Regiodivergent Construction of Medium-Sized Heterocycles from Vinylethylene Carbonates and Allylidenemalononitrils

Xiang Zhang,[a,c,d] Xiang Li,[b] Jun-Long Li,[d] Qi-Wei Wang,[c,d] Wen-Lin Zou,[d] Yan-Qing Liu,[b,d] Zhi-Qiang Jia,[d] Fu Peng*,[a] and Bo Han*,[b]

[a] *West China School of Pharmacy, Sichuan University, Chengdu 610041, China. E-mail: pengf@scu.edu.cn.*

[b] *State Key Laboratory of Southwestern Chinese Medicine Resources, School of Pharmacy, Chengdu University of Traditional Chinese Medicine, Chengdu 611137, China. E-mail: hanbo@cdutcm.edu.cn.*

[c] *Chengdu Institute of Organic Chemistry, Chinese Academy of Sciences, Chengdu 610041, China.*

[d] *Antibiotics Research and Re-evaluation Key Laboratory of Sichuan Province, Sichuan Industrial Institute of Antibiotics, Chengdu University, Chengdu 610052, China.*

Supporting Information

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1. General Information

General Procedures

- All reactions were performed in oven-dried or flame-dried reaction vessels, modified Schlenk flasks, or round-bottom flasks. The flasks were fitted with Teflon screw caps and reactions were conducted under an atmosphere of argon if needed. Gas-tight syringes with stainless steel needles were used to transfer air- and moisture-sensitive liquids. All moisture and/or air sensitive solid compounds were manipulated inside normal desiccators. Flash column chromatography was performed using silica gel (40–63 µm, 230–400 mesh).
- Analytical thin layer chromatography (TLC) was performed on silica gel 60 F_{254} aluminum plates (Merck) containing a 254 nm fluorescent indicator. TLC plates were visualized by exposure to short wave ultraviolet light (254 nm) and I_2.
- Organic solutions were concentrated at 30-50 °C on rotary evaporators at ~10 torr followed by drying on vacuum pump at ~1 torr. Reaction temperatures are reported as the temperature of the bath surrounding the vessel unless otherwise stated.

Materials

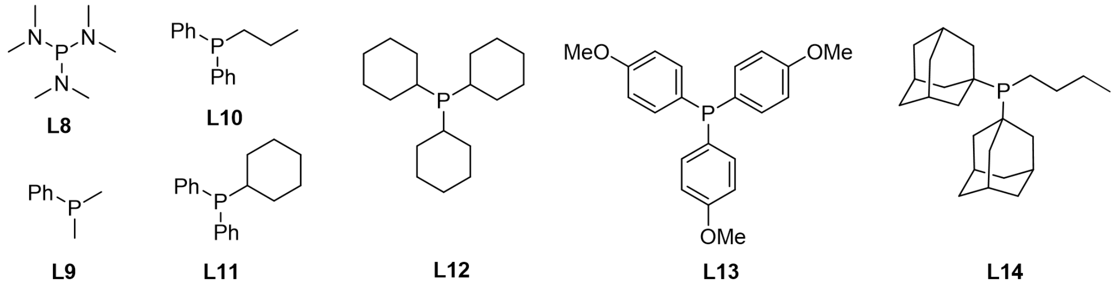
- Commercial reagents and solvents were were purchased from Adamas-beta, Aldrich Chemical Co., Alfa Aesar, Macklin and Energy Chemical and used as received with the following exceptions: THF, Et_2O and toluene were purified by refluxing over Na-benzophenone under positive argon pressure followed by distillation.[1] The allylidenemalononitriles **1**[2], vinylethylene carbonates **2**[3], and oxazolidinone **9**[4] were prepared according to literature procedure.

Instrumentation

- Proton nuclear magnetic resonance (^1H NMR) spectra were recorded with JEOL-600M. Proton chemical shifts are reported in parts per million (δ scale), and are referenced using residual protium in the NMR solvent ($CDCl_3$: δ 7.26 ($CHCl_3$)). Data are reported as follows: chemical shift [multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br s = broad singlet), coupling constant(s) (Hz), integration].
- Carbon-13 nuclear magnetic resonance (^{13}C NMR) spectra were recorded with JEOL 150 MHz spectrometers. Carbon chemical shifts are reported in parts per million (δ scale), and are referenced using the carbon resonances of the solvent (δ 77.0 ($CHCl_3$)). Data are reported as follows: chemical shift [multiplicity (if not singlet), assignment (C_q = fully substituted carbon)].
- High resolution mass spectra (HRMS) were recorded on a Waters SYNAPT G2 using an electrospray (ESI) ionization source.
- Melting points were recorded on WRX-X-4A melting point apparatus.
- The reaction temperature of 20 °C and 10 °C were controlled with a DHJF-8002 Zhengzhou Changsheng cryogenic thermostatic reaction bath.

2. Further Optimization Studies

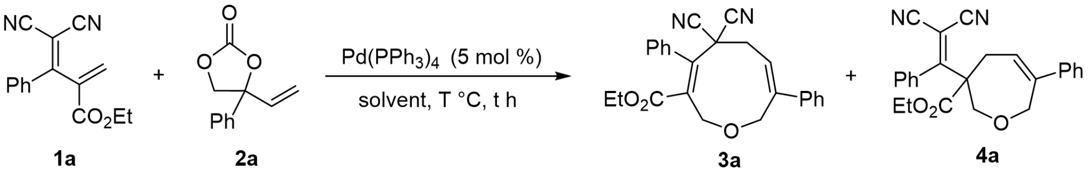
Table S1. Further screening of ligands and additives [a]



entry	catalyst	ligand	additive	yield (%)[b]	**3a**:**4a**[c]
1	$Pd_2(dba)_3 \cdot CHCl_3$	–	–	/	/
2[d]	$Pd_2(dba)_3 \cdot CHCl_3$	**L8**	–	<5	/
3[d]	$Pd_2(dba)_3 \cdot CHCl_3$	**L9**	–	/	/
4[d]	$Pd_2(dba)_3 \cdot CHCl_3$	**L10**	–	/	/
5[d]	$Pd_2(dba)_3 \cdot CHCl_3$	**L11**	–	/	/
6[d]	$Pd_2(dba)_3 \cdot CHCl_3$	**L12**	–	/	/
7[d]	$Pd_2(dba)_3 \cdot CHCl_3$	**L13**	–	<5	/
8[d]	$Pd_2(dba)_3 \cdot CHCl_3$	**L14**	–	/	/
9	$Pd(PPh_3)_4$	–	$Sc(OTf)_3$	<5	/
10	$Pd(PPh_3)_4$	–	$Al(OTf)_3$	81	2.0:1
11	$Pd(PPh_3)_4$	–	$Ti(O\textit{i}Pr)_4$	75	9.6:1
12	$Pd(PPh_3)_4$	–	$Mg(O\textit{t}Bu)_2$	89	2.8:1
13	$Pd(PPh_3)_4$	–	$PhB(OH)_2$	86	1.3:1
14[e]	$Pd(PPh_3)_4$	–	Cs_2CO_3	89	2.2:1
15[e]	$Pd(PPh_3)_4$	–	TMSCl	<5	/

[a] Unless noted otherwise, the reactions were carried out with **1a** (0.10 mmol), **2a** (0.15 mmol), Pd catalyst (5 mol %) and additive (0.02 mmol) in solvent (1.0 mL) for 12 h. [b] Yield was determined by ^{1}H-NMR analysis with CH_2Br_2 as the internal standard. [c] The ratio of **3a**:**4a** was determined by ^{1}H-NMR analysis of the crude reaction mixture. [d] The Pd/ligand complex was pre-prepared with $Pd_2(dba)_3 \cdot CHCl_3$ and ligand in THF at rt for 1 h. [e] The reactions were carried out with additive (0.12 mmol).

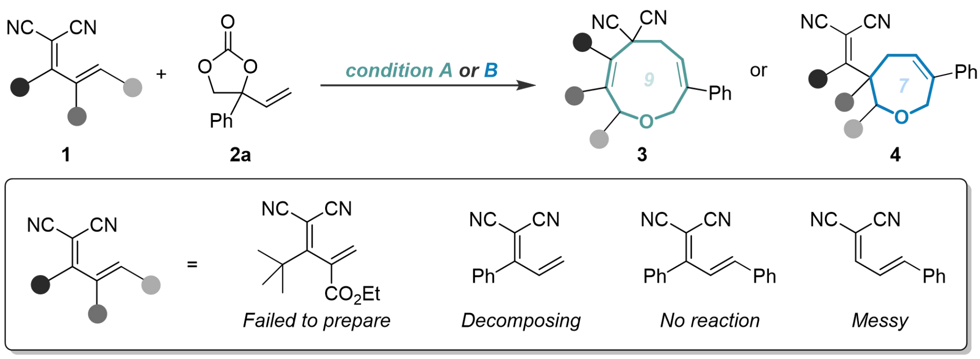
Table S2. Further screening of solvents and temperature [a]



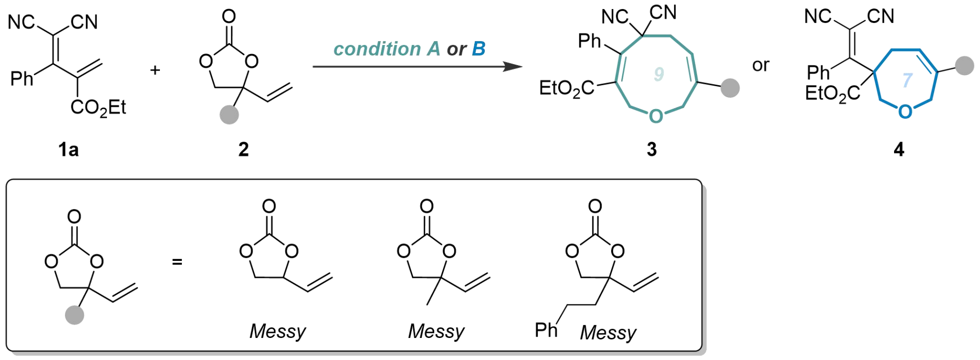
entry	solvent	T (°C)	t (h)	yield (%)[b]	**3a**:**4a**[c]
1	acetone	20	24	30	>20:1
2	ethyl acetate	20	24	84	3.1:1
3	DMSO	20	24	<5	/
4	acetone	60	12	64	12.8:1
5	ethyl acetate	60	12	77	1.8:1
6	DMSO	60	12	83	>20:1
7	DME	60	12	72	>20:1
8	MTBE	60	12	65	2.9:1

[a] Unless noted otherwise, the reactions were carried out with **1a** (0.10 mmol), **2a** (0.15 mmol), and Pd(PPh$_3$)$_4$ (5 mol %) in solvent (1.0 mL). [b] Yield was determined by ^{1}H-NMR analysis with CH$_2$Br$_2$ as the internal standard. [c] The ratio of **3a**:**4a** was determined by ^{1}H-NMR analysis of the crude reaction mixture.

3. Further Substrate Scope Investigation



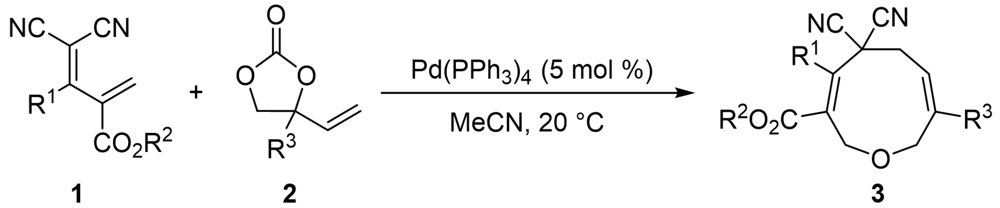
Scheme S1. Further substrate scope investigation of allylidenemalononitriles



Scheme S2. Further substrate scope investigation of VECs

4. General Procedure for the Preparation of Nine-Membered Products 3

*General procedure for the synthesis of nine-membered products **3***

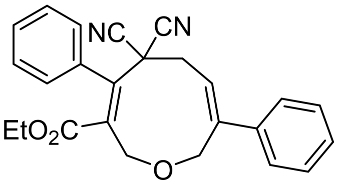


To an over-dried Schlenk tube was added Pd(PPh$_3$)$_4$ (5 mol %), after which the tube was evacuated and back-filled with argon three times. Subsequently, under the protection of argon, a solution of dried allylidenemalononitriles **1** (0.10 mmol) and vinylethylene carbonates **2** (0.15 mmol) in dry MeCN (1.0 mL) was added *via* syringe and the reaction mixture was stirred at 20 °C for 24 hours. Then the mixture was concentrated and purified by column chromatography on silica gel (petroleum ether/ dichloromethane = 3/1 to 1/1, then petroleum ether/ethyl acetate = 10/1) to afford the corresponding **3** in 51–96% yields, which were dried under vacuum and further analyzed by ^{1}H NMR, ^{13}C NMR, HRMS, *etc.*

*Gram-scale synthesis of the nine-membered product **3a***

To an over-dried 100 mL Schlenk flask, was added Pd(PPh$_3$)$_4$ (0.20 mmol, 0.23 g), after which the tube was evacuated and back-filled with argon three times. Subsequently, under the protection of argon, a solution of dried allylidenemalononitrile **1a** (4.00 mmol, 1.01 g) and vinylethylene carbonate **2a** (6.00 mmol, 1.14 g) in dry MeCN (40 mL) was added *via* syringe and the reaction mixture was stirred at 20 °C for 24 hours. Then the mixture was concentrated and purified by column chromatography on silica gel (petroleum ether/ dichloromethane = 3/1 to 1/1, then petroleum ether/ethyl acetate = 10/1) to afford **3a** (1.08 g) as white solid in 68% yields.

ethyl-(3*E*,7*Z*)-5,5-dicyano-4,8-diphenyl-2,5,6,9-tetrahydrooxonine-3-carboxylate 3a



Prepared according to the general procedure to afford **3a** (35.8 mg, m. p. = 131 – 135 °C) in

90% yield as white solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

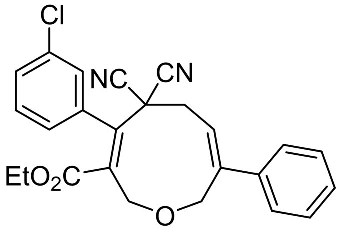
NMR and HRMS data for the product **3a**:

^{1}H NMR (600 MHz, **CDCl$_3$)** δ (ppm): 7.55 (d, *J* = 6.6 Hz, 2H), 7.45 – 7.33 (m, 6H), 7.20 (d, *J* = 8.4 Hz, 2H), 6.25 (t, *J* = 9.0 Hz, 1H), 4.61 (s, 2H), 4.57 (s, 2H), 3.85 (q, *J* = 7.2 Hz, 2H), 3.63 (d, *J* = 9.0 Hz, 2H), 0.80 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, **CDCl$_3$)** δ (ppm): 167.6, 143.8, 139.4, 138.9, 137.4, 135.9, 129.7, 128.7, 128.6, 128.1, 126.6, 122.2, 114.2, 66.6, 63.4, 61.5, 40.2, 39.0, 13.4.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{25}H_{22}N_2O_3Na^+$: 421.1523, found: 421.1530.

ethyl-(3*E*,7*Z*)-4-(3-chlorophenyl)-5,5-dicyano-8-phenyl-2,5,6,9-tetrahydrooxonine-3-carboxylate 3b



Prepared according to the general procedure to afford **3b** (29.9 mg, m. p. = 142 – 145 °C) in 69% yield as pale yellow solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

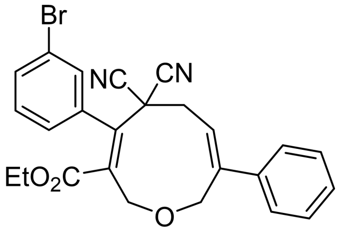
NMR and HRMS data for the product **3b**:

^{1}H NMR (600 MHz, **CDCl$_3$)** δ (ppm): 7.54 (d, *J* = 7.8 Hz, 2H), 7.41 – 7.36 (m, 4H), 7.33 (t, *J* = 8.4 Hz, 1H), 7.20 (s, 1H), 7.10 (d, *J* = 7.2 Hz, 1H), 6.24 (t, *J* = 9.0 Hz, 1H), 4.61 (s, 2H), 4.56 (d, *J* = 4.8 Hz, 2H), 3.91 (q, *J* = 6.0 Hz, 2H), 3.62 (d, *J* = 11.4 Hz, 2H), 0.87 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, **CDCl$_3$)** δ (ppm): 167.2, 143.9, 139.2, 138.8, 137.5, 136.8, 134.6, 130.0, 129.8, 128.74, 128.68, 128.3, 126.6, 126.4, 122.0, 114.0, 66.8, 63.4, 61.7, 39.9, 39.1, 13.8.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{25}H_{21}{}^{35}ClN_2O_3Na^+$: 455.1133, found: 455.1131; calculated for $C_{25}H_{21}{}^{37}ClN_2O_3Na^+$: 457.1103, found: 457.1114.

ethyl-(3*E*,7*Z*)-4-(3-bromophenyl)-5,5-dicyano-8-phenyl-2,5,6,9-tetrahydrooxonine-3-carboxylate 3c



Prepared according to the general procedure for 48 h to afford **3c** (25.3 mg) in 53% yield as yellow semisolid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

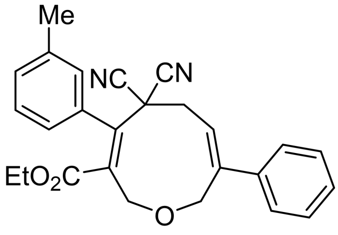
NMR and HRMS data for the product **3c**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.59 – 7.51 (m, 3H), 7.44 – 7.36 (m, 3H), 7.36 – 7.32 (m, 1H), 7.28 (d, *J* = 8.4 Hz, 1H), 7.15 (d, *J* = 7.8 Hz, 1H), 6.23 (t, *J* = 9.0 Hz, 1H), 4.60 (s, 2H), 4.56 (d, *J* = 4.2 Hz, 2H), 3.91 (q, *J* = 7.2 Hz, 2H), 3.62 (dd, *J* = 9.0, 5.4 Hz, 2H), 0.87 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 167.2, 143.9, 139.2, 139.1, 137.7, 136.8, 132.7, 131.1, 130.1, 128.7, 128.8, 126.9, 126.5, 122.5, 122.0, 114.0, 66.8, 63.4, 61.7, 39.9, 39.1, 13.4.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{25}H_{21}{}^{79}BrN_2O_3Na^+$: 499.0628, found: 499.0629; calculated for $C_{25}H_{21}{}^{81}BrN_2O_3Na^+$: 501.0607, found: 501.0607.

ethyl-(3*E*,7*Z*)-5,5-dicyano-8-phenyl-4-(m-tolyl)-2,5,6,9-tetrahydrooxonine-3-carboxylate 3d



Prepared according to the general procedure to afford **3d** (33.8 mg) in 82% yield as colorless semisolid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

NMR and HRMS data for the product **3d**:

