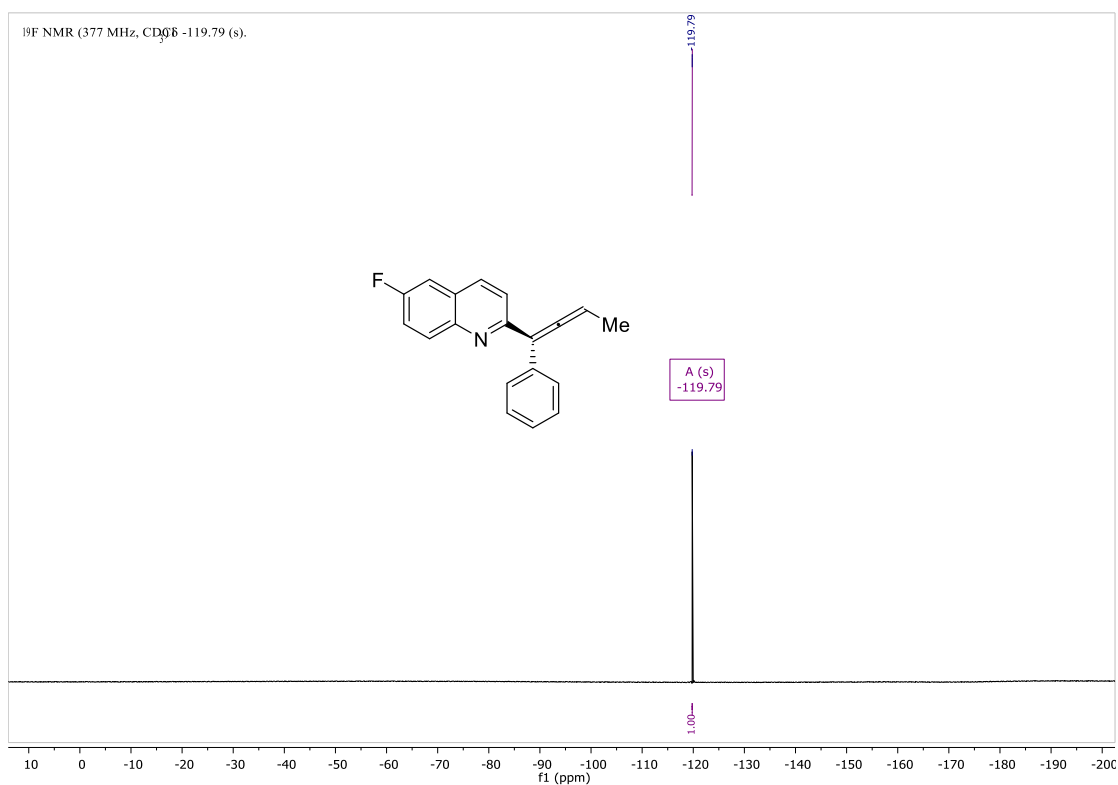
Supplementary Figure 96. ¹³C NMR spectra for **3ak**



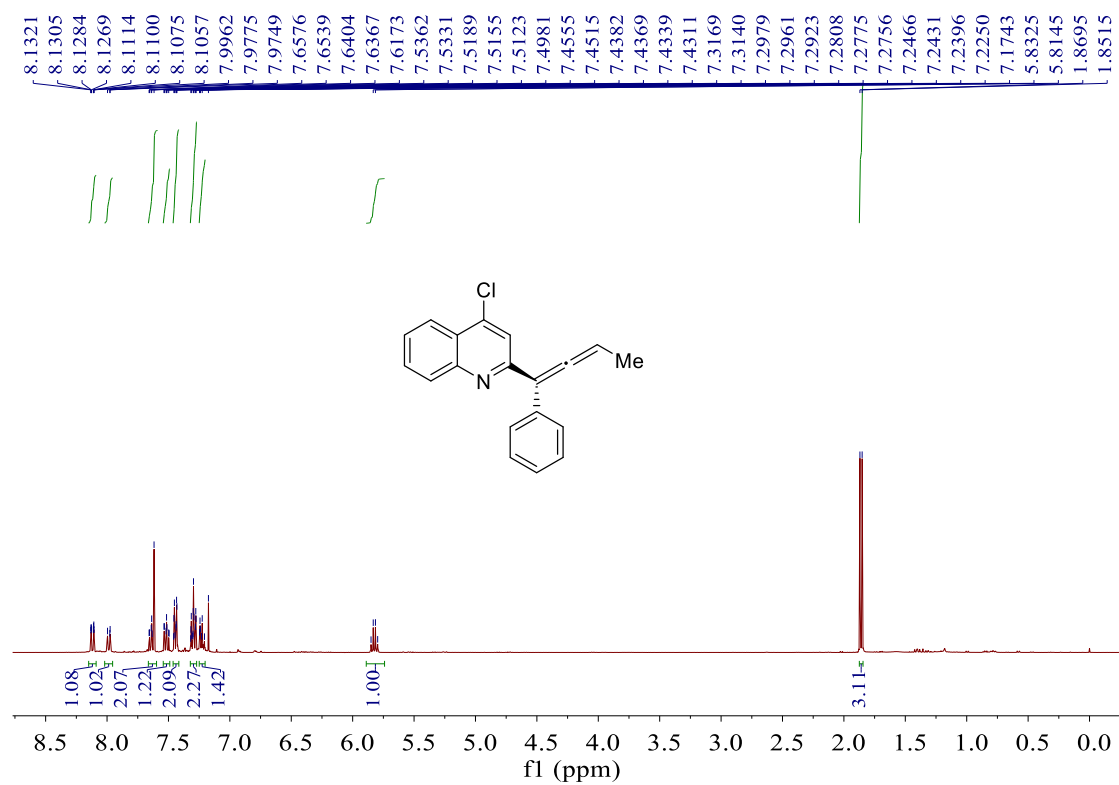
Supplementary Figure 97. ¹H NMR spectra for **3al**



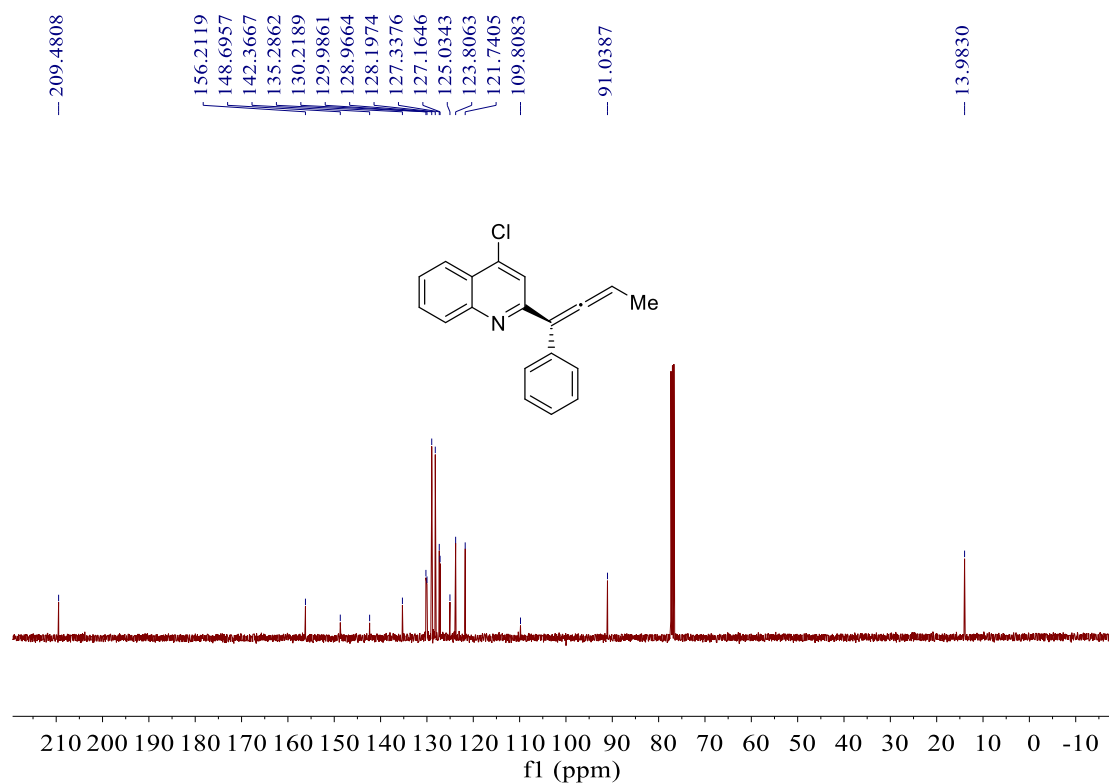
Supplementary Figure 98. ¹³C NMR spectra for **3al**



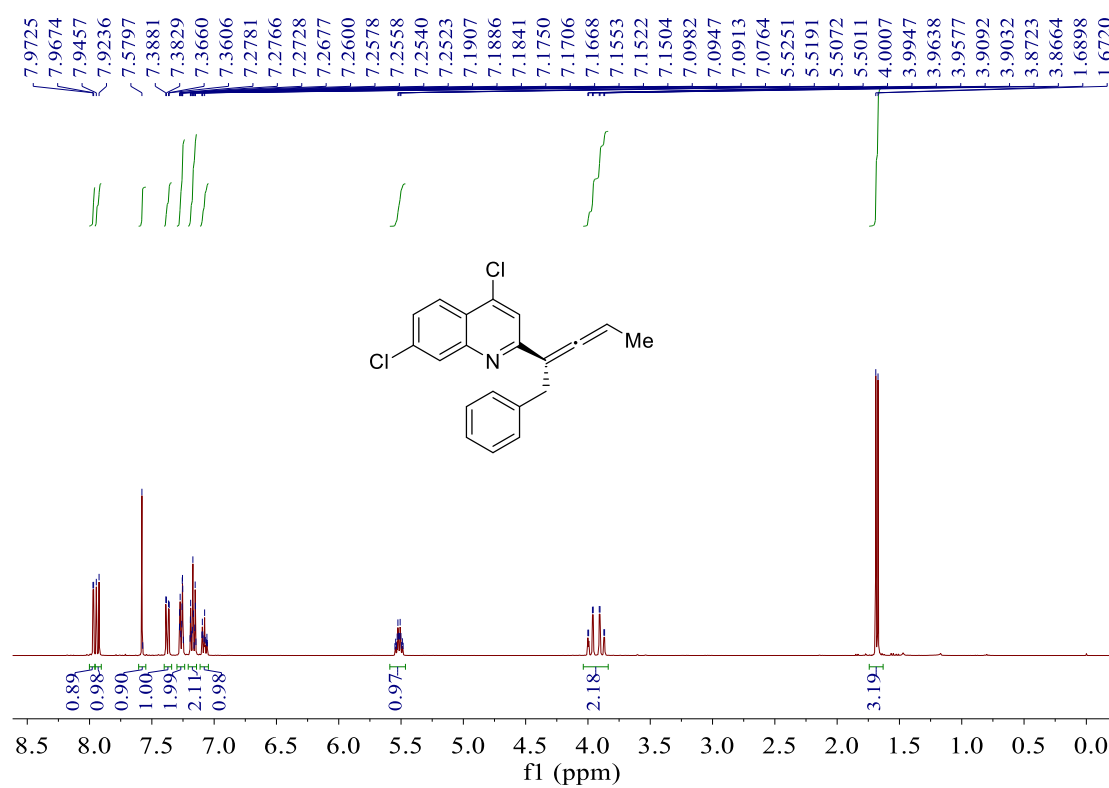
Supplementary Figure 99. ¹⁹F NMR spectra for **3al**



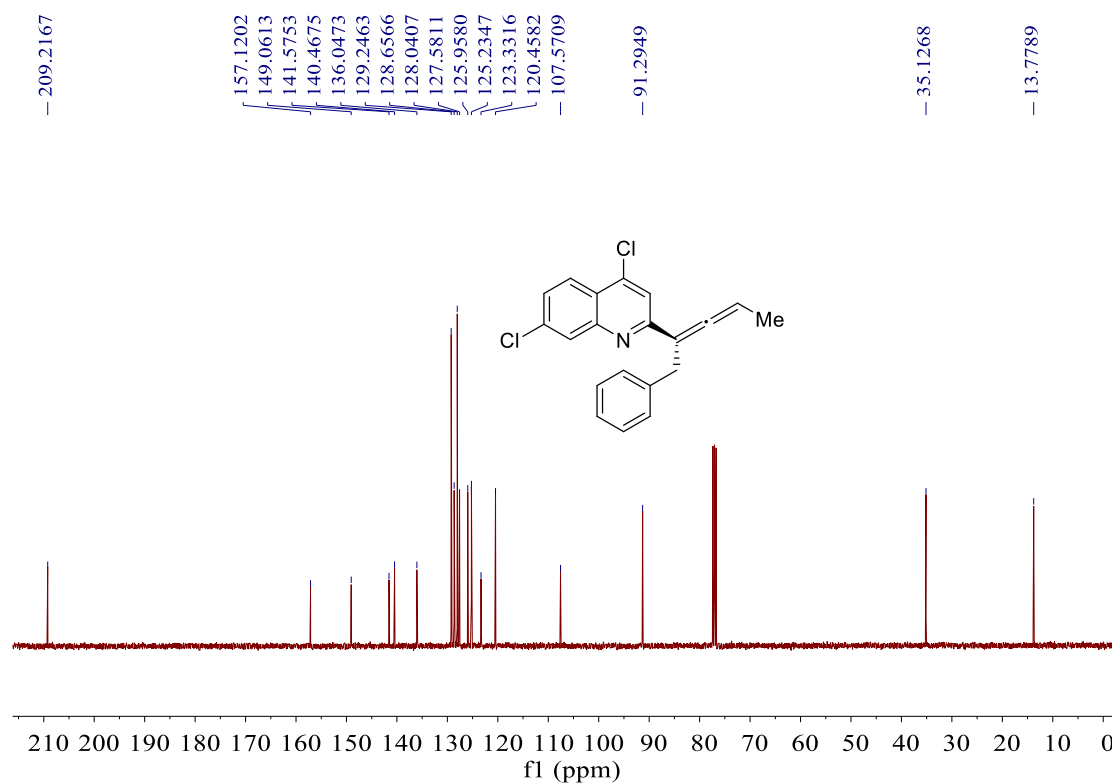
Supplementary Figure 100. ¹H NMR spectra for **3am**



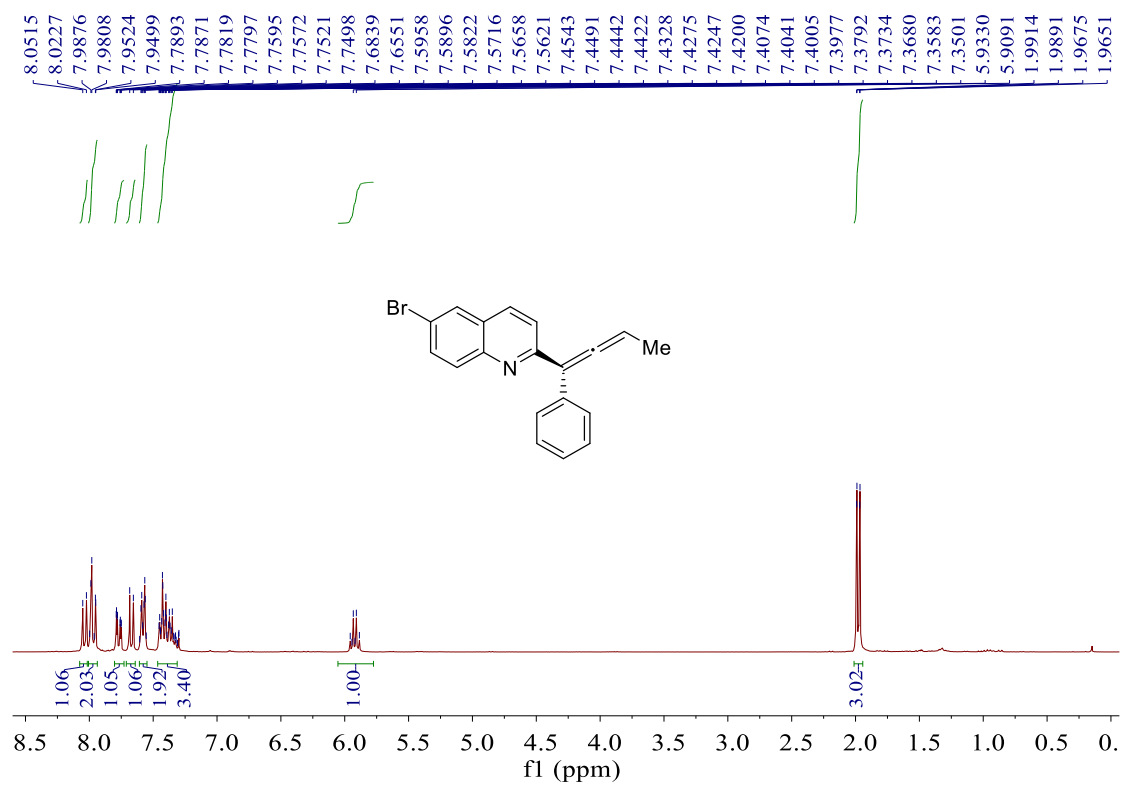
Supplementary Figure 101. ¹³C NMR spectra for **3am**



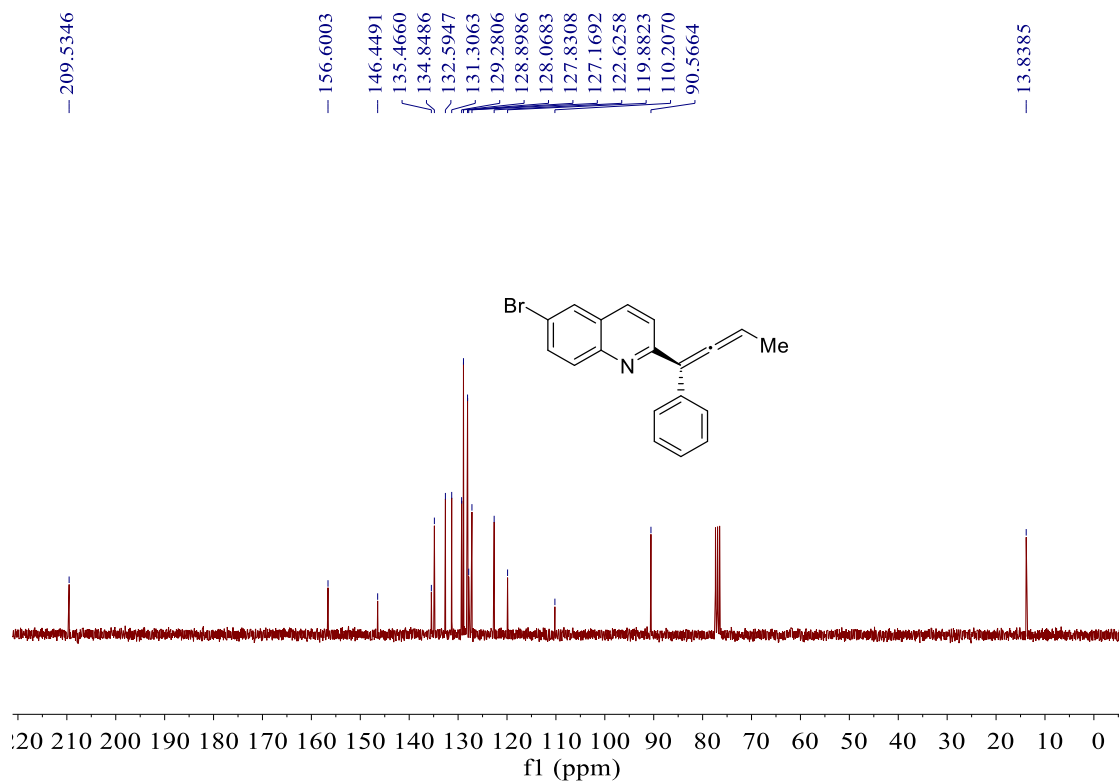
Supplementary Figure 102. ¹H NMR spectra for **3an**



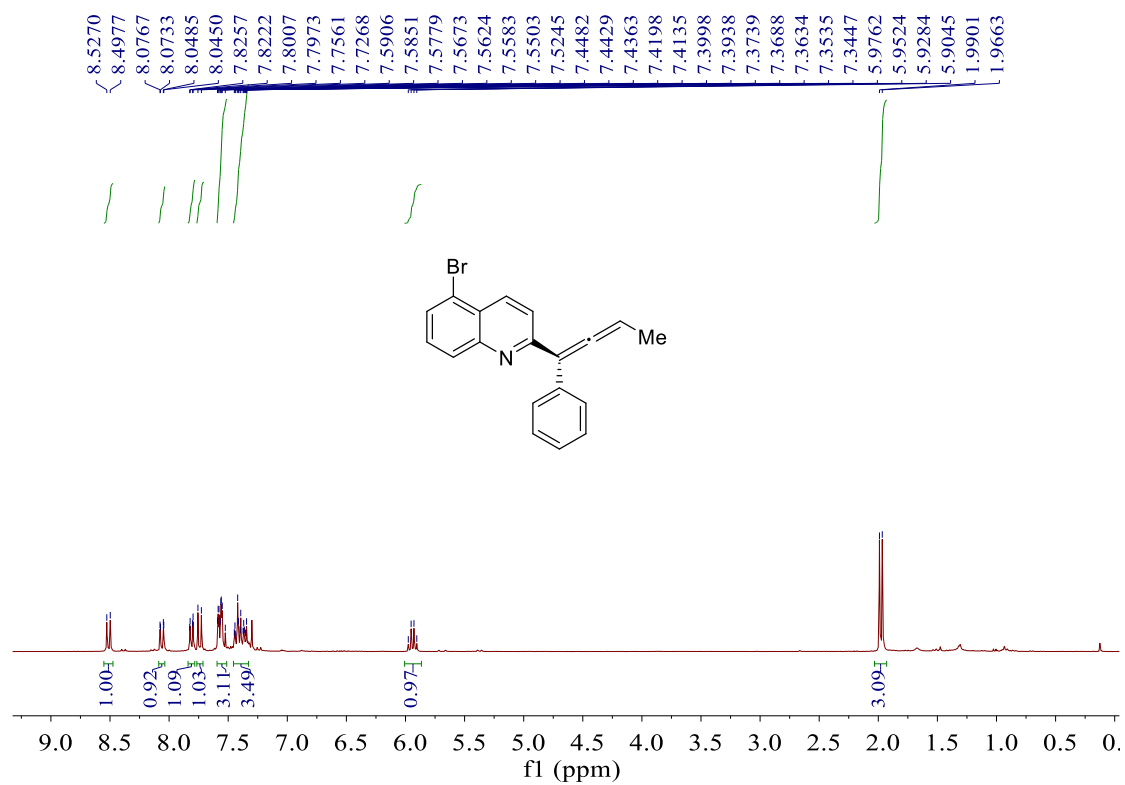
Supplementary Figure 103. ¹³C NMR spectra for **3an**



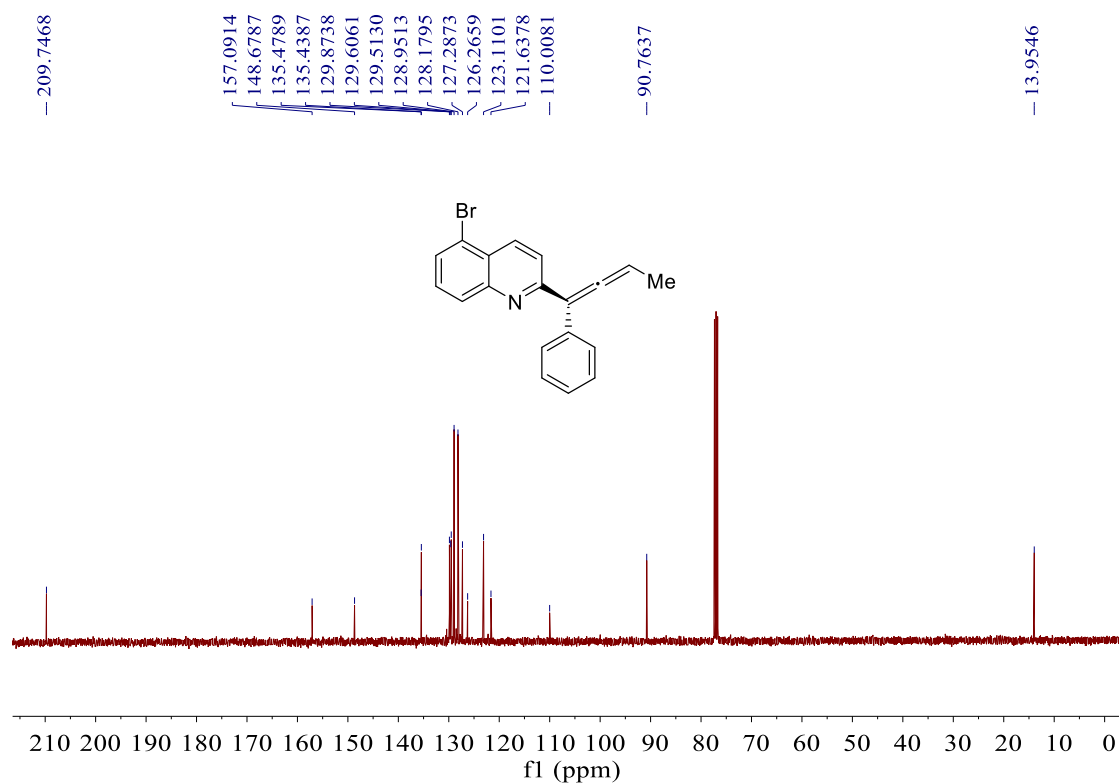
Supplementary Figure 104. ¹H NMR spectra for **3ao**



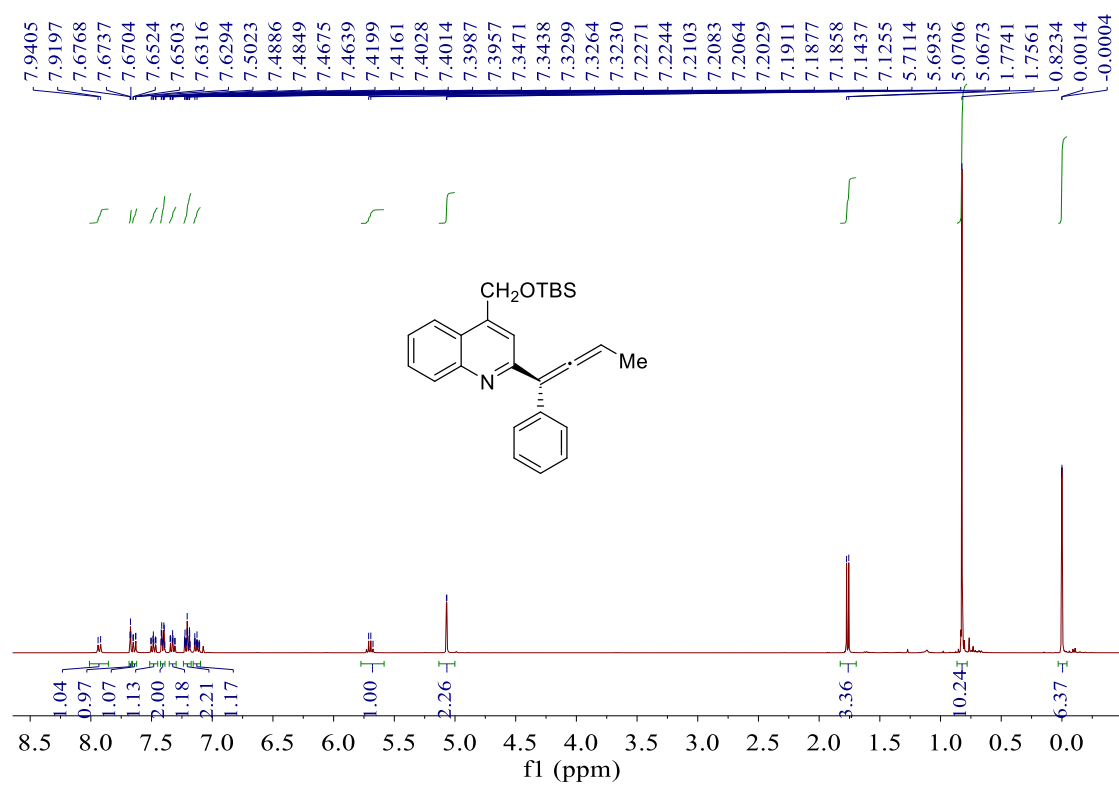
Supplementary Figure 105. ¹³C NMR spectra for **3ao**



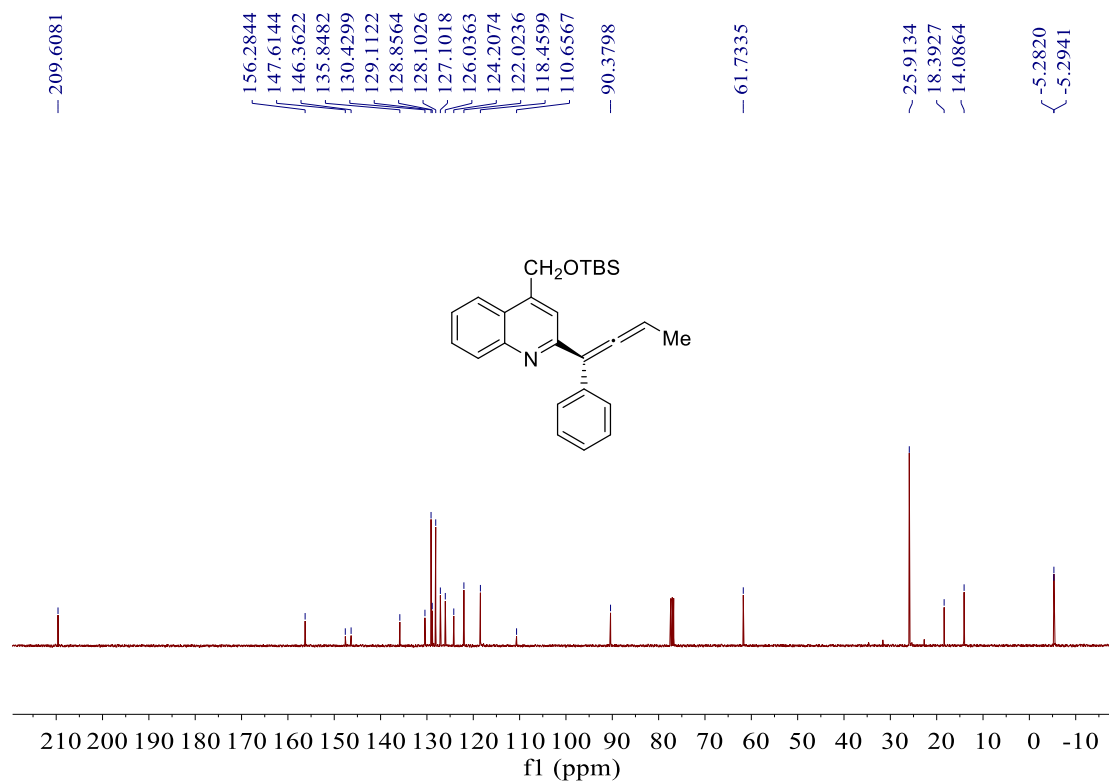
Supplementary Figure 106. ¹H NMR spectra for **3ap**



