Supporting Information

Visible-Light-Promoted Photoredox Syntheses of α,β-Epoxy Ketones from Styrenes and Benzaldehydes under Alkaline Condition

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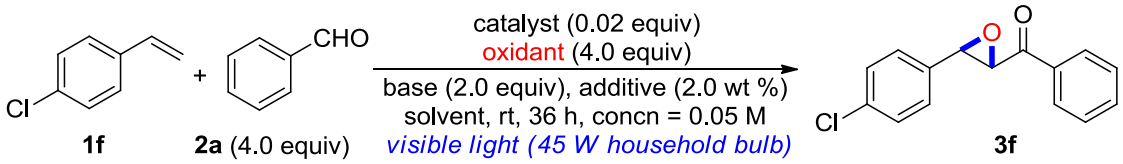
Materials and methods

All reactions were carried out under a nitrogen atmosphere with dry solvents under anhydrous conditions, unless otherwise noted. All the chemicals were purchased commercially, and used without further purification. Anhydrous THF and toluene were distilled from sodium-benzophenone. Dichloromethane and acetonitrile were distilled from calcium hydride. Thin-layer chromatography (TLC) was conducted with 0.25 mm Tsingdao silica gel plates (60F-254) and visualized by exposure to UV light (254 nm) or stained with potassium permanganate. Flash column chromatography was performed using Tsingdao silica gel (60, particle size 0.040–0.063 mm). Reagents were purchased at the highest commercial quality and used without further purification, unless otherwise stated. ^{1}H NMR spectra were recorded on Bruker spectrometers (at 300, 400 or 500 MHz) and are reported relative to deuterated solvent signals. Data for ^{1}H NMR spectra are reported as follows: chemical shift (δ ppm), multiplicity, coupling constant (Hz) and integration. ^{13}C NMR spectrawere recorded on Bruker Spectrometers (at 75, 100 or 125 MHz). Data for ^{13}C NMR spectra are reported in terms of chemical shift. Mass spectrometric data were obtained using Bruker Apex IV RTMS. The following abbreviations were used to explain the multiplicities: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br = broad.

Table 1. Identification of the optimal reaction conditions

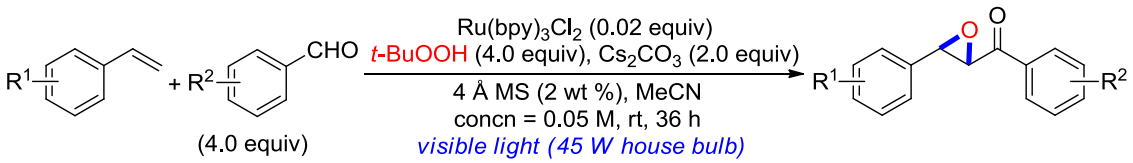


1f **2a** (4.0 equiv) **3f**

entry	catalyst	base	additive	solvent	oxidant[f]	yield[g] (%)
1	$Ru(bpy)_3Cl_2$	K_2CO_3	-	MeCN	*t*-BuOOH	39
2	$Ru(bpy)_3Cl_2$	Et_3N	-	MeCN	*t*-BuOOH	trace
3	$Ru(bpy)_3Cl_2$	Cs_2CO_3	-	MeCN	*t*-BuOOH	61
4[a]	$Ru(bpy)_3Cl_2$	Cs_2CO_3	-	MeCN	*t*-BuOOH	46
5[b]	$Ru(bpy)_3Cl_2$	Cs_2CO_3	$Mg(ClO_4)_2$	MeCN	*t*-BuOOH	trace
6	**$Ru(bpy)_3Cl_2$**	**Cs_2CO_3**	**4 Å MS**	**MeCN**	***t*-BuOOH**	**82**
7	$Ru(bpy)_3Cl_2$	Cs_2CO_3	4 Å MS	DMSO	*t*-BuOOH	trace
8	$Ru(bpy)_3Cl_2$	Cs_2CO_3	4 Å MS	DMF	*t*-BuOOH	37
9	$Ru(bpy)_3Cl_2$	Cs_2CO_3	4 Å MS	toluene	*t*-BuOOH	trace
10	$Ru(bpy)_3Cl_2$	Cs_2CO_3	4 Å MS	CH_2Cl_2	*t*-BuOOH	trace
11	$Ru(bpy)_3Cl_2$	Cs_2CO_3	4 Å MS	Et_2O	*t*-BuOOH	21
12	$Ru(bpy)_3Cl_2$	Cs_2CO_3	4 Å MS	MeOH	*t*-BuOOH	trace
13	$Ru(bpy)_3Cl_2$	Cs_2CO_3	4 Å MS	THF	*t*-BuOOH	35
14	$Ru(bpy)_3Cl_2$	Cs_2CO_3	4 Å MS	MeCN	$(BzO)_2$	0
15	$Ru(bpy)_3Cl_2$	Cs_2CO_3	4 Å MS	MeCN	$(t\text{-BuO})_2$	0
16	$Ru(bpy)_3Cl_2$	Cs_2CO_3	4 Å MS	MeCN	$K_2S_2O_8$	0
17	$Ru(bpy)_3Cl_2$	Cs_2CO_3	4 Å MS	MeCN	H_2O_2	0
18	$Ru(bpy)_3Cl_2$	Cs_2CO_3	4 Å MS	MeCN	*m*-CPBA	0
19	$Ir(ppy)_3$	Cs_2CO_3	4 Å MS	MeCN	*t*-BuOOH	trace
20	Eosin Y	Cs_2CO_3	4 Å MS	MeCN	*t*-BuOOH	0
21[c]	$Ru(bpy)_3Cl_2$	Cs_2CO_3	4 Å MS	MeCN	*t*-BuOOH	0
22	-	Cs_2CO_3	4 Å MS	MeCN	*t*-BuOOH	0
23	$Ru(bpy)_3Cl_2$	Cs_2CO_3	4 Å MS	MeCN	-	0
24	$Ru(bpy)_3Cl_2$	DBU	4 Å MS	MeCN	*t*-BuOOH	trace
25	$Ru(bpy)_3Cl_2$	pyridine	4 Å MS	MeCN	*t*-BuOOH	0
26	$Ru(bpy)_3Cl_2$	NaH	4 Å MS	MeCN	*t*-BuOOH	0
27	$Ru(bpy)_3Cl_2$	$NaHCO_3$	4 Å MS	MeCN	*t*-BuOOH	trace
28	$Ru(bpy)_3Cl_2$	Na_2CO_3	4 Å MS	MeCN	*t*-BuOOH	32
29	$Ru(bpy)_3Cl_2$	CsF	4 Å MS	MeCN	*t*-BuOOH	52
30	$Ru(bpy)_3Cl_2$	LiOH	4 Å MS	MeCN	*t*-BuOOH	54
31	$Ru(bpy)_3Cl_2$	NaOH	4 Å MS	MeCN	*t*-BuOOH	51
32	$Ru(bpy)_3Cl_2$	KOH	4 Å MS	MeCN	*t*-BuOOH	21
33	$Ru(bpy)_3Cl_2$	LiO*t*-Bu	4 Å MS	MeCN	*t*-BuOOH	36
34	$Ru(bpy)_3Cl_2$	NaO*t*-Bu	4 Å MS	MeCN	*t*-BuOOH	0
35	$Ru(bpy)_3Cl_2$	KO*t*-Bu	4 Å MS	MeCN	*t*-BuOOH	0
36[d]	$Ru(bpy)_3Cl_2$	Cs_2CO_3	4 Å MS	MeCN	*t*-BuOOH	64
37[e]	$Ru(bpy)_3Cl_2$	Cs_2CO_3	4 Å MS	MeCN	*t*-BuOOH	61

[a] Cs_2CO_3 (0.5 equiv) was used. [b] $Mg(ClO_4)_2$ (1.0 equiv) was used.
[c] No light. [d] **2a** (2.0 equiv) was used. [e] *t*-BuOOH 70% in water.
[f] *t*-BuOOH 5.5 M in decane. [g] Yield was determined by ^1H NMR.

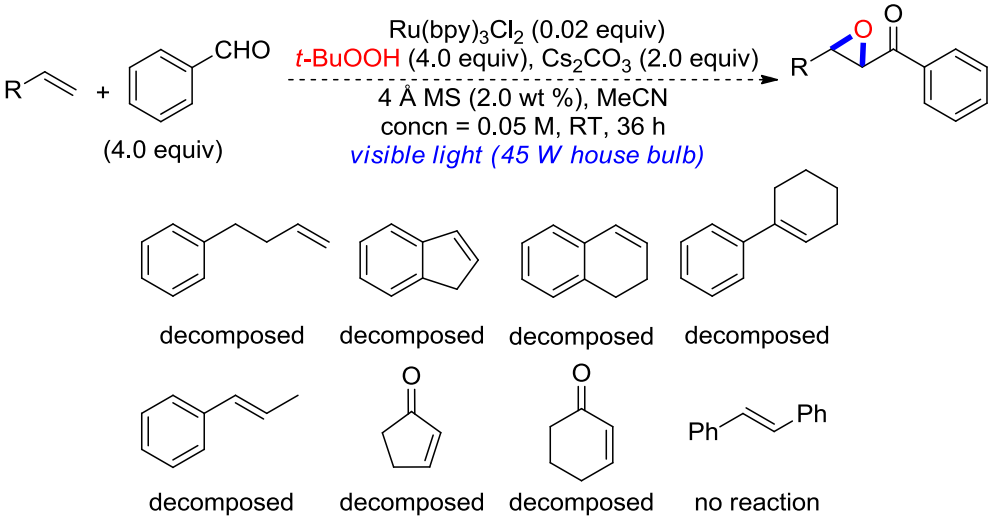
General procedure for visible-light-promoted photoredox reactions



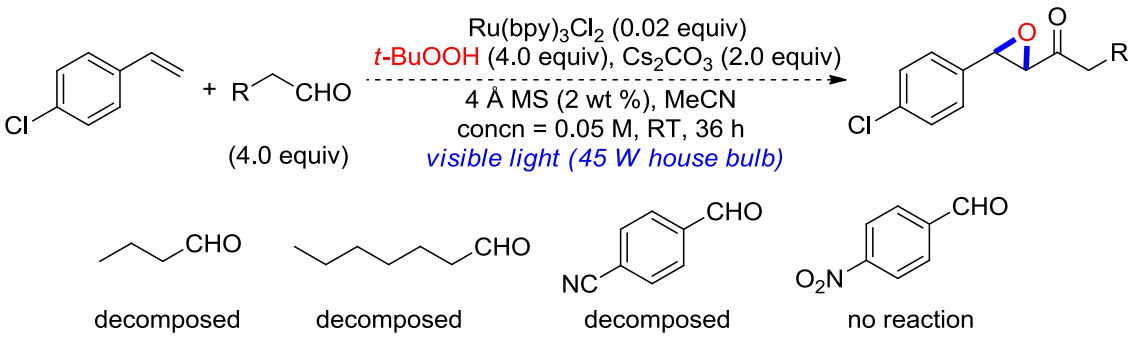
To a solution of alkenes compounds (0.2 mmol, 1.0 equiv), aldehydes compounds (0.8 mmol, 4.0 equiv), $Ru(bpy)_3Cl_2$ (0.004 mmol, 0.02 equiv), 4 Å MS (80 mg, 2 wt %), Cs_2CO_3 (0.4 mmol, 2.0 equiv) in a solvent of MeCN (4.0 mL) was added *t*-BuOOH (5.5 M in decane) (0.8 mmol, 4.0 equiv). Then the reaction was irradiated by a household bulb (45 *W*) under a balloon-argon atmosphere at room temperature. The reaction was monitored by TLC to establish the consumption of starting material. After the reaction was complete, the reaction mixture was filtrated through celite and washed with ether. Then the filtrate was concentrated under reduced pressure, and the crude product was purified by flash column chromatography on silica gel (*n*-Hexane/Ethyl Acetate = 20/1) to afford desired pure products in 51–86% isolated yields.[1–4]

Examinations of other alkenes and aldehydes under standard conditions

1. Examinations of other alkenes



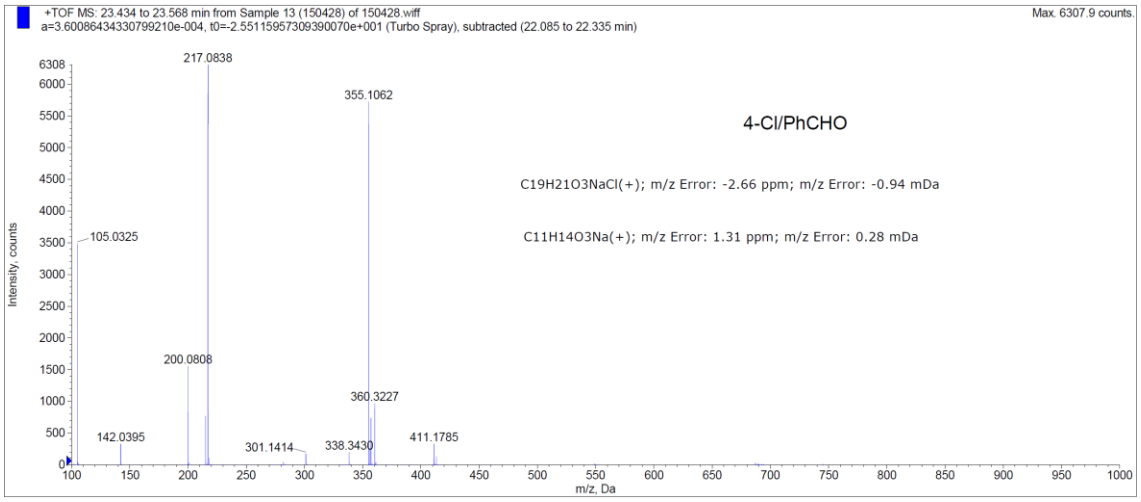
2. Examinations of other aldehydes

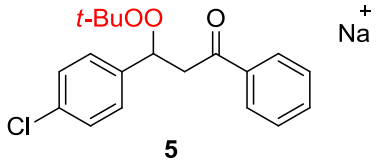


Other alkenes and aldehydes had been examined. However, we did not obtain desired products under standard comditions.

Experimental probes on reaction mechanism

High resolution mass spectrumof 5 and 6

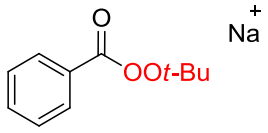




5

Chemical Formula: $C_{19}H_{21}ClNaO_3^+$

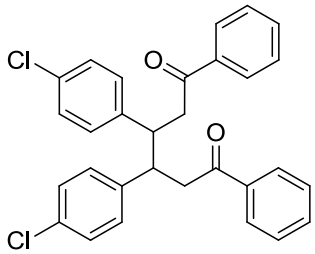
Exact Mass: 355.1071



6

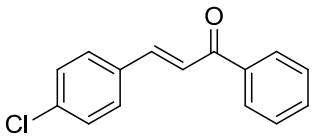
Chemical Formula: $C_{11}H_{14}NaO_3^+$

Exact Mass: 217.0835



7

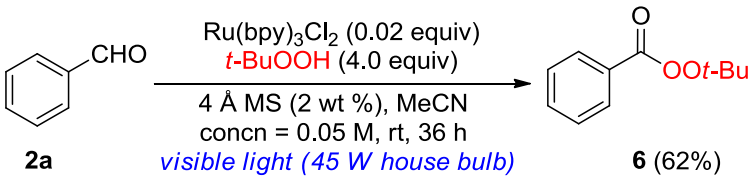
(not been observed)



8

(not been observed)

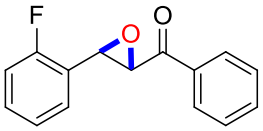
Both structures **5** and **6** were detected by high-resolution mass spectrum (HRMS) analysis of the reaction mixture when the base Cs_2CO_3 was absent. Structure **5** was inseparable and labile. Futhermore, structures **7** and **8** were not detected by HRMS and NMR under standard conditions.



2a **6** (62%)

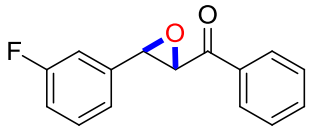
Structure **6** was isolated in 62% yield under the above condition.

^{1}H NMR and ^{13}C NMR spectra data of products



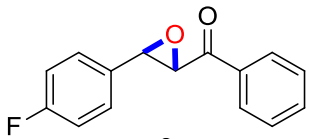
3a

3-(2-fluorophenyl)oxiran-2-yl)(phenyl)methanone (3a): ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.02 (d, *J* = 7.5 Hz, 2H), 7.61 (t, *J* = 7.4 Hz, 1H), 7.48 (t, *J* = 7.7 Hz, 2H), 7.34 (dd, *J* = 13.6, 7.0 Hz, 2H), 7.18 (t, *J* = 7.5 Hz, 1H), 7.11 – 7.04 (m, 1H), 4.33 (s, 1H), 4.30 (d, *J* = 1.7 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 192.8, 162.6, 160.2, 135.2, 134.0, 130.3, 128.8, 128.2, 126.3, 124.5, 122.9, 115.5, 115.3, 59.8, 54.1; HRMS calculated for $C_{15}H_{11}FO_2Na$ ($M + Na^+$): 265.0635, found: 265.0635. (Pale yellow oil, 30.5 mg, 63% isolated yield).



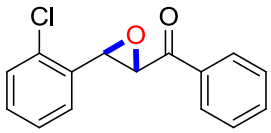
3b

3-(3-fluorophenyl)oxiran-2-yl)(phenyl)methanone (3b): ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.06 – 7.94 (m, 2H), 7.63 (t, *J* = 7.4 Hz, 1H), 7.50 (t, *J* = 7.7 Hz, 2H), 7.37 (ddd, *J* = 8.8, 7.9, 5.7 Hz, 1H), 7.17 (d, *J* = 7.7 Hz, 1H), 7.12 – 7.01 (m, 2H), 4.26 (d, *J* = 1.8 Hz, 1H), 4.08 (d, *J* = 1.5 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 192.6, 164.2, 161.8, 138.1, 135.2, 134.0, 130.4, 128.8, 128.3, 121.5, 116.1, 115.8, 112.6, 112.3, 60.7, 58.5; HRMS calculated for $C_{15}H_{11}FO_2Na$ ($M + Na^+$): 265.0635, found: 265.0636. (White solid, 29.6 mg, 61% isolated yield).



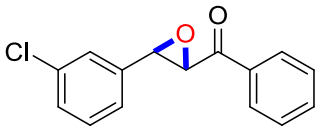
3c

3-(4-fluorophenyl)oxiran-2-yl)(phenyl)methanone (3c): ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.03 – 7.96 (m, 2H), 7.62 (t, *J* = 7.4 Hz, 1H), 7.48 (t, *J* = 7.7 Hz, 2H), 7.37 – 7.31 (m, 2H), 7.08 (dd, *J* = 12.0, 5.3 Hz, 2H), 4.26 (d, *J* = 1.8 Hz, 1H), 4.06 (d, *J* = 1.7 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 192.8, 164.3, 161.8, 135.3, 134.0, 131.2, 128.8, 128.2, 127.5, 115.8, 115.6, 60.8, 58.7; HRMS calculated for $C_{15}H_{11}FO_2Na$ ($M + Na^+$): 265.0635, found: 265.0633. (Pale yellow oil, 30.5 mg, 63% isolated yield).



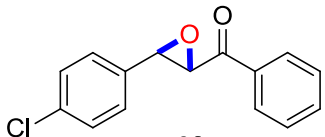
3d

3-(2-chlorophenyl)oxiran-2-yl)(phenyl)methanone (3d): ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.09 – 7.99 (m, 2H), 7.62 (t, *J* = 7.4 Hz, 1H), 7.49 (t, *J* = 7.6 Hz, 2H), 7.39 (tt, *J* = 5.7, 3.0 Hz, 2H), 7.31 (dt, *J* = 4.7, 3.6 Hz, 2H), 4.40 (d, *J* = 1.7 Hz, 1H), 4.17 (d, *J* = 1.8 Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 192.8, 135.3, 134.1, 133.7, 133.3, 129.8, 129.3, 128.9, 128.4, 127.3, 126.1, 60.0, 57.1; HRMS calculated for $C_{15}H_{11}ClO_2Na$ ($M + Na^+$): 281.0340, found: 281.0338. (Pale yellow oil, 32.1 mg, 62% isolated yield).



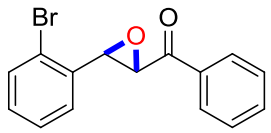
3e

3-(3-chlorophenyl)oxiran-2-yl)(phenyl)methanone (3e): ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.04 – 7.95 (m, 2H), 7.62 (dd, *J* = 10.6, 4.3 Hz, 1H), 7.49 (t, *J* = 7.7 Hz, 2H), 7.37 – 7.23 (m, 4H), 4.26 (d, *J* = 1.8 Hz, 1H), 4.05 (d, *J* = 1.7 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 192.5, 137.5, 135.2, 134.8, 134.0, 130.0, 129.1, 128.8, 128.3, 125.6, 124.0, 60.7, 58.4; HRMS calculated for $C_{15}H_{11}ClO_2Na$ ($M + Na^+$): 281.0340, found: 281.0338. (Pale yellow oil, 35.2 mg, 68% isolated yield).



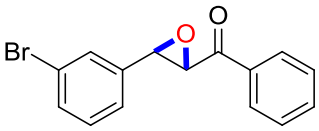
3f

3-(4-chlorophenyl)oxiran-2-yl)(phenyl)methanone (3f): ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.05 – 7.94 (m, 2H), 7.63 (t, *J* = 7.4 Hz, 1H), 7.49 (t, *J* = 7.7 Hz, 2H), 7.38 (dd, *J* = 6.2, 4.6 Hz, 2H), 7.30 (d, *J* = 8.5 Hz, 2H), 4.25 (d, *J* = 1.8 Hz, 1H), 4.06 (d, *J* = 1.7 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 192.6, 135.3, 134.8, 134.0, 133.9, 128.9, 128.8, 128.2, 127.0, 60.8, 58.6; HRMS calculated for $C_{15}H_{11}ClO_2Na$ ($M + Na^+$): 281.0340, found: 281.0341. (Pale yellow oil, 37.2 mg, 72% isolated yield).



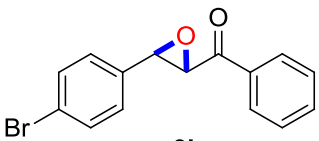
3g

3-(2-bromophenyl)oxiran-2-yl)(phenyl)methanone (3g): ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.08 – 8.00 (m, 2H), 7.61 (t, *J* = 7.4 Hz, 1H), 7.54 (d, *J* = 7.9 Hz, 1H), 7.48 (t, *J* = 7.8 Hz, 2H), 7.40 – 7.31 (m, 2H), 7.22 (td, *J* = 8.0, 2.1 Hz, 1H), 4.32 (d, *J* = 1.7 Hz, 1H), 4.15 (d, *J* = 1.9 Hz, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 192.7, 135.4, 135.3, 134.0, 132.5, 130.1, 128.8, 128.4, 127.8, 126.4, 122.5, 60.0, 59.3; HRMS calculated for $C_{15}H_{11}BrO_2Na$ (M + Na^+): 324.9835, found: 324.9835. (Pale yellow oil, 44.9 mg, 74% isolated yield).



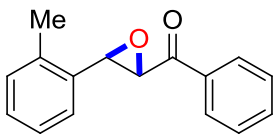
3h

3-(3-bromophenyl)oxiran-2-yl)(phenyl)methanone (3h): ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.04 – 7.91 (m, 2H), 7.61 (t, *J* = 7.4 Hz, 1H), 7.47 (dd, *J* = 9.1, 4.3 Hz, 4H), 7.26 (dt, *J* = 14.5, 7.8 Hz, 2H), 4.25 (d, *J* = 1.8 Hz, 1H), 4.02 (d, *J* = 1.6 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 192.5, 137.8, 135.2, 134.0, 132.0, 130.3, 128.8, 128.5, 128.3, 124.5, 122.9, 60.7, 58.3; HRMS calculated for $C_{15}H_{11}BrO_2Na$ (M + Na^+): 324.9835, found: 324.9834. (Pale yellow oil, 44.3 mg, 73% isolated yield).



3i

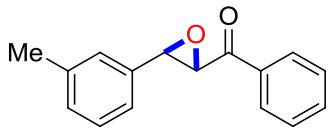
3-(4-bromophenyl)oxiran-2-yl)(phenyl)methanone (3i): ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.99 (d, *J* = 7.5 Hz, 2H), 7.62 (t, *J* = 7.4 Hz, 1H), 7.55 – 7.43 (m, 4H), 7.25 (t, *J* = 6.2 Hz, 2H), 4.25 (d, *J* = 1.8 Hz, 1H), 4.04 (d, *J* = 1.4 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 192.6, 135.2, 134.5, 134.0, 131.9, 128.8, 128.2 127.3, 123.0, 60.8, 58.6; HRMS calculated for $C_{15}H_{11}BrO_2Na$ (M + Na^+): 324.9835, found: 324.9833. (Pale yellow oil, 50.3 mg, 83% isolated yield).



3j

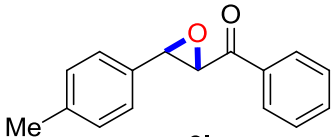
phenyl(3-(*o*-tolyl)oxiran-2-yl)methanone (3j): ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.09 – 8.01 (m, 2H), 7.64 (t, *J* = 7.4 Hz, 1H), 7.51 (t, *J* = 7.8 Hz, 2H), 7.34 (dd, *J* = 6.9, 2.1 Hz, 1H), 7.29 – 7.23 (m, 2H), 7.21 – 7.17 (m, 1H), 4.23 (d, *J* = 1.7 Hz, 1H), 4.21 (d, *J* = 1.9

Hz, 1H), 2.37 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 193.3, 136.3, 135.4, 134.0, 133.9, 130.1, 128.9, 128.5, 128.3, 126.3, 124.2, 60.1, 57.7, 18.8; HRMS calculated for $C_{16}H_{14}O_2Na$ ($M + Na^+$): 261.0886, found: 261.0884. (Pale yellow oil, 40.5 mg, 85% isolated yield).



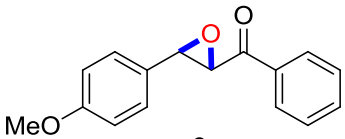
3k

phenyl(3-(*m*-tolyl)oxiran-2-yl)methanone (3k): ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.05 – 7.97 (m, 2H), 7.67 – 7.56 (m, 1H), 7.48 (t, *J* = 7.7 Hz, 2H), 7.33 – 7.26 (m, 1H), 7.19 (t, *J* = 6.5 Hz, 3H), 4.30 (d, *J* = 1.9 Hz, 1H), 4.04 (d, *J* = 1.8 Hz, 1H), 2.38 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 193.0, 138.5, 135.4, 135.3, 133.9, 129.7, 128.8, 128.6, 128.2, 126.2, 122.9, 60.9, 59.4, 21.3; HRMS calculated for $C_{16}H_{14}O_2Na$ ($M + Na^+$): 261.0886, found: 261.0888. (White solid, 32.4 mg, 68% isolated yield).



3l

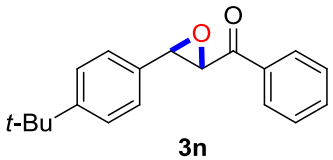
phenyl(3-(*p*-tolyl)oxiran-2-yl)methanone (3l): ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.01 (dd, *J* = 8.3, 1.1 Hz, 2H), 7.64 – 7.58 (m, 1H), 7.48 (dd, *J* = 10.7, 4.7 Hz, 2H), 7.24 (dd, *J* = 21.9, 8.0 Hz, 4H), 4.30 (d, *J* = 1.9 Hz, 1H), 4.04 (d, *J* = 1.8 Hz, 1H), 2.38 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 193.1, 139.0, 135.4, 133.8, 132.4, 129.4, 128.8, 128.2, 125.7, 61.0, 59.3, 21.2; HRMS calculated for $C_{16}H_{14}O_2Na$ ($M + Na^+$): 261.0886, found: 261.0883. (Pale yellow oil, 36.2 mg, 76% isolated yield).



3m

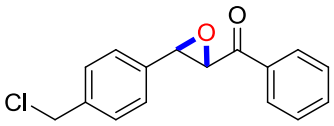
(3-(4-methoxyphenyl)oxiran-2-yl)(phenyl)methanone (3m): ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.05 – 7.96 (m, 2H), 7.61 (dd, *J* = 10.6, 4.3 Hz, 1H), 7.49 (t, *J* = 7.7 Hz, 2H), 7.34 – 7.27 (m, 2H), 6.97 – 6.90 (m, 2H), 4.29 (d, *J* = 1.9 Hz, 1H), 4.03 (d, *J* = 1.8 Hz, 1H), 3.83 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 193.2, 160.2, 135.4, 133.8, 128.7, 128.2, 127.2, 127.1, 114.1, 61.0, 59.3, 55.3; HRMS calculated for $C_{16}H_{14}O_3Na$ ($M +$

Na^+): 277.0835, found: 277.0837. (Pale yellow oil, 38.6 mg, 76% isolated yield).



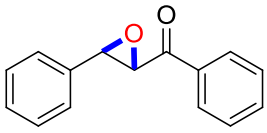
3n

(3-(4-(*tert*-butyl)phenyl)oxiran-2-yl)(phenyl)methanone (3n): ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.01 (d, *J* = 8.0 Hz, 2H), 7.61 (t, *J* = 7.4 Hz, 1H), 7.51 – 7.41 (m, 4H), 7.32 (d, *J* = 8.2 Hz, 2H), 4.33 (s, 1H), 4.06 (s, 1H), 1.34 (s, 9H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 193.2, 152.3, 135.5, 133.9, 132.5, 128.8, 128.3, 125.7, 125.6, 60.9, 59.4, 34.7, 31.3; HRMS calculated for $C_{19}H_{20}O_2Na$ (M + Na^+): 303.1356, found: 303.1356. (Pale yellow oil, 35.9 mg, 64% isolated yield).



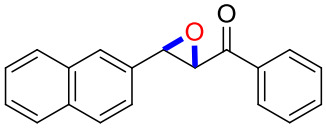
3o

(3-(4-(chloromethyl)phenyl)oxiran-2-yl)(phenyl)methanone (3o): ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.07 – 7.94 (m, 2H), 7.63 (dd, *J* = 10.5, 4.3 Hz, 1H), 7.56 – 7.32 (m, 6H), 4.61 (s, 2H), 4.29 (d, *J* = 1.8 Hz, 1H), 4.08 (d, *J* = 1.7 Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 192.8, 138.4, 135.8, 135.3, 134.1, 129.0, 128.9, 128.3, 126.2, 61.0, 59.0, 45.7; HRMS calculated for $C_{16}H_{13}ClO_2Na$ (M + Na^+): 295.0496, found: 295.0499. (Pale yellow oil, 33.3 mg, 61% isolated yield).



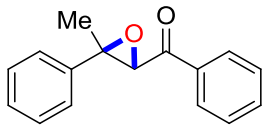
3p

phenyl(3-phenyloxiran-2-yl)methanone (3p): ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.07 – 7.95 (m, 2H), 7.62 (dd, *J* = 10.6, 4.3 Hz, 1H), 7.49 (t, *J* = 7.8 Hz, 2H), 7.43 – 7.34 (m, 5H), 4.30 (d, *J* = 1.9 Hz, 1H), 4.08 (d, *J* = 1.7 Hz, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 193.1, 135.5, 134.0, 129.0, 128.9, 128.8, 128.3, 125.8, 61.0, 59.4; HRMS calculated for $C_{15}H_{12}O_2Na$ (M + Na^+): 247.0730, found: 247.0730. (White solid, 29.6 mg, 66% isolated yield).



3q

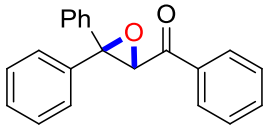
(3-(naphthalen-2-yl)oxiran-2-yl)(phenyl)methanone (3q): ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.07 – 7.98 (m, 2H), 7.93 – 7.82 (m, 4H), 7.62 (t, *J* = 7.4 Hz, 1H), 7.55 – 7.39 (m, 5H), 4.40 (d, *J* = 1.8 Hz, 1H), 4.25 (d, *J* = 1.6 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 192.9, 135.4, 133.9, 133.6, 133.0, 132.8, 128.8, 128.7, 128.3, 127.8, 127.7, 126.6, 126.5, 125.8, 122.3, 61.1, 59.5; HRMS calculated for $C_{19}H_{15}O_2$ ($M + H^+$): 275.1067, found: 275.1067. (Pale yellow oil, 31.8 mg, 58% isolated yield).



3r

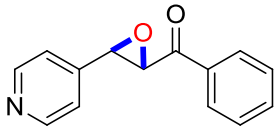
(3-methyl-3-phenyloxiran-2-yl)(phenyl)methanone (3r): ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.01 – 7.91 (m, 2H), 7.61 (d, *J* = 7.4 Hz, 1H), 7.52 – 7.46 (m, 4H), 7.43 (t, *J* = 7.5 Hz, 2H), 7.38 (d, *J* = 7.2 Hz, 1H), 4.16 (s, 1H), 1.64 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 193.0, 140.4, 135.6, 133.9, 128.9, 128.7, 128.2, 125.1, 66.8, 62.8, 17.0;

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.86 – 7.78 (m, 2H), 7.53 (t, *J* = 7.4 Hz, 1H), 7.41 (t, *J* = 7.7 Hz, 2H), 7.34 – 7.29 (m, 2H), 7.22 – 7.12 (m, 3H), 4.34 (s, 1H), 1.93 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 192.5, 136.7, 135.5, 133.5, 128.6, 128.1, 128.0, 127.8, 126.2, 66.1, 64.5, 24.4; HRMS calculated for $C_{16}H_{14}O_2Na$ ($M + Na^+$): 261.0886, found: 261.0890. (Pale yellow oil, 30.0 mg, 63% isolated yield, dr = 1:1).



3s

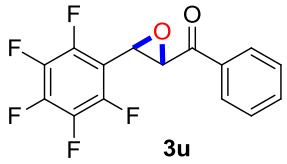
(3,3-diphenyloxiran-2-yl)(phenyl)methanone (3s): ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.94 (d, *J* = 7.4 Hz, 2H), 7.58 (t, *J* = 7.4 Hz, 1H), 7.49 – 7.30 (m, 9H), 7.24 – 7.19 (m, 3H), 4.68 (s, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 191.8, 139.0, 135.6, 134.8, 133.6, 128.7, 128.6, 128.5, 128.2, 128.0, 127.9, 126.8, 67.6, 66.7; HRMS calculated for $C_{21}H_{16}O_2Na$ ($M + Na^+$): 323.1043, found: 323.1045. (White solid, 38.4 mg, 64% isolated yield).



3t

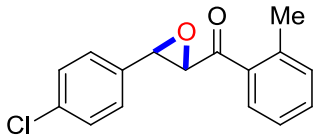
phenyl(3-(pyridin-4-yl)oxiran-2-yl)methanone (3t): ^{1}H NMR (500 MHz, $CDCl_3$) δ

8.59 (d, *J* = 5.3 Hz, 2H), 7.95 (d, *J* = 7.6 Hz, 2H), 7.58 (d, *J* = 7.4 Hz, 1H), 7.45 (t, *J* = 7.7 Hz, 2H), 7.26 (d, *J* = 5.2 Hz, 2H), 4.23 (d, *J* = 1.1 Hz, 1H), 4.04 (s, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 192.1, 150.1, 144.6, 135.2, 134.2, 128.9, 128.3, 120.5, 60.5, 57.5; HRMS calculated for $C_{14}H_{11}NO_2Na$ (M + Na^+): 248.0682, found: 248.0683. (Yellow solid, 28.4 mg, 63% isolated yield).



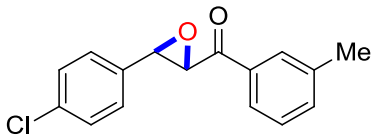
3u

(3-(perfluorophenyl)oxiran-2-yl)(phenyl)methanone (3u): ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.22 – 7.95 (m, 2H), 7.67 (t, *J* = 7.4 Hz, 1H), 7.54 (t, *J* = 7.7 Hz, 2H), 4.79 (d, *J* = 2.0 Hz, 1H), 4.25 (d, *J* = 1.8 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 192.3, 135.0, 134.3, 128.9, 128.3, 55.6, 55.5, 50.4; HRMS calculated for $C_{15}H_7F_5O_2Na$ (M + Na^+): 337.0258, found: 337.0258. (Pale yellow oil, 32.0 mg, 51% isolated yield).



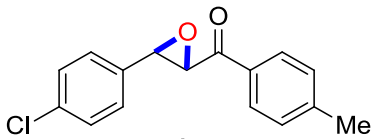
4a

(3-(4-chlorophenyl)oxiran-2-yl)(*o*-tolyl)methanone (4a): ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.82 – 7.75 (m, 2H), 7.43 (d, *J* = 7.6 Hz, 1H), 7.40 – 7.34 (m, 3H), 7.33 – 7.28 (m, 2H), 4.25 (d, *J* = 1.9 Hz, 1H), 4.05 (d, *J* = 1.8 Hz, 1H), 2.41 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 192.8, 138.8, 135.3, 134.8, 134.0, 128.9, 128.7, 128.6, 127.0, 125.5, 60.7, 58.6, 21.2; HRMS calculated for $C_{16}H_{13}ClO_2Na$ (M + Na^+): 295.0496, found: 295.0494. (Pale yellow oil, 35.4 mg, 65% isolated yield).



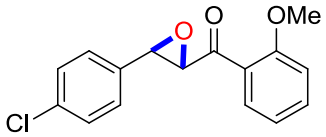
4b

(3-(4-chlorophenyl)oxiran-2-yl)(*m*-tolyl)methanone (4b): ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.79 (d, *J* = 11.5 Hz, 2H), 7.43 (d, *J* = 7.6 Hz, 1H), 7.37 (dt, *J* = 7.1, 3.2 Hz, 3H), 7.30 (d, *J* = 8.5 Hz, 2H), 4.24 (d, *J* = 1.8 Hz, 1H), 4.05 (d, *J* = 1.7 Hz, 1H), 2.40 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 192.8, 138.8, 135.3, 134.9, 134.8, 134.0, 128.9, 128.7, 128.6, 127.0, 125.5, 60.7, 58.6, 21.2; HRMS calculated for $C_{16}H_{13}ClO_2Na$ (M + Na^+): 295.0496, found: 295.0494. (Pale yellow oil, 36.5 mg, 67% isolated yield).



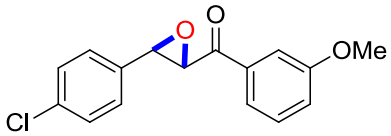
4c

(3-(4-chlorophenyl)oxiran-2-yl)(*p*-tolyl)methanone (4c): ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.90 (d, *J* = 8.2 Hz, 2H), 7.37 (d, *J* = 8.4 Hz, 2H), 7.32 – 7.26 (m, 4H), 4.23 (d, *J* = 1.7 Hz, 1H), 4.04 (d, *J* = 1.5 Hz, 1H), 2.42 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 192.2, 145.2, 134.8, 134.2, 132.9, 129.6, 129.0, 128.4, 127.1, 60.8, 58.6, 21.8; HRMS calculated for $C_{16}H_{13}ClO_2Na$ ($M + Na^+$): 295.0496, found: 295.0495. (White solid, 37.1 mg, 68% isolated yield).



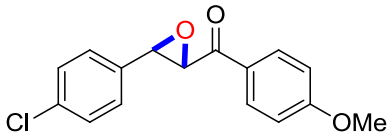
4d

3-(4-chlorophenyl)oxiran-2-yl)(2-methoxyphenyl)methanone (4d): ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.81 (dd, *J* = 7.7, 1.6 Hz, 1H), 7.59 – 7.46 (m, 1H), 7.34 (dd, *J* = 22.8, 8.5 Hz, 4H), 7.04 (t, *J* = 7.5 Hz, 1H), 6.93 (d, *J* = 8.4 Hz, 1H), 4.26 (d, *J* = 1.8 Hz, 1H), 3.97 (d, *J* = 1.5 Hz, 1H), 3.62 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 194.3, 159.4, 135.0, 134.9, 134.4, 130.6, 128.7, 127.0, 125.7, 121.0, 111.5, 64.3, 58.9, 55.6; HRMS calculated for $C_{16}H_{13}ClO_3Na$ ($M + Na^+$): 311.0445, found: 311.0447. (White solid, 35.8mg, 62% isolated yield).



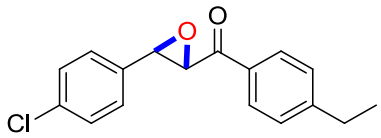
4e

3-(4-chlorophenyl)oxiran-2-yl)(3-methoxyphenyl)methanone (4e): ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.59 – 7.48 (m, 2H), 7.41 – 7.33 (m, 3H), 7.29 (d, *J* = 8.5 Hz, 2H), 7.18 – 7.13 (m, 1H), 4.23 (d, *J* = 1.8 Hz, 1H), 4.04 (d, *J* = 1.7 Hz, 1H), 3.84 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 192.5, 160.0, 136.6, 134.9, 134.0, 129.9, 129.0, 127.1, 120.9, 120.6, 112.4, 60.9, 58.7, 55.5; HRMS calculated for $C_{16}H_{13}ClO_3Na$ ($M + Na^+$): 311.0445, found: 311.0445. (White solid, 47.4 mg, 82% isolated yield).



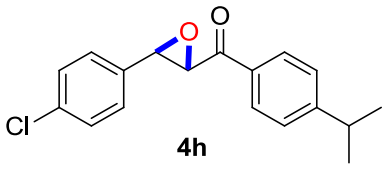
4f

3-(4-chlorophenyl)oxiran-2-yl)(4-methoxyphenyl)methanone (4f): ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.02 – 7.96 (m, 2H), 7.39 – 7.34 (m, 2H), 7.29 (d, *J* = 8.5 Hz, 2H), 6.98 – 6.92 (m, 2H), 4.20 (d, *J* = 1.8 Hz, 1H), 4.04 (d, *J* = 1.7 Hz, 1H), 3.87 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 190.9, 164.3, 134.8, 134.3, 130.7, 129.0, 128.5, 127.1, 114.1, 60.8, 58.4, 55.5; HRMS calculated for $C_{16}H_{13}ClO_3Na$ ($M + Na^+$): 311.0445, found: 311.0445. (White solid, 41.6 mg, 72% isolated yield).



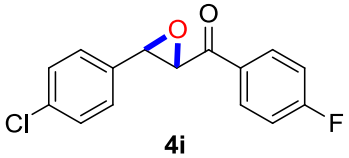
4g

3-(4-chlorophenyl)oxiran-2-yl)(4-ethylphenyl)methanone (4g): ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.96 – 7.89 (m, 2H), 7.40 – 7.34 (m, 2H), 7.34 – 7.28 (m, 4H), 4.24 (d, *J* = 1.9 Hz, 1H), 4.05 (d, *J* = 1.8 Hz, 1H), 2.72 (q, *J* = 7.6 Hz, 2H), 1.25 (t, *J* = 7.6 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 192.2, 151.3, 134.9, 134.2, 133.1, 129.0, 128.6, 128.4, 127.1, 60.9, 58.6, 29.0, 15.1; HRMS calculated for $C_{17}H_{15}ClO_2Na$ ($M + Na^+$): 309.0653, found: 309.0652. (Pale yellow oil, 38.9 mg, 68% isolated yield).



4h

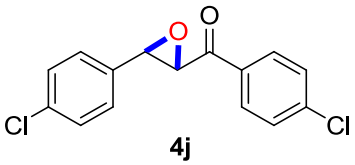
(3-(4-chlorophenyl)oxiran-2-yl)(4-isopropylphenyl)methanone (4h): ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.97 – 7.91 (m, 2H), 7.41 – 7.27 (m, 6H), 4.24 (d, *J* = 1.9 Hz, 1H), 4.04 (d, *J* = 1.8 Hz, 1H), 2.97 (dt, *J* = 13.8, 6.9 Hz, 1H), 1.26 (d, *J* = 6.9 Hz, 6H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 192.1, 155.8, 134.8, 134.1, 133.2, 128.9, 128.5, 127.0, 126.9, 60.8, 58.5, 34.3, 23.5; HRMS calculated for $C_{18}H_{17}ClO_2Na$ ($M + Na^+$): 323.0809, found: 323.0804. (Pale yellow oil, 36.7 mg, 61% isolated yield).



4i

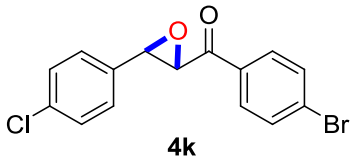
3-(4-chlorophenyl)oxiran-2-yl)(4-fluorophenyl)methanone (4i): ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.05 (dd, *J* = 8.7, 5.4 Hz, 2H), 7.37 (d, *J* = 8.4 Hz, 2H), 7.29 (d, *J* = 8.4 Hz, 2H), 7.16 (t, *J* = 8.6 Hz, 2H), 4.19 (d, *J* = 1.6 Hz, 1H), 4.05 (d, *J* = 1.2 Hz, 1H); ^{13}C

NMR (101 MHz, $CDCl_3$) δ 191.1, 167.5, 164.9, 134.9, 133.8, 131.7, 131.6, 131.1, 131.0, 128.9, 127.0, 116.2, 116.0, 60.8, 58.5; HRMS calculated for $C_{15}H_{10}ClFO_2Na$ ($M + Na^+$): 299.0246, found: 299.0244. (Pale yellow oil, 39.3 mg, 71% isolated yield).



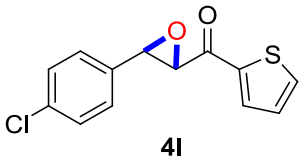
4j

(4-chlorophenyl)(3-(4-chlorophenyl)oxiran-2-yl)methanone (4j): ^1H NMR (400 MHz, $CDCl_3$) δ 7.96 (d, *J* = 8.6 Hz, 2H), 7.47 (d, *J* = 8.6 Hz, 2H), 7.38 (d, *J* = 8.5 Hz, 2H), 7.29 (d, *J* = 8.5 Hz, 2H), 4.18 (d, *J* = 1.8 Hz, 1H), 4.05 (d, *J* = 1.6 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 191.1, 140.6, 135.0, 133.7, 133.5, 129.7, 129.2, 129.0, 127.0, 60.9, 58.6; HRMS calculated for $C_{15}H_{10}Cl_2O_2Na$ ($M + Na^+$): 314.9950, found: 314.9950. (Pale yellow oil, 36.3 mg, 62% isolated yield).



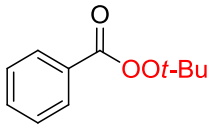
4k

(4-bromophenyl)(3-(4-chlorophenyl)oxiran-2-yl)methanone (4k): ^1H NMR (400 MHz, $CDCl_3$) δ 7.87 (d, *J* = 8.6 Hz, 2H), 7.64 (d, *J* = 8.6 Hz, 2H), 7.33 (dd, *J* = 34.6, 8.5 Hz, 4H), 4.18 (d, *J* = 1.8 Hz, 1H), 4.05 (d, *J* = 1.6 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 191.8, 135.0, 133.9, 133.7, 132.2, 129.7, 129.4, 129.0, 127.0, 60.8, 58.6; HRMS calculated for $C_{15}H_{10}ClBrO_2Na$ ($M + Na^+$): 358.9445, found: 358.9443. (White solid, 52.6 mg, 78% isolated yield).



4l

(4-chlorophenyl)oxiran-2-yl)(thiophen-2-yl)methanone (4l): ^1H NMR (500 MHz, $CDCl_3$) δ 7.99 (dd, *J* = 3.9, 1.0 Hz, 1H), 7.75 (dd, *J* = 4.9, 1.0 Hz, 1H), 7.39 – 7.33 (m, 2H), 7.30 – 7.25 (m, 2H), 7.18 (dd, *J* = 4.9, 3.9 Hz, 1H), 4.14 (d, *J* = 1.6 Hz, 1H), 4.03 (d, *J* = 1.8 Hz, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 186.1, 140.8, 135.4, 134.9, 133.8, 133.7, 129.0, 128.5, 127.1, 61.9, 58.7; HRMS calculated for $C_{13}H_9ClSO_2Na$ ($M + Na^+$): 286.9904, found: 286.9909. (White solid, 43.9 mg, 83% isolated yield).



6

***tert*-butyl benzoperoxoate (6):** ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.00 – 7.88 (m, 2H), 7.61 – 7.54 (m, 1H), 7.48 – 7.41 (m, 2H), 1.41 (s, 9H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 164.3, 133.2, 129.0, 128., 127.6, 83.8, 26.16 (s); HRMS calculated for $C_{11}H_{13}O_3Na$ (M + Na^+): 217.0835, found: 217.0837. (Pale yellow oil, 38.8 mg, 62% isolated yield).

References:

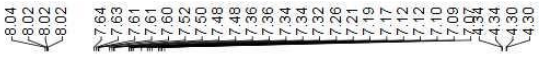
(1) Liu, W.; Li, Y.; Liu, K.; Li, Z. *J. Am. Chem. Soc.* **2011**, *133*, 10756.

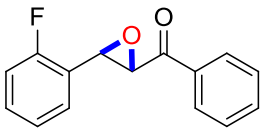
(2) Wei, W. T; Yang, X. H.; Li, H. B.; Li, J. H. *Adv. Synth. Catal.* **2015**, *357*, 59.

(3) Ke, Q.; Zhang, B.; Hu, B.; Jin, Y.; Lu, G. *Chem. Commun.* **2015**, *51*, 1012.

(4) Xiang, M.; Ni, X.; Yi, X.; Zheng, A.; Wang, W.; He, M.; Xiong, J.; Liu, T.; Ma, Y.; Zhu, P.; Zheng, X.; Tang, T. *ChemCatChem* **2015**, *7*, 521.

Copies of ^{1}H NMR and ^{13}C NMR spectra





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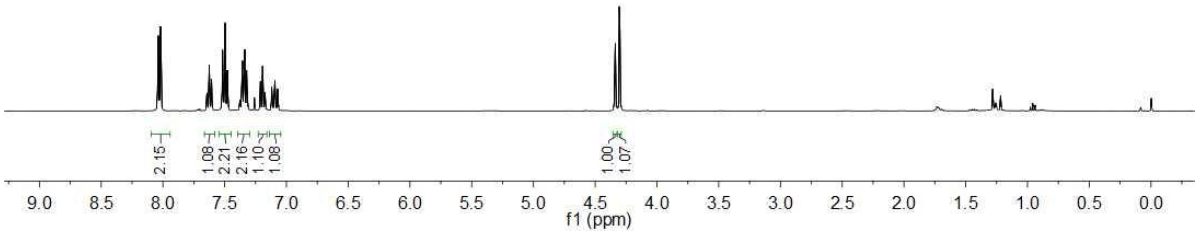

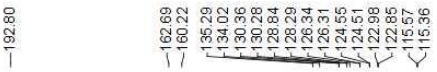

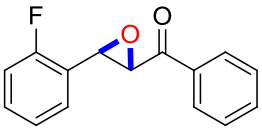

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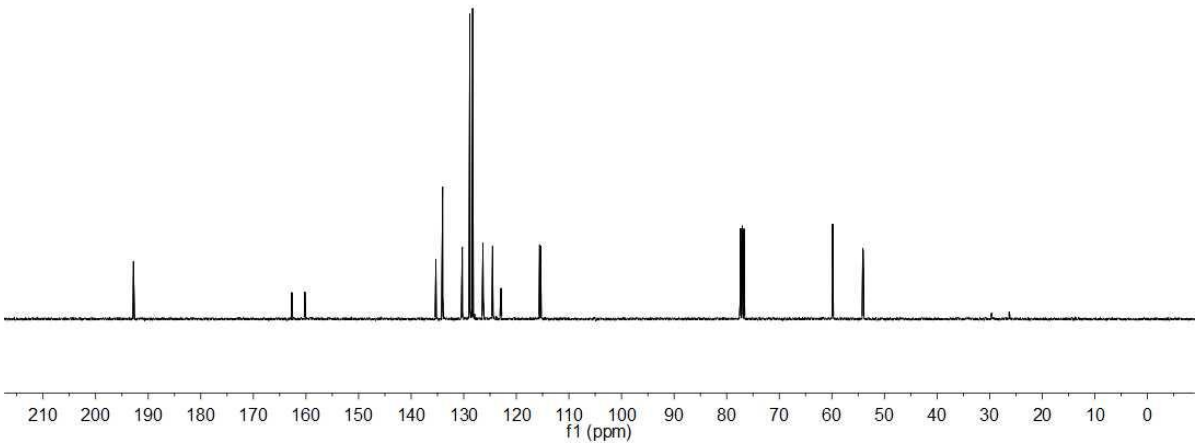

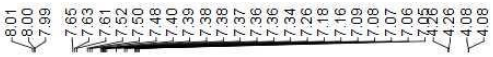
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7.07
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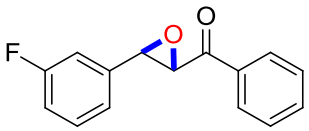
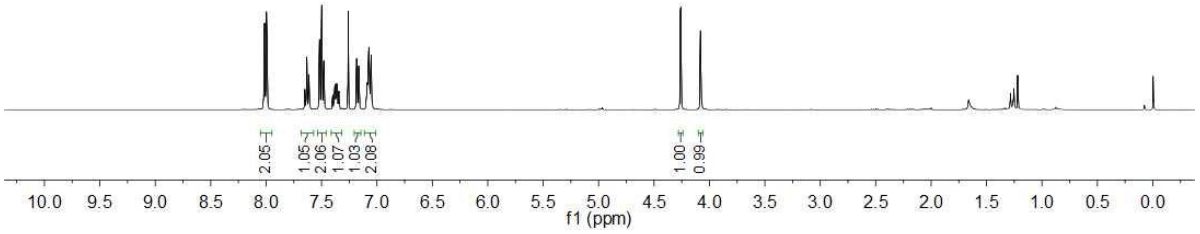
4.26
4.08
4.08


F
O
O

3b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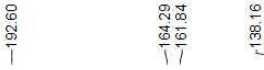
2.06
1.07
1.03
2.08
1.00
0.99
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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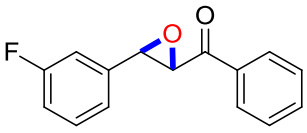
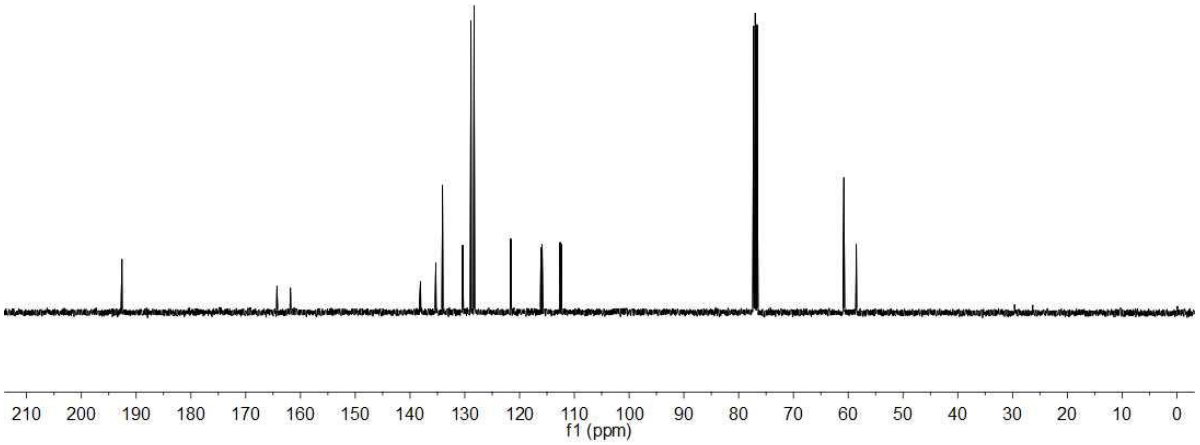
58.50


F
O
O

3b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f1 (ppm)


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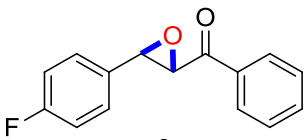
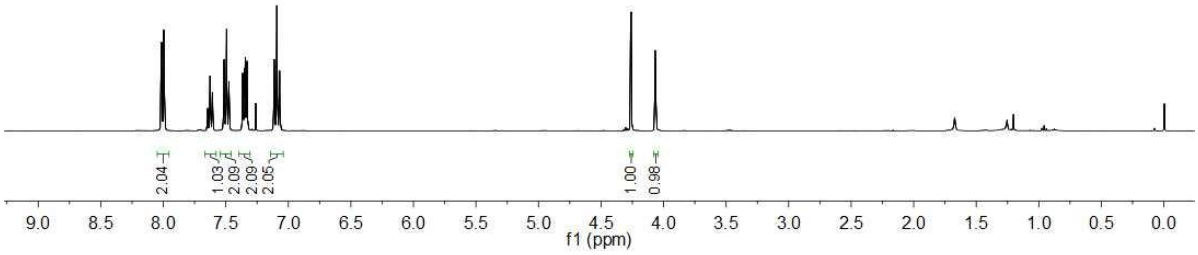

O
O
F

3c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6.0
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4.5
4.0
3.5
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2.5
2.0
1.5
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0.5
0.0
f1 (ppm)


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162.69
160.22
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126.34
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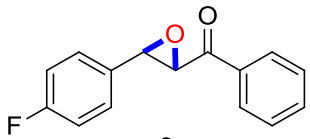
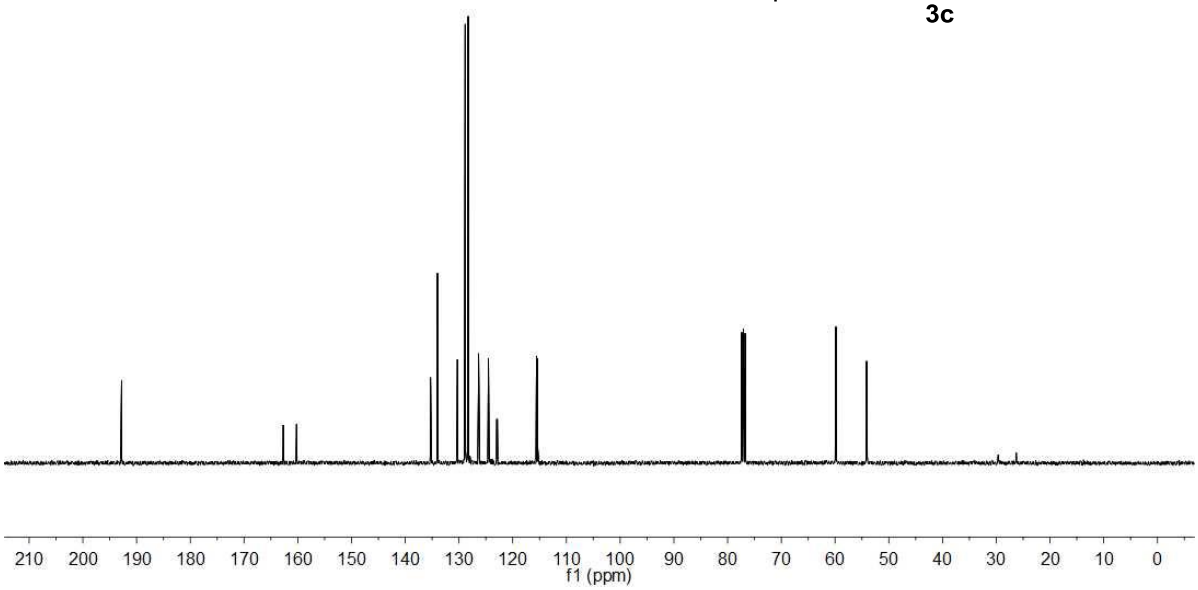

O
O
F

3c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10
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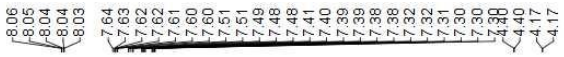
f1 (ppm)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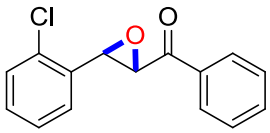
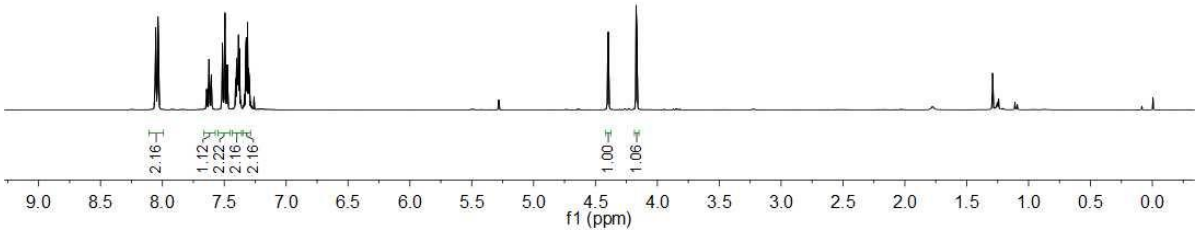

Cl
O
O

3d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f1 (ppm)


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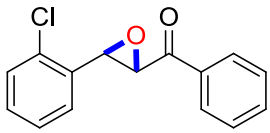
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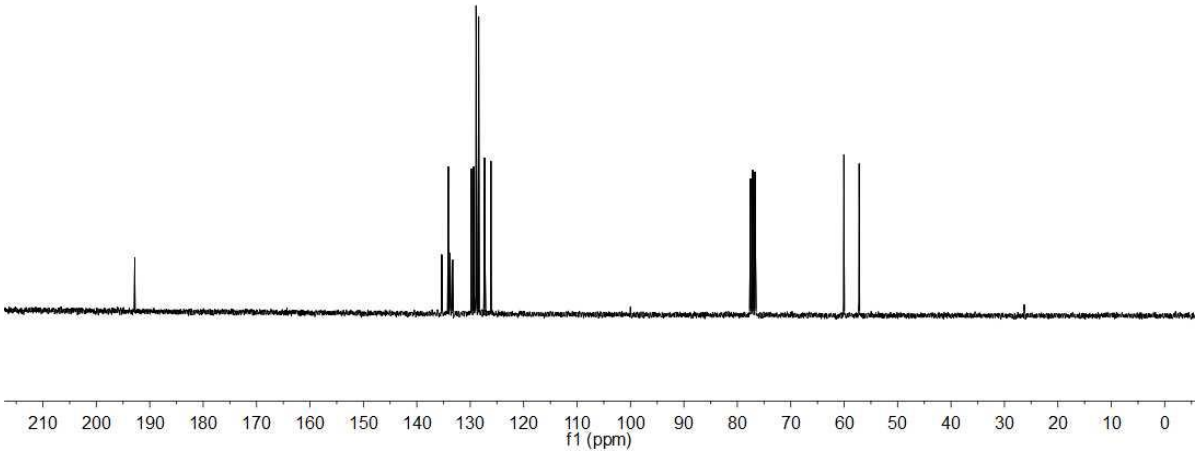
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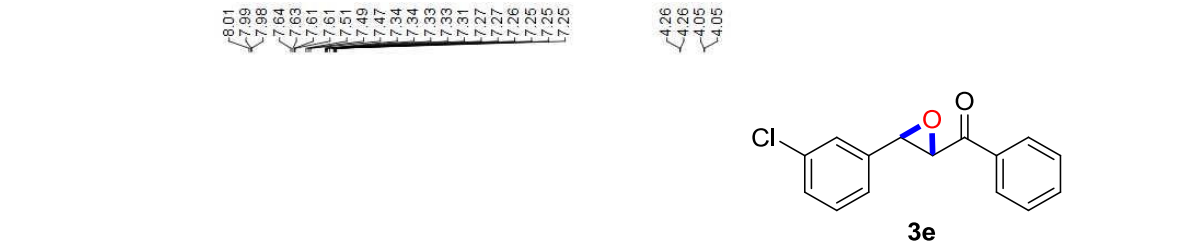
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4.05
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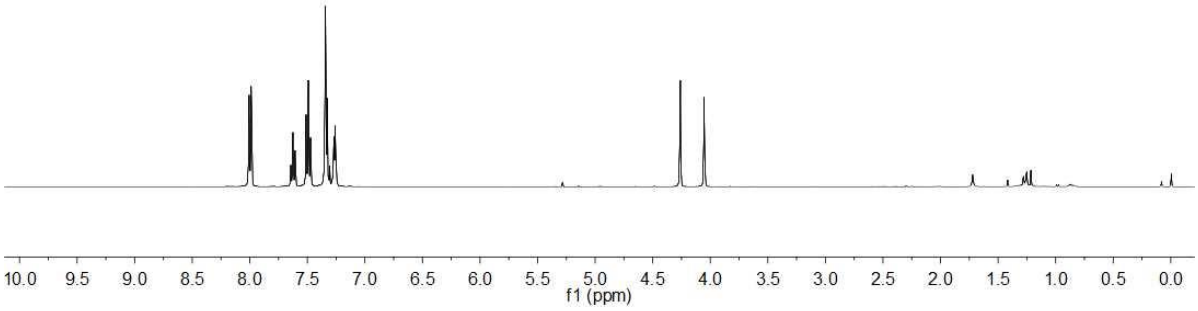
Cl
O
O
3e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1.0
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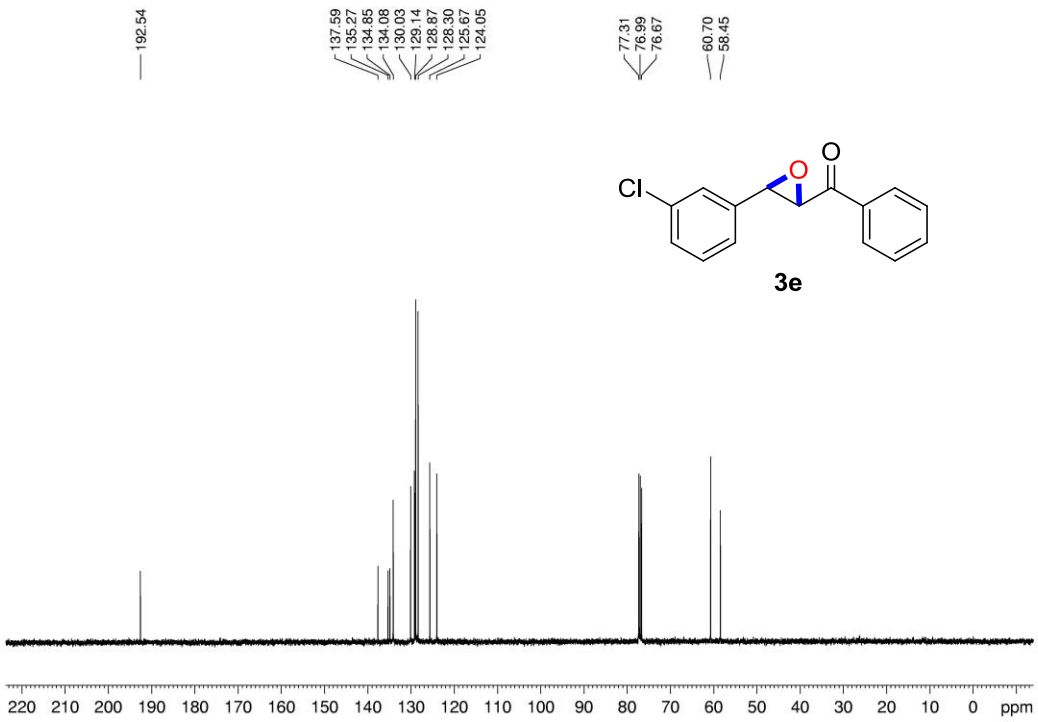
f1 (ppm)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Cl
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O
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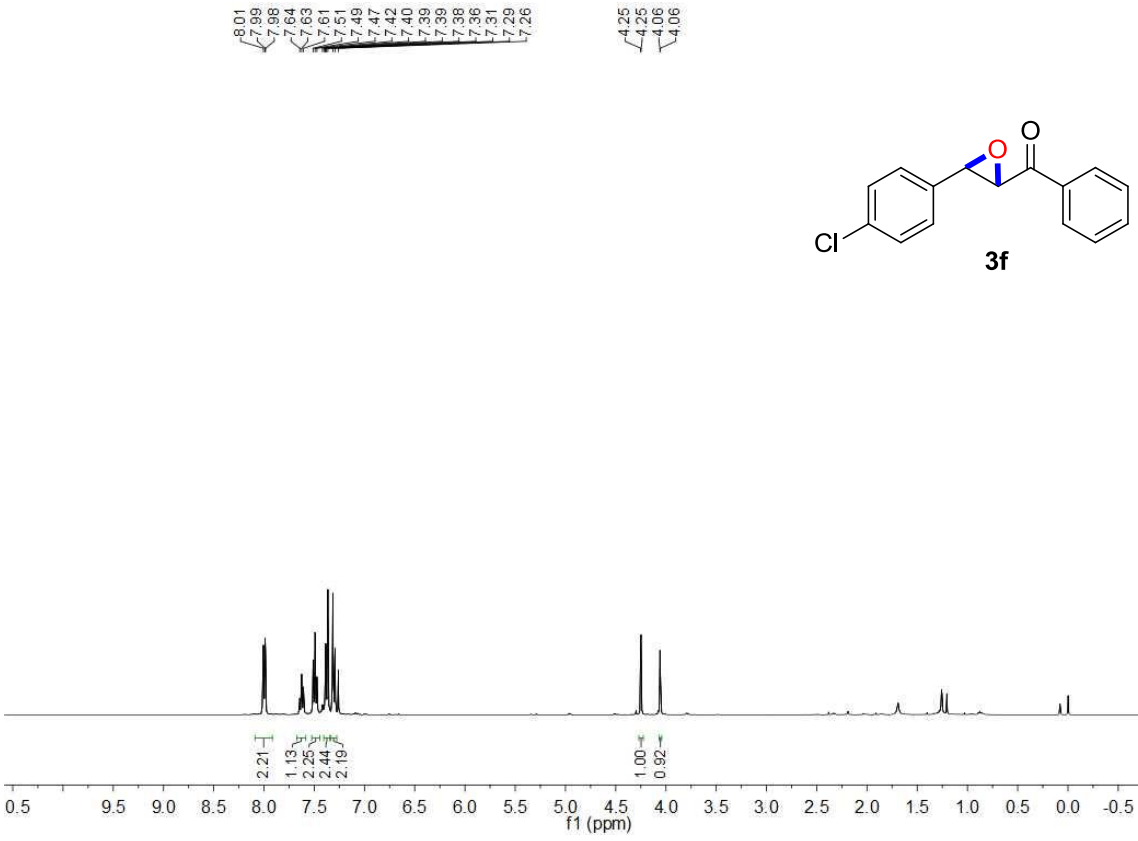
ppm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4.25
4.06
4.06
O
O
Cl
3f
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2.25
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2.19
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133.98
128.96
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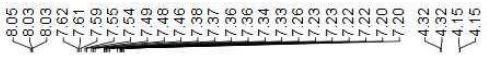
Cl
3f
f1 (ppm)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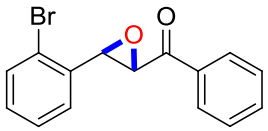
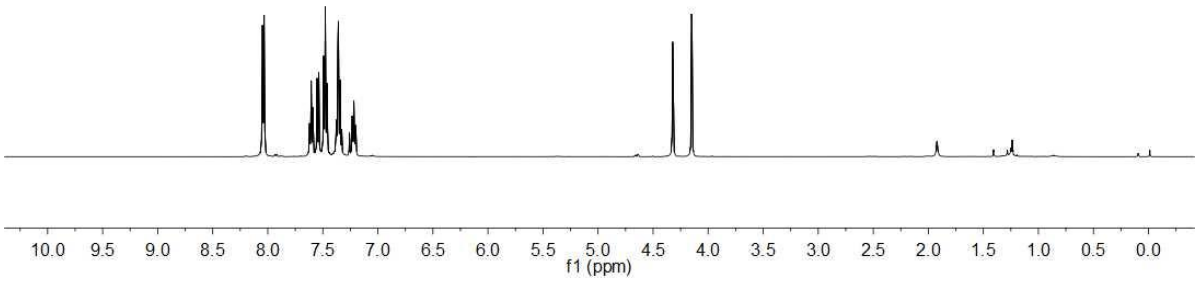
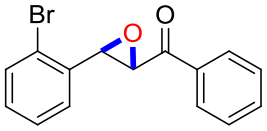
7.20
7.20
4.32
4.32
4.15
4.15


Br
O
O

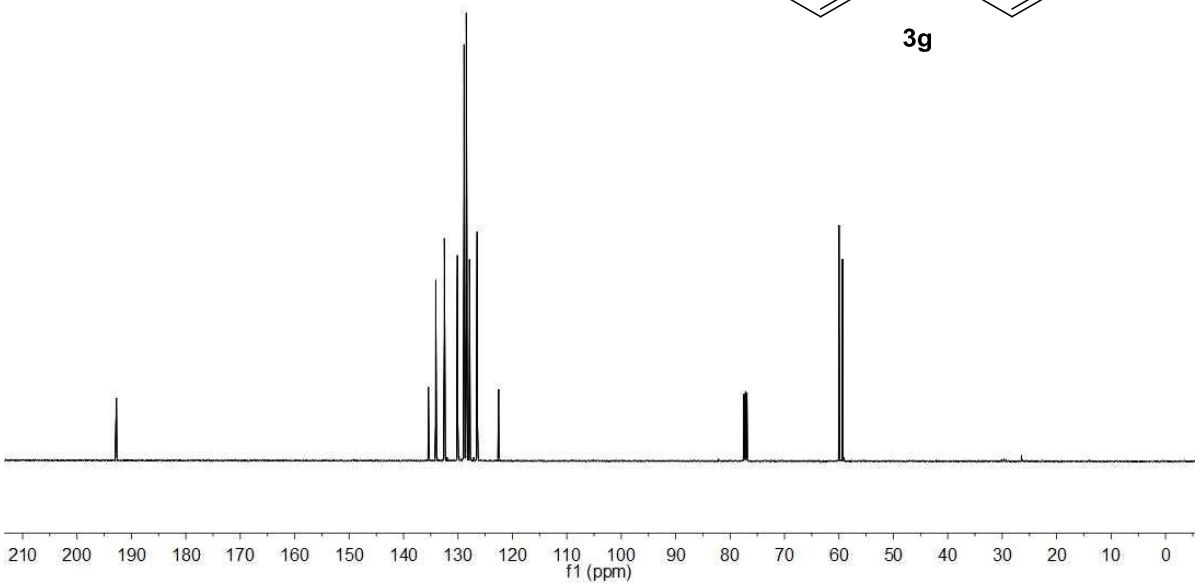
3g

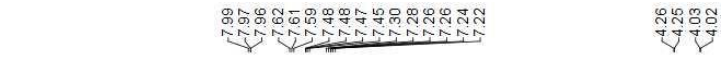

10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

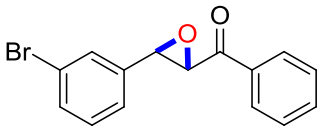

192.76
135.44
135.36
134.09
132.50
130.10
128.88
128.47
127.87
126.48
122.55
77.43
77.17
76.92
60.00
59.34


Br
O
O

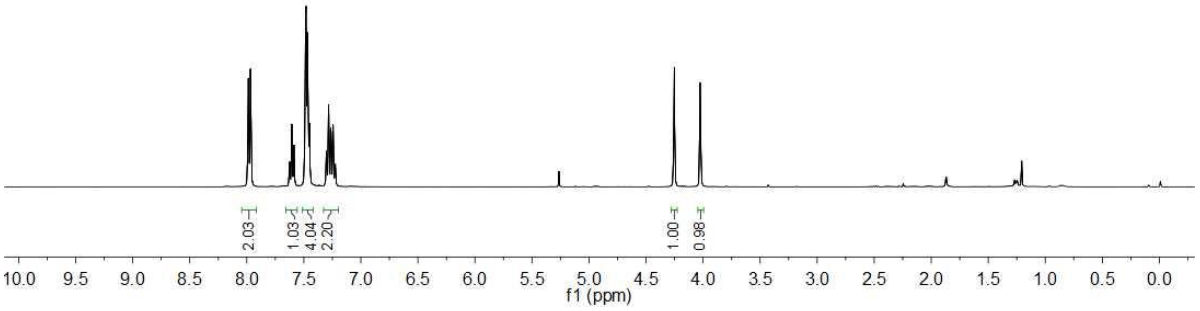
3g


210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

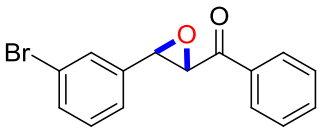

7.99
7.97
7.96
7.62
7.61
7.59
7.48
7.48
7.47
7.45
7.30
7.28
7.26
7.26
7.24
7.22
4.26
4.25
4.03
4.02


Br
O
O

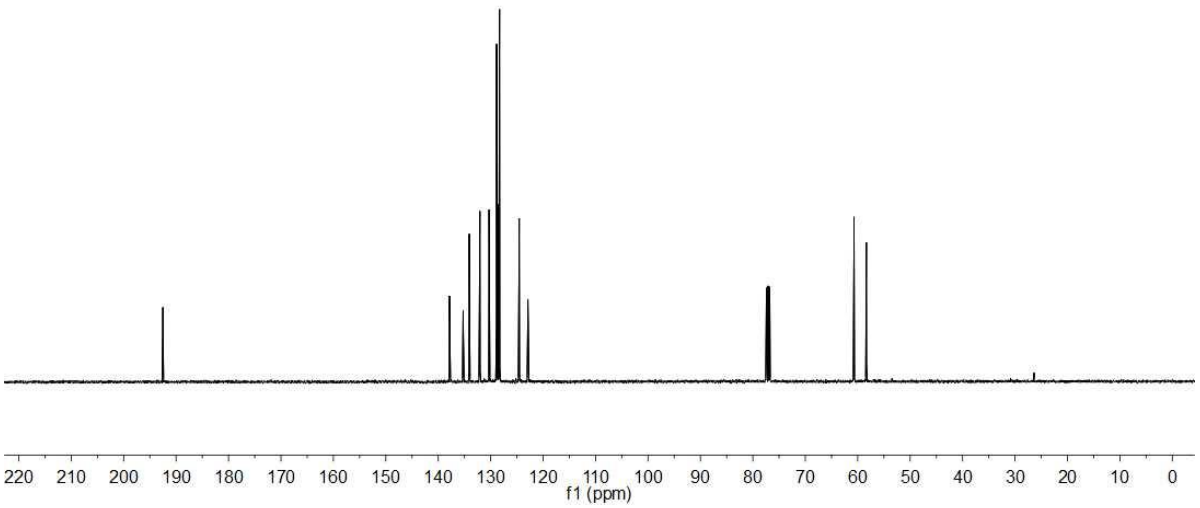
3h

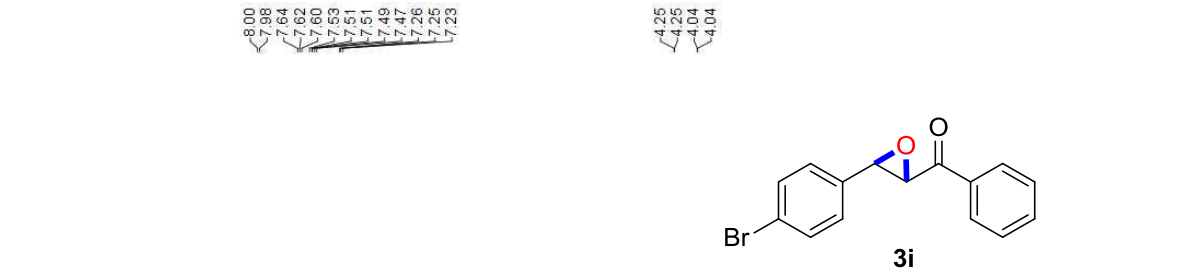

2.03
1.03
4.04
2.20
1.00
0.98
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

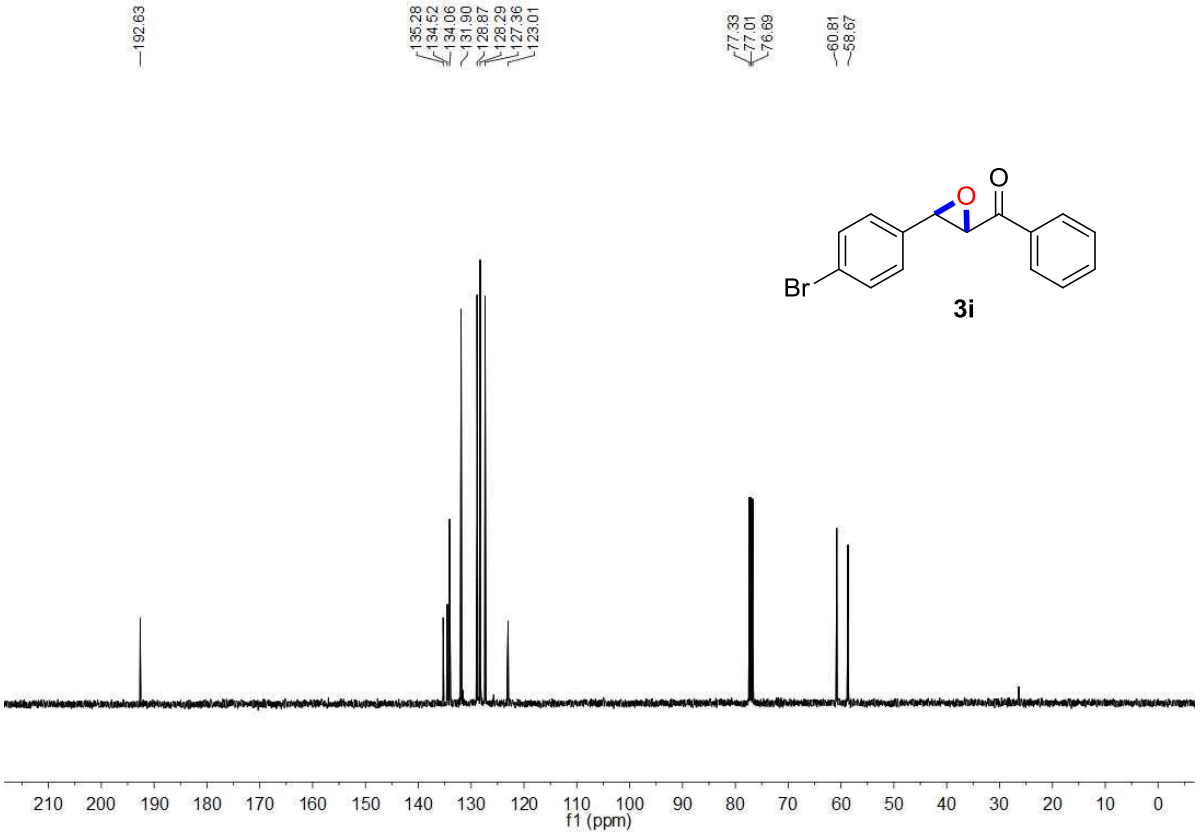

192.51
137.86
135.26
134.08
132.06
130.30
128.88
128.58
128.31
124.55
122.90
77.41
77.09
76.77
60.70
58.35

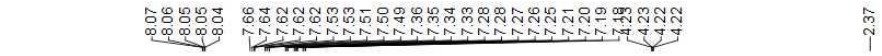

Br
O
O

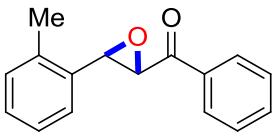
3h


220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

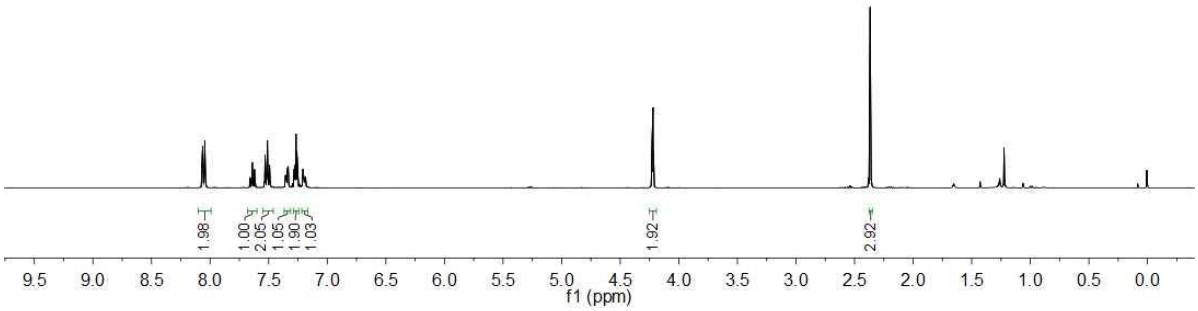

8.00
7.98
7.64
7.62
7.60
7.53
7.51
7.51
7.49
7.47
7.26
7.25
7.23
4.25
4.25
4.04
4.04
O
O
Br
3i
2.08
1.11
4.25
2.29
1.00
1.00
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


192.63
135.28
134.52
134.06
131.90
128.87
128.29
127.36
123.01
77.33
77.01
76.69
60.81
58.67
O
O
Br
3i
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

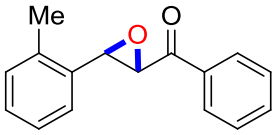

8.07
8.06
8.05
8.05
8.04
7.66
7.64
7.62
7.62
7.62
7.53
7.53
7.51
7.50
7.49
7.36
7.35
7.34
7.33
7.28
7.28
7.27
7.26
7.25
7.21
7.20
7.19
4.23
4.22
4.22
2.37


Me
O
O

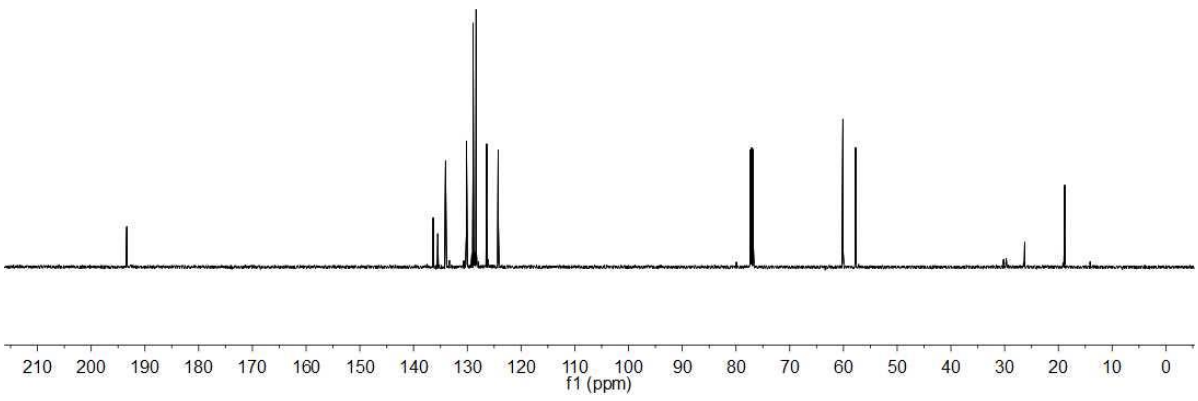
3j


1.98
1.00
2.05
1.05
1.90
1.03
1.92
2.92
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


193.36
136.35
135.49
134.05
133.95
130.16
128.93
128.51
128.35
126.39
124.26
77.32
77.06
76.81
60.10
57.74
18.82


Me
O
O

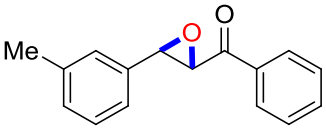
3j


210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

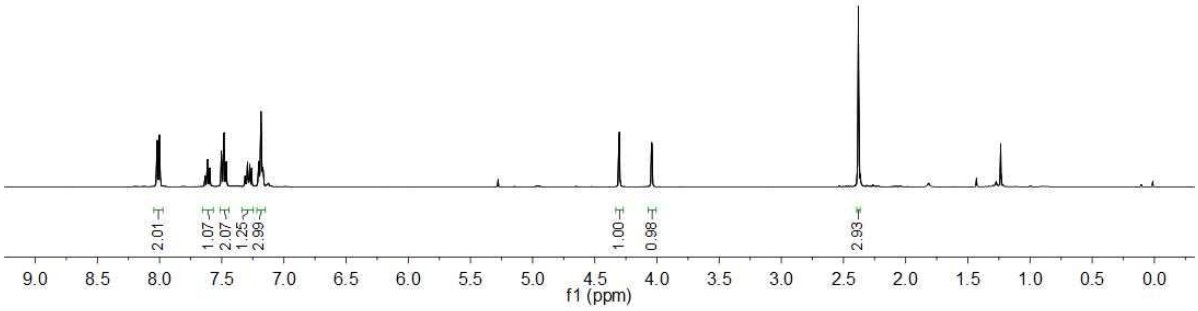

8.02
8.00
8.00
7.64
7.63
7.63
7.61
7.60
7.60
7.59
7.50
7.48
7.46
7.31
7.29
7.28
7.27
7.26
7.20
7.18
7.17


4.31
4.30
4.04
4.04


2.38


Me
O
O

3k


2.01
1.07
2.07
1.25
2.99
1.00
0.98
2.93
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

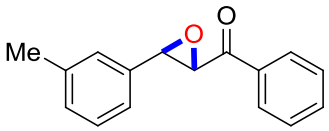

193.36


136.35
135.49
134.05
133.95
130.16
128.93
128.51
128.35
126.39
124.26

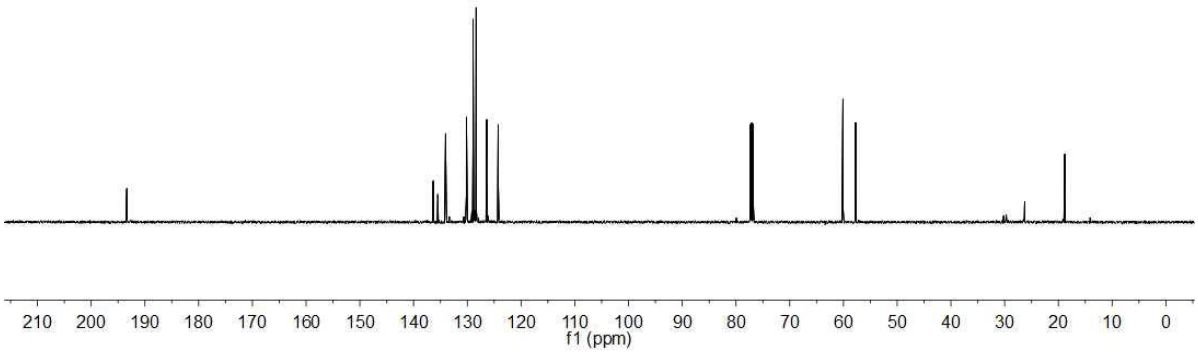

77.32
77.06
76.81

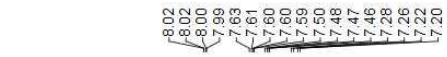

60.10
57.74


18.82


Me
O
O

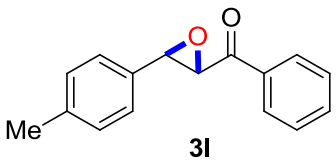
3k


210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

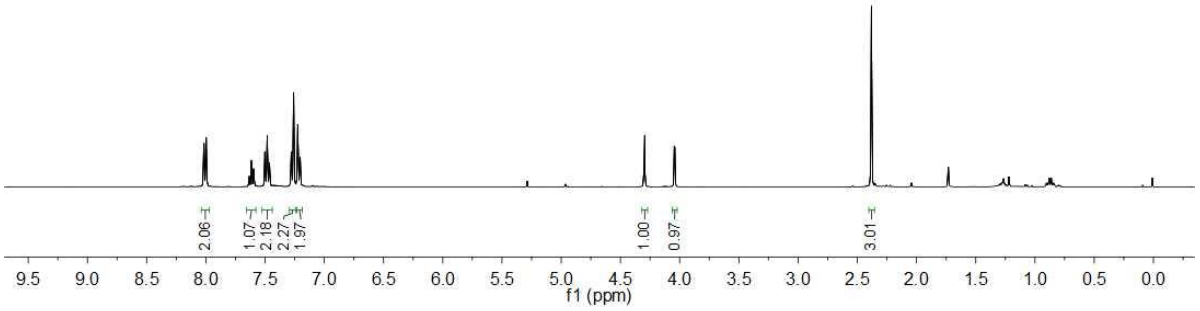

8.02
8.02
8.00
7.99
7.63
7.61
7.60
7.60
7.59
7.50
7.48
7.47
7.46
7.28
7.26
7.22
7.20


4.30
4.29
4.04
4.04

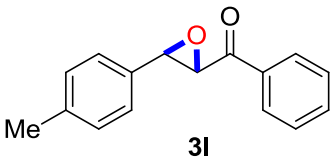
2.38


O
O
Me

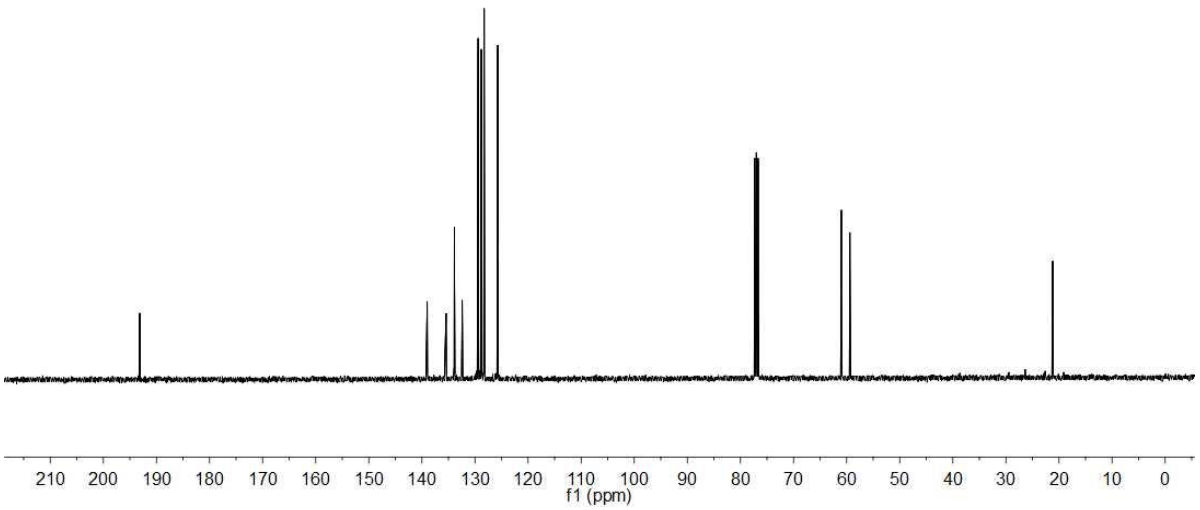
3l

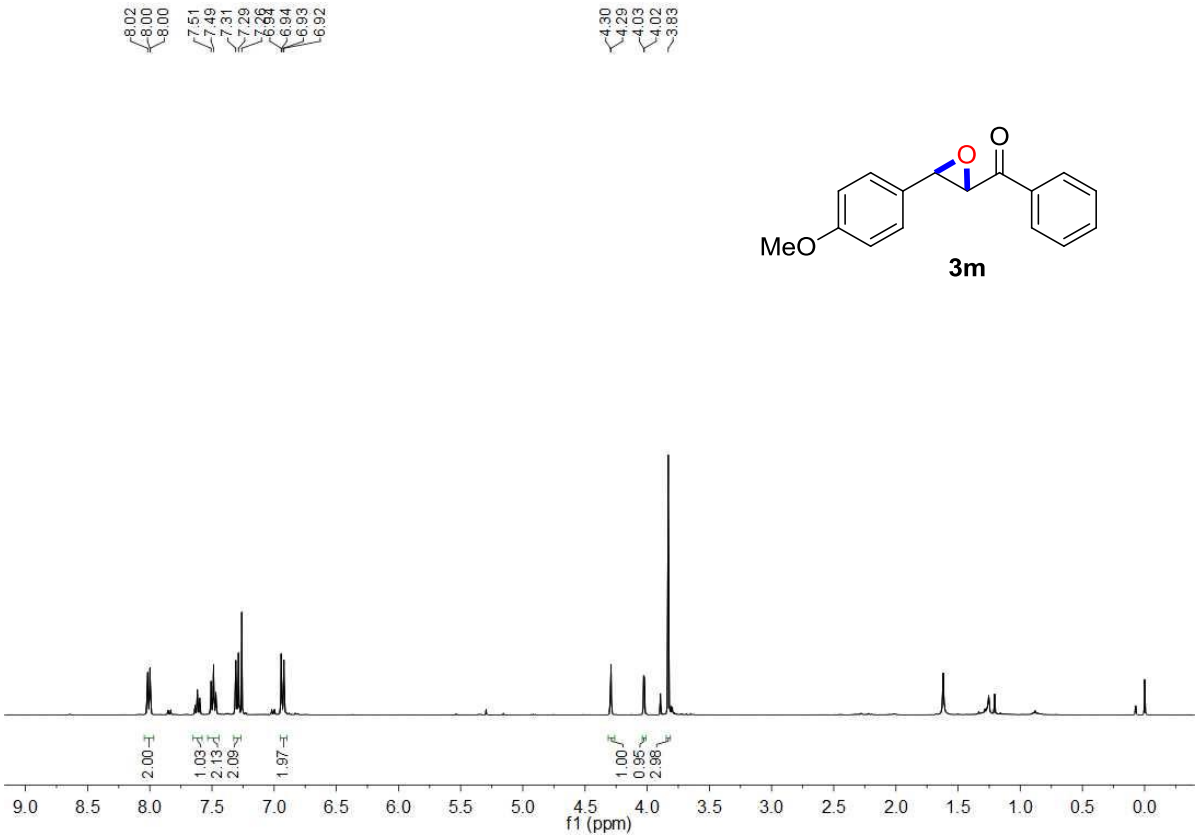

2.06
1.07
2.18
2.27
1.97
1.00
0.97
3.01
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

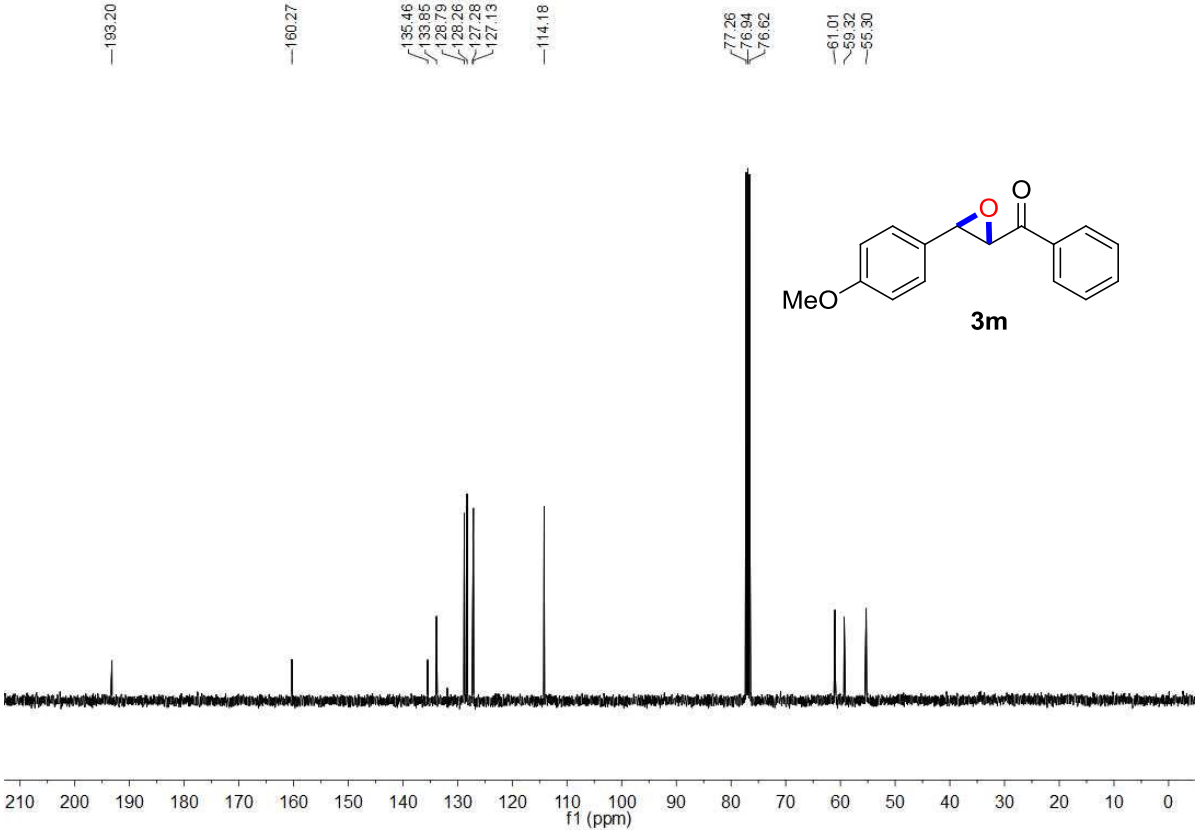

193.15
139.00
135.44
133.88
132.40
129.40
128.80
128.27
125.72
77.31
77.00
76.68
61.00
59.39
21.20

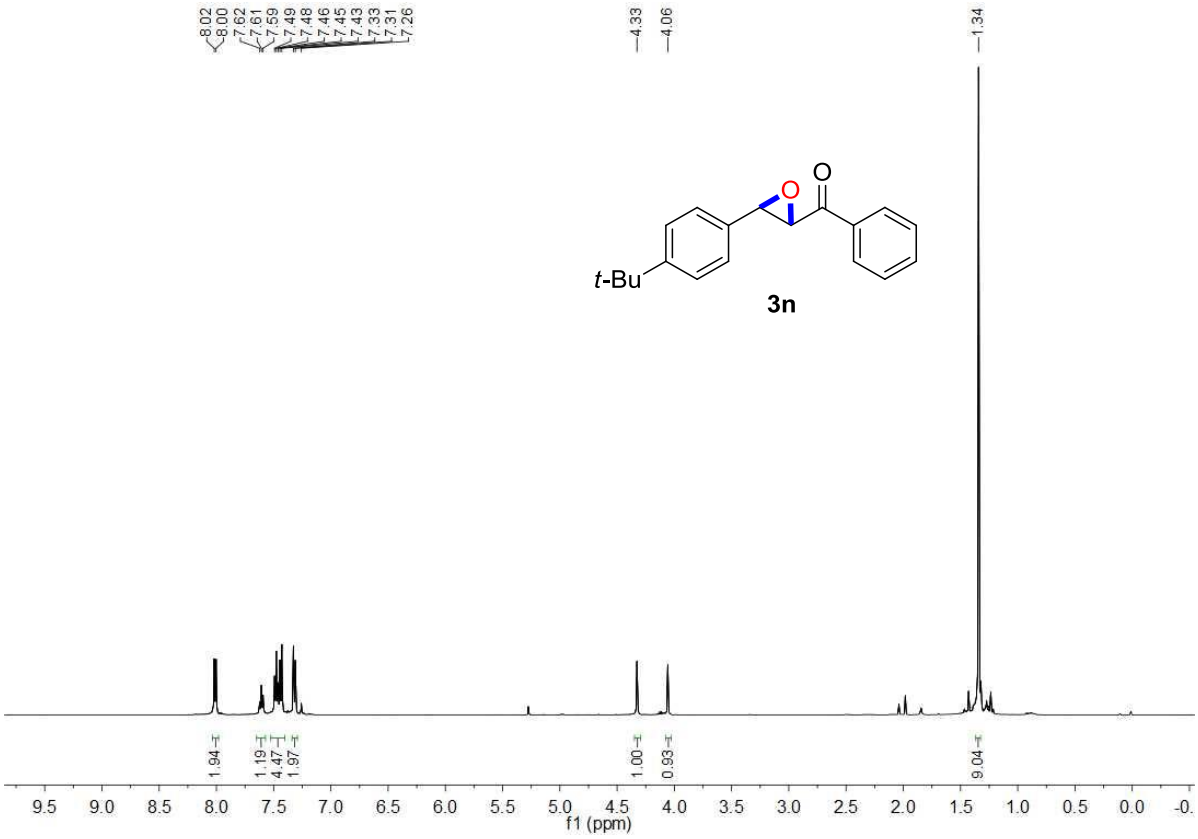

O
O
Me

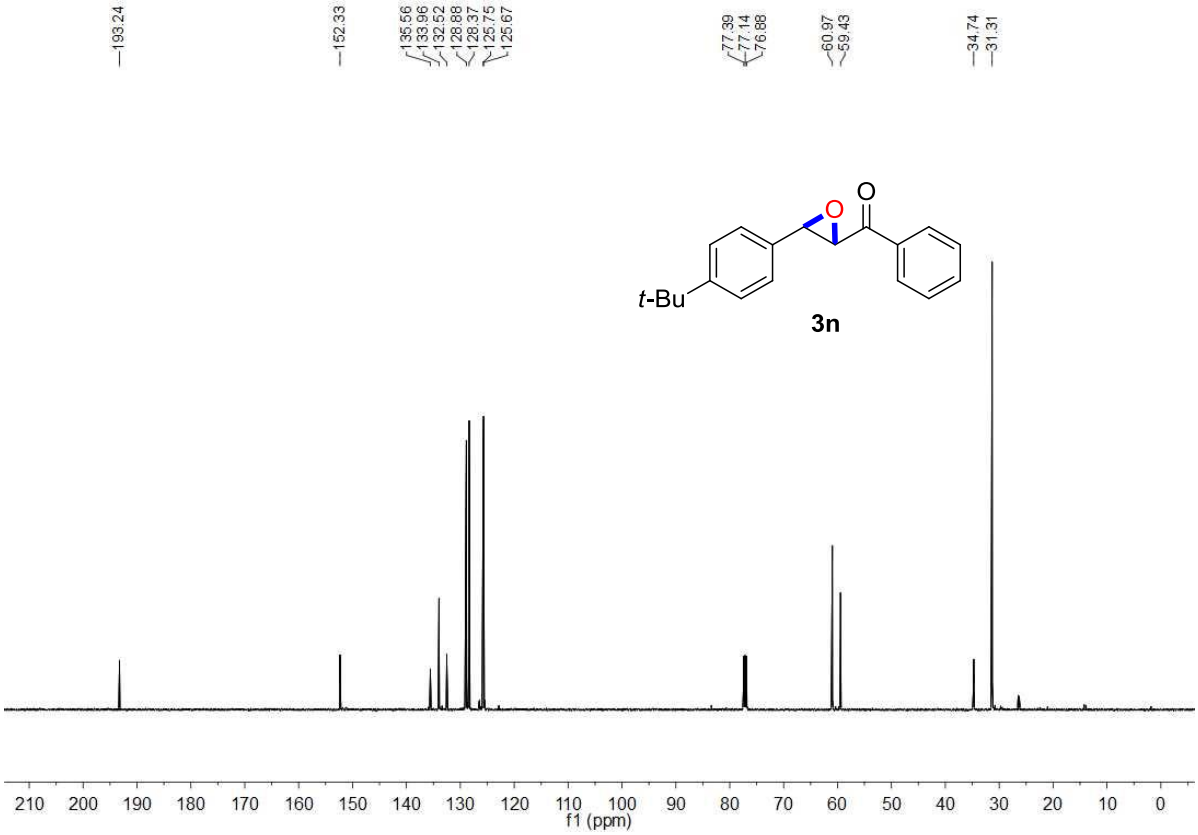
3l

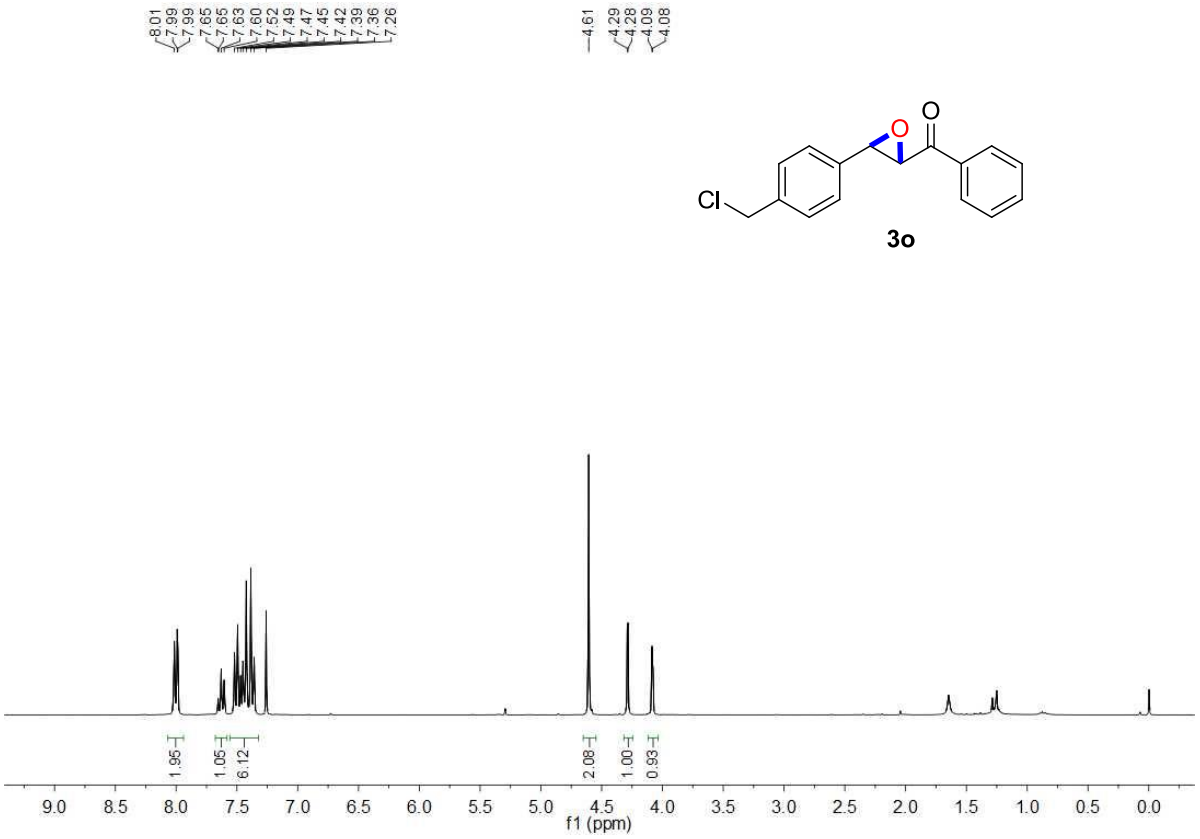

210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

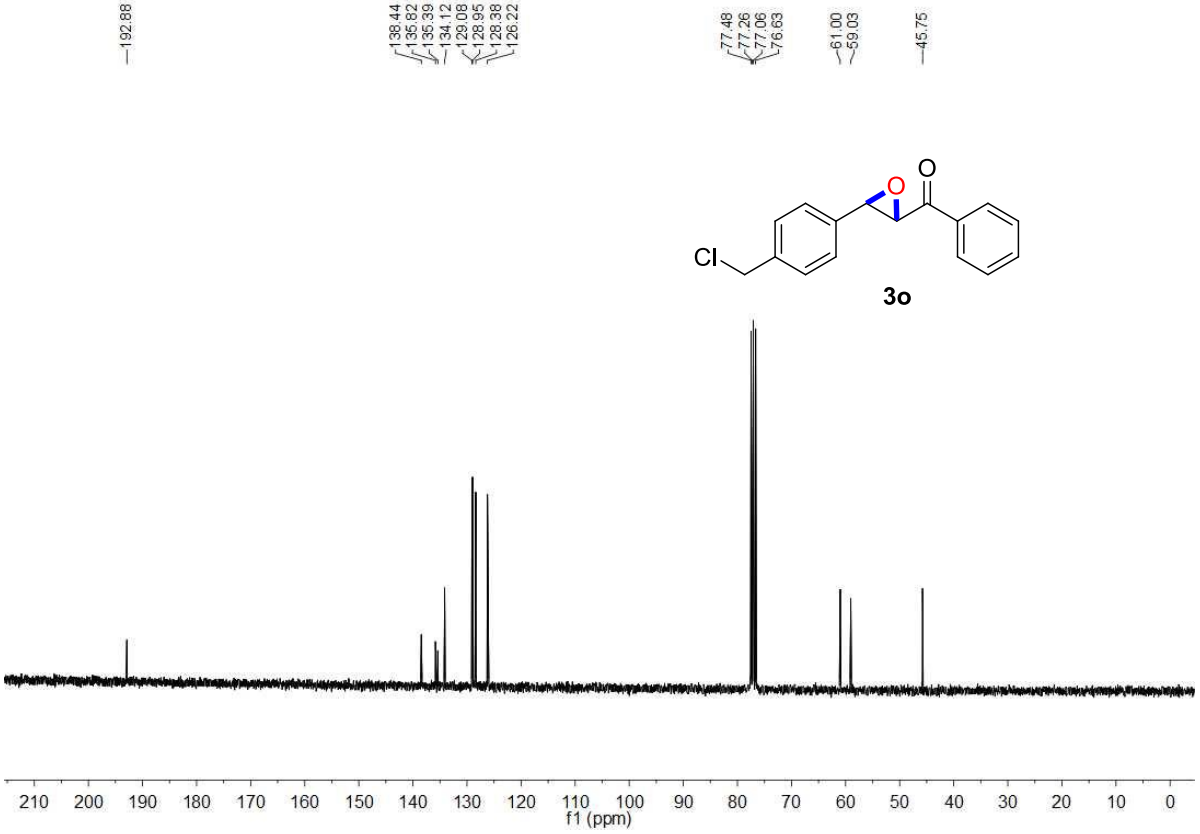

8.02
8.00
8.00
7.51
7.49
7.31
7.29
7.26
6.94
6.94
6.93
6.92
4.30
4.29
4.03
4.02
3.83
O
O
MeO
3m
2.00
1.03
2.13
2.09
1.97
1.00
0.95
2.98
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

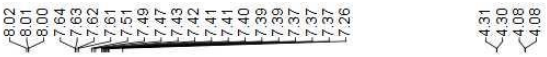

193.20
160.27
135.46
133.85
128.79
128.26
127.28
127.13
114.18
77.26
76.94
76.62
61.01
59.32
55.30
O
O
MeO
3m
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

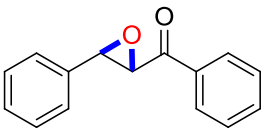

8.02
8.00
7.62
7.61
7.59
7.49
7.48
7.46
7.45
7.43
7.33
7.31
7.26
4.33
4.06
1.34
O
O
t-Bu
3n
1.94
1.19
4.47
1.97
1.00
0.93
9.04
f1 (ppm)


193.24
152.33
135.56
133.96
132.52
128.88
128.37
125.75
125.67
77.39
77.14
76.88
60.97
59.43
34.74
31.31
O
O
t-Bu
3n
f1 (ppm)

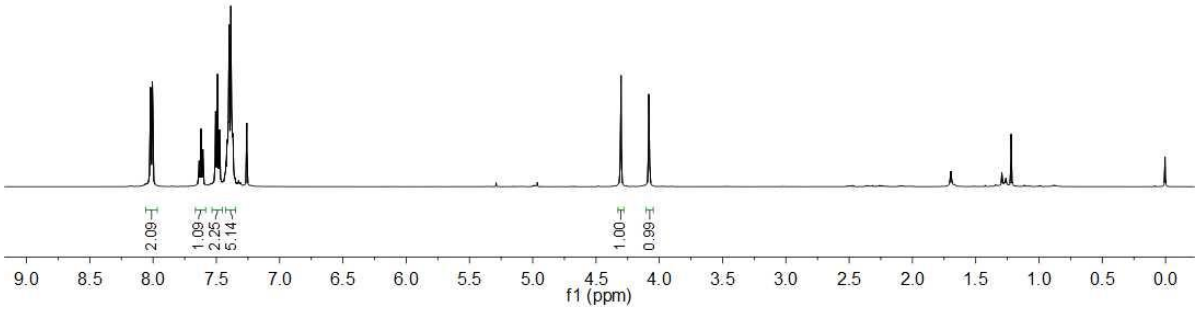

8.01
7.99
7.99
7.65
7.65
7.63
7.60
7.52
7.49
7.47
7.45
7.42
7.39
7.36
7.26
4.61
4.29
4.28
4.09
4.08
O
O
Cl
3o
1.95
1.05
6.12
2.08
1.00
0.93
f1 (ppm)

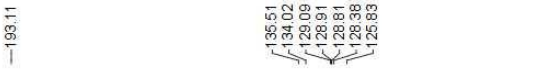

192.88
138.44
135.82
135.39
134.12
129.08
128.95
128.38
126.22
77.48
77.26
77.06
76.63
61.00
59.03
45.75
O
O
Cl
3o
f1 (ppm)

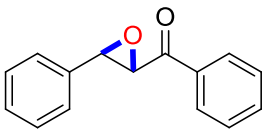

8.02
8.01
8.00
7.64
7.63
7.62
7.61
7.51
7.49
7.47
7.43
7.42
7.41
7.41
7.40
7.39
7.39
7.37
7.37
7.37
7.26
4.31
4.30
4.08
4.08



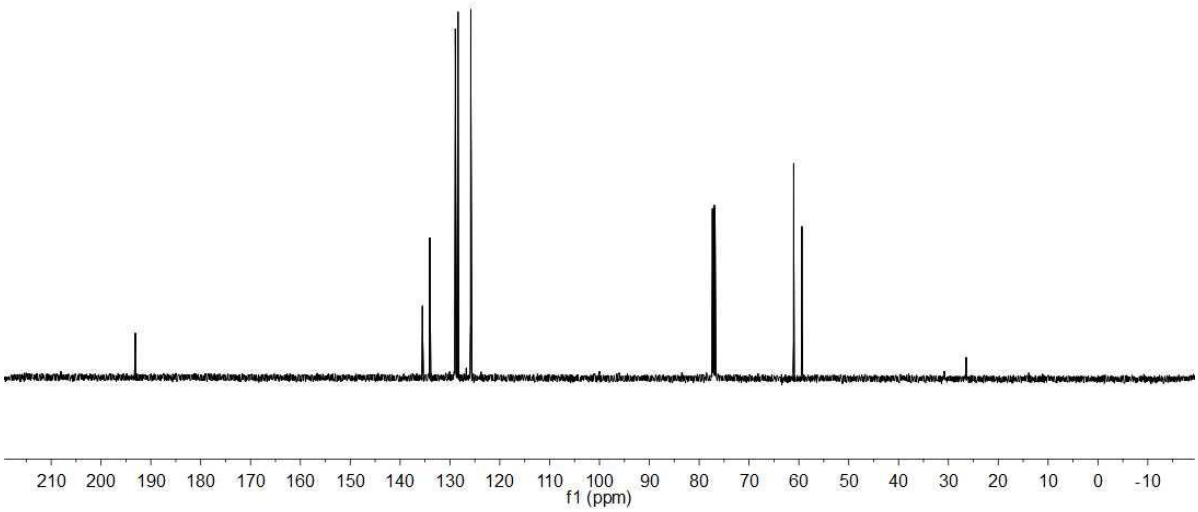
3p

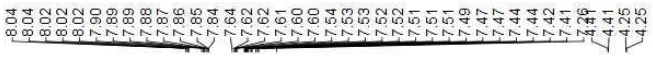

2.09
1.09
2.25
5.14
1.00
0.99
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

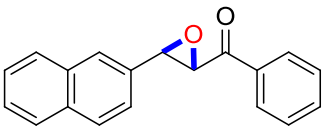

193.11
135.51
134.02
129.09
128.91
128.81
128.38
125.83
77.33
77.07
76.82
61.05
59.41



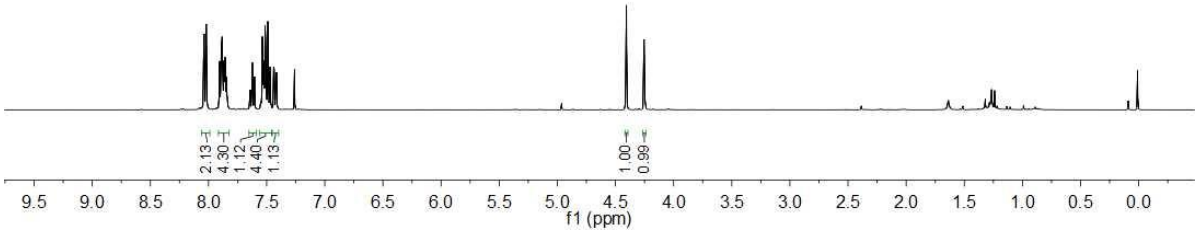
3p


210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

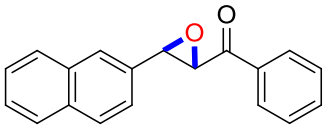

8.04
8.04
8.02
8.02
8.02
7.90
7.89
7.89
7.88
7.87
7.86
7.85
7.84
7.64
7.62
7.62
7.61
7.60
7.60
7.54
7.53
7.53
7.52
7.52
7.51
7.51
7.51
7.49
7.47
7.47
7.44
7.44
7.42
7.41
4.41
4.25
4.25


O
O

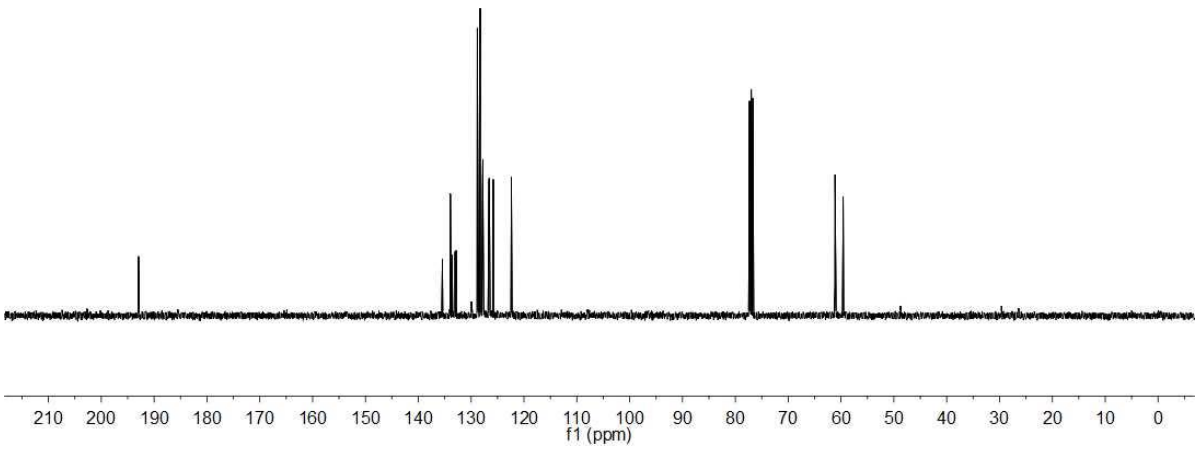
3q


2.13
4.30
1.12
4.40
1.13
1.00
0.99
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


192.96
135.44
133.94
133.60
133.03
132.84
128.84
128.74
128.30
127.84
127.79
126.64
126.55
125.82
122.38
77.31
76.99
76.67
61.12
59.59


O
O

3q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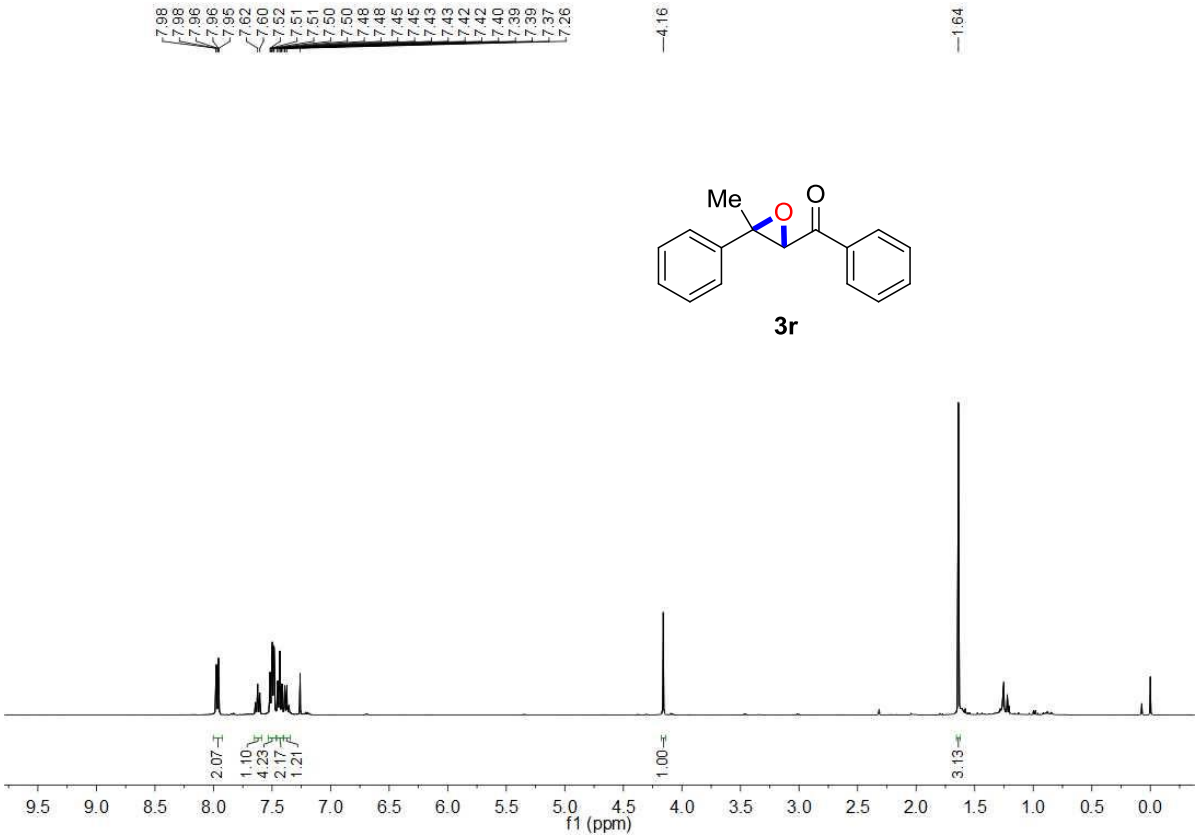
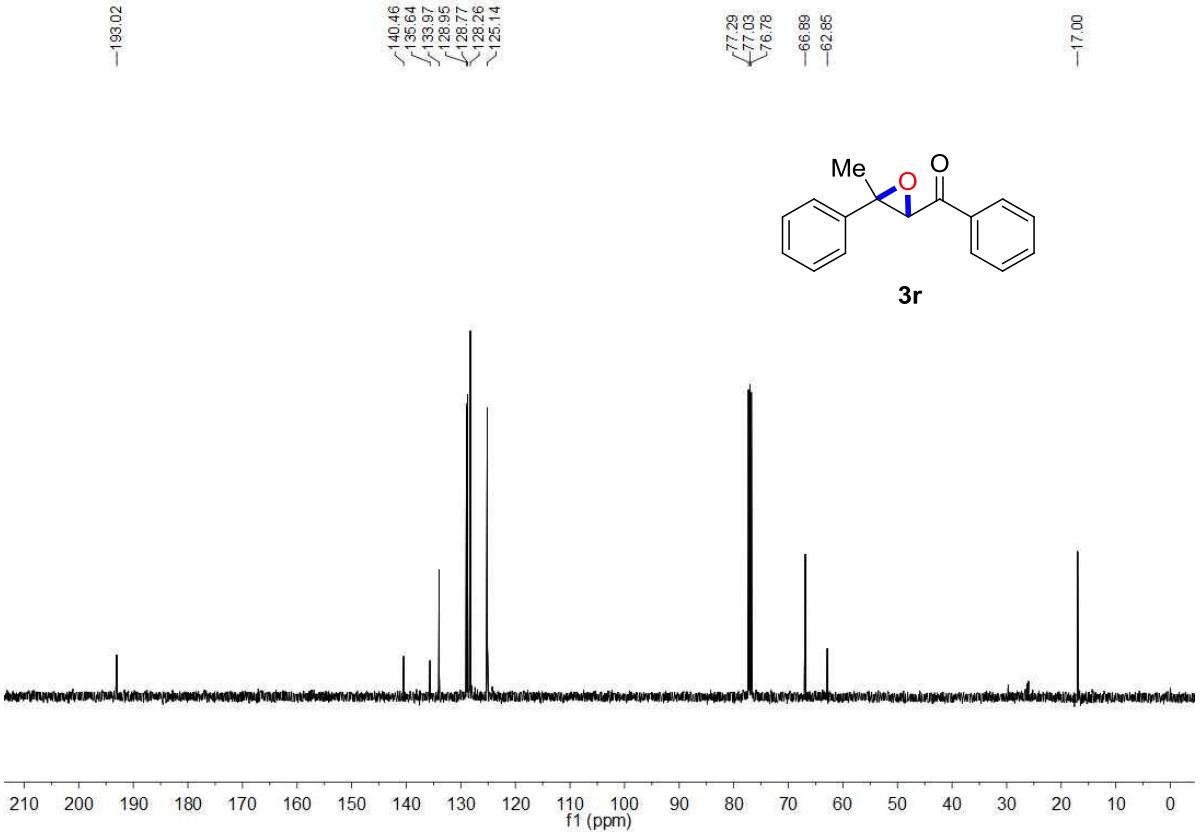
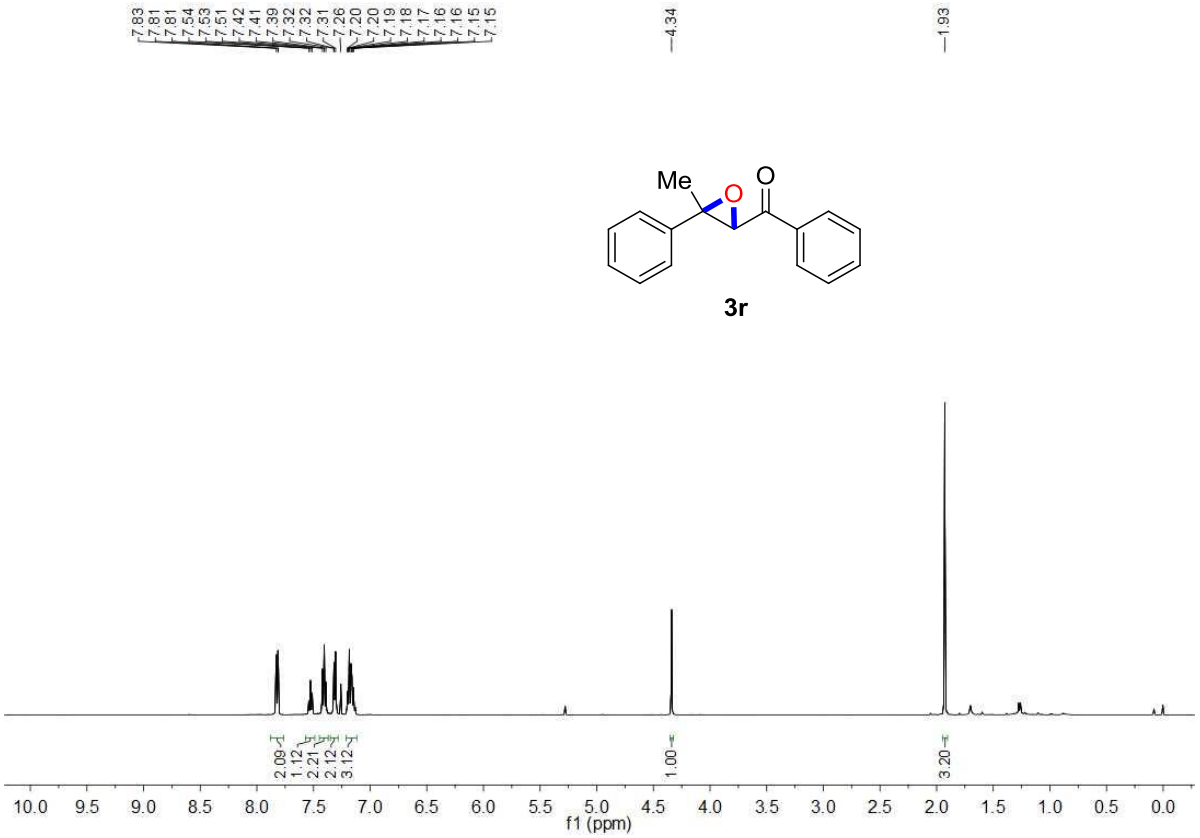
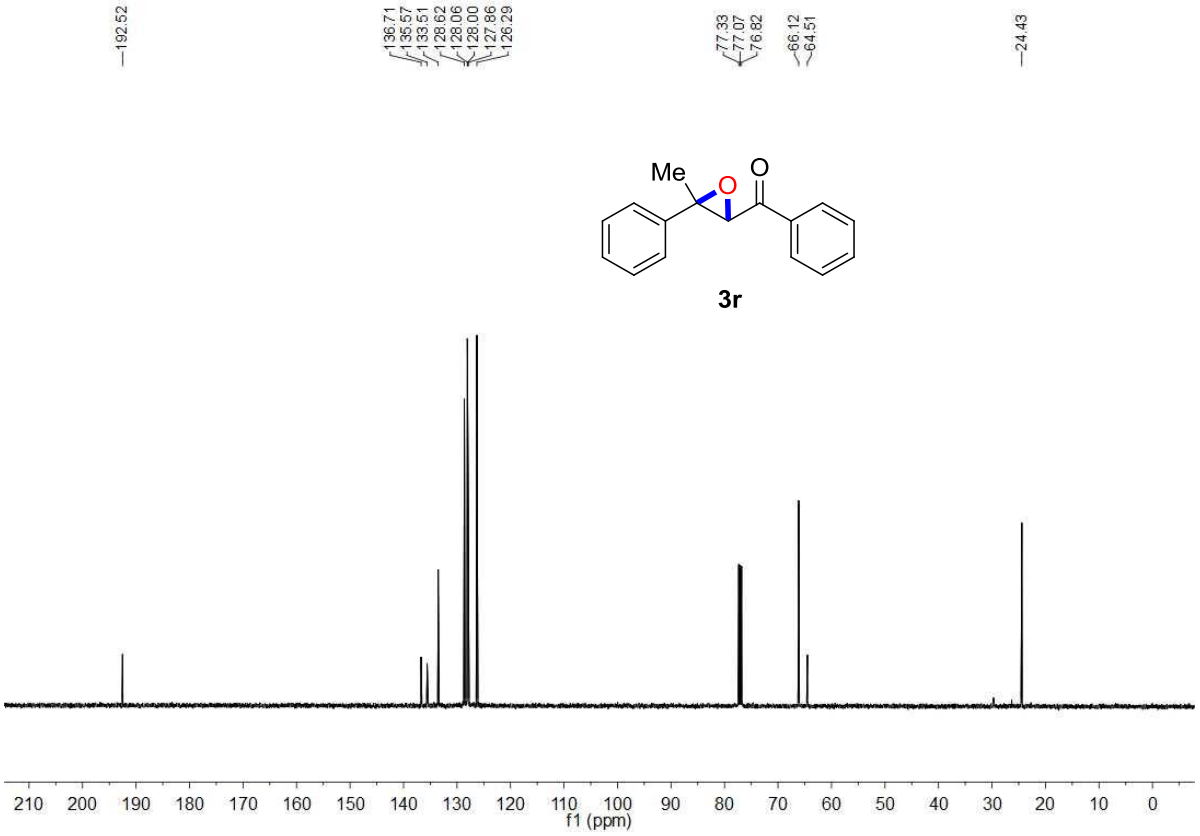
f1 (ppm)


7.98
7.98
7.96
7.96
7.95
7.62
7.60
7.52
7.51
7.51
7.50
7.50
7.48
7.48
7.45
7.45
7.43
7.43
7.42
7.42
7.40
7.39
7.39
7.37
7.26
4.16
1.64
Me
O
O
3r
2.07
1.10
4.23
2.17
1.21
1.00
3.13
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


193.02
140.46
135.64
133.97
128.95
128.77
128.26
125.14
77.29
77.03
76.78
66.89
62.85
17.00
Me
O
O
3r
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


7.83
7.81
7.81
7.54
7.53
7.51
7.42
7.41
7.39
7.32
7.32
7.31
7.26
7.20
7.20
7.19
7.18
7.17
7.16
7.16
7.15
7.15
4.34
1.93
Me
O
O
3r
2.09
1.12
2.21
2.12
3.12
1.00
3.20
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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136.71
135.57
133.51
128.62
128.06
128.00
127.86
126.29
77.33
77.07
76.82
66.12
64.51
24.43
Me
O
O
3r
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


7.94
7.93
7.59
7.58
7.56
7.47
7.45
7.43
7.42
7.41
7.40
7.38
7.36
7.33
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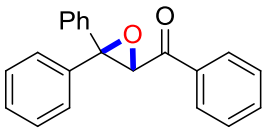
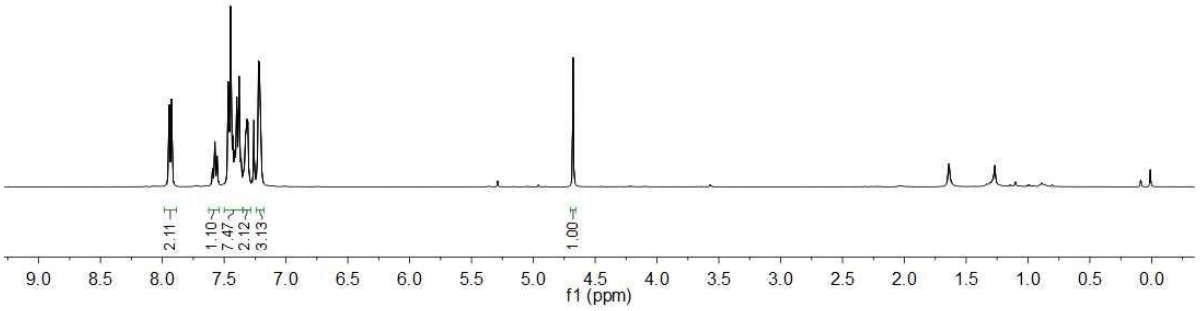
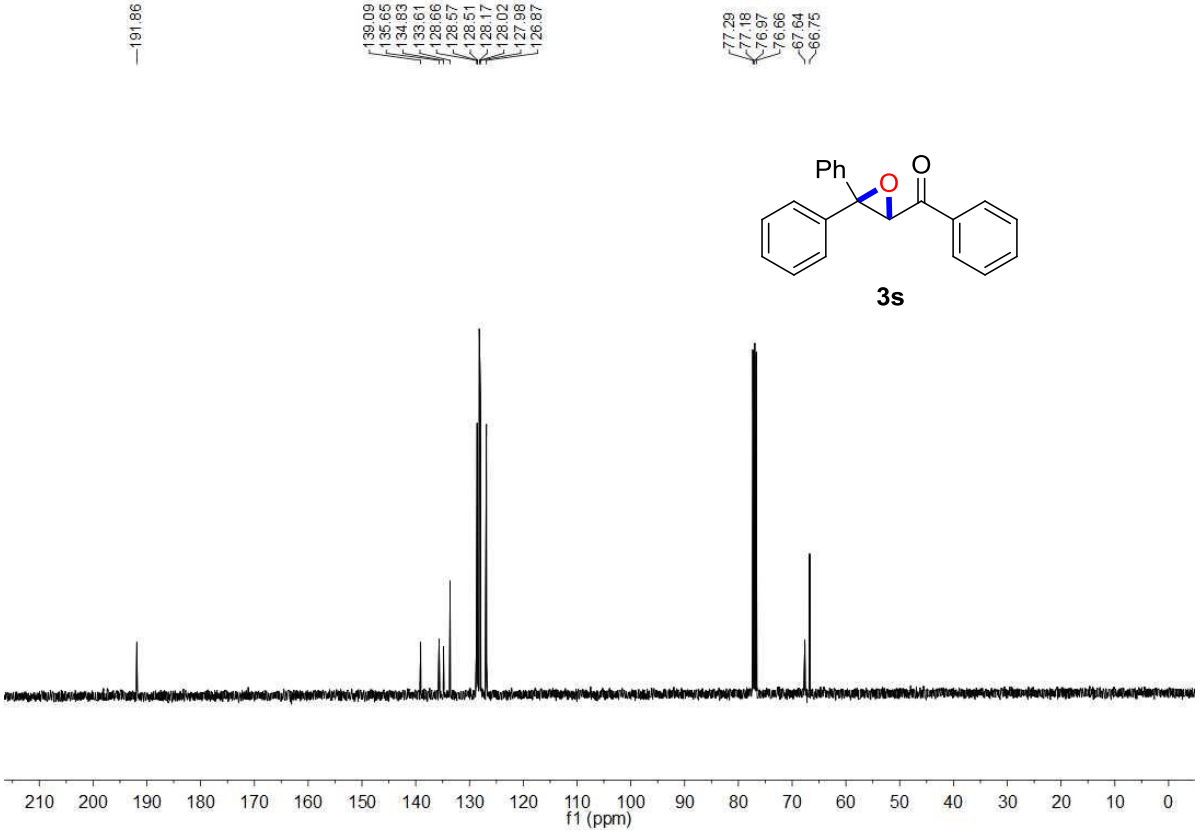
7.31
7.26
7.22
7.21
7.21
4.68


Ph
O
O

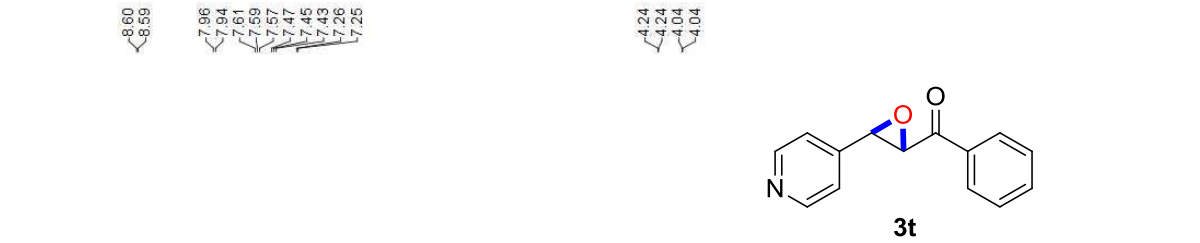
3s


2.11
1.10
7.47
2.12
3.13
1.00
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

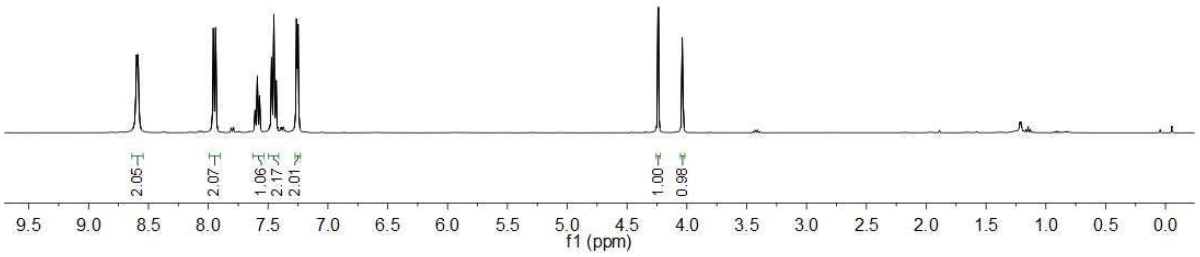

191.86
139.09
135.65
134.83
133.61
128.66
128.57
128.51
128.17
128.02
127.98
126.87
77.29
77.18
76.97
76.66
67.64
66.75
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

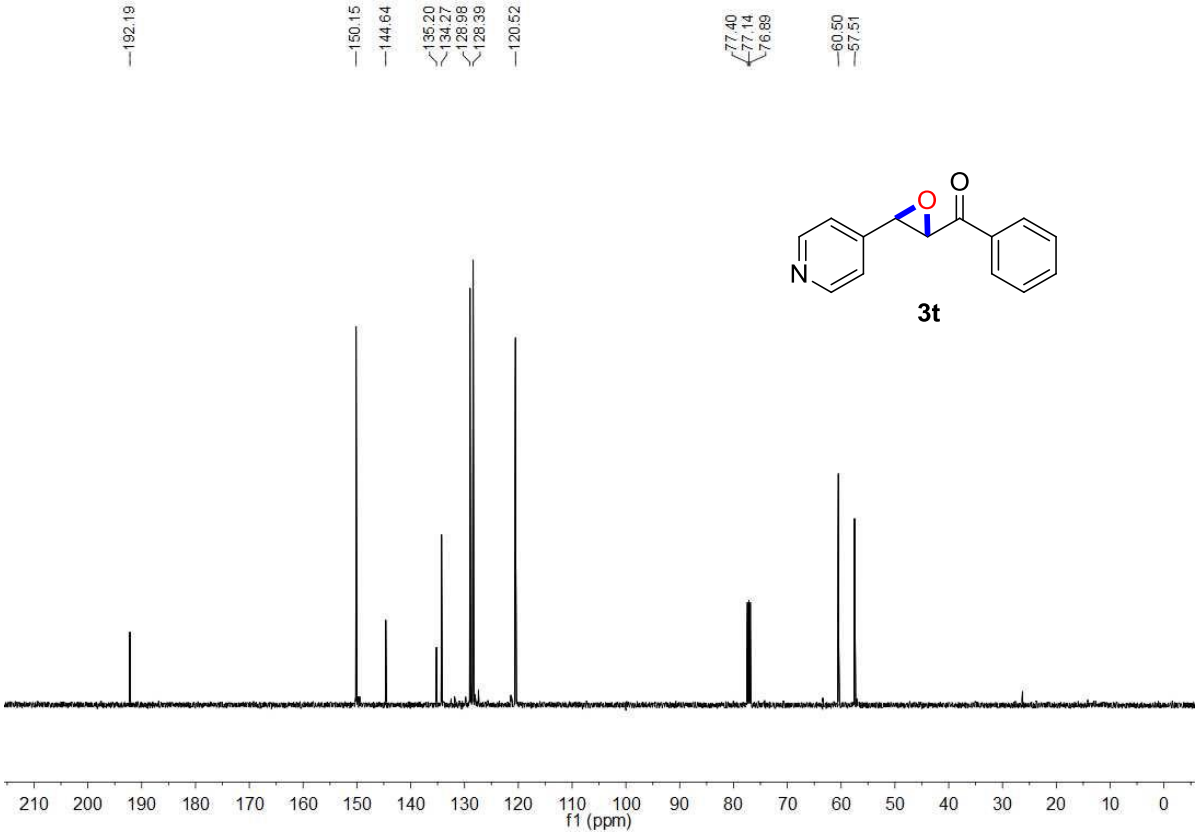
Ph
O
O

3s

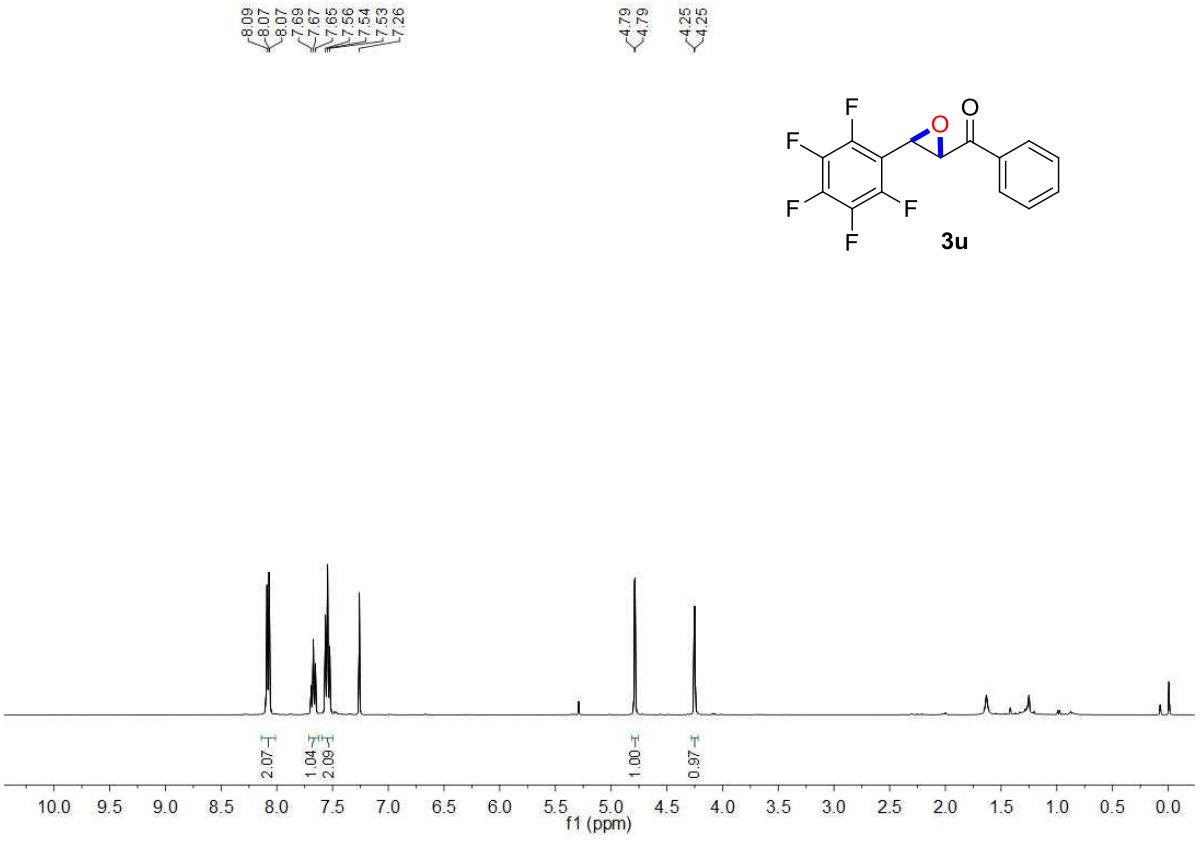

8.60
8.59
7.96
7.94
7.61
7.59
7.57
7.47
7.45
7.43
7.26
7.25
4.24
4.24
4.04
4.04
O
O
N

3t


2.05
2.07
1.06
2.17
2.01
1.00
0.98
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


192.19
150.15
144.64
135.20
134.27
128.98
128.39
120.52
77.40
77.14
76.89
60.50
57.51
O
O
N
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

3t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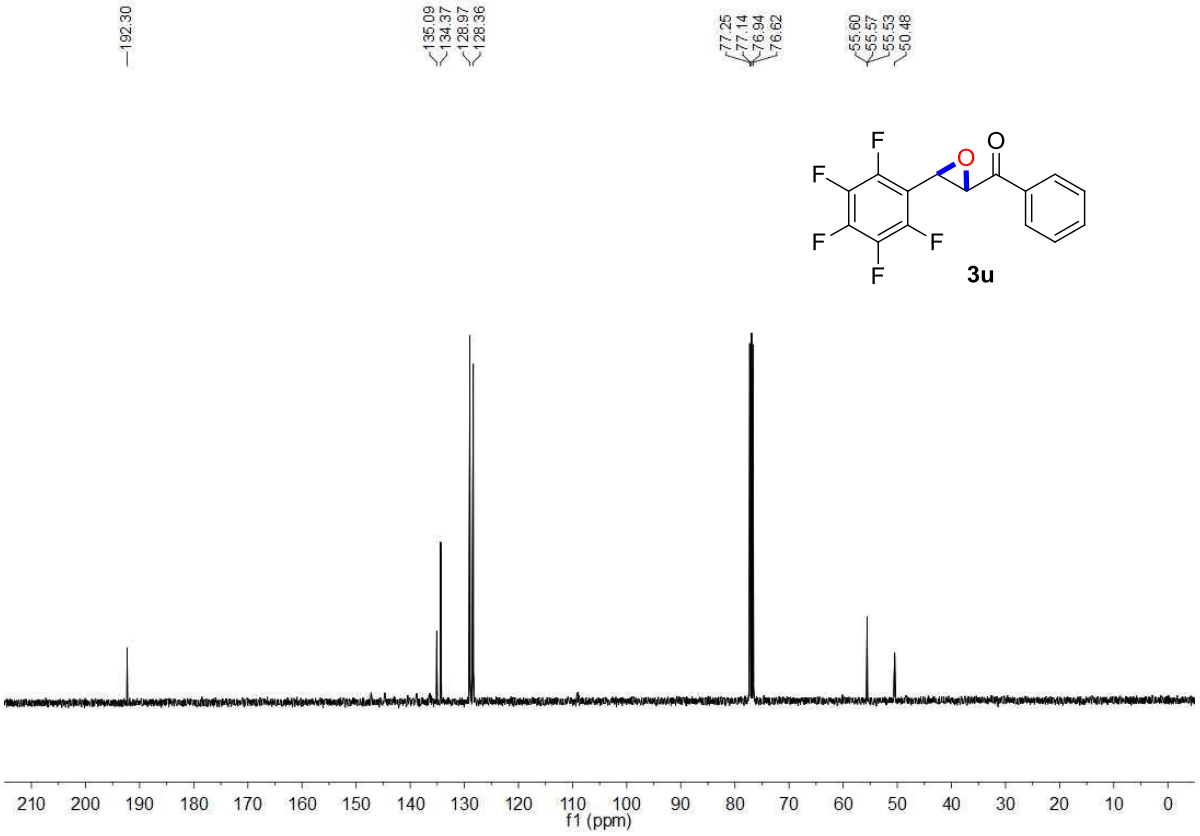
8.07
8.07
7.69
7.67
7.65
7.56
7.54
7.53
7.26
4.79
4.79
4.25
4.25
F
F
F
F
F
O
O
3u
2.07
1.04
2.09
1.00
0.97
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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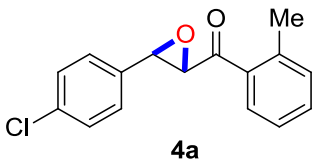
135.09
134.37
128.97
128.36
77.25
77.14
76.94
76.62
55.60
55.57
55.53
50.48
F
F
F
F
F
O
O
3u
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

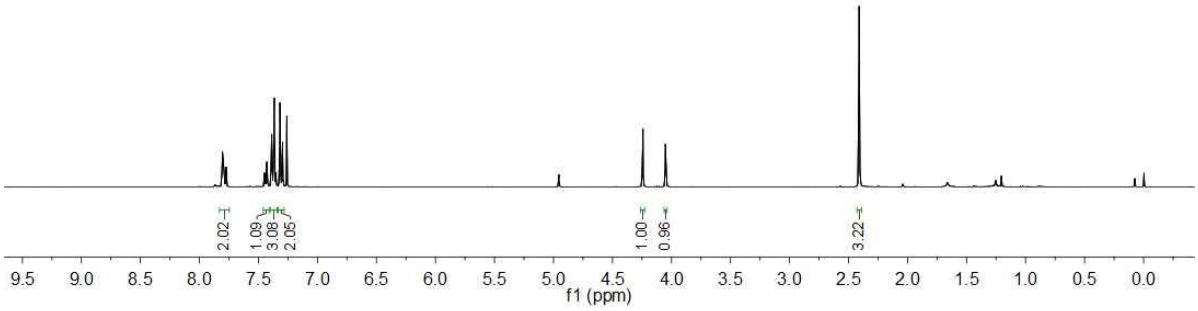

7.80
7.79
7.77
7.43
7.39
7.38
7.37
7.37
7.36
7.32
7.31
7.30
7.30
7.26


4.25
4.24
4.05
4.05

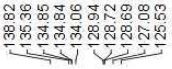

2.41


O
Me
O
Cl

4a


2.02
1.09
3.08
2.05
1.00
0.96
3.22
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


192.83


138.82
135.36
134.85
134.84
134.06
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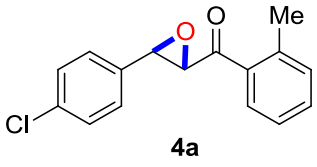
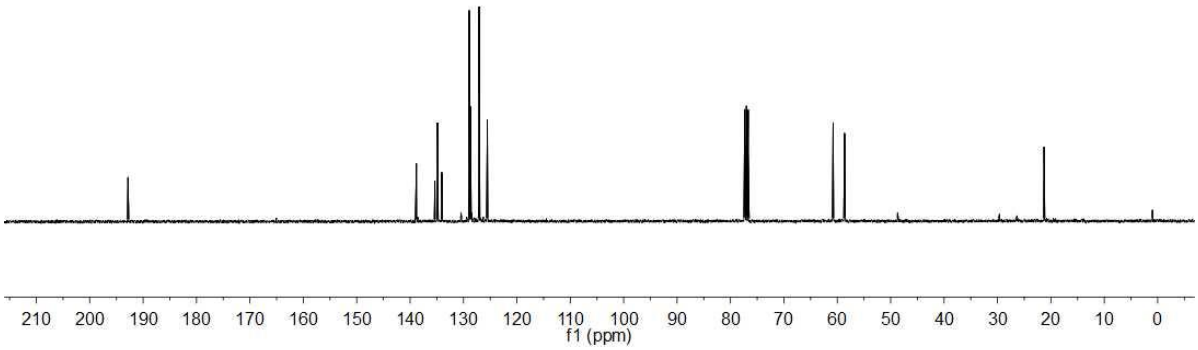
128.72
128.69
127.08
125.53

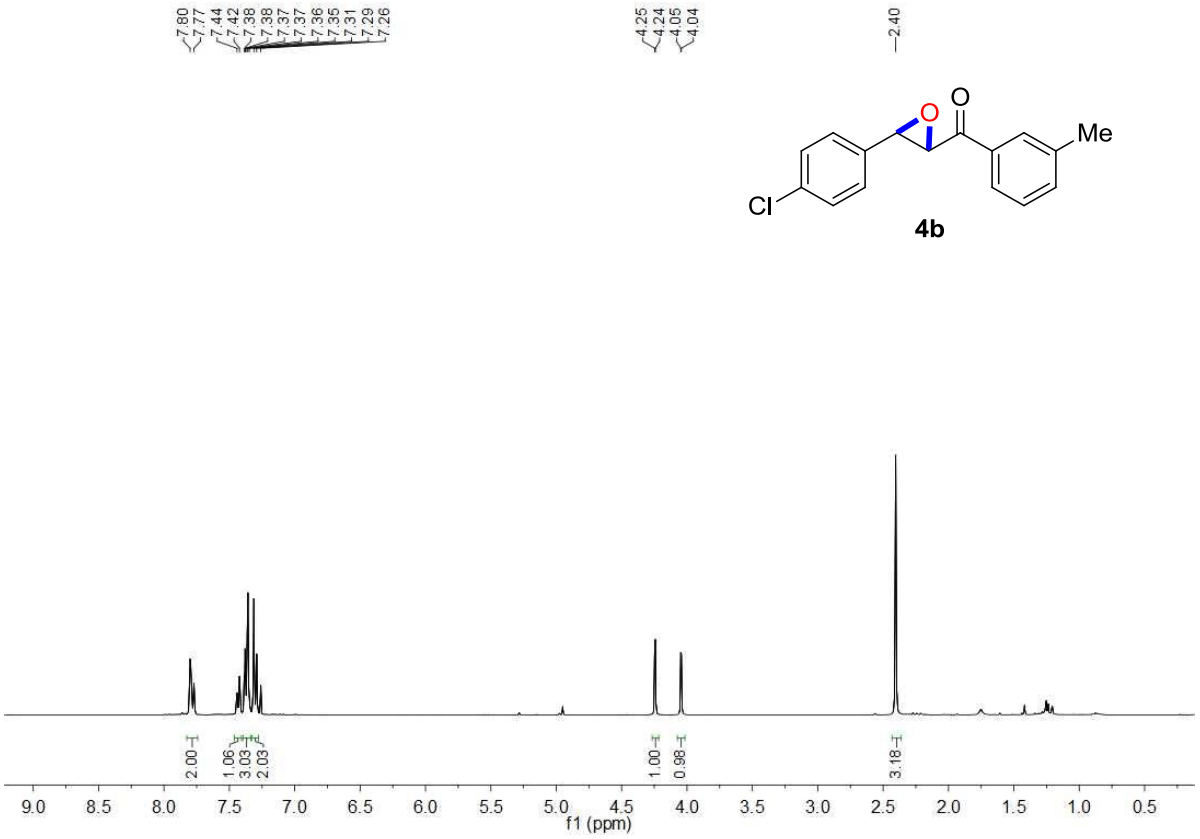

77.33
77.01
76.69
60.78
58.64


21.27


O
Me
O
Cl

4a


210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)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7.77
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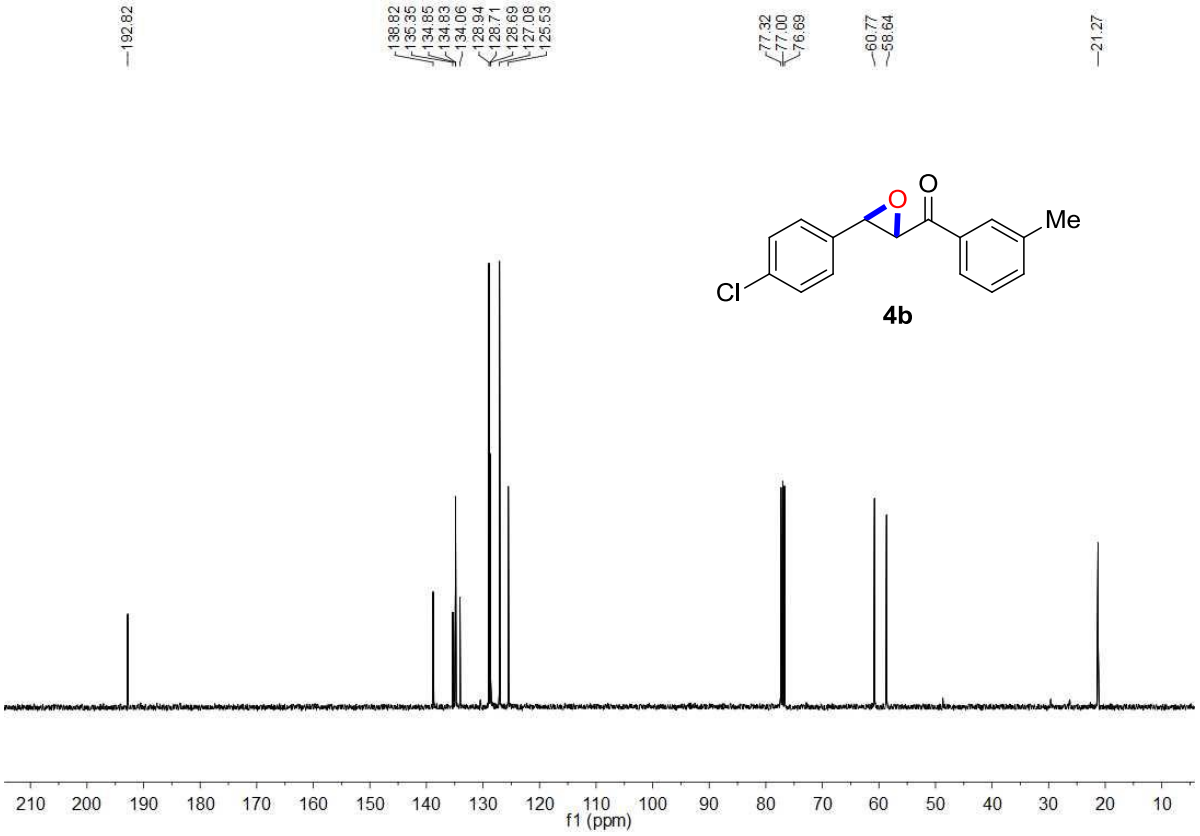
7.38
7.37
7.37
7.36
7.35
7.31
7.29
7.26
4.25
4.24
4.05
4.04
2.40
O
O
Me
Cl
4b
2.00
1.06
3.03
2.03
1.00
0.98
3.18
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)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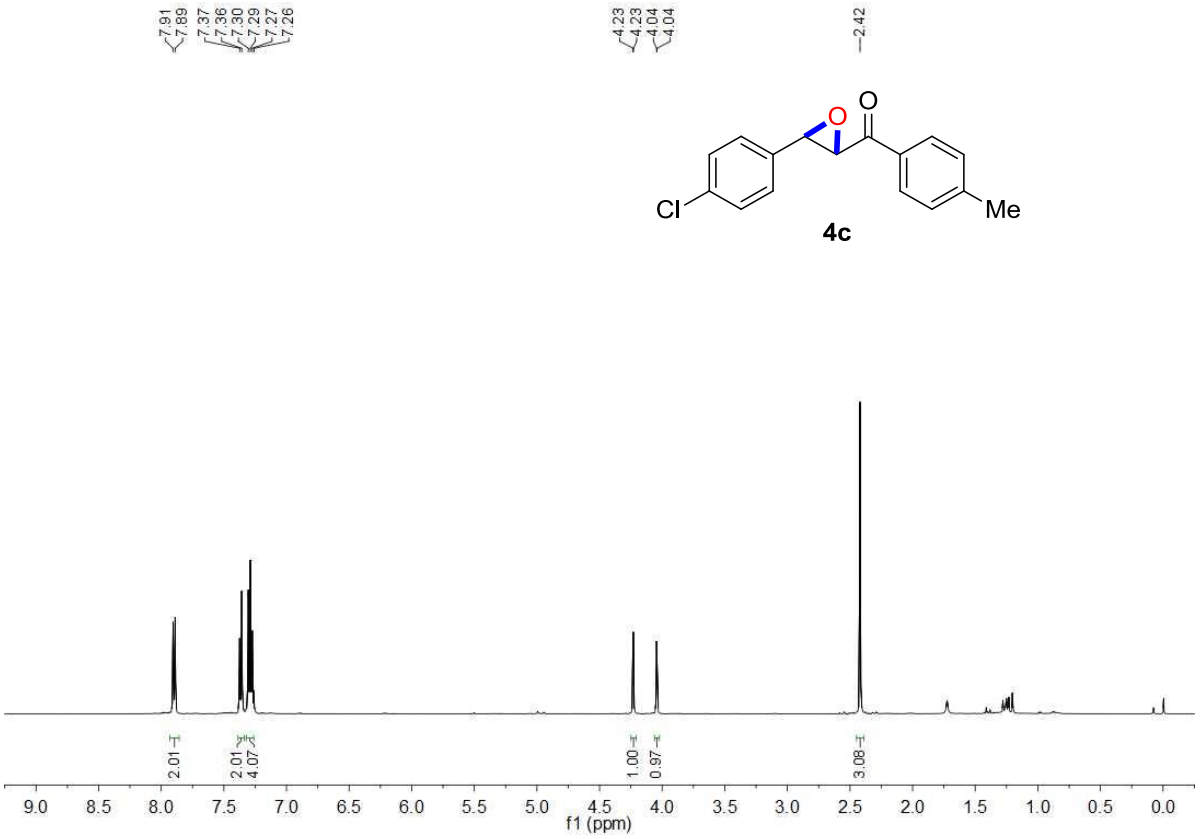
138.82
135.35
134.85
134.83
134.06
128.94
128.71
128.69
127.08
125.53
77.32
77.00
76.69
60.77
58.64
21.27
O
O
Me
Cl
4b
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)


7.91
7.89
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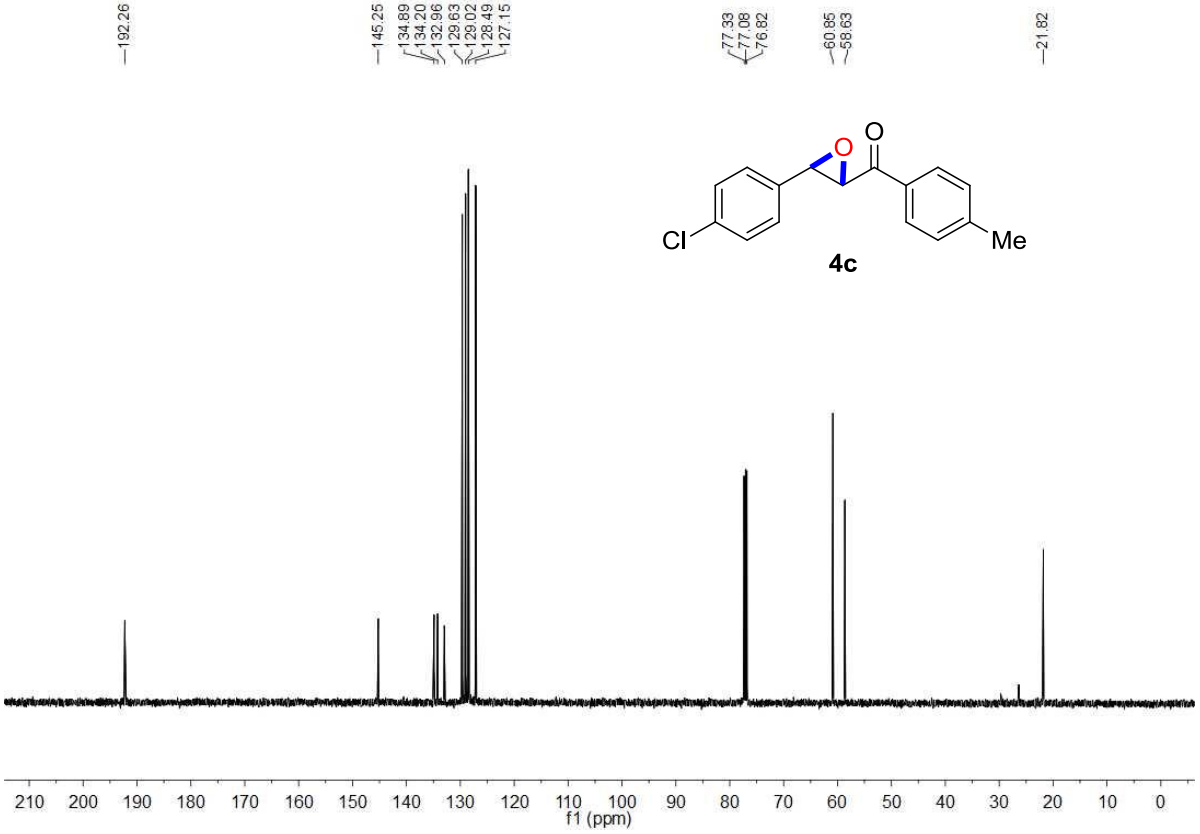
7.36
7.30
7.29
7.27
7.26
4.23
4.23
4.04
4.04
2.42
O
O
Cl
Me
4c
2.01
2.01
4.07
1.00
0.97
3.08
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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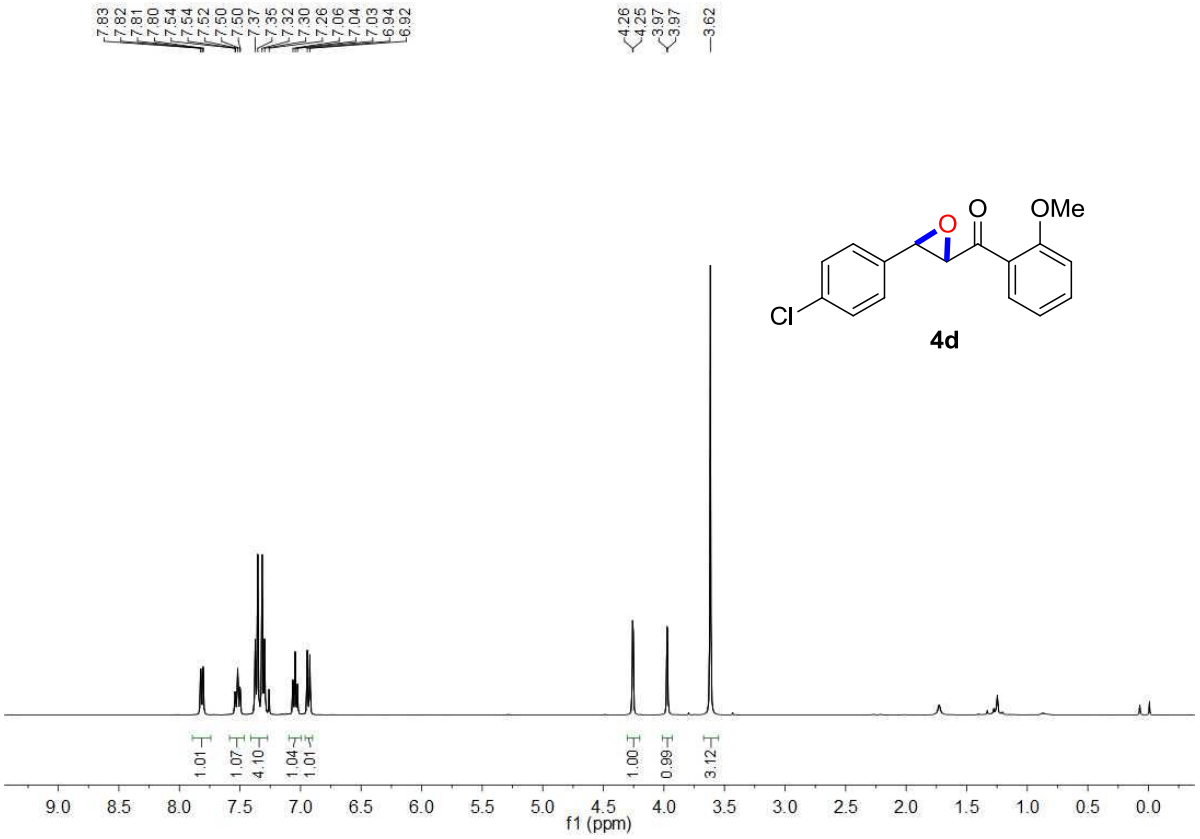
145.25
134.89
134.20
132.96
129.63
129.02
128.49
127.15
77.33
77.08
76.82
60.85
58.63
21.82
O
O
Cl
Me
4c
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)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7.54
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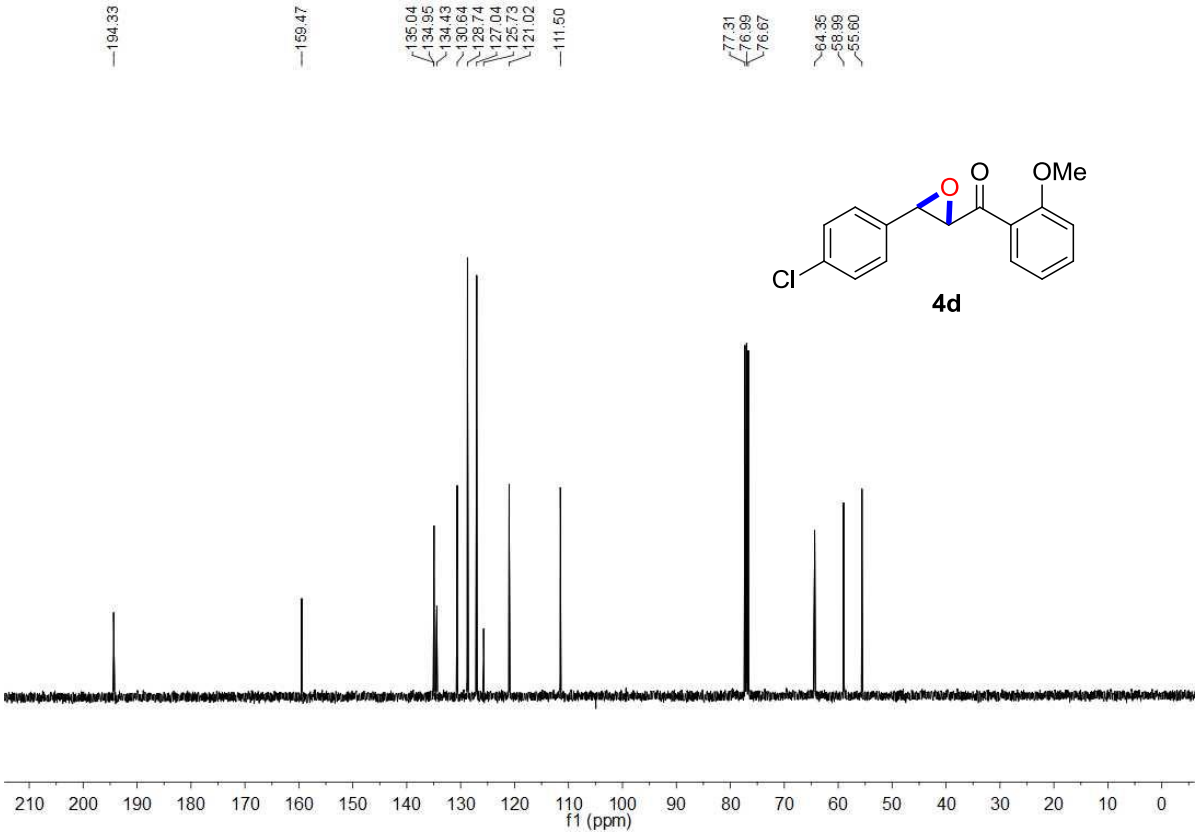
7.50
7.50
7.37
7.35
7.32
7.30
7.26
7.06
7.04
7.03
6.94
6.92
4.26
4.25
3.97
3.97
3.62
O
O
OMe
Cl
4d
1.01
1.07
4.10
1.04
1.01
1.00
0.99
3.12
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)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134.95
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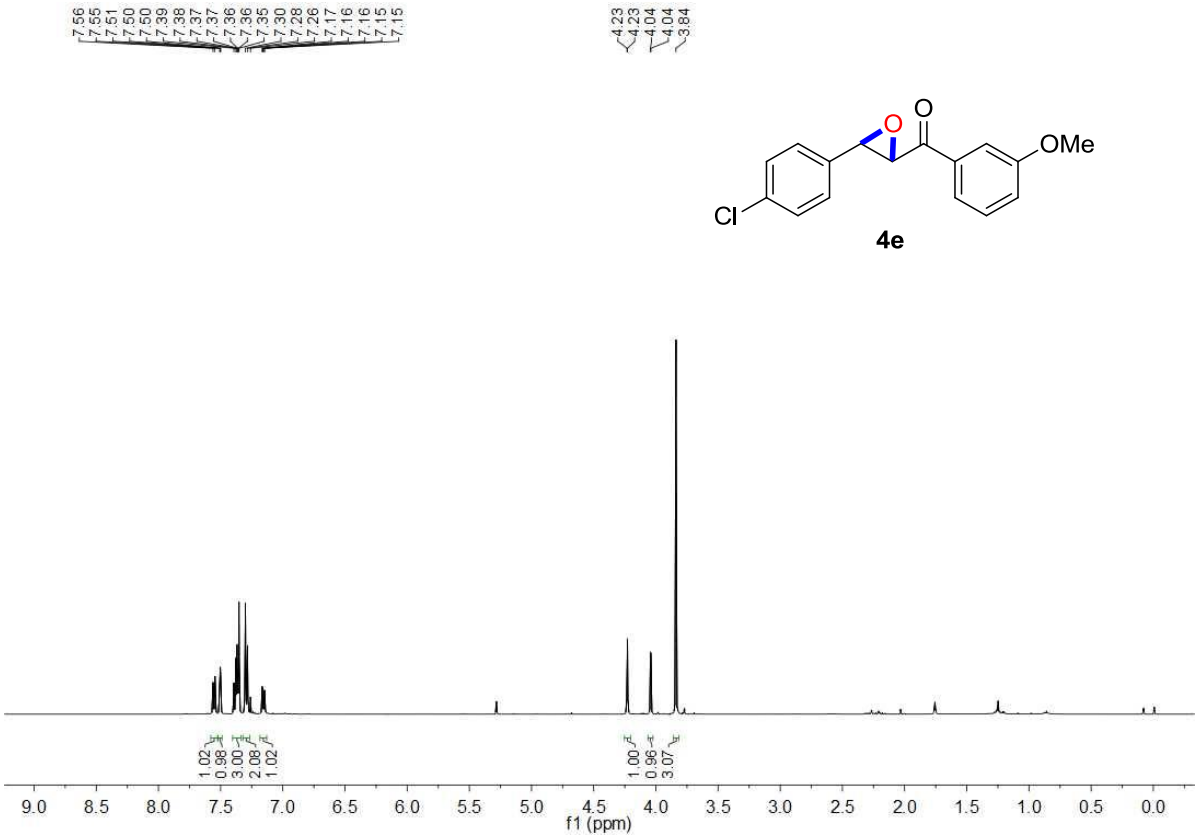
130.64
128.74
127.04
125.73
121.02
111.50
77.31
76.99
76.67
64.35
58.99
55.60
O
O
OMe
Cl
4d
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)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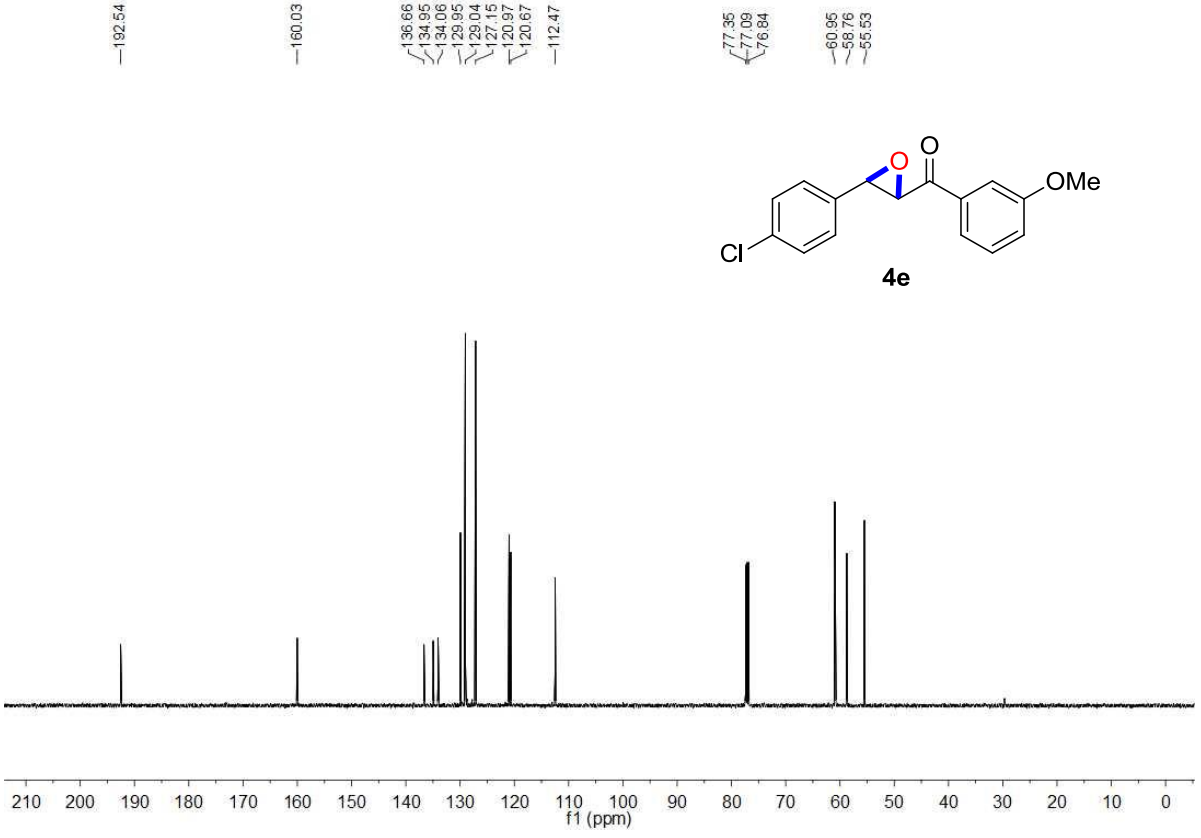
7.39
7.38
7.37
7.37
7.36
7.36
7.35
7.30
7.28
7.26
7.17
7.16
7.16
7.15
7.15
4.23
4.23
4.04
4.04
3.84
O
O
OMe
Cl
4e
1.02
0.98
3.00
2.08
1.02
1.00
0.96
3.07
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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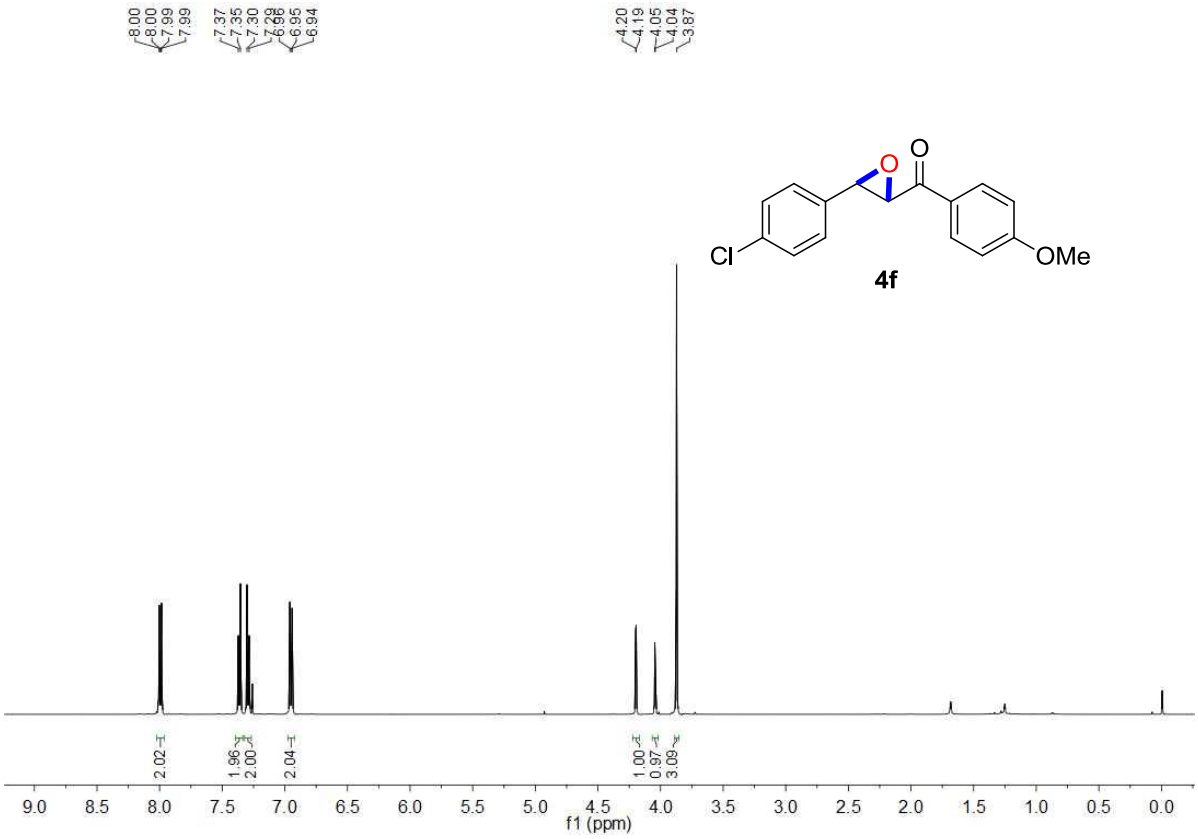
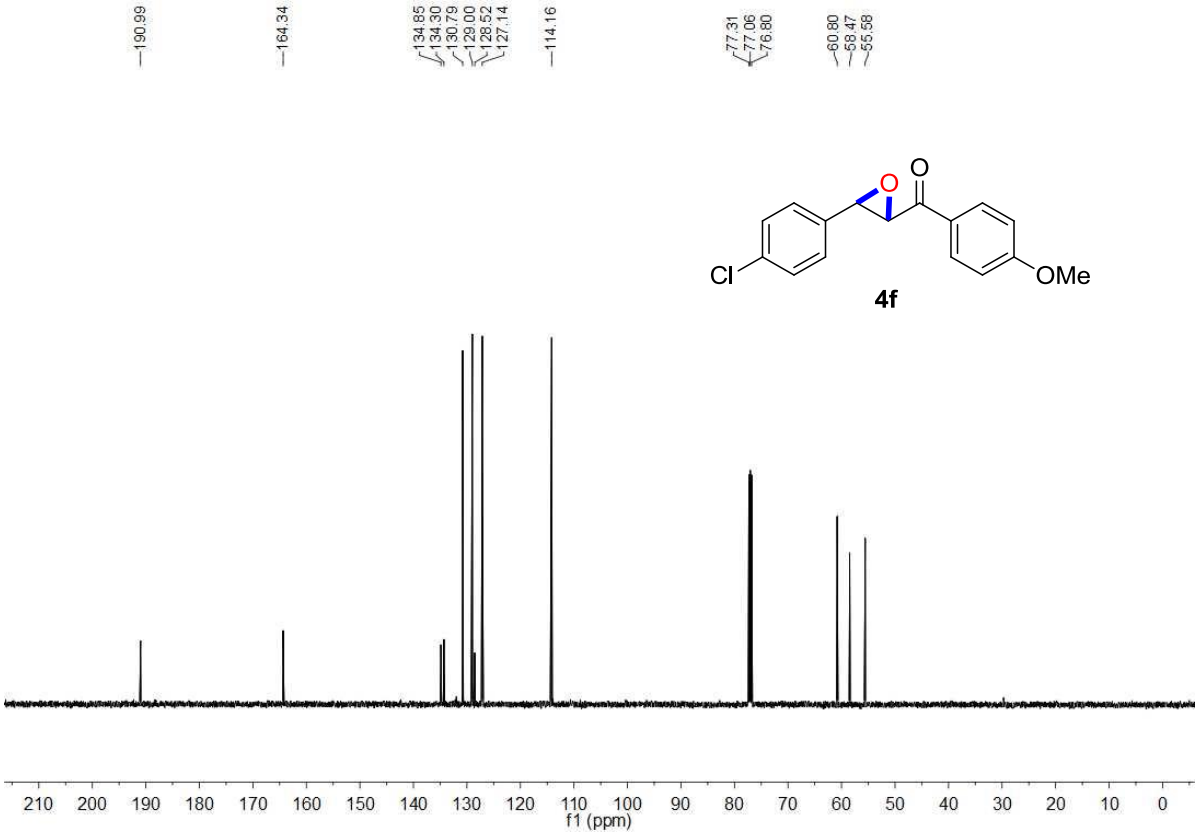
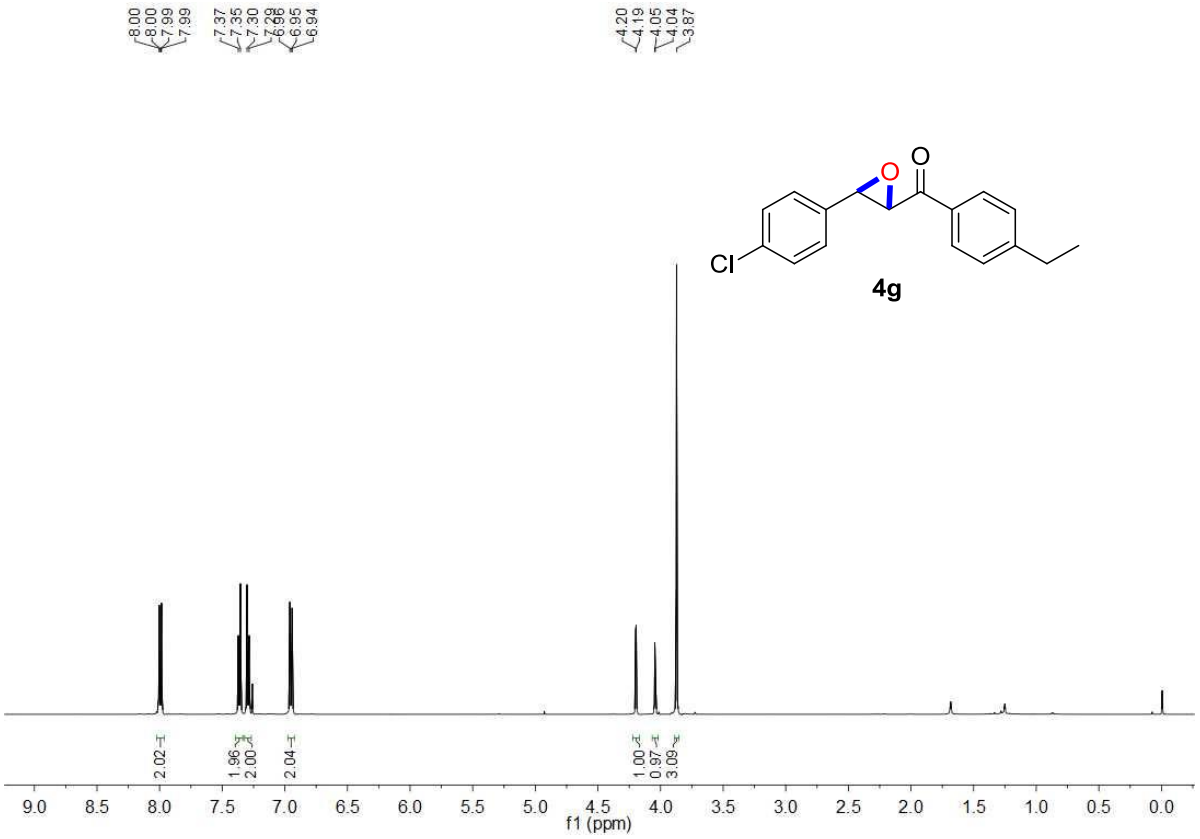
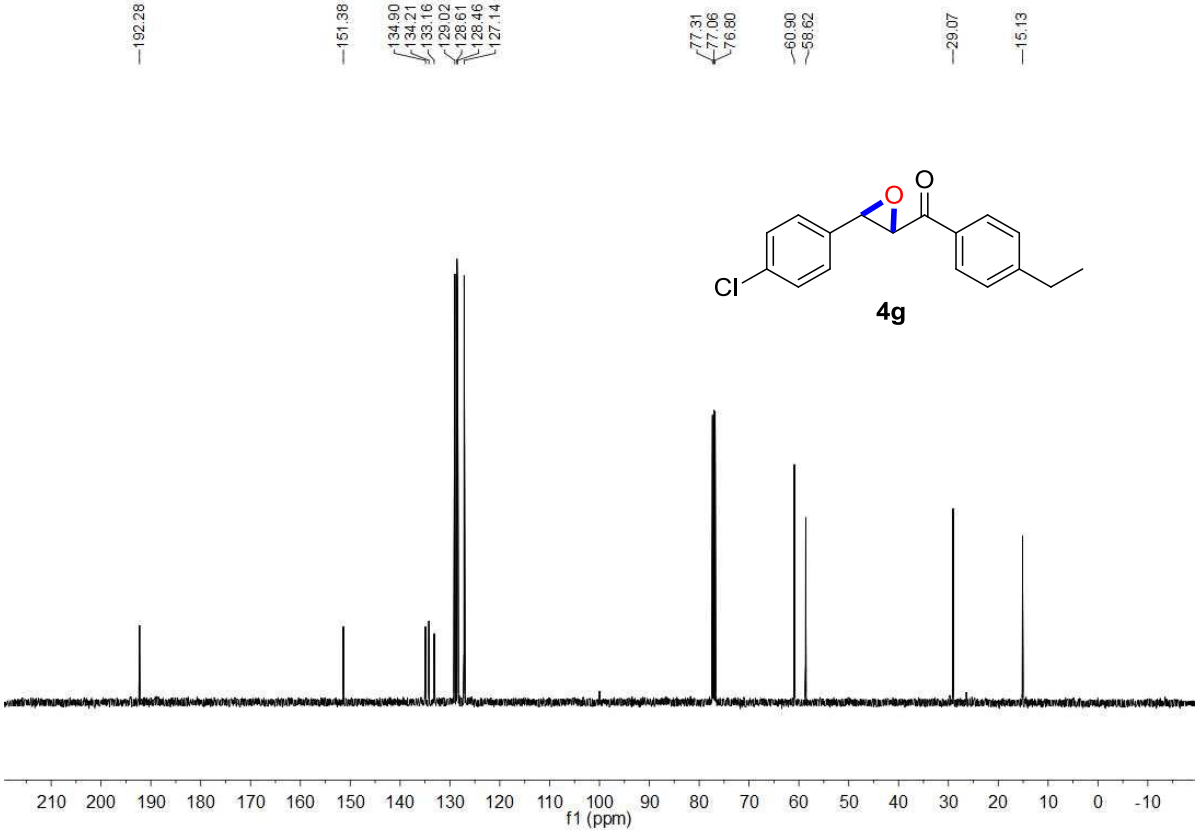
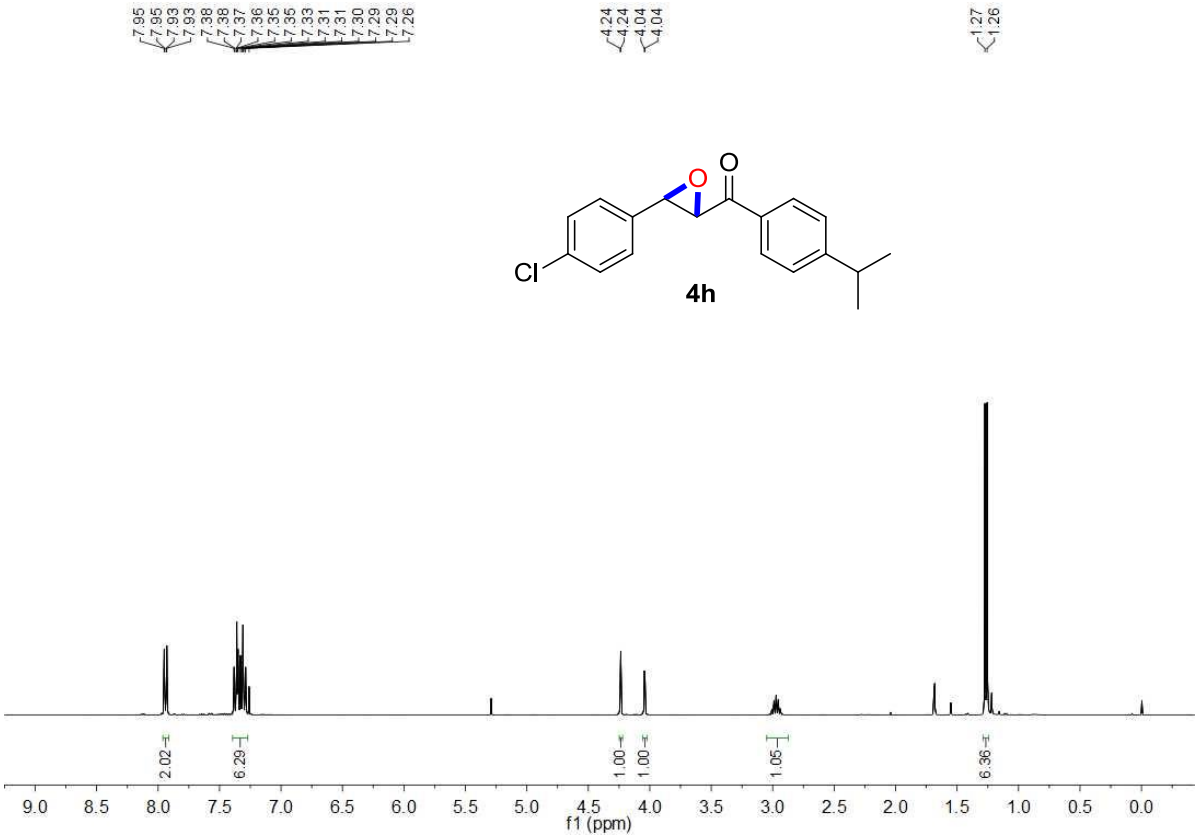
160.03
136.66
134.95
134.06
129.95
129.04
127.15
120.97
120.67
112.47
77.35
77.09
76.84
60.95
58.76
55.53
O
O
OMe
Cl
4e
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

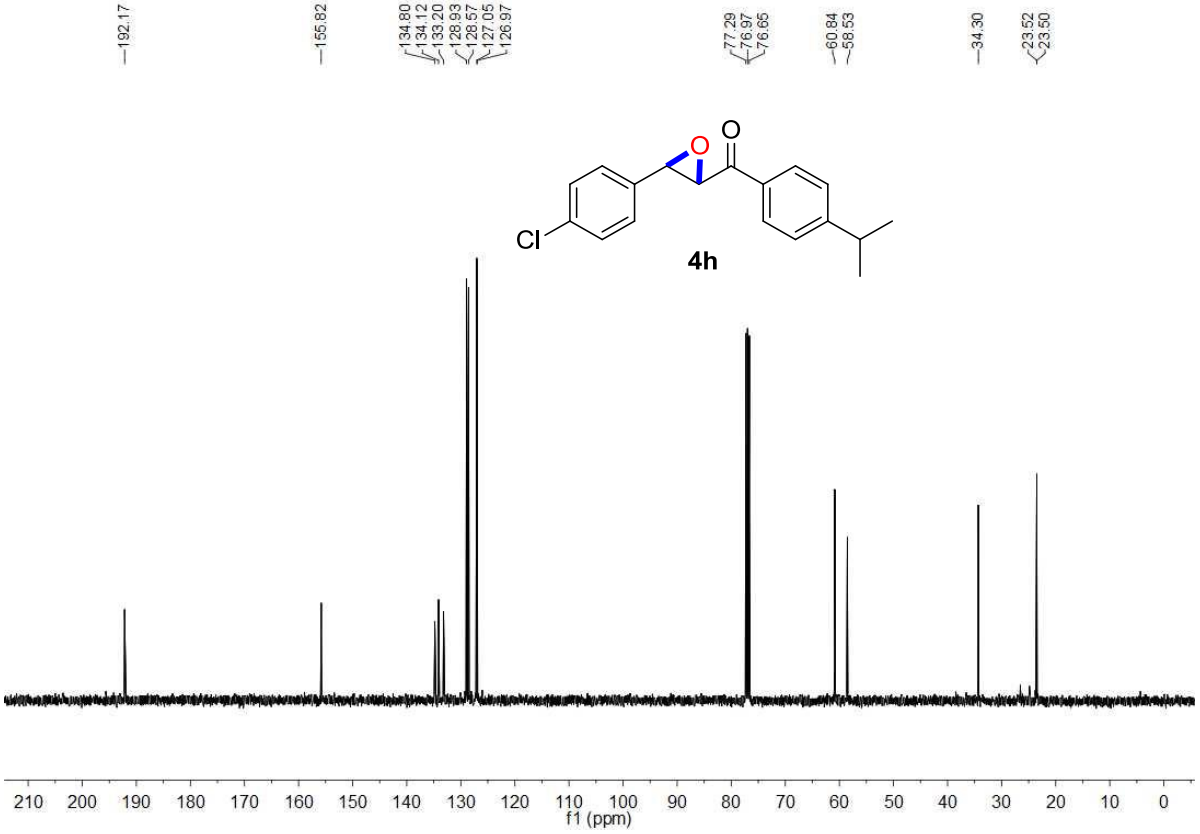

8.00
8.00
7.99
7.99
7.37
7.35
7.30
7.29
6.96
6.95
6.94
4.20
4.19
4.05
4.04
3.87
O
O
Cl
OMe
4f
2.02
1.96
2.00
2.04
1.00
0.97
3.09
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


190.99
164.34
134.85
134.30
130.79
129.00
128.52
127.14
114.16
77.31
77.06
76.80
60.80
58.47
55.58
O
O
Cl
OMe
4f
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


8.00
8.00
7.99
7.99
7.37
7.35
7.30
7.29
6.96
6.95
6.94
4.20
4.19
4.05
4.04
3.87
O
O
Cl
4g
2.02
1.96
2.00
2.04
1.00
0.97
3.09
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

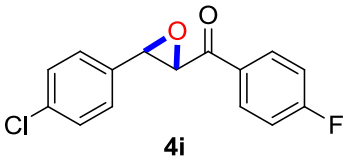

192.28
151.38
134.90
134.21
133.16
129.02
128.61
128.46
127.14
77.31
77.06
76.80
60.90
58.62
29.07
15.13
O
O
Cl
4g
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


7.95
7.95
7.93
7.93
7.38
7.38
7.37
7.36
7.35
7.35
7.33
7.31
7.31
7.30
7.29
7.29
7.26
4.24
4.24
4.04
4.04
1.27
1.26
O
O
Cl
4h
2.02
6.29
1.00
1.00
1.05
6.36
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

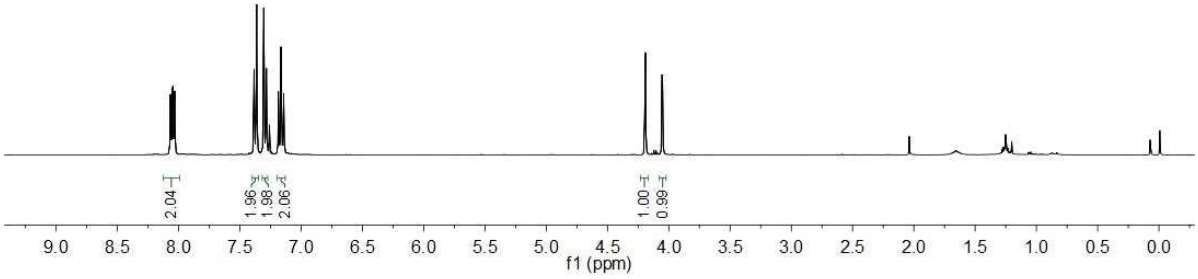

192.17
155.82
134.80
134.12
133.20
128.93
128.57
127.05
126.97
77.29
76.97
76.65
60.84
58.53
34.30
23.52
23.50
O
O
Cl
4h
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


8.07
8.06
8.05
8.05
8.05
8.04
8.03
7.39
7.38
7.37
7.36
7.31
7.30
7.29
7.28
7.26
7.19
7.18
7.16
7.15
7.14


4.20
4.19
4.06
4.05

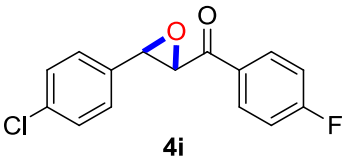

O
O
Cl
F

4i

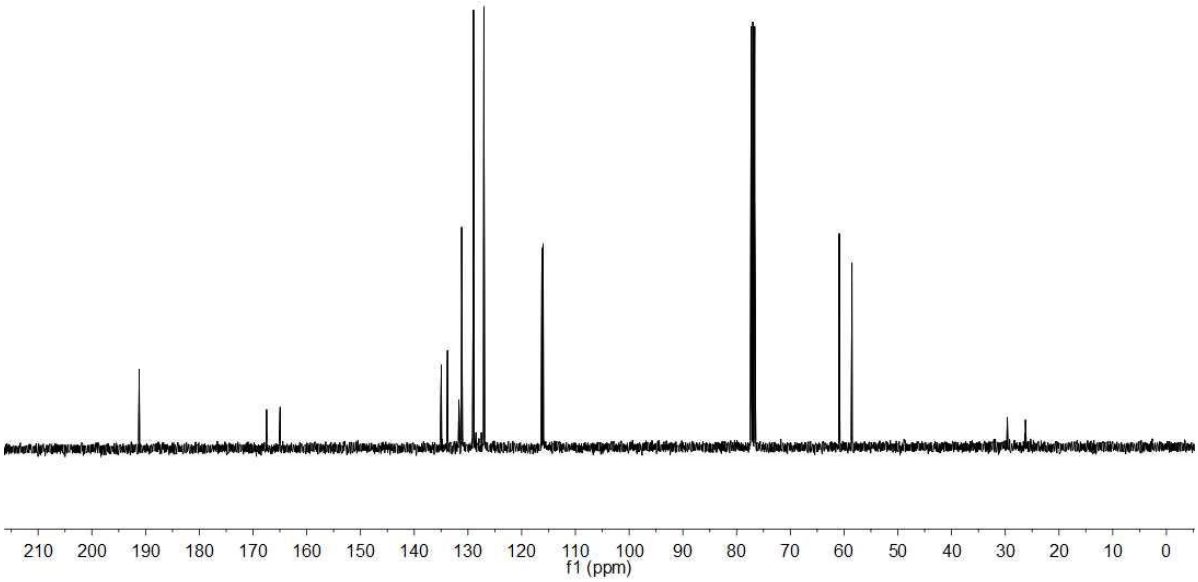

2.04
1.96
1.98
2.06
1.00
0.99
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

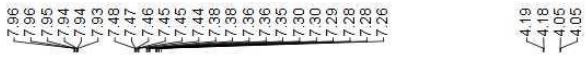

191.19
167.50
164.95
134.96
133.80
131.72
131.69
131.16
131.06
128.99
127.04
116.22
116.01

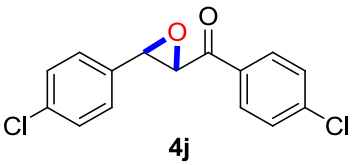

77.28
76.96
76.64
60.89
58.53


O
O
Cl
F

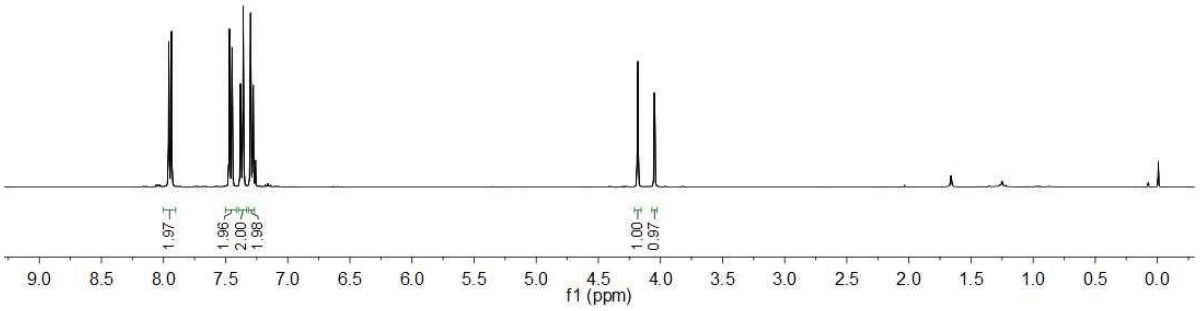
4i

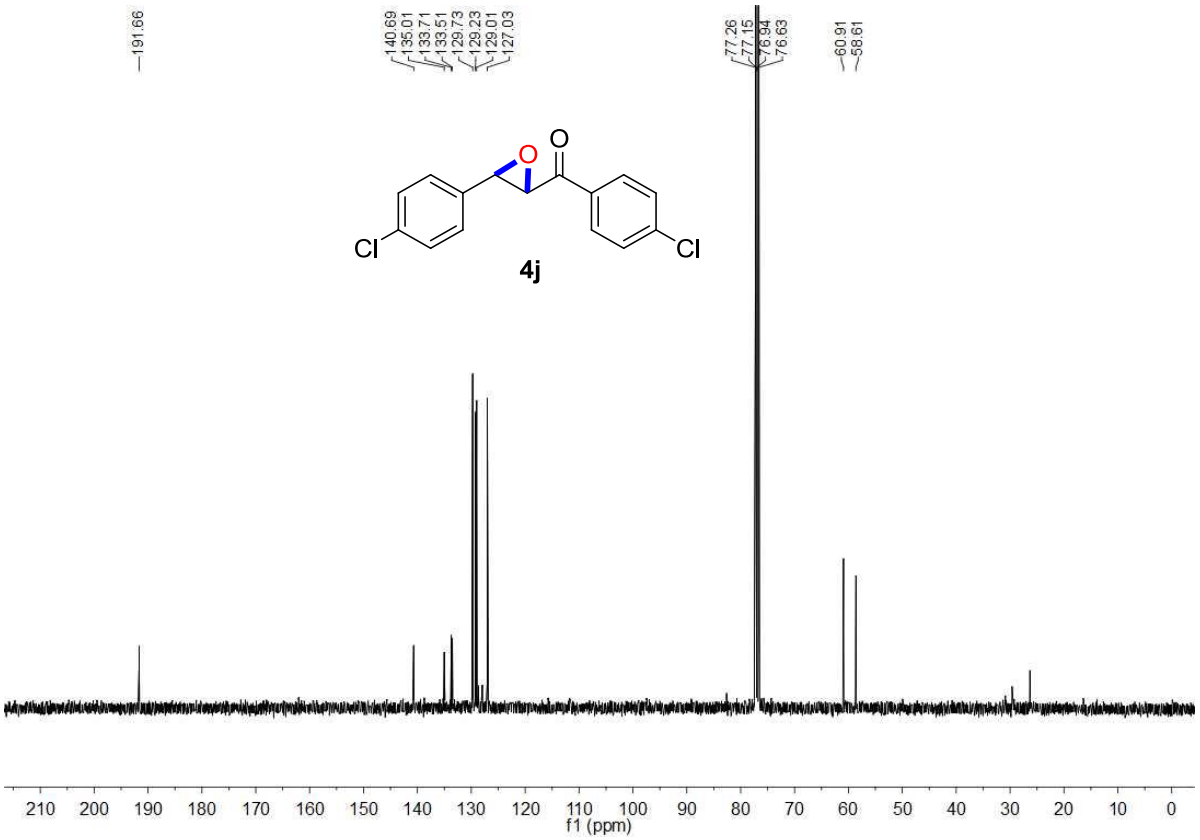

210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


7.96
7.96
7.95
7.94
7.94
7.93
7.48
7.47
7.46
7.45
7.45
7.44
7.38
7.38
7.36
7.36
7.35
7.30
7.30
7.29
7.28
7.28
7.26
4.19
4.18
4.05
4.05

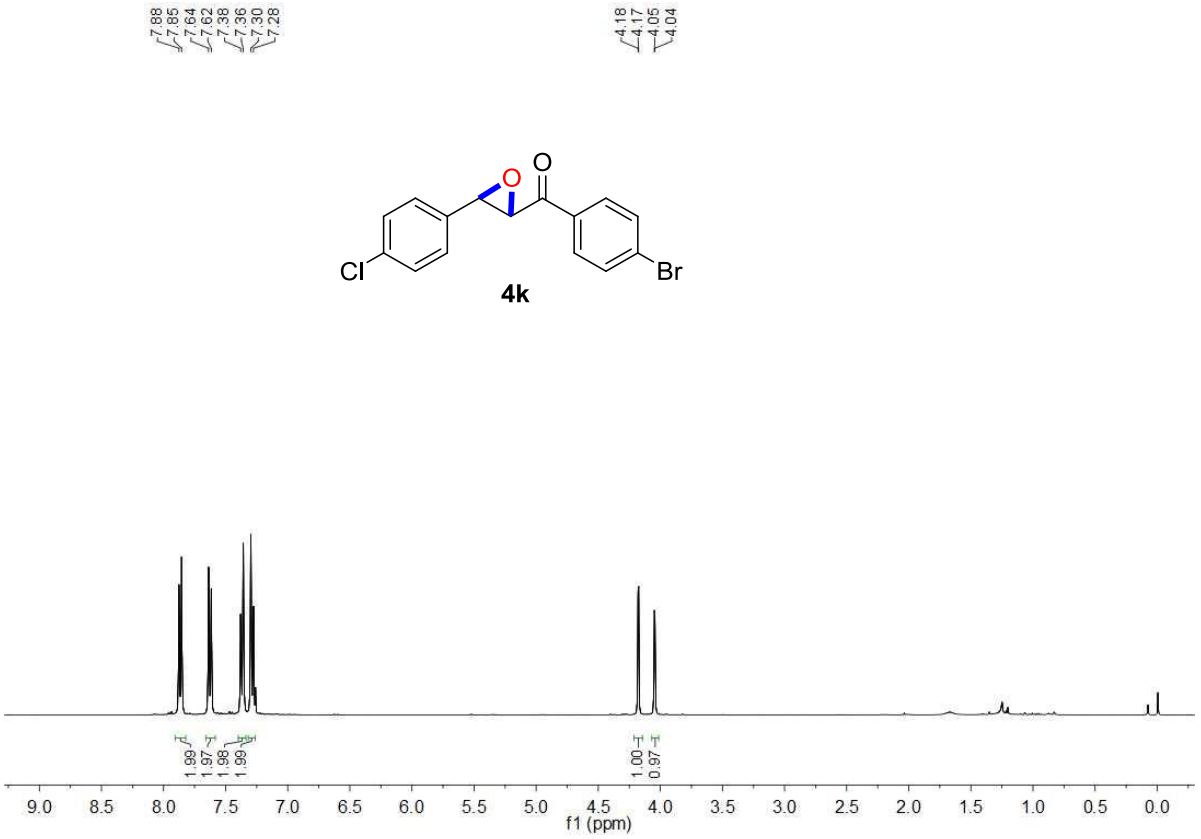

O
O
Cl
Cl

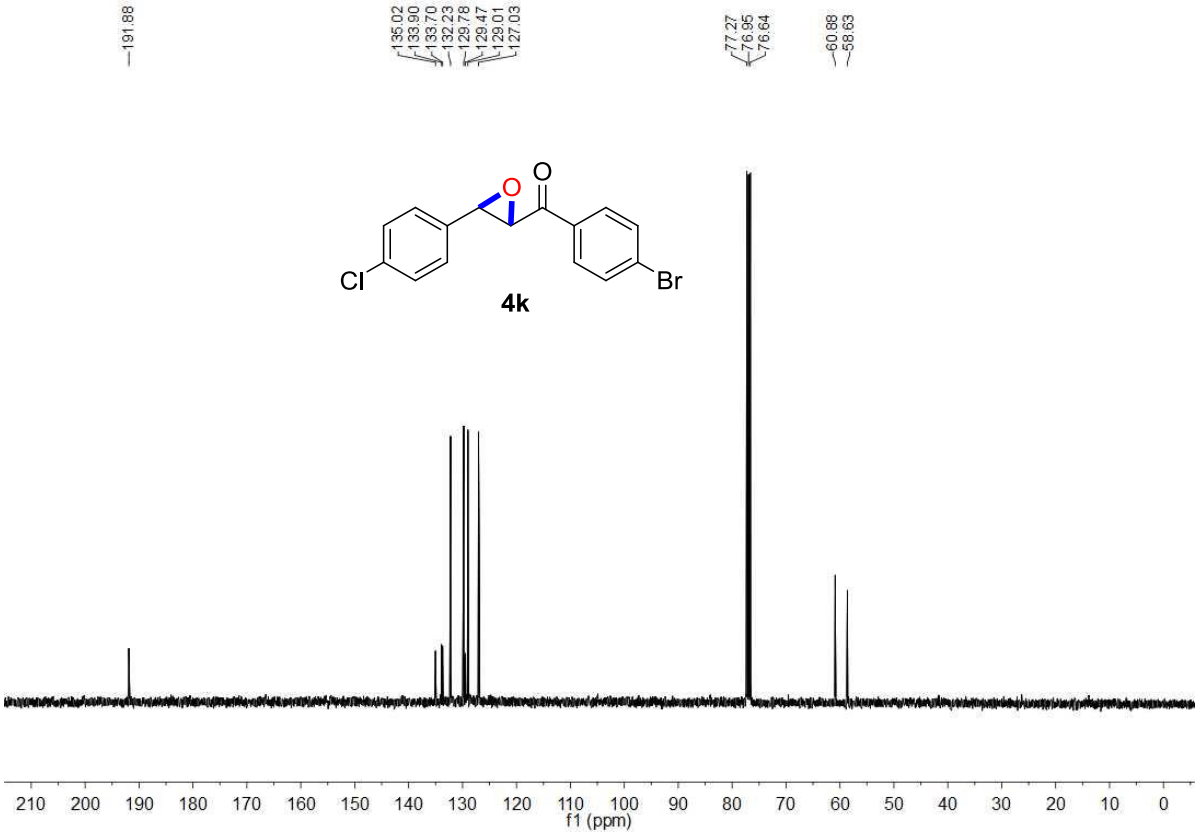
4j


1.97
1.96
2.00
1.98
1.00
0.97
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

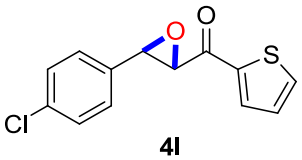

191.66
140.69
135.01
133.71
133.51
129.73
129.23
129.01
127.03
77.26
77.15
76.94
76.63
60.91
58.61
O
O
Cl
Cl
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

4j

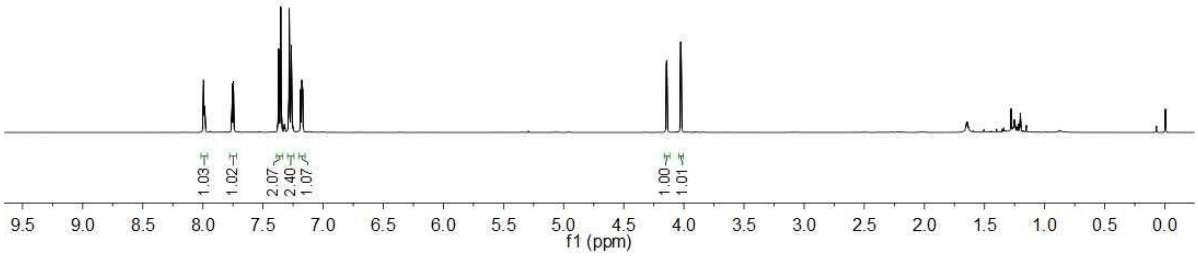

7.88
7.85
7.64
7.62
7.38
7.36
7.30
7.28
4.18
4.17
4.05
4.04
O
O
Cl
Br
4k
1.99
1.97
1.98
1.99
1.00
0.97
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


191.88
135.02
133.90
133.70
132.23
129.78
129.47
129.01
127.03
77.27
76.95
76.64
60.88
58.63
O
O
Cl
Br
4k
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

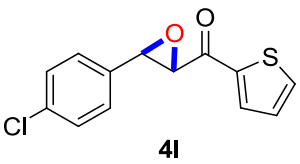

8.00
7.99
7.99
7.99
7.76
7.75
7.75
7.74
7.37
7.37
7.36
7.35
7.28
7.27
7.26
7.19
7.18
7.18
7.17
4.15
4.14
4.03
4.02


O
O
S
Cl

4l

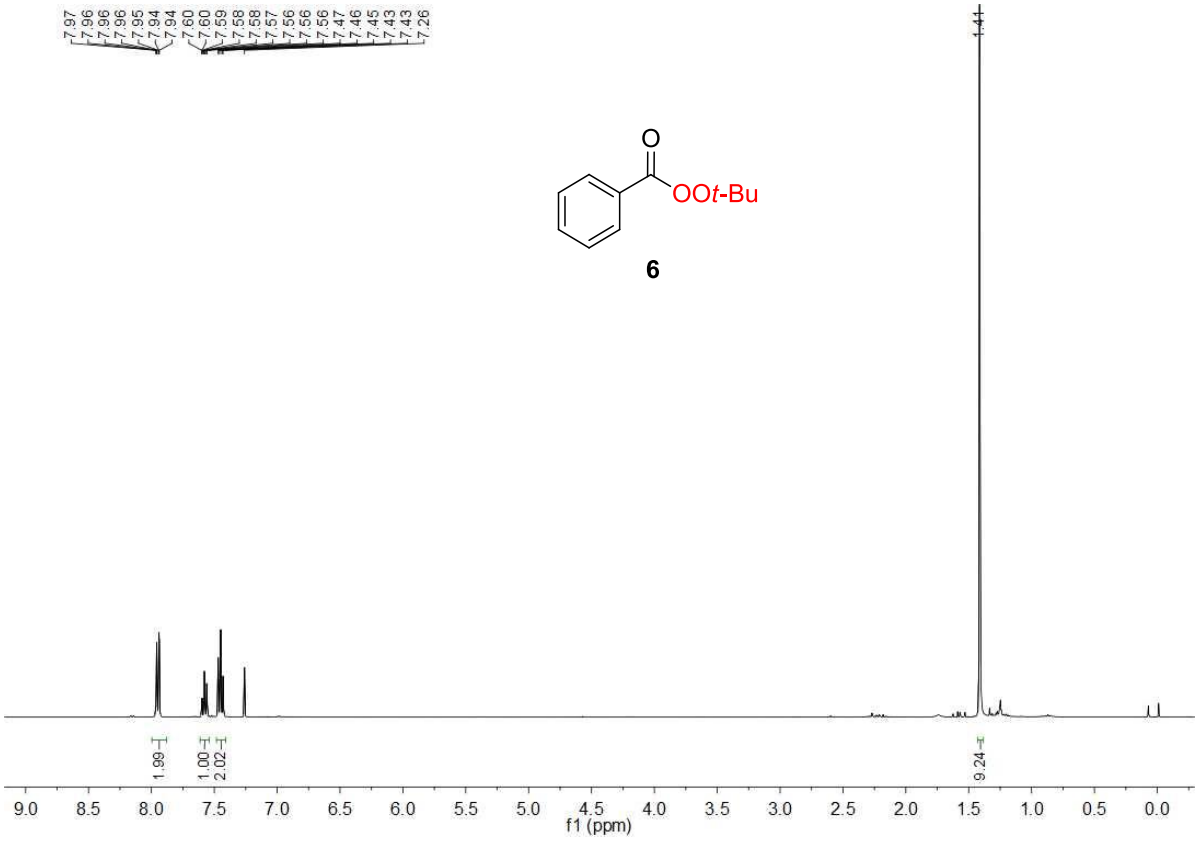

1.03
1.02
2.07
2.40
1.07
1.00
1.01
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

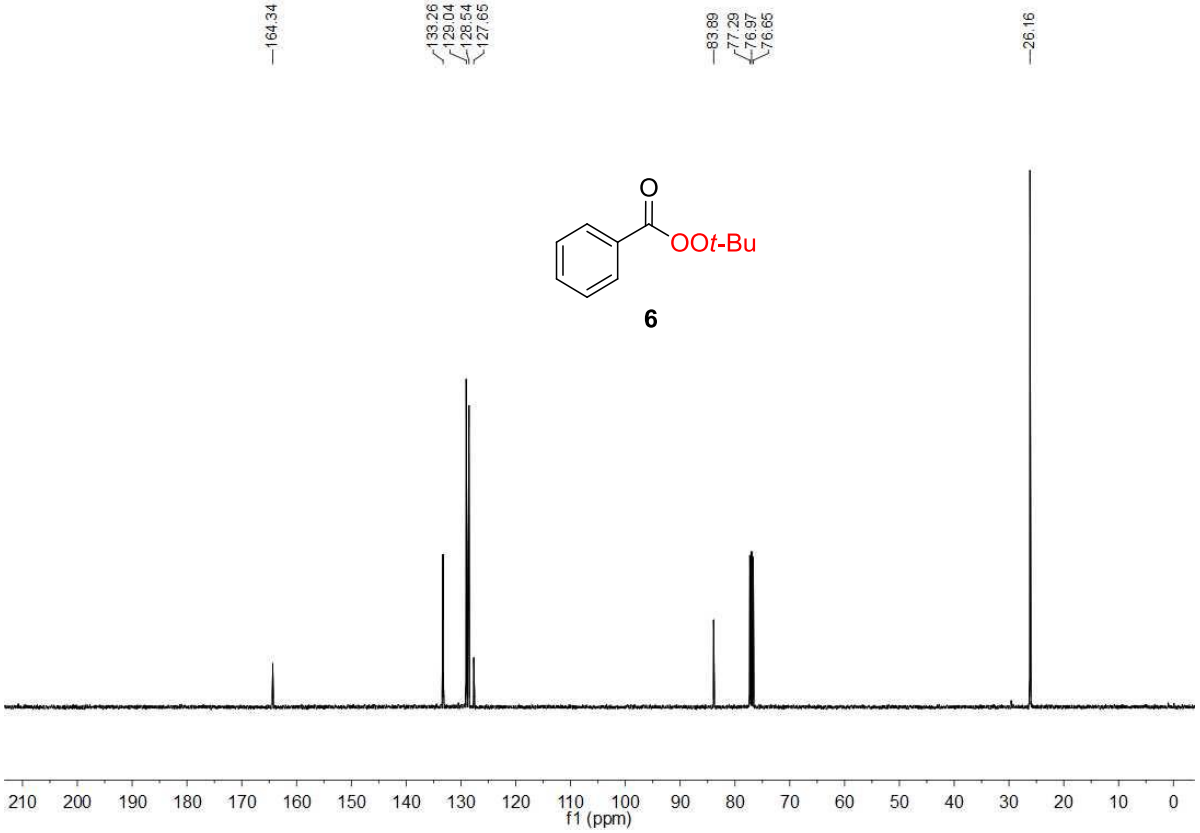

186.10
140.85
135.41
134.98
133.85
133.69
129.02
128.53
127.13
77.31
77.05
76.80
61.92
58.77


O
O
S
Cl

4l

210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


7.97
7.96
7.96
7.96
7.95
7.94
7.94
7.60
7.60
7.59
7.58
7.58
7.57
7.56
7.56
7.56
7.47
7.46
7.45
7.43
7.43
7.26
1.41
O
OOt-Bu
6
1.99
1.00
2.02
9.24
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


164.34
133.26
129.04
128.54
127.65
83.89
77.29
76.97
76.65
26.16
O
OOt-Bu
6
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)