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Supporting Information

Formal [5+1] Annulation Reactions of Dielectrophilic Peroxides: Facile Access to Functionalized Dihydropyrans

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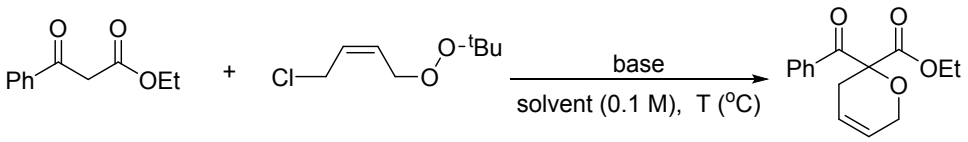
1. General Information

Unless otherwise stated, all reagents obtained from Adamas, Accela, or Acros were used without further purification. All solvents employed in the reactions were distilled from appropriate drying agents prior to use. ^{1}H and ^{13}C NMR spectra were recorded on Agilent 400MR DD2 (400 MHz) spectrometer or Agilent 600MR DD2 (600 MHz) spectrometer. Chemical shifts were reported in parts per million (ppm), and tetramethylsilane (TMS) or the residual solvent peak was used as an internal reference: ^{1}H NMR (TMS, δ 0.00; $CDCl_3$, δ 7.26), ^{13}C NMR ($CDCl_3$, δ 77.00). Data are reported as follows: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br = broad), coupling constants (Hz) and integration. High resolution mass spectra (HRMS) were acquired on a 7 Tesla SolariX FT-ICR MS (Bruker Daltonics, Bremen, Germany) with an ESI source.

2. Optimization of the annulation reaction

Table S1: Reaction of **1a** and **2d** under different basic conditions

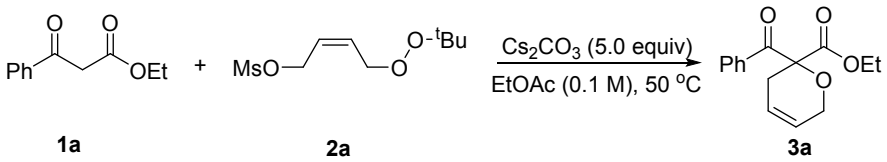


1a **2d** **3a**

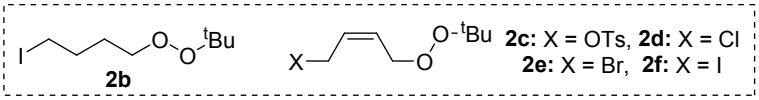
Entry	t (h)	T (°C)	base (equiv)	solvent	results
1	6	25	Cs_2CO_3 (2.0 eq.)	EtOAc	N.R.
2	6	25	KOH (2.0 eq.)	EtOAc	N.R.
3	6	25	Cs_2CO_3 (5.0 eq.)	EtOAc	N.R.
4	6	25	KOH (5.0 eq.)	EtOAc	N.R.
5	6	50	Cs_2CO_3 (5.0 eq.)	EtOAc	12%
6	6	50	KOH (5.0 eq.)	EtOAc	<10%
7	2	25	Cs_2CO_3 (2.0 eq.)	DMF	decomposed
8	2	25	KOH (2.0 eq.)	DMF	decomposed

Conditions: **1a** (0.12 mmol), **2d** (0.1 mmol), and base in EtOAc (1 mL) for 6 h.

Table S2: Reaction of **1a** with different peroxides **2a-2f**



1a **2a** **3a**

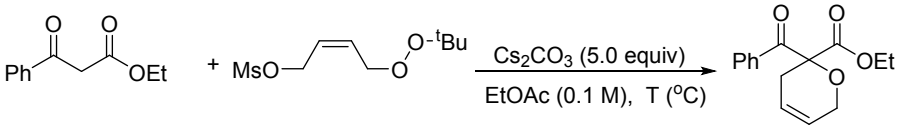


2b

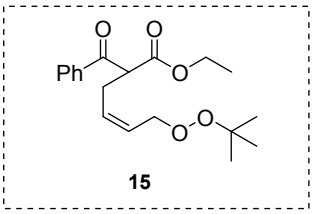
Entry	t (h)	**2**	results
1	6	**2a**	77%
2	6	**2b**	N.R.
3	6	**2c**	50%
4	6	**2d**	12%
5	6	**2e**	75%
6	6	**2f**	0%[b]

[a]Conditions: **1a** (0.12 mmol), **2a** - **2f** (0.1 mmol), and Cs_2CO_3 (5.0 equiv) in EtOAc (1 mL) at 50 °C for 6 h. [b]Isomerization of the double bond was observed.

Table S3: Reaction of **1a** and **2a** at different temperatures



1a **2a** **3a**

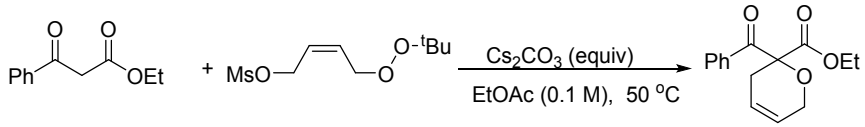


15

Entry	t (h)	T (°C)	results
1	6	25	**15** (78% yield)
2	6	30	25%
3	6	40	58%
4	6	45	70%
5	6	50	77%
6	6	55	74%
7	6	60	62%
8	6	75	31%
9	6	90	27%

Conditions: **1a** (0.12 mmol), **2a** (0.1 mmol), and Cs_2CO_3 (5.0 equiv) in EtOAc (1 mL) for 6 h.

Table S4: Reaction of **1a** and **2a** under different amount of base

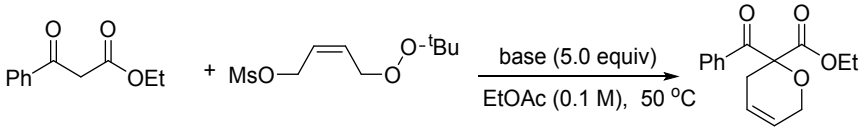


1a **2a** **3a**

Entry	t (h)	base (equiv)	results
1	6	Cs_2CO_3 (3.0 eq.)	35%
2	6	Cs_2CO_3 (5.0 eq.)	77%
3	6	Cs_2CO_3 (10.0 eq.)	58%

Conditions: **1a** (0.12 mmol), **2a** (0.1 mmol), and Cs_2CO_3 in EtOAc (1 mL) at 50 °C for 6 h.

Table S5: Reaction of **1a** and **2a** with different bases

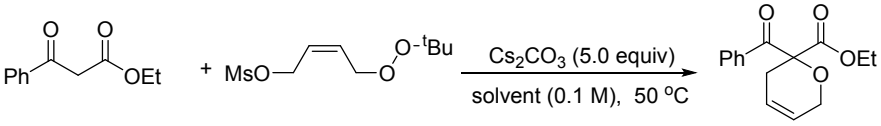


1a **2a** **3a**

Entry	t (h)	base (equiv)	results
1	12	K_2CO_3 (5.0 eq.)	**15** (75% yield)
2	12	K_3PO_4 (5.0 eq.)	54%
3	6	Cs_2CO_3 (5.0 eq.)	77%
4	8	KOH (5.0 eq.)	27%

Conditions: **1a** (0.12 mmol), **2a** (0.1 mmol), and base (5.0 equiv) in EtOAc (1 mL) at 50 °C for 6-12 h.

Table S6: Reaction of **1a** and **2a** with different solvents

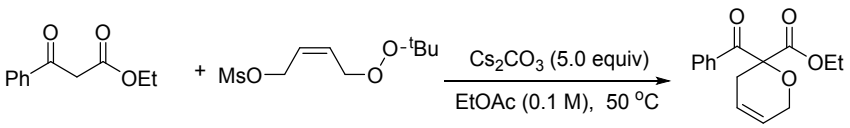


1a **2a** **3a**

Entry	t (h)	solvent	results
1	6	EtOAC	77%
2	1	DMF	decomposed
3	6	CH_3CN	16%
4	6	THF	46%
5	6	DCM	24%

Conditions: **1a** (0.12 mmol), **2a** (0.1 mmol), and base (5.0 equiv) in solvent (1 mL) at 50 °C for 1-6 h.

Table S7: Reaction of **1a** and **2a** with different ratios of **2a**



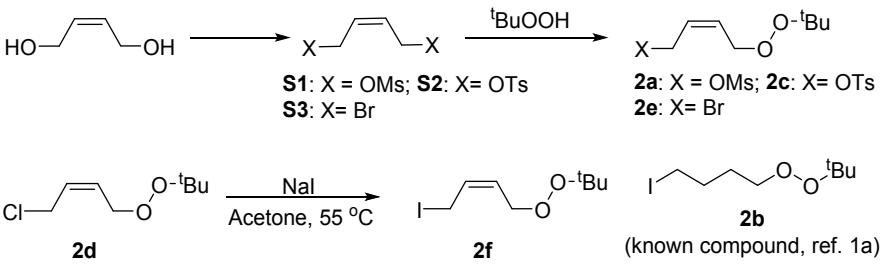
1a **2a** **3a**

Entry	t (h)	**1a : 2a**	results
1	6	1.5 : 1	76%
2	6	1.2 : 1	77%
3	6	1 : 1	59%
4	6	1 : 2	73%

Conditions: Cs_2CO_3 (5.0 equivl) in EtOAc (1 mL) at 50 °C for 6 h.

3. Preparation of the peroxides

3.1 Peroxides 2a-f were prepared as following procedure[1-2]

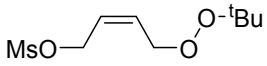


To a solution of (*Z*)-but-2-ene-1,4-diol (500 mg, 5.67 mmol, 1.0 equiv) and triethylamine (1.7 mL, 12 mmol, 2.12 equiv) in CH_2Cl_2 (20 mL) was added a solution of methanesulfonyl chloride (1.0 mL, 12 mmol, 2.12 equiv) in CH_2Cl_2 (20 mL) at 0 °C. After stirring at room temperature for 0.5 h, the mixture was poured into ice water and extracted with CH_2Cl_2 (30 mL x 3). The organic layers were combined, dried over Na_2SO_4, filtered, and evaporated under vacuum to give crude **S1**,[1b] which was judged by NMR to be sufficiently pure for direct use in the next step without purification. **^{1}HNMR (400 MHz, $CDCl_3$)** δ 5.93 (s, 2H), 4.83 (d, *J* = 5.1 Hz, 4H), 3.03 (s, 6H).

(*Z*)-but-2-ene-1,4-diol (441 mg, 5.0 mmol, 1.0 equiv) and benzyltrimethyl-ammonium chloride (46 mg, 0.25 mmol, 0.05 equiv) were dissolved in dioxane (7.5 mL). After addition of a 50 % KOH solution (7.5 mL), the reaction was cooled to 0 °C. Tosylchloride (2.38 g, 12.5 mmol, 2.5 equiv) was dissolved in dioxane (2.5 mL) and added dropwise to the reaction mixture. Stirring was continued for 0.5 h at 0 °C and 3 h at room temperature. After completion, the reaction was quenched by water

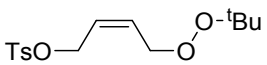
(20 mL). The organic layer was separated, and the aqueous layer was extracted with EtOAc (20 mL x 3). The combined organic layer was washed with brine (20 mL), dried over Na_2SO_4, and concentrated. The residue was purified by column chromatography on silica gel (petroleum ether / EtOAc = 10:1) to give as a highly viscous oil **S2**[1c] (1.3 g, 66% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.75 (d, *J* = 8.0 Hz, 4H), 7.34 (d, *J* = 8.0 Hz, 4H), 5.66 (t, *J* = 4.0 Hz, 2H), 4.52 (d, *J* = 4.4 Hz, 4H), 2.44 (s, 6H).

To a solution of the **S1** or **S2** (4.1 mmol, 1.0 equiv), *tert*-butyl hydroperoxide (1.1 mL, 6.1 mmol, 5.5 M solution in hexane, 1.5 equiv), and PEG600 (700 mg) in THF (30 mL) was added powder KOH (342 mg, 6.1 mmol, 1.5 equiv). The resulting solution was stirred at room temperature for 6 h. After completion, the reaction was quenched by water (30 mL). The organic layer was separated, and the aqueous layer was extracted with EtOAc (30 mL x 3). The combined organic layer was washed with brine (30 mL), dried over Na_2SO_4, and concentrated. The residue was purified by column chromatography on silica gel (petroleum ether / EtOAc = 10:1) to give peroxides **2a** and **2c** as light yellow oils in 35-40% yields.



2a

Following the above procedure, **2a** was obtained as a light yellow oil (390 mg, 40% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 5.97 – 5.91 (m, 1H), 5.84 – 5.78 (m, 1H), 4.85 (d, *J* = 6.8 Hz, 2H), 4.55 (d, *J* = 6.4 Hz, 2H), 3.02 (s, 3H), 1.24 (s, 9H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 131.1, 125.8, 80.6, 70.0, 65.2, 38.2, 26.2. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_9H_{18}NaO_5S, M + Na]^+$: 261.07623, Found: 261.07672.



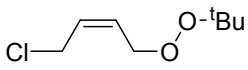
2c

Following the above procedure, **2c** was obtained as a light yellow oil (451 mg, 35% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.78 (d, *J* = 8.1 Hz, 2H), 7.33 (d, *J* = 8.1 Hz, 2H), 5.82 – 5.76 (m, 1H), 5.69 – 5.62 (m, 1H), 4.65 (d, *J* = 6.7 Hz, 2H), 4.39 (d, *J* = 6.4 Hz, 2H), 2.44 (s, 3H), 1.18 (s, 9H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 144.8, 133.1,

130.2, 129.8, 127.9, 125.8, 80.4, 69.9, 65.8, 26.2, 21.6. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{15}H_{22}NaO_5S, M + Na]^+$: 337.1069, Found: 337.10802.

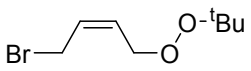
To a solution of (*Z*)-but-2-ene-1,4-diol (1.87 mL, 22.7 mmol, 1.0 equiv) and pyridine (2.2 mL, 27.2 mmol, 1.2 equiv) in 40 mL of Et_2O was dropwise added PBr_3 (4.27 mL, 45.4 mmol, 2.0 equiv) at 0 °C. After 1 h, the solution was allowed to warm up to room temperature and stirring was continued for 2 h. The mixture was poured into cold H_2O. The organic layer was separated, and the aqueous layer was extracted with EtOAc (30 mL x 3). The combined organic layer was washed with brine (30 mL), dried over Na_2SO_4, and concentrated. The product **S3** was obtained as a light yellow oil in 75% yield, which was judged by NMR to be sufficiently pure for direct use in the next step without purification. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 5.88 (td, *J* = 5.5, 2.8 Hz, 2H), 4.05 – 3.95 (m, 4H).

To a solution of the **S3** or commercial available *cis*-1,4-dichloro-2-butene (4.5 mmol, 1.0 equiv), *tert*-butyl hydroperoxide (0.9 mL, 4.5 mmol, 5.5 M solution in hexane, 1.0 equiv), and Tetrabutylammonium bromide (166 mg, 0.45 mmol, 0.1 equiv) in DCM (30 mL) was added powder KOH (252 mg, 4.5 mmol, 1.0 equiv). The resulting solution was stirred at room temperature for 6 h. After completion, the reaction was quenched by water (30 mL). The organic layer was separated, and the aqueous layer was extracted with DCM (30 mL x 3). The combined organic layer was washed with brine (30 mL), dried over Na_2SO_4, and concentrated. The residue was purified by column chromatography on silica gel (petroleum ether / EtOAc = 200:1) to give peroxides **2d-e** as light yellow oils in 36-70% yields.



2d

Following the above procedure, **2d** was obtained as a light yellow oil (389 mg, 36% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 5.86 – 5.76 (m, 2H), 4.53 (d, *J* = 6.4 Hz, 2H), 4.13 (d, *J* = 7.4 Hz, 2H), 1.24 (s, 9H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 129.8, 128.3, 80.4, 69.6, 39.0, 26.3. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_8H_{15}ClNaO_2, M + Na]^+$: 201.0651, Found: 201.0652.

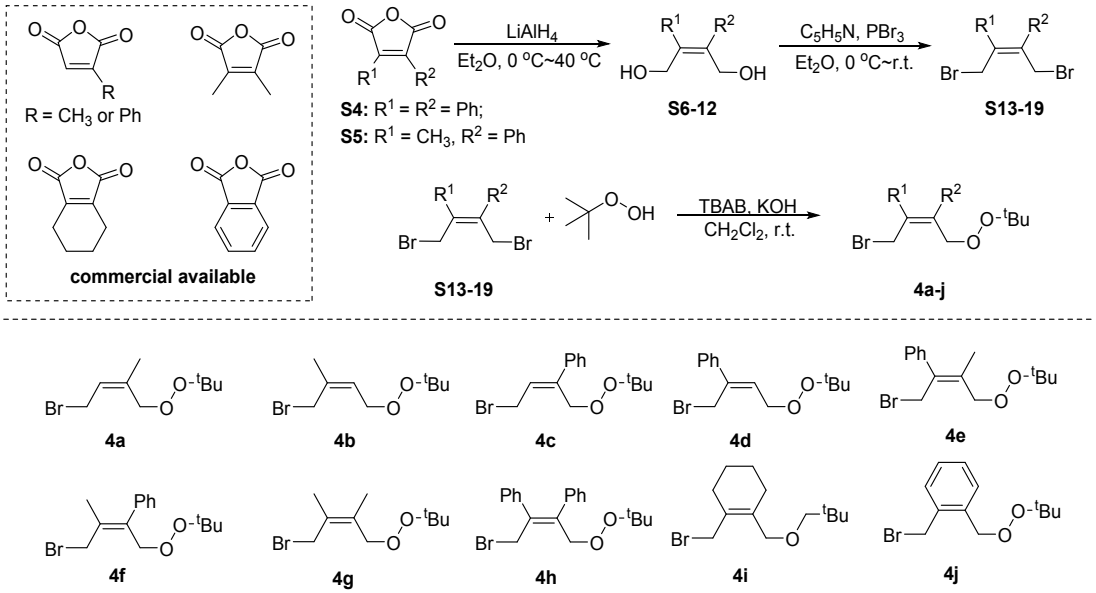


2e

Following the above procedure, **2e** was obtained as a light yellow oil (432 mg, 43% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 5.93 (dd, *J* = 14.3, 4.7 Hz, 1H), 5.74 (dt, *J* = 10.8, 6.8 Hz, 1H), 4.55 (d, *J* = 6.9 Hz, 2H), 4.01 (d, *J* = 8.3 Hz, 2H), 1.24 (s, 9H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 129.8, 128.6, 80.5, 69.4, 26.3, 26.2. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_9H_{19}BrNaO_3$, M + CH_3OH + Na$]^+$: 277.0401, Found: 277.0409.

A mixture of **2d** (200 mg, 1.12 mmol, 1.0 equiv) and sodium iodide (893 mg, 5.6 mmol, 5.0 equiv) in acetone (15 mL) was heated to reflux for overnight. After completion, the mixture was allowed to cool to room temperature and evaporated under reduced pressure. The residue was treated with water (20 mL) and DCM (20 mL). After shaking and separation of layers, the aqueous layer was extracted with DCM (20 mL x 3) and the organic layer was washed with brine, dried, and carefully concentrated. The residue was purified by column chromatography on silica gel (petroleum ether / EtOAc = 200:1) to give peroxide **2f** as a light yellow oil (210 mg, 70% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 5.99 (dt, *J* = 15.6, 7.8 Hz, 1H), 5.82 (dt, *J* = 15.2, 6.2 Hz, 1H), 4.40 (d, *J* = 6.2 Hz, 2H), 3.87 (d, *J* = 7.9 Hz, 2H), 1.24 (s, 9H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 132.2, 128.2, 80.4, 74.4, 26.3, 4.4. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_8H_{15}INaO_2$, M + Na$]^+$: 293.0007, Found: 293.0008.

3.2 Peroxides 4a-j were prepared as following procedure[3]

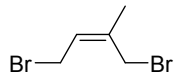


To a suspension of $LiAlH_4$ (3.0 equiv) in Et_2O, a solution of **S4**[4], **S5**[5] or other commercial available acid anhydrides (5.0 mmol ~ 10 mmol, 1.0 equiv) in 30 mL ~ 40 mL of Et_2O was added dropwise at 0 °C. The mixture was allowed to warm up to 40 °C. After completion of the reaction (monitored by the TLC), the reaction mixture was quenched by slowly adding CH_3OH until the evolution of gas ceased, then was added 2.0 M HCl until pH to 7. The reaction was filtered through a pad of celite and the filtrate was concentrated. The crude products **S6-12** were used for the next step without further purification.

To a solution of crude product **S6-12** (6.0 mmol ~ 10 mmol, 1.0 equiv) and pyridine (1.2 equiv) in Et_2O (0.5 M) was dropwise added PBr_3 (2.0 equiv) at 0 °C. After 1 h, the solution was allowed to warm up to room temperature and stirring was continued for 2 h. The mixture was poured into cold H_2O. The organic layer was separated, and the aqueous layer was extracted with EtOAc (30 mL x 3). The combined organic layer was washed with brine (30 mL), dried over Na_2SO_4, and concentrated. The products **S13-19** were obtained as light yellow oils without further purification in 38-80% yields.

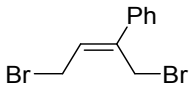
To a solution of the **S13-19** (2.4 mmol ~ 5 mmol, 1.0 equiv), *tert*-butyl hydroperoxide (1.0 equiv), and tetrabutylammonium bromide (0.1 equiv) in DCM (0.5 M) was added powder KOH (1.0 equiv). The resulting solution was stirred at

room temperature for 6 h. After completion, the reaction was quenched by water (30 mL). The organic layer was separated, and the aqueous layer was extracted with DCM (30 mL x 3). The combined organic layer was washed with brine (30 mL), dried over Na_2SO_4, and concentrated. The residue was purified by column chromatography on silica gel (petroleum ether / EtOAc = 200:1) to give peroxides **4a-j** as light yellow oils in 39-58% yields.



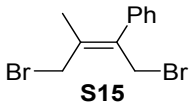
S13

Following the general procedure (7.2 mmol scale), **S13** was obtained as a light yellow oil (600 mg, 38% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 5.72 (t, J = 8.6 Hz, 1H), 4.00 (t, J = 4.1 Hz, 4H), 1.93 (s, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 138.3, 125.9, 29.3, 26.6, 22.1. The spectral data of **S13** was consistent with that reported in the literature.[3]



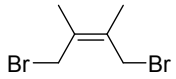
S14

Following the general procedure (6.0 mmol scale), **S14** was obtained as a light yellow oil (680 mg, 39% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.49 (d, *J* = 7.6 Hz, 2H), 7.42 – 7.36 (m, 3H), 6.24 (t, *J* = 8.6 Hz, 1H), 4.41 (s, 2H), 4.23 (d, *J* = 8.7 Hz, 2H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 140.9, 138.7, 128.6, 128.5, 127.9, 126.1, 26.8, 26.6. The spectral data of **S14** was consistent with that reported in the literature.[3]



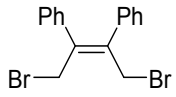
S15

Following the general procedure (6.0 mmol scale), **S15** was obtained as a light yellow oil (1.27 g, 70% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.39 – 7.32 (m, 3H), 7.22 (d, *J* = 7.5 Hz, 2H), 4.30 (s, 2H), 4.20 (s, 2H), 1.77 (s, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 139.7, 137.4, 135.6, 128.4, 128.3, 127.6, 32.5, 32.3, 19.4. The spectral data of **S15** was consistent with that reported in the literature.[3]



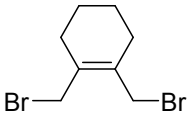
S16

Following the general procedure (8.0 mmol scale), **S16** was obtained as a light yellow oil (1.2 g, 62% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 4.05 (s, 4H), 1.84 (s, 6H). The spectral data of **S16** was consistent with that reported in the literature.[3]



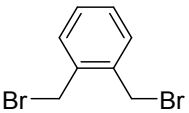
S17

Following the general procedure (8.0 mmol scale), **S17** was obtained as a light yellow oil (2.9 g, 80% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.15 (d, J = 2.2 Hz, 6H), 7.11 – 7.06 (m, 4H), 4.52 (s, 4H). The spectral data of **S17** was consistent with that reported in the literature.[3]



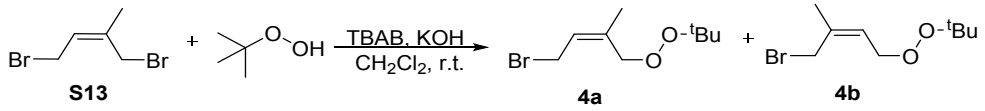
S18

Following the general procedure (10.0 mmol scale), **S18** was obtained as a light yellow oil (1.4 g, 52% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 4.01 (s, 4H), 2.20 (s, 4H), 1.65 (s, 4H). The spectral data of **S18** was consistent with that reported in the literature.[6]

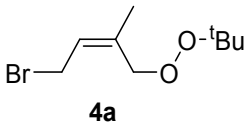


S19

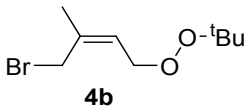
Following the general procedure (10.0 mmol scale), **S19** was obtained as a light yellow oil (1.6 g, 60% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.37 (dt, *J* = 7.1, 3.6 Hz, 2H), 7.34 – 7.27 (m, 2H), 4.67 (s, 4H). The spectral data of **S19** was consistent with that reported in the literature.[7]



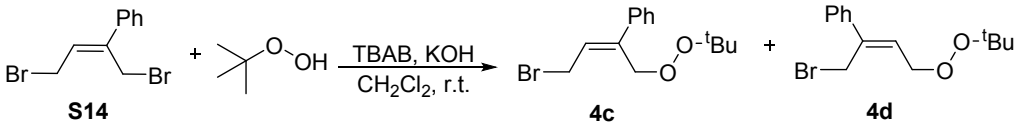
Note: Following the general procedure (2.6 mmol scale), peroxides **4a** and **4b** were prepared as a pair of mixture from the corresponding dibromide **S13** in 39% combined yield. They were separated as pure forms after careful chromatography (petroleum ether / ether = 400:1 ~ 200:1).



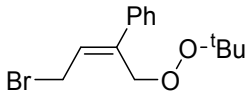
4a was obtained as a light yellow oil (112 mg, 18% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 5.74 (t, *J* = 8.5 Hz, 1H), 4.48 (s, 2H), 4.05 (d, *J* = 8.5 Hz, 2H), 1.87 (s, 3H), 1.25 (s, 9H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 137.1, 126.0, 80.4, 72.6, 27.8, 26.3, 22.3. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_9H_{17}BrNaO_2, M + Na]^+$: 259.0309, Found: 259.0304.



4b was obtained as a light yellow oil (131 mg, 21% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 5.56 (t, *J* = 7.1 Hz, 1H), 4.47 (d, *J* = 7.1 Hz, 2H), 3.99 (s, 2H), 1.90 (s, 3H), 1.24 (s, 9H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 138.1, 124.2, 80.4, 70.3, 30.9, 26.3, 22.1. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_9H_{17}BrNaO_2, M + Na]^+$: 259.0309, Found: 259.0304.

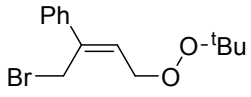


Note: Following the general procedure (2.4 mmol scale), peroxides **4c** and **4d** were prepared as a pair of mixture from the corresponding dibromide **S14** in 55% combined yield. They were separated as pure forms after careful chromatography (petroleum ether / ether = 400:1 ~ 150:1).



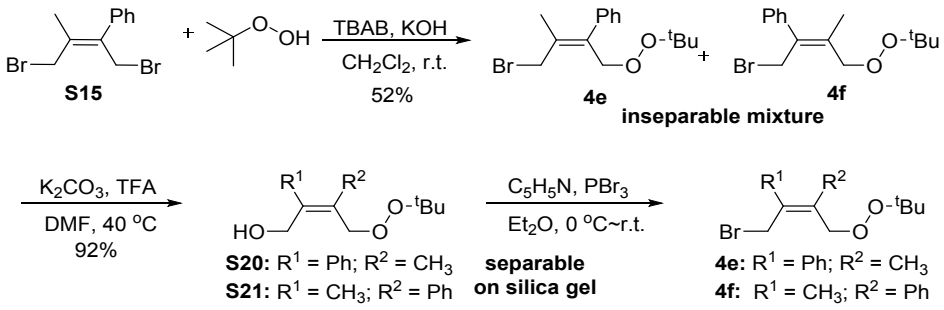
4c

4c was obtained as a light yellow oil (50 mg, 7% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.47 (d, *J* = 7.2 Hz, 2H), 7.33 (dt, *J* = 11.4, 7.0 Hz, 3H), 6.28 (t, *J* = 8.5 Hz, 1H), 4.88 (s, 2H), 4.29 (d, *J* = 8.5 Hz, 2H), 1.24 (s, 9H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 140.1, 138.5, 129.3, 128.4, 127.9, 126.4, 80.4, 71.0, 28.1, 26.4. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{14}H_{19}BrNaO_2, M + Na]^+$: 321.0457, Found: 321.0460.



4d

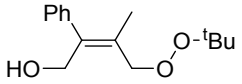
4d was obtained as a light yellow oil (345 mg, 48% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.49 (d, *J* = 6.9 Hz, 2H), 7.39 – 7.33 (m, 3H), 6.13 (t, *J* = 6.8 Hz, 1H), 4.73 (d, *J* = 6.8 Hz, 2H), 4.39 (s, 2H), 1.29 (s, 9H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 140.1, 139.3, 128.5, 128.1, 127.5, 126.1, 80.6, 70.9, 28.0, 26.4. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{14}H_{19}BrNaO_2, M + Na]^+$: 321.0457, Found: 321.0460.



Note: Following the general procedure (4.0 mmol scale), peroxides **4e** and **4f** were prepared as a pair of mixture from the corresponding dibromide **S15** in 52% combined yield. Peroxides **4e** and **4f** were inseparable on silica gel; however, the corresponding hydroxyl peroxides **S20** and **S21** were separable by simple chromatography. Thus pure peroxides **4e** and **4f** were obtained after two more steps of transformations.[8]

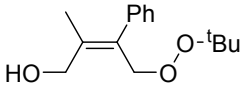
The mixture compound **4e** and **4f** (350 mg, 1.12 mmol, 1.0 equiv) in DMF (2 mL) was added to a DMF (2 mL) suspension of K_2CO_3 (386 mg, 2.79 mmol, 2.5 equiv)

and TFA (0.2 mL, 2.79 mmol, 2.5 equiv). The mixture was stirred at 40 °C for 1 h, and when it had been cooled to room temperature, water (10 mL) was added. The mixture was extracted with EtOAc (10 mL x 3) and the combined organics were washed with brine (10 mL) and dried over Na_2SO_4, filtered, and concentrated. The residue was purified by column chromatography on silica gel (petroleum ether / EtOAc = 20:1) to give peroxides **S20** and **S21** as light yellow oils in 92% yields.



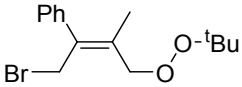
S20

Following the above procedure, **S20** was obtained as a light yellow oil (159 mg, 57% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.35 (t, *J* = 7.3 Hz, 2H), 7.25 (dt, *J* = 8.1, 7.2 Hz, 3H), 4.64 (s, 2H), 4.39 (s, 2H), 2.14 (br s, 1H), 1.74 (s, 3H), 1.29 (s, 9H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 141.6, 141.2, 131.0, 128.4, 128.2, 126.9, 80.7, 75.3, 63.0, 26.3, 19.6. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{15}H_{22}NaO_3, M + Na]^+$: 273.1457, Found: 273.1461.



S21

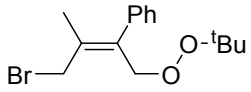
Following the above procedure, **S21** was obtained as a light yellow oil (98 mg, 35% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.33 (t, *J* = 7.4 Hz, 2H), 7.24 (d, *J* = 4.6 Hz, 1H), 7.20 (d, *J* = 7.1 Hz, 2H), 4.74 (s, 2H), 4.28 (d, *J* = 4.3 Hz, 2H), 2.20 (br s, 1H), 1.77 (s, 3H), 1.22 (s, 9H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 141.7, 140.1, 133.2, 128.5, 128.4, 128.2, 128.1, 126.7, 80.6, 75.5, 63.5, 26.4, 19.2. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{15}H_{22}NaO_3, M + Na]^+$: 273.1457, Found: 273.1461.



4e

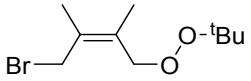
Following the above procedure, **4e** was obtained as a light yellow oil (146 mg, 65% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.37 (t, *J* = 7.2 Hz, 2H), 7.31 (d, *J* = 7.2 Hz, 1H), 7.26 – 7.22 (m, 2H), 4.66 (s, 2H), 4.34 (s, 2H), 1.71 (s, 3H), 1.30 (s, 9H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 140.2, 137.4, 134.3, 128.6, 128.3, 127.3, 80.5, 74.6, 33.6,

26.4, 19.6. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{15}H_{21}BrNaO_2$, M + Na$]^+$: 335.0603, Found: 335.0617.



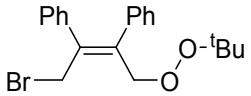
4f

Following the above procedure, **4f** was obtained as a light yellow oil (155 mg, 69% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.34 (t, *J* = 7.2 Hz, 2H), 7.27 (t, *J* = 3.4 Hz, 1H), 7.20 (d, *J* = 7.9 Hz, 2H), 4.73 (s, 2H), 4.26 (s, 2H), 1.80 (s, 3H), 1.20 (s, 9H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 141.0, 136.1, 135.1, 128.4, 128.1, 127.0, 80.5, 74.8, 34.2, 26.3, 19.2. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{15}H_{21}BrNaO_2$, M + Na$]^+$: 335.0603, Found: 335.0617.



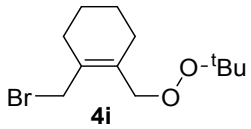
4g

Following the general procedure (3.5 mmol scale), **4g** was obtained as a light yellow oil (440 mg, 50% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 4.46 (s, 2H), 4.09 (s, 2H), 1.81 (d, *J* = 13.3 Hz, 6H), 1.25 (s, 9H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 132.3, 130.7, 80.3, 74.9, 34.7, 26.3, 18.5, 17.7. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{11}H_{23}BrNaO_3$, M + MeOH + Na$]^+$: 305.0725, Found: 305.0722.



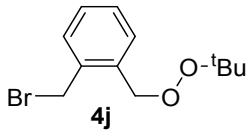
4h

Following the general procedure (3.5 mmol scale), **4h** was obtained as a light yellow oil (591 mg, 45% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.18 – 7.03 (m, 10H), 4.99 (s, 2H), 4.58 (s, 2H), 1.25 (s, 9H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 140.5, 140.5, 139.9, 137.7, 129.3, 129.2, 127.9, 127.6, 127.1, 126.8, 80.6, 75.0, 33.7, 26.4. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{20}H_{23}BrNaO_2$, M + Na$]^+$: 397.0773, Found: 397.0773.



4i

Following the general procedure (5.0 mmol scale), **4i** was obtained as a light yellow oil (803 mg, 58% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 4.44 (s, 2H), 4.05 (s, 2H), 2.23 – 2.11 (m, 4H), 1.67 – 1.56 (m, 4H), 1.24 (s, 9H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 134.3, 132.6, 80.3, 74.2, 33.4, 29.3, 28.1, 26.4, 22.5, 22.3. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{12}H_{21}BrNaO_2, M + Na]^+$: 299.0611, Found: 299.0617.

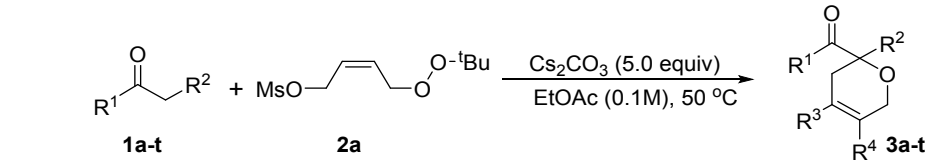


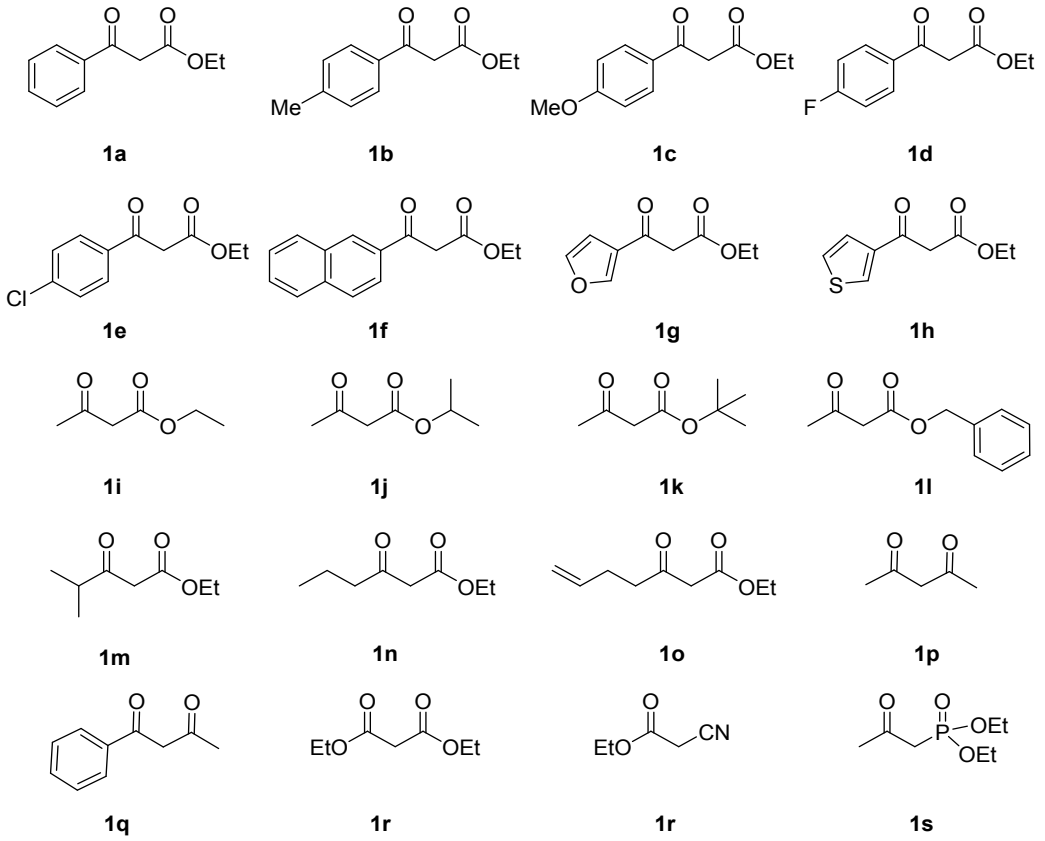
4j

Following the general procedure (5.0 mmol scale), **4j** was obtained as a light yellow oil (751 mg, 55% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.39 – 7.37 (m, 2H), 7.33 – 7.30 (m, 2H), 5.11 (s, 2H), 4.65 (s, 2H), 1.25 (s, 9H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 136.9, 134.6, 131.2, 130.5, 129.0, 128.8, 80.5, 74.2, 30.8, 26.3. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{12}H_{17}BrNaO_2, M + Na]^+$: 295.0294, Found: 295.0304.

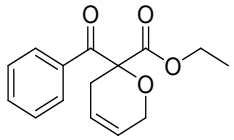
4. General procedure for the annulations of peroxide 2a with 1a-t

Note: Compounds **1a**, **1i**, and **1p-s** are commercial available. Other known substrates **1b-h**, **1j-o**, and **1t** were prepared according to the reported method.[2]



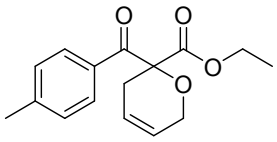


To a solution of substrates **1a-t** (0.24 mmol, 1.2 equiv) and peroxide **2a** (0.2 mmol, 1.0 equiv) in ethyl acetate (2 mL) was added Cs_2CO_3 solid (326 mg, 1.0 mmol, 5.0 equiv) at room temperature. The resulting solution was vigorously stirred at 50 °C for 6-12 h. After completion of the reaction as monitored by the TLC, the reaction mixture was diluted with ethyl acetate (5 mL) and water (5 mL). The ethyl acetate layer was separated and the aqueous layer was extracted with EtOAc (5 mL x 3). The combined extracts were washed with brine (10 mL), dried over Na_2SO_4, filtered, and concentrated. The residue was purified by flash column chromatography on silica gel (petroleum ether / EtOAc= 50:1 or petroleum ether / DCM = 10:3) to afford the desired dihydropyrans products **3a-t** in 70-86% yields.



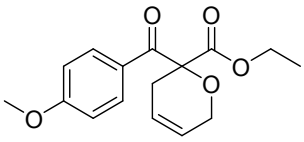
3a

Following the general procedure, **3a** was obtained as a light yellow oil (40 mg, 77% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 8.19 (d, *J* = 7.7 Hz, 2H), 7.55 (t, *J* = 7.3 Hz, 1H), 7.42 (t, *J* = 7.7 Hz, 2H), 5.89 (dd, *J* = 6.2, 3.3 Hz, 1H), 5.67 (d, *J* = 10.3 Hz, 1H), 4.47 (d, *J* = 16.9 Hz, 1H), 4.19 (q, *J* = 7.0 Hz, 2H), 4.07 (d, *J* = 16.9 Hz, 1H), 3.00 (d, *J* = 17.2 Hz, 1H), 2.52 (d, *J* = 17.2 Hz, 1H), 1.12 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 193.3, 169.9, 134.1, 133.5, 129.6, 128.4, 124.3, 122.2, 83.1, 63.4, 62.0, 29.0, 13.9. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{15}H_{16}NaO_4, M + Na]^+$: 283.0937, Found: 283.0940.



3b

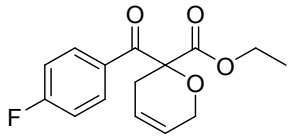
Following the general procedure, **3b** was obtained as a light yellow oil (44 mg, 80% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 8.10 (d, *J* = 7.9 Hz, 2H), 7.23 (d, *J* = 7.9 Hz, 2H), 5.88 (br s, 1H), 5.66 (d, *J* = 9.8 Hz, 1H), 4.45 (d, *J* = 16.9 Hz, 1H), 4.21 – 4.17 (m, 2H), 4.06 (d, *J* = 16.9 Hz, 1H), 3.00 (d, *J* = 17.1 Hz, 1H), 2.50 (d, *J* = 17.1 Hz, 1H), 2.39 (s, 3H), 1.13 (t, *J* = 7.0 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 192.8, 170.1, 144.5, 131.5, 129.7, 129.2, 124.2, 122.3, 83.1, 63.3, 61.9, 29.0, 21.7, 13.9. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{16}H_{18}NaO_4, M + Na]^+$: 297.1093, Found: 297.1097.



3c

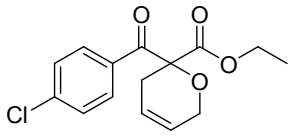
Following the general procedure, **3c** was obtained as a light yellow oil (48 mg, 83% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 8.22 (d, *J* = 9.0 Hz, 2H), 6.90 (d, *J* = 9.0 Hz, 2H), 5.88 (br s, 1H), 5.66 (d, *J* = 10.4 Hz, 1H), 4.46 (d, *J* = 16.9 Hz, 1H), 4.20 – 4.17

(m, 2H), 4.08 (d, *J* = 16.9 Hz, 1H), 3.86 (s, 3H), 3.01 (d, *J* = 17.2 Hz, 1H), 2.50 (d, *J* = 17.2 Hz, 1H), 1.14 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 191.6, 170.2, 163.8, 132.1, 127.0, 124.2, 122.4, 113.6, 83.1, 63.3, 61.9, 55.4, 29.0, 13.9. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{16}H_{18}NaO_4, M + Na]^+$: 313.1042, Found: 313.1046.



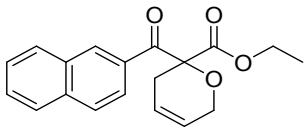
3d

Following the general procedure, **3d** was obtained as a light yellow solid (41 mg, 73% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 8.26 (dd, *J* = 8.2, 5.7 Hz, 2H), 7.10 (t, *J* = 8.5 Hz, 2H), 5.88 (br s, 1H), 5.67 (d, *J* = 10.2 Hz, 1H), 4.50 (d, *J* = 16.9 Hz, 1H), 4.19 (dd, *J* = 13.2, 6.5 Hz, 2H), 4.07 (d, *J* = 16.9 Hz, 1H), 2.98 (d, *J* = 17.3 Hz, 1H), 2.53 (d, *J* = 17.3 Hz, 1H), 1.14 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 191.7, 169.8, 167.2 (d, $^1J_{C\text{-}F}$ = 255.8 Hz), 132.6 (d, $^2J_{C\text{-}F}$ = 9.4 Hz), 130.4, 124.2, 122.1, 115.7 (d, $^3J_{C\text{-}F}$ = 22.6 Hz), 83.1, 63.4, 62.0, 28.9, 13.9. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{15}H_{15}FNaO_4, M + Na]^+$: 301.0843, Found: 301.0846. **Melting point:** 48.0 – 49.4 °C.



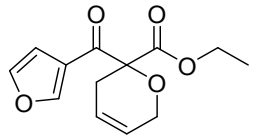
3e

Following the general procedure, **3e** was obtained as a white solid (44 mg, 75% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 8.16 (d, *J* = 8.6 Hz, 2H), 7.41 (d, *J* = 8.6 Hz, 2H), 5.90 (dd, *J* = 6.5, 3.9 Hz, 1H), 5.67 (d, *J* = 10.4 Hz, 1H), 4.49 (d, *J* = 17.0 Hz, 1H), 4.20 (qd, *J* = 7.1, 3.0 Hz, 2H), 4.07 (d, *J* = 17.0 Hz, 1H), 2.98 (d, *J* = 17.3 Hz, 1H), 2.53 (d, *J* = 17.3 Hz, 1H), 1.14 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 192.2, 169.7, 140.1, 132.3, 131.2, 128.8, 124.2, 122.1, 83.1, 63.4, 62.1, 28.9, 13.9. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{15}H_{15}ClNaO_4, M + Na]^+$: 317.0548, Found: 317.0551. **Melting point:** 38.8 – 39.8 °C.



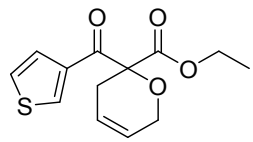
3f

Following the general procedure, **3f** was obtained as a white solid (47 mg, 76% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 8.87 (s, 1H), 8.16 (d, *J* = 8.7 Hz, 1H), 7.98 (d, *J* = 8.0 Hz, 1H), 7.86 (dd, *J* = 8.2, 4.4 Hz, 2H), 7.57 (dt, *J* = 14.5, 7.1 Hz, 2H), 6.02 – 5.86 (m, 1H), 5.69 (d, *J* = 10.3 Hz, 1H), 4.50 (d, *J* = 17.0 Hz, 1H), 4.22 – 4.13 (m, 3H), 3.08 (d, *J* = 17.2 Hz, 1H), 2.56 (d, *J* = 17.2 Hz, 1H), 1.12 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 193.1, 170.1, 135.7, 132.4, 131.7, 131.3, 130.1, 128.8, 128.2, 127.6, 126.6, 124.9, 124.2, 122.3, 83.3, 63.4, 62.0, 29.1, 13.9. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{19}H_{18}NaO_4$, M + Na$]^+$: 333.1093, Found: 333.1097. **Melting point:** 91.7 – 93.0 °C.



3g

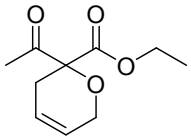
Following the general procedure, **3g** was obtained as a light yellow oil (41 mg, 82% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.63 (dd, *J* = 6.6, 2.2 Hz, 2H), 6.53 (dd, *J* = 3.6, 1.6 Hz, 1H), 5.87 – 5.82 (m, 1H), 5.70 – 5.67 (m, 1H), 4.51 – 4.46 (m, 1H), 4.26 – 4.17 (m, 3H), 2.89 (d, *J* = 17.4 Hz, 1H), 2.59 (d, *J* = 17.4 Hz, 1H), 1.17 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 182.0, 169.2, 149.3, 147.5, 124.4, 122.0, 121.7, 112.3, 82.5, 63.4, 62.0, 28.1, 13.9. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{13}H_{14}NaO_5$, M + Na$]^+$: 273.0730, Found: 273.0733.



3h

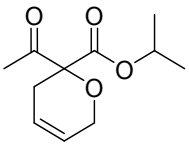
Following the general procedure, **3h** was obtained as a light yellow solid (42 mg, 80% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 8.19 – 8.18 (m, 1H), 7.67 (dd, *J* = 4.9, 0.8 Hz, 1H), 7.12 – 7.10 (m, 1H), 5.90 – 5.87 (m, 1H), 5.71 – 5.68 (m, 1H), 4.49 (d, *J* =

16.9 Hz, 1H), 4.34 – 4.07 (m, 3H), 2.91 (d, *J* = 17.3 Hz, 1H), 2.59 (d, *J* = 17.3 Hz, 1H), 1.16 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 186.8, 169.3, 139.5, 135.13, 135.0, 128.2, 124.4, 122.1, 83.4, 63.4, 62.0, 28.5, 13.9. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{13}H_{14}NaO_4S, M + Na]^+$: 289.0501, Found: 289.0505. **Melting point:** 57.6 – 58.8 °C.



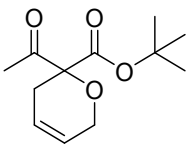
3i

Following the general procedure, **3i** was obtained as a light yellow oil (34 mg, 86% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 5.83 – 5.79 (m, 1H), 5.68 (d, *J* = 10.4 Hz, 1H), 4.42 (d, *J* = 16.2 Hz, 1H), 4.29 – 4.19 (m, 3H), 2.69 (d, *J* = 17.4 Hz, 1H), 2.43 (d, *J* = 17.4 Hz, 1H), 2.27 (s, 3H), 1.25 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 203.9, 168.6, 124.9, 121.9, 84.0, 63.4, 62.0, 27.9, 24.7, 14.0. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{10}H_{14}NaO_4, M + Na]^+$: 221.0782, Found: 221.0784.



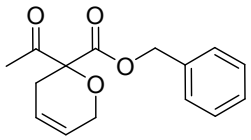
3j

Following the general procedure, **3j** was obtained as a light yellow oil (34 mg, 81% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 5.84 – 5.80 (m, 1H), 5.68 (d, *J* = 10.4 Hz, 1H), 5.09 – 5.06 (m , 1H), 4.43 (d, *J* = 16.9 Hz, 1H), 4.26 (d, *J* = 16.9 Hz, 1H), 2.67 (d, *J* = 17.4 Hz, 1H), 2.43 (d, *J* = 17.4 Hz, 1H), 2.27 (s, 3H), 1.24 (dd, *J* = 8.8, 6.3 Hz, 6H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 203.8, 168.1, 124.9, 121.9, 84.1, 69.7, 63.4, 27.8, 24.7, 21.5. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{11}H_{16}NaO_4, M + Na]^+$: 235.0938, Found: 235.0940.



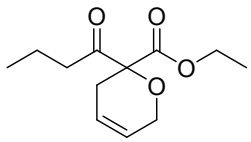
3k

Following the general procedure, **3k** was obtained as a light yellow oil (37 mg, 83% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 5.83 – 5.78 (m, 1H), 5.67 (d, *J* = 10.4 Hz, 1H), 4.42 (d, *J* = 16.9 Hz, 1H), 4.23 (d, *J* = 16.9 Hz, 1H), 2.60 (d, *J* = 19.0 Hz, 1H), 2.40 (d, *J* = 19.0 Hz, 1H), 2.25 (s, 3H), 1.44 (s, 9H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 204.0, 167.6, 124.8, 122.0, 84.2, 82.8, 63.4, 27.7, 24.7. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{12}H_{18}NaO_4, M + Na]^+$: 249.1095, Found: 249.1097.



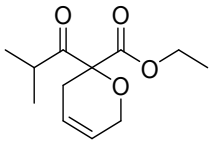
3l

Following the above method, **3l** was obtained as a light yellow oil (41 mg, 78% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.37 – 7.31 (m, 5H), 5.83 – 5.80 (m, 1H), 5.67 (d, *J* = 10.3 Hz, 1H), 5.20 (q, *J* = 12.3 Hz, 2H), 4.40 (d, *J* = 16.9 Hz, 1H), 4.26 (d, *J* = 16.9Hz, 1H), 2.72 (d, *J* = 17.4 Hz, 1H), 2.45 (d, *J* = 17.4 Hz, 1H), 2.24 (s, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 203.8, 168.5, 135.1, 128.6, 128.4, 128.1, 125.0, 121.8, 84.2, 67.5, 63.5, 28.0, 24.8. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{15}H_{16}NaO_4, M + Na]^+$: 283.0938, Found: 283.0940.



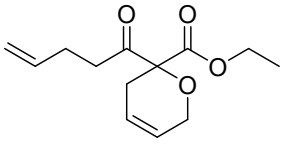
3m

Following the general procedure, **3m** was obtained as a light yellow oil (38 mg, 85% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 5.83 – 5.80 (m, 1H), 5.68 (d, *J* = 10.2 Hz, 1H), 4.41 (d, *J* = 16.9 Hz, 1H), 4.28 – 4.20 (m, 3H), 2.71 – 2.62 (m, 3H), 2.42 (d, *J* = 17.4 Hz, 1H), 1.61 – 1.57 (m, 2H), 1.25 (t, *J* = 7.1Hz, 3H), 0.88 (t, *J* = 7.4 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 205.8, 168.7, 124.9, 122.0, 84.1, 63.4, 61.9, 38.60, 28.1, 16.6, 14.0, 13.5. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{12}H_{18}NaO_4, M+Na]^+$: 249.1094, Found: 249.1097.



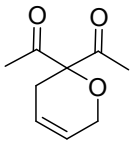
3n

Following the general procedure, **3n** was obtained as a light yellow oil (36 mg, 80% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 5.83 – 5.79 (m, 1H), 5.69 (d, *J* = 10.4 Hz, 1H), 4.43 (d, *J* = 17.0 Hz, 1H), 4.28 (d, *J* = 17.0 Hz, 1H), 4.21 (q, *J* = 7.1 Hz, 2H), 3.32 (dt, *J* = 13.6, 6.8 Hz, 1H), 2.72 (d, *J* = 17.5 Hz, 1H), 2.40 (d, *J* = 17.5 Hz, 1H), 1.25 (t, *J* = 7.1 Hz, 3H), 1.07 (dd, *J* = 6.7, 4.1 Hz, 6H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 210.2, 168.8, 125.0, 121.9, 84.1, 63.5, 61.8, 34.9, 28.6, 19.3, 19.0, 14.1. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{12}H_{18}NaO_4, M + Na]^+$: 249.1094, Found: 249.1097.



3o

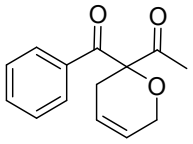
Following the general procedure, **3o** was obtained as a light yellow oil (40 mg, 83% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 5.83 – 5.77 (m, 2H), 5.69 (d, *J* = 10.4 Hz, 1H), 5.03 (dd, *J* = 17.1, 1.5 Hz, 1H), 4.96 (dd, *J* = 10.2, 1.0 Hz, 1H), 4.42 (d, *J* = 16.9 Hz, 1H), 4.29 – 4.19 (m, 3H), 2.79 (q, *J* = 7.2 Hz, 2H), 2.71 (d, *J* = 16.1 Hz, 1H), 2.42 (d, *J* = 16.1 Hz, 1H), 2.31 (q, *J* = 7.2 Hz, 2H), 1.26 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 205.1, 168.6, 136.8, 124.9, 121.9, 115.3, 84.1, 63.4, 62.0, 36.0, 28.1, 27.1, 14.1. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{13}H_{18}NaO_4, M + Na]^+$: 261.1094, Found: 261.1097.



3p

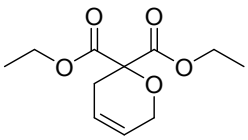
Following the general procedure, **3p** was obtained as a light yellow oil (23 mg, 70% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 5.82 (d, *J* = 10.3 Hz, 1H), 5.68 (d, *J* = 10.3 Hz, 1H), 4.31 (s, 2H), 2.52 (s, 2H), 2.22 (s, 6H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 204.9,

125.2, 121.7, 89.3, 63.2, 27.1, 25.2. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_9H_{12}NaO_3, M + Na]^+$: 191.0677, Found: 191.0678.



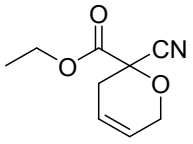
3q

Following the general procedure, **3q** was obtained as a light yellow oil (34 mg, 73% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 8.08 (d, *J* = 7.7 Hz, 2H), 7.56 (t, *J* = 7.4 Hz, 1H), 7.43 (t, *J* = 7.7 Hz, 2H), 5.91 – 5.87 (m, 1H), 5.66 (d, *J* = 10.4 Hz, 1H), 4.31 (d, *J* = 17.1 Hz, 1H), 4.04 (d, *J* = 17.1 Hz, 1H), 2.97 (d, *J* = 17.2 Hz, 1H), 2.36 (d, *J* = 17.2 Hz, 1H), 2.32 (s, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 204.8, 195.5, 134.3, 133.6, 129.5, 128.5, 124.5, 122.3, 89.2, 63.1, 28.0, 24.8. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{14}H_{14}NaO_3, M + Na]^+$: 253.0834, Found: 253.0835.



3r

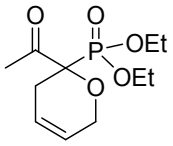
Following the general procedure, **3r** was obtained as a light yellow oil (36 mg, 79% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 5.83 – 5.80 (m, 1H), 5.71 – 5.68 (m, 1H), 4.38 – 4.37 (m, 2H), 4.25 (q, *J* = 7.1 Hz, 4H), 2.67 (d, *J* = 2.7 Hz, 2H), 1.27 (t, *J* = 7.1 Hz, 6H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 168.2, 124.8, 121.6, 79.2, 63.7, 62.1, 29.0, 14.0. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{11}H_{16}NaO_5, M + Na]^+$: 251.0887, Found: 251.0889.



3s

Following the general procedure, **3s** was obtained as a light yellow oil (29 mg, 81% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 5.89 – 5.81 (m, 2H), 4.48 (s, 2H), 4.35 (q, *J* = 7.1 Hz, 2H), 2.72 (d, *J* = 17.1 Hz, 1H), 2.57 (d, *J* = 17.1 Hz, 1H), 1.35 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 165.2, 125.5, 119.8, 115.3, 71.3, 64.1, 63.5,

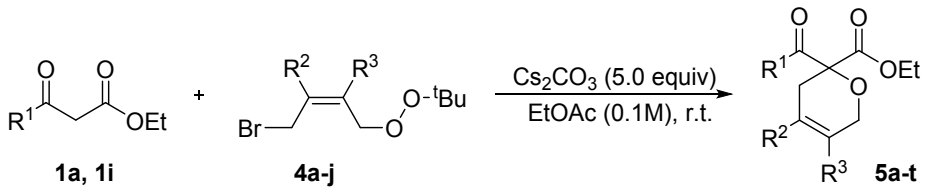
32.1, 13.9. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_9H_{11}NNaO_3, M + Na]^+$: 204.0630, Found: 204.0631.



3t

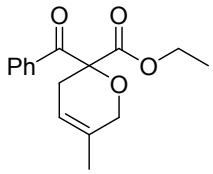
Following the general procedure, **3t** was obtained as a light yellow oil (39 mg, 75% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 5.85 – 5.81 (m, 1H), 5.69 (d, *J* = 10.5 Hz, 1H), 4.36 (s, 2H), 4.23 – 4.18 (m, 4H), 2.80 (d, *J* = 17.3 Hz, 1H), 2.69 (d, *J* = 12.3 Hz, 1H), 2.36 (s, 3H), 1.33 (td, *J* = 7.0, 2.1 Hz, 6H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 205.7, 125.2, 121.70, 83.9, 82.3, 63.9, 63.7, 63.3, 26.6, 26.3, 16.4. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{11}H_{19}NaO_5P, M + Na]^+$: 285.0858, Found: 285.0862.

5. General procedure for the annulations of peroxides 4a-j with 1a and 1i



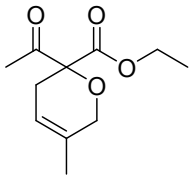
1a, 1i **4a-j** **5a-t**

To a solution of *β*-keto ester **1a** or **1i** (0.24 mmol, 1.2 equiv) and peroxides **4a-j** (0.2 mmol, 1.0 equiv) in EtOAc (2 mL) was added Cs_2CO_3 solid (1.0 mmol, 5.0 equiv), and the resulting solution was vigorously stirred at room temperature for 6-12 h. After completion of the reaction as monitored by the TLC, the reaction mixture was diluted with ethyl acetate (5 mL) and water (5 mL). The ethyl acetate layer was separated and the aqueous layer was extracted with EtOAc (5 mL x 3). The combined extracts were washed with brine (5 mL), dried over Na_2SO_4, filtered, and concentrated. The residue was purified by flash column chromatography on silica gel (petroleum ether / EtOAc = 50:1 ~ 40:1) to afford the desired dihydropyrans products **5a-t** in 74-86% yields.



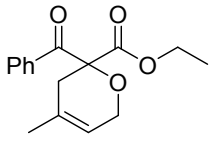
5a

Following the general procedure, **5a** was obtained as a light yellow oil (41 mg, 76% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 8.19 (d, *J* = 7.7 Hz, 2H), 7.55 (t, *J* = 7.2 Hz, 1H), 7.43 (t, *J* = 7.6 Hz, 2H), 5.56 (s, 1H), 4.27 (d, *J* = 16.3 Hz, 1H), 4.19 (dd, *J* = 14.1, 7.0 Hz, 2H), 3.90 (d, *J* = 16.3 Hz, 1H), 2.97 (d, *J* = 16.9 Hz, 1H), 2.49 (d, *J* = 16.9 Hz, 1H), 1.54 (s, 3H), 1.12 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 193.5, 170.1, 134.1, 133.5, 131.0, 129.6, 128.4, 116.4, 83.0, 66.3, 61.9, 28.9, 18.4, 13.9. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{16}H_{18}NaO_4, M + Na]^+$: 297.1093, Found: 297.1097.



5b

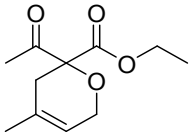
Following the general procedure, **5b** was obtained as a light yellow oil (31 mg, 74% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 5.49 (s, 1H), 4.28 – 4.20 (m, 3H), 4.09 (d, *J* = 16.3 Hz, 1H), 2.66 (d, *J* = 17.2 Hz, 1H), 2.41 (d, *J* = 17.2 Hz, 1H), 2.27 (s, 3H), 1.58 (s, 3H), 1.26 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 204.0, 168.7, 131.7, 116.1, 84.0, 66.4, 62.0, 27.9, 24.8, 18.4, 14.0. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{11}H_{16}NaO_4, M + Na]^+$: 235.0938, Found: 235.0940.



5c

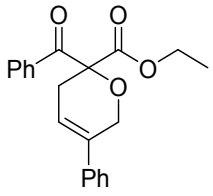
Following the general procedure, **5c** was obtained as a light yellow oil (42 mg, 77% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 8.18 (d, *J* = 7.7 Hz, 2H), 7.55 (t, *J* = 7.3 Hz, 1H), 7.41 (d, *J* = 7.6 Hz, 2H), 5.33 (s, 1H), 4.40 (d, *J* = 16.1 Hz, 1H), 4.21 – 4.18 (m, 2H), 4.01 (d, *J* = 16.1 Hz, 1H), 2.86 (d, *J* = 16.7 Hz, 1H), 2.40 (d, *J* = 16.7 Hz, 1H),

1.79 (s, 3H), 1.13 (t, J = 7.1 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 193.6, 170.0, 134.1, 133.5, 130.2, 129.5, 128.4, 117.5, 83.6, 63.5, 61.9, 33.5, 23.0, 13.9. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{16}H_{18}NaO_4, M + Na]^+$: 297.1093, Found: 297.1097.



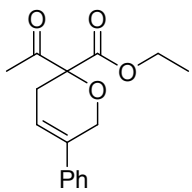
5d

Following the general procedure, **5d** was obtained as a light yellow oil (35 mg, 82% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 5.35 (s, 1H), 4.35 (d, J = 16.3 Hz, 1H), 4.28 – 4.15 (m, 3H), 2.54 (d, J = 16.9 Hz, 1H), 2.34 (d, J = 16.9 Hz, 1H), 2.27 (s, 3H), 1.73 (s, 3H), 1.25 (t, J = 7.1 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 204.2, 168.6, 129.9, 118.2, 84.6, 63.6, 61.9, 32.4, 24.8, 22.9, 14.0. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{11}H_{16}NaO_4, M + Na]^+$: 235.0938, Found: 235.0940.



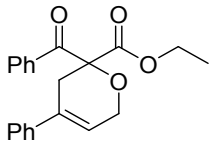
5e

Following the general procedure, **5e** was obtained as a light yellow oil (50 mg, 75% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 8.22 (d, J = 7.4 Hz, 2H), 7.56 (d, J = 7.4 Hz, 1H), 7.44 (t, J = 7.7 Hz, 2H), 7.29 – 7.22 (m, 5H), 6.22 (s, 1H), 4.85 (d, J = 16.2 Hz, 1H), 4.38 (d, J = 16.2 Hz, 1H), 4.21 (q, J = 6.7 Hz, 2H), 3.20 (d, J = 17.6 Hz, 1H), 2.70 (d, J = 17.6 Hz, 1H), 1.14 (t, J = 7.1 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 193.1, 169.9, 137.1, 134.0, 133.9, 133.6, 129.6, 128.5, 128.5, 127.7, 124.8, 118.9, 82.9, 64.5, 62.1, 29.3, 13.9. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{21}H_{20}NaO_4, M + Na]^+$: 359.1248, Found: 359.1253.



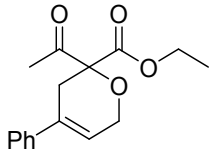
5f

Following the general procedure, **5f** was obtained as a light yellow oil (42 mg, 78% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.37 – 7.22 (m, 5H), 6.16 (s, 1H), 4.77 (d, *J* = 16.1 Hz, 1H), 4.65 (d, *J* = 16.1 Hz, 1H), 4.25 (q, *J* = 7.1 Hz, 2H), 2.90 (dd, *J* = 17.7, 2.1 Hz, 1H), 2.63 (dd, *J* = 17.7, 2.1 Hz, 1H), 2.34 (s, 3H), 1.27 (t, *J* = 7.2 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 203.8, 168.5, 137.1, 134.6, 128.5, 127.8, 124.9, 118.6, 83.9, 64.6, 62.1, 28.3, 24.9, 14.1. **HRMS (ESI-FT-ICR)** m/z Calcd for [$C_{16}H_{18}NaO_4$, M + Na]$^+$: 297.1093, Found: 297.1097.



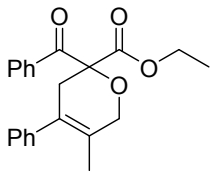
5g

Following the general procedure, **5g** was obtained as a light yellow oil (54 mg, 81% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 8.23 (d, *J* = 7.5 Hz,2H), 7.57 (t, *J* = 7.4 Hz, 1H), 7.45 (t, *J* = 7.8 Hz, 4H), 7.37 (t, *J* = 7.5 Hz, 2H), 7.29 (t, *J* = 7.2 Hz, 1H), 5.97 (s, 1H), 4.69 (dd, *J* = 17.4, 1.8 Hz, 1H), 4.29 – 4.20 (m, 3H), 3.40 (d, *J* = 16.7 Hz, 1H), 2.89 (dd, *J* = 16.7, 1.7 Hz, 1H), 1.15 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 193.3, 169.8, 139.7, 134.0, 133.6, 132.9, 129.6, 128.4, 127.6, 125.2, 124.8, 120.0, 83.9, 64.0, 62.1, 31.2, 13.9. **HRMS (ESI-FT-ICR)** m/z Calcd for [$C_{21}H_{20}NaO_4$, M + Na]$^+$: 359.1248, Found: 359.1253.



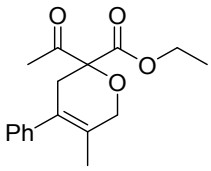
5h

Following the general procedure, **5h** was obtained as a light yellow oil (44 mg, 80% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.41 – 7.33 (m, 4H), 7.29 (d, *J* = 7.2 Hz, 1H), 6.00 (s, 1H), 4.63 (dd, *J* = 17.5, 2.7 Hz, 1H), 4.50 (d, *J* = 17.5 Hz, 1H), 4.28 – 4.19 (m, 2H), 3.15 (d, *J* = 16.8 Hz, 1H), 2.77 (dd, *J* = 16.8, 2.4 Hz, 1H), 2.34 (s, 3H), 1.25 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 203.9, 168.4, 139.6, 132.7, 128.5, 127.7, 125.10, 120.7, 84.9, 64.1, 62.1, 30.3, 25.0, 14.1. **HRMS (ESI-FT-ICR)** m/z Calcd for [$C_{16}H_{18}NaO_4$, M + Na]$^+$: 297.1093, Found: 297.1097.



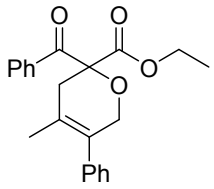
5i

Following the general procedure, **5i** was obtained as a light yellow oil (55 mg, 79% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 8.24 (d, *J* = 7.5 Hz, 2H), 7.58 (t, *J* = 7.3 Hz, 1H), 7.46 (t, *J* = 7.6 Hz, 2H), 7.37 (t, *J* = 7.4 Hz, 2H), 7.31 (d, *J* = 7.2 Hz, 2H), 7.27 (d, *J* = 5.2 Hz, 1H), 4.38 (d, *J* = 16.5 Hz, 1H), 4.22 – 3.98 (m, 2H), 4.00 (d, *J* = 16.5 Hz, 1H), 3.24 (d, *J* = 16.7 Hz, 1H), 2.73 (d, *J* = 16.7 Hz, 1H), 1.46 (s, 3H), 1.13 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 193.5, 169.8, 140.8, 134.0, 133.6, 129.5, 128.5, 128.4, 128.2, 128.1, 126.9, 125.7, 84.0, 67.0, 62.0, 34.5, 15.0, 13.9. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{22}H_{22}NaO_4, M + Na]^+$: 373.1403, Found: 373.1410.



5j

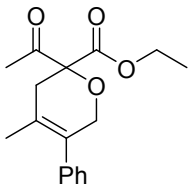
Following the general procedure, **5j** was obtained as a light yellow oil (47 mg, 81% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.35 (t, *J* = 7.4 Hz, 2H), 7.27 (d, *J* = 6.3 Hz, 1H), 7.22 – 7.20 (m, 2H), 4.36 (d, *J* = 16.8 Hz, 1H), 4.32 – 4.21 (m, 3H), 2.94 (d, *J* = 16.8 Hz, 1H), 2.67 (dd, *J* = 16.8, 2.0 Hz, 1H), 2.32 (s, 3H), 1.51 (s, 3H), 1.29 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 203.9, 168.6, 140.7, 128.7, 128.2, 127.8, 126.9, 126.5, 85.2, 67.2, 62.0, 33.4, 24.9, 15.0, 14.1. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{17}H_{20}NaO_4, M + Na]^+$: 311.1249, Found: 311.1253.



5k

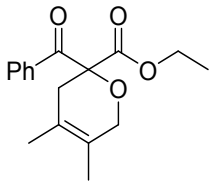
Following the general procedure, **5k** was obtained as a light yellow oil (54 mg, 77% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 8.21 (d, *J* = 7.6 Hz, 2H), 7.55 (t, *J* = 7.4 Hz,

1H), 7.44 (t, *J* = 7.6 Hz, 2H), 7.27 (dt, *J* = 18.6, 7.1 Hz, 3H), 7.06 (d, *J* = 7.1 Hz, 2H), 4.52 (d, *J* = 16.2 Hz, 1H), 4.28 – 4.20 (m, 2H), 4.12 (d, *J* = 16.2, 1H), 3.03 (d, *J* = 16.9 Hz, 1H), 2.57 (d, *J* = 16.9 Hz, 1H), 1.71 (s, 3H), 1.16 (t, *J* = 7.0 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 193.5, 169.9, 137.8, 134.1, 133.5, 129.5, 129.2, 128.7, 128.5, 128.2, 127.1, 125.6, 83.8, 66.8, 62.0, 34.1, 19.6, 13.9. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{22}H_{22}NaO_4, M + Na]^+$: 373.1403, Found: 373.1410.



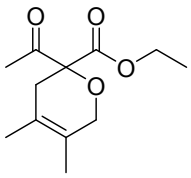
5l

Following the general procedure, **5l** was obtained as a light yellow oil (46 mg, 80% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.33 (t, *J* = 7.2 Hz, 2H), 7.28 (s, 1H), 7.10 – 7.08 (m, 2H), 4.47 (dd, *J* = 16.2, 2.1 Hz, 1H), 4.41 – 4.33 (m, 1H), 4.28 (qd, *J* = 7.1, 2.4 Hz, 2H), 2.70 (d, *J* = 17.0 Hz, 1H), 2.52 (d, *J* = 17.0 Hz, 1H), 2.33 (s, 3H), 1.65 (s, 3H), 1.29 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 204.1, 168.6, 137.8, 129.9, 128.6, 128.3, 127.2, 125.3, 84.9, 67.0, 62.0, 33.1, 24.9, 19.7, 14.2. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{17}H_{20}NaO_4, M + Na]^+$: 311.1249, Found: 311.1253.



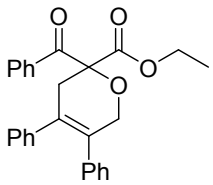
5m

Following the general procedure, **5m** was obtained as a light yellow oil (47 mg, 82% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 8.18 (d, *J* = 7.8 Hz, 2H), 7.54 (t, *J* = 7.3 Hz, 1H), 7.42 (t, *J* = 7.7 Hz, 2H), 4.22 – 4.15 (m, 3H), 3.84 (d, *J* = 15.9 Hz, 1H), 2.85 (d, *J* = 16.6 Hz, 1H), 2.41 (d, *J* = 16.6 Hz, 1H), 1.73 (s, 3H), 1.46 (s, 3H), 1.12 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 193.8, 170.0, 134.1, 133.4, 129.5, 128.4, 122.4, 122.0, 84.0, 66.8, 61.9, 34.1, 18.3, 13.9, 13.7. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{17}H_{20}NaO_4, M + Na]^+$: 311.1250, Found: 311.1253.



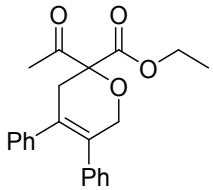
5n

Following the general procedure, **5n** was obtained as a yellow oil (38 mg, 85% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 4.20 (dt, *J* = 17.0, 8.5 Hz, 3H), 4.03 (d, *J* = 15.8 Hz, 1H), 2.52 (d, *J* = 16.9 Hz, 1H), 2.35 (d, *J* = 16.9 Hz, 1H), 2.27 (s, 3H), 1.67 (s, 3H), 1.50 (s, 3H), 1.25 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 204.3, 168.7, 123.0, 121.8, 85.0, 67.0, 61.9, 33.1, 24.8, 18.3, 14.1, 13.7. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{12}H_{18}NaO_4, M + Na]^+$: 249.1094, Found: 249.1097.