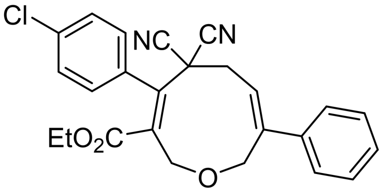
^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.56 (d, *J* = 6.6 Hz, 2H), 7.43 – 7.34 (m, 3H), 7.27 (t, *J* = 7.2 Hz, 1H), 7.21 (d, *J* = 7.2 Hz, 1H), 7.00 (d, *J* = 5.4 Hz, 2H), 6.27 (t, *J* = 9.0 Hz, 1H), 4.59

(s, 2H), 4.56 (d, *J* = 3.0 Hz, 2H), 3.87 (q, *J* = 7.2 Hz, 2H), 3.61 (d, *J* = 9.0 Hz, 2H), 2.34 (s, 3H), 0.81 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, **CDCl$_3$)** δ (ppm): 167.7, 143.5, 139.4, 139.3, 138.4, 137.3, 135.5, 130.4, 128.7, 128.65, 128.58, 128.5, 126.6, 125.1, 122.4, 114.2, 66.2, 63.1, 61.4, 40.2, 39.0, 21.3, 13.4.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{26}H_{24}N_2O_3Na^+$: 435.1679, found: 435.1677.

ethyl-(3*E*,7*Z*)-4-(4-chlorophenyl)-5,5-dicyano-8-phenyl-2,5,6,9-tetrahydrooxonine-3-carboxylate 3e



Prepared according to the general procedure for 48 h to afford **3e** (31.2 mg, m. p. = 86 – 89 °C) in 72% yield as pale yellow solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

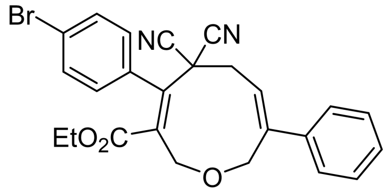
NMR and HRMS data for the product **3e**:

^{1}H NMR (600 MHz, **CDCl$_3$)** δ (ppm): 7.54 (d, *J* = 6.6 Hz, 2H), 7.43 – 7.36 (m, 4H), 7.34 (t, *J* = 7.2 Hz, 1H), 7.20 (brs, 1H), 7.10 (d, *J* = 7.2 Hz, 1H), 6.24 (t, *J* = 9.0 Hz, 1H), 4.61 (s, 2H), 4.56 (d, *J* = 4.2 Hz, 2H), 3.91 (q, *J* = 7.2 Hz, 2H), 3.62 (d, *J* = 9.0 Hz, 2H), 0.87 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, **CDCl$_3$)** δ (ppm): 167.2, 143.9, 139.2, 138.8, 136.8, 134.6, 129.8, 128.74, 128.68, 128.3, 126.6, 126.4, 122.0, 114.0, 66.8, 63.4, 61.7, 39.9, 39.1, 13.5.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{25}H_{21}{}^{35}ClN_2O_3Na^+$: 455.1133, found: 455.1128; calculated for $C_{25}H_{21}{}^{37}ClN_2O_3Na^+$: 457.1103, found: 457.1107.

ethyl-(3*E*,7*Z*)-4-(4-bromophenyl)-5,5-dicyano-8-phenyl-2,5,6,9-tetrahydrooxonine-3-carboxylate 3f



Prepared according to the general procedure to afford **3f** (24.3 mg, m. p. = 121 – 125 °C) in 51% yield as pale yellow solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

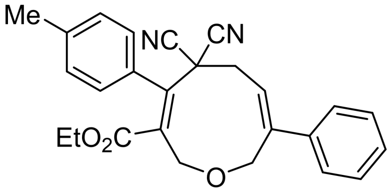
NMR and HRMS data for the product **3f**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.57 – 7.48 (m, 4H), 7.44 – 7.33 (m, 3H), 7.06 (d, *J* = 8.4 Hz, 2H), 6.19 (t, *J* = 9.0 Hz, 1H), 4.61 (s, 2H), 4.57 (s, 2H), 3.90 (q, *J* = 7.2 Hz, 2H), 3.64 (d, *J* = 9.0 Hz, 2H), 0.88 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 167.3, 144.3, 139.3, 137.7, 136.7, 136.2, 131.8, 129.9, 128.8, 128.7, 126.6, 124.1, 121.9, 114.1, 67.2, 63.8, 61.7, 39.9, 39.2, 13.5.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{25}H_{21}{}^{79}BrN_2O_3Na^+$: 499.0628, found: 499.0626; calculated for $C_{25}H_{21}{}^{81}BrN_2O_3Na^+$: 501.0607, found: 501.0608.

ethyl-(3*E*,7*Z*)-5,5-dicyano-8-phenyl-4-(p-tolyl)-2,5,6,9-tetrahydrooxonine-3-carboxylate 3g



Prepared according to the general procedure to afford **3g** (31.7 mg, m. p. = 129 – 132 °C) in 77% yield as white solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

NMR and HRMS data for the product **3g**:

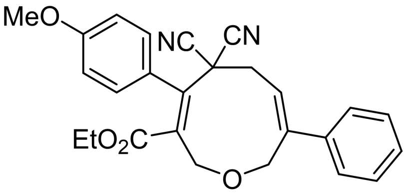
^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.55 (d, *J* = 7.8 Hz, 2H), 7.44 – 7.33 (m, 3H), 7.18 (d, *J* = 7.2 Hz, 2H), 7.08 (d, *J* = 7.8 Hz, 2H), 6.25 (t, *J* = 9.0 Hz, 1H), 4.59 (s, 2H), 4.55 (s, 2H), 3.87 (q, *J* = 7.2 Hz, 2H), 3.60 (d, *J* = 9.0 Hz, 2H), 2.36 (s, 3H), 0.84 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 167.7, 143.6, 139.7, 139.4, 139.1, 135.6, 134.4, 129.2, 128.7, 128.6, 128.0, 126.6, 122.4, 114.3, 66.3, 63.3, 61.5, 40.3, 38.9, 21.4, 13.5.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{26}H_{24}N_2O_3Na^+$: 435.1679, found:

435.1680.

ethyl-(3*E*,7*Z*)-5,5-dicyano-4-(4-methoxyphenyl)-8-phenyl-2,5,6,9-tetrahydrooxonine-3-carboxylate 3h



The reaction was performed according to the general procedure by using 0.30 mmol of the corresponding vinylethylene carbonates **2** to afford **3h** (37.7 mg) in 88% yield as pale yelow semisolid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

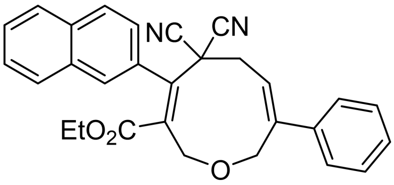
NMR and HRMS data for the product **3h**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.55 (d, *J* = 7.2 Hz, 2H), 7.43 – 7.32 (m, 3H), 7.12 (d, *J* = 9.0 Hz, 2H), 6.88 (d, *J* = 8.3 Hz, 2H), 6.24 (t, *J* = 8.4 Hz, 1H), 4.59 (s, 2H), 4.55 (s, 2H), 3.89 (q, *J* = 7.2 Hz, 2H), 3.81 (s, 3H), 3.60 (d, *J* = 9.0 Hz, 2H), 0.87 (t, *J* = 7.8 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 167.8, 160.4, 143.7, 139.4, 138.7, 135.9, 129.6, 129.5, 128.7, 128.6, 126.6, 122.3, 114.3, 113.9, 66.5, 63.4, 61.5, 55.3, 40.4, 39.0, 13.6.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{26}H_{24}N_2O_4Na^+$: 451.1628, found: 451.1631.

ethyl-(3*E*,7*Z*)-5,5-dicyano-4-(naphthalen-2-yl)-8-phenyl-2,5,6,9-tetrahydrooxonine-3-carboxylate 3i



Prepared according to the general procedure to afford **3i** (31.9 mg, m. p. = 165 – 168 °C) in 71% yield as pale yellow solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

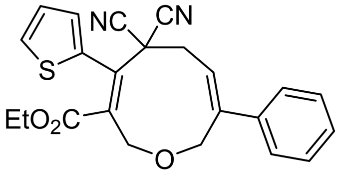
NMR and HRMS data for the product **3i**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.87 (d, *J* = 7.8 Hz, 1H), 7.84 (d, *J* = 7.8 Hz, 1H), 7.74 (d, *J* = 8.4 Hz, 1H), 7.63 (s, 1H), 7.59 (d, *J* = 6.6 Hz, 2H), 7.56 – 7.48 (m, 2H), 7.46 – 7.37 (m, 3H), 7.34 (dd, *J* = 8.4, 2.4 Hz, 1H), 6.28 (t, *J* = 9.0 Hz, 1H), 4.83 – 4.52 (m, 4H), 3.85 – 3.69 (m, 3H), 3.69 – 3.58 (m, 1H), 0.60 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 167.7, 143.9, 139.4, 139.1, 136.3, 134.8, 133.3, 132.6, 128.7, 128.6, 128.3, 128.2, 127.9, 127.8, 127.2, 126.9, 126.6, 125.2, 122.3, 114.3, 114.2, 66.8, 63.5, 61.5, 40.2, 39.2, 13.3.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{29}H_{24}N_2O_3Na^+$: 471.1679, found: 471.1680.

ethyl-(3*Z*,7*Z*)-5,5-dicyano-8-phenyl-4-(thiophen-2-yl)-2,5,6,9-tetrahydrooxonine-3-carboxylate 3j



Prepared according to the general procedure to afford **3j** (38.8 mg) in 96% yield as yellow semisolid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

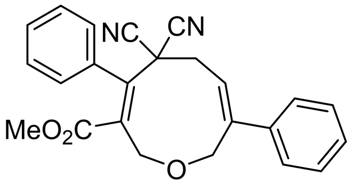
NMR and HRMS data for the product **3j**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.54 (d, *J* = 8.4 Hz, 2H), 7.42 (dd, *J* = 6.6, 1.8 Hz, 1H), 7.41 – 7.33 (m, 3H), 7.06 – 7.01 (m, 2H), 6.23 (t, *J* = 9.0 Hz, 1H), 4.61 (s, 2H), 4.54 (s, 2H), 3.96 (q, *J* = 7.2 Hz, 2H), 3.58 (d, *J* = 9.0 Hz, 2H), 0.94 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 167.2, 143.9, 139.3, 139.2, 136.3, 131.8, 129.4, 128.65, 128.55, 127.9, 127.0, 126.6, 122.2, 114.0, 67.1, 63.7, 61.7, 40.7, 38.8, 13.6.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{23}H_{20}N_2O_3SNa^+$: 427.1087, found: 427.1086.

methyl-(3*E*,7*Z*)-5,5-dicyano-4,8-diphenyl-2,5,6,9-tetrahydrooxonine-3-carboxylate 3k



Prepared according to the general procedure to afford **3k** (33.4 mg) in 87% yield as pale yellow semisolid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

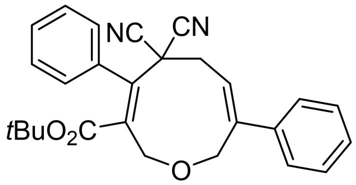
NMR and HRMS data for the product **3k**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.56 (d, *J* = 8.4 Hz, 2H), 7.45 – 7.35 (m, 6H), 7.20 (d, *J* = 7.8 Hz, 2H), 6.29 (t, *J* = 9.0 Hz, 1H), 4.60 (s, 2H), 4.55 (s, 2H), 3.60 (d, *J* = 9.0 Hz, 2H), 3.38 (s, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 168.0, 143.5, 139.5, 139.3, 137.3, 135.6, 129.7, 128.7, 128.6, 127.9, 126.6, 122.4, 114.1, 66.2, 63.0, 52.3, 40.2, 38.9.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{24}H_{20}N_2O_3Na^+$: 407.1366, found: 407.1362.

tert-butyl-(3*E*,7*Z*)-5,5-dicyano-4,8-diphenyl-2,5,6,9-tetrahydrooxonine-3-carboxylate 3l



The reaction was performed according to the general procedure by using 0.30 mmol of the corresponding vinylethylene carbonate **2** to afford **3l** (35.0 mg, m. p. = 125 – 129 °C) in 82% yield as white solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

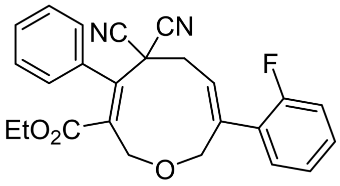
NMR and HRMS data for the product **3l**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.56 (d, *J* = 7.2 Hz, 2H), 7.45 – 7.33 (m, 6H), 7.20 (d, *J* = 7.2 Hz, 2H), 6.23 (t, *J* = 9.0 Hz, 1H), 4.58 (s, 2H), 4.57 (s, 2H), 3.62 (d, *J* = 9.0 Hz, 2H), 1.07 (s, 9H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 166.7, 143.8, 139.5, 137.5, 137.3, 136.7, 129.5, 128.7, 128.6, 128.5, 126.6, 125.5, 122.2, 114.3, 82.7, 66.7, 63.7, 40.1, 39.0, 27.3.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{27}H_{26}N_2O_3Na^+$: 449.1836, found: 449.1836.

ethyl-(3*E*,7*Z*)-5,5-dicyano-8-(2-fluorophenyl)-4-phenyl-2,5,6,9-tetrahydrooxonine-3-carboxylate 3m



Prepared according to the general procedure to afford **3m** (35.4 mg, m. p. = 109 – 111 °C) in 85% yield as white solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

NMR and HRMS data for the product **3m**:

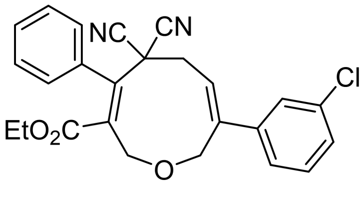
^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.50 – 7.37 (m, 4H), 7.36 – 7.30 (1H), 7.23 (d, J = 6.6 Hz, 2H), 7.17 (t, J = 7.2 Hz, 1H), 7.10 (dd, J = 10.2, 8.4 Hz, 1H), 6.16 (t, J = 9.0 Hz, 1H), 4.63 (s, 2H), 4.54 (s, 2H), 3.84 (q, J = 7.2 Hz, 2H), 3.67 (d, J = 9.0 Hz, 2H), 0.80 (t, J = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 167.5, 159.6 (d, $J_{C\text{-}F}$ = 247.1 Hz), 140.2, 138.6, 137.4, 135.9, 130.2 (d, $J_{C\text{-}F}$ = 2.9 Hz), 130.1 (d, $J_{C\text{-}F}$ = 8.7 Hz), 129.7, 128.6, 128.1, 127.4 (d, $J_{C\text{-}F}$ = 12.9 Hz), 125.8, 124.5 (d, $J_{C\text{-}F}$ = 3.0 Hz), 116.0 (d, $J_{C\text{-}F}$ = 21.5 Hz), 114.2, 67.4, 64.1, 61.5, 40.1, 38.7, 13.4.

^{19}F NMR (564 MHz, CDCl$_3$) δ (ppm): -115.0.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{25}H_{21}FN_2O_3Na^+$ 439.1428, found: 439.1427.

<u>ethyl-(3*E*,7*Z*)-8-(3-chlorophenyl)-5,5-dicyano-4-phenyl-2,5,6,9-tetrahydrooxonine-3-carboxylate 3n</u>



Prepared according to the general procedure to afford **3n** (37.7 mg, m. p. = 89 – 92 °C) in 87% yield as pale yellow solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

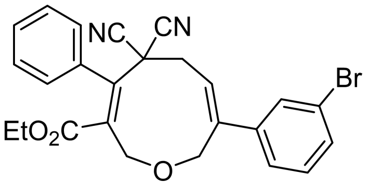
NMR and HRMS data for the product **3n**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.55 (s, 1H), 7.47 – 7.36 (m, 4H), 7.36 – 7.30 (m, 2H), 7.19 (d, *J* = 8.4 Hz, 2H), 6.27 (t, *J* = 9.0 Hz, 1H), 4.60 (s, 2H), 4.52 (s, 2H), 3.86 (q, *J* = 7.2 Hz, 2H), 3.62 (d, *J* = 9.0 Hz, 2H), 0.80 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 167.5, 142.6, 141.2, 138.8, 137.2, 135.8, 134.7, 130.0, 129.7, 128.6, 128.1, 126.8, 124.8, 123.5, 114.1, 66.4, 63.4, 61.6, 40.0, 38.9, 13.4.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{25}H_{21}{}^{35}ClN_2O_3Na^+$: 455.1133, found: 455.1135; calculated for $C_{25}H_{21}{}^{37}ClN_2O_3Na^+$: 457.1103, found: 457.1115.

ethyl-(3*E*,7*Z*)-8-(3-bromophenyl)-5,5-dicyano-4-phenyl-2,5,6,9-tetrahydrooxonine-3-carboxylate 3o



Prepared according to the general procedure to afford **3o** (44.4 mg, m. p. = 104 – 106 °C) in 93% yield as white solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

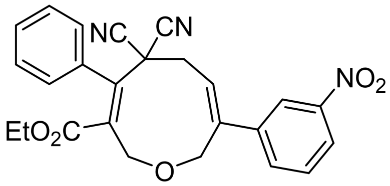
NMR and HRMS data for the product **3o**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.70 (s, 1H), 7.53 – 7.46 (m, 2H), 7.45 – 7.35 (m, 3H), 7.27 (t, *J* = 8.4 Hz, 1H), 7.19 (d, *J* = 7.2 Hz, 2H), 6.26 (t, *J* = 9.0 Hz, 1H), 4.61 (s, 2H), 4.52 (s, 2H), 3.86 (q, *J* = 7.2 Hz, 2H), 3.62 (d, *J* = 9.0 Hz, 2H), 0.80 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 167.5, 142.5, 141.5, 138.8, 137.2, 135.8, 131.6, 130.2, 129.73, 129.69, 128.6, 128.1, 125.2, 123.5, 122.8, 114.1, 66.4, 63.5, 61.6, 40.0, 38.9, 13.4.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{25}H_{21}{}^{79}BrN_2O_3Na^+$: 499.0628, found: 499.0628; calculated for $C_{25}H_{21}{}^{81}BrN_2O_3Na^+$: 501.0607, found: 501.0599.

ethyl-(3*E*,7*Z*)-5,5-dicyano-8-(3-nitrophenyl)-4-phenyl-2,5,6,9-tetrahydrooxonine-3-carboxylate 3p



Prepared according to the general procedure to afford **3p** (42.1 mg, m. p. = 145 – 148 °C) in 95% yield as pale yellow solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