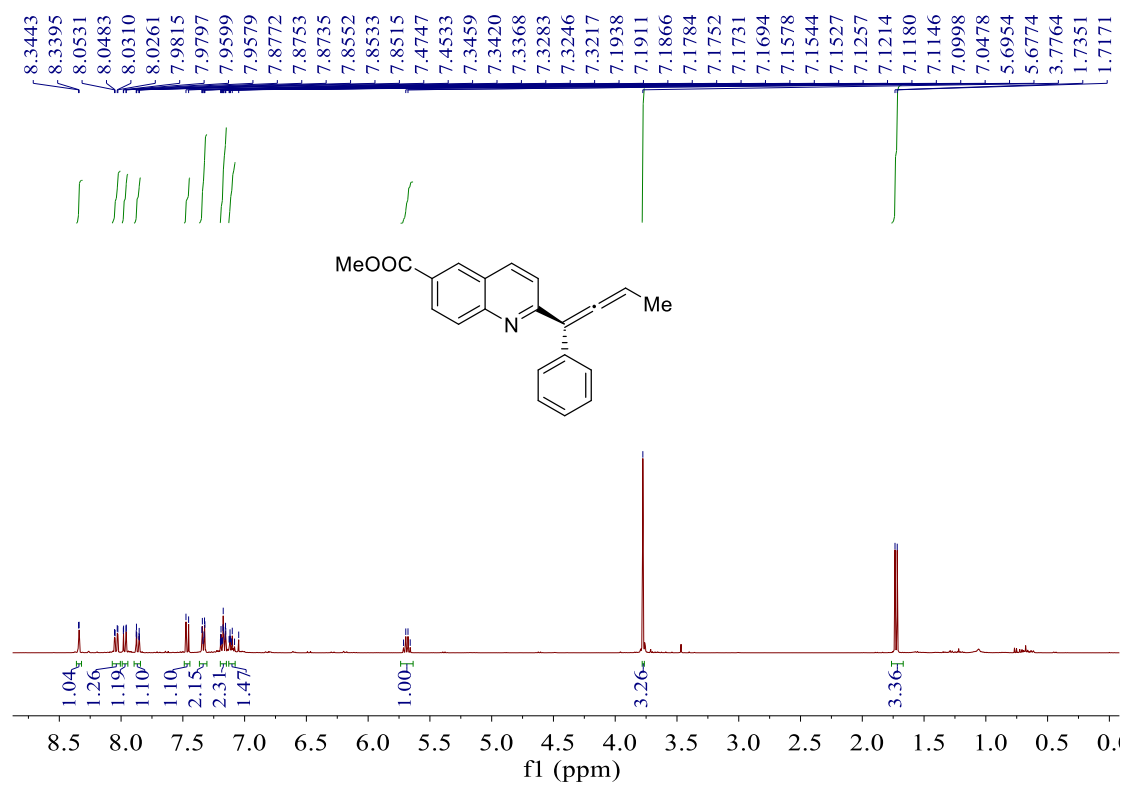
Supplementary Figure 107. ¹³C NMR spectra for **3ap**



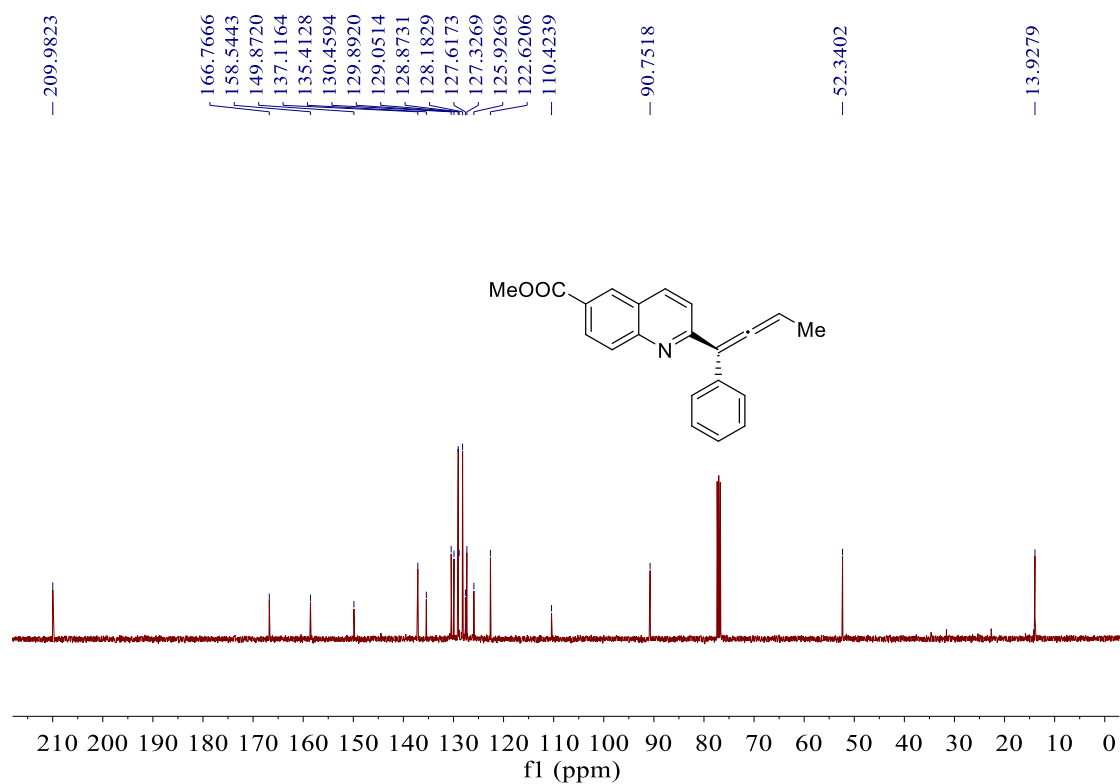
Supplementary Figure 108. ¹H NMR spectra for **3aq**



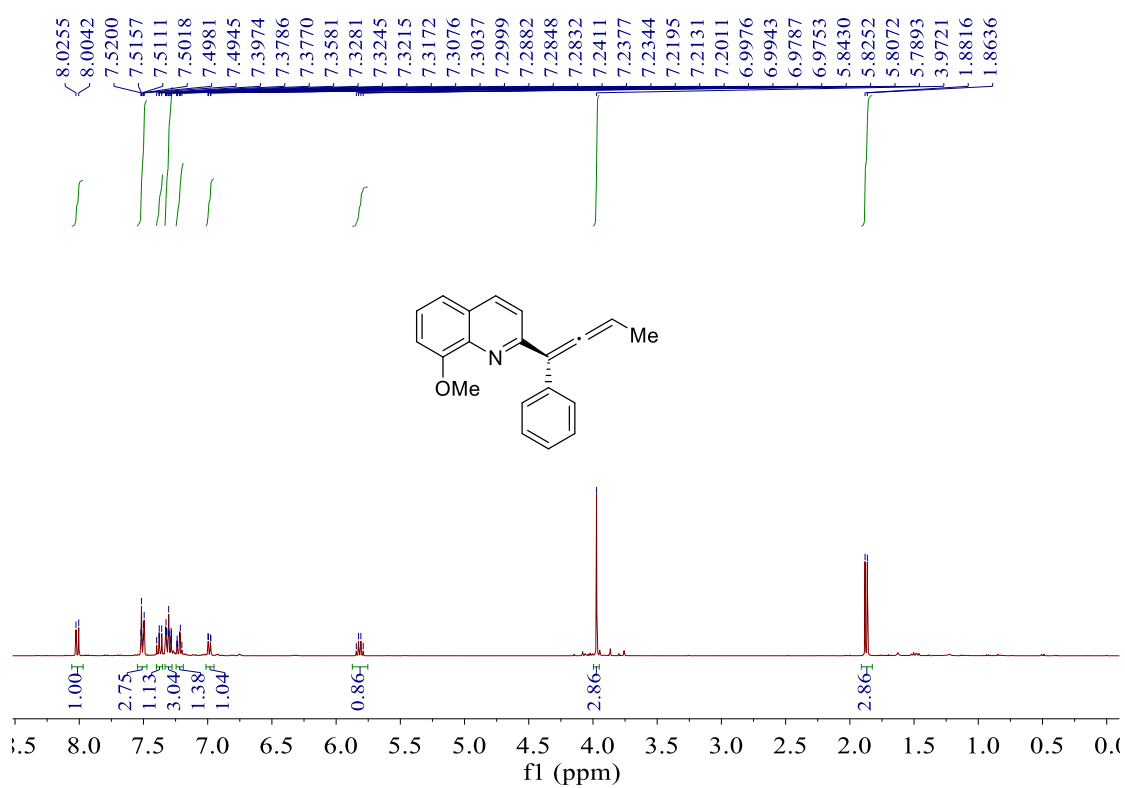
Supplementary Figure 109. ¹³C NMR spectra for **3aq**



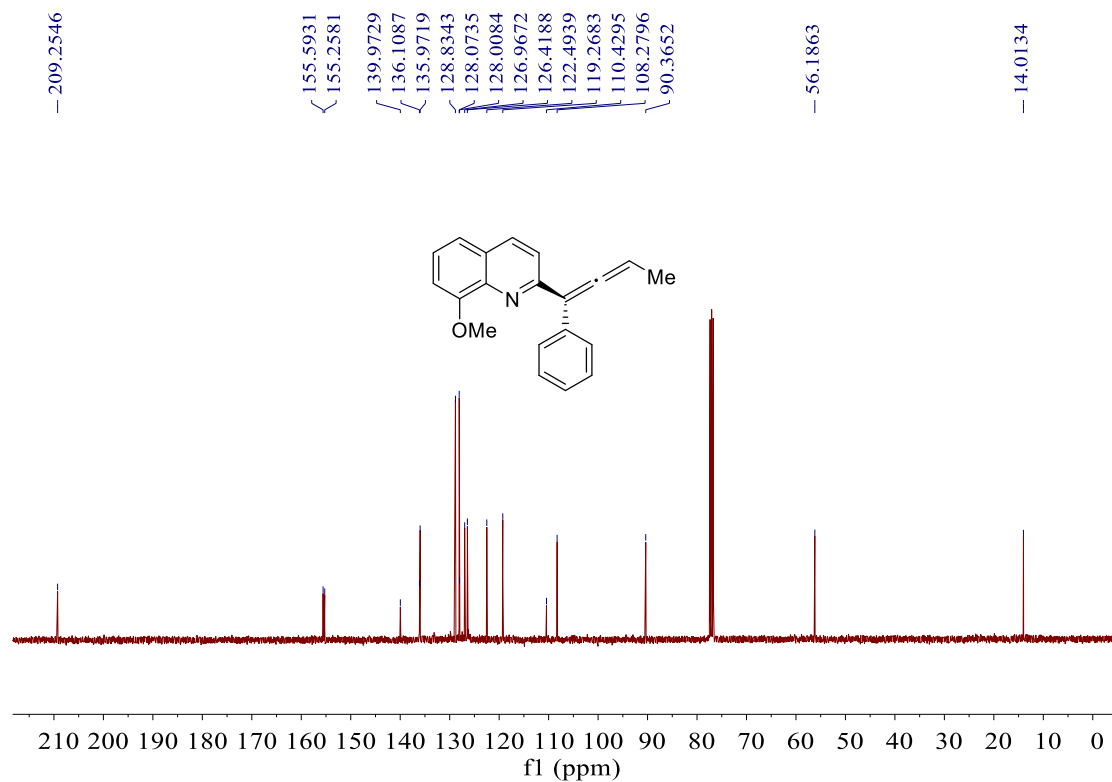
Supplementary Figure 110. ¹H NMR spectra for **3ar**



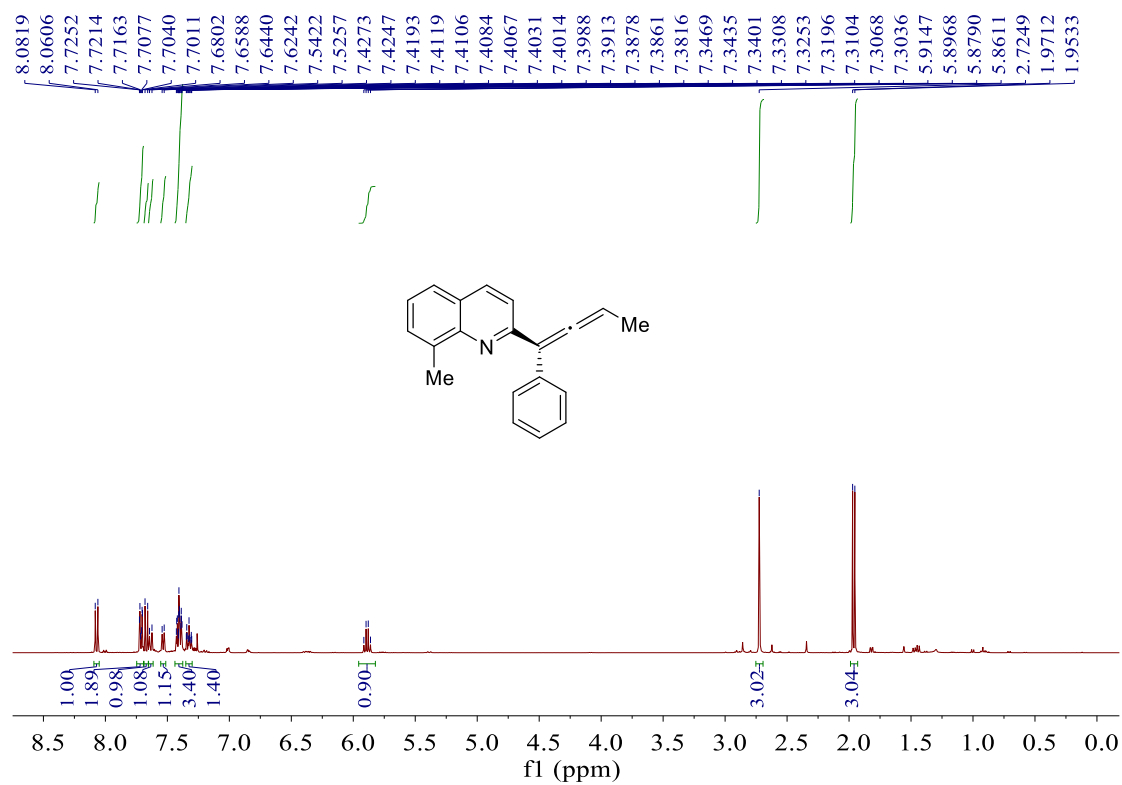
Supplementary Figure 111. ¹³C NMR spectra for **3ar**



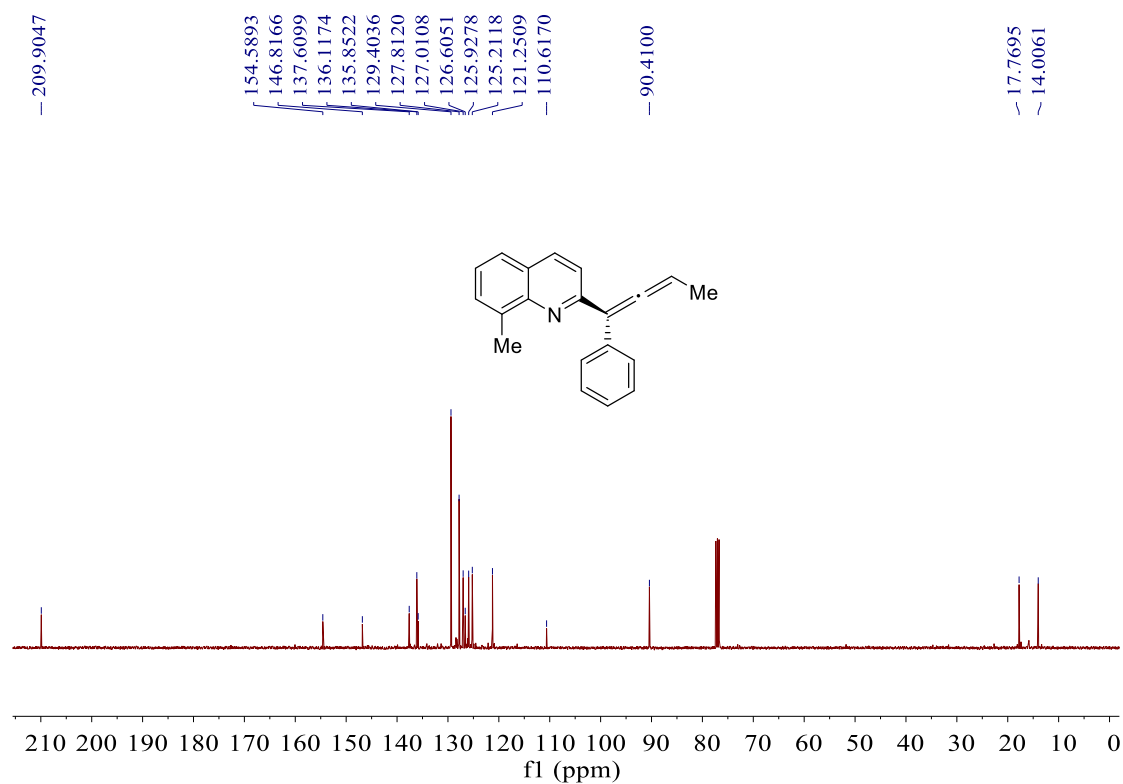
Supplementary Figure 112. ¹H NMR spectra for **3as**



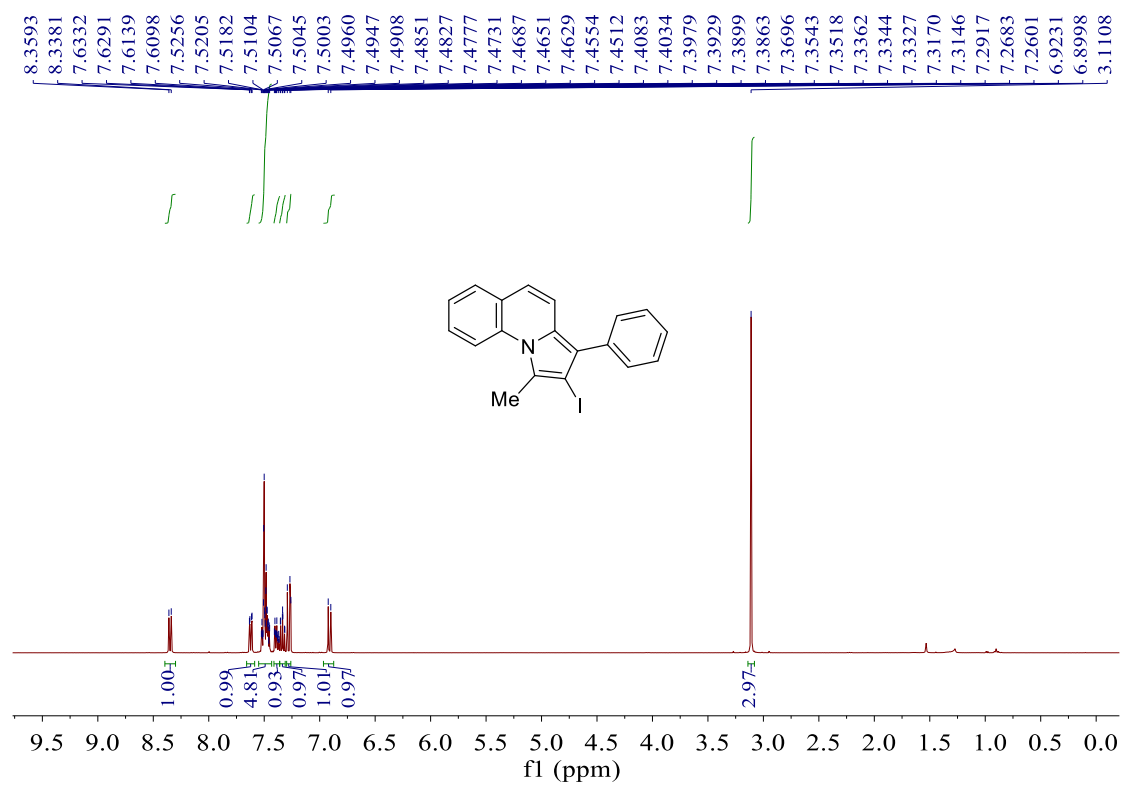
Supplementary Figure 113. ¹³C NMR spectra for **3as**



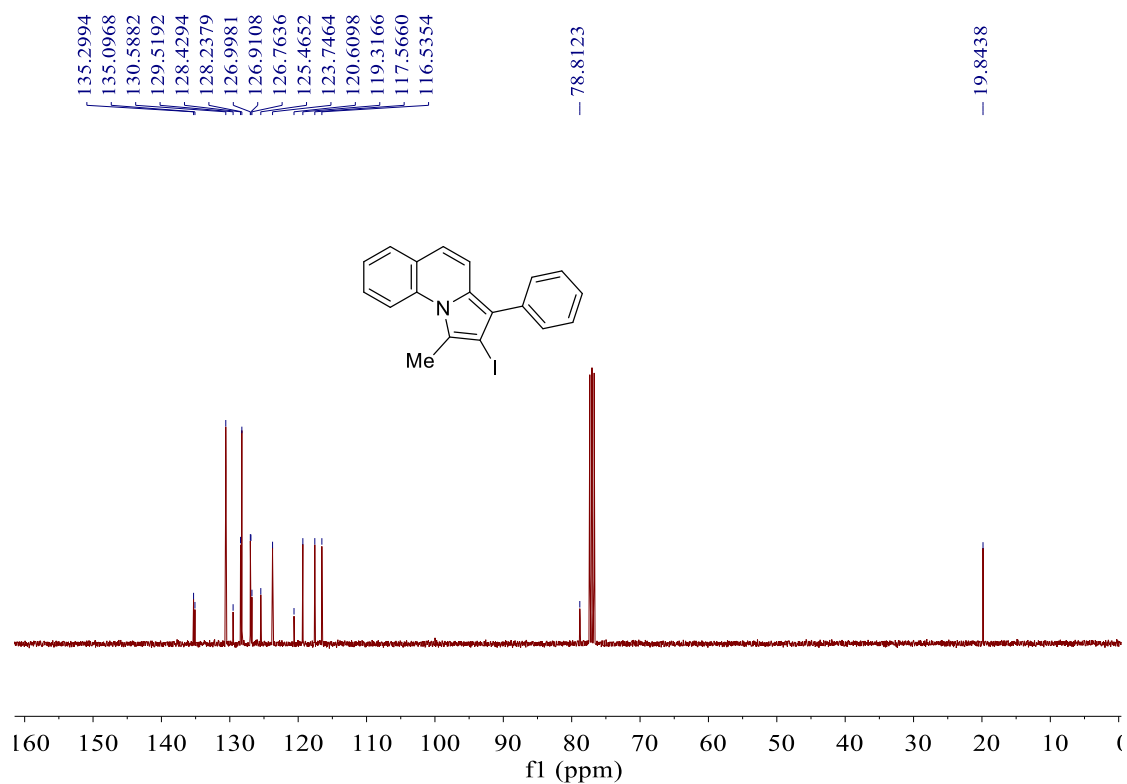
Supplementary Figure 114. ¹H NMR spectra for **3at**



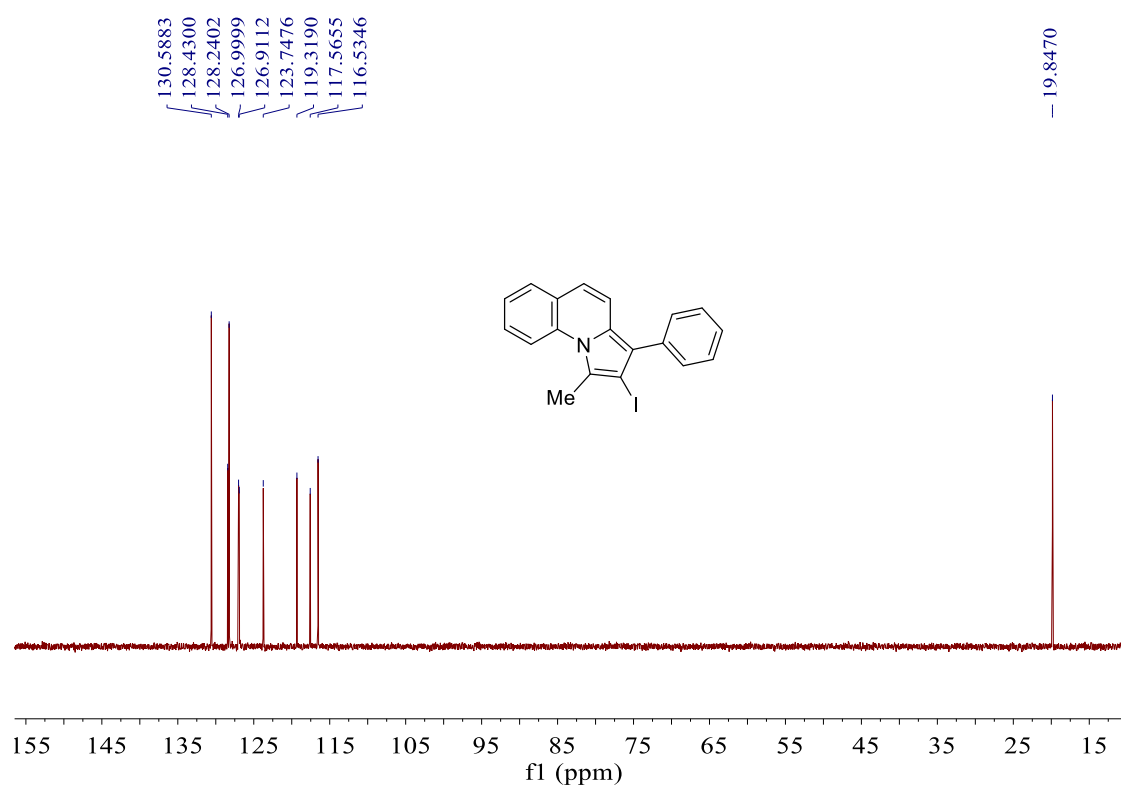
Supplementary Figure 115. ¹³C NMR spectra for **3at**



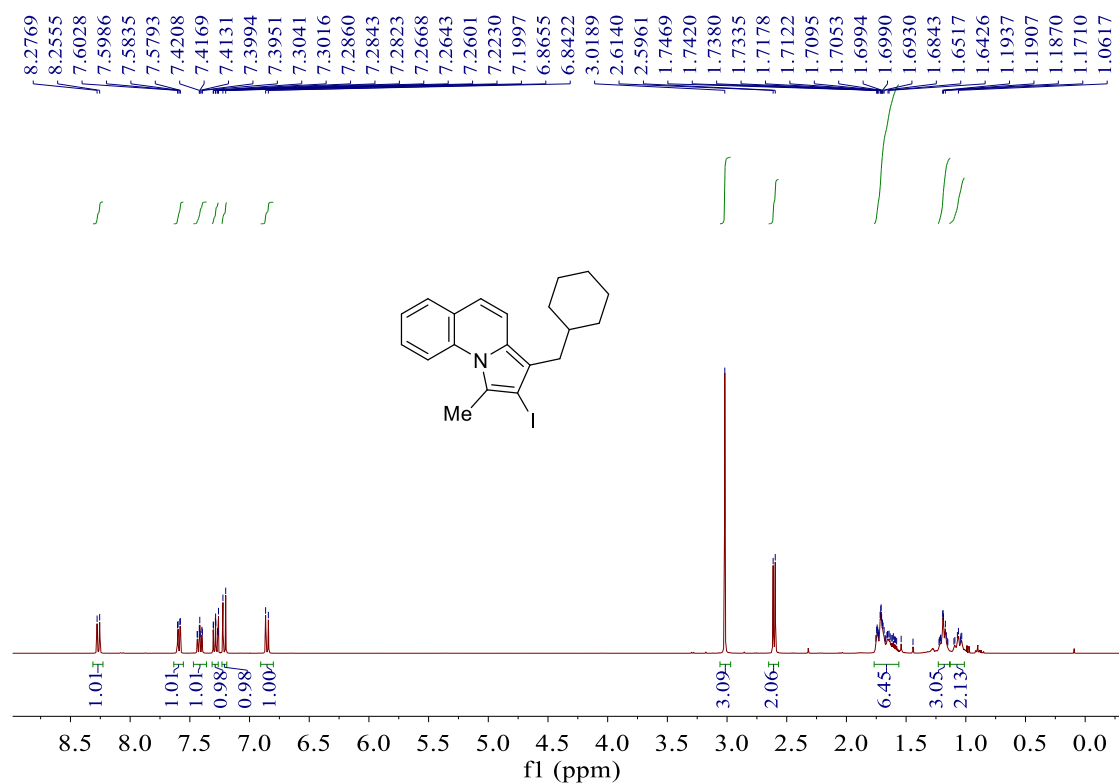
Supplementary Figure 116. ¹H NMR spectra for **4a**



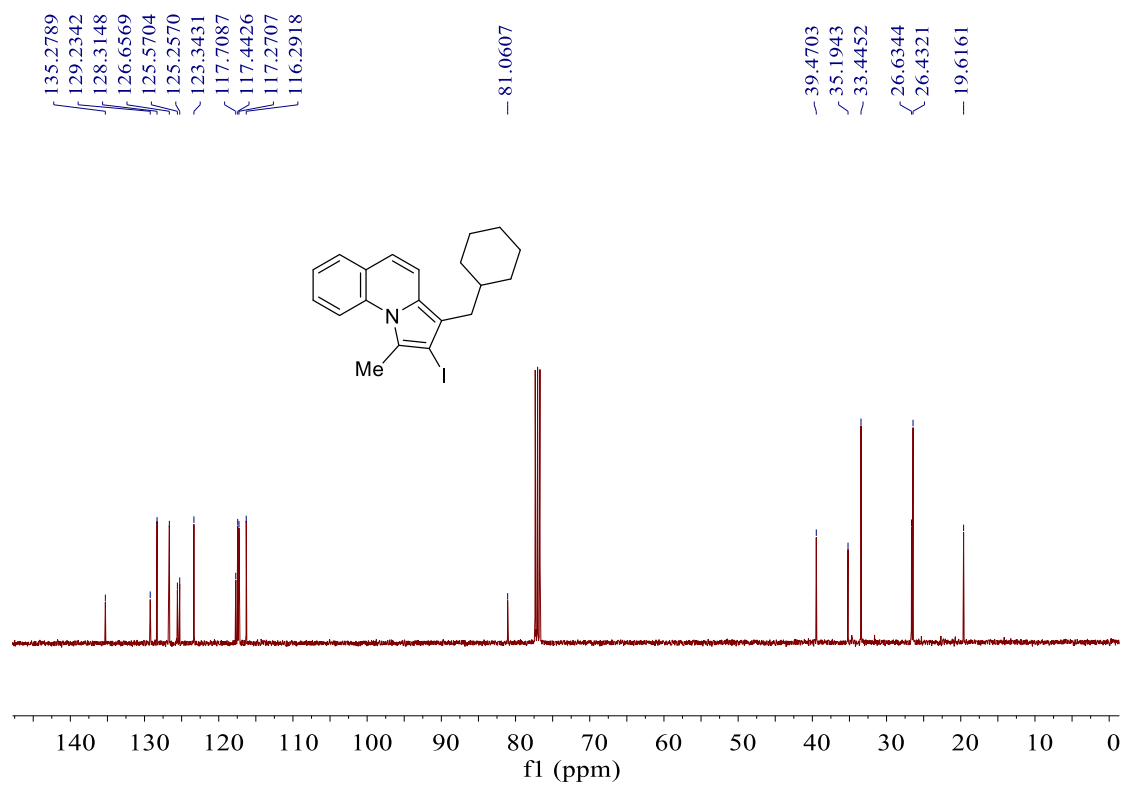
Supplementary Figure 117. ¹³C NMR spectra for **4a**



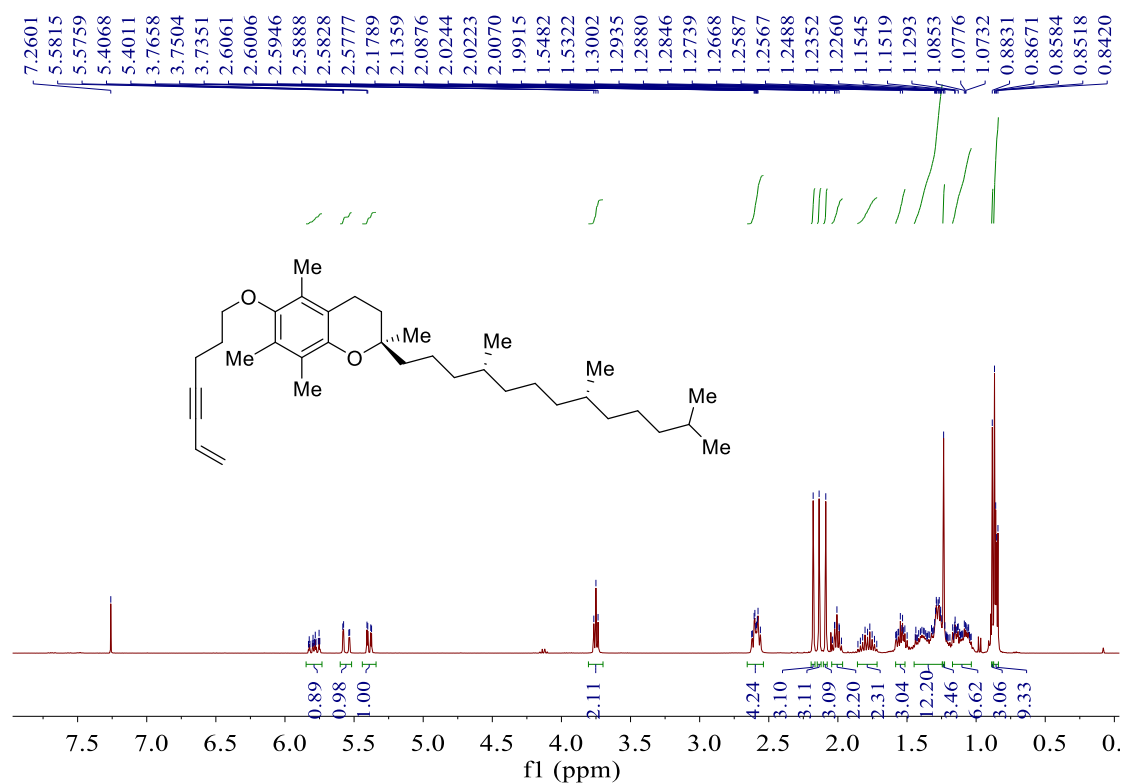
Supplementary Figure 118. ¹³C(DEPT135) NMR spectra for **4a**



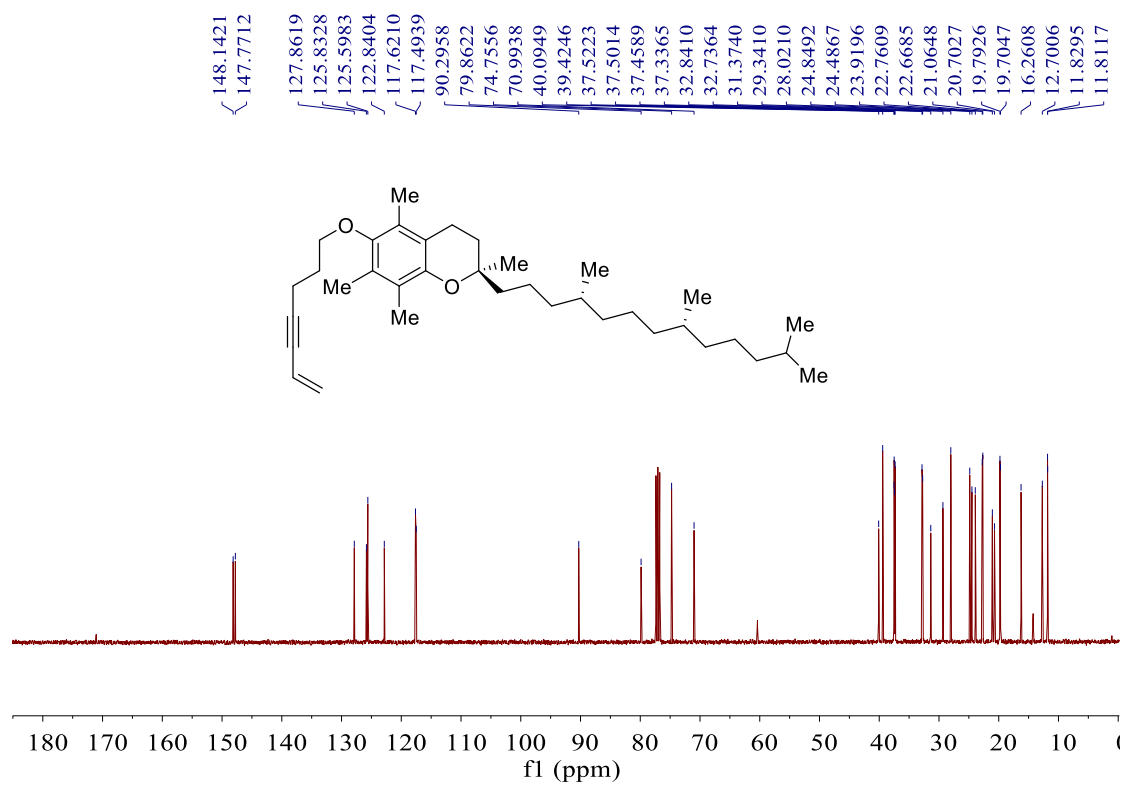
Supplementary Figure 119. ¹H NMR spectra for **4b**



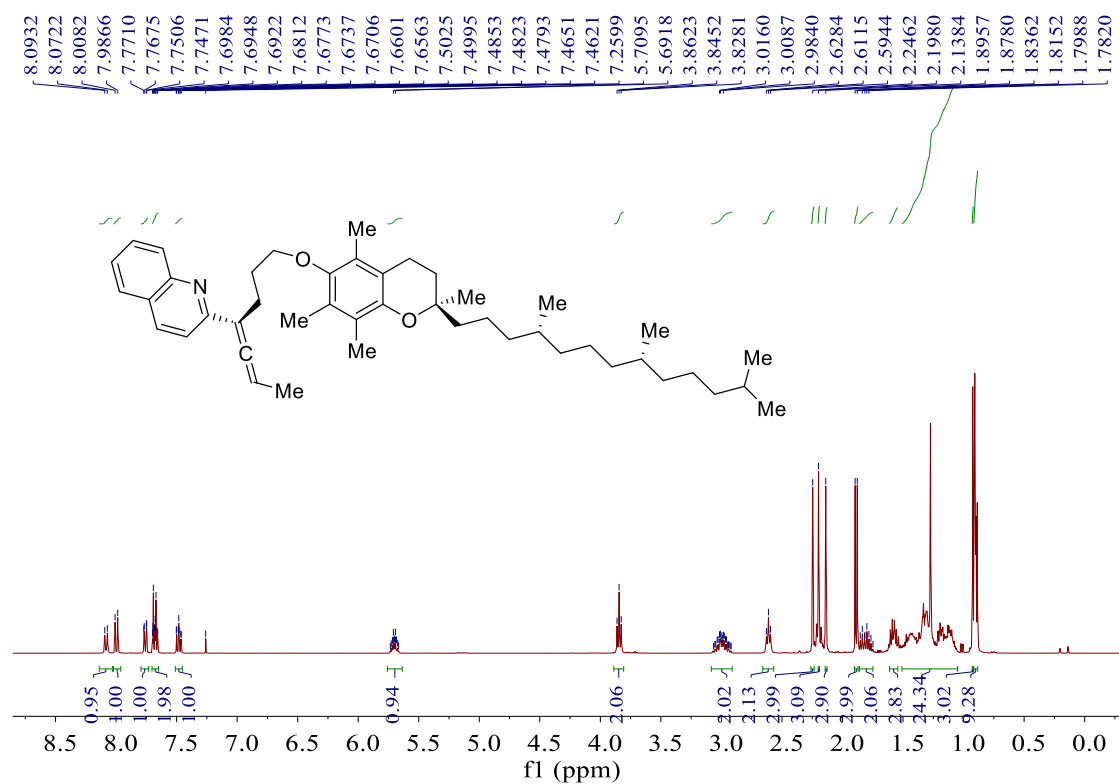
Supplementary Figure 120. ¹³C NMR spectra for **4b**



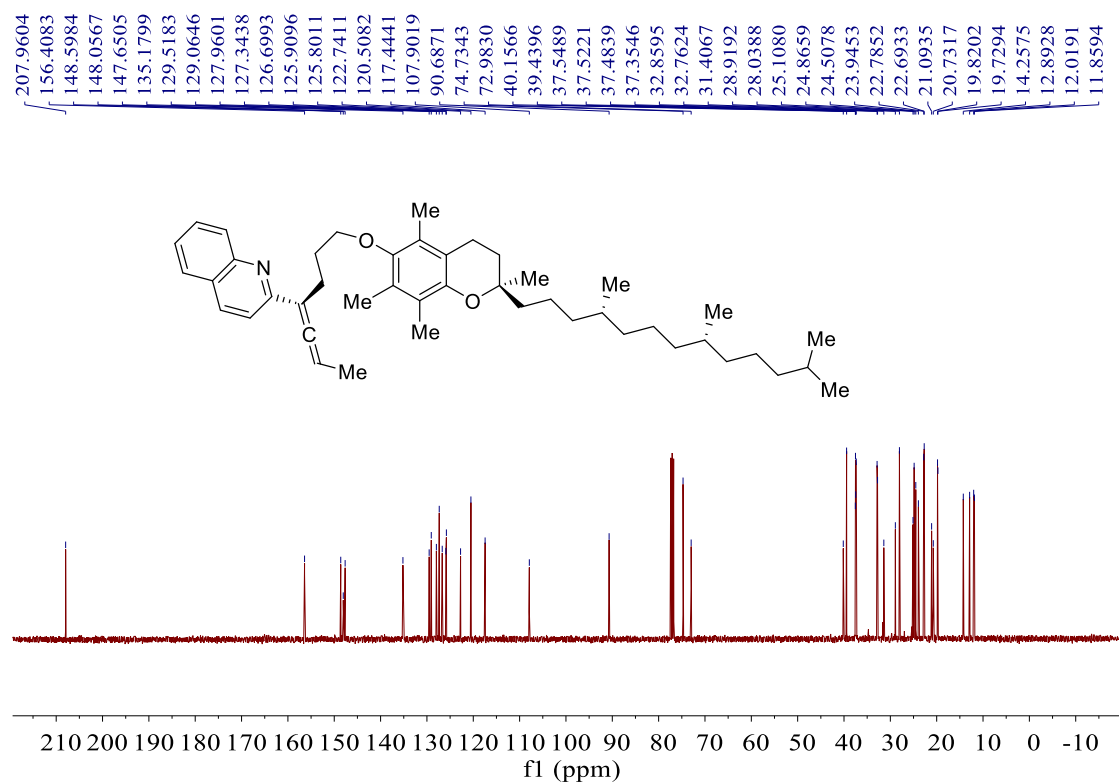
Supplementary Figure 121. ^1H NMR spectra for **5**



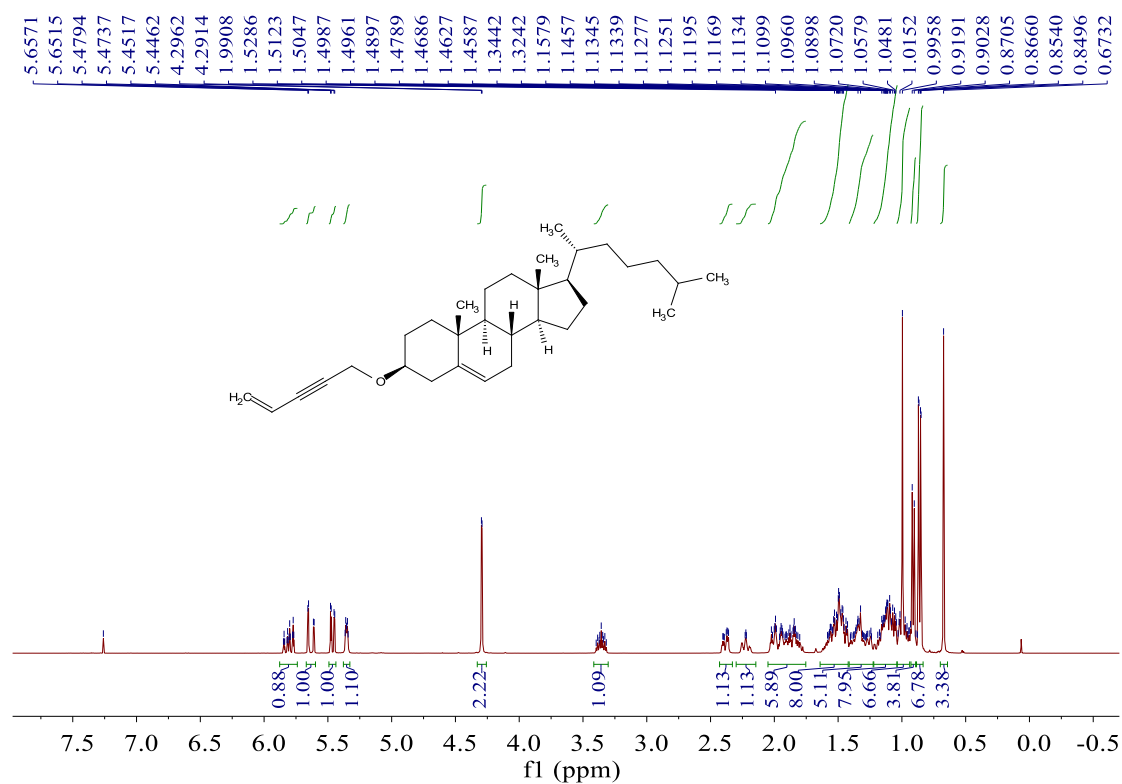
Supplementary Figure 122. ^{13}C NMR spectra for **5**



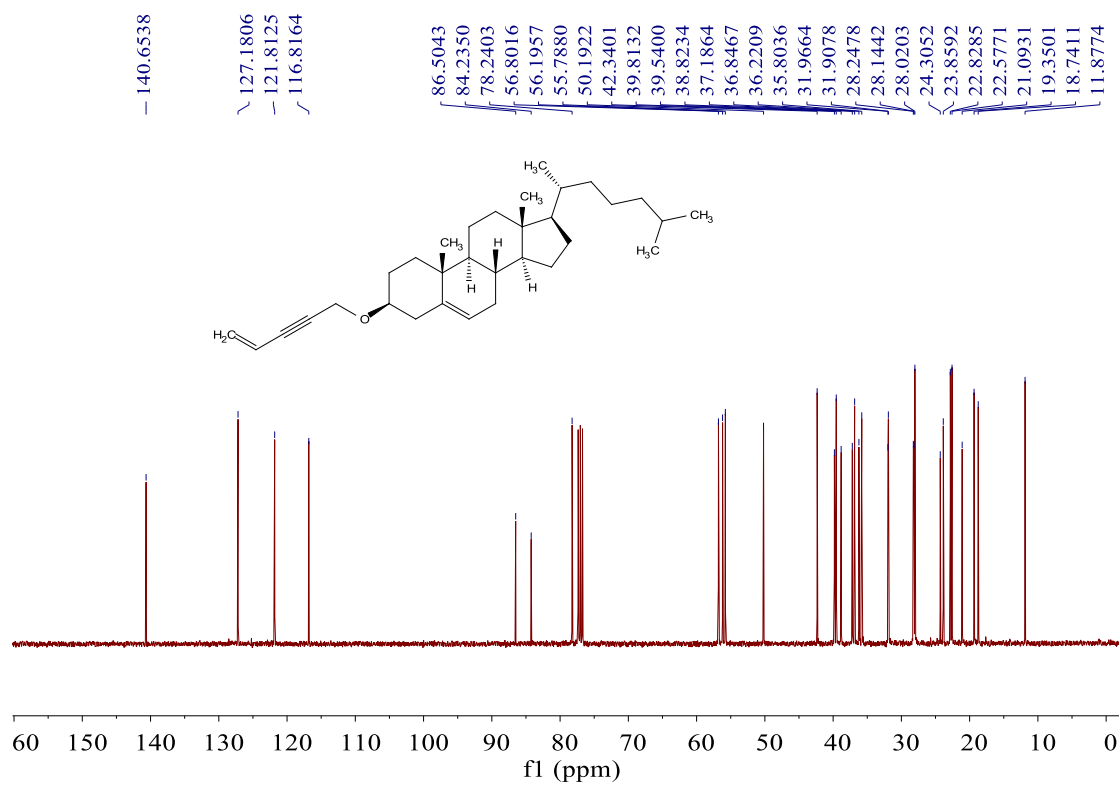
Supplementary Figure 123. ¹H NMR spectra for **6**



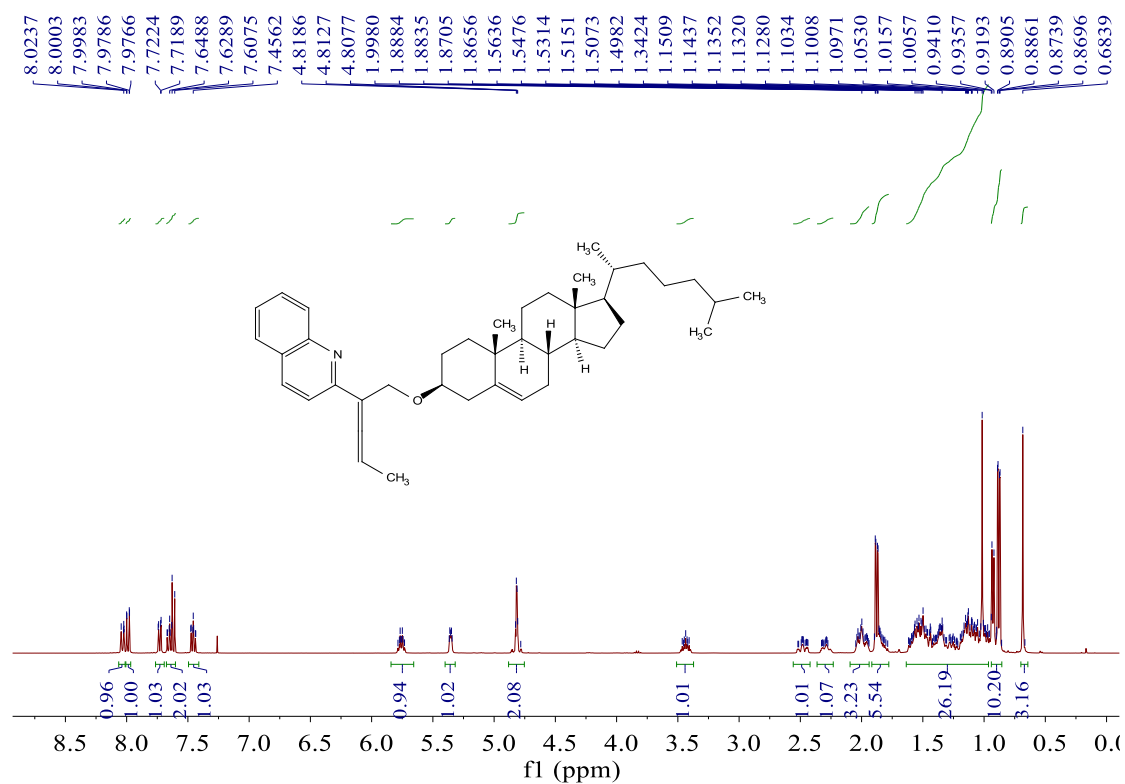
Supplementary Figure 124. ¹³C NMR spectra for **6**



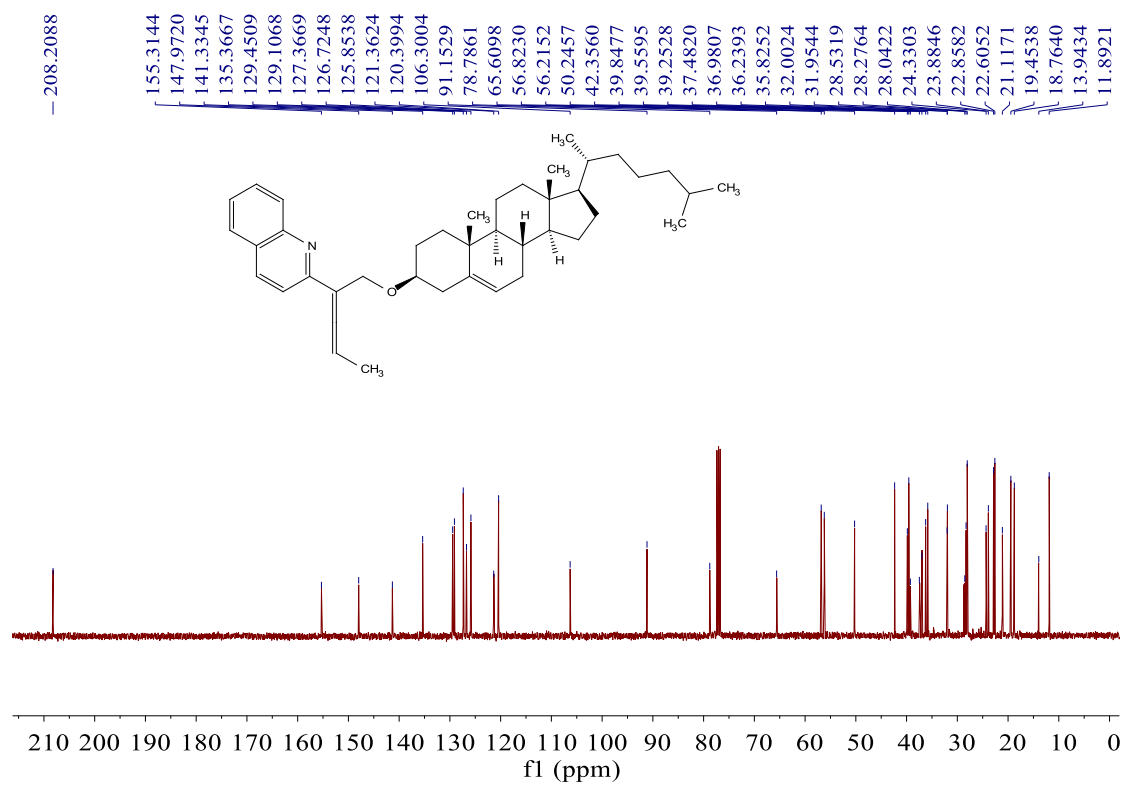
Supplementary Figure 125. ^1H NMR spectra for **7**



Supplementary Figure 126. ^{13}C NMR spectra for **7**



Supplementary Figure 127. ¹H NMR spectra for **8**



Supplementary Figure 128. ¹³C NMR spectra for **8**