5o

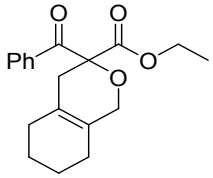
Following the general procedure, **5o** was obtained as a light yellow solid (66 mg, 80% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 8.27 (d, *J* = 7.6 Hz, 2H), 7.58 (t, *J* = 7.4 Hz, 1H), 7.46 (t, *J* = 7.7 Hz, 2H), 7.18 – 7.09 (m, 8H), 6.94 – 6.92 (m, 2H), 4.78 (d, *J* = 16.9 Hz, 1H), 4.28 – 4.22 (m, 3H), 3.47 (d, *J* = 17.1 Hz, 1H), 2.89 (d, *J* = 17.1 Hz, 1H), 1.17 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 193.3, 169.8, 140.5, 137.4, 134.1, 133.7, 131.5, 130.7, 129.5, 129.0, 128.9, 128.6, 128.0, 127.9, 127.0, 126.8, 83.9, 66.9, 62.2, 34.6, 14.0. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{27}H_{24}NaO_4$, M + Na]$^+$: 435.1559, Found: 435.1566. **Melting point:** 102.1 – 103.1 °C.



5p

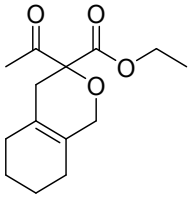
Following the general procedure, **5p** was obtained as a light yellow oil (55 mg, 78% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.15 – 7.06 (m, 8H), 6.95 (dd, *J* = 6.8, 2.7 Hz, 2H), 4.63 (d, *J* = 2.0 Hz, 2H), 4.35 – 4.27 (m, 2H), 3.15 (d, *J* = 17.2 Hz, 1H), 2.84 (d,

J = 17.2 Hz, 1H), 2.38 (s, 3H), 1.31 (t, J = 7.1 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 203.9, 168.4, 140.3, 137.4, 132.3, 130.3, 129.0, 128.8, 128.1, 127.9, 127.1, 126.8, 85.0, 67.1, 62.2, 33.5, 25.0, 14.2. **HRMS (ESI-FT-ICR)** m/z Calcd for [$C_{22}H_{22}NaO_4$, M + Na]$^+$: 373.1403, Found: 373.1410.



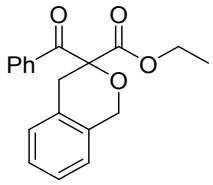
5q

Following the general procedure, **5q** was obtained as a light yellow oil (54 mg, 86% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 8.18 (d, J = 7.7 Hz, 2H), 7.54 (t, J = 7.4 Hz, 1H), 7.42 (t, J = 7.7 Hz, 2H), 4.24 – 4.14 (m, 3H), 3.83 (d, J = 15.7 Hz, 1H), 2.81 (d, J = 16.4 Hz, 1H), 2.36 (d, J = 16.4 Hz, 1H), 1.98 (dd, J = 43.8, 16.4 Hz, 2H), 1.63 (dt, J = 13.9, 7.3 Hz, 6H), 1.12 (t, J = 7.1 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 193.8, 170.1, 134.2, 133.4, 129.6, 128.4, 125.1, 124.3, 84.0, 66.1, 61.9, 33.1, 29.2, 24.7, 22.6, 22.2, 13.9. **HRMS (ESI-FT-ICR)** m/z Calcd for [$C_{19}H_{22}NaO_4$, M + Na]$^+$: 337.1405, Found: 337.1410.



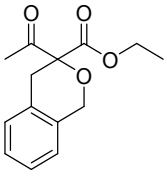
5r

Following the general procedure, **5r** was obtained as a light yellow oil (42 mg, 84% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 4.26 – 4.15 (m, 3H), 4.03 (d, J = 15.7 Hz, 1H), 2.48 (d, J = 16.6 Hz, 1H), 2.31 (d, J = 24.4 Hz, 4H), 1.92 (s, 2H), 1.73 (s, 2H), 1.63 – 1.53 (m, 4H), 1.26 (t, J = 7.0 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 204.4, 168.7, 125.7, 124.1, 85.0, 66.3, 61.9, 32.1, 29.2, 24.9, 24.7, 22.6, 22.2, 14.1. **HRMS (ESI-FT-ICR)** m/z Calcd for [$C_{14}H_{20}NaO_4$, M + Na]$^+$: 275.1250, Found: 275.1253.



5s

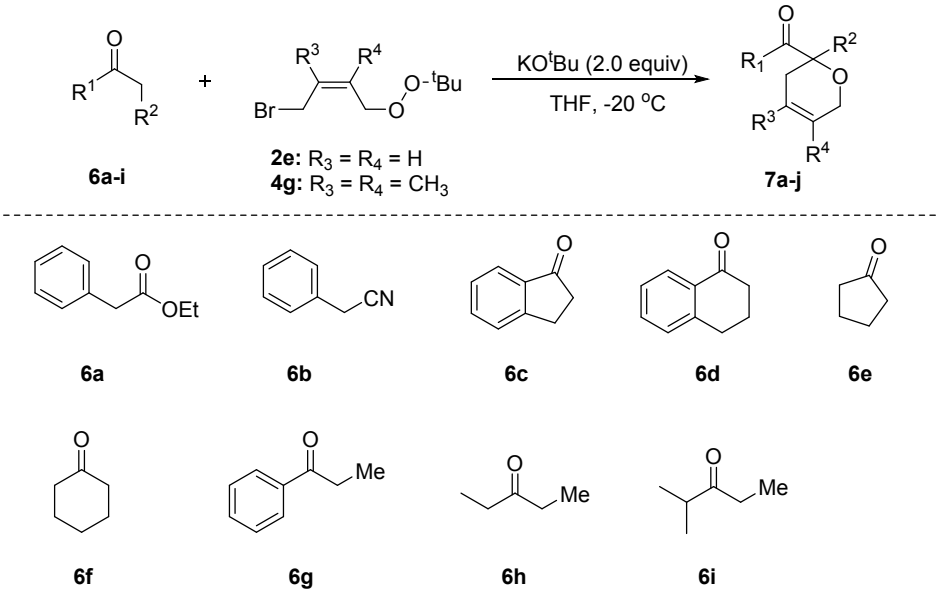
Following the general procedure, **5s** was obtained as a light yellow oil (51 mg, 83% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 8.19 (d, *J* = 7.6 Hz, 2H), 7.57 (t, *J* = 7.4 Hz, 1H), 7.44 (t, *J* = 7.7 Hz, 2H), 7.23 – 7.15 (m, 3H), 6.95 (d, *J* = 7.4 Hz, 1H), 5.09 (d, *J* = 15.1 Hz, 1H), 4.73 (d, *J* = 15.1 Hz, 1H), 4.18 (qd, *J* = 7.0, 1.9 Hz, 2H), 3.69 (d, *J* = 16.1 Hz, 1H), 3.22 (d, *J* = 16.1 Hz, 1H), 1.10 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 193.1, 170.1, 134.0, 133.6, 132.5, 130.9, 129.7, 128.5, 127.1, 126.4, 123.9, 83.8, 65.5, 62.1, 32.6, 13.9. **HRMS (ESI-FT-ICR)** m/z Calcd for [$C_{19}H_{18}NaO_4$, M + Na]$^+$: 333.1093, Found: 333.1097.



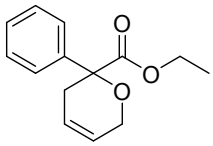
5t

Following the general procedure, **5t** was obtained as a light yellow oil (40 mg, 81% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.19 (t, *J* = 4.4 Hz, 3H), 7.02 – 7.00 (m, 1H), 5.02 (d, *J* = 15.0 Hz, 1H), 4.90 (d, *J* = 15.0 Hz, 1H), 4.18 (q, *J* = 7.1 Hz, 2H), 3.35 (d, *J* = 16.2 Hz, 1H), 3.17 (d, *J* = 16.2 Hz, 1H), 2.31 (s, 3H), 1.20 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 204.1, 168.6, 132.9, 130.5, 128.6, 127.1, 126.6, 124.1, 84.9, 65.5, 62.1, 31.6, 25.2, 14.0. **HRMS (ESI-FT-ICR)** m/z Calcd for [$C_{14}H_{16}NaO_4$, M + Na]$^+$: 271.0937, Found: 271.0940.

6. General procedure for the annulations of simple ester and ketones



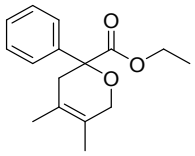
To a solution of esters**,** nitrile or ketones **6a-i** (0.24 mmol, 1.2 equiv) and peroxide **2e** or **4g** (0.2 mmol, 1.0 equiv) in dry THF (2 mL) was dropwise added ^{t}BuOK (0.4 mL, 0.4 mmol, 2.0 equiv, 1.0 M solution in THF) at -20 °C under N_2 atmosphere. The resulting solution was stirred at -20 °C for 5 ~ 10 minutes. After completion of the reaction as monitored by the TLC, the reaction mixture was quenched with water (5 mL) and extracted with EtOAc (5 mL x 3). The combined extracts were washed with brine (5 mL), dried over Na_2SO_4, filtered, and concentrated. The residue was purified by flash column chromatography on silica gel (petroleum ether / EtOAc = 150:1 ~ 50:1) to afford the desired dihydropyrans products **7a-h** in 60-70% yields.



7a

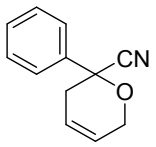
Following the general procedure, **7a** was obtained as a light yellow oil (28 mg, 61% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.56 – 7.53 (m, 2H), 7.35 (t, *J* = 7.4 Hz, 2H), 7.30 (d, *J* = 7.1 Hz, 1H), 5.90 (ddd, *J* = 10.0, 4.9, 2.5 Hz, 1H), 5.73 (d, *J* = 10.2 Hz, 1H), 4.52 (d, *J* = 17.1 Hz, 1H), 4.28 (d, *J* = 17.1 Hz, 1H), 4.17 (qd, *J* = 7.1, 1.2 Hz, 2H), 3.07 (ddd, *J* = 17.2, 3.2, 1.6 Hz, 1H), 2.58 – 2.52 (m, 1H), 1.19 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 172.1, 140.4, 128.3, 127.9, 125.7, 125.1, 122.6,

78.6, 63.4, 61.4, 32.4, 14.0. **HRMS (ESI-FT-ICR)** m/z Calcd for [$C_{14}H_{16}NaO_3$, M + Na]$^+$: 255.0989, Found:. 255.0991.



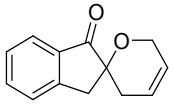
7b

Following the general procedure, **7b** was obtained as a light yellow oil (34 mg, 66% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.52 (d, *J* = 7.7 Hz, 2H), 7.34 (t, *J* = 7.4 Hz, 2H), 7.28 (d, *J* = 7.2 Hz, 1H), 4.29 (d, *J* = 15.8 Hz, 1H), 4.15 (q, *J* = 7.1 Hz, 2H), 4.05 (d, *J* = 15.8 Hz, 1H), 2.89 (d, *J* = 16.5 Hz, 1H), 2.44 (d, *J* = 16.5 Hz, 1H), 1.72 (s, 3H), 1.51 (s, 3H), 1.18 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 172.2, 140.5, 128.3, 127.7, 125.1, 123.6, 122.3, 79.3, 66.9, 61.3, 37.9, 18.5, 14.1, 13.6. **HRMS (ESI-FT-ICR)** m/z Calcd for [$C_{16}H_{20}NaO_3$, M + Na]$^+$: 283.1297, Found: 283.1304.



7c

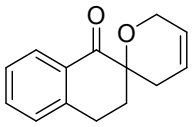
Following the general procedure, **7c** was obtained as a light yellow oil (25 mg, 68% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.59 (d, *J* = 7.4 Hz, 2H), 7.41 (dq, *J* = 10.1, 6.9 Hz, 3H), 5.97 – 5.89 (m, 2H), 4.67 (d, *J* = 17.1 Hz, 1H), 4.52 (d, *J* = 17.1 Hz, 1H), 2.63 (d, *J* = 2.3 Hz, 2H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 139.0, 129.0, 128.8, 125.8, 124.8, 121.2, 118.5, 73.1, 64.6, 37.3. **HRMS (ESI-FT-ICR)** m/z Calcd for [$C_{11}H_{16}NaO_5$, M + Na]$^+$: 208.0735, Found: 208.0732.



7d

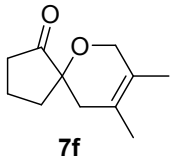
Following a slight modification procedure described above, reaction was carried out at -40 ^{o}C. Compound **7d** was obtained as a light yellow oil (25 mg, 63% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.79 (d, *J* = 7.6 Hz, 1H), 7.61 (t, *J* = 7.4 Hz, 1H), 7.39 (dd, *J* = 15.1, 7.6 Hz, 2H), 5.89 (ddd, *J* = 22.5, 15.5, 6.7 Hz, 2H), 4.46 (d, *J* = 17.2 Hz,

1H), 4.31 (d, *J* = 17.2 Hz, 1H), 3.30 (d, *J* = 16.7 Hz, 1H), 3.13 (d, *J* = 16.7 Hz, 1H), 2.53 (d, *J* = 17.3 Hz, 1H), 1.95 (d, *J* = 17.3 Hz, 1H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 204.0, 150.8, 135.6, 134.45, 127.9, 126.7, 125.7, 124.8, 122.3, 79.0, 63.0, 38.6, 31.5. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{13}H_{12}NaO_2, M + Na]^+$: 223.0728 , Found:.223.0729.



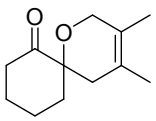
7e

Following a slight modification procedure described above, reaction was carried out at -40 °C. Compound **7e** was obtained as a light yellow solid (26 mg, 61% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 8.00 (d, *J* = 7.8 Hz, 1H), 7.46 (dd, *J* = 10.7, 4.2 Hz, 1H), 7.30 (t, *J* = 7.5 Hz, 1H), 7.22 (d, *J* = 7.7 Hz, 1H), 5.88 – 5.85 (m, 1H), 5.81 – 5.68 (m, 1H), 4.22 (d, *J* = 2.5 Hz, 2H), 3.28 (ddd, *J* = 16.9, 8.9, 5.2 Hz, 1H), 2.87 (dt, *J* = 17.2, 5.3 Hz, 1H), 2.59 (dd, *J* = 17.6, 1.8 Hz, 1H), 2.34 (dt, *J* = 13.9, 5.3 Hz, 1H), 2.18 (ddd, *J* = 14.1, 9.0, 5.2 Hz, 1H), 2.06 (d, *J* = 17.6 Hz, 1H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 196.6, 143.2, 133.3, 131.4, 128.5, 128.1, 126.6, 124.7, 122.11, 74.1, 62.9, 33.7, 29.3, 25.1. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{14}H_{14}NaO_2, M + Na]^+$: 237.0878, Found: 237.0886. **Melting point:** 90.2 – 91.4 °C.



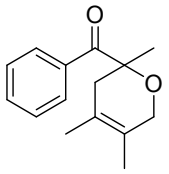
7f

Following a slight modification procedure described above, reaction was carried out at -40 °C. Compound **7f** was obtained as a light yellow oil (25 mg, 66% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 3.97 (q, *J* = 15.7 Hz, 2H), 2.47 – 2.33 (m, 1H), 2.25 (ddd, *J* = 19.5, 8.6, 5.4 Hz, 1H), 2.05 (ddd, *J* = 19.5, 15.3, 6.1 Hz, 3H), 1.95 – 1.75 (m, 3H), 1.66 (s, 3H), 1.54 (s, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 216.0, 123.4, 121.1, 78.4, 66.1, 35.7, 34.5, 33.7, 18.6, 17.5, 13.9. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{11}H_{16}NaO_2, M + Na]^+$: 203.1035, Found: 203.1042.



7g

Following the general procedure, **7g** was obtained as a light yellow oil (25 mg, 65% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 3.96 (d, *J* = 15.8 Hz, 1H), 3.86 (d, *J* = 15.8 Hz, 1H), 2.81 (d, *J* = 5.4 Hz, 1H), 2.35 (d, *J* = 17.8 Hz, 1H), 2.25 (dd, *J* = 8.3, 4.0 Hz, 1H), 2.04 (dd, *J* = 17.4, 7.0 Hz, 3H), 1.77 (d, *J* = 17.8 Hz, 1H), 1.66 – 1.55 (m, 6H), 1.48 (s, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 212.7, 122.2, 122.1, 79.3, 66.1, 39.6, 38.9, 35.0, 28.8, 20.7, 18.4, 13.8. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{12}H_{18}NaO_2$, M + Na$]^+$: 217.1194, Found: 217.1199.



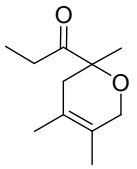
7h

Following the general procedure, **7h** was obtained as a light yellow oil (32 mg, 70% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 8.26 (d, *J* = 8.2 Hz, 2H), 7.53 (t, *J* = 6.8 Hz, 1H), 7.42 (t, *J* = 7.3 Hz, 2H), 3.95 (d, *J* = 16.1 Hz, 1H), 3.84 (d, *J* = 16.1 Hz, 1H), 2.76 (d, *J* = 16.6 Hz, 1H), 2.02 (d, *J* = 16.6 Hz, 1H), 1.67 (s, 3H), 1.58 (s, 3H), 1.42 (s, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 202.5, 134.9, 132.8, 129.6, 128.3, 123.1, 122.2, 81.6, 66.9, 38.2, 25.8, 18.5, 13.6. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{15}H_{18}NaO_2$, M + Na$]^+$: 253.1198, Found: 253.1199.

Note: Compounds **7i** and **7j** were prepared by a slight modification procedure as following:

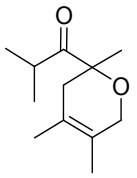
Commercial available 1.0 M ^{t}BuOK in THF(1.0 mmol, 1.0 mL) was added into a flame dried round bottom flask with a magnetic stir bar. The base was dissolved into dry THF (5 mL) and stirred for 10 minutes. To a solution of ketones **6h** or **6i** (0.3 mmol, 1.5 equiv) in dry THF (3 mL) was dropwise added ^{t}BuOK (3.0 mL, 0.6 mmol, 3.0 equiv) at -20 ^{o}C and the reaction stirred for 15 minutes, whereupon a solution of **4g** (0.2 mmol, 50 mg, 1.0equiv) in THF (1 mL, 0.2 M) was added dropwise slowly. After completion of the reaction as monitored by the TLC, the reaction mixture was

quenched with water (5 mL) and extracted with EtOAc (5 mL x 3). The combined extracts were washed with brine (5 mL), dried over Na_2SO_4, filtered, and concentrated. The residue was purified by flash column chromatography on silica gel (petroleum ether / EtOAc = 100:1) to afford the desired dihydropyrans products **7i-j** in 60-64% yields.



7i

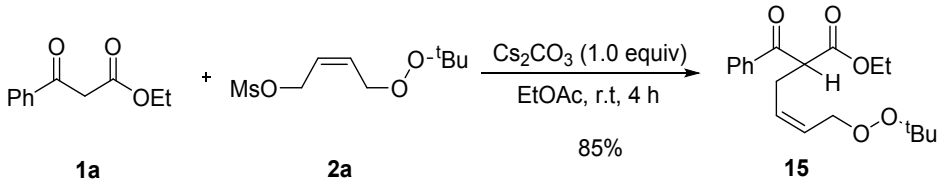
Following the above procedure, compound **7i** was obtained as a light yellow oil (23 mg, 64% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 4.04 – 3.95 (m, 2H), 2.61 (q, *J* = 7.1 Hz, 2H), 2.36 (d, *J* = 16.8 Hz, 1H), 1.90 (d, *J* = 16.8 Hz, 1H), 1.64 (s, 3H), 1.51 (s, 3H), 1.29 (s, 3H), 1.03 (t, *J* = 7.2 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 214.5, 122.8, 122.2, 79.7, 66.0, 36.7, 29.2, 22.3, 18.5, 13.7, 7.7. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{11}H_{18}NaO_2, M + Na]^+$: 205.1192, Found: 205.1199.



7j

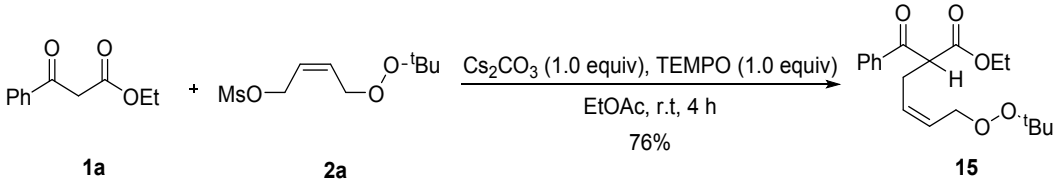
Following the above procedure, compound **7j** was obtained as a light yellow oil (22 mg, 60% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 4.03 (s, 2H), 3.27 (dt, *J* = 13.5, 6.8 Hz, 1H), 2.32 (d, *J* = 16.8 Hz, 1H), 1.89 (d, *J* = 16.8 Hz, 1H), 1.64 (s, 3H), 1.52 (s, 3H), 1.31 (s, 3H), 1.05 (dd, *J* = 6.6, 3.4 Hz, 6H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 218.1, 123.0, 122.1, 79.8, 65.9, 37.0, 33.8, 21.8, 19.8, 19.2, 18.5, 13.7. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{12}H_{20}NaO_2, M + Na]^+$: 219.1351, Found: 219.1355.

7. Control experiments and proposed mechanism for the [5+1] annulations



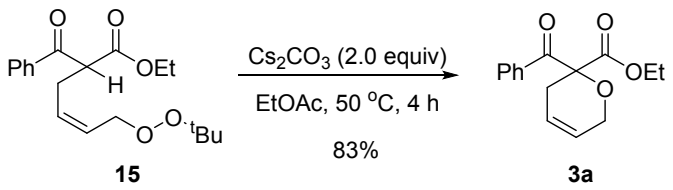
1a **2a** **15**

To a solution of **1a** (19 mg, 0.1 mmol, 1.0 equiv) and peroxide **2a** (24 mg, 0.1 mmol, 1.0 equiv) in ethyl acetate (1 mL) was added powder Cs_2CO_3 solid (33 mg, 0.1 mmol, 1.0 equiv) at room temperature. The resulting solution was vigorously stirred at room temperature for 4 h until peroxide **2a** was completely consumed (monitored by the TLC). The reaction mixture was diluted with ethyl acetate (5 mL) and water (5 mL). The ethyl acetate layer was separated and the aqueous layer was extracted with ethyl acetate (5 mL x 3). The combined extracts were washed with brine (5 mL), dried over Na_2SO_4, and concentrated. The residue was purified by flash column chromatography on silica gel (petroleum ether / EtOAc = 50:1) to afford the C-alkylation intermediate **15** (28 mg) as a light yellow oil in 85% yield. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.98 (d, *J* = 7.5 Hz, 2H), 7.57 (dd, *J* = 10.5, 4.2 Hz, 1H), 7.46 (t, *J* = 7.5 Hz, 2H), 5.64 (t, *J* = 4.2 Hz, 2H), 4.51 (d, *J* = 5.1 Hz, 2H), 4.36 (t, *J* = 7.3 Hz, 1H), 4.12 (q, *J* = 7.1 Hz, 2H), 2.79 (dd, *J* = 12.4, 6.1 Hz, 2H), 1.23 (s, 9H), 1.18 – 1.13 (m, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 194.4, 169.2, 136.0, 133.5, 130.5, 128.7, 128.6, 126.6, 80.2, 70.2, 61.4, 54.0, 27.1, 26.3, 13.9. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{19}H_{26}NaO_5, M + Na]^+$: 357.1661, Found: 357.1672.

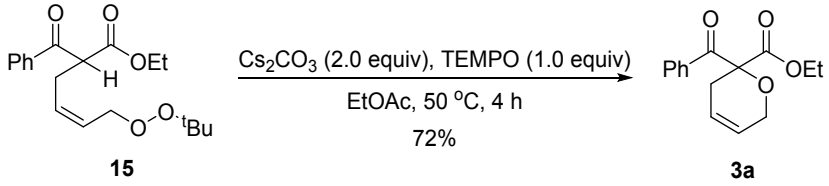


1a **2a** **15**

When 1.0 equiv of TEMPO was added to the reaction mixture of **1a** and **2a** under the same conditions as described above, the *C*-alkylation intermediate **15** was obtained in 76% yield.

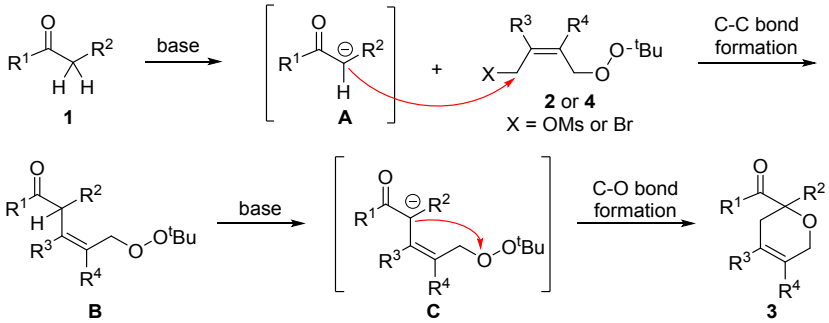


In another reaction flask, the above mentioned intermediate **15** (33 mg, 0.1 mmol, 1.0 equiv) was dissolved with ethyl acetate (1 mL) and powder Cs_2CO_3 solid (66 mg, 0.2 mmol, 2.0 equiv) was added to the solution. The reaction was vigorously stirred at 50 °C for 4 h until compound **15** was completely consumed (monitored by the TLC). After completion, the reaction mixture was diluted with ethyl acetate (5 mL) and water (5 mL). The ethyl acetate layer was separated and the aqueous layer was extracted with ethyl acetate (5 mL x 3). The combined extracts were washed with brine (5 mL), dried over Na_2SO_4, and concentrated. The residue was purified by flash column chromatography on silica gel (petroleum ether / EtOAc = 50:1) to afford the final product **3a** (22 mg) as a light yellow oil in 83% yield.



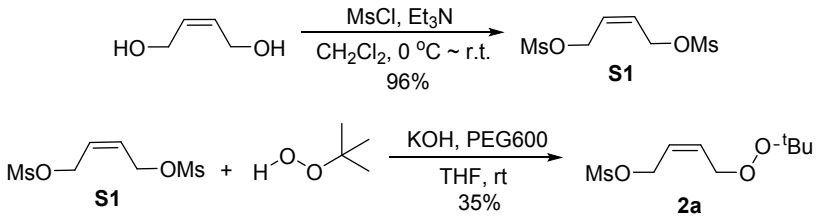
When 1.0 equiv of TEMPO was added to the reaction mixture of **15** under the same conditions as described above, the product **3a** was obtained in 72% yield.

The above results indicated that the C-C and C-O bonds in the tandem process were formed more likely via a nucleophilic substitution mechanism instead of a radical pathway. Thus a plausible mechanism of the [5+1] annulation reaction was proposed as following:



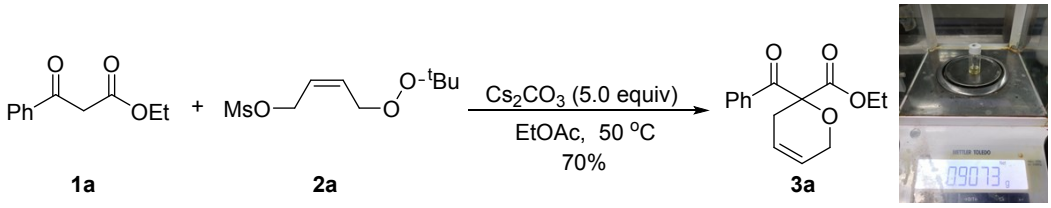
8. Gram-scale synthesis and synthetic applications

8.1 Gram-scale synthesis of compounds 3a and 3i



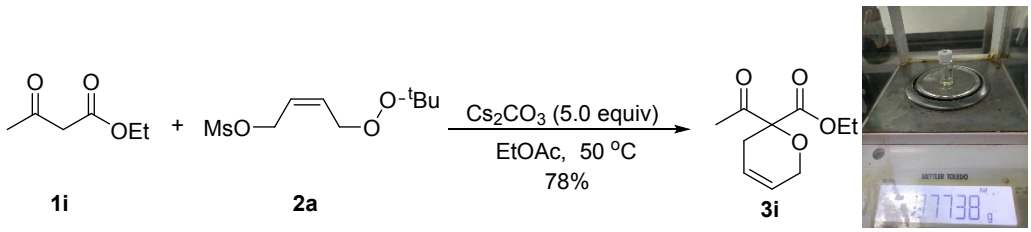
To a solution of (*Z*)-but-2-ene-1,4-diol (1.76 g, 20 mmol, 1.0 equiv) and triethylamine (6 mL, 42.4 mmol, 2.12 equiv) in CH_2Cl_2 (60 mL) was dropwise added a solution of methanesulfonyl chloride (3.5 mL, 42.4 mmol, 2.12 equiv) in CH_2Cl_2 (60 mL) at 0 °C. After stirring at room temperature for 0.5 h, the mixture was poured into ice water and extracted with CH_2Cl_2 (50 mL x 3). The organic layers were combined, dried over Na_2SO_4, filtered, and and concentrated. The compound **S1** was obtained by flash silica chromatography (petroleum ether/EtOAc = 1:1) as a white solid (4.7 g, 96% yield).

To a solution of the **S1** (4.7 g, 19.2 mmol, 1.0 equiv), *tert*-butyl hydroperoxide (5.3 mL, 28.9 mmol, 5.5 M solution in hexane, 1.5 equiv), and PEG600 (3.3 g) in THF (100 mL) was added powder KOH (1.62 g, 28.9 mmol, 1.5 equiv). The resulting solution was stirred at room temperature for 6 h. After completion, the reaction was quenched by water (50 mL). The organic layer was separated, and the aqueous layer was extracted with EtOAc (50 mL x 3). The combined organic layer was washed with brine (50 mL), dried over Na_2SO_4, and concentrated. The residue was purified by column chromatography on silica gel (petroleum ether / EtOAc = 10:1) to give peroxide **2a** as light yellow oil (1.6 g, 35% yield).



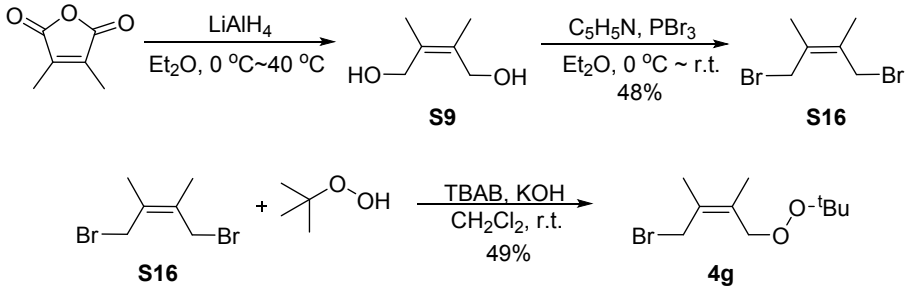
To a solution of substrate **1a** (1.15 g, 6.0 mmol, 1.2 equiv) and peroxide **2a** (1.19 g, 5.0 mmol, 1.0 equiv) in ethyl acetate (50 mL) was added Cs_2CO_3 solid (8.15 g, 25.0

mmol, 5.0 equiv) at room temperature. The resulting solution was vigorously stirred at 50 °C for 8 h. After completion of the reaction as monitored by the TLC, the reaction mixture was diluted with ethyl acetate (20 mL) and water (50 mL). The ethyl acetate layer was separated and the aqueous layer was extracted with EtOAc (50 mL x 3). The combined extracts were washed with brine (30 mL), dried over Na_2SO_4, filtered, and concentrated. The residue was purified by flash column chromatography on silica gel (petroleum ether / EtOAc= 50:1) to afford the desired dihydropyran product **3a** (907 mg, 70% yield) as a yellow oil.



To a solution of substrate **1i** (780 mg, 6.0 mmol, 1.2 equiv) and peroxide **2a** (1.19 g, 5.0 mmol, 1.0 equiv) in ethyl acetate (50 mL) was added Cs_2CO_3 solid (8.15 g, 25.0 mmol, 5.0 equiv) at room temperature. The resulting solution was vigorously stirred at 50 °C for 6 h. After completion of the reaction as monitored by the TLC, the reaction mixture was diluted with ethyl acetate (20 mL) and water (50 mL). The ethyl acetate layer was separated and the aqueous layer was extracted with EtOAc (50 mL x 3). The combined extracts were washed with brine (30 mL), dried over Na_2SO_4, filtered, and concentrated. The residue was purified by flash column chromatography on silica gel (petroleum ether / EtOAc= 50:1) to afford the desired dihydropyran product **3i** (774 mg, 78% yield) as a yellow oil.

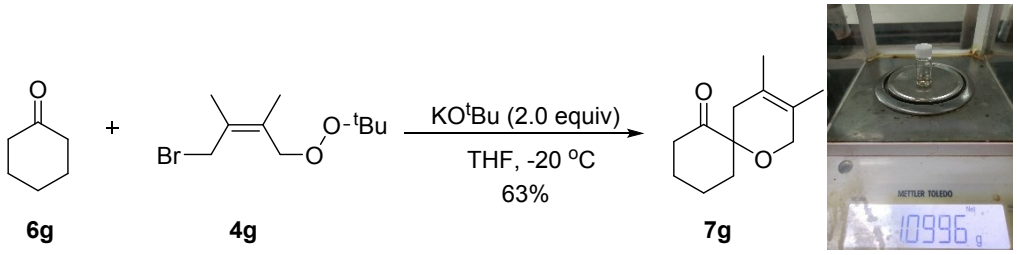
8.2 Gram-scale synthesis of the 7g



To a suspension of $LiAlH_4$ (1.8 g, 48 mmol, 3.0 equiv) in 40 ml Et_2O, a solution of commercial available 2,3-dimethylmaleic anhydride (2.0 g, 16 mmol, 1.0 equiv) in 40 mL of Et_2O was added dropwise at 0 °C. The mixture was allowed to warm up to 40 ^oC for stirring 4 h. After completion of the reaction (monitored by the TLC), the reaction mixture was quenched by slowly adding CH_3OH until the evolution of gas ceased, then was added 2.0 M HCl until pH to 7. The reaction mixture was filtered through a pad of celite and the filtrate was concentrated. The crude product **S9** was used for the next step without further purification.

To a solution of crude product **S9** (1.8 g, 15.5 mmol, 1.0 equiv) and pyridine (1.5 mL, 18.6 mmol, 1.2 equiv) in 30 mL Et_2O was dropwise added PBr_3 (2.9 mL, 31 mmol, 2.0 equiv) at 0 ^oC. After 1 h, the solution was allowed to warm up to room temperature and stirring was continued for 2 h. The mixture was poured into cold H_2O. The organic layer was separated, and the aqueous layer was extracted with EtOAc (30 mL x 3). The combined organic layer was washed with brine (30 mL), dried over Na_2SO_4, and concentrated. The residue was purified by flash column chromatography on silica gel (petroleum ether / EtOAc= 400:1) to afford the product **S16** (1.6 g, 48% yield for 2 steps) as a yellow oil.

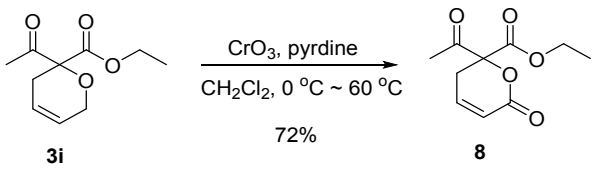
To a solution of the **S16** (1.6 g, 6.61 mmol, 1.0 equiv), *tert*-butyl hydroperoxide (1.2 mL, 6.61 mmol, 5.5 M solution in hexane, 1.0 equiv), and tetrabutylammonium bromide (213 mg, 0.66 mmol, 0.1 equiv) in 30 mL DCM was added powder KOH (1.0 equiv). The resulting solution was stirred at room temperature for 6 h. After completion, the reaction was quenched by water (30 mL). The organic layer was separated, and the aqueous layer was extracted with DCM (30 mL x 3). The combined organic layer was washed with brine (30 mL), dried over Na_2SO_4, and concentrated. The residue was purified by column chromatography on silica gel (petroleum ether / EtOAc = 200:1) to give peroxide **4g** as light yellow oil (800 mg, 49% yield).



6g **4g** **7g**

To a solution of cyclohexanone **6g** (1.2 g, 10.8 mmol, 1.2 equiv) and peroxide **4g** (2.26 g, 9.0 mmol, 1.0 equiv) in dry THF (90 mL) was slowly added a solution of *t*-BuOK (18 mL, 18 mmol, 1.0 M solution in THF, 2.0 equiv) over 30 min at -20 °C under N_2 atmosphere. The resulting solution was stirred at -20 °C for 10 minutes. After completion of the reaction as monitored by the TLC, the reaction mixture was quenched with water (50 mL) and extracted with EtOAc (50 mL x 3). The combined extracts were washed with brine (30 mL), dried over Na_2SO_4, filtered, and concentrated. The residue was purified by flash column chromatography on silica gel (petroleum ether / EtOAc = 150:1) to afford the desired dihydropyran product **7g** as a yellow oil (1.1 g, 63% yield).

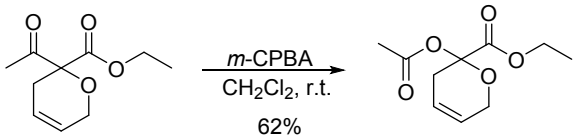
8.3 Synthetic applications



3i **8**

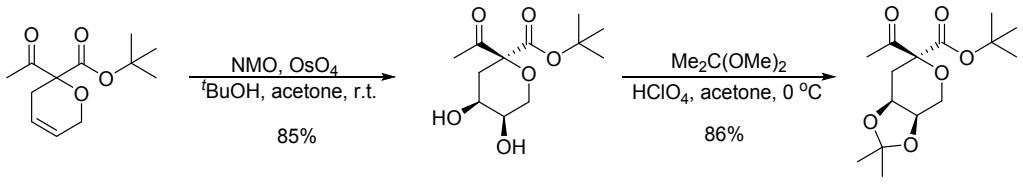
To a solution of pyridine (0.3 mL, 0.4 mmol, 2.0 equiv) and CrO_3 (220 mg, 2.2 mmol, 11.0 equiv) in CH_2Cl_2 (4 mL) was stirred for 20 minutes at 0 °C, whereupon a solution of compound **3i** (40 mg, 0.2 mmol, 1.0 equiv) in CH_2Cl_2 (2 mL) was added dropwise slowly for 5 minutes and then refluxed at 60 °C for a further 3 h. After completion of the reaction as monitored by the TLC, the filtrate was washed with CH_2Cl_2 (5 mL) and saturated $NaHCO_3$ (5 mL x 3). Then the mixture was extracted with CH_2Cl_2 (5 mL x 3) and washed with 2 M HCl (5 mL x 2) for a second time. The combined extracts were washed with brine (5 mL), dried over Na_2SO_4, filtered, and concentrated. The residue was purified by flash column chromatography on silica gel (petroleum ether / EtOAc = 5:1) to afford product **8** (30 mg, 72% yield) as a colorless

oil. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 6.83 (ddd, *J* = 9.7, 5.2, 3.1 Hz, 1H), 6.05 (d, *J* = 9.9 Hz, 1H), 4.26 (q, *J* = 7.1 Hz, 2H), 3.04 (dd, *J* = 19.0, 5.2 Hz, 1H), 2.91 (dt, *J* = 19.0, 2.7 Hz, 1H), 2.36 (s, 3H), 1.27 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 199.3, 166.5, 160.9, 142.9, 121.3, 87.8, 63.4, 28.0, 25.4, 13.9. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{10}H_{12}NaO_5, M + Na]^+$: 235.0575, Found: 235.0577.



3i **9**

To a solution of **3i** (40 mg, 0.2 mmol, 1.0 equiv) in CH_2Cl_2 (2 mL) was added *m*-CPBA (69 mg, 0.4 mmol, 2.0 equiv). After stirring at room temperature for 6 h, the reaction was quenched with water (5 mL) and the aqueous layer was extracted with CH_2Cl_2 (5 mL x 3). The combined extracts were washed with 2 M Na_2CO_3 (5 mL x 2), brine (5 mL), dried over Na_2SO_4, and concentrated. The residue was purified by flash column chromatography on silica gel (petroleum ether / EtOAc = 5:1) to afford product **9** (26 mg, 62% yield) as a colorless oil. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 5.81 – 5.74 (m, 2H), 4.41 (d, *J* = 17.2 Hz, 1H), 4.33 – 4.20 (m, 3H), 2.58 (d, *J* = 18.0 Hz, 1H), 2.44 (d, *J* = 18.0 Hz, 1H), 2.11 (s, 3H), 1.31 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 169.3, 168.0, 123.9, 119.9, 95.5, 62.2, 62.1, 31.0, 20.7, 13.9. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{10}H_{14}NaO_5, M + Na]^+$: 237.0731, Found: 237.0733.

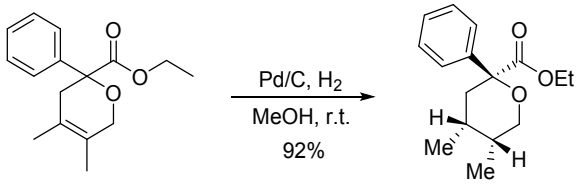


3k **10,** dr = 5 : 1 **11**, dr = 5 : 1

To a solution of **3k** (45.3 mg, 0.2 mmol, 1.0 equiv) in *t*-BuOH/acetone (2 mL, 1:1 (v/v)) was added another solution of *N*-methylmorpholine-*N*-oxide/water (50% w/v, 0.2 mL) at 0 °C. Crystalline OsO_4 (2.8 mg, 5 mol %) was added and the reaction mixture was stirred for 12 h. The reaction mixture was quenched with 5 mL of saturated aqueous $Na_2S_2O_3$, extracted with EtOAc (5 mL x 3). The combined extracts

were washed with brine (5 mL), dried over Na_2SO_4, filtered, and concentrated. The residue was purified by flash column chromatography on silica gel (petroleum ether / EtOAc = 1:1) to afford **10** (44 mg, 85% yield, dr = 5:1) as a colorless oil. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 3.94 (d, *J* = 9.6 Hz, 2H), 3.77 (d, *J* = 12.4 Hz, 2H), 2.62 (s, 2H), 2.36 (dd, *J* = 13.3, 4.2 Hz, 1H), 2.27 (s, 3H), 2.05 – 1.91 (m, 1H), 1.46 (s, 9H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 204.3, 167.2, 86.2, 83.5, 66.9, 66.6, 65.9, 31.9, 27.8, 24.8. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{12}H_{20}NaO_6, M + Na]^+$: 283.1148, Found: 283.1152.

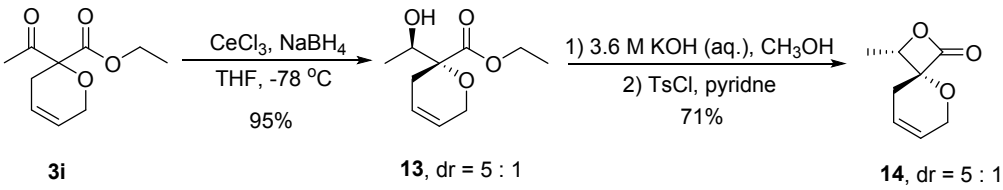
Perchloric acid (70%, 7 μL) was added to a suspension of **10** (44 mg, 0.17 mmol, 1.0 equiv) in acetone (1 mL) and 2,2-dimethoxypropane (12 μL, 0.1 mmol, 0.6 equiv) at 0 °C and the reaction mixture was stirred for 4 h. The reaction mixture was quenched with water (5 mL), extracted with EtOAc (5 mL x 3), and washed with brine (5 mL), dried with Na_2SO_4, and concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel (petroleum ether / EtOAc = 5:1) to afford **11** (43 mg, 84% yield, dr = 5:1) as a colorless oil. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 4.46 (dt, *J* = 7.3, 4.8 Hz, 1H), 4.13 (d, *J* = 7.1 Hz, 1H), 3.95 (d, *J* = 13.3 Hz, 1H), 3.80 (dd, *J* = 13.3, 2.2 Hz, 1H), 2.55 (dd, *J* = 15.0, 5.1 Hz, 1H), 2.30 (s, 3H), 2.22 (dd, *J* = 15.0, 3.7 Hz, 1H), 1.45 (s, 3H), 1.43 (s, 9H), 1.30 (s, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 205.2, 168.1, 108.8, 83.8, 83.0, 71.8, 69.2, 64.8, 28.5, 27.7, 26.7, 25.2, 24.8. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{15}H_{24}NaO_6, M + Na]^+$: 323.1462, Found: 323.1465.



7b **12**

To a solution of **7b** (52 mg, 0.2 mmol) in MeOH (2 mL) was added 10% Pd/C (20 mg, 40 wt%) and the mixture was stirred for 12 h at room temperature under H_2 atmosphere (balloon). The reaction was filtered through a pad of celite and the filtrate was concentrated. The residue was purified by flash column chromatography on silica

gel (petroleum ether / EtOAc = 5:1) to afford **12** (48 mg, 92% yield, dr > 20:1) as a colorless oil. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.54 (d, *J* = 7.4 Hz, 2H), 7.36 (t, *J* = 7.5 Hz, 2H), 7.31 – 7.26 (m, 1H), 4.17 – 4.03 (m, 2H), 3.69 (dd, *J* = 11.6, 3.3 Hz, 1H), 3.59 (dd, *J* = 11.6, 2.9 Hz, 1H), 2.36 (dd, *J* = 14.0, 3.5 Hz, 1H), 2.02 (dd, *J* = 14.0, 11.0 Hz, 1H), 1.94 – 1.82 (m, 1H), 1.55 (dd, *J* = 6.9, 3.6 Hz, 1H), 1.14 (t, *J* = 7.1 Hz, 3H), 0.95 (dd, *J* = 15.7, 7.0 Hz, 6H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 172.7, 138.7, 128.4, 127.7, 126.8, 79.6, 68.2, 61.2, 33.9, 32.9, 28.7, 18.0, 13.9, 11.2. **HRMS (ESI-FT-ICR)** m/z Calcd for $[C_{16}H_{22}NaO_3, M + Na]^+$: 285.1453, Found: 285.1461.



3i **13**, dr = 5 : 1 **14**, dr = 5 : 1

A solution of $NaBH_4$ (3.8 mg, 0.1 mmol, 0.5 equiv) and $CeCl_3$ (4.9 mg, 0.02 mmol, 0.1 equiv) in THF (2.0 mL) was cooled to -78°C for 30 minutes under nitrogen. Then the compound **3i** (40 mg, 0.2 mmol, 1.0 equiv) in THF (2 mL) was added slowly for 30 minutes. After stirring at -78 °C for 4 h, the reaction was quenched with water (5 mL) and the aqueous layer was extracted with EtOAc (5 mL x 3), and washed with brine (5 mL), dried with Na_2SO_4, and concentrated under reduced pressure. The product **13** (38 mg, 95% yield, dr = 5:1) was obtained as a colorless oil without further purification.

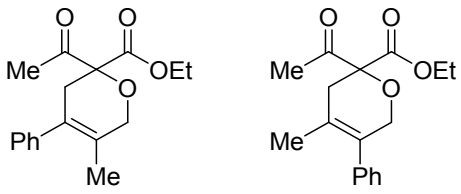
A solution of **13** (38 mg, 0.19 mmol, 1.0 equiv) in MeOH (8 mL) was treated with 3.6 M KOH (4 mL) and heated at 60 °C for 1 h. The solution was cooled and neutralized with 10 % aqueous HCl. MeOH was removed under reduced pressure. The aqueous layer was saturated with NaCl and extracted with EtOAc (10 mL x 3). The EtOAc extracts were then dried Na_2SO_4 and concentrated to give 36 mg of crude hydroxyl acid that was used without purification.

A solution of the crude hydroxyl acid in pyridine (2 mL) was cooled to 0 °C and TsCl (7.22 mg, 0.38 mmol, 1.0 equiv) was added. The mixture was stirred at 0 °C overnight. The mixture was poured into water (5 mL) and extracted with EtOAc (10 mL x 3). The combined extracts were washed with saturated $NaHCO_3$ (5 mL), brine

(5 mL), dried with Na_2SO_4, and concentrated. The residue was purified by flash column chromatography on silica gel (petroleum ether / DCM = 10:3) to afford the product **14** as a colorless oil (20 mg, 71% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 5.84 (s, 2H), 4.59 (d, *J* = 16.2Hz, 1H), 4.48 (q, *J* = 6.2 Hz, 1H), 4.35 (d, *J* = 16.2 Hz, 1H), 2.49 (s, 2H), 1.51 (d, J = 6.3Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 169.9, 126.0, 120.1, 83.7, 80.2, 64.4, 28.3, 14.2. **HRMS (ESI-FT-ICR)** m/z Calcd for [$C_9H_{14}NaO_4$, M + CH_3OH + Na]$^+$: 209.0779, Found: 209.0784.

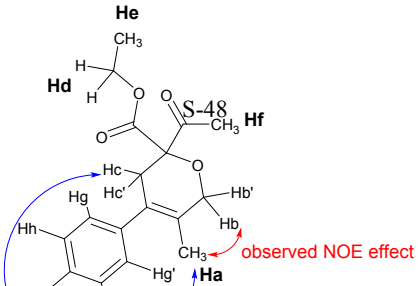
9. Determination of the diastereoselectivity and relative configuration of compounds 5j, 11, 12, and 14

9.1 Determination of the structure of compound 5j



5j **5l**

Compounds **5j** and **5l** are structurally similar, thus NOE experiment was used to determine the structure of compound **5j**. As shown in **Figure S1**, clear NOE between the methyl group (Ha, 1.5 ppm) and one methylene group (Hb and Hb', 4.2 - 4.5 ppm) was observed, when selecting to irradiate the methyl (Ha) signal in compound **5j**. Meanwhile, the absence of NOE was also observed between proton Ha and the other methylene group (Hc and Hc', 2.5 – 3.0 ppm). These results indicate the methyl group (Ha, 1.5 ppm) and the methylene group (Hb and Hb', 4.2 – 4.5 ppm) are on the same side of the dihydropyran ring. Therefore, the structure of compounds **5j** was finally confirmed as above. Subsequently, the structure of **5l** was determined by comparison of its ^{1}HNMR spectrum with compound **5j**. Similarly, the structures of compounds **5i** and **5k** were determined followed the same procedure.



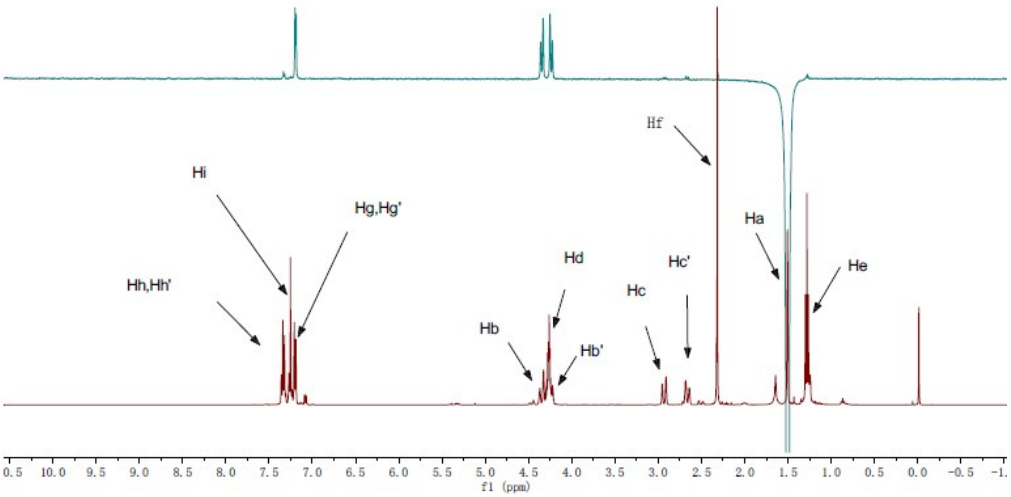


Figure S1. Comparison of ^{1}H NMR and NOE spectra of compound **5k**

9.2 Determination of the diasteroselectivity of dihydroxylation reaction and the relative configuration of major product 11

Treatment of dihydropyran **3k** with OsO_4 (5 mol%) and NMO, followed by the protection of the resulting diol, led to the acetonide product **11** in 71% overall yield and 5:1 dr. The diastereoselectivity of the dihydroxylation reaction was determined by the comparison of ^{1}H NMR spectra of crude reaction mixture with the purified major product **11** and the minor diastereomer. As shown in **Figures S2-S3**, proton Hc' from the major product **11** and proton H_3' from the minor product are well characterized. Their integration ratio was determined be 5:1. Accordingly, we conclude that the diastereoselectivity of the reaction should be 5:1.

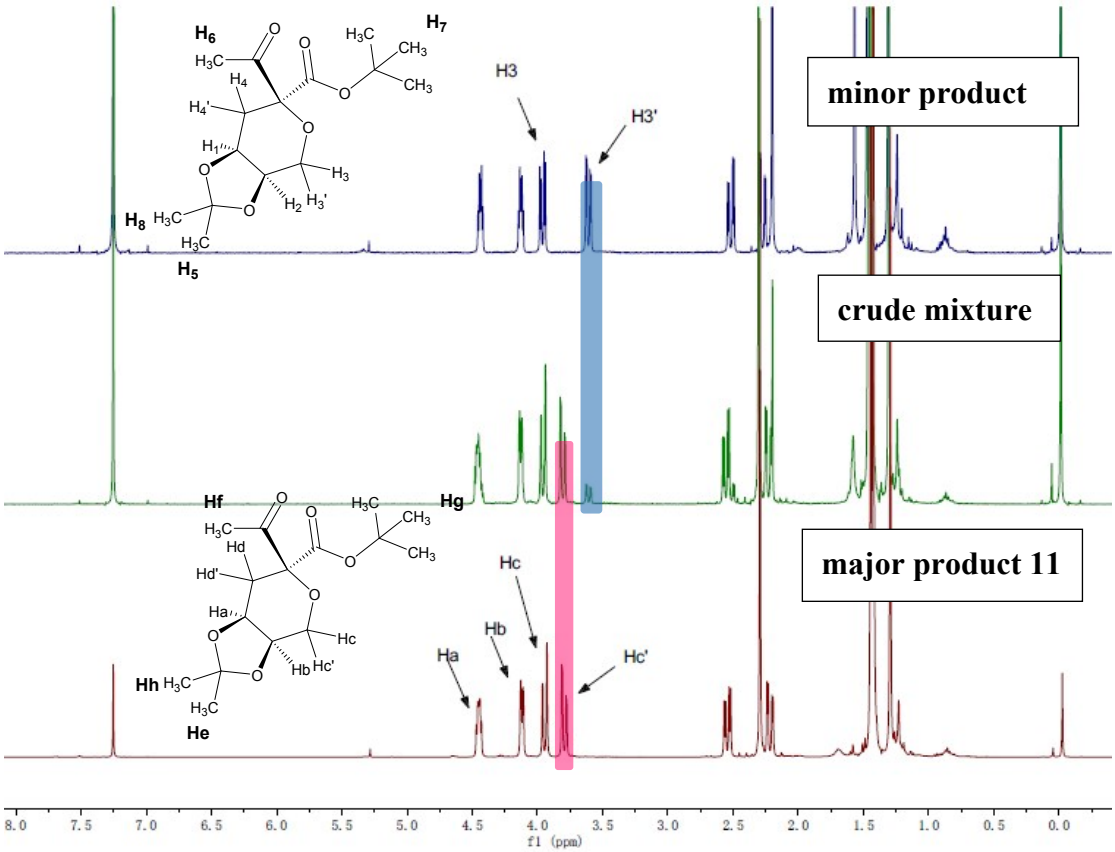


Figure S2. ^{1}H NMR of crude mixture, major, and minor diastereomers of the dihydroxylation reaction

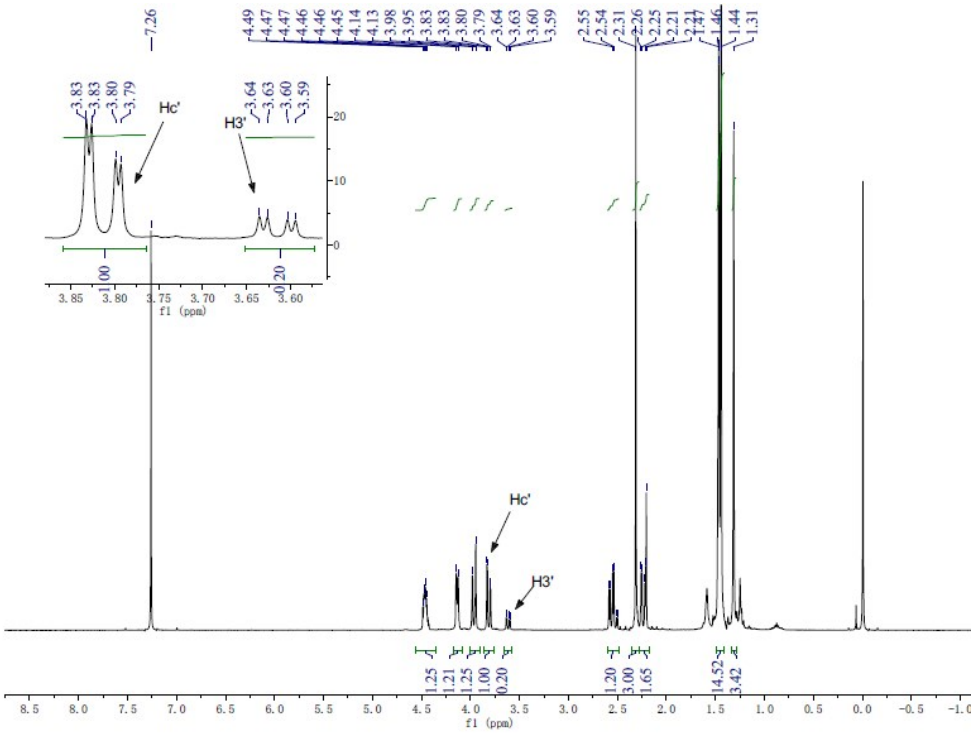


Figure S3. ^{1}H NMR of crude mixture of the dihydroxylation reaction

Next, the relative configuration of major product **11** was determined by NOE experiment. As shown in **Figure S4,** clear NOE effects between proton Ha and its adjacent protons (Hd, Hd', and Hb) were observed, when selecting to irradiate the Ha proton signal in compound **11**. Among them, NOE of Ha-Hd' is stronger than that of Ha-Hd, which suggests that protons Ha and Hd' are on the same side of the dihydropyaran ring. More importantly, the NOE between Ha and the *tert*-butyl group (Hg) was also observed. Further evidence was from the observed NOE between Hd' and the *tert*-butyl group (Hg), when irradiating the Hd' proton signal (**Figure S5**). These data indicate that proton Ha and *tert*-butyl group are on the same side of the dihydropyaran ring. Namely, the newly installed dihydroxyl groups are *trans* to the *tert*-butyl carboxylate group. Such result is consistent with the predicted stereoselectivity, because *tert*-butyl carboxylate is much larger than the acetyl group. Thus, OsO_4 reagent has to approach the double bond of compound **11** from the less hindered face.

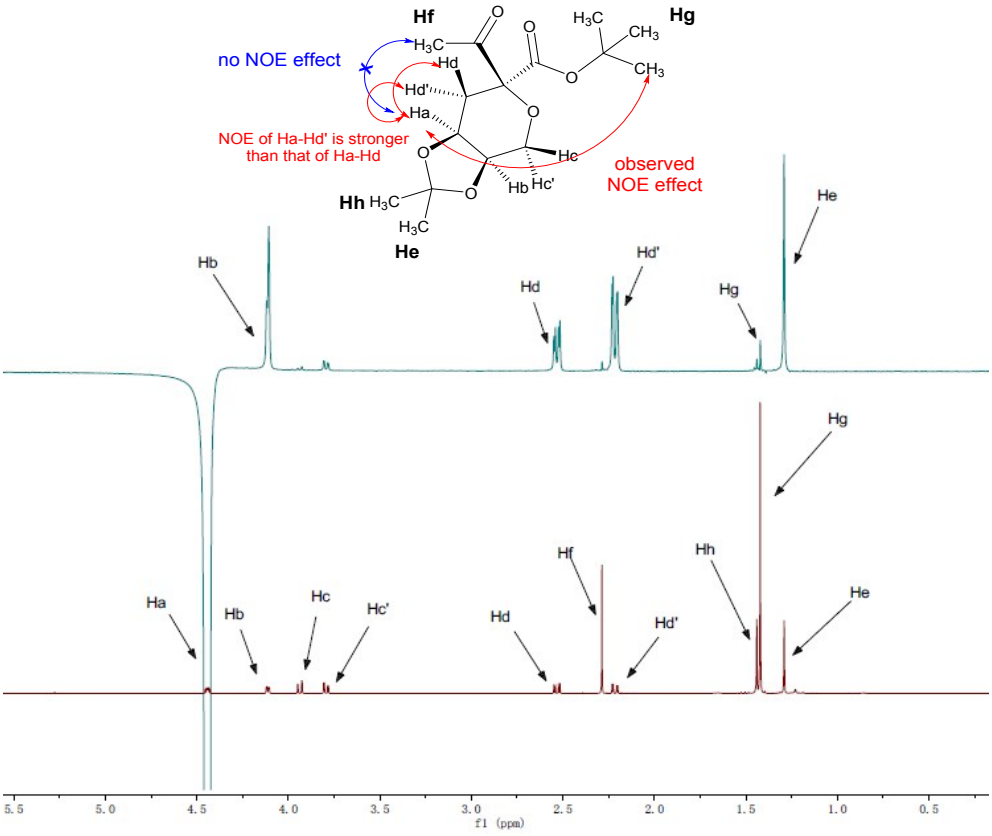


Figure S4. Comparison of ^{1}H NMR and NOE spectra of compound **11**

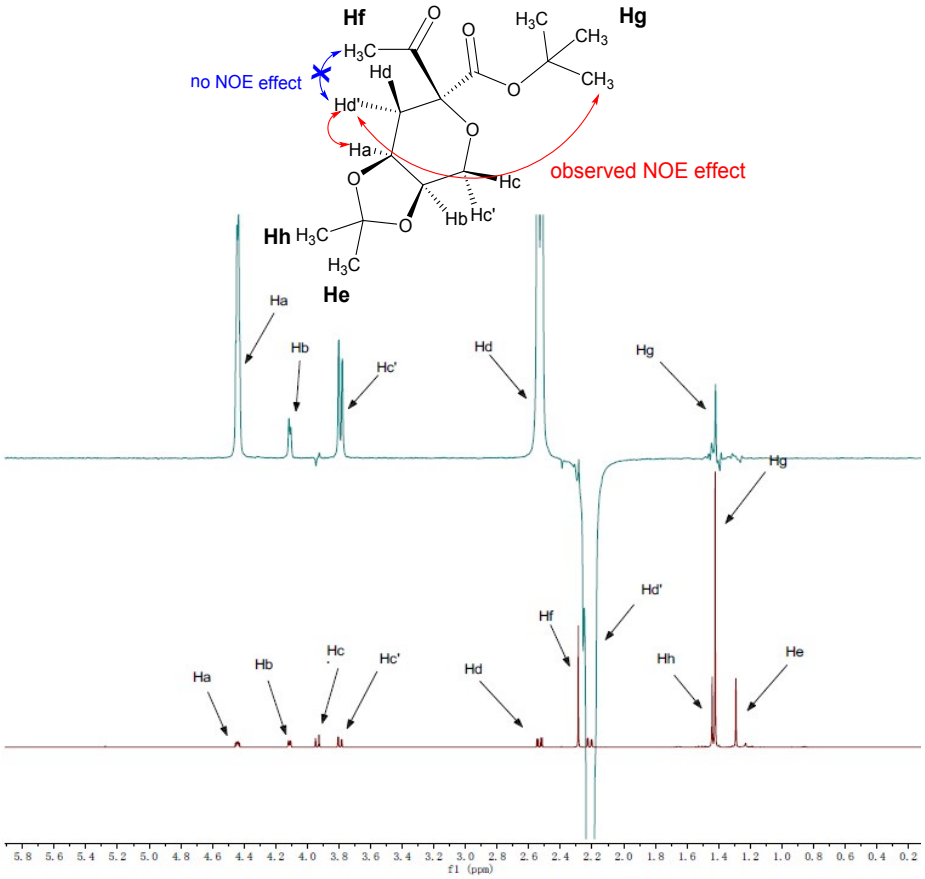


Figure S5. Comparison of ^{1}H NMR and NOE spectra of compound **11**

9.3 Determination of the diasteroselectivity of hydrogenation reaction and the relative configuration of major product 12

Hydrogenation of dihydropyran **7b** in the presence of Pd/C (10 mol%) and H_2 (balloon) resulted in the product in 92% yield and excellent diastereoselectivity (> 20 : 1). The diastereoselectivity of the reaction was determined by the comparison of ^{1}H NMR spectra of crude reaction mixture with the purified product **12**. As shown in **Figure S6**, both the crude and the purified product spectra only exist a single set of characteristic signal peaks. Thus we concluded that the diastereoselectivity of the hydrogenation reaction should be > 20:1.

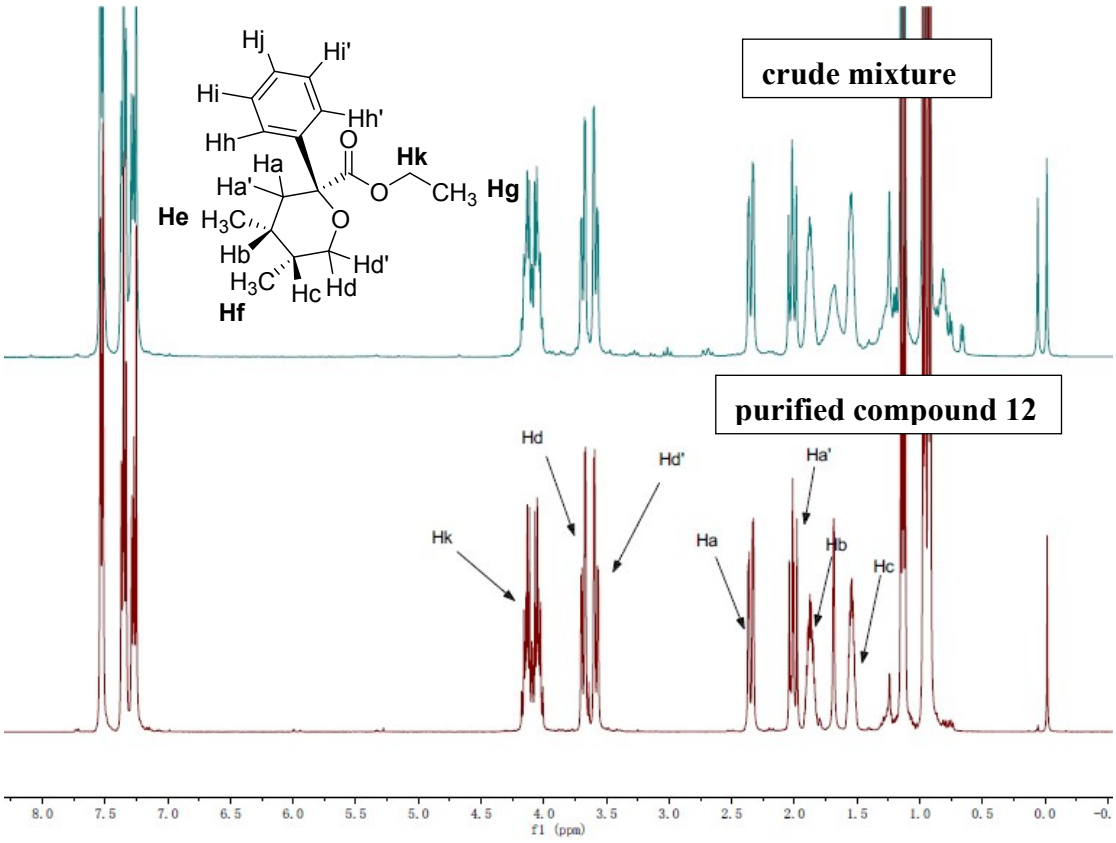


Figure S6. ^{1}H NMR of crude mixture and purified compound **12**

Next, the relative configuration of major product **12** was determined by NOESY experiment. As shown in **Figures S7-S8**, clear NOE between protons Hb and Hh was observed, when selecting to irradiate the Ha proton signal in compound **12**, which indicates that the phenyl group and the dimethyl groups are *trans* to each other

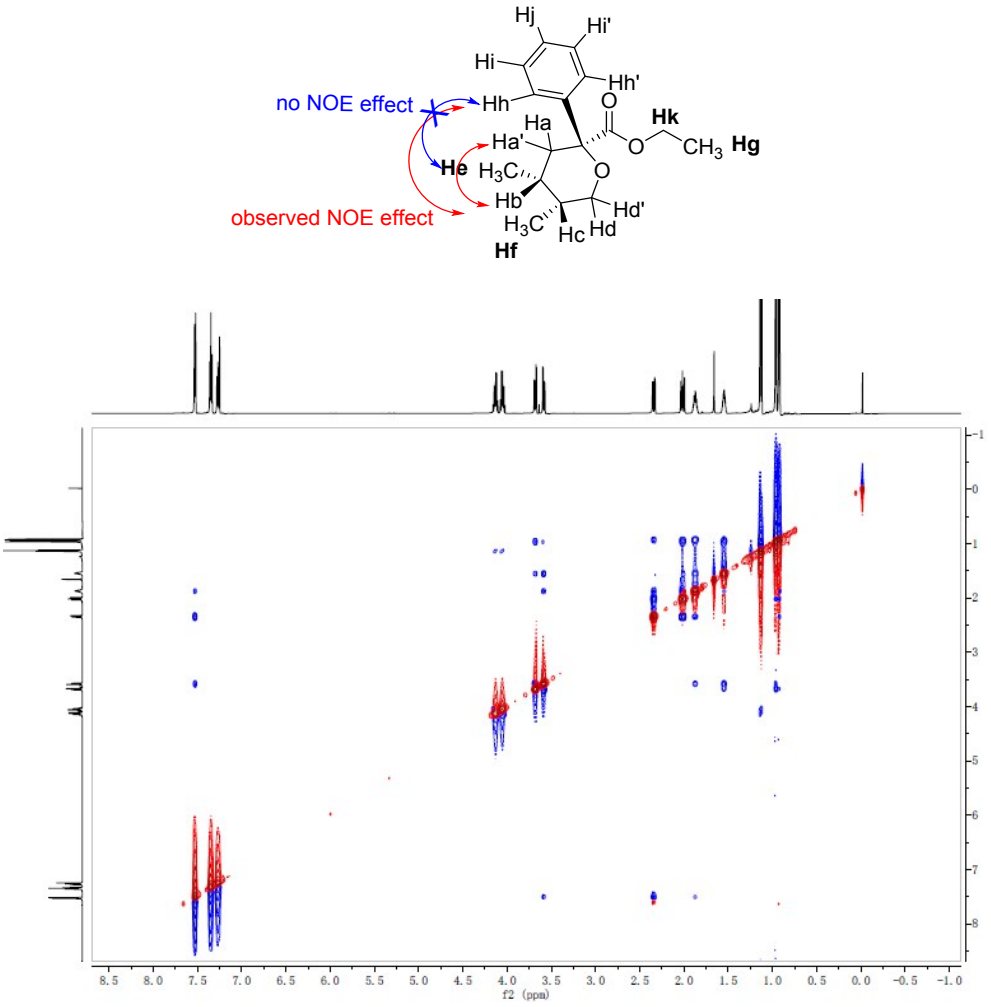


Figure S7. NOESY spectra of compound **12**

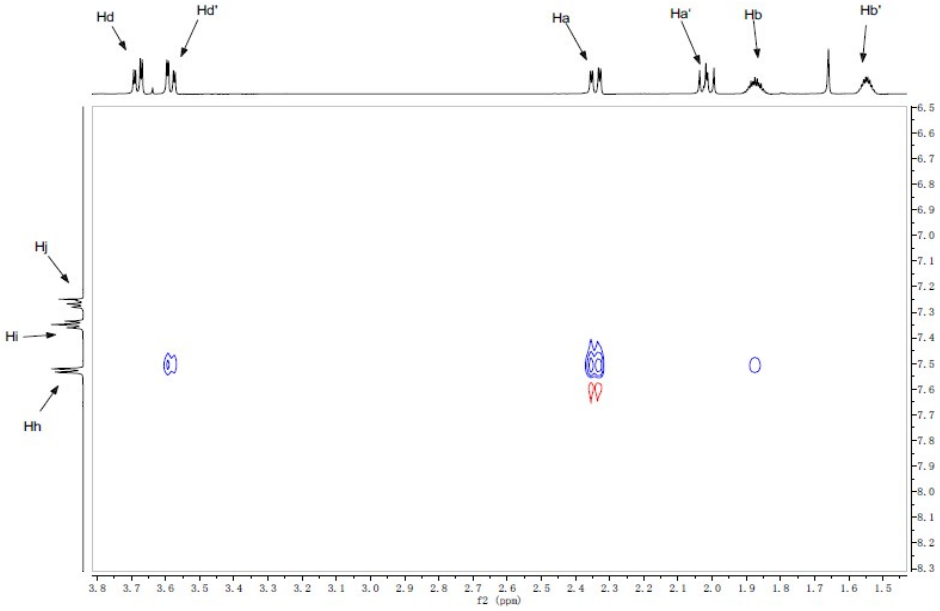


Figure S8. Enlarged NOESY spectra of compound **12**

9.4 Determination of the diasteroselectivity of the carbonyl reduction reaction and the relative configuration of major product 14

Treatment of dihydropyran **3i** with $NaBH_4$, followed by the annulation of the *β*-hydroxyl ester, led to the *β*-lactone product **14** in 67% overall yield and 5:1 dr. The diastereoselectivity of the reaction was determined by the comparison of ^1H NMR spectra of crude reaction mixture with the purified major product **14** and the minor diastereomer. As shown in **Figures S9-S10**, proton Ha from the major product **11** and proton H_1 from the minor product are well characterized. Their integration ratios were determined be 5:1. Accordingly, we conclude that the diastereoselectivity of the reaction should be 5:1.

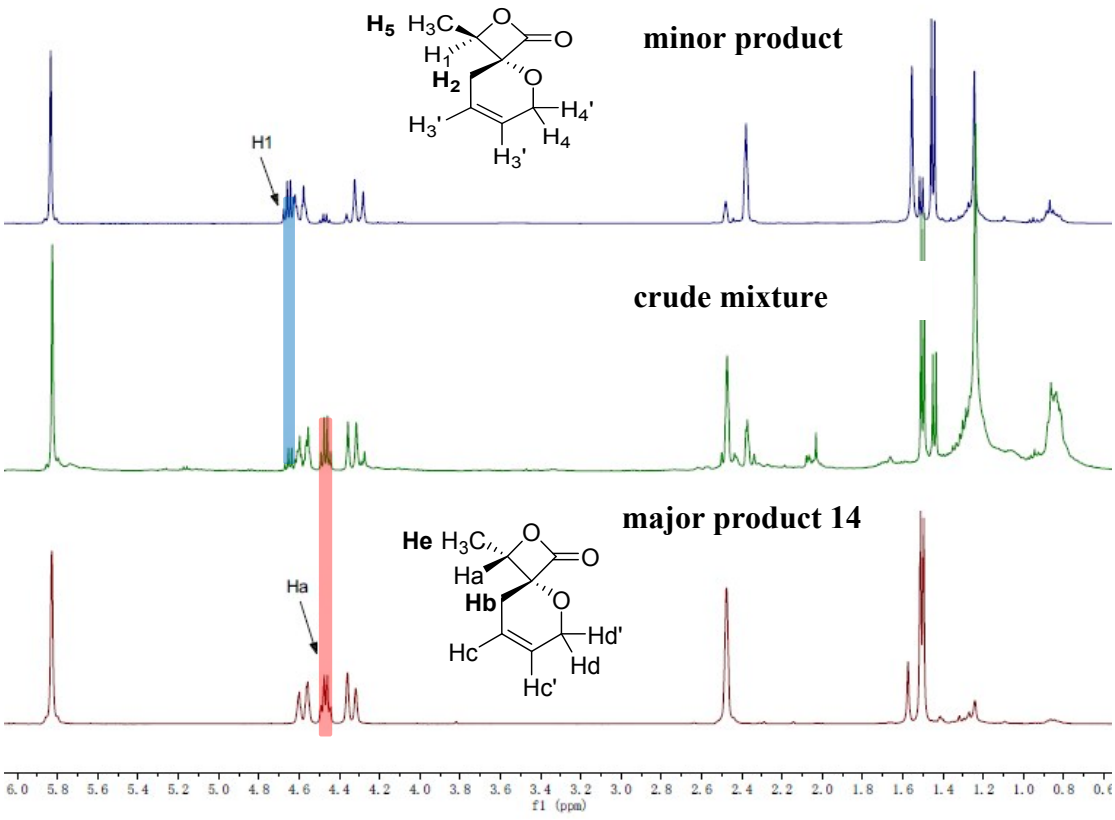


Figure S9. ^1H NMR of crude mixture, major and minor diastereomers of the carbonyl reduction reaction

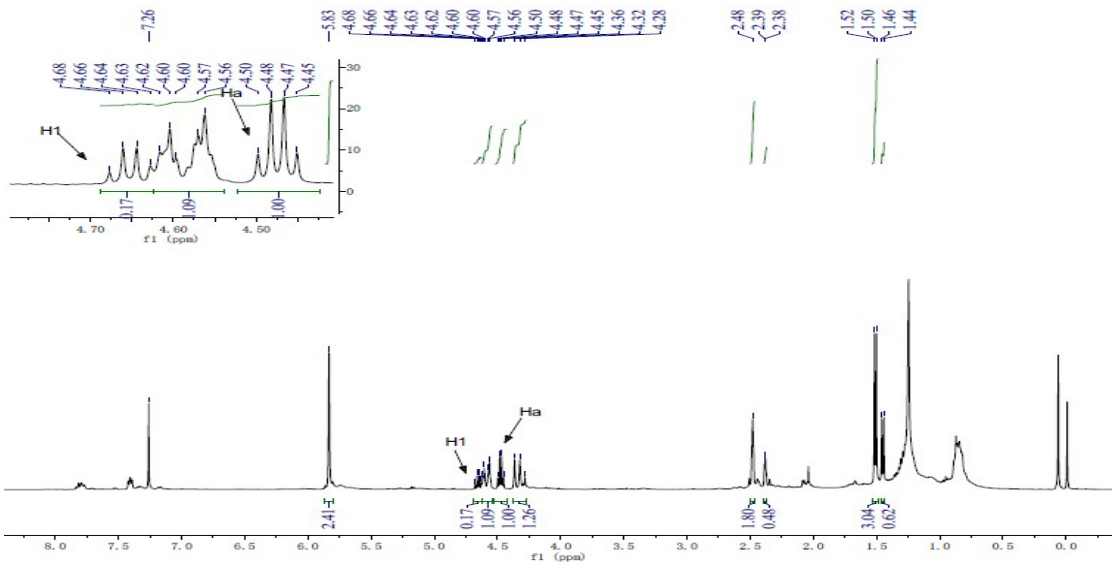


Figure 10. [1]H NMR of crude mixture of the carbonyl reduction reaction

Next, the relative configuration of major product **14** was determined by NOE experiment. As shown in **Figure S11**, clear NOE between proton Hb and proton Ha was observed, when selecting to irradiate the Hb proton signal in compound **14**. Meanwhile, the absence of NOE between the proton Hb and proton He (methyl group) was also observed. These results indicate that the methyl group and the allylic methylene group (Hb) in the spirocyclic structure are *trans* to each other.

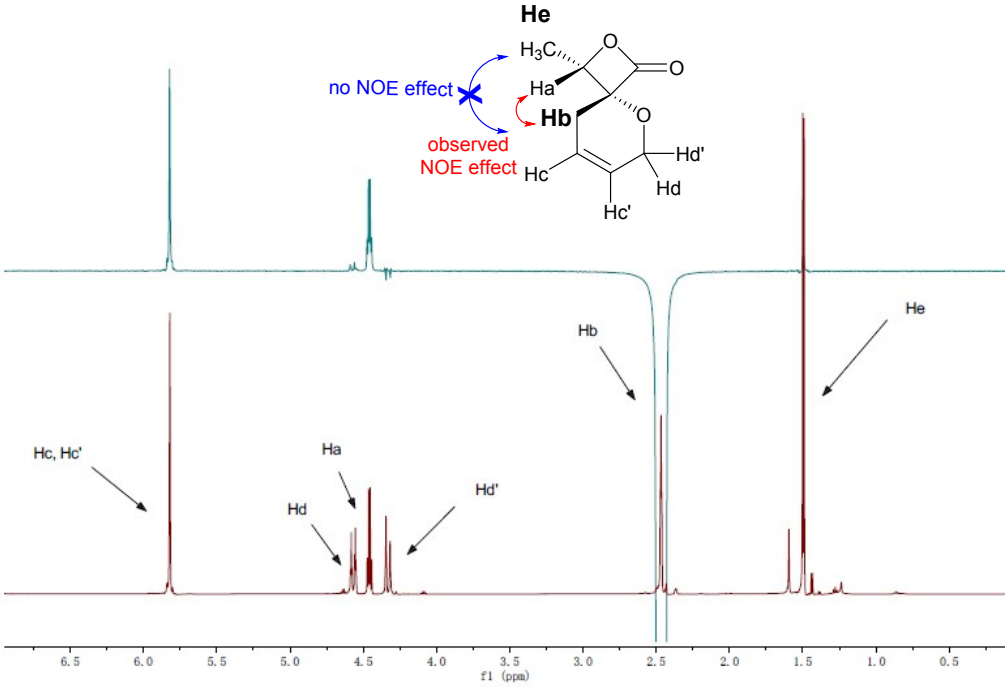


Figure S11. Comparison of [1]H NMR and NOE spectra of compound **14**

10. References

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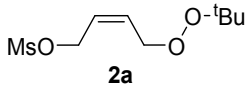
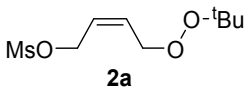
11. NMR Spectra for New Compounds

^{1}H NMR (400 MHz, $CDCl_3$)



2a

^{13}C NMR (100 MHz, $CDCl_3$)



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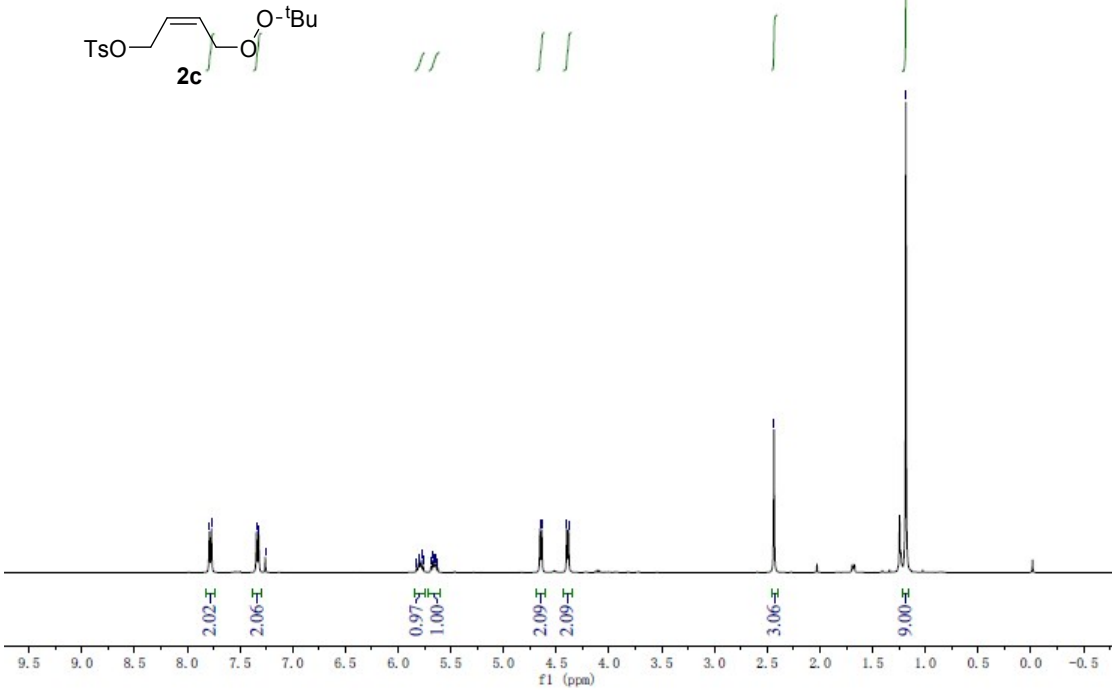

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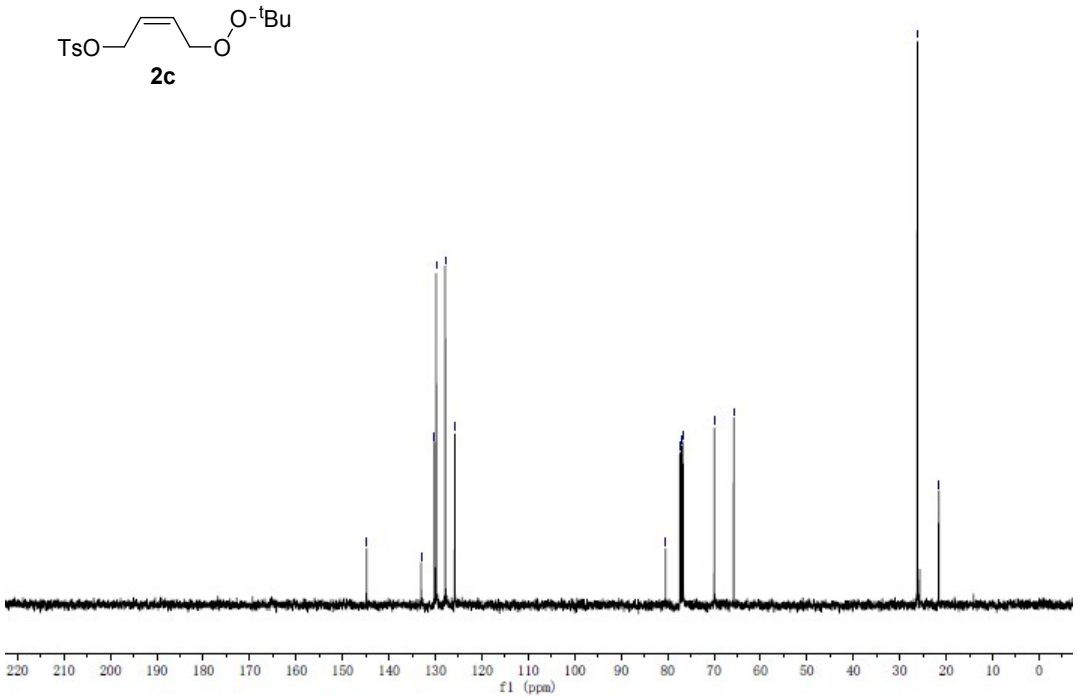

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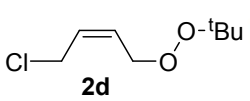

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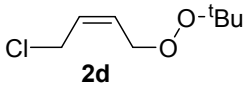

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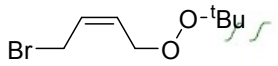

2e

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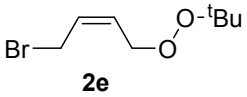

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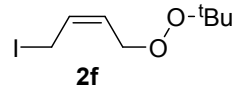

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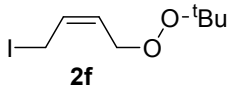

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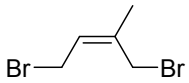

S13

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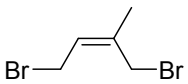

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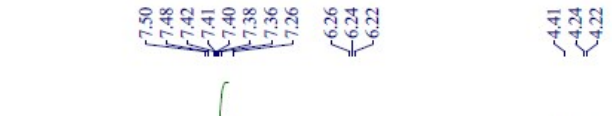

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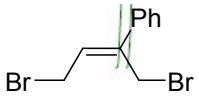

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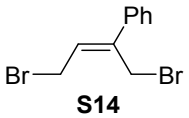

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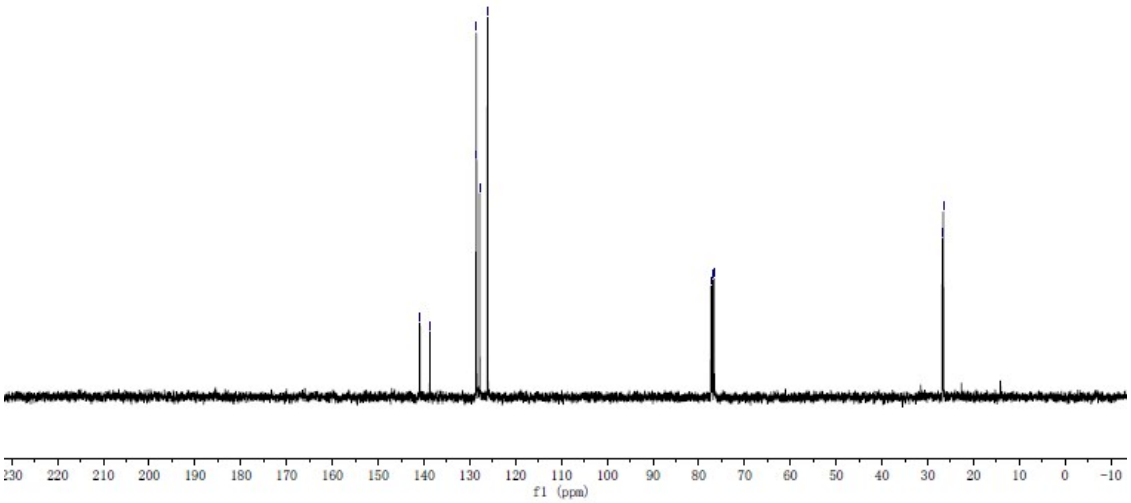

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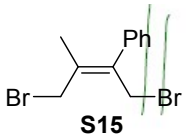

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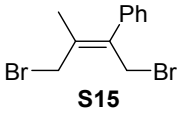

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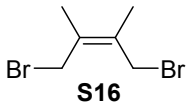

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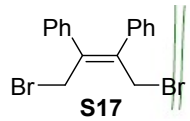

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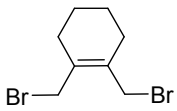

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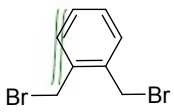

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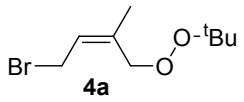

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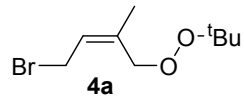

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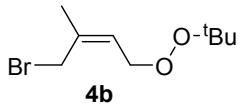

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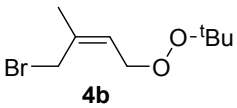

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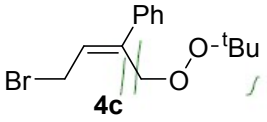

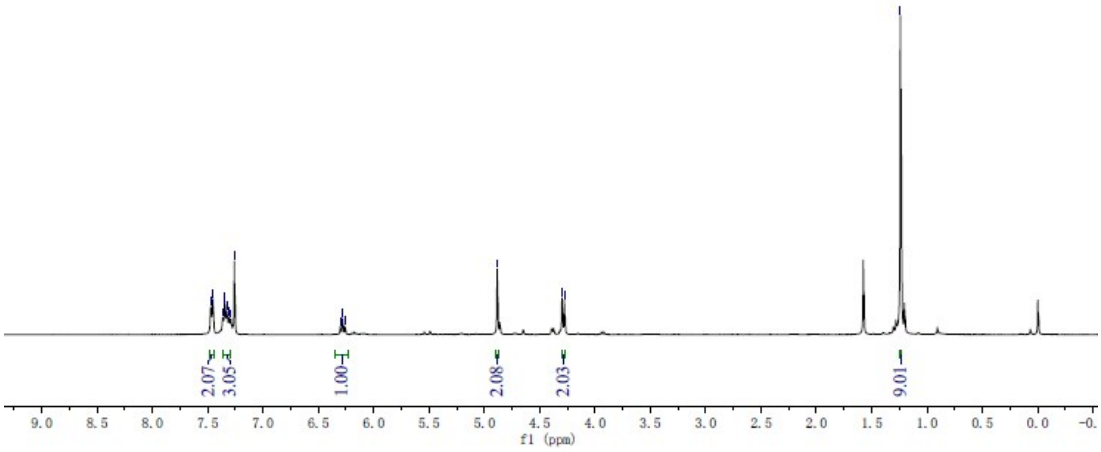

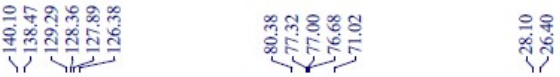

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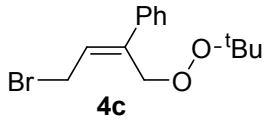

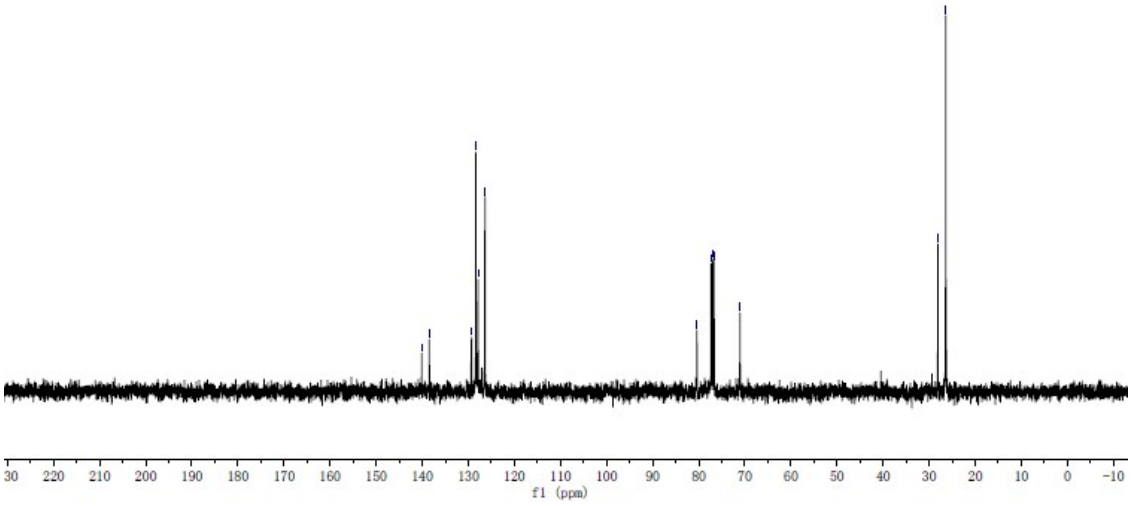

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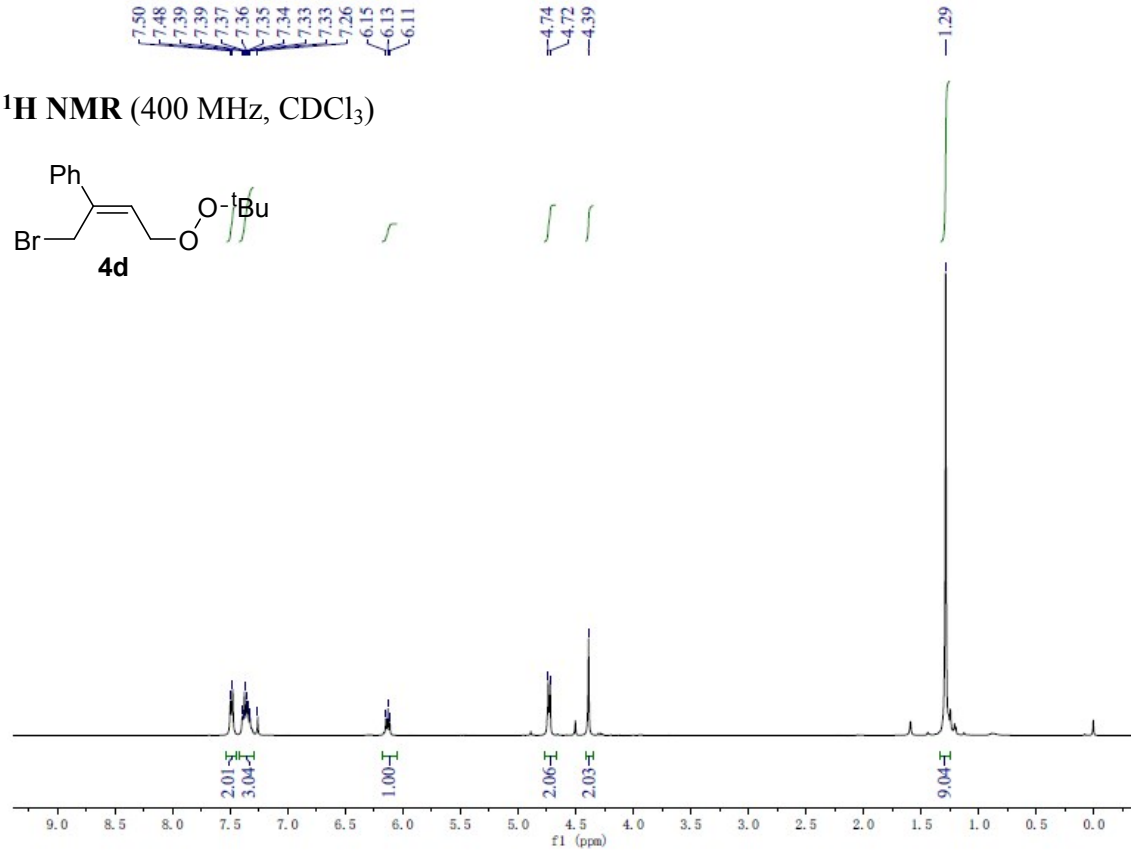

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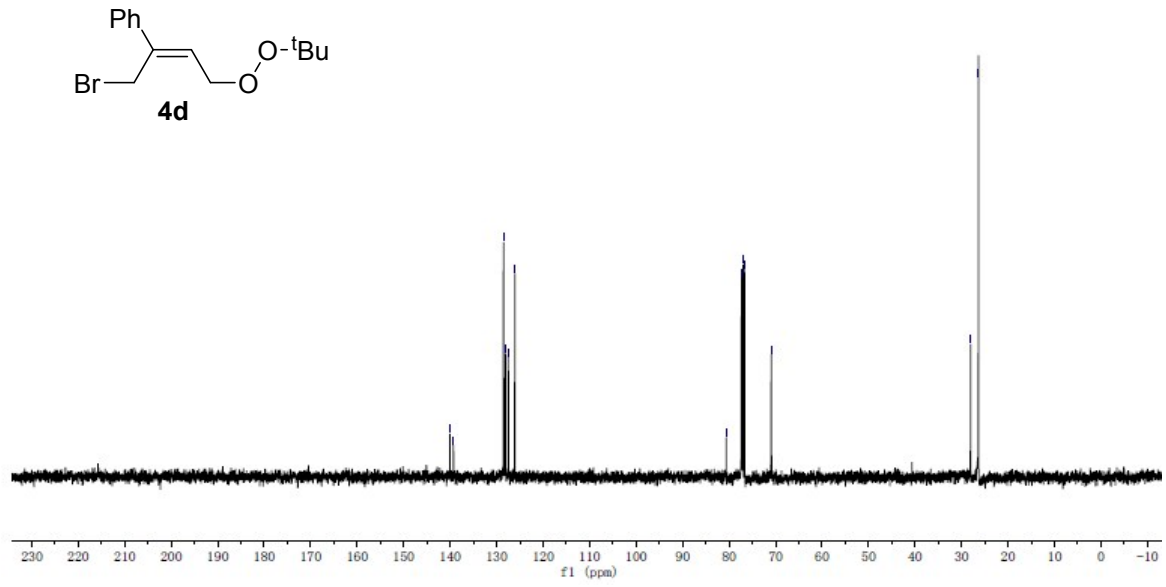

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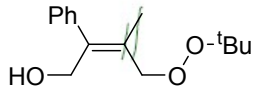

S20

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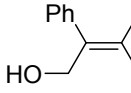

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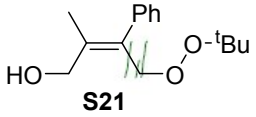

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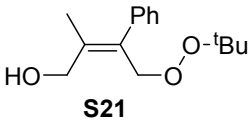

S21

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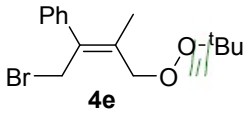

4e

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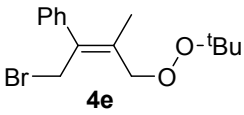
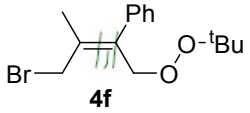


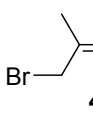
4e

^{1}H NMR (400 MHz, $CDCl_3$)



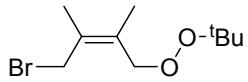
4f

^{13}C NMR (100 MHz, $CDCl_3$)



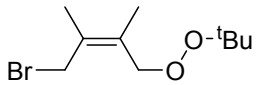
4f

^{1}H NMR (400 MHz, $CDCl_3$)



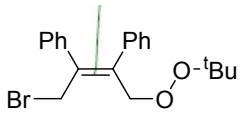
4g

^{13}C NMR (100 MHz, $CDCl_3$)



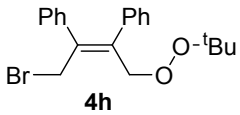
4g

^{1}H NMR (400 MHz, $CDCl_3$)



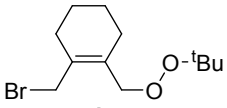
4h

^{13}C NMR (100 MHz, $CDCl_3$)



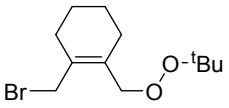
4h

^{1}H NMR (400 MHz, $CDCl_3$)



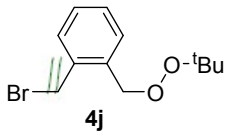
4i

^{13}C NMR (100 MHz, $CDCl_3$)



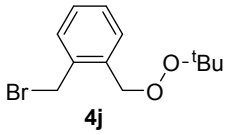
4i

^{1}H NMR (400 MHz, $CDCl_3$)



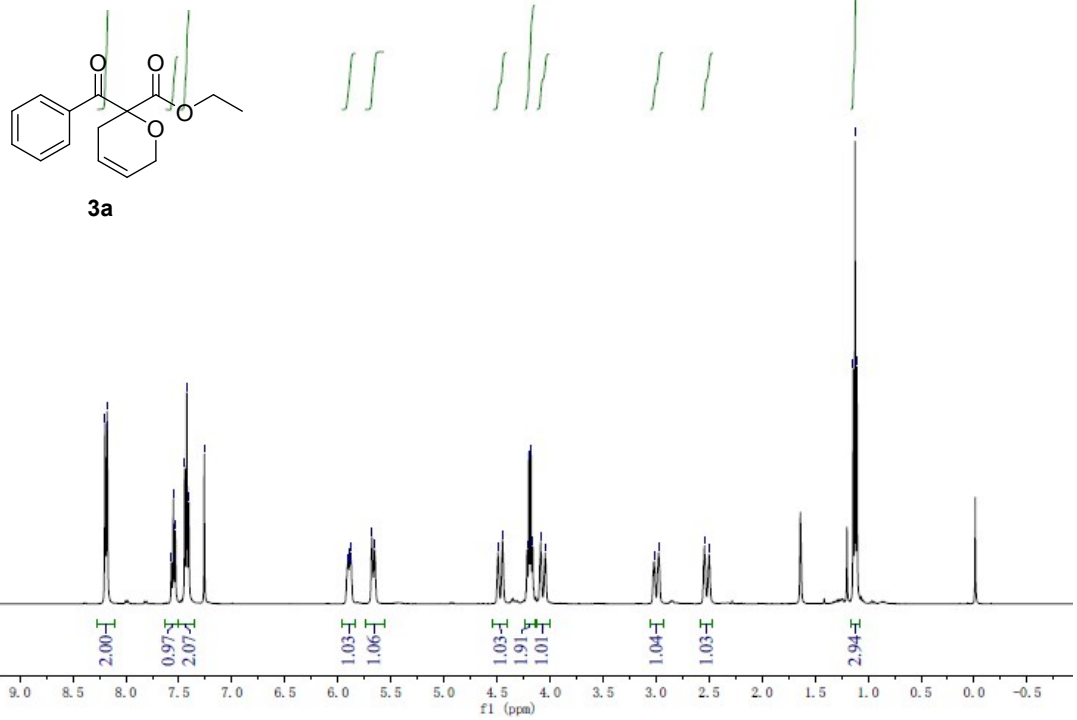
4j

^{13}C NMR (100 MHz, $CDCl_3$)



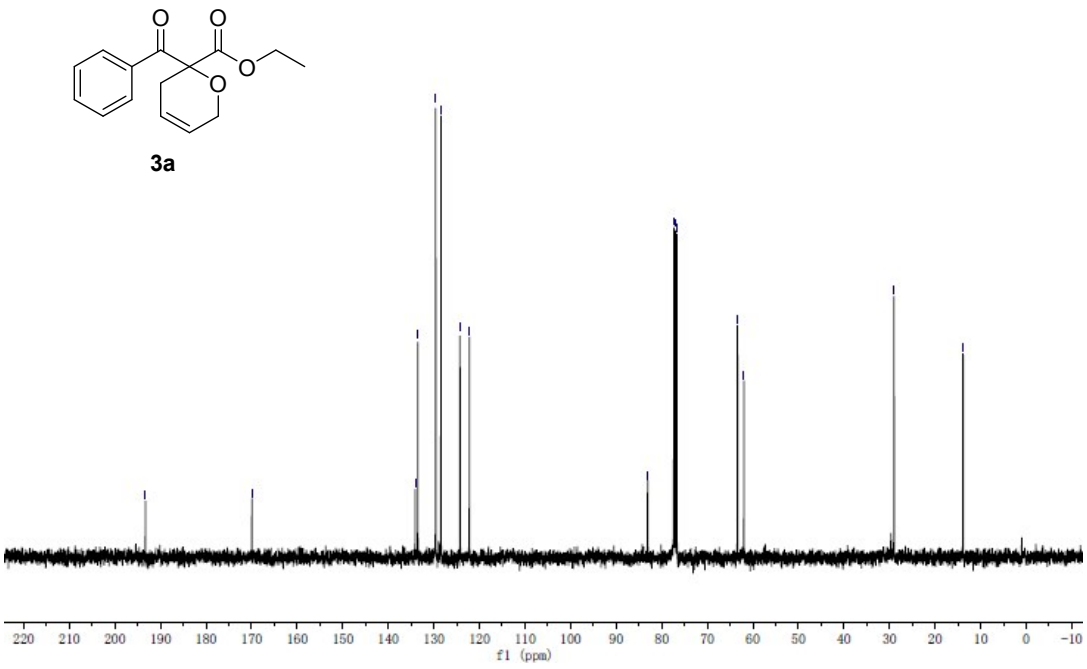
4j

^{1}H NMR (400 MHz, $CDCl_3$)



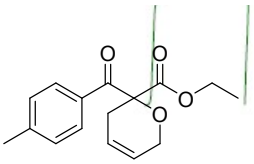
3a

^{13}C NMR (100 MHz, $CDCl_3$)



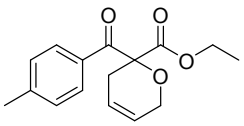
3a

^{1}H NMR (400 MHz, $CDCl_3$)



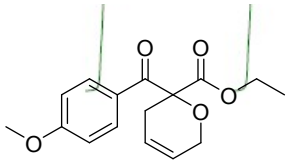
3b

^{13}C NMR (100 MHz, $CDCl_3$)



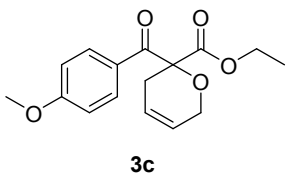
3b

^{1}H NMR (400 MHz, $CDCl_3$)



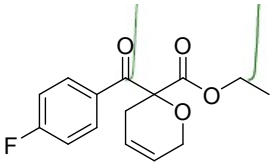
3c

^{13}C NMR (100 MHz, $CDCl_3$)

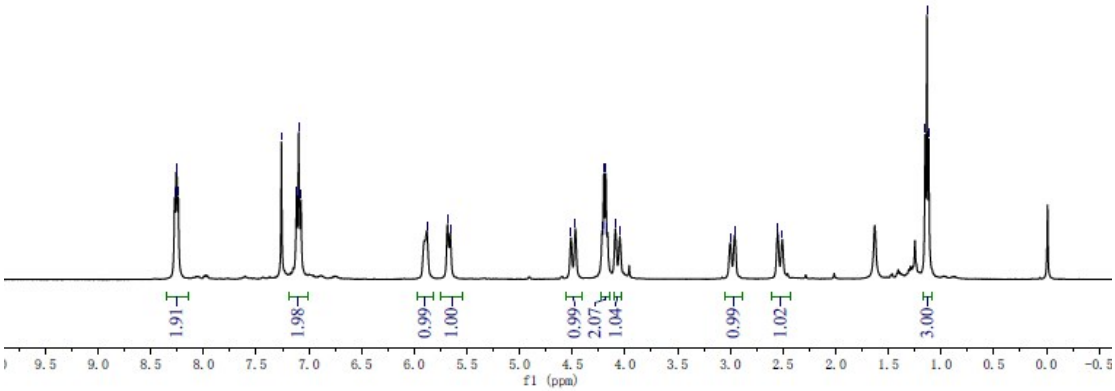


3c

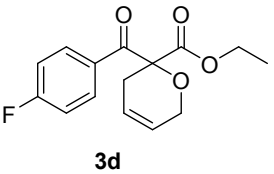
^{1}H NMR (400 MHz, $CDCl_3$)



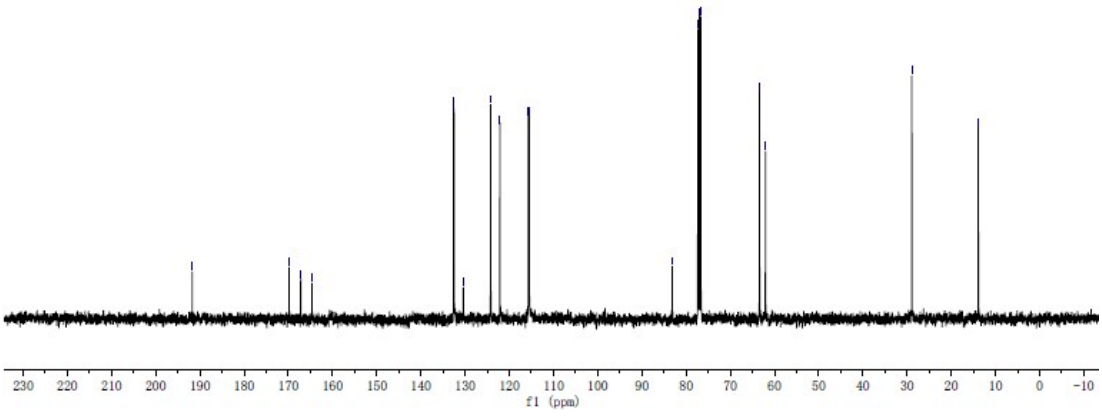
3d



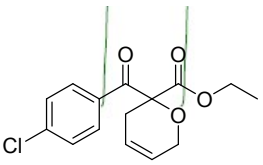
^{13}C NMR (100 MHz, $CDCl_3$)



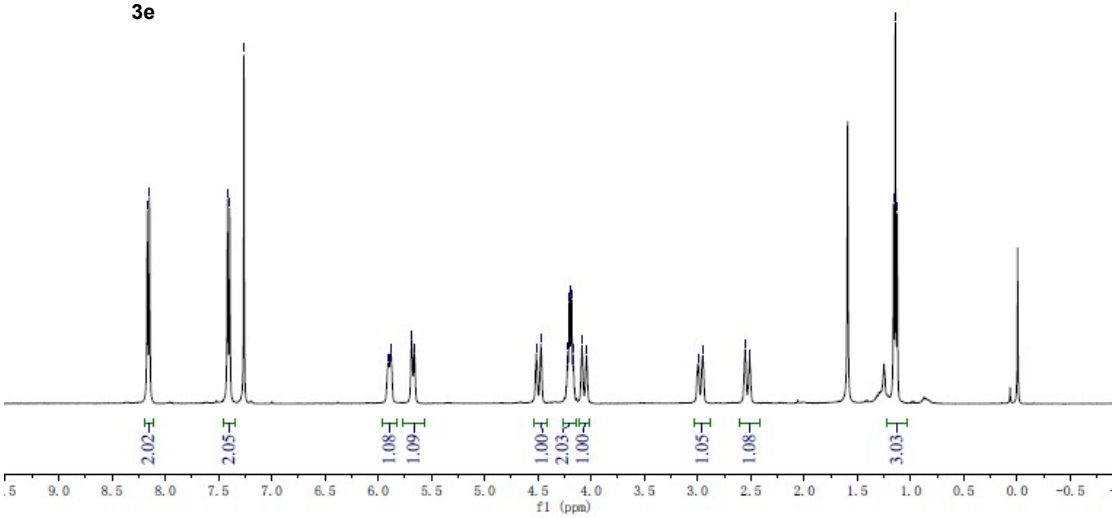
3d



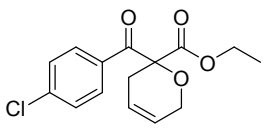
^{1}H NMR (400 MHz, $CDCl_3$)



3e

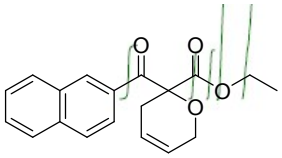


^{13}C NMR (100 MHz, $CDCl_3$)



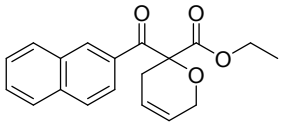
3e

^{1}H NMR (400 MHz, $CDCl_3$)

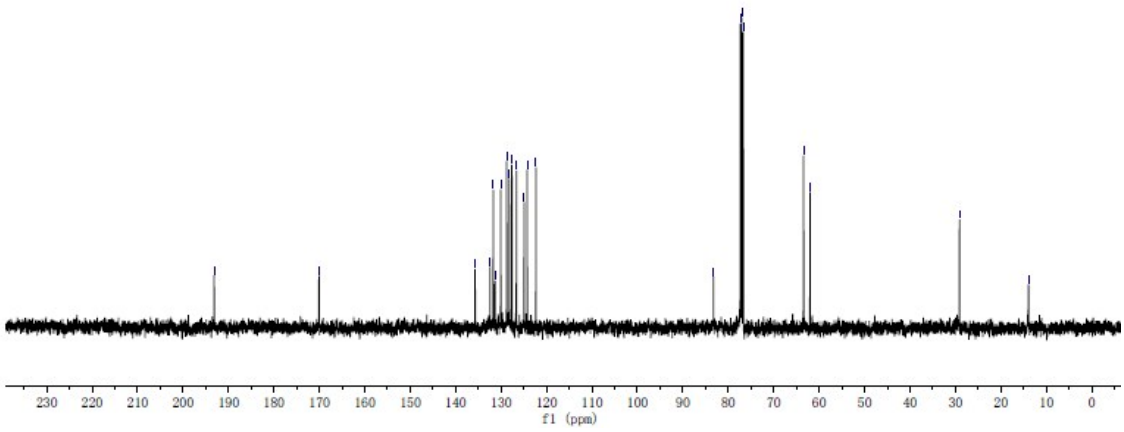


3f

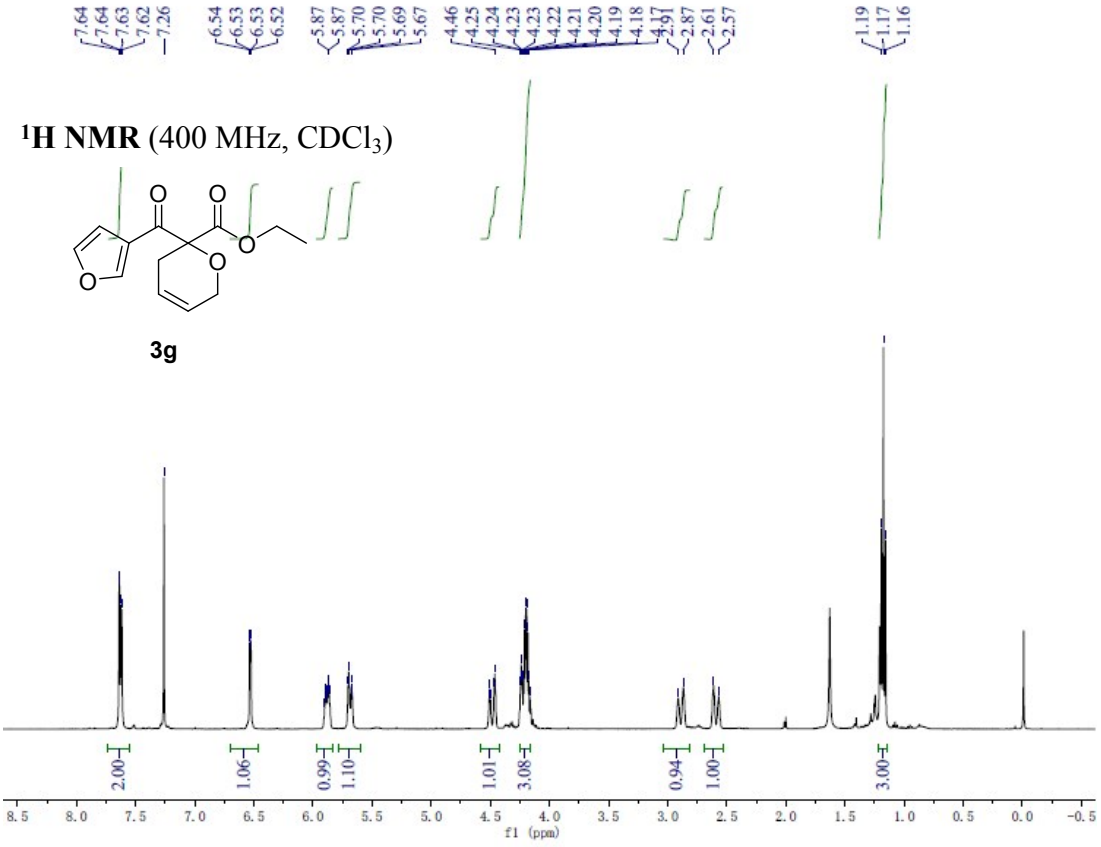
^{13}C NMR (100 MHz, $CDCl_3$)



3f

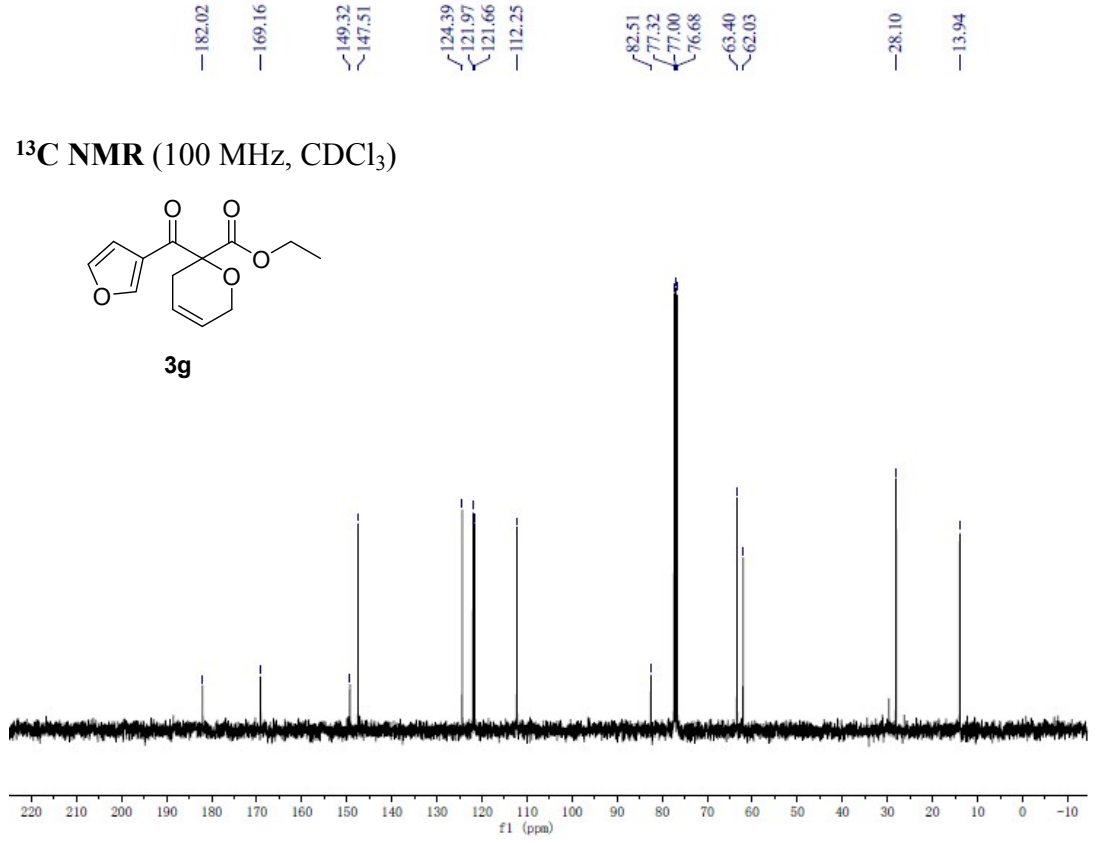


^{1}H NMR (400 MHz, $CDCl_3$)



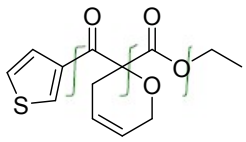
3g

^{13}C NMR (100 MHz, $CDCl_3$)



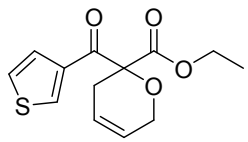
3g

^{1}H NMR (400 MHz, $CDCl_3$)



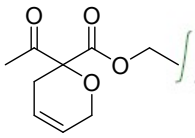
3h

^{13}C NMR (100 MHz, $CDCl_3$)



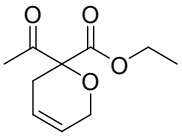
3h

^{1}H NMR (400 MHz, $CDCl_3$)



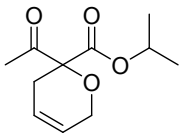
3i

^{13}C NMR (100 MHz, $CDCl_3$)



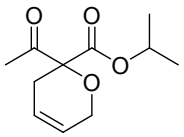
3i

^{1}H NMR (400 MHz, $CDCl_3$)



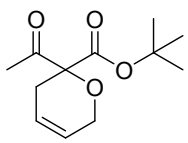
3j

^{13}C NMR (100 MHz, $CDCl_3$)



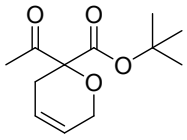
3j

^{1}H NMR (400 MHz, $CDCl_3$)

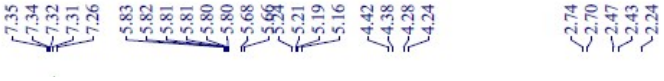


3k

^{13}C NMR (100 MHz, $CDCl_3$)

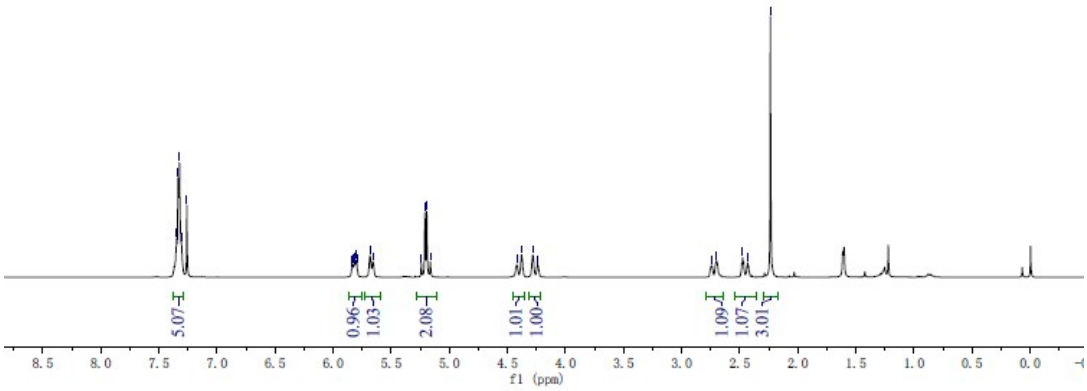


3k

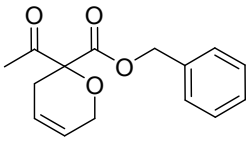


^{1}H NMR (400 MHz, $CDCl_3$)

3l

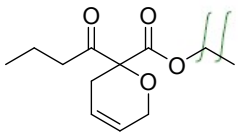


^{13}C NMR (100 MHz, $CDCl_3$)



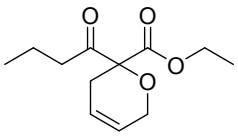
3l

^{1}H NMR (400 MHz, $CDCl_3$)



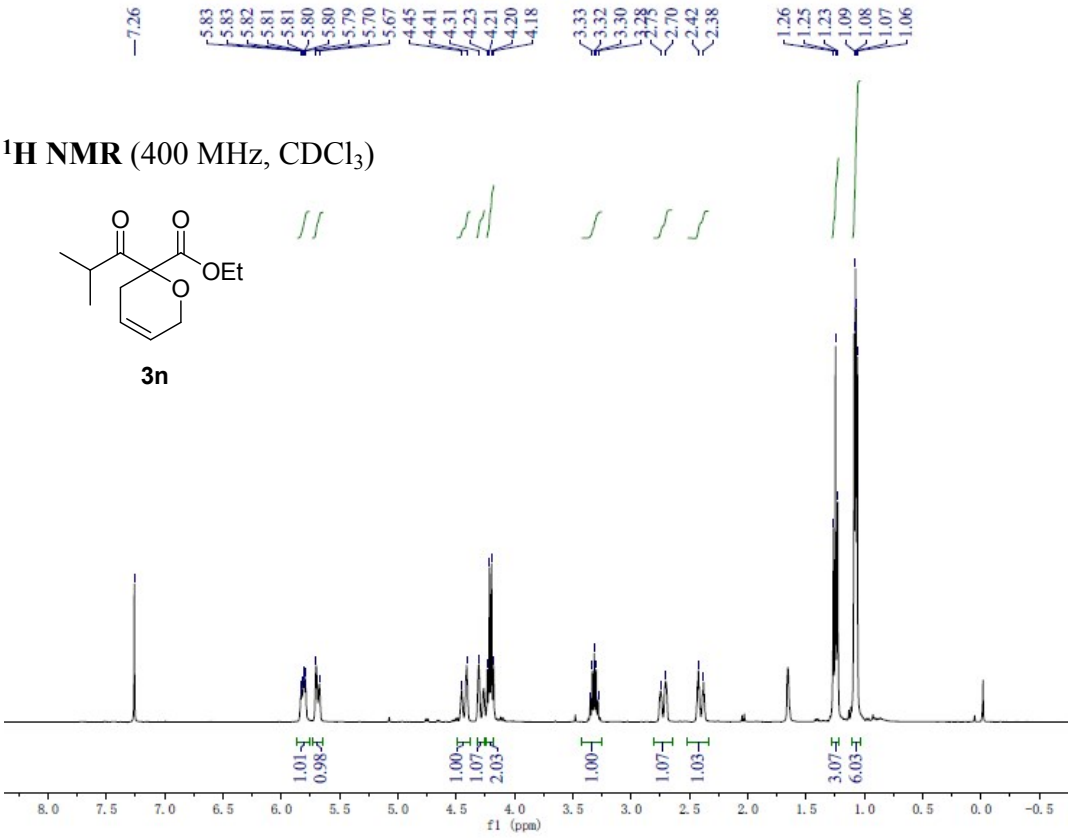
3m

^{13}C NMR (100 MHz, $CDCl_3$)



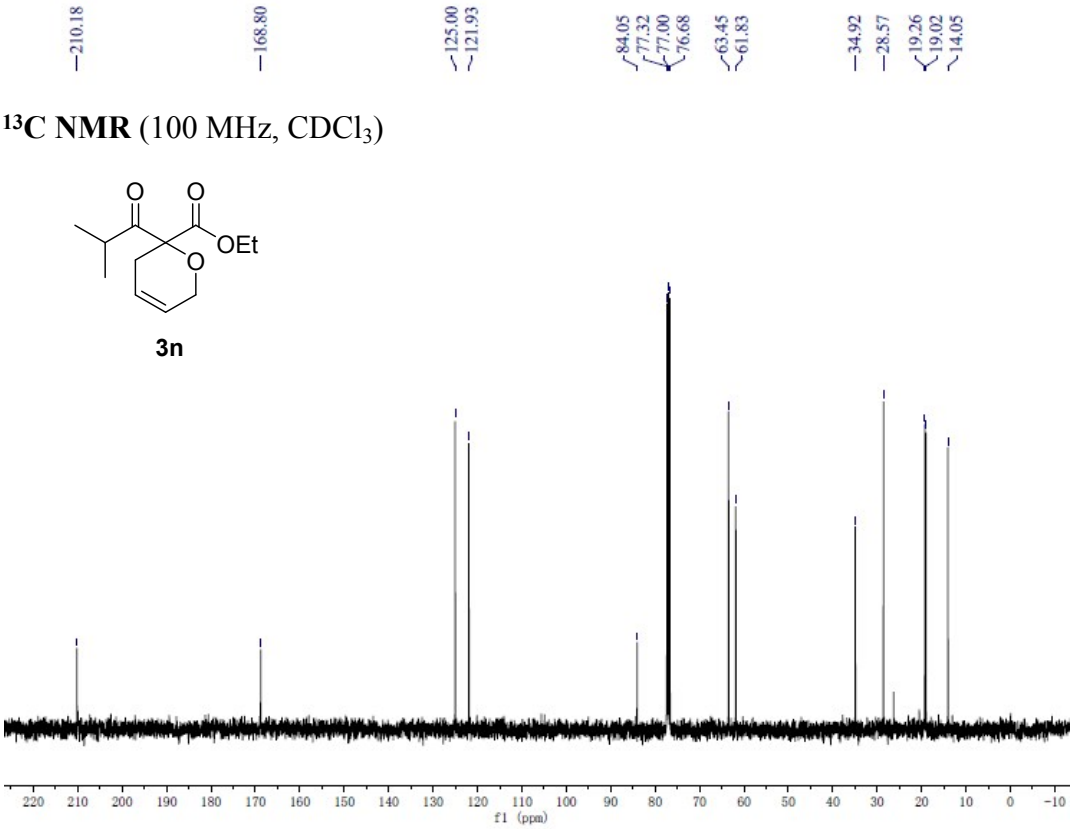
3m

^{1}H NMR (400 MHz, $CDCl_3$)



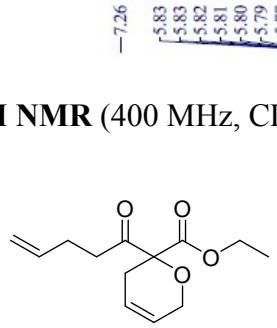
3n

^{13}C NMR (100 MHz, $CDCl_3$)



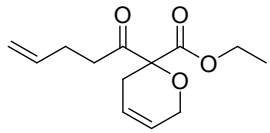
3n

^{1}H NMR (400 MHz, $CDCl_3$)



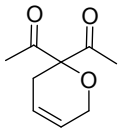
3o

^{13}C NMR (100 MHz, $CDCl_3$)



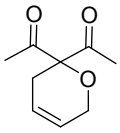
3o

^{1}H NMR (400 MHz, $CDCl_3$)



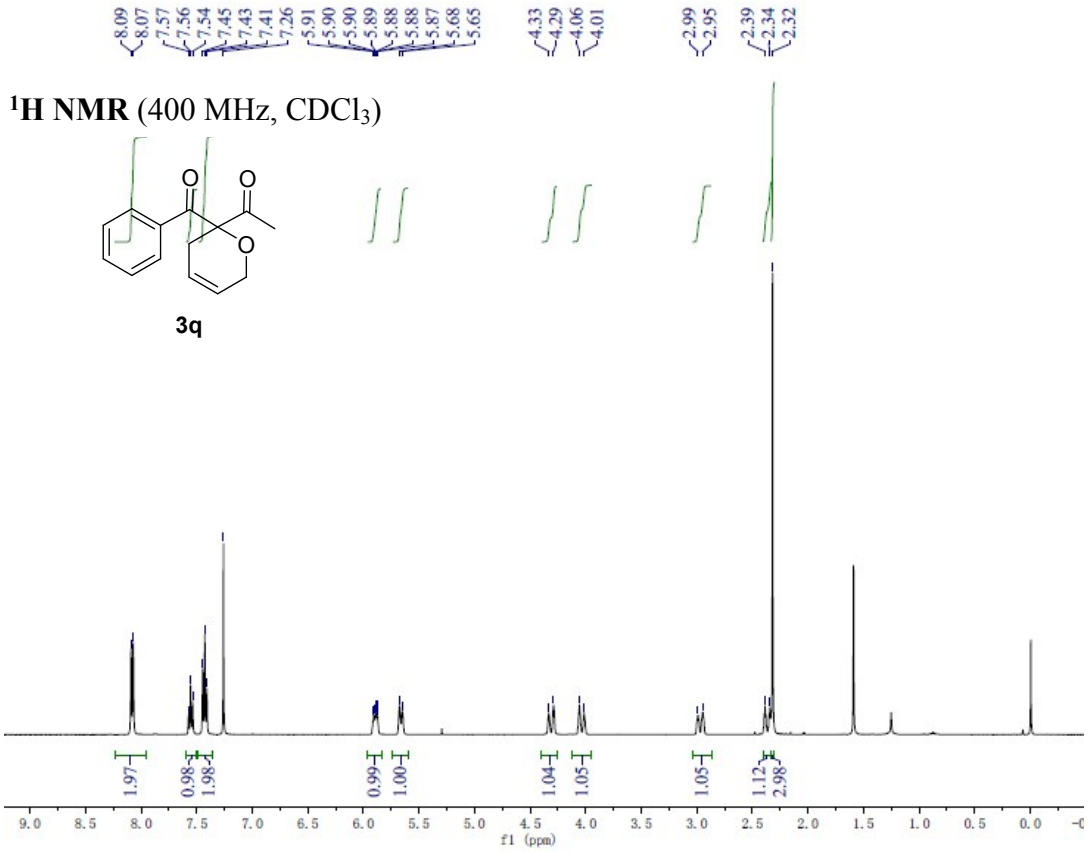
3p

^{13}C NMR (100 MHz, $CDCl_3$)

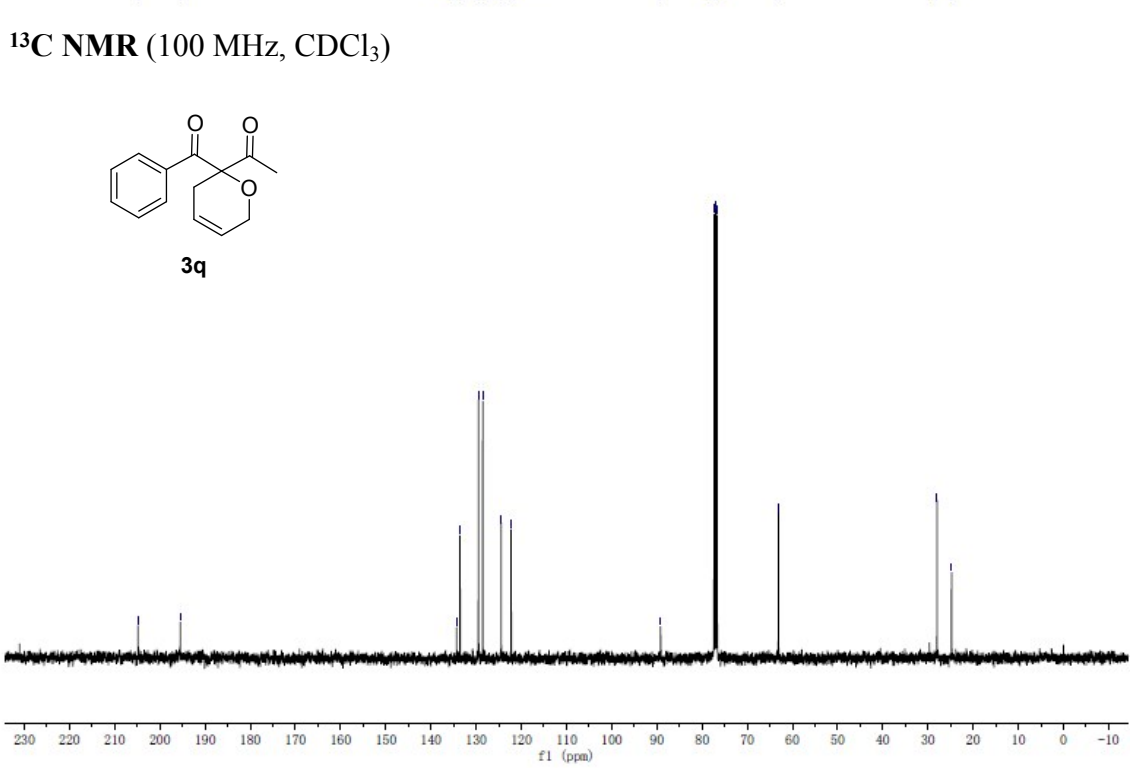


3p

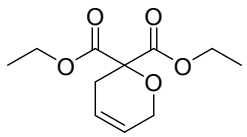
^{1}H NMR (400 MHz, $CDCl_3$)



^{13}C NMR (100 MHz, $CDCl_3$)

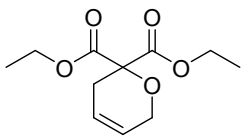


^{1}H NMR (400 MHz, $CDCl_3$)



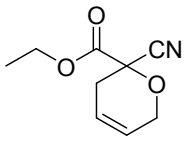
3r

^{13}C NMR (100 MHz, $CDCl_3$)



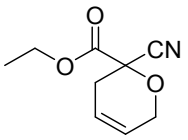
3r

^{1}H NMR (400 MHz, $CDCl_3$)



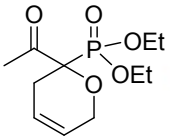
3s

^{13}C NMR (100 MHz, $CDCl_3$)



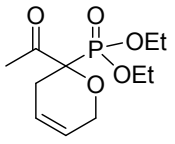
3s

^{1}H NMR (400 MHz, $CDCl_3$)



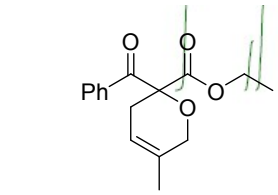
3t

^{13}C NMR (100 MHz, $CDCl_3$)



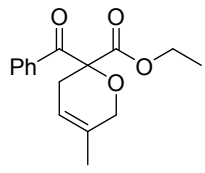
3t

^{1}H NMR (400 MHz, $CDCl_3$)



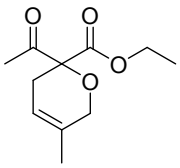
5a

^{13}C NMR (100 MHz, $CDCl_3$)



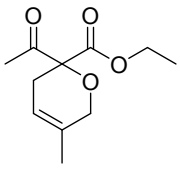
5a

^{1}H NMR (400 MHz, $CDCl_3$)



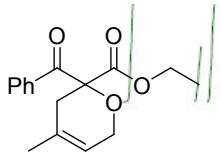
5b

^{13}C NMR (100 MHz, $CDCl_3$)



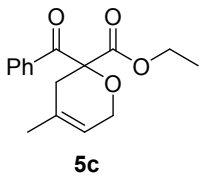
5b

^{1}H NMR (400 MHz, $CDCl_3$)



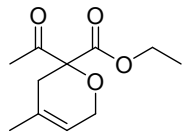
5c

^{13}C NMR (100 MHz, $CDCl_3$)



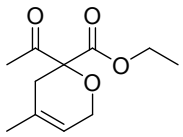
5c

^{1}H NMR (400 MHz, $CDCl_3$)



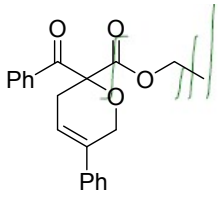
5d

^{13}C NMR (100 MHz, $CDCl_3$)

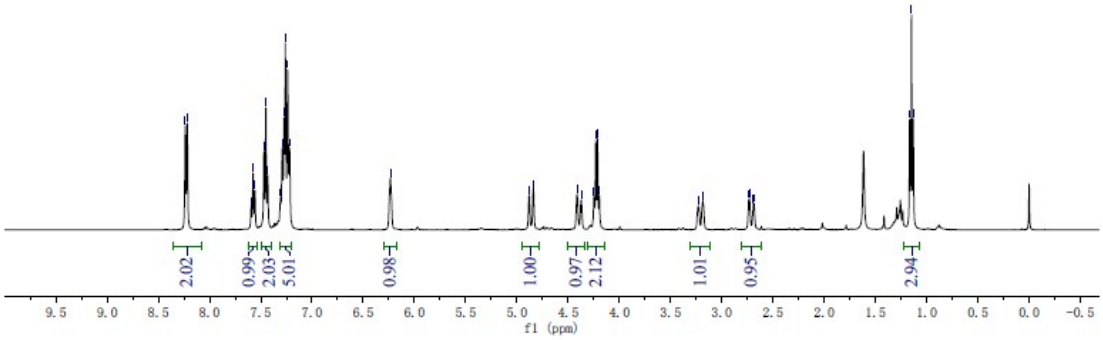


5d

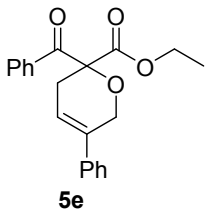
^{1}H NMR (400 MHz, $CDCl_3$)



5e

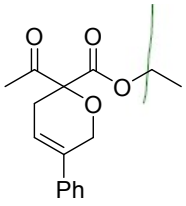


^{13}C NMR (100 MHz, $CDCl_3$)



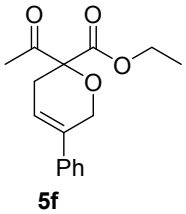
5e

^{1}H NMR (400 MHz, $CDCl_3$)

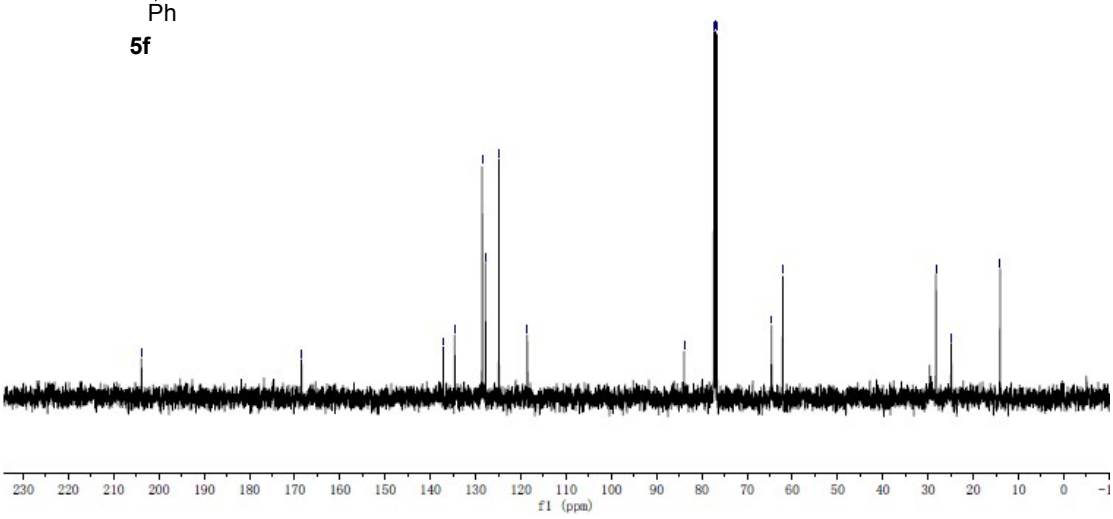


5f

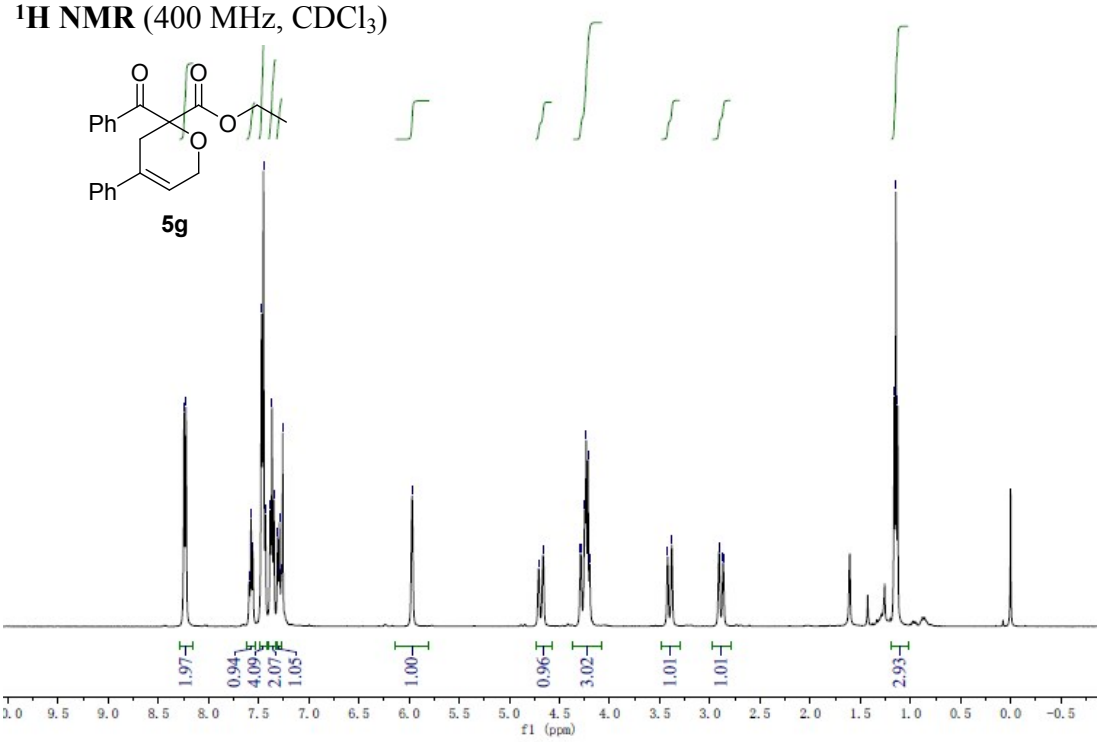
^{13}C NMR (100 MHz, $CDCl_3$)



5f

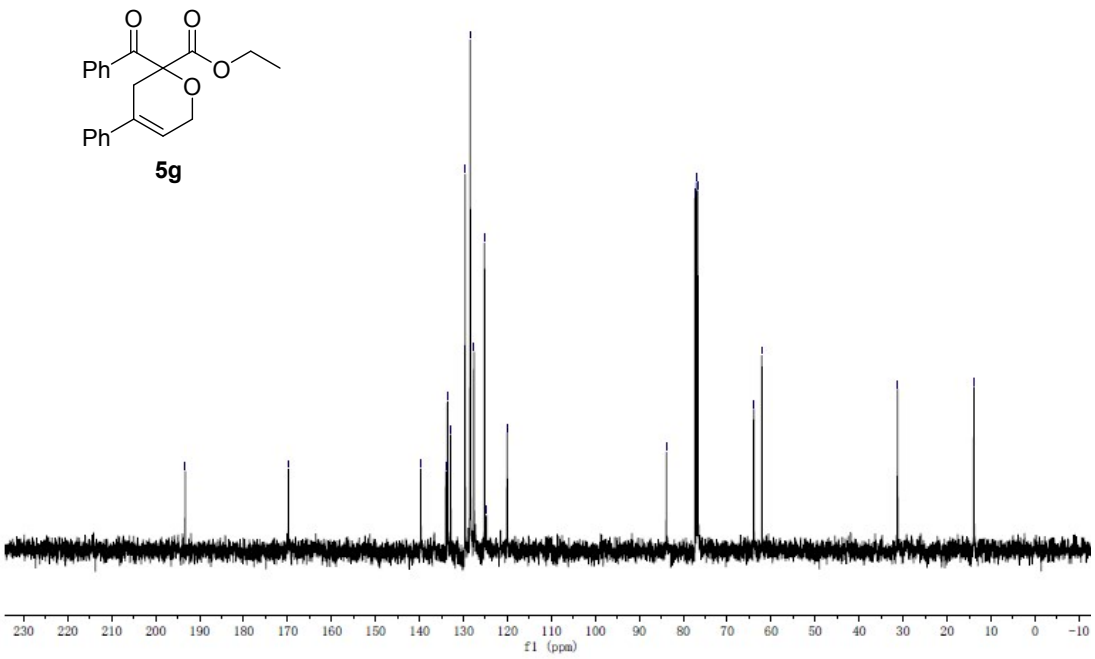


^{1}H NMR (400 MHz, $CDCl_3$)



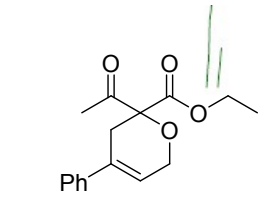
5g

^{13}C NMR (100 MHz, $CDCl_3$)



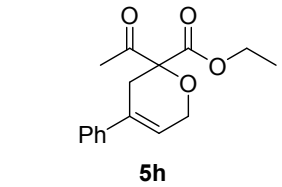
5g

^{1}H NMR (400 MHz, $CDCl_3$)



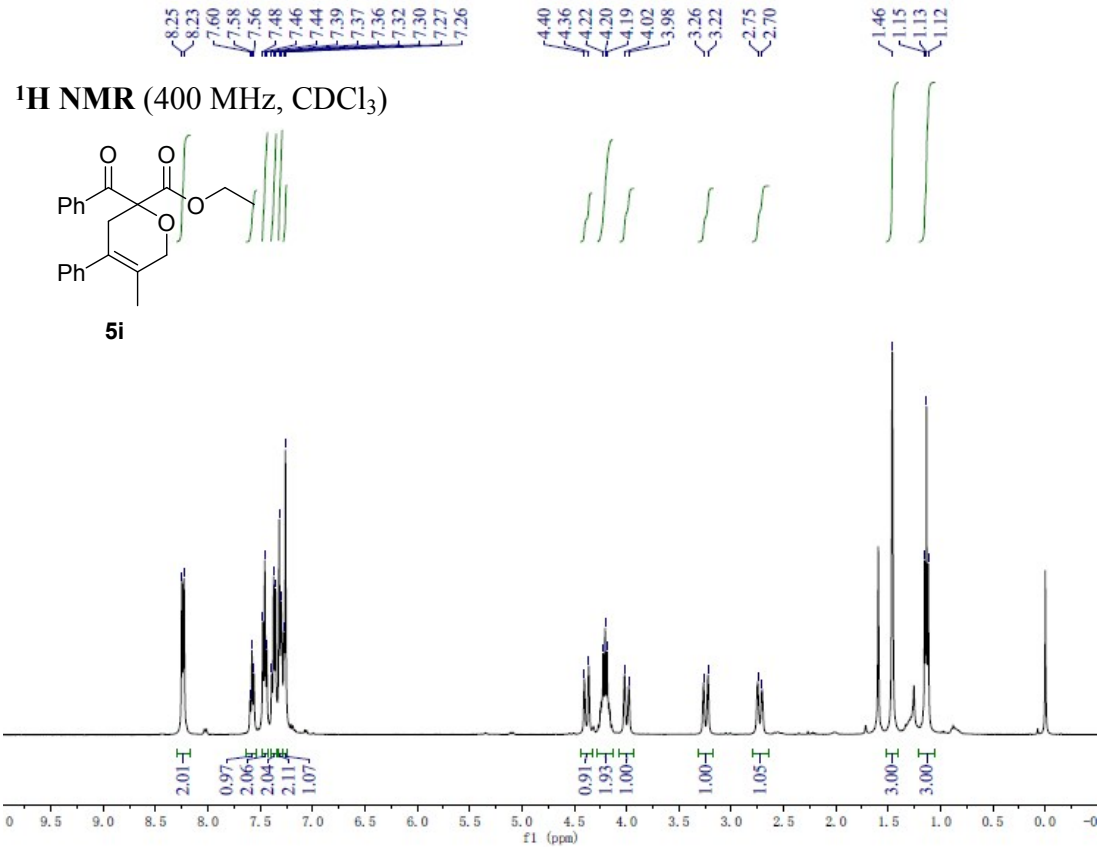
5h

^{13}C NMR (100 MHz, $CDCl_3$)

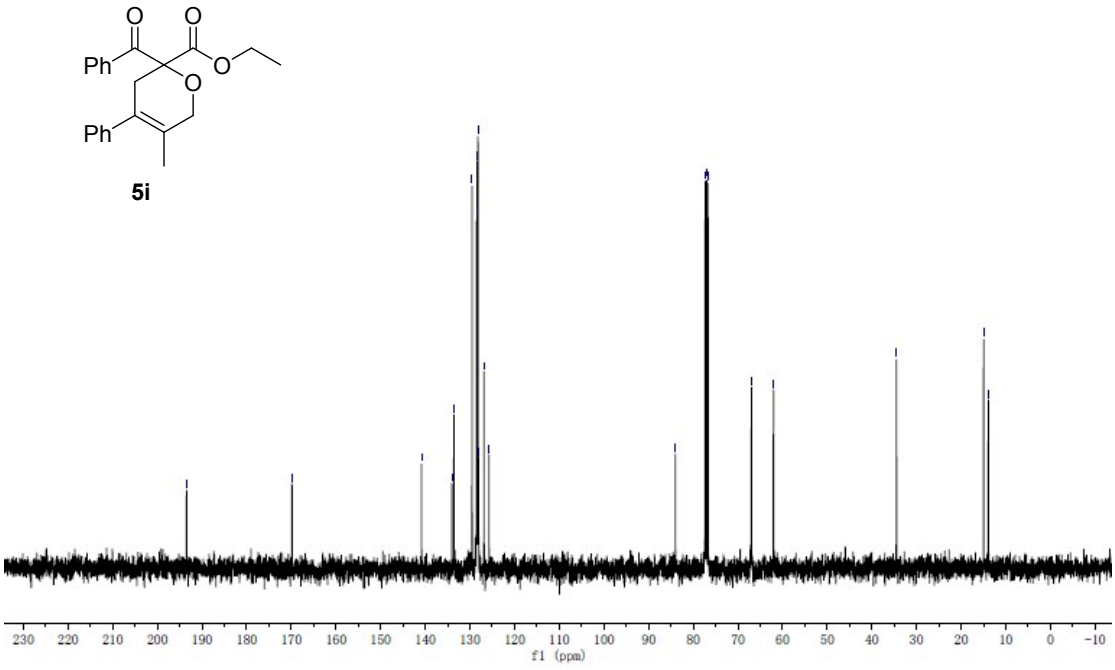


5h

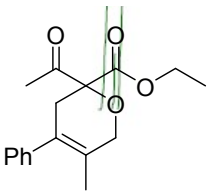
^{1}H NMR (400 MHz, $CDCl_3$)



^{13}C NMR (100 MHz, $CDCl_3$)

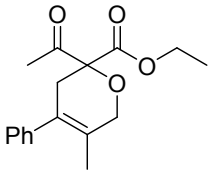


^{1}H NMR (400 MHz, $CDCl_3$)



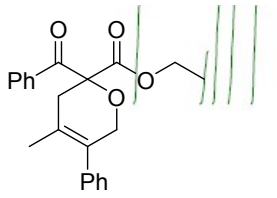
5j

^{13}C NMR (100 MHz, $CDCl_3$)

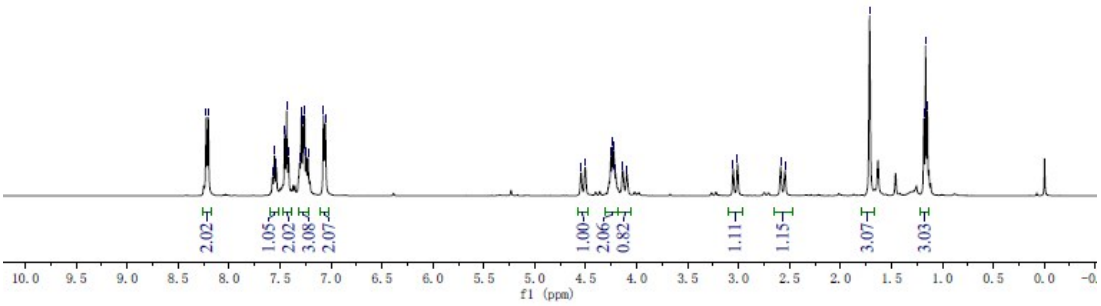


5j

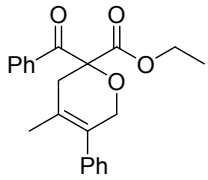
^{1}H NMR (400 MHz, $CDCl_3$)



5k

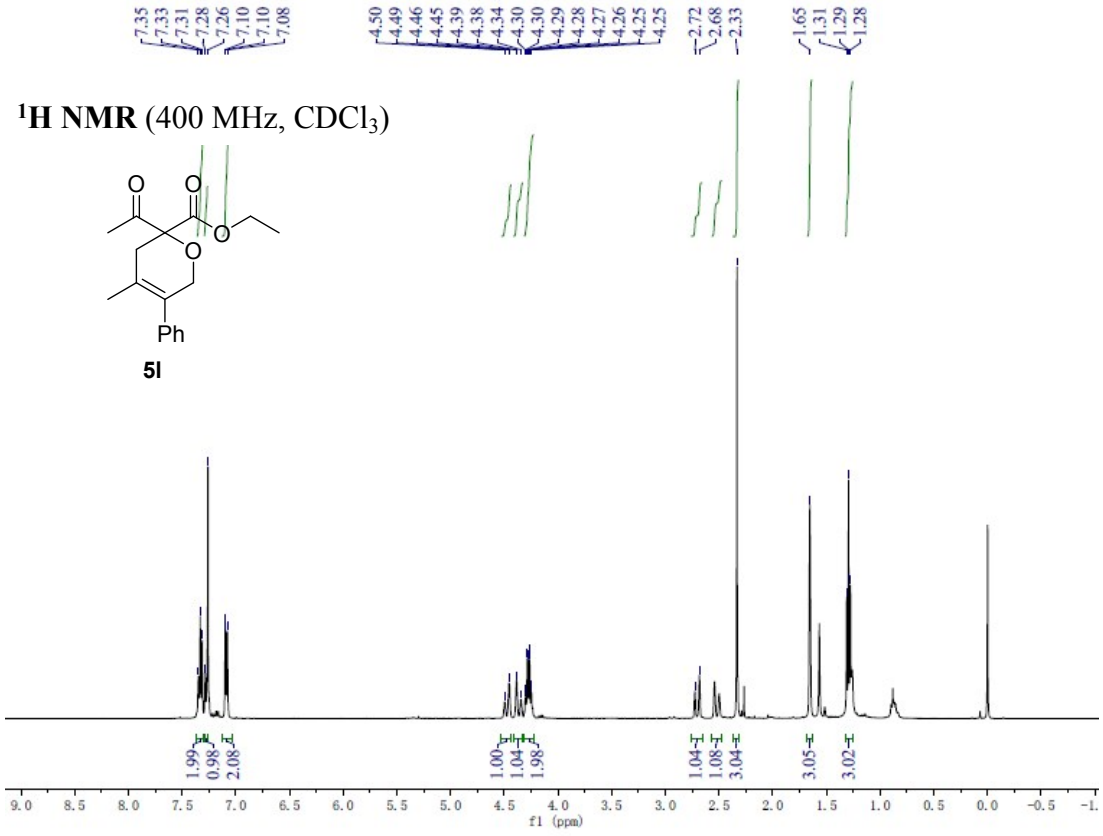


^{13}C NMR (100 MHz, $CDCl_3$)



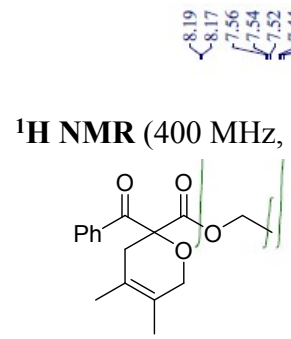
5k

^{1}H NMR (400 MHz, $CDCl_3$)



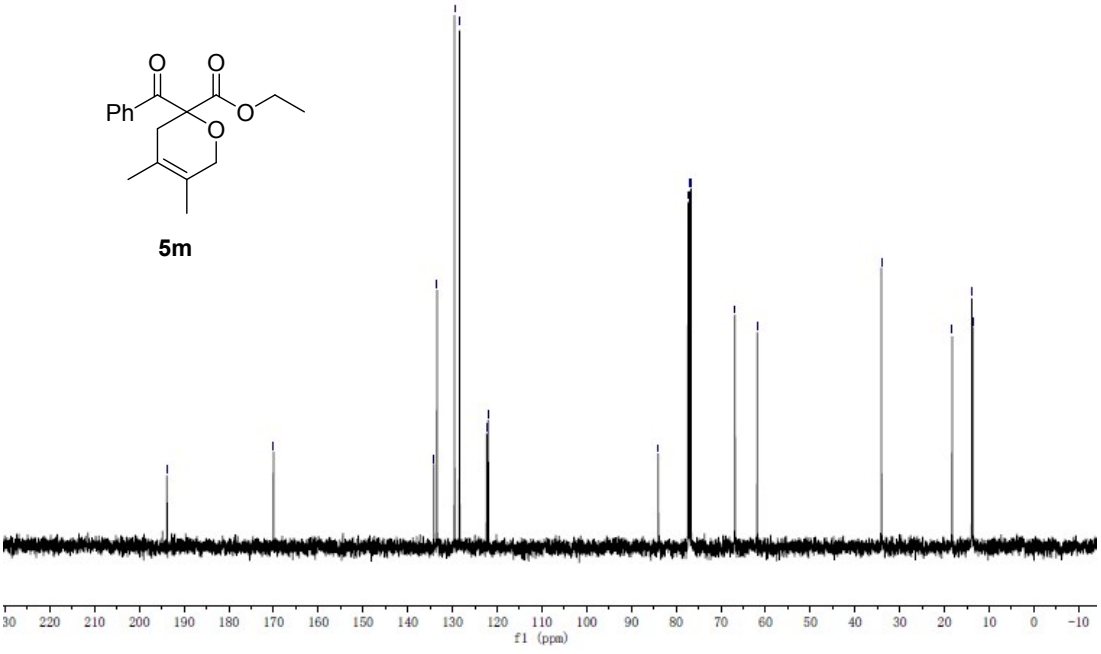
^{13}C NMR (100 MHz, $CDCl_3$)

^{1}H NMR (400 MHz, $CDCl_3$)

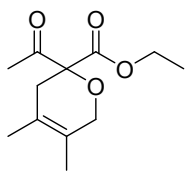


5m

^{13}C NMR (100 MHz, $CDCl_3$)

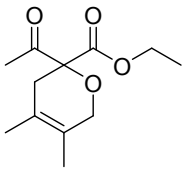


^{1}H NMR (400 MHz, $CDCl_3$)



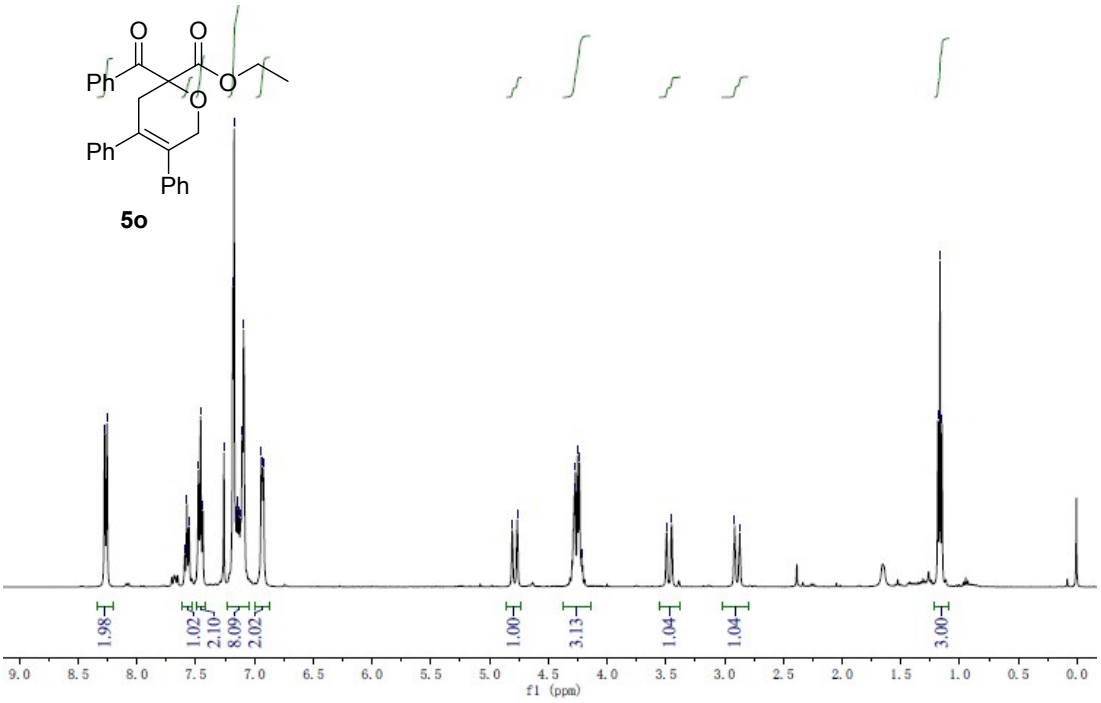
5n

^{13}C NMR (100 MHz, $CDCl_3$)



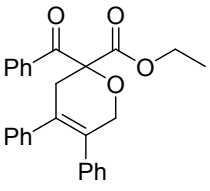
5n

^{1}H NMR (400 MHz, $CDCl_3$)

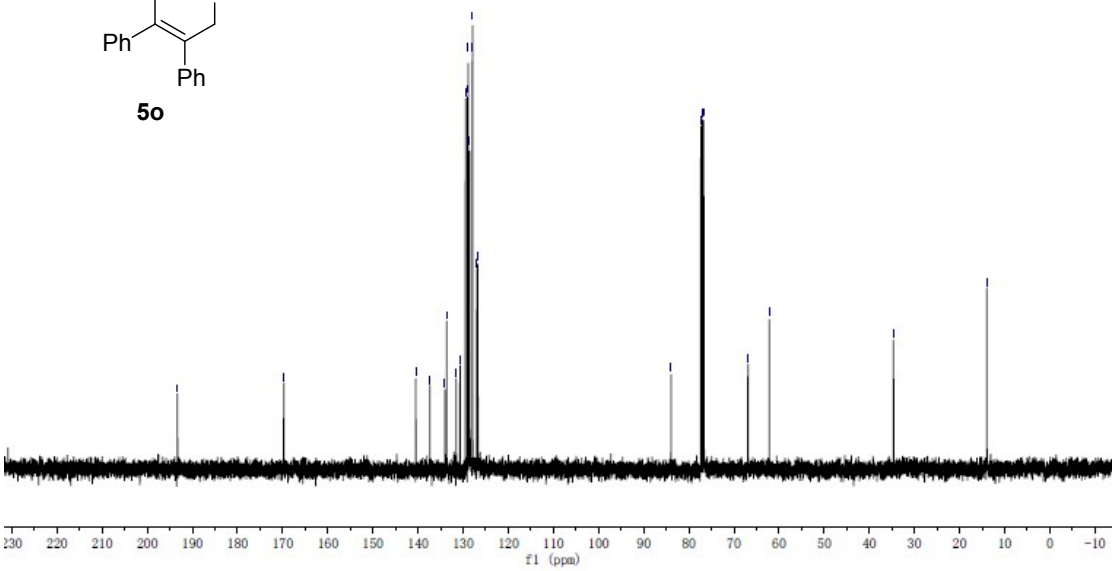


5o

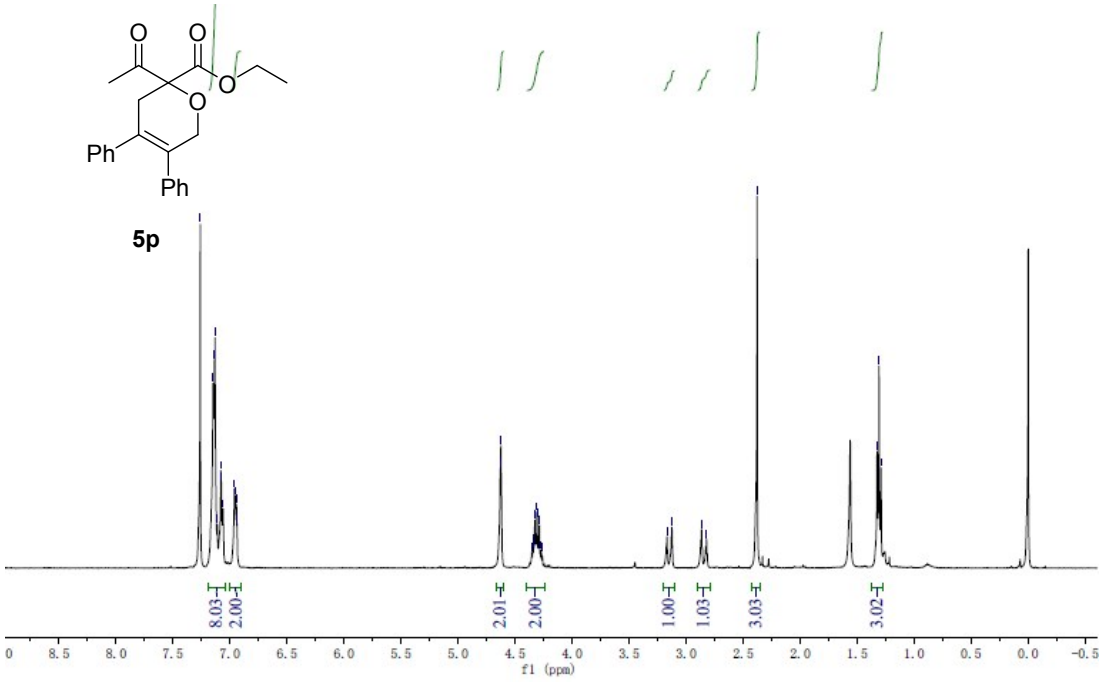
^{13}C NMR (100 MHz, $CDCl_3$)

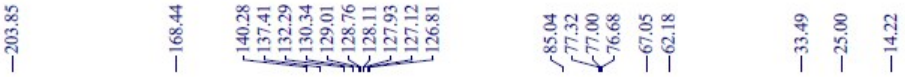


5o

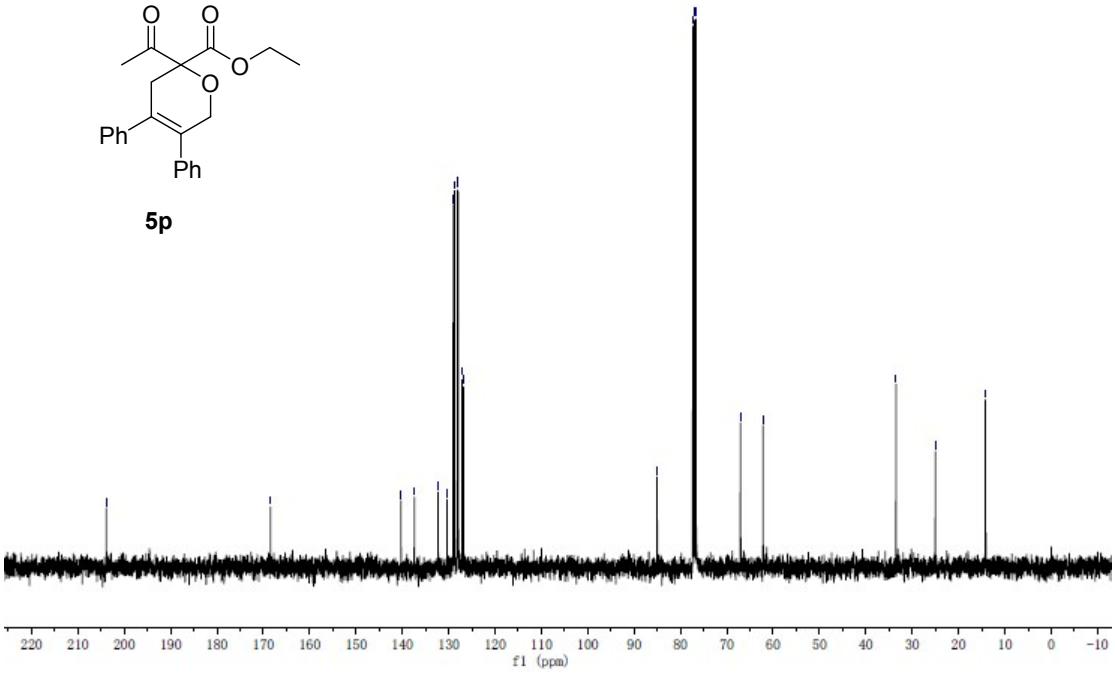


^{1}H NMR (400 MHz, $CDCl_3$)

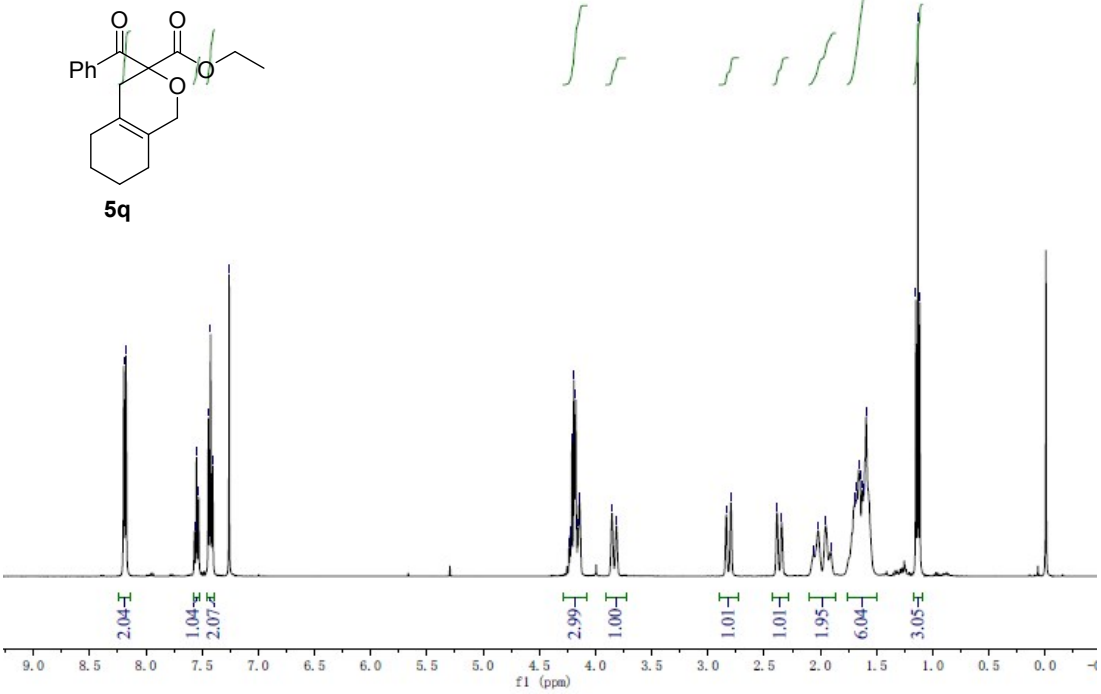




^{13}C NMR (100 MHz, $CDCl_3$)

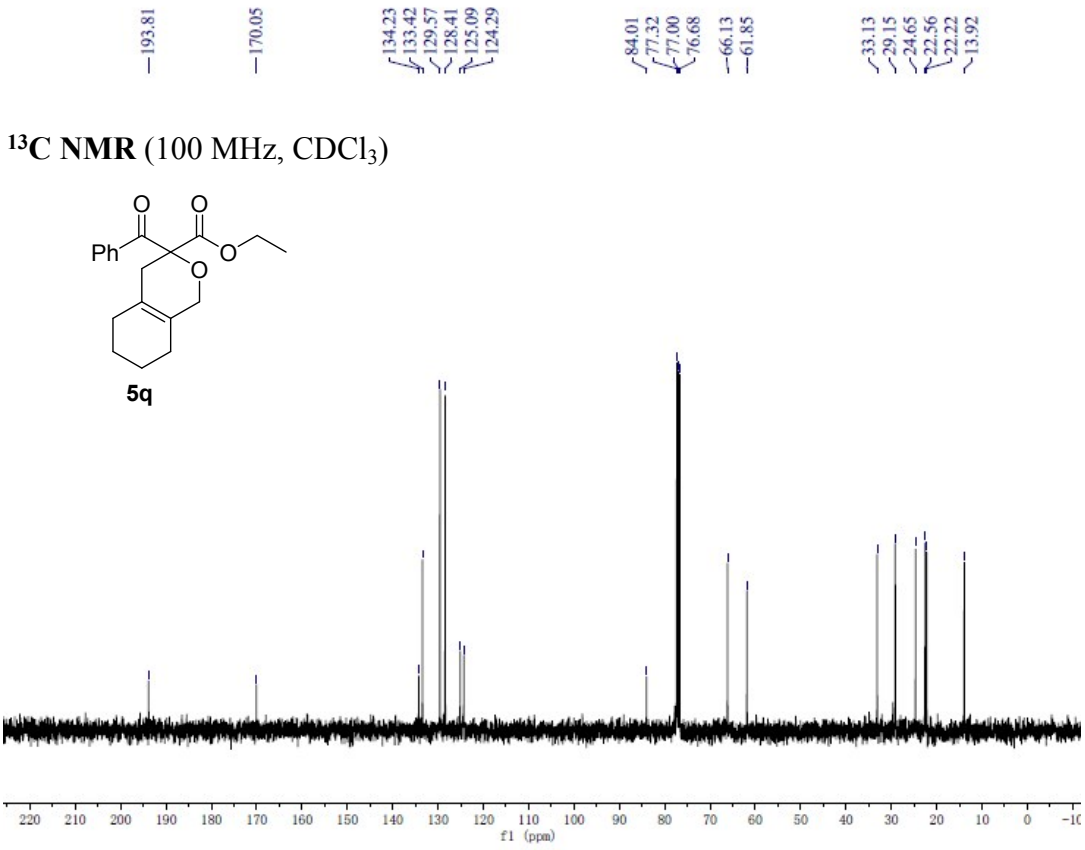


^{1}H NMR (400 MHz, $CDCl_3$)



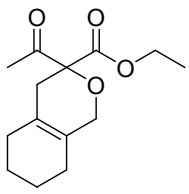
5q

^{13}C NMR (100 MHz, $CDCl_3$)



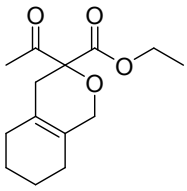
5q

^{1}H NMR (400 MHz, $CDCl_3$)



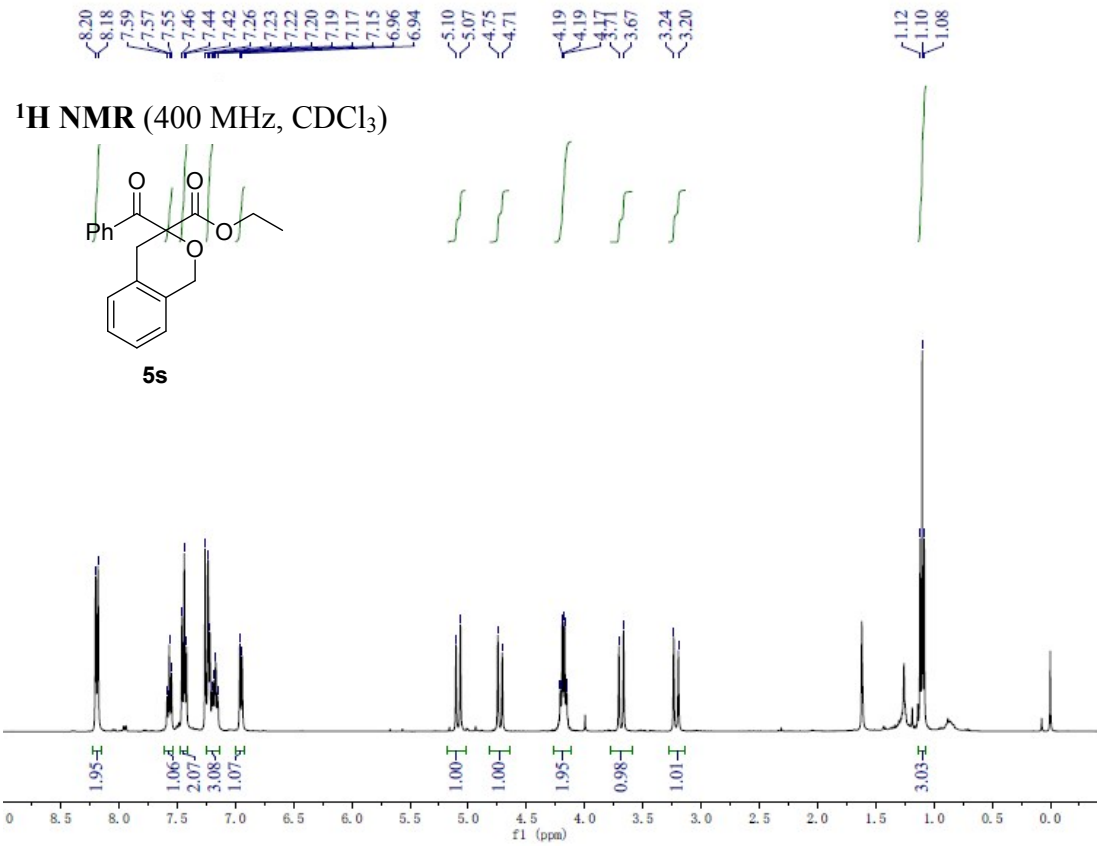
5r

^{13}C NMR (100 MHz, $CDCl_3$)

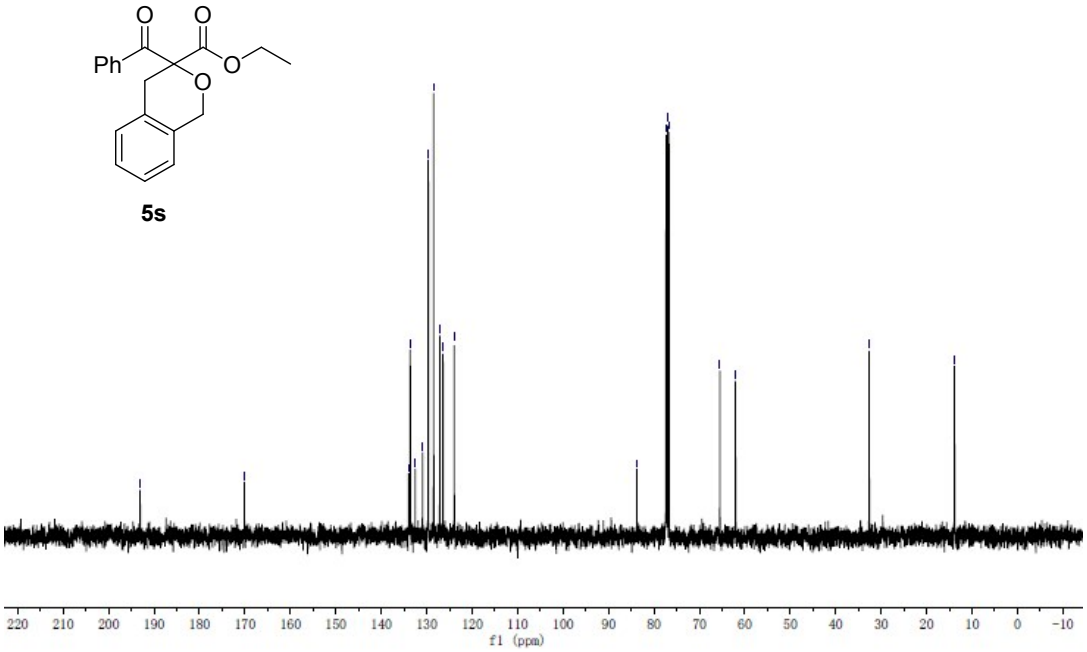


5r

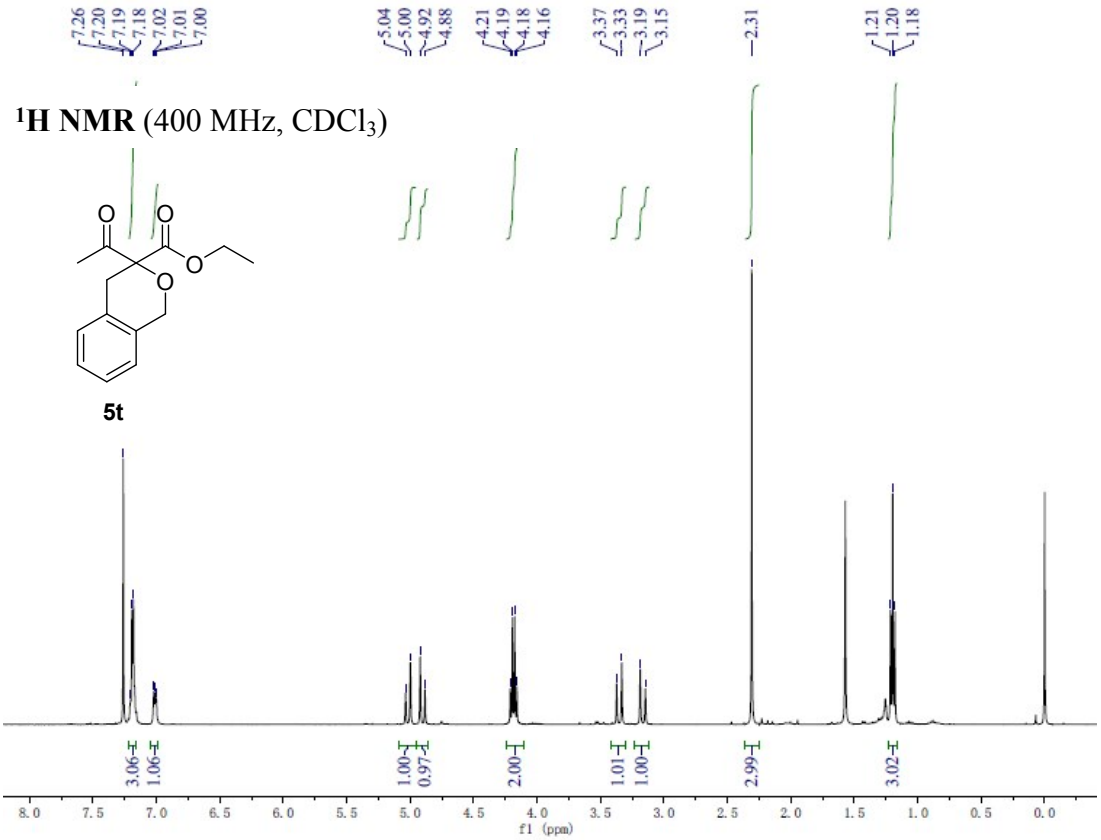
^{1}H NMR (400 MHz, $CDCl_3$)



^{13}C NMR (100 MHz, $CDCl_3$)

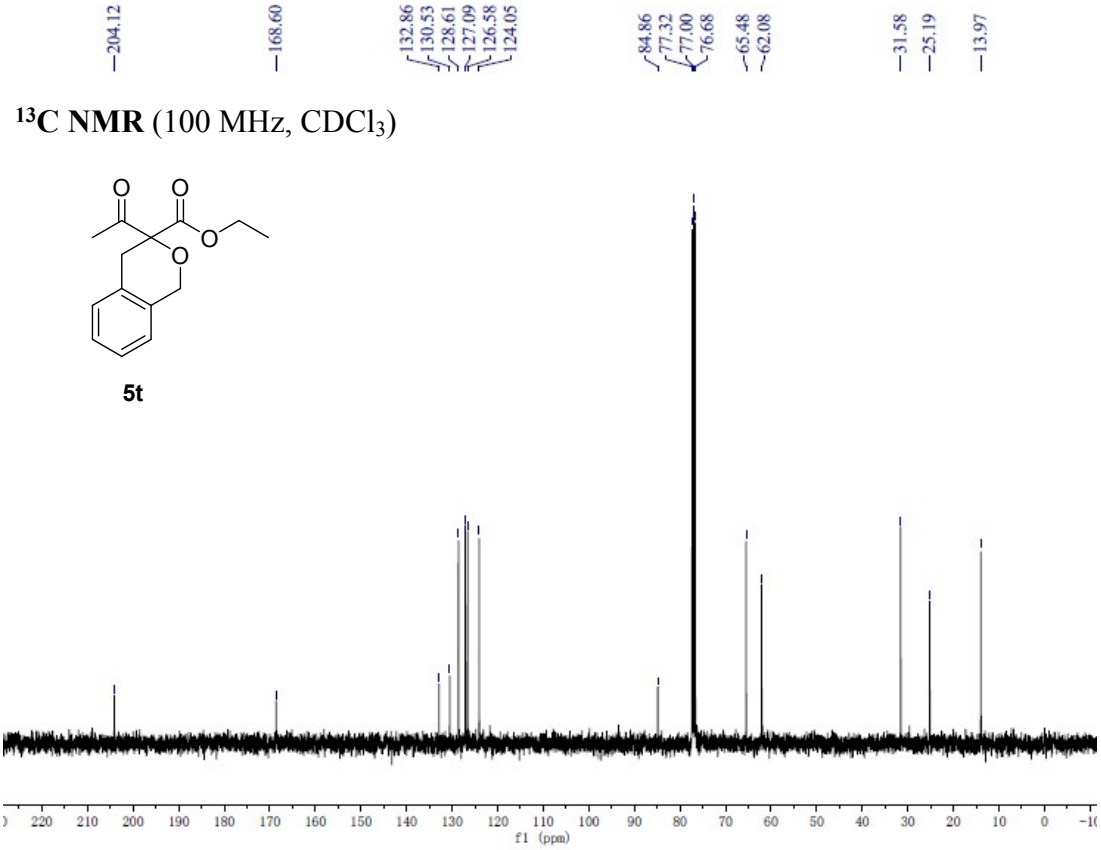


^{1}H NMR (400 MHz, $CDCl_3$)



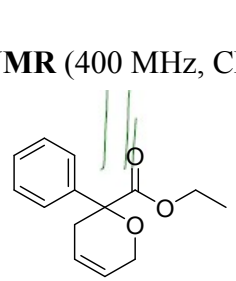
5t

^{13}C NMR (100 MHz, $CDCl_3$)



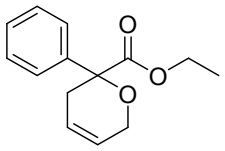
5t

^{1}H NMR (400 MHz, $CDCl_3$)



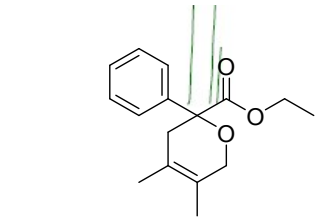
7a

^{13}C NMR (100 MHz, $CDCl_3$)



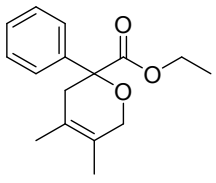
7a

^{1}H NMR (400 MHz, $CDCl_3$)



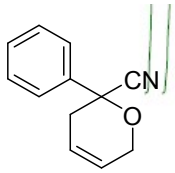
7b

^{13}C NMR (100 MHz, $CDCl_3$)

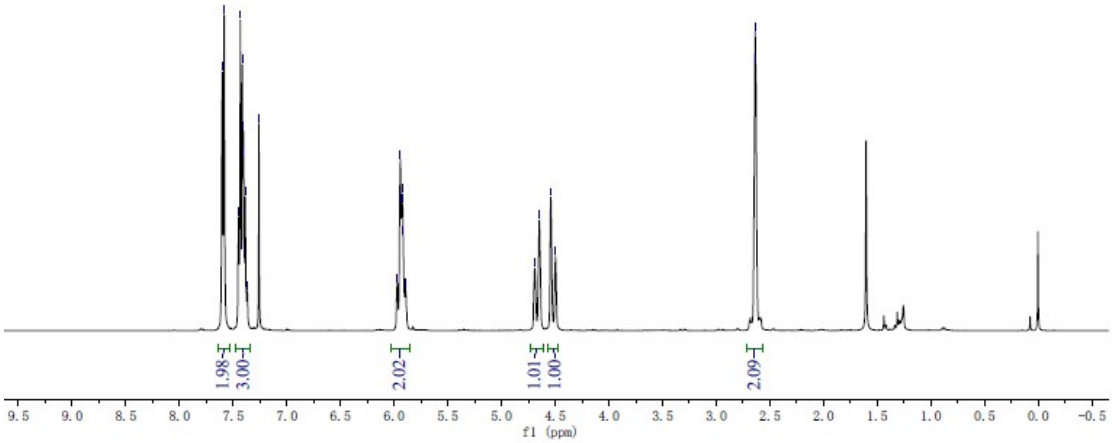


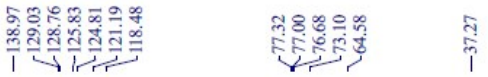
7b

^{1}H NMR (400 MHz, $CDCl_3$)

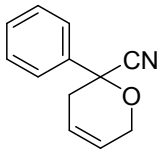


7c



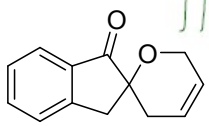


^{13}C NMR (100 MHz, $CDCl_3$)

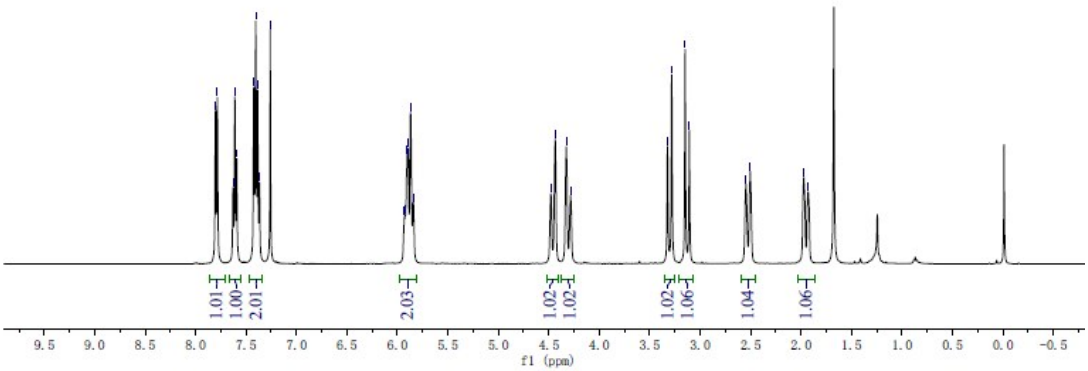


7c

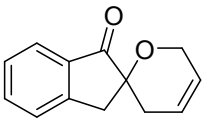
^{1}H NMR (400 MHz, $CDCl_3$)



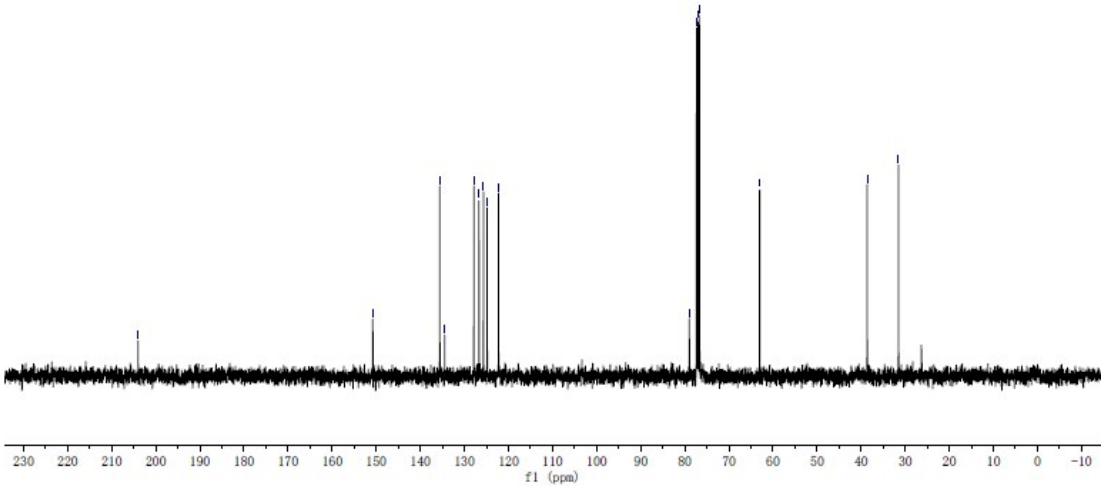
7d

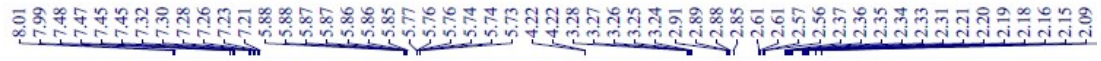


^{13}C NMR (100 MHz, $CDCl_3$)

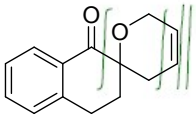


7d

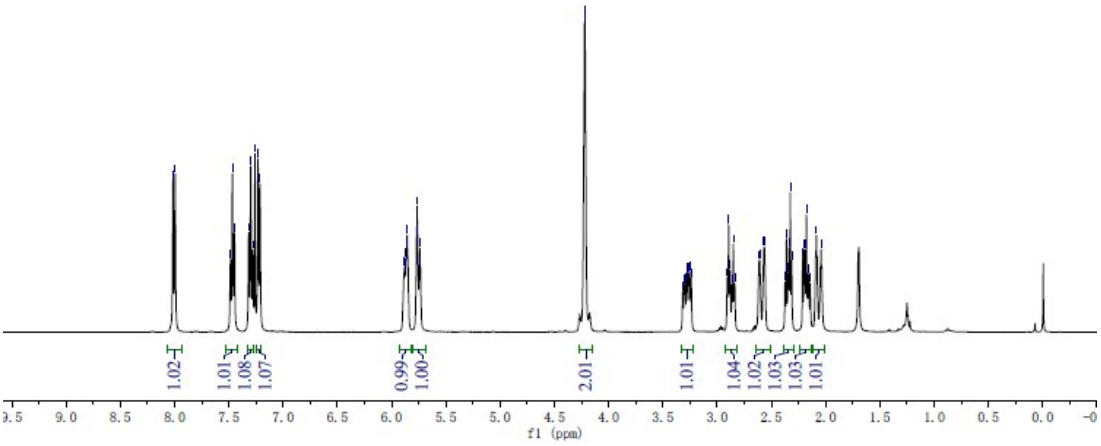


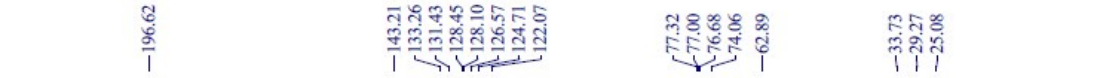


^{1}H NMR (400 MHz, $CDCl_3$)

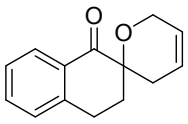


7e

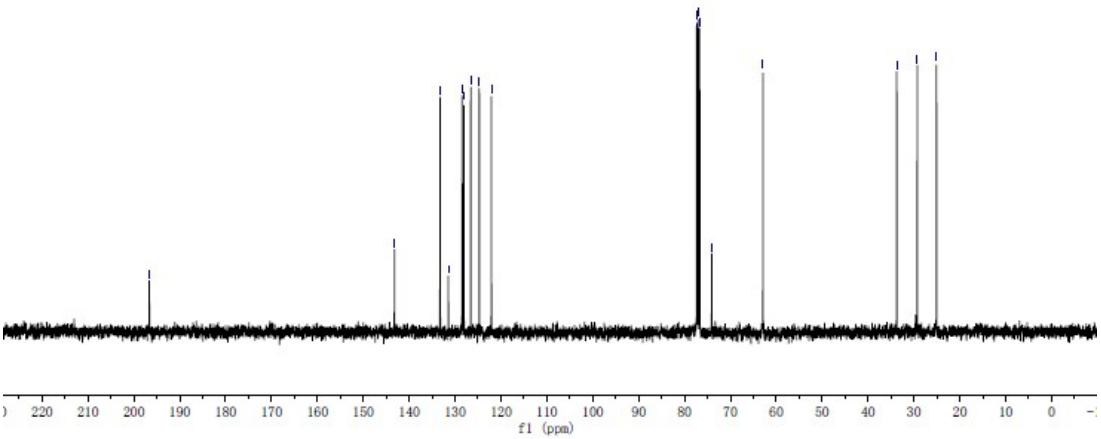




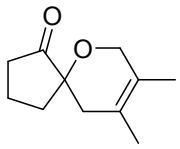
^{13}C NMR (100 MHz, $CDCl_3$)



7e

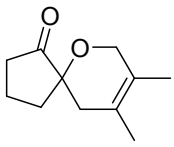


^{1}H NMR (400 MHz, $CDCl_3$)



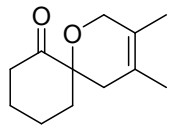
7f

^{13}C NMR (100 MHz, $CDCl_3$)



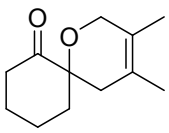
7f

^{1}H NMR (400 MHz, $CDCl_3$)



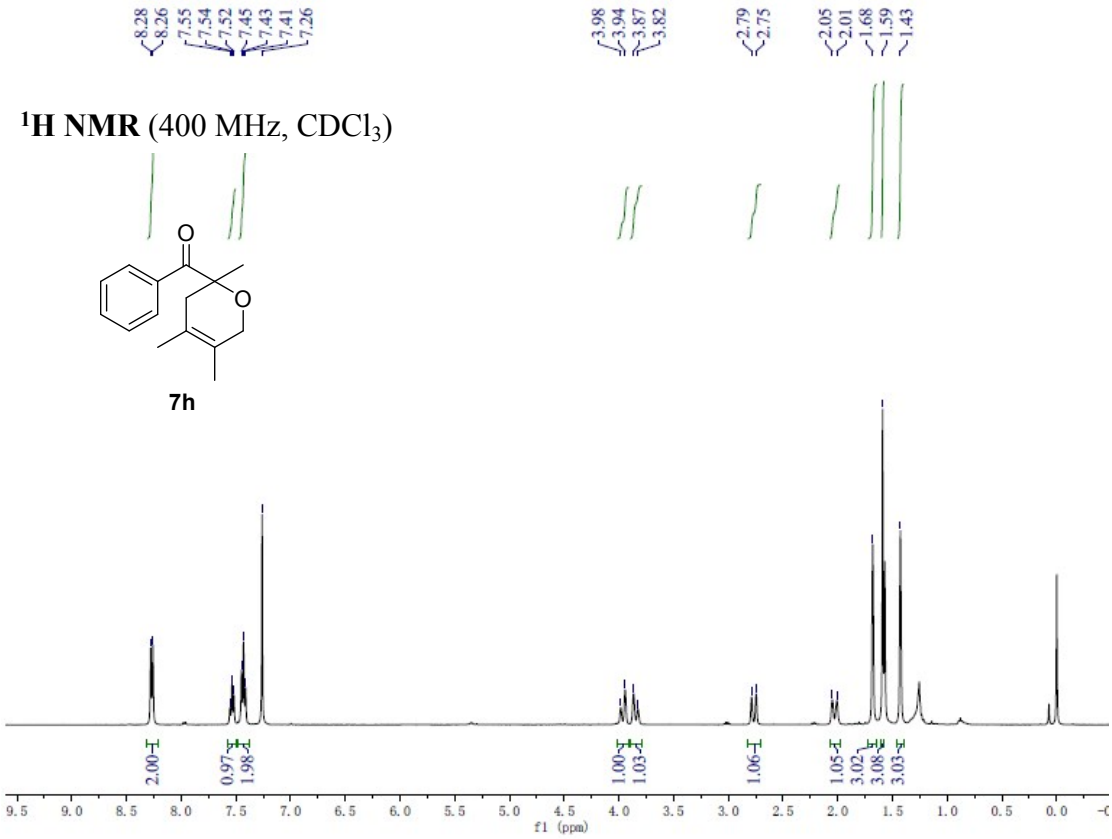
7g

^{13}C NMR (100 MHz, $CDCl_3$)



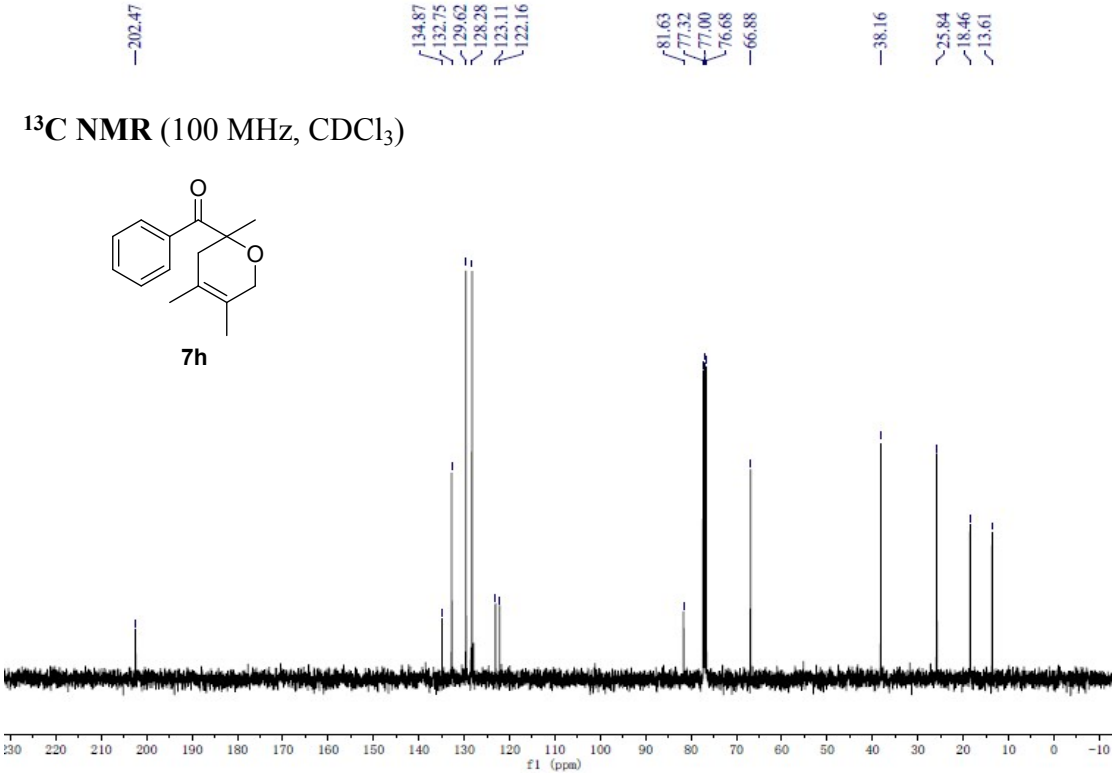
7g

^{1}H NMR (400 MHz, $CDCl_3$)



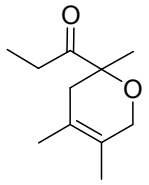
7h

^{13}C NMR (100 MHz, $CDCl_3$)



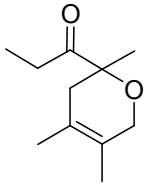
7h

^{1}H NMR (400 MHz, $CDCl_3$)



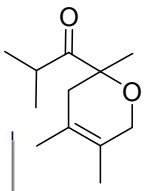
7i

^{13}C NMR (100 MHz, $CDCl_3$)



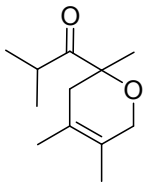
7i

^{1}H NMR (400 MHz, $CDCl_3$)



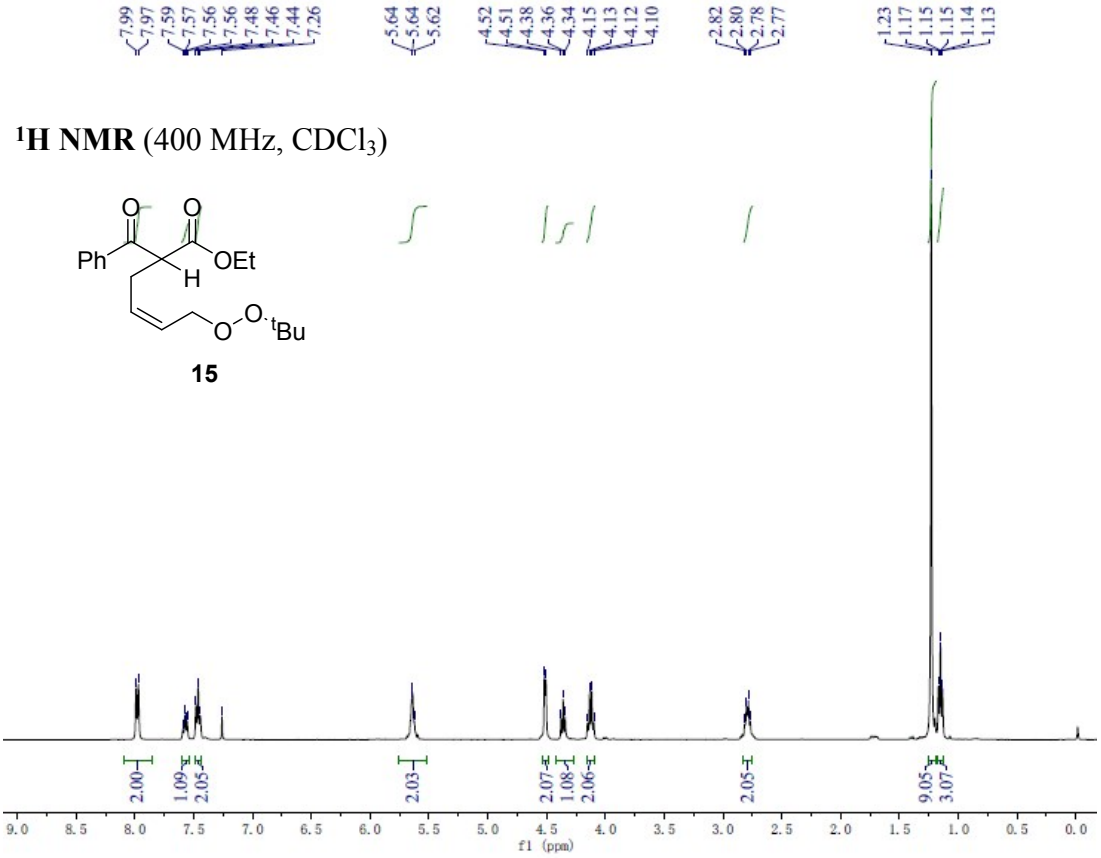
7j

^{13}C NMR (100 MHz, $CDCl_3$)



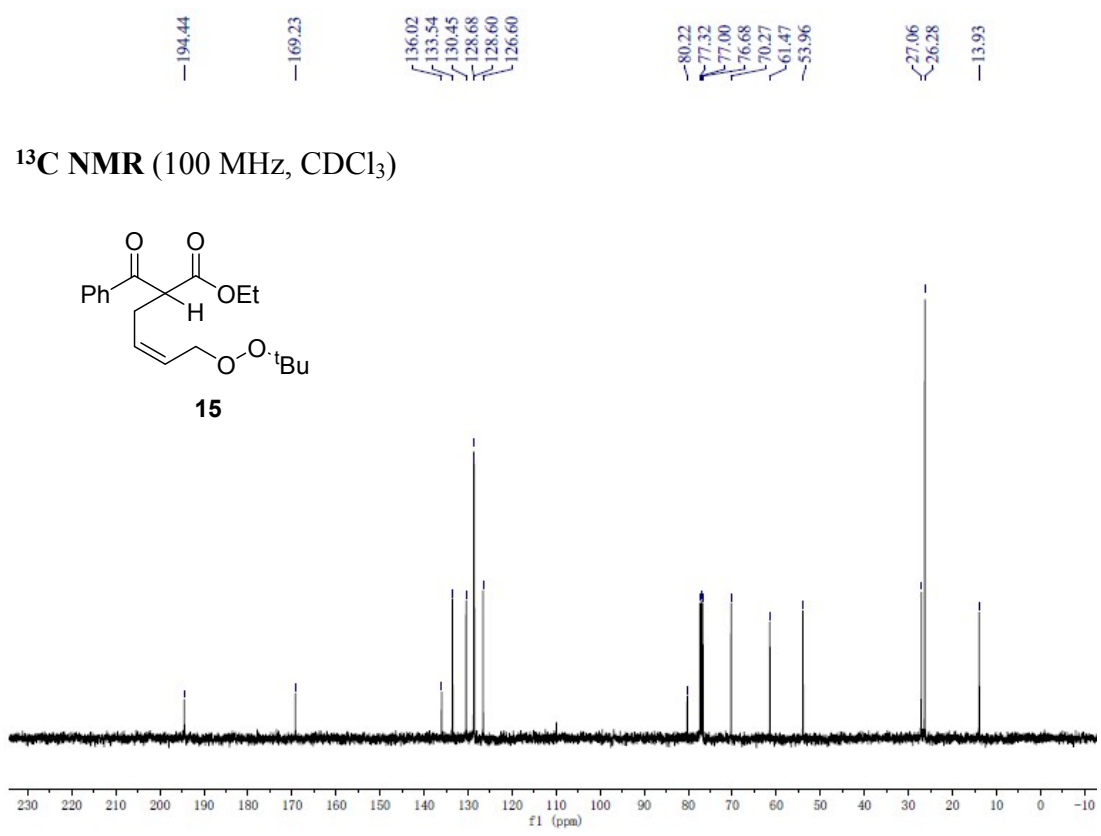
7j

^{1}H NMR (400 MHz, $CDCl_3$)



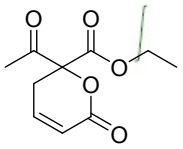
15

^{13}C NMR (100 MHz, $CDCl_3$)



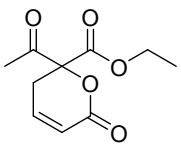
15

^{1}H NMR (400 MHz, $CDCl_3$)



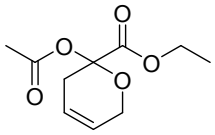
8

^{13}C NMR (100 MHz, $CDCl_3$)



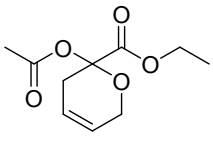
8

^{1}H NMR (400 MHz, $CDCl_3$)



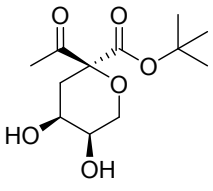
9

^{13}C NMR (100 MHz, $CDCl_3$)



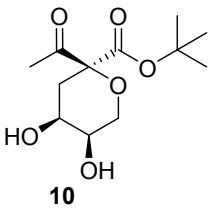
9

^{1}H NMR (400 MHz, $CDCl_3$)



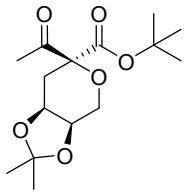
10

^{13}C NMR (100 MHz, $CDCl_3$)



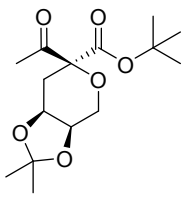
10

^{1}H NMR (400 MHz, $CDCl_3$)



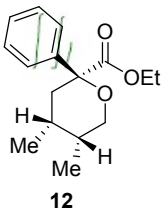
11

^{13}C NMR (100 MHz, $CDCl_3$)



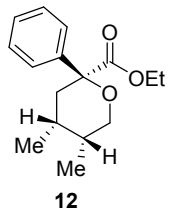
11

^{1}H NMR (400 MHz, $CDCl_3$)

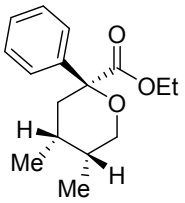


12

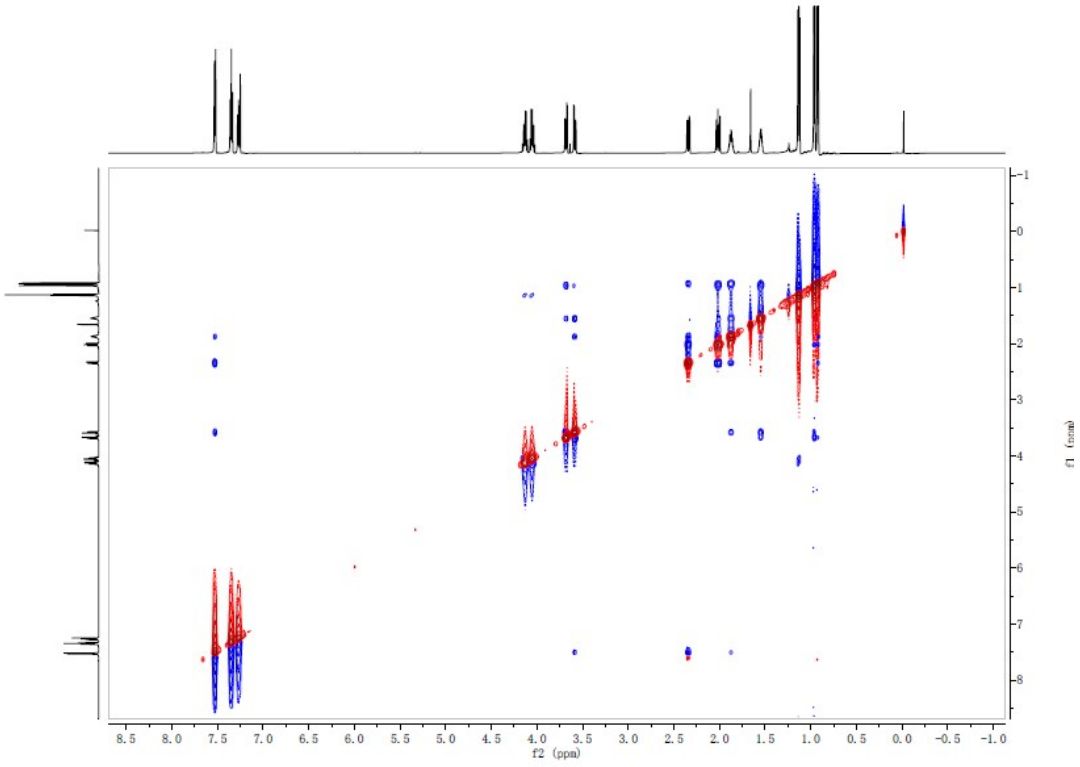
^{13}C NMR (100 MHz, $CDCl_3$)

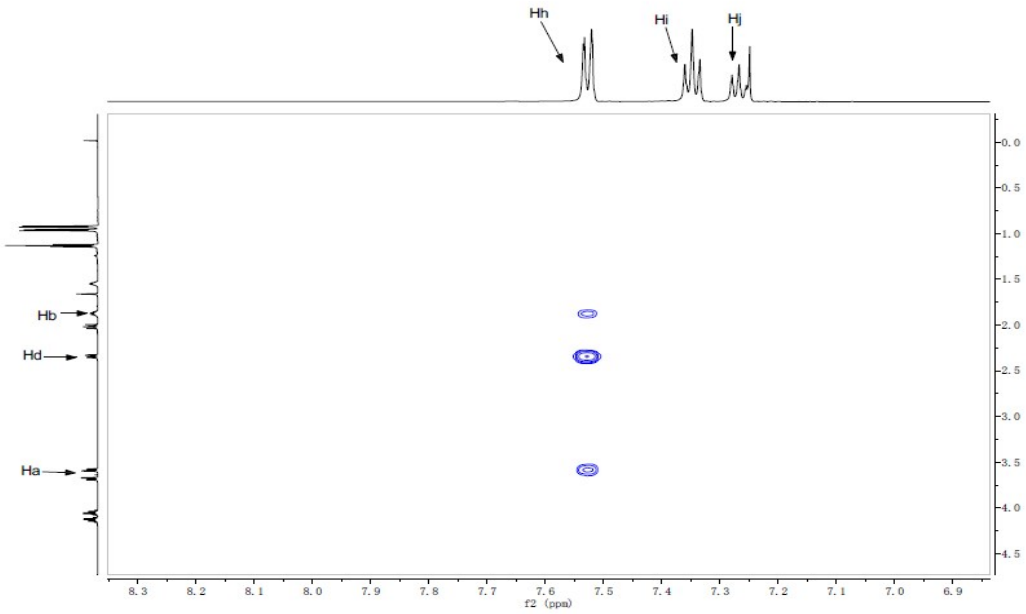


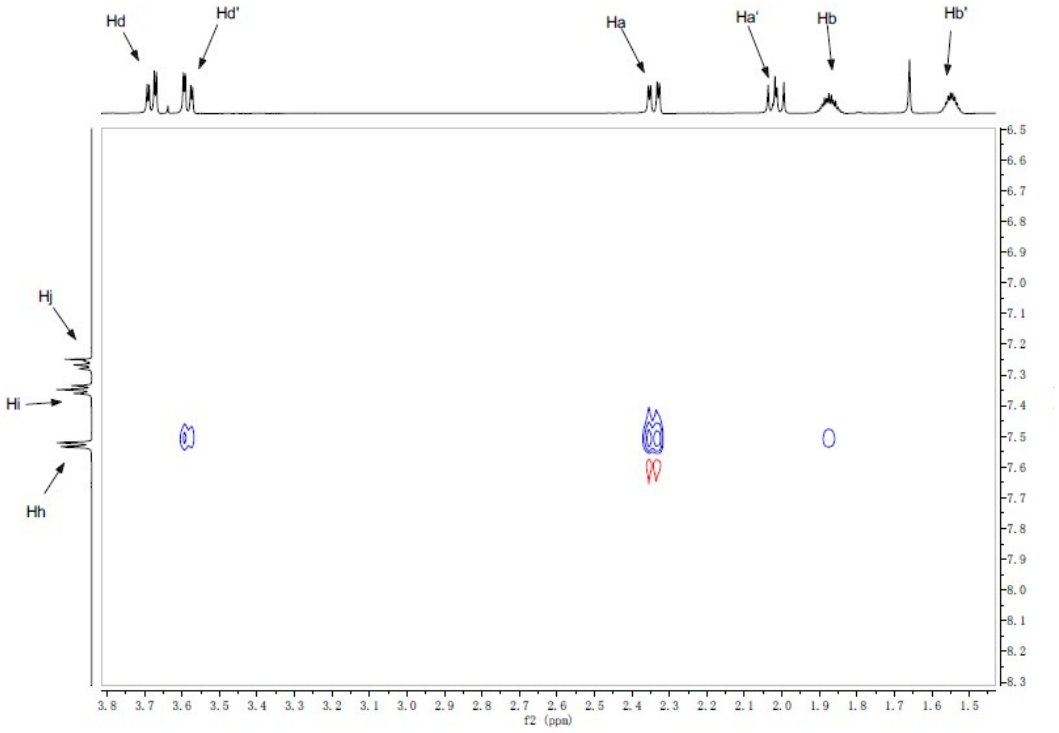
12

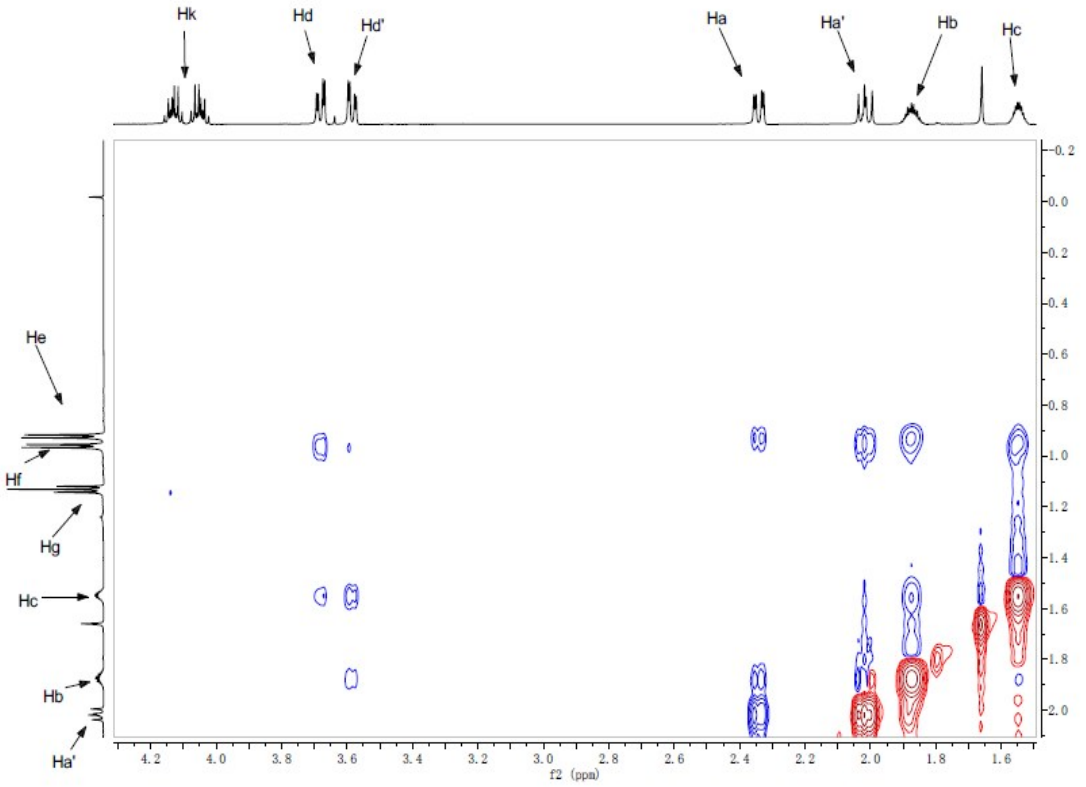


12 (NOESY Spectra)

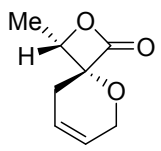





Hd
Hd'
Ha
Ha'
Hb
Hb'
Hj
Hi
Hh
f2 (ppm)

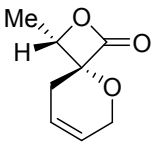

Hk
Hd
Hd'
Ha
Ha'
Hb
Hc
He
Hf
Hg
Hc
Hb
Ha'
f2 (ppm)

^{1}H NMR (400 MHz, $CDCl_3$)



14

^{13}C NMR (100 MHz, $CDCl_3$)



14