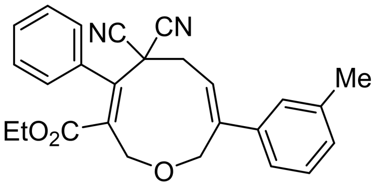
NMR and HRMS data for the product **3p**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 8.43 (s, 1H), 8.23 (d, *J* = 8.4 Hz, 1H), 7.92 (d, *J* = 8.4 Hz, 1H), 7.59 (t, *J* = 8.4 Hz, 1H), 7.46 – 7.35 (m, 3H), 7.19 (d, *J* = 6.0 Hz, 2H), 6.39 (t, *J* = 9.0 Hz, 1H), 4.62 (s, 2H), 4.57 (s, 2H), 3.87 (q, *J* = 7.2 Hz, 2H), 3.65 (d, *J* = 8.4 Hz, 2H), 0.79 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 167.4, 148.5, 141.6, 141.1, 138.8, 137.0, 135.8, 132.6, 129.83, 129.81, 128.7, 128.0, 125.0, 123.3, 121.5, 113.9, 66.0, 63.4, 61.7, 39.9, 38.8, 13.4.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{25}H_{21}N_3O_5Na^+$: 466.1373, found: 466.1374.

ethyl-(3*E*,7*Z*)-5,5-dicyano-4-phenyl-8-(m-tolyl)-2,5,6,9-tetrahydrooxonine-3-carboxylate 3q



The reaction was performed according to the general procedure by using 0.30 mmol of the corresponding vinylethylene carbonates **2** to afford **3q** (37.5 mg) in 91% yield as colorless semisolid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

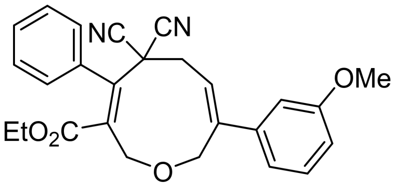
NMR and HRMS data for the product **3q**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.46 – 7.34 (m, 5H), 7.28 (t, *J* = 8.4 Hz, 1H), 7.23 – 7.16 (m, 3H), 6.26 (t, *J* = 8.4 Hz, 1H), 4.61 (s, 2H), 4.55 (s, 2H), 3.86 (q, *J* = 7.2 Hz, 2H), 3.61 (q, *J* = 9.0 Hz, 2H), 2.39 (s, 3H), 0.80 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 167.6, 143.7, 139.4, 139.0, 138.3, 137.4, 135.8, 129.6, 129.3, 128.6, 128.1, 127.3, 123.7, 122.1, 114.2, 66.4, 63.2, 61.5, 40.2, 39.0, 21.5, 13.4.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{26}H_{24}N_2O_3Na^+$: 435.1679, found: 435.1674.

ethyl-(3*E*,7*Z*)-5,5-dicyano-8-(3-methoxyphenyl)-4-phenyl-2,5,6,9-tetrahydrooxonine-3-carboxylate 3r



Prepared according to the general procedure to afford **3r** (34.7 mg, m. p. = 101 – 106 °C) in 81% yield as white solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

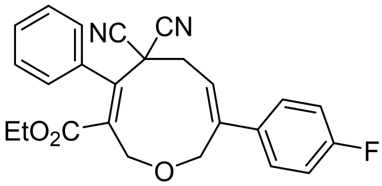
NMR and HRMS data for the product **3r**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.44 – 7.35 (m, 3H), 7.31 (t, *J* = 8.4 Hz, 1H), 7.20 (d, *J* = 6.0 Hz, 2H), 7.13 (d, *J* = 8.4 Hz, 1H), 7.10 (s, 1H), 6.91 (d, *J* = 7.2 Hz, 1H), 6.24 (t, *J* = 9.0 Hz, 1H), 4.61 (s, 2H), 4.55 (s, 2H), 3.85 (q, *J* = 7.2 Hz, 2H), 3,84 (s, 3H), 3.62 (d, *J* = 9.0 Hz, 2H), 0.79 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 167.6, 159.8, 143.8, 140.9, 138.9, 137.4, 135.9, 129.7, 129.6, 128.6, 128.1, 122.4, 119.0, 114.2, 114.0, 112.4, 66.7, 63.5, 61.5, 55.3, 40.2, 39.0, 13.4.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{26}H_{24}N_2O_4Na^+$: 451.1628, found: 451.1631.

ethyl-(3*E*,7*Z*)-5,5-dicyano-8-(4-fluorophenyl)-4-phenyl-2,5,6,9-tetrahydrooxonine-3-carboxylate 3s



Prepared according to the general procedure to afford **3s** (35.8 mg, m. p. = 115 – 117 °C) in 86% yield as pale yellow solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

NMR and HRMS data for the product **3s**:

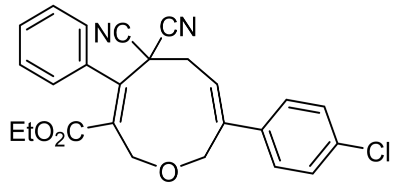
^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.57 – 7.50 (m, 2H), 7.44 – 7.35 (m, 3H), 7.19 (d, *J* = 7.2 Hz, 2H), 7.08 (t, *J* = 7.8 Hz, 2H), 6.20 (t, *J* = 8.4 Hz, 1H), 4.60 (s, 2H), 4.53 (s, 2H), 3.85 (q, *J* = 7.8 Hz, 2H), 3.61 (d, *J* = 9.0 Hz, 2H), 0.80 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 167.6, 163.0 (d, $J_{C\text{-}F}$ = 247.1 Hz), 142.8, 138.9, 137.3, 135.8, 135.5 (d, $J_{C\text{-}F}$ = 2.9 Hz), 129.7, 128.6, 128.4 (d, $J_{C\text{-}F}$ = 8.7 Hz), 128.1, 122.3, 115.6 (d, $J_{C\text{-}F}$ = 21.6 Hz), 114.1, 66.5, 63.4, 61.5, 40.2, 39.0, 13.4.

^{19}F NMR (564 MHz, CDCl$_3$) δ (ppm): -112.9.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{25}H_{21}FN_2O_3Na^+$: 439.1428, found: 439.1427.

ethyl-(3*E*,7*Z*)-8-(4-chlorophenyl)-5,5-dicyano-4-phenyl-2,5,6,9-tetrahydrooxonine-3-carboxylate 3t



Prepared according to the general procedure to afford **3t** (35.1 mg) in 81% yield as colorless semisolid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

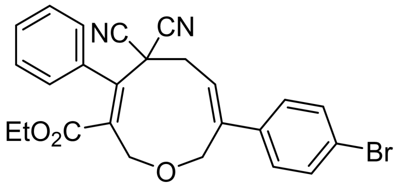
NMR and HRMS data for the product **3t**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.49 (d, *J* = 8.4 Hz, 2H), 7.44 – 7.34 (m, 5H), 7.18 (d, *J* = 7.2 Hz, 2H), 6.24 (t, *J* = 9.0 Hz, 1H), 4.59 (s, 2H), 4.53 (s, 2H), 3.85 (q, *J* = 7.2 Hz, 2H), 3.61 (d, *J* = 9.0 Hz, 2H), 0.79 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 167.6, 142.7, 138.9, 137.8, 137.3, 135.8, 134.6, 129.7, 128.9, 128.6, 128.1, 127.9, 122.8, 114.1, 66.4, 63.4, 61.6, 40.1, 39.0, 13.4.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{25}H_{21}{}^{35}ClN_2O_3Na^+$: 455.1133, found: 455.1135; calculated for $C_{25}H_{21}{}^{37}ClN_2O_3Na^+$: 457.1103, found: 457.1112.

ethyl-(3*E*,7*Z*)-8-(4-bromophenyl)-5,5-dicyano-4-phenyl-2,5,6,9-tetrahydrooxonine-3-carboxylate 3u



Prepared according to the general procedure to afford **3u** (36.7 mg, m. p. = 149 – 152 °C) in 77% yield as white solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H

NMR analysis.

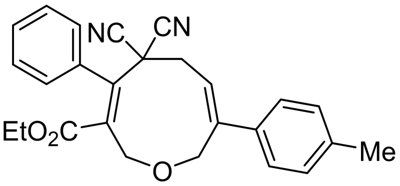
NMR and HRMS data for the product **3u**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.52 (d, *J* = 9.0 Hz, 2H), 7.46 – 7.36 (m, 5H), 7.18 (d, *J* = 7.2 Hz, 2H), 6.24 (t, *J* = 9.0 Hz, 1H), 4.59 (s, 2H), 4.52 (s, 2H), 3.85 (q, *J* = 7.2 Hz, 2H), 3.61 (d, *J* = 9.0 Hz, 2H), 0.79 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 167.6, 142.7, 138.9, 138.3, 137.2, 135.8, 131.8, 129.7, 128.6, 128.2, 128.1, 122.84, 122.81, 114.1, 66.3, 63.4, 61.6, 40.0, 39.0, 13.4.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{25}H_{21}{}^{79}BrN_2O_3Na^+$: 499.0628, found: 499.0632; calculated for $C_{25}H_{21}{}^{81}BrN_2O_3Na^+$: 501.0607, found: 501.0609.

ethyl-(3*E*,7*Z*)-5,5-dicyano-4-phenyl-8-(p-tolyl)-2,5,6,9-tetrahydrooxonine-3-carboxylate 3v



Prepared according to the general procedure to afford **3v** (33.8 mg, m. p. = 110 – 115 °C) in 82% yield as pale yellow solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

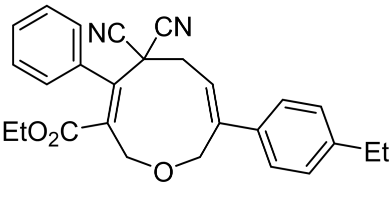
NMR and HRMS data for the product **3v**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.45 (d, *J* = 8.4 Hz, 2H), 7.43 – 7.36 (m, 3H), 7.23 – 7.18 (m, 4H), 6.24 (t, *J* = 9.0 Hz, 1H), 4.59 (s, 2H), 4.54 (s, 2H), 3.85 (q, *J* = 7.8 Hz, 2H), 3.60 (d, *J* = 9.0 Hz, 2H), 2.38 (s, 3H), 0.80 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 167.6, 143.4, 139.0, 138.6, 137.4, 136.4, 135.8, 129.6, 129.4, 128.6, 128.1, 126.5, 121.5, 114.2, 66.3, 63.2, 61.5, 40.2, 39.0, 21.2, 13.4.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{26}H_{24}N_2O_3Na^+$: 435.1679, found: 435.1682.

ethyl-(3*E*,7*Z*)-5,5-dicyano-8-(4-ethylphenyl)-4-phenyl-2,5,6,9-tetrahydrooxonine-3-carboxylate 3w



Prepared according to the general procedure to afford **3w** (38.9 mg, m. p. = 94 – 97 °C) in 91% yield as white solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

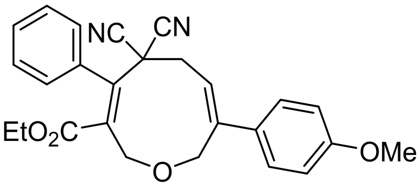
NMR and HRMS data for the product **3w**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.48 (d, *J* = 7.8 Hz, 2H), 7.44 – 7.35 (m, 3H), 7.25 – 7.19 (m, 4H), 6.25 (t, *J* = 9.0 Hz, 1H), 4.60 (s, 2H), 4.55 (s, 2H), 3.85 (q, *J* = 7.2 Hz, 2H), 3.60 (d, *J* = 8.4 Hz, 2H), 2.67 (q, *J* = 7.8 Hz, 2H), 1.26 (t, *J* = 7.8 Hz, 3H), 0.80 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 167.6, 144.9, 143.4, 139.0, 137.4, 136.7, 135.8, 129.6, 128.6, 128.2, 128.1, 126.6, 121.5, 114.2 66.3, 63.2, 61.5, 40.3, 39.0, 28.5, 15.4, 13.4.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{27}H_{26}N_2O_3Na^+$: 449.1836, found: 449.1836.

ethyl-(3*E*,7*Z*)-5,5-dicyano-8-(4-methoxyphenyl)-4-phenyl-2,5,6,9-tetrahydrooxonine-3-carboxylate 3x



Prepared according to the general procedure to afford **3x** (34.7 mg) in 81% yield as pale yellow semisolid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

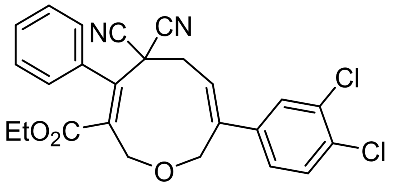
NMR and HRMS data for the product **3x**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.51 (d, *J* = 9.0 Hz, 2H), 7.44 – 7.35 (m, 3H), 7.20 (d, *J* = 6.6 Hz, 2H), 6.92 (d, *J* = 9.0 Hz, 2H), 6.21 (t, *J* = 9.0 Hz, 1H), 4.59 (s, 2H), 4.53 (s, 2H), 3.85 (q, *J* = 7.2 Hz, 2H), 3.84 (s, 3H), 3.59 (d, *J* = 9.0 Hz, 2H), 0.80 (t, *J* = 6.6 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 167.7, 159.9, 142.8, 139.0, 137.4, 135.8, 131.7, 129.6, 128.6, 128.1, 127.9, 120.7, 114.2, 114.0, 66.2, 63.1, 61.5, 55.3, 40.3, 39.1, 13.4.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{26}H_{24}N_2O_4Na^+$: 451.1628, found: 451.1629.

ethyl-(3*E*,7*Z*)-5,5-dicyano-8-(3,4-dichlorophenyl)-4-phenyl-2,5,6,9-tetrahydrooxonine-3-carboxylate 3y



Prepared according to the general procedure to afford **3y** (36.4 mg, m. p. = 118 – 121 °C) in 78% yield as white solid. The regioisomeric ratio was determined to be >20:1 by crude ^1H NMR analysis.

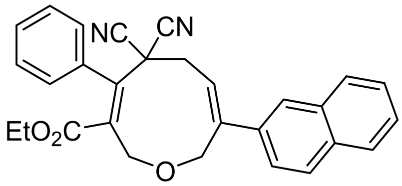
NMR and HRMS data for the product **3y**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.66 (d, *J* = 2.4 Hz, 1H), 7.46 (d, *J* = 8.4 Hz, 1H), 7.44 – 7.36 (m, 4H), 7.18 (d, *J* = 6.6 Hz, 2H), 6.27 (t, *J* = 9.0 Hz, 1H), 4.59 (s, 2H), 4.50 (s, 2H), 3.86 (q, *J* = 7.2 Hz, 2H), 3.61 (d, *J* = 9.6 Hz, 2H), 0.80 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 167.5, 141.6, 139.4, 138.8, 137.1, 135.8, 132.9, 132.8, 130.6, 129.8, 128.65, 128.59, 128.1, 125.9, 123.8, 114.0, 66.1, 63.4, 61.6, 40.0, 38.9, 13.4.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{25}H_{20}{}^{35}Cl_2N_2O_3Na^+$: 489.0743, found: 489.0740; calculated for $C_{25}H_{20}{}^{35}Cl^{37}ClN_2O_3Na^+$: 491.0714, found: 491.0717; calculated for $C_{25}H_{20}{}^{37}Cl_2N_2O_3Na^+$: 493.0684, found: 493.0689.

ethyl-(3*E*,7*Z*)-5,5-dicyano-8-(naphthalen-2-yl)-4-phenyl-2,5,6,9-tetrahydrooxonine-3-carboxylate 3z



Prepared according to the general procedure to afford **3z** (40.9 mg, m. p. = 116 – 118 °C) in 91% yield as white solid. The regioisomeric ratio was determined to be >20:1 by crude ^1H NMR analysis.

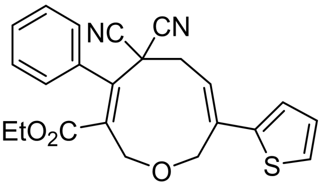
NMR and HRMS data for the product **3z**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 8.04 (s, 1H), 7.92 – 7.82 (m, 3H), 7.68 (d, *J* = 10.2 Hz, 1H), 7.56 – 7.47 (m, 2H), 7.44 – 7.35 (m, 3H), 7.21 (d, *J* = 6.0 Hz, 2H), 6.41 (t, *J* = 9.0 Hz, 1H), 4.68 (s, 2H), 4.66 (s, 2H), 3.86 (q, *J* = 7.8 Hz, 2H), 3.68 (d, *J* = 8.4 Hz, 2H), 0.79 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 167.6, 143.4, 138.9, 137.4, 136.5, 135.9, 133.3, 133.1, 129.7, 128.8, 128.6, 128.4, 128.1, 127.6, 126.6, 126.5, 126.0, 124.2, 122.7, 114.2, 66.4, 63.4, 61.5, 40.2, 39.2, 13.4.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{29}H_{24}N_2O_3Na^+$: 471.1679, found: 471.1680.

<u>ethyl-(3*E*,7*E*)-5,5-dicyano-4-phenyl-8-(thiophen-2-yl)-2,5,6,9-tetrahydrooxonine-3-carboxylate 3aa</u>



Prepared according to the general procedure to afford **3aa** (25.5 mg, m. p. = 146 – 150 °C) in 63% yield as pale yellow solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

NMR and HRMS data for the product **3aa**:

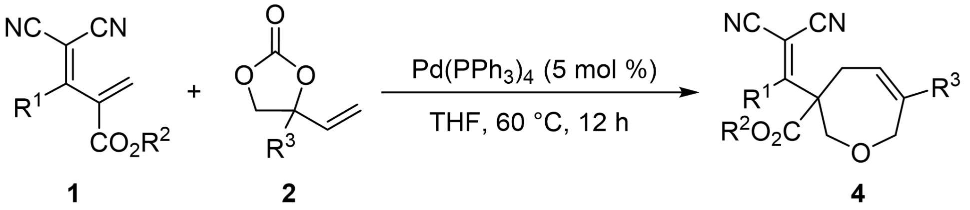
^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.44 – 7.36 (m, 3H), 7.29 (d, *J* = 4.2 Hz, 1H), 7.25 (d, *J* = 3.6 Hz, 1H), 7.21 (d, *J* = 6.6 Hz, 2H), 7.05 (dd, *J* = 4.8, 3.6 Hz, 1H), 6.36 (t, *J* = 9.0 Hz, 1H), 4.60 (s, 2H), 4.58 (s, 2H), 3.83 (q, *J* = 7.2 Hz, 2H), 3.60 (d, *J* = 9.0 Hz, 2H), 0.77 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 167.5, 142.1, 139.2, 137.3, 137.2, 135.7, 129.7, 128.6, 128.1, 127.9, 125.9, 125.7, 120.0, 114.1, 65.8, 63.4, 61.5, 40.2, 39.0, 13.4.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{23}H_{20}N_2O_3SNa^+$: 427.1087, found: 427.1089.

5. General Procedure for the Preparation of Seven-Membered Products 4

*General procedure for the synthesis of seven-membered products **4***

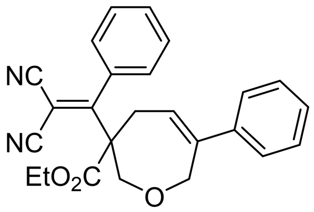


To an over-dried Schlenk tube was added Pd(PPh$_3$)$_4$ (5 mol %), after which the tube was evacuated and back-filled with argon three times. Subsequently, under the protection of argon, a solution of dried allylidenemalononitriles **1** (0.10 mmol) and vinylethylene carbonates **2** (0.15 mmol) in dry THF (1.0 mL) was added via syringe and the reaction mixture was stirred at 60 °C for 12 hours. Then the mixture was concentrated and purified by column chromatography on silica gel (petroleum ether/ dichloromethane = 3/1 to 1/1, then petroleum ether/ethyl acetate = 10/1) to afford the corresponding **4** in 71–94% yields, which were dried under vacuum and further analyzed by ^{1}H NMR, ^{13}C NMR, HRMS, *etc.*

*Gram-scale synthesis of the seven-membered product **4a***

To an over-dried 100 mL Schlenk flask, was added Pd(PPh$_3$)$_4$ (0.20 mmol, 231 mg), after which the tube was evacuated and back-filled with argon three times. Subsequently, under the protection of argon, a solution of dried allylidenemalononitrile **1a** (4.00 mmol, 1.01 g) and vinylethylene carbonate **2a** (6.00 mmol, 1.14 g) in dry THF (40 mL) was added via syringe and the reaction mixture was stirred at 60 °C for 12 hours. Then the mixture was concentrated and purified by column chromatography on silica gel (petroleum ether/ dichloromethane = 3/1 to 1/1, then petroleum ether/ethyl acetate = 10/1) to afford **4a** (1.16 g) as pale yellow solid in 73% yields.

ethyl-3-(2,2-dicyano-1-phenylvinyl)-6-phenyl-2,3,4,7-tetrahydrooxepine-3-carboxylate 4a



Prepared according to the general procedure to afford **4a** (33.4 mg, m. p. = 104 – 108 °C) in

84% yield as pale yellow solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

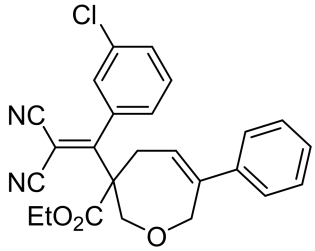
NMR and HRMS data for the product **4a**:

^{1}H NMR (600 MHz, **CDCl$_3$)** δ (ppm): 7.55 – 7.44 (m, 3H), 7.34 – 7.20 (m, 5H), 7.09 (d, *J* = 6.6 Hz, 2H), 5.50 (t, *J* = 6.6 Hz, 1H), 4.69 (d, *J* = 16.2 Hz, 1H), 4.64 (d, *J* = 16.2 Hz, 1H), 4.55 (d, *J* = 13.2 Hz, 1H), 4.39 – 4.25 (m, 2H), 4.18 (d, *J* = 12.0 Hz, 1H), 3.01 (dd, *J* = 14.4, 6.0 Hz, 1H), 2.94 (dd, *J* = 15.0, 6.6 Hz, 1H), 1.35 (t, *J* = 6.6 Hz, 3H).

^{13}C NMR (150 MHz, **CDCl$_3$)** δ (ppm): 180.7, 170.5, 141.4, 139.1, 135.5, 130.4, 128.8, 128.5, 127.7, 126.7, 125.6, 122.2, 111.8, 111.3, 90.2, 75.0, 74.3, 62.7, 60.9, 32.5, 14.1.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{25}H_{22}N_2O_3Na^+$: 421.1523, found: 421.1521.

ethyl-3-(1-(3-chlorophenyl)-2,2-dicyanovinyl)-6-phenyl-2,3,4,7-tetrahydrooxepine-3-carboxylate 4b



Prepared according to the general procedure to afford **4b** (35.5 mg) in 82% yield as pale yellow semisolid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

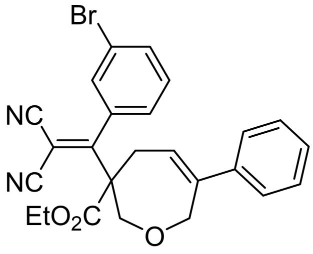
NMR and HRMS data for the product **4b**:

^{1}H NMR (600 MHz, **CDCl$_3$)** δ (ppm): 7.40 (d, *J* = 7.8 Hz, 2H), 7.30 – 7.19 (m, 3H), 7.13 (d, *J* = 8.4 Hz, 2H), 7.06 (d, *J* = 8.4 Hz, 2H), 5.53 (t, *J* = 6.6 Hz, 1H), 4.62 (d, *J* = 15.6 Hz, 1H), 4.58 (d, *J* = 15.6 Hz, 1H), 4.40 (d, *J* = 13.2 Hz, 1H), 4.34 – 4.22 (m, 2H), 4.17 (d, *J* = 13.2 Hz, 1H), 2.98 (dd, *J* = 14.4, 6.6 Hz, 1H), 2.88 (dd, *J* = 14.4, 6.0 Hz, 1H), 1.30 (t, *J* = 6.6 Hz, 3H).

^{13}C NMR (150 MHz, **CDCl$_3$)** δ (ppm): 179.7, 170.2, 142.0, 139.1, 136.8, 133.9, 129.2, 128.7, 128.6, 128.3, 127.9, 126.6, 125.6, 122.2, 111.6, 111.1, 90.7, 74.9, 74.7, 62.7, 60.5, 32.7, 14.1.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{25}H_{21}{}^{35}ClN_2O_3Na^+$: 455.1133, found: 455.1131; calculated for $C_{25}H_{21}{}^{37}ClN_2O_3Na^+$: 457.1103, found: 457.1108.

ethyl-3-(1-(3-bromophenyl)-2,2-dicyanovinyl)-6-phenyl-2,3,4,7-tetrahydrooxepine-3-carboxylate 4c



Prepared according to the general procedure to afford **4c** (33.9 mg, m. p. = 106 – 111 °C) in 71% yield as pale yellow solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

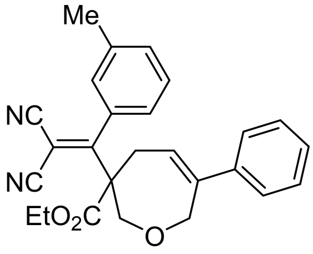
NMR and HRMS data for the product **4c**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.64 (d, *J* = 8.4 Hz, 1H), 7.41 – 7.27 (m, 5H), 7.18 (d, *J* = 6.6 Hz, 1H), 7.12 (d, *J* = 6.6 Hz, 2H), 5.52 (brs, 1H), 4.66 (brs, 2H), 4.49 (d, *J* = 12.6 Hz, 1H), 4.39 – 4.27 (m, 2H), 4.22 (d, *J* = 13.2 Hz, 1H), 3.01 (dd, *J* = 14.4, 6.6 Hz, 1H), 2.95 (dd, *J* = 14.4, 6.6 Hz, 1H), 1.37 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 179.0, 170.2, 142.1, 139.0, 137.3, 133.4, 130.3, 129.6, 128.6, 127.9, 125.7, 125.5, 122.8, 122.1, 111.4, 111.0, 91.0, 74.9, 74.7, 62.9, 60.4, 32.7, 14.1.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{25}H_{21}{}^{79}BrN_2O_3Na^+$: 499.0628, found: 499.0633; calculated for $C_{25}H_{21}{}^{81}BrN_2O_3Na^+$: 501.0607, found: 501.0607.

ethyl-3-(2,2-dicyano-1-(m-tolyl)vinyl)-6-phenyl-2,3,4,7-tetrahydrooxepine-3-carboxylate 4d



The reaction was performed according to the general procedure at 80 °C to afford **4d** (26.0 mg) in 63% yield as pale yellow semisolid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

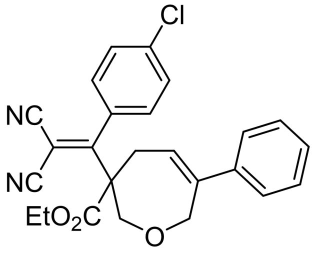
NMR and HRMS data for the product **4d**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.37 (t, *J* = 7.8 Hz, 1H), 7.33 – 7.26 (m, 4H), 7.08 (d, *J* = 7.2 Hz, 2H), 7.05 – 6.94 (m, 2H), 5.46 (brs, 1H), 4.71 (d, *J* = 15.6 Hz, 1H), 4.63 (d, *J* = 16.8 Hz, 1H), 4.58 (d, *J* = 12.6 Hz, 1H), 4.37 – 4.27 (m, 2H), 4.15 (d, *J* = 12.0 Hz, 1H), 3.04 – 2.89 (m, 2H), 2.37 (s, 3H), 1.35 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 181.0, 170.6, 141.2, 139.1, 138.7, 135.5, 131.1, 128.7, 128.5, 127.7, 127.2, 125.6, 123.7, 122.3, 111.8, 111.4, 89.9, 75.0, 74.2, 62.7, 61.0, 32.4, 21.4, 14.1.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{26}H_{24}N_2O_3Na^+$: 435.1679, found: 435.1677.

ethyl-3-(1-(4-chlorophenyl)-2,2-dicyanovinyl)-6-phenyl-2,3,4,7-tetrahydrooxepine-3-carboxylate 4e



The reaction was performed according to the general procedure at 80 °C to afford **4e** (23.4 mg) in 54% yield as yellow semisolid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

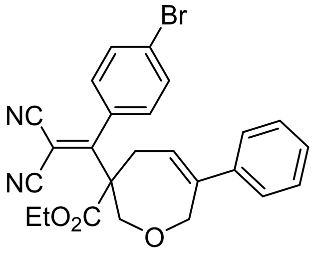
NMR and HRMS data for the product **4e**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.46 (d, *J* = 8.4 Hz, 2H), 7.34 – 7.27 (m, 3H), 7.18 (d, *J* = 8.4 Hz, 2H), 7.11 (d, *J* = 6.6 Hz, 2H), 5.59 (t, *J* = 6.0 Hz, 1H), 4.67 (d, *J* = 16.2 Hz, 1H), 4.64 (d, *J* = 16.8 Hz, 1H), 4.46 (d, *J* = 13.2 Hz, 1H), 4.38 – 4.27 (m, 2H), 4.22 (d, *J* = 12.6 Hz, 1H), 3.03 (dd, *J* = 13.8, 6.6 Hz, 1H), 2.93 (dd, *J* = 14.4, 7.2 Hz, 1H), 1.35 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 179.7, 170.2, 141.9, 139.0, 136.8, 133.9, 129.2, 128.6, 128.3, 127.9, 125.6, 122.2, 111.6, 111.1, 90.7, 74.9, 74.7, 62.9, 60.5, 32.7, 14.1.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{25}H_{21}{}^{35}ClN_2O_3Na^+$: 455.1133, found: 455.1130; calculated for $C_{25}H_{21}{}^{37}ClN_2O_3Na^+$: 457.1103, found: 457.1107.

ethyl-3-(1-(4-bromophenyl)-2,2-dicyanovinyl)-6-phenyl-2,3,4,7-tetrahydrooxepine-3-carboxylate 4f



The reaction was performed according to the general procedure at 100 °C to afford **4f** (20.0 mg) in 42% yield as pale yellow semisolid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

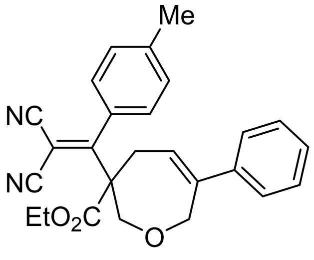
NMR and HRMS data for the product **4f**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.62 (d, *J* = 8.4 Hz, 2H), 7.34 – 7.27 (m, 3H), 7.16 – 7.06 (m, 4H), 5.59 (t, *J* = 6.6 Hz, 1H), 4.67 (d, *J* = 16.8 Hz, 1H), 4.64 (d, *J* = 16.8 Hz, 1H), 4.45 (d, *J* = 12.0 Hz, 1H), 4.37 – 4.27 (m, 2H), 4.22 (d, *J* = 12.6 Hz, 1H), 3.03 (dd, *J* = 14.4, 6.0 Hz, 1H), 2.93 (dd, *J* = 14.4, 6.0 Hz, 1H), 1.35 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 179.7, 170.2, 142.0, 139.0, 134.4, 132.1, 128.6, 128.4, 127.9, 125.6, 125.0, 122.2, 111.6, 111.1, 90.7, 74.9, 74.7, 62.9, 60.5, 32.7, 14.1.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{25}H_{21}{}^{79}BrN_2O_3Na^+$: 499.0628, found: 499.0622; calculated for $C_{25}H_{21}{}^{81}BrN_2O_3Na^+$: 501.0607, found: 501.0607.

ethyl-3-(2,2-dicyano-1-(p-tolyl)vinyl)-6-phenyl-2,3,4,7-tetrahydrooxepine-3-carboxylate 4g



Prepared according to the general procedure to afford **4g** (30.1 mg, m. p. = 104 – 107 °C) in 73% yield as pale yellow solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

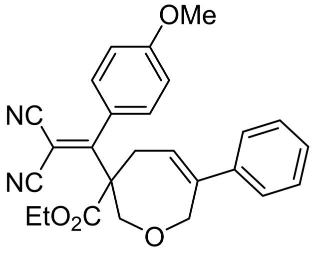
NMR and HRMS data for the product **4g**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.35 – 7.26 (m, 5H), 7.12 (d, *J* = 8.4 Hz, 2H), 7.09 (d, *J* = 6.6 Hz, 2H), 5.55 (t, *J* = 7.2 Hz, 1H), 4.69 (d, *J* = 16.2 Hz, 1H), 4.64 (d, *J* = 16.2 Hz, 1H), 4.53 (d, *J* = 12.6 Hz, 1H), 4.37 – 4.24 (m, 2H), 4.16 (d, *J* = 12.6 Hz, 1H), 3.03 (dd, *J* = 14.4, 6.0 Hz, 1H), 2.93 (dd, *J* = 15.0, 6.6 Hz, 1H), 2.42 (s, 3H), 1.34 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 181.0, 170.6, 141.3, 140.7, 139.1, 132.6, 129.5, 128.5, 127.7, 126.7, 125.6, 122.3, 112.0, 111.4, 89.8, 75.0, 74.2, 62.7, 61.0, 32.4, 21.4, 14.0.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{26}H_{24}N_2O_3Na^+$: 435.1679, found: 435.1677.

ethyl-3-(2,2-dicyano-1-(4-methoxyphenyl)vinyl)-6-phenyl-2,3,4,7-tetrahydrooxepine-3-carboxylate 4h



Prepared according to the general procedure to afford **4h** (38.9 mg) in 91% yield as yellow semisolid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

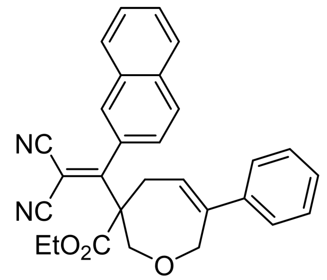
NMR and HRMS data for the product **4h**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.33 – 7.27 (m, 3H), 7.18 (d, *J* = 9.0 Hz, 2H), 7.11 (d, *J* = 8.4 Hz, 2H), 6.98 (d, *J* = 9.0 Hz, 2H), 5.56 (t, *J* = 7.2 Hz, 1H), 4.69 (d, *J* = 17.4 Hz, 1H), 4.65 (d, *J* = 15.6 Hz, 1H), 4.53 (d, *J* = 12.6 Hz, 1H), 4.37 – 4.24 (m, 2H), 4.18 (d, *J* = 12.0 Hz, 1H), 3.85 (s, 3H), 3.05 (dd, *J* = 14.4, 6.0 Hz, 1H), 2.93 (dd, *J* = 15.0, 6.6 Hz, 1H), 1.33 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 180.8, 170.6, 161.1, 141.3, 139.1, 128.6, 128.5, 127.7, 127.6, 125.6, 122.4, 114.2, 112.2, 111.6, 89.7, 75.0, 74.3, 62.7, 61.2, 55.4, 32.4, 14.0.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{26}H_{24}N_2O_4Na^+$: 451.1628, found: 451.1624.

ethyl-3-(2,2-dicyano-1-(naphthalen-2-yl)vinyl)-6-phenyl-2,3,4,7-tetrahydrooxepine-3-carboxylate 4i



The reaction was performed according to the general procedure at 80 °C to afford **4i** (31.0 mg) in 69% yield as yellow semisolid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

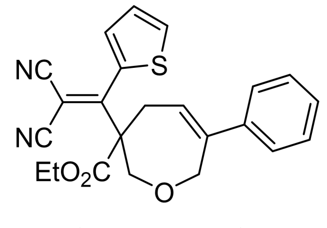
NMR and HRMS data for the product **4i**:

^{1}H NMR (600 MHz, **CDCl$_3$)** δ (ppm): 7.96 (d, *J* = 9.0 Hz, 1H), 7.91 (d, *J* = 7.8 Hz, 1H), 7.86 (d, *J* = 8.4 Hz, 1H), 7.72 (s, 1H), 7.65 – 7.55 (m, 2H), 7.34 (d, *J* = 7.8 Hz, 1H), 7.24 (brs, 3H), 7.00 (brs, 2H), 5.46 (brs, 1H), 4.70 (d, *J* = 15.6 Hz, 1H), 4.64 (d, *J* = 16.8 Hz, 1H), 4.61 (d, *J* = 13.2 Hz, 1H), 4.42 – 4.30 (m, 2H), 4.26 (d, *J* = 12.6 Hz, 1H), 3.07 (brs, 1H), 2.99 (dd, *J* = 15.0, 7.2 Hz, 1H), 1.38 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, **CDCl$_3$)** δ (ppm): 180.8, 170.6, 141.4, 139.0, 133.6, 132.9, 132.4, 128.8, 128.5, 128.4, 128.0, 127.8, 127.7, 127.3, 126.9, 125.5, 123.4, 122.2, 111.9, 111.4, 90.3, 75.0, 74.4, 62.8, 61.1, 32.5, 14.1.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{29}H_{24}N_2O_3Na^+$: 471.1679, found: 471.1679.

<u>ethyl-3-(2,2-dicyano-1-(thiophen-2-yl)vinyl)-6-phenyl-2,3,4,7-tetrahydrooxepine-3-carboxylate 4j</u>



Prepared according to the general procedure to afford **4j** (35.1 mg) in 87% yield as dark yellow semisolid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

NMR and HRMS data for the product **4j**:

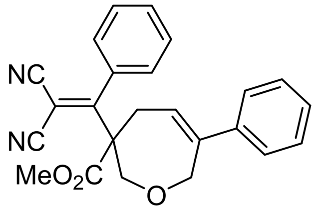
^{1}H NMR (600 MHz, **CDCl$_3$)** δ (ppm): 7.62 (d, *J* = 3.6 Hz, 1H), 7.36 – 7.26 (m, 3H), 7.19 (dd, *J* = 3.6, 1.2 Hz, 1H), 7.17 – 7.12 (m, 3H), 5.68 (t, *J* = 6.6 Hz, 1H), 4.69 (s, 2H), 4.48 (d, *J* =

12.0 Hz, 1H), 4.37 – 4.26 (m, 2H), 4.24 (d, *J* = 13.8 Hz, 1H), 3.16 (dd, *J* = 15.6, 7.2 Hz, 1H), 3.00 (dd, *J* = 14.4, 6.0 Hz, 1H), 1.34 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 172.8, 170.3, 141.7, 139.2, 134.2, 130.4, 130.1, 128.5, 127.8, 127.7, 125.7, 122.2, 112.1, 111.3, 90.9, 75.0, 74.2, 62.8, 61.5, 32.5, 14.0.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{23}H_{20}N_2O_3SNa^+$: 427.1087, found: 427.1084.

methyl-3-(2,2-dicyano-1-phenylvinyl)-6-phenyl-2,3,4,7-tetrahydrooxepine-3-carboxylate 4k



Prepared according to the general procedure to afford **4k** (30.0 mg, m. p. = 83 – 87 °C) in 78% yield as yellow solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

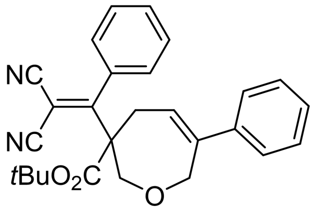
NMR and HRMS data for the product **4k**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.54 – 7.45 (m, 3H), 7.33 – 7.20 (m, 5H), 7.07 (d, *J* = 8.4 Hz, 2H), 5.47 (t, *J* = 6.6 Hz, 1H), 4.70 (d, *J* = 18.0 Hz, 1H), 4.64 (d, *J* = 15.0 Hz, 1H), 4.56 (d, *J* = 12.0 Hz, 1H), 4.16 (d, *J* = 12.6 Hz, 1H), 3.86 (s, 3H), 2.99 (dd, *J* = 15.0, 6.6 Hz, 1H), 2.94 (q, *J* = 15.6, 7.2 Hz, 1H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 180.4, 171.2, 141.4, 139.0, 135.4, 130.4, 128.8, 128.5, 127.8, 126.7, 125.6, 122.0, 111.7, 111.2, 90.3, 75.1, 74.1, 61.0, 53.5, 32.4.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{24}H_{20}N_2O_3Na^+$: 407.1366, found: 407.1363.

tert-butyl-3-(2,2-dicyano-1-phenylvinyl)-6-phenyl-2,3,4,7-tetrahydrooxepine-3-carboxylate 4l



Prepared according to the general procedure to afford **4l** (40.1 mg, m. p. = 87 – 90 °C) in 94% yield as pale yellow solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

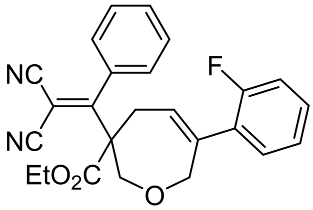
NMR and HRMS data for the product **4l**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.54 – 7.43 (m, 3H), 7.33 – 7.26 (m, 3H), 7.22 (d, J = 6.6 Hz, 2H), 7.10 (d, J = 7.2 Hz, 2H), 5.51 (t, J = 6.6 Hz, 1H), 4.68 (d, J = 16.2 Hz, 1H), 4.64 (d, J = 15.6 Hz, 1H), 4.52 (d, J = 12.0 Hz, 1H), 4.19 (d, J = 12.0 Hz, 1H), 3.01 (dd, J = 15.6, 7.2 Hz, 1H), 2.90 (q, J = 15.0, 7.8 Hz, 1H), 1.53 (s, 9H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 181.6, 169.1, 141.4, 139.2, 135.9, 130.3, 128.7, 128.5, 127.7, 126.7, 125.5, 122.5, 111.9, 111.6, 89.8, 84.0, 74.9, 74.8, 61.4, 32.7, 27.8.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{27}H_{26}N_2O_3Na^+$: 449.1836, found: 449.1832.

ethyl-3-(2,2-dicyano-1-phenylvinyl)-6-(2-fluorophenyl)-2,3,4,7-tetrahydrooxepine-3-carboxylate 4m



The reaction was performed according to the general procedure at 100 °C to afford **4m** (23.3 mg) in 56% yield as pale yellow semisolid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

NMR and HRMS data for the product **4m**:

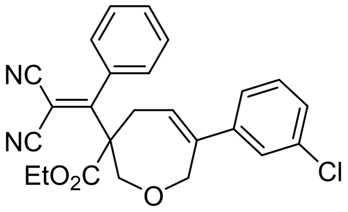
^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.52 – 7.43 (m, 3H), 7.31 – 7.21 (m, 3H), 7.06 (t, J = 7.2 Hz, 1H), 7.04 – 6.97 (m, 2H), 5.41 (t, J = 6.0 Hz, 1H), 4.56 (brs, 2H), 4.52 (d, J = 13.2 Hz, 1H), 4.38 – 4.29 (m, 2H), 4.27 (d, J = 12.6 Hz, 1H), 3.02 (dd, J = 14.4, 6.0 Hz, 1H), 2.92 (dd, J = 15.6, 7.2 Hz, 1H), 1.36 (t, J = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 180.6, 170.4, 159.5 (d, $J_{C\text{-}F}$ = 245.6 Hz), 138.4, 135.5, 130.4, 129.6 (d, $J_{C\text{-}F}$ = 4.4 Hz), 129.4 (d, $J_{C\text{-}F}$ = 8.7 Hz), 128.8, 127.3 (d, $J_{C\text{-}F}$ = 14.4 Hz), 126.8, 125.6, 124.2 (d, $J_{C\text{-}F}$ = 2.9 Hz), 115.7 (d, $J_{C\text{-}F}$ = 21.6 Hz), 111.8, 111.3, 90.3, 74.9 (d, $J_{C\text{-}F}$ = 5.7 Hz), 74.6, 62.8, 60.6, 32.9, 14.0.

^{19}F NMR (564 MHz, CDCl$_3$) δ (ppm): -114.5.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{25}H_{21}FN_2O_3Na^+$: 439.1428, found: 439.1433.

ethyl-6-(3-chlorophenyl)-3-(2,2-dicyano-1-phenylvinyl)-2,3,4,7-tetrahydrooxepine-3-carboxylate 4n



Prepared according to the general procedure to afford **4n** (35.1 mg, m. p. = 96 – 101 °C) in 81% yield as yellow solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

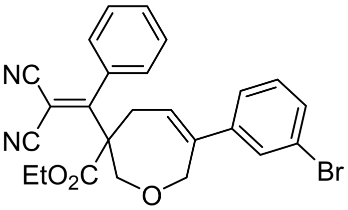
NMR and HRMS data for the product **4n**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.56 – 7.47 (m, 3H), 7.25 – 7.17 (m, 4H), 7.03 (s, 1H), 6.95 (d, J = 7.2 Hz, 1H), 5.47 (t, J = 7.2 Hz, 1H), 4.66 (d, J = 16.2 Hz, 1H), 4.62 – 4.52 (m, 2H), 4.37 – 4.26 (m, 2H), 4.17 (d, J = 12.6 Hz, 1H), 2.99 (dd, J = 15.0, 6.6 Hz, 1H), 2.93 (dd, J = 14.4, 6.0 Hz, 1H), 1.35 (t, J = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 180.4, 170.4, 140.9, 140.2, 135.5, 134.4, 130.5, 129.7, 128.9, 127.8, 126.7, 125.9, 123.7, 123.5, 111.7, 111.3, 90.2, 74.8, 74.3, 62.8, 60.9, 32.4, 14.0.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{25}H_{21}{}^{35}ClN_2O_3Na^+$: 455.1133, found: 455.1135; calculated for $C_{25}H_{21}{}^{37}ClN_2O_3Na^+$: 457.1103, found: 457.1112.

ethyl-6-(3-bromophenyl)-3-(2,2-dicyano-1-phenylvinyl)-2,3,4,7-tetrahydrooxepine-3-carboxylate 4o



Prepared according to the general procedure to afford **4o** (41.0 mg, m. p. = 130 – 132 °C) in 86% yield as pale yellow solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

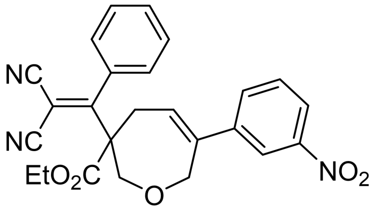
NMR and HRMS data for the product **4o**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.57 – 7.47 (m, 3H), 7.38 (d, *J* = 7.2 Hz, 1H), 7.23 (d, *J* = 6.6 Hz, 2H), 7.18 (s, 1H), 7.15 (t, *J* = 8.4 Hz, 1H), 6.99 (d, *J* = 7.8 Hz, 1H), 5.45 (t, *J* = 6.6 Hz, 1H), 4.65 (d, *J* = 16.2 Hz, 1H),4.57 (d, *J* = 17.4 Hz, 1H), 4.56 (d, *J* = 12.0 Hz, 1H), 4.37 – 4.26 (m, 2H), 4.17 (d, *J* = 12.0 Hz, 1H), 2.99 (dd, *J* = 15.6, 6.6 Hz, 1H), 2.93 (dd, *J* = 14.4, 6.6 Hz, 1H), 1.35 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 180.4, 170.4, 141.1, 140.1, 135.5, 130.7, 130.5, 130.0, 128.9, 128.8, 126.7, 124.1, 123.6, 122.6, 111.7, 111.3, 90.2, 74.7, 74.3, 62.8, 60.9, 32.4, 14.0.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{25}H_{21}{}^{79}BrN_2O_3Na^+$: 499.0628, found: 499.0622; calculated for $C_{25}H_{21}{}^{81}BrN_2O_3Na^+$: 501.0607, found: 501.0607.

ethyl-3-(2,2-dicyano-1-phenylvinyl)-6-(3-nitrophenyl)-2,3,4,7-tetrahydrooxepine-3-carboxylate 4p



The reaction was performed according to the general procedure at 80 °C to afford **4p** (40.3 mg) in 91% yield as yellow semisolid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

NMR and HRMS data for the product **4p**:

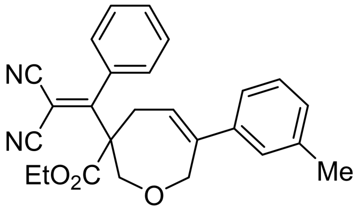
^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 8.11 (d, *J* = 8.4 Hz, 1H), 7.89 (s, 1H), 7.60 – 7.50 (m, 3H), 7.47 (t, *J* = 8.4 Hz, 1H), 7.39 (d, *J* = 8.4 Hz, 1H), 7.25 (d, *J* = 7.2 Hz, 2H), 5.55 (t, *J* = 6.6 Hz, 1H), 4.73 (d, *J* = 16.2 Hz, 1H), 4.63 (d, *J* = 16.2 Hz, 1H), 4.60 (d, *J* = 12.6 Hz, 1H), 4.37 –

4.28 (m, 2H), 4.21 (d, *J* = 12.6 Hz, 1H), 3.02 (dd, *J* = 14.4, 7.2 Hz, 1H), 2.97 (dd, *J* = 14.4, 6.0 Hz, 1H), 1.36 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 180.0, 170.3, 148.3, 140.7, 139.4, 135.4, 131.4, 130.7, 129.5, 129.0, 126.7, 125.2, 122.5, 120.6, 111.6, 111.2, 90.3, 74.6, 74.5, 62.9, 60.9, 32.5, 14.0.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{25}H_{21}N_3O_5Na^+$: 466.1373, found: 466.1363.

ethyl-3-(2,2-dicyano-1-phenylvinyl)-6-(m-tolyl)-2,3,4,7-tetrahydrooxepine-3-carboxylate 4q



Prepared according to the general procedure to afford **4q** (36.7 mg, m. p. = 126 – 129 °C) in 89% yield as pale yellow solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

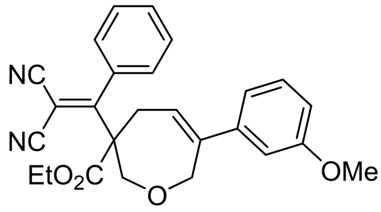
NMR and HRMS data for the product **4q**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.56 – 7.46 (m, 3H), 7.24 (d, *J* = 6.6 Hz, 2H), 7.18 (t, *J* = 7.8 Hz, 1H), 7.08 (d, *J* = 7.2 Hz, 1H), 6.88 (d, *J* = 6.0 Hz, 2H), 5.48 (t, *J* = 6.0 Hz, 1H), 4.69 (d, *J* = 16.8 Hz, 1H), 4.62 (d, *J* = 15.0 Hz, 1H), 4.56 (d, *J* = 12.6 Hz, 1H), 4.38 – 4.26 (m, 2H), 4.17 (d, *J* = 12.0 Hz, 1H), 3.00 (dd, *J* = 14.4, 7.2 Hz, 1H), 2.95 (dd, *J* = 14.4, 6.6 Hz, 1H), 2.33 (s, 3H), 1.36 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 180.7, 170.5, 141.5, 139.1, 138.0, 135.6, 130.3, 128.8, 128.4, 128.3, 126.7, 126.4, 122.6, 121.9, 111.8, 111.3, 90.1, 75.0, 74.2, 62.7, 60.9, 32.4, 21.4, 14.0.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{26}H_{24}N_2O_3Na^+$: 435.1679, found: 435.1677.

ethyl-3-(2,2-dicyano-1-phenylvinyl)-6-(3-methoxyphenyl)-2,3,4,7-tetrahydrooxepine-3-carboxylate 4r



Prepared according to the general procedure to afford **4r** (34.7 mg, m. p. = 149 – 152 °C) in 81% yield as yellow solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

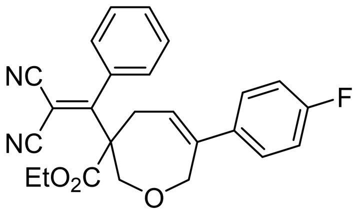
NMR and HRMS data for the product **4r**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.54 – 7.45 (m, 3H), 7.25 – 7.17 (m, 3H), 6.81 (d, *J* = 8.4 Hz, 1H), 6.67 (d, *J* = 7.8 Hz, 1H), 6.60 (s, 1H), 5.50 (t, *J* = 6.0 Hz, 1H), 4.67 (d, *J* = 16.8 Hz, 1H), 4.62 (d, *J* = 15.6 Hz, 1H), 4.55 (d, *J* = 13.2 Hz, 1H), 4.38 – 4.26 (m, 2H), 4.18 (d, *J* = 12.6 Hz, 1H), 3.79 (s, 3H), 3.00 (dd, *J* = 14.4, 6.6 Hz, 1H), 2.93 (dd, *J* = 15.0, 6.6 Hz, 1H), 1.35 (t, *J* = 6.6 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 180.7, 170.5, 159.6, 141.3, 140.6, 135.5, 130.4, 129.5, 128.8, 126.7, 122.3, 118.0, 112.8, 111.8, 111.7, 111.3, 90.2, 75.0, 74.3, 62.7, 60.9, 55.2, 32.5, 14.1.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{26}H_{24}N_2O_4Na^+$: 451.1628, found: 451.1628.

ethyl-3-(2,2-dicyano-1-phenylvinyl)-6-(4-fluorophenyl)-2,3,4,7-tetrahydrooxepine-3-carboxylate 4s



The reaction was performed according to the general procedure at 80 °C to afford **4s** (29.5 mg, m. p. = 107 – 112 °C) in 71% yield as pale yellow solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

NMR and HRMS data for the product **4s**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.53 – 7.41 (m, 3H), 7.21 (d, *J* = 6.6 Hz, 2H), 7.07 – 7.01 (m, 2H), 6.96 (t, *J* = 9.0 Hz, 2H), 5.44 (t, *J* = 6.6 Hz, 1H), 4.63 (d, *J* = 16.8 Hz, 1H), 4.59

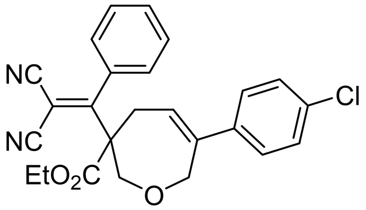
(d, J = 17.4 Hz, 1H), 4.53 (d, J = 12.6 Hz, 1H), 4.35 – 4.25 (m, 2H), 4.17 (d, J = 13.2 Hz, 1H), 2.99 (dd, J = 14.4, 6.6 Hz, 1H), 2.89 (dd, J = 15.0, 6.6 Hz, 1H), 1.33 (t, J = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 180.6, 170.4, 162.3 (d, $J_{C\text{-}F}$ = 245.6 Hz), 140.6, 135.5, 135.2 (d, $J_{C\text{-}F}$ = 2.9 Hz), 130.4, 128.8, 127.3 (d, $J_{C\text{-}F}$ = 7.2 Hz), 126.7, 122.3, 115.4 (d, $J_{C\text{-}F}$ = 21.5 Hz), 111.7, 111.3, 90.2, 75.0, 74.4, 62.8, 60.9, 32.4, 14.1.

^{19}F NMR (564 MHz, CDCl$_3$) δ (ppm): -114.1.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{25}H_{21}FN_2O_3Na^+$: 439.1428, found: 439.1434.

ethyl-6-(4-chlorophenyl)-3-(2,2-dicyano-1-phenylvinyl)-2,3,4,7-tetrahydrooxepine-3-carboxylate 4t



Prepared according to the general procedure to afford **4t** (37.7 mg, m. p. = 103 – 107 °C) in 87% yield as yellow solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

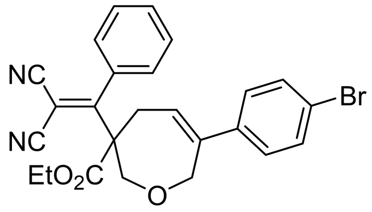
NMR and HRMS data for the product **4t**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.53 – 7.44 (m, 3H), 7.25 (d, J = 7.8 Hz, 2H), 7.22 (d, J = 6.6 Hz, 2H), 7.01 (d, J = 8.4 Hz, 2H), 5.49 (t, J = 6.6 Hz, 1H), 4.64 (d, J = 15.6 Hz, 1H), 4.60 (d, J = 16.2 Hz, 1H), 4.54 (d, J = 12.6 Hz, 1H), 4.35 – 4.25 (m, 2H), 4.19 (d, J = 13.2 Hz, 1H), 3.00 (dd, J = 14.4, 6.6 Hz, 1H), 2.91 (dd, J = 14.4, 6.0 Hz, 1H), 1.34 (t, J = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 180.5, 170.4, 140.4, 137.5, 135.5, 133.6, 130.4, 128.8, 128.6, 126.9, 126.7, 122.9, 111.7, 111.3, 90.2, 74.8, 74.4, 62.8, 60.8, 32.5, 14.0.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{25}H_{21}{}^{35}ClN_2O_3Na^+$: 455.1133, found: 455.1124; calculated for $C_{25}H_{21}{}^{37}ClN_2O_3Na^+$: 457.1103, found: 457.1106.

ethyl-6-(4-bromophenyl)-3-(2,2-dicyano-1-phenylvinyl)-2,3,4,7-tetrahydrooxepine-3-carboxylate 4u



Prepared according to the general procedure to afford **4u** (42.0 mg, m. p. = 128 – 132 °C) in 88% yield as pale yellow solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

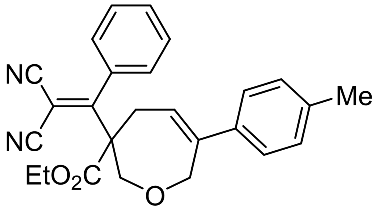
NMR and HRMS data for the product **4u**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.55 – 7.44 (m, 3H), 7.41 (d, J = 8.4 Hz, 2H), 7.22 (d, J = 6.6 Hz, 2H), 6.95 (d, J = 8.4 Hz, 2H), 5.49 (t, J = 6.0 Hz, 1H), 4.64 (d, J = 15.6 Hz, 1H), 4.59 (d, J = 17.4 Hz, 1H), 4.54 (d, J = 13.2 Hz, 1H), 4.36 – 4.25 (m, 2H), 4.19 (d, J = 13.2 Hz, 1H), 3.00 (dd, J = 15.0, 6.6 Hz, 1H), 2.91 (dd, J = 14.4, 6.0 Hz, 1H), 1.34 (t, J = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 180.5, 170.4, 140.5, 137.9, 135.5, 131.6, 130.4, 128.8, 127.2, 126.7, 122.9, 121.7, 111.7, 111.3, 90.2, 74.7, 74.4, 62.8, 60.8, 32.5, 14.0.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{25}H_{21}{}^{79}BrN_2O_3Na^+$: 499.0628, found: 499.0619; calculated for $C_{25}H_{21}{}^{81}BrN_2O_3Na^+$: 501.0607, found: 501.0603.

ethyl-3-(2,2-dicyano-1-phenylvinyl)-6-(p-tolyl)-2,3,4,7-tetrahydrooxepine-3-carboxylate 4v



Prepared according to the general procedure to afford **4v** (34.2 mg, m. p. = 78 – 83 °C) in 83% yield as yellow solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

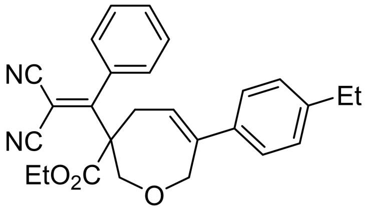
NMR and HRMS data for the product **4v**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.55 – 7.44 (m, 3H), 7.23 (d, J = 6.6 Hz, 2H), 7.10 (d, J = 8.4 Hz, 2H), 6.98 (d, J = 8.4 Hz, 2H), 5.47 (t, J = 6.6 Hz, 1H), 4.67 (d, J = 15.6 Hz, 1H), 4.62 (d, J = 16.2 Hz, 1H), 4.55 (d, J = 12.6 Hz, 1H), 4.37 – 4.25 (m, 2H), 4.16 (d, J = 12.6 Hz, 1H), 2.99 (dd, *J* = 15.6, 7.2 Hz, 1H), 2.93 (dd, *J* = 14.4, 6.0 Hz, 1H), 2.33 (s, 3H), 1.35 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 180.8, 170.5, 141.2, 137.6, 136.2, 135.6, 130.4, 129.1, 128.8, 126.7, 125.4, 121.4, 111.8, 111.3, 90.1, 75.0, 74.3, 62.7, 61.0, 32.4, 21.1, 14.1.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{26}H_{24}N_2O_3Na^+$: 435.1679, found: 435.1682.

ethyl-3-(2,2-dicyano-1-phenylvinyl)-6-(4-ethylphenyl)-2,3,4,7-tetrahydrooxepine-3-carboxylate 4w



Prepared according to the general procedure to afford **4w** (31.6 mg) in 74% yield as yellow semisolid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

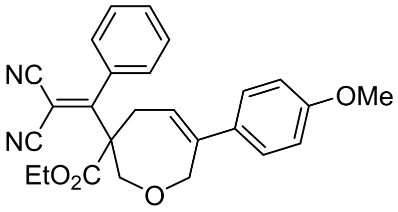
NMR and HRMS data for the product **4w**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.55 – 7.44 (m, 3H), 7.23 (d, *J* = 6.0 Hz, 2H), 7.13 (d, *J* = 8.4 Hz, 2H), 7.01 (d, *J* = 8.4 Hz, 2H), 5.48 (t, *J* = 6.6 Hz, 1H), 4.68 (d, *J* = 17.4 Hz, 1H), 4.63 (d, *J* = 15.0 Hz, 1H), 4.55 (d, *J* = 12.6 Hz, 1H), 4.37 – 4.26 (m, 2H), 4.16 (d, *J* = 12.0 Hz, 1H), 3.00 (dd, *J* = 15.0, 6.6 Hz, 1H), 2.94 (dd, *J* = 14.4, 6.0 Hz, 1H), 2.62 (q, *J* = 7.2 Hz, 2H), 1.35 (t, *J* = 7.2 Hz, 3H), 1.22 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 180.8, 170.5, 143.9, 141.2, 136.4, 135.6, 130.4, 128.8, 127.9, 126.7, 125.5, 121.4, 111.8, 111.3, 90.1, 75.0, 74.2, 62.7, 61.0, 32.4, 28.4, 15.5, 14.0.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{27}H_{26}N_2O_3Na^+$: 449.1836, found: 449.1839.

ethyl-3-(2,2-dicyano-1-phenylvinyl)-6-(4-methoxyphenyl)-2,3,4,7-tetrahydrooxepine-3-carboxylate 4x



Prepared according to the general procedure to afford **4x** (32.5 mg) in 76% yield as yellow semisolid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

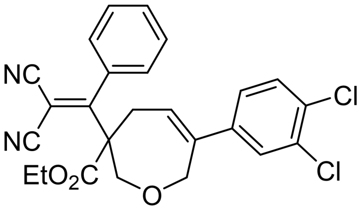
NMR and HRMS data for the product **4x**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.55 – 7.44 (m, 3H), 7.22 (d, *J* = 6.6 Hz, 2H), 7.02 (d, *J* = 9.0 Hz, 2H), 6.82 (d, *J* = 8.4 Hz, 2H), 5.42 (t, *J* = 6.6 Hz, 1H), 4.66 (d, *J* = 16.2 Hz, 1H), 4.61 (d, *J* = 16.2 Hz, 1H), 4.55 (d, *J* = 12.6 Hz, 1H), 4.37 – 4.25 (m, 2H), 4.15 (d, *J* = 13.2 Hz, 1H), 3.79 (s, 3H), 2.99 (dd, *J* = 15.0, 7.2 Hz, 1H), 2.92 (dd, *J* = 14.4, 6.6 Hz, 1H), 1.35 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 180.8, 170.5, 159.2, 140.8, 135.6, 131.5, 130.3, 128.8, 126.7, 120.6, 113.8, 111.8, 111.3, 90.1, 75.0, 74.2, 62.7, 61.0, 55.3, 32.4, 14.1.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{26}H_{24}N_2O_4Na^+$: 451.1628, found: 451.1628.

ethyl-6-(3,4-dichlorophenyl)-3-(2,2-dicyano-1-phenylvinyl)-2,3,4,7-tetrahydrooxepine-3-carboxylate 4y



The reaction was performed according to the general procedure at 80 °C to afford **4y** (36.9 mg, m. p. = 125 – 129 °C) in 79% yield as pale yellow solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

NMR and HRMS data for the product **4y**:

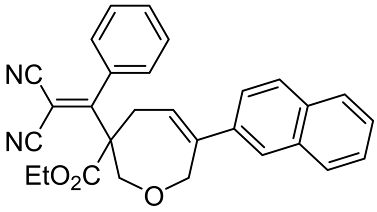
^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.56 – 7.47 (m, 3H), 7.35 (d, *J* = 7.8 Hz, 1H), 7.22 (d, *J* = 7.2 Hz, 2H), 7.13 (s, 1H), 6.90 (d, *J* = 8.4 Hz, 1H), 5.48 (t, *J* = 6.6 Hz, 1H), 4.63 (d, *J* = 16.2 Hz, 1H), 4.56 (d, *J* = 15.6 Hz, 1H), 4.55 (d, *J* = 12.0 Hz, 1H), 4.37 – 4.25 (m, 2H), 4.18 (d, *J* =

13.2 Hz, 1H), 2.99 (dd, J = 14.4, 6.0 Hz, 1H), 2.92 (dd, J = 15.6, 7.2 Hz, 1H), 1.34 (t, J = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 180.2, 170.3, 139.4, 139.0, 135.4, 132.6, 131.8, 130.5, 130.4, 128.9, 127.6, 126.7, 124.8, 124.1, 111.7, 111.2, 90.3, 74.6, 74.4, 62.9, 60.9, 32.5, 14.0.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{25}H_{20}{}^{35}Cl_2N_2O_3Na^+$: 489.0743, found: 489.0734; calculated for $C_{25}H_{20}{}^{35}Cl^{37}ClN_2O_3Na^+$: 491.0714, found: 491.0714; calculated for $C_{25}H_{20}{}^{37}Cl_2N_2O_3Na^+$: 493.0684, found: 493.0681.

ethyl-3-(2,2-dicyano-1-phenylvinyl)-6-(naphthalen-2-yl)-2,3,4,7-tetrahydrooxepine-3-carboxylate 4z



Prepared according to the general procedure to afford **4z** (36.8 mg, m. p. = 131 – 133 °C) in 82% yield as yellow solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

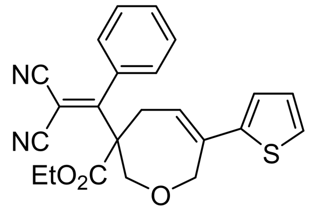
NMR and HRMS data for the product **4z**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.83 – 7.74 (m, 3H), 7.57 – 7.43 (m, 6H), 7.30 – 7.19 (m, 3H), 5.63 (t, J = 6.6 Hz, 1H), 4.81 (d, J = 17.4 Hz, 1H), 4.76 (d, J = 15.0 Hz, 1H), 4.61 (d, J = 12.0 Hz, 1H), 4.39 – 4.28 (m, 2H), 4.22 (d, J = 13.2 Hz, 1H), 3.06 (dd, J = 14.4, 7.2 Hz, 1H), 3.01 (dd, J = 14.4, 6.0 Hz, 1H), 1.36 (t, J = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 180.7, 170.5, 141.2, 136.3, 135.6, 133.1, 132.7, 130.4, 128.8, 128.1, 128.0, 127.6, 126.8, 126.4, 126.2, 124.2, 123.8, 122.8, 111.8, 111.3, 90.2, 75.0, 74.4, 62.8, 61.0, 32.6, 14.1.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{29}H_{24}N_2O_3Na^+$: 471.1679, found: 471.1680.

ethyl-3-(2,2-dicyano-1-phenylvinyl)-6-(thiophen-2-yl)-2,3,4,7-tetrahydrooxepine-3-carboxylate 4aa



Prepared according to the general procedure to afford **4aa** (36.0 mg) in 89% yield as dark yellow semisolid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

NMR and HRMS data for the product **4aa**:

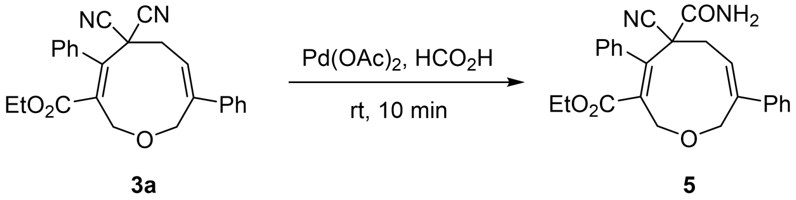
^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.54 – 7.45 (m, 3H), 7.22 (brs, 2H), 7.14 (d, *J* = 5.4 Hz, 1H), 6.94 (dd, *J* = 5.4, 4.2 Hz, 1H), 6.77 (d, *J* = 3.6 Hz, 1H), 5.55 (t, *J* = 6.0 Hz, 1H), 4.70 (d, *J* = 18.0 Hz, 1H), 4.66 (d, *J* = 18.0 Hz, 1H), 4.61 (d, *J* = 12.0 Hz, 1H), 4.37 – 4.26 (m, 2H), 4.10 (d, *J* = 12.6 Hz, 1H), 2.94 (dd, *J* = 14.4, 7.2 Hz, 1H), 2.89 (dd, *J* = 15.6, 7.2 Hz, 1H), 1.35 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 180.6, 170.5, 141.6, 135.4, 134.6, 130.4, 128.9, 127.5, 126.7, 124.3, 122.6, 120.7, 111.7, 111.3, 90.2, 74.5, 74.0, 62.8, 61.4, 32.1, 14.0.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{23}H_{20}N_2O_3SNa^+$: 427.1087, found: 427.1096.

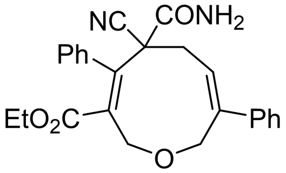
6. Synthetic Transformation of 3a and 4a

*6.1 Procedure for the hydrolysis of cyano group on **3a***



A mixture of nine-membered product **3a** (39.8 mg, 0.10 mmol) and $Pd(OAc)_2$ (1.1 mg, 0.005 mmol) in HCOOH (1.0 mL) was stirred at room temperature for 10 min and then diluted with water. The mixture was saturated with sodium carbonate until the pH = 7 – 8, followed by extraction with ethyl acetate (3 × 5 mL). The combined organic phase was washed with saturated brine (3 × 5 mL), dried over Na_2SO_4, filtered, and concentrated in vacuo. The crude product was purified by column chromatography on silica gel (petroleum ether/ ethyl acetate = 6/1 to 2/1) to afford **5** (33.7 mg) as colorless semisolid in 81% yields, which was dried under vacuum and further analyzed by ^{1}H NMR, ^{13}C NMR, HRMS, *etc.*

ethyl-(3*E*,7*Z*)-5-carbamoyl-5-cyano-4,8-diphenyl-2,5,6,9-tetrahydrooxonine-3-carboxylate 5



Purification of the crude product *via* column chromatography delivered **5** (33.7 mg) in 81% yield as colorless semisolid.

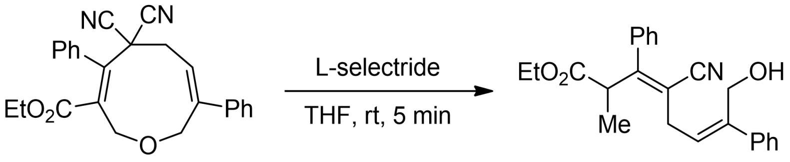
NMR and HRMS data for the product **5**:

^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm): 7.52 (d, *J* = 7.8 Hz, 2H), 7.39 – 7.26 (m, 6H), 7.10 (brs, 2H), 6.21 (dd, *J* = 12.0, 7.2 Hz, 1H), 6.00 (d, *J* = 127.2 Hz, 2H), 4.77 (d, *J* = 13.8 Hz, 1H), 4.62 (d, *J* = 13.8 Hz, 1H), 4.61 (d, *J* = 13.8 Hz, 1H), 4.55 (d, *J* = 13.2 Hz, 1H), 4.00 (dd, *J* = 14.4, 12.0 Hz, 1H), 3.79 – 3.63 (m, 2H), 3.27 (dd, *J* = 14.4, 6.6 Hz, 1H), 0.69 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm): 168.9, 166.6, 142.2, 141.5, 138.7, 137.7, 137.0, 129.4, 128.8, 128.3, 128.0, 127.6, 126.3, 126.1, 119.7, 68.5, 66.1, 61.0, 54.7, 36.6, 13.3.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{25}H_{24}N_2O_4Na^+$: 439.1628, found: 439.1634.

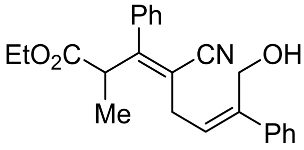
*6.2 Procedure for the reductive ring-opening reaction of **3a***



3a **6**

Nine-membered product **3a** (39.8 mg, 0.10 mmol) was dissolved in THF (1.0 mL) and stirred at room temperature. To this solution was slowly added L-Selectride (0.15 mL, 1.0 M in THF). The reaction mixture was stirred for 5 min at the same temperature, diluted with brine (5 mL) and extracted with ethyl acetate (3 × 5 mL). The combined organic phase was dried over Na_2SO_4, filtered and concentrated in vacuo. The crude product was purified by column chromatography on silica gel (petroleum ether/ ethyl acetate = 10/1 to 3/1) to afford **6** (17.6 mg) as pale yellow oil in 47% yields, which was dried under vacuum and further analyzed by ^{1}H NMR, ^{13}C NMR, HRMS, *etc*.

ethyl-(3*Z*,6*Z*)-4-cyano-8-hydroxy-2-methyl-3,7-diphenylocta-3,6-dienoate 6



Purification of the crude product *via* column chromatography delivered **6** (17.6 mg) in 47% yield as pale yellow oil.

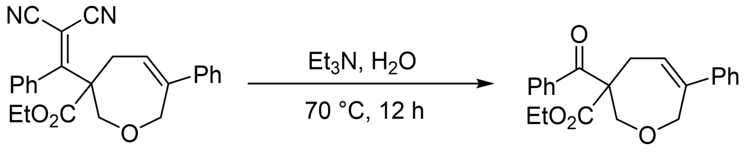
NMR and HRMS data for the product **6**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.49 (d, *J* = 6.6 Hz, 2H), 7.41 – 7.34 (m, 5H), 7.30 (t, *J* = 6.6 Hz, 1H), 7.23 – 7.19 (m, 2H), 5.92 (t, *J* = 7.2 Hz, 1H), 4.66 (s, 2H), 4.21 – 4.09 (m, 2H), 3.94 (q, *J* = 7.2 Hz, 1H), 3.46 (t, *J* = 7.8 Hz, 2H), 1.88 (brs, 1H), 1.26 (d, *J* = 6.6 Hz, 3H), 1.22 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 171.7, 156.7, 142.5, 140.3, 137.6, 129.0, 128.6, 128.5, 128.0, 127.7, 126.5, 124.9, 118.8, 113.5, 61.6, 59.9, 43.0, 29.7, 15.3, 14.0.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{24}H_{25}NO_3Na^+$: 398.1727, found: 398.1731.

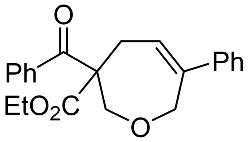
6.3 Procedure for the retro-Knoevenagel reaction of seven-membered product ***4a***



4a **7**

A glass tube was charged with seven-membered product **4a** (39.8 mg, 0.1 mmol), triethylamine (50 μL) in H_2O (1.0 mL). The mixture was stirred at 70 °C for 12 hour. Then the mixture was added with water (5 mL) and extracted with ethyl acetate (5 mL × 3). The organic layer was dried over Na_2SO_4, filtered and concentrated in vacuo. The crude product was purified by column chromatography on silica gel (petroleum ether/dichloromethane = 3/1 to 1/1) to afford **7** (18.2 mg) as pale yellow oil in 52% yields, which was dried under vacuum and further analyzed by ^{1}H NMR, ^{13}C NMR, HRMS, *etc*.

ethyl-3-benzoyl-6-phenyl-2,3,4,7-tetrahydrooxepine-3-carboxylate 7



Purification of the crude product *via* column chromatography delivered **7** (18.2 mg) in 52% yield as pale yellow oil.

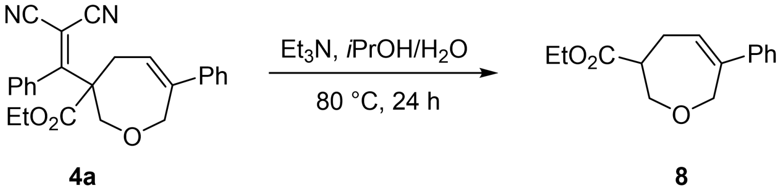
NMR and HRMS data for the product **7**:

^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm): 7.80 (d, *J* = 7.8 Hz, 2H), 7.54 (t, *J* = 7.8 Hz, 1H), 7.43 (t, *J* = 8.4 Hz, 2H), 7.32 – 7.22 (m, 3H), 7.19 (d, *J* = 8.4 Hz, 2H), 5.88 (t, *J* = 6.6 Hz, 1H), 4.76 (d, *J* = 16.2 Hz, 1H), 4.69 (d, *J* = 18.0 Hz, 1H), 4.51 (d, *J* = 12.6 Hz, 1H), 4.34 (d, *J* = 12.0 Hz, 1H), 4.22 – 4.10 (m, 2H), 3.14 (d, *J* = 6.6 Hz, 2H), 1.10 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm): 195.3, 172.1, 140.6, 139.5, 135.6, 133.0, 128.6, 128.5, 128.3, 127.4, 125.9, 122.9, 74.9, 72.3, 65.8, 61.8, 29.7, 13.9.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{22}H_{22}O_4Na^+$: 373.1410, found: 373.1411.

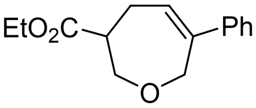
6.4 Procedure for the removal of benzylidene malononitrile of ***4a***



4a **8**

A glass tube was charged with seven-membered product **4a** (39.8 mg, 0.1 mmol), triethylamine (100 μL) in *i*-PrOH/H_2O (2 mL, 3:1 (*v*/*v*)). The mixture was stirred at 80 °C for 24 hour. Then the mixture was added with water (5 mL) and extracted with ethyl acetate (5 mL × 3). The organic layer was dried over Na_2SO_4, filtered and concentrated in vacuo. The crude product was purified by column chromatography on silica gel (petroleum ether/dichloromethane = 3/1 to 1/1) to afford **8** (22.9 mg) as pale yellow oil in 93% yields, which was dried under vacuum and further analyzed by ^1H NMR, ^{13}C NMR, HRMS, *etc*.

ethyl-6-phenyl-2,3,4,7-tetrahydrooxepine-3-carboxylate 8



Prepared according to the general procedure to afford **8** (22.9 mg) in 93% yield as pale yellow oil.

NMR and HRMS data for the product **8**:

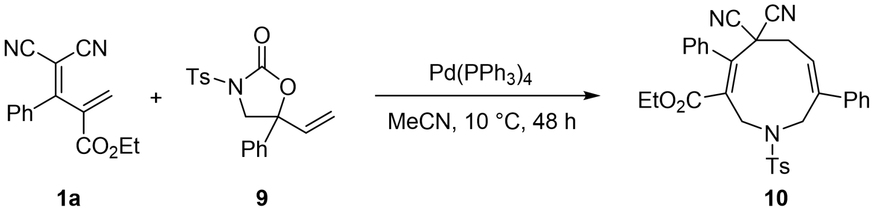
^1H NMR (600 MHz, $CDCl_3$) δ (ppm): 7.33 – 7.28 (m, 2H), 7.27 – 7.22 (m, 3H), 6.05 (t, *J* = 6.0 Hz, 1H), 4.61 (t, *J* = 14.4 Hz, 1H), 4.59 – 4.55 (m, 1H), 4.21 – 4.07 (m, 4H), 3.05 – 2.98 (m, 1H), 2.82 – 2.74 (m, 1H), 2.72 – 2.66 (m, 1H), 1.26 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, $CDCl_3$) δ (ppm): 173.1, 142.3, 140.8, 128.3, 127.2, 127.0, 125.9, 72.8, 72.5, 60.7, 45.3, 27.9, 14.2.

HRMS (ESI-TOF) m/z: **$[M + Na]^+$** calculated for $C_{15}H_{18}O_3Na^+$: 269.1148, found: 269.1147.

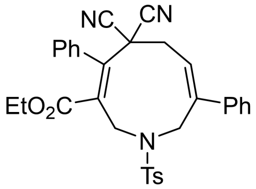
7. Procedure for the Synthesis of Medium-Sized Azacycles

*7.1 Procedure for the synthesis of nine-membered product **10***



To an over-dried Schlenk tube was added $Pd(PPh_3)_4$ (5 mol %), after which the tube was evacuated and back-filled with argon three times. Subsequently, under the protection of argon, a solution of allylidenemalononitrile **1a** (0.10 mmol) and oxazolidinone **9**[4] (0.15 mmol) in dry MeCN (1.0 mL) was added via syringe and the reaction mixture was stirred at 10 °C for 48 hours. Then the mixture was concentrated and purified by column chromatography on silica gel (petroleum ether/ ethyl acetate = 20/1 to 6/1) to afford the corresponding **10** (33.7 mg) as white solid in 61% yield, which were dried under vacuum and further analyzed by ^{1}H NMR, ^{13}C NMR, HRMS, *etc*.

ethyl-(3*E*,7*Z*)-5,5-dicyano-4,8-diphenyl-1-tosyl-2,5,6,9-tetrahydro-1H-azonine-3-carboxylate 10



Prepared according to the general procedure to afford **10** (33.7 mg, m. p. = 152 – 154 °C) in 61% yield as white solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

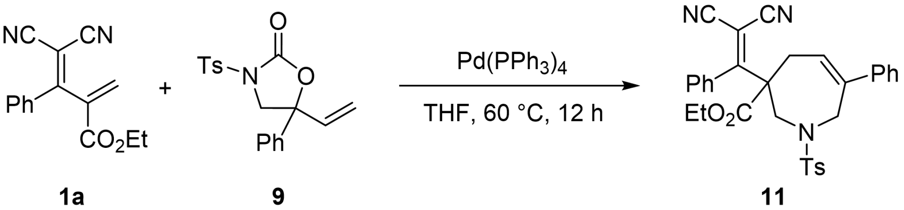
NMR and HRMS data for the product **10**:

^{1}H NMR (600 MHz, $CDCl_3$, 55 °C) δ (ppm): 7.43 – 7.34 (m, 7H), 7.34 – 7.27 (m, 3H), 7.18 (d, *J* = 5.4 Hz, 2H), 7.12 (d, *J* = 8.4 Hz, 2H), 6.05 (t, *J* = 9.0 Hz, 1H), 4.32 (brs, 4H), 3.84 (q, *J* = 7.8 Hz, 2H), 3.57 (brs, 2H), 2.38 (s, 3H), 0.85 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, $CDCl_3$, 55 °C) δ (ppm): 166.4, 143.6, 143.3, 140.0, 137.1, 136.7, 135.8, 135.6, 129.73, 129.70, 128.7, 128.6, 128.4, 128.2, 127.2, 126.8, 123.7, 114.1, 61.7, 46.8, 45.2, 40.1, 38.8, 21.4, 13.4.

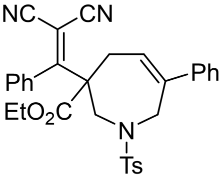
HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{32}H_{29}N_3O_4SNa^+$: 574.1771, found: 574.1769.

*7.2 Procedure for the synthesis of seven-membered product **11***



To an over-dried Schlenk tube was added $Pd(PPh_3)_4$ (5 mol %), after which the tube was evacuated and back-filled with argon three times. Subsequently, under the protection of argon, a solution of allylidenemalononitrile **1a** (0.10 mmol) and oxazolidinone **9** (0.15 mmol) in dry THF (1.0 mL) was added via syringe and the reaction mixture was stirred at 60 °C for 12 hours. Then the mixture was concentrated and purified by column chromatography on silica gel (petroleum ether/ dichloromethane = 3/1 to 1/1, then petroleum ether/ethyl acetate = 10/1 to 6/1) to afford the corresponding **11** (46.9 mg) as white solid in 85% yield, which were dried under vacuum and further analyzed by ^{1}H NMR, ^{13}C NMR, HRMS, *etc*.

ethyl-3-(2,2-dicyano-1-phenylvinyl)-6-phenyl-1-tosyl-2,3,4,7-tetrahydro-1H-azepine-3-carboxylate 11



Prepared according to the general procedure to afford **11** (46.9 mg, m. p. = 101 – 105 °C) in 85% yield as white solid. The regioisomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

NMR and HRMS data for the product **11**:

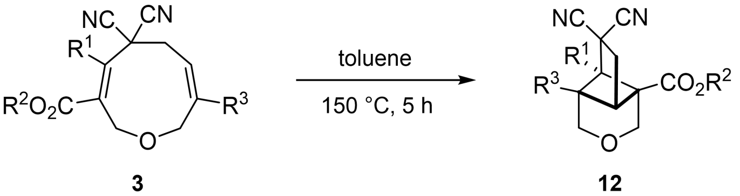
^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm): 7.78 (d, J = 8.4 Hz, 2H), 7.63 – 7.47 (m, 4H), 7.41 (d, J = 7.8 Hz, 2H), 7.34 – 7.28 (m, 4H), 7.17 (d, J = 8.4 Hz, 2H), 5.52 (t, J = 7.8 Hz, 1H), 4.64 (d, J = 16.2 Hz, 1H), 4.45 – 4.33 (m, 3H), 4.23 (d, J = 15.0 Hz, 1H), 3.88 (d, J = 16.8 Hz, 1H), 3.07 (dd, J = 14.4, 6.0 Hz, 1H), 2.50 (s, 3H), 2.45 (dd, J = 14.4, 8.4 Hz, 1H), 1.41 (t, J = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, **CDCl$_3$)** δ (ppm): 181.3, 170.1, 144.2, 140.0, 139.9, 135.2, 134.8, 130.3, 130.1, 128.9, 128.5, 127.9, 127.1, 126.8, 125.9, 122.2, 111.7, 111.4, 90.4, 63.1, 58.2, 54.3, 53.6, 33.6, 21.5, 14.1.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{32}H_{29}N_3O_4SNa^+$: 574.1771, found: 574.1772.

8. General Procedure and Mechanism Studies for the [2+2] Cycloaddition

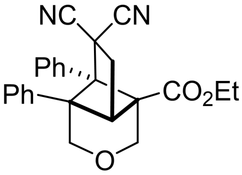
8.1 General procedure for the transannular [2+2] cycloaddition



3 **12**

To an over-dried Schlenk tube was added the nine-membered products **3** (0.10 mmol), after which the tube was evacuated and back-filled with argon three times. Subsequently, under the protection of argon, dry toluene (1.0 mL) was added via syringe and the reaction mixture was stirred at 150 °C for 5 hours. Then the mixture was cooled to room temperature and purified by column chromatography on silica gel (petroleum ether/ ethyl acetate = 20/1 to 10/1 to afford the corresponding **12** in 64–86% yields.

ethyl-9,9-dicyano-1,6-diphenyl-4-oxatricyclo[4.3.0.0^{2,7}]nonane-2-carboxylate 12a



Prepared according to the general procedure to afford **12a** (30.2 mg, m. p. = 158 – 160 °C) in 76% yield as white solid. The diastereomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

NMR and HRMS data for the product **12a**:

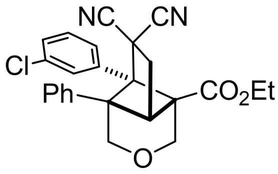
^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 8.15 (d, *J* = 7.2 Hz, 2H), 7.61 – 7.47 (m, 4H), 7.46 – 7.33 (m, 3H), 7.10 (brs, 1H), 4.48 (d, *J* = 12.0 Hz, 1H), 4.33 – 4.26 (m, 1H), 4.24 – 4.20 (m, 1H), 4.18 (d, *J* = 12.0 Hz, 1H), 4.14 (d, *J* = 11.4 Hz, 1H), 3.86 (d, *J* = 11.4 Hz, 1H), 3.31 (d, *J* = 12.6 Hz, 1H), 3.28 (s, 1H), 3.02 (d, *J* = 12.6 Hz, 1H), 1.30 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 169.1, 135.1, 131.9, 130.0, 129.1, 128.9, 128.8, 128.7, 127.4, 115.5, 114.9, 71.1, 70.8, 66.5, 62.4, 58.2, 57.8, 46.3, 38.3, 37.8, 13.6.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{25}H_{22}N_2O_3Na^+$: 421.1523, found: 420.1524.

ethyl-1-(3-chlorophenyl)-9,9-dicyano-6-phenyl-4-oxatricyclo[4.3.0.0^{2,7}]nonane-2-carboxyl

ate 12b



Prepared according to the general procedure to afford **12b** (33.3 mg, m. p. = 187 – 192 °C) in 77% yield as white solid. The diastereomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

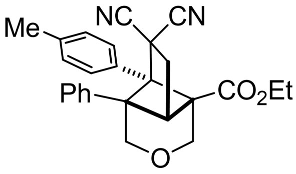
NMR and HRMS data for the product **12b**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 8.22 (s, 1H), 8.09 – 7.99 (m, 1H), 7.65 – 7.46 (m, 3H), 7.44 – 7.37 (m, 3H), 7.10 (brs, 1H), 4.45 (d, *J* = 11.4 Hz, 1H), 4.34 – 4.21 (m, 2H), 4.13 (t, *J* = 10.8 Hz, 2H), 3.86 (d, *J* = 11.4 Hz, 1H), 3.30 (d, *J* = 12.6 Hz, 1H), 3.27 (s, 1H), 3.02 (d, *J* = 12.0 Hz, 1H), 1.35 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 168.9, 135.0, 134.7, 134.1, 130.1, 129.4, 129.2, 129.0, 128.9, 127.5, 126.6, 115.1, 114.6, 70.8, 70.5, 66.5, 62.7, 58.3, 58.1, 46.6, 38.3, 37.8, 13.6.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{25}H_{21}{}^{35}ClN_2O_3Na^+$: 455.1133, found: 455.1129; calculated for $C_{25}H_{21}{}^{37}ClN_2O_3Na^+$: 457.1103, found: 457.1110.

ethyl-9,9-dicyano-6-phenyl-1-(p-tolyl)-4-oxatricyclo[4.3.0.0^{2,7}]nonane-2-carboxylate 12c



Prepared according to the general procedure to afford **12c** (30.1 mg, m. p. = 161 – 165 °C) in 73% yield as white solid. The diastereomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

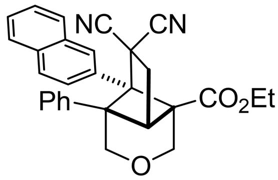
NMR and HRMS data for the product **12c**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 8.02 (d, *J* = 8.4 Hz, 2H), 7.52 (brs, 1H), 7.44 – 7.30 (m, 5H), 7.08 (brs, 1H), 4.47 (d, *J* = 10.8 Hz, 1H), 4.33 – 4.26 (m, 1H), 4.24 – 4.15 (m, 1H), 4.18 (d, *J* = 12.0 Hz, 1H), 4.13 (d, *J* = 11.4 Hz, 1H), 3.84 (d, *J* = 11.4 Hz, 1H), 3.30 (d, *J* = 13.2 Hz, 1H), 3.26 (s, 1H), 3.00 (d, *J* = 12.6 Hz, 1H), 2.44 (s, 3H), 1.30 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 169.2, 139.0, 135.2, 129.6, 128.9, 128.8, 128.7, 128.6, 127.4, 115.6, 115.0, 71.1, 70.8, 66.5, 62.3, 58.1, 57.7, 46.2, 38.3, 37.7, 21.2, 13.6.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{26}H_{24}N_2O_3Na^+$: 435.1679, found: 435.1685.

ethyl-9,9-dicyano-1-(naphthalen-2-yl)-6-phenyl-4-oxatricyclo[4.3.0.0^{2,7}]nonane-2-carboxylate 12d



Prepared according to the general procedure to afford **12d** (36.8 mg, m. p. = 205 – 206 °C) in 82% yield as white solid. The diastereomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

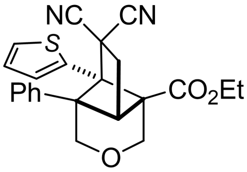
NMR and HRMS data for the product **12d**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 8.68 (s, 1H), 8.24 (d, J = 11.4 Hz, 1H), 8.03 (d, J = 9.0 Hz, 1H), 7.98 – 7.91 (m, 2H), 7.67 – 7.51 (m, 3H), 7.48 – 7.33 (m, 3H), 7.14 (brs, 1H), 4.57 (d, J = 11.4 Hz, 1H), 4.37 – 4.29 (m, 1H), 4.28 – 4.21 (m, 1H), 4.24 (d, J = 11.4 Hz, 1H), 4.19 (d, J = 12.0 Hz, 1H), 3.90 (d, J = 11.4 Hz, 1H), 3.36 (d, J = 13.2 Hz, 1H), 3.33 (s, 1H), 3.07 (d, J = 12.0 Hz, 1H), 1.33 (t, J = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 169.2, 135.1, 133.11, 133.08, 130.1, 129.4, 129.1, 129.0, 128.8, 128.7, 128.6, 127.6, 127.2, 126.7, 125.4, 115.6, 115.0, 71.3, 70.9, 66.6, 62.5, 58.4, 58.0, 46.4, 38.4, 37.9, 13.7.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{29}H_{24}N_2O_3Na^+$: 471.1679, found: 471.1684.

ethyl-9,9-dicyano-6-phenyl-1-(thiophen-2-yl)-4-oxatricyclo[4.3.0.0^{2,7}]nonane-2-carboxylate 12e



Prepared according to the general procedure to afford **12e** (29.9 mg, m. p. = 171 – 175 °C) in 74% yield as colorless semisolid. The diastereomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

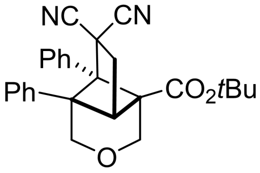
NMR and HRMS data for the product **12e**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 7.80 (d, *J* = 4.8 Hz, 1H), 7.56 (d, *J* = 4.8 Hz, 1H), 7.39 (t, *J* = 7.8 Hz, 1H), 7.34 (t, *J* = 7.2 Hz, 1H), 7.32 – 7.26 (m, 2H), 7.23 (dd, *J* = 4.8, 3.0 Hz, 1H), 7.04 (d, *J* = 7.2 Hz, 1H), 4.57 (d, *J* = 10.8 Hz, 1H), 4.35 (d, *J* = 11.4 Hz, 1H), 4.27 – 4.20 (m, 1H), 4.16 – 4.08 (m, 1H), 4.13 (d, *J* = 12.0 Hz, 1H), 3.84 (d, *J* = 12.6 Hz, 1H), 3.37 (s, 1H), 3.32 (d, *J* = 13.2 Hz, 1H), 3.02 (d, *J* = 13.2 Hz, 1H), 1.21 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 168.7, 134.5, 132.7, 129.4, 128.91, 128.86, 127.6, 127.3, 126.8, 115.4, 114.5, 70.0, 68.0, 65.7, 62.2, 58.6, 58.0, 45.2, 38.6, 37.3, 13.5.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{23}H_{20}N_2O_3SNa^+$: 427.1087, found: 427.1092.

tert-butyl-9,9-dicyano-1,6-diphenyl-4-oxatricyclo[4.3.0.0^{2,7}]nonane-2-carboxylate 12f



Prepared according to the general procedure to afford **12f** (29.9 mg) in 70% yield as colorless semisolid. The diastereomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

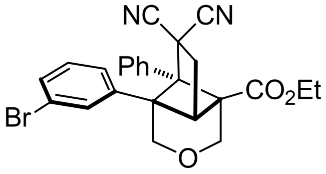
NMR and HRMS data for the product **12f**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 8.17 (d, *J* = 7.8 Hz, 2H), 7.63 (brs, 1H), 7.55 (t, *J* = 7.2 Hz, 2H), 7.48 (t, *J* = 9.6 Hz, 1H), 7.45 – 7.35 (m, 3H), 7.11 (brs, 1H), 4.40 (d, *J* = 11.4 Hz, 1H), 4.14 (d, *J* = 12.0 Hz, 1H), 4.08 (d, *J* = 10.8 Hz, 1H), 3.80 (d, *J* = 12.6 Hz, 1H), 3.24 (d, *J* = 13.8 Hz, 2H), 3.04 (d, *J* = 13.2 Hz, 1H), 1.54 (s, 9H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 168.2, 135.4, 132.1, 130.1, 129.0, 128.9, 128.79, 128.76, 127.6, 115.6, 115.1, 84.3, 71.2, 70.8, 67.0, 58.8, 57.7, 46.0, 38.6, 37.9, 27.9.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{27}H_{26}N_2O_3Na^+$: 449.1836, found: 449.1838.

ethyl-6-(3-bromophenyl)-9,9-dicyano-1-phenyl-4-oxatricyclo[4.3.0.0^{2,7}]nonane-2-carboxylate 12g



Prepared according to the general procedure to afford **12g** (41.0 mg, m. p. = 160 – 162 °C) in 86% yield as colorless semisolid. The diastereomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

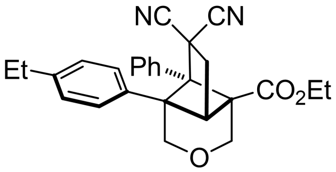
NMR and HRMS data for the product **12g**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 8.11 (d, *J* = 7.8 Hz, 2H), 7.56 (t, *J* = 6.6 Hz, 2H), 7.53 – 7.41 (m, 3H), 7.26 (brs, 2H), 4.55 – 4.40 (m, 1H), 4.34 – 4.27 (m, 1H), 4.24 – 4.17 (m, 1H), 4.17 – 4.11 (m, 2H), 3.84 (d, *J* = 11.4 Hz, 1H), 3.33 (d, *J* = 13.2 Hz, 1H), 3.26 (s, 1H), 2.96 (d, *J* = 13.2 Hz, 1H), 1.30 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 168.9, 137.5, 131.9, 131.5, 130.4, 129.3, 129.2, 129.0, 128.6, 125.6, 122.9, 115.3, 114.9, 71.2, 70.6, 66.4, 62.5, 58.1, 57.6, 46.3, 38.2, 37.7, 13.6.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{25}H_{21}{}^{79}BrN_2O_3Na^+$: 499.0628, found: 499.0622; calculated for $C_{25}H_{21}{}^{81}BrN_2O_3Na^+$: 501.0607, found: 501.0606.

ethyl-9,9-dicyano-6-(4-ethylphenyl)-1-phenyl-4-oxatricyclo[4.3.0.0^{2,7}]nonane-2-carboxylate 12h



Prepared according to the general procedure to afford **12h** (31.6 mg, m. p. = 168 – 169 °C) in 74% yield as colorless semisolid. The diastereomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

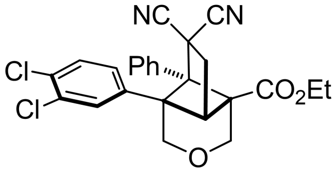
NMR and HRMS data for the product **12h**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 8.15 (d, *J* = 7.8 Hz, 2H), 7.55 (t, *J* = 7.8 Hz, 2H), 7.49 (t, *J* = 7.8 Hz, 1H), 7.43 (brs, 1H), 7.21 (d, *J* = 8.4 Hz, 2H), 7.01 (brs, 1H), 4.45 (d, *J* = 11.4 Hz, 1H), 4.34 – 4.27 (m, 1H), 4.25 – 4.18 (m, 1H), 4.15 (d, *J* = 11.4 Hz, 1H), 4.12 (d, *J* = 11.4 Hz, 1H), 3.83 (d, J = 11.4 Hz, 1H), 3.28 (d, J = 13.2 Hz, 1H), 3.25 (s, 1H), 3.02 (d, J = 12.0 Hz, 1H), 2.65 (q, J = 7.2 Hz, 2H), 1.31 (t, J = 7.2 Hz, 3H), 1.23 (t, J = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 169.2, 144.9, 132.11, 132.06, 130.0, 129.0, 128.8, 128.7, 128.3, 115.6, 114.9, 71.2, 70.9, 66.5, 62.3, 58.2, 57.7, 46.4, 38.3, 37.8, 28.4, 15.2, 13.6.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{27}H_{26}N_2O_3Na^+$: 449.1836, found: 449.1839.

ethyl-9,9-dicyano-6-(3,4-dichlorophenyl)-1-phenyl-4-oxatricyclo[4.3.0.0^{2,7}]nonane-2-carboxylate 12i



Prepared according to the general procedure to afford **12i** (39.2 mg, m. p. = 189 – 193 °C) in 84% yield as colorless semisolid. The diastereomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

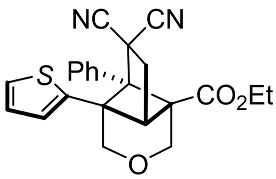
NMR and HRMS data for the product **12i**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 8.09 (d, J = 8.4 Hz, 2H), 7.74 – 7.29 (m, 5H), 7.20 – 6.89 (m, 1H), 4.45 (d, J = 12.0 Hz, 1H), 4.34 – 4.27 (m, 1H), 4.25 – 4.17 (m, 1H), 4.12 (d, J = 11.4 Hz, 2H), 3.82 (d, J = 11.4 Hz, 1H), 3.35 (d, J = 12.6 Hz, 1H), 3.25 (s, 1H), 2.92 (d, J = 12.6 Hz, 1H), 1.30 (t, J = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 168.8, 135.4, 133.2, 131.4, 131.0, 129.4, 129.3, 129.2, 129.1, 128.5, 126.7, 115.1, 115.0, 71.2, 70.5, 66.4, 62.6, 58.2, 57.3, 46.3, 38.2, 37.7, 13.6.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{25}H_{20}{}^{35}Cl_2N_2O_3Na^+$: 489.0743, found: 489.0750; calculated for $C_{25}H_{20}{}^{35}Cl^{37}ClN_2O_3Na^+$: 491.0714, found: 491.0726; calculated for $C_{25}H_{20}{}^{37}Cl_2N_2O_3Na^+$: 493.0684, found: 493.0688.

ethyl-9,9-dicyano-1-phenyl-6-(thiophen-2-yl)-4-oxatricyclo[4.3.0.0^{2,7}]nonane-2-carboxylate 12j



Prepared according to the general procedure to afford **12j** (25.9 mg, m. p. = 198 – 199 °C) in 64% yield as colorless semisolid. The diastereomeric ratio was determined to be >20:1 by crude ^{1}H NMR analysis.

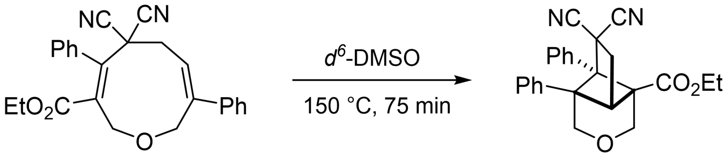
NMR and HRMS data for the product **12j**:

^{1}H NMR (600 MHz, CDCl$_3$) δ (ppm): 8.17 (d, J = 7.2 Hz, 2H), 7.55 (t, J = 6.6 Hz, 2H), 7.49 (t, J = 7.8 Hz, 1H), 7.45 (d, J = 4.8 Hz, 1H), 7.10 (d, J = 2.4 Hz, 1H), 7.07 (dd, J = 4.8, 3.6 Hz, 1H), 4.45 – 4.33 (m, 1H), 4.36 (d, J = 10.8 Hz, 1H), 4.33 – 4.25 (m, 1H), 4.15 (d, J = 11.4 Hz, 1H), 4.05 (d, J = 12.0 Hz, 1H), 3.81 (d, J = 11.4 Hz, 1H), 3.37 (s, 2H), 3.28 (s, 1H), 1.40 (t, J = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, CDCl$_3$) δ (ppm): 169.1, 137.8, 131.3, 129.3, 129.0, 128.9, 128.1, 127.2, 127.0, 114.9, 114.2, 73.0, 70.7, 66.1, 62.7, 58.3, 54.9, 46.8, 39.1, 38.1, 13.8.

HRMS (ESI-TOF) m/z: **[M + Na]$^+$** calculated for $C_{23}H_{20}N_2O_3SNa^+$: 427.1087, found: 427.1087.

8.2 Mechanism studies for the transannular [2+2] cycloaddition



3a **12a**

To an over-dried NMR tube was added the nine-membered products **3** (20 mg). Subsequently, dry d^6-DMSO (0.6 mL) was added via syringe and the reaction mixture was probed by ^{1}H NMR at 150 °C for 75 min and ^{1}H NMR spectra results were collected every 15 minutes.

From the ^{1}H NMR spectra results, it is clear that the peaks of the product are increasing and the peaks of the substrate material are decreasing. When zooming in on the spectrum at 6.29 ppm, we could still observe a new small triplet peak overlapping in the substrate's triplet peak, which might support an isomerization of the styryl moiety (E to Z).

9. Preliminary Evaluation of Biological Activity for Compounds 12

9.1 Cell culture and cellular proliferation assay

The A549, PC12, SH-SY5Y, A375 and MDA-MB231 cell line were obtained from the Type Culture Collection of the Chinese Academy of Sciences, Shanghai, China. A549 and PC12 cells were grown in RPMI 1640 (Hyclone, USA) supplemented with 10% fetal bovine serum (FBS, Gibco, USA), while SH-SY5Y, A375 and MDA-MB231 cells were grown in DMEM (Hyclone, USA) supplemented with 10% fetal bovine serum (FBS, Gibco, USA). All the cells were maintained at 37 °C in a humidified incubator containing 5% CO_2. A 20 μM chemical stock solution was prepared by dissolving in DMSO before cell viability assays. Cell viability was determined by MTT (Sigma-Aldrich) assays. All the five cell lines were seeded in 96-well plates 24 h earlier before treated by the chemicals for 24 h. Chemical treatment concentration set to 20 μM and paclitaxel was prepared as a positive control (5 μM, 24 h). After the treatment, 200 μL fresh medium containing 20 μL MTT (5 mg/mL) was added to each pore to replace the chemical containing medium and incubated for 4 h. Then discarded the medium and added 150 μL DMSO to dissolve purple crystals. The absorbance value at 570 nm was determined. The mean percentage of cell survival rates was determined from data of three individual experiments.

*9.2 The Mean Inhibitory Ratio of Compounds **12** against A Panel of Cancer Cell Lines*

MTT assay was applied to determine the cell viability after 24 h treatment of tested compounds. All the typical cancer cell lines were obtained from American Type Culture Collection (ATCC, USA). PTX is FDA approved to be used for AIDS-related Kaposi sarcoma, breast cancer, non-small cell lung cancer, and ovarian cancer. Results exerted that PTX showed a significant inhibitory effect on most type of cancer, except triple negative breast cancer (TNBC) MDA-MB-231 at the concentration of 5 μM. Interestingly, compound **12a** had a more critical effect on MDA-MB-231 than other compounds at the concentration of 20 μM, suggesting a promising application for TNBC therapy after further exploration. However, its effect on lung cancer A-549 was least effective compare to other compounds. Compounds **12c**, **12j** and **12i** could suppress A-549 proliferation significantly, while compounds **12e** and **12f** displayed a moderate inhibitory effect. PC12 is a rat pheochromocytoma cell line. Compounds **12c** and **12h** could block the growth of PC12 slightly, while compounds **12i** and **12j** manifested a dramatic inhibitory effect. SH-SY-5Y is a neuroblastoma cell line. Most of synthesized compounds could interfere with the proliferative ability of SH-SY-5Y, except compound **12j**. A375 cells are human melanoma cancer cells containing the endogenous B-Raf mutation V600E. The ratio of inhibited A375 cells for all the tested compounds were above 50%.

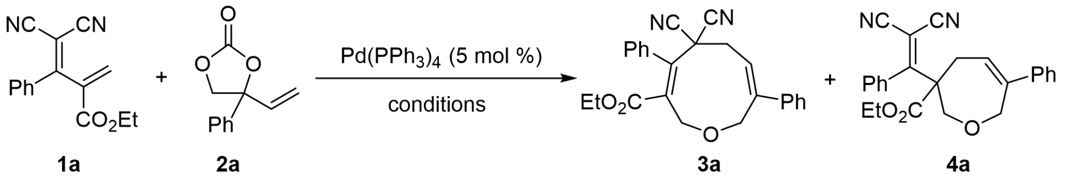
Table S3. The mean inhibitory ratio.[a]

Compounds	Inhibitory Ratio (%)				
	A549	PC12	SH-SY5Y	A375	MDA-MB231
12a	6.82	25.41	68.31	64.36	46.33
12b	27.72	4.41	31.10	54.72	40.32
12c	74.76	43.18	22.39	38.23	9.53
12d	9.07	14.14	64.31	79.73	41.57
12e	59.50	16.88	67.40	70.63	35.63
12f	51.40	22.66	29.92	42.25	17.58
12g	30.57	19.77	56.87	40.53	30.00
12h	38.93	45.39	46.35	66.19	37.04
12i	73.76	61.87	39.36	36.22	22.27
12j	74.89	72.66	10.87	35.98	1.48
PTX	66.14	67.63	57.47	77.23	38.75

[a] Each compound was tested in triplicate; the data are presented as the mean values.

10. Experiments for Mechanism Studies

10.1 The tracking experiments



I. The tracking experiments of the [5+4] cyclization

Five reactions were parallelly carried out following the same operational procedure:

To over-dried Schlenk tubes was added Pd(PPh$_3$)$_4$ (5 mol %), after which the tube was evacuated and back-filled with argon three times. Subsequently, under the protection of argon, a solution of allylidenemalononitrile **1a** (0.10 mmol) and vinylethylene carbonate **2a** (0.15 mmol) in dry MeCN (1.0 mL) was added.

Then, the five reactions were stirred at 20 °C for 3 hours, 6 hours, 12 hours, 18 hours and 24 hours, respectively. After the corresponding time, the reaction mixture was filtered through a plug of silica (eluting with ethyl acetate) and concentrated, which were dried under vacuum and further analyzed by ^{1}H NMR with CH$_2$Br$_2$ as the internal standard. The results were listed as follow:

Table S4. The results of the tracking experiments **I**.

reaction time (h)	3	6	12	18	24
NMR yield of **3a** (%)	22	57	71	85	96
NMR yield of **4a** (%)	<1	<1	<1	<1	<1

II. The tracking experiments of the [5+2] cyclization

Six reactions were parallelly carried out following the same operational procedure:

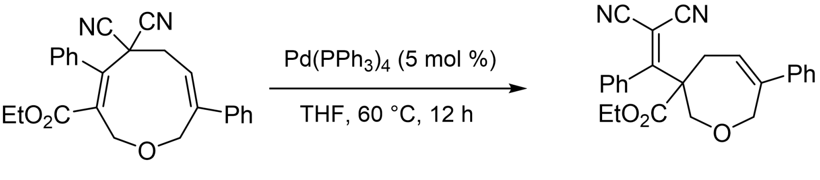
To over-dried Schlenk tubes was added Pd(PPh$_3$)$_4$ (5 mol %), after which the tube was evacuated and back-filled with argon three times. Subsequently, under the protection of argon, a solution of allylidenemalononitrile **1a** (0.10 mmol) and vinylethylene carbonate **2a** (0.15 mmol) in dry THF (1.0 mL) was added.

Then, the six reactions were stirred at 60 °C for 45 min, 1.5 hours, 3 hours, 6 hours, 9 hours and 12 hours, respectively. After the corresponding time, the reaction mixture was cooled to room temperature, filtered through a plug of silica (eluting with ethyl acetate) and concentrated, which were dried under vacuum and further analyzed by ^{1}H NMR with CH_2Br_2 as the internal standard. The results were listed as follow:

Table S5. The results of the tracking experiments **II**.

reaction time (h)	0.75	1.5	3	6	9	12
NMR yield of **3a** (%)	87	85	71	60	36	<1
NMR yield of **4a** (%)	6	8	21	32	55	91

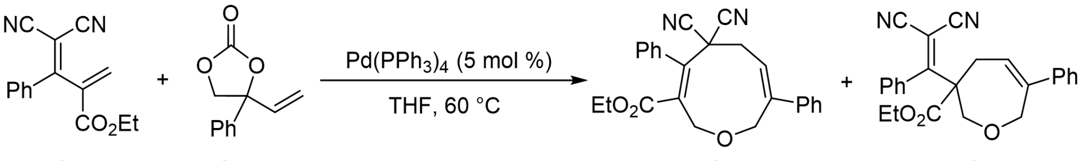
*10.2 The transformation from **3a** to **4a***



3a **4a**

To an over-dried Schlenk tube was added $Pd(PPh_3)_4$ (5 mol %), after which the tube was evacuated and back-filled with argon three times. Subsequently, under the protection of argon, a solution of nine-membered product **3a** (39.8 mg, 0.10 mmol) in dry THF (1.0 mL) was added *via* syringe and the reaction mixture was stirred at 60 °C for 12 hours. Then the mixture was concentrated and purified by column chromatography on silica gel (petroleum ether/ethyl acetate = 10/1) to afford **4a** (38.2 mg) as pale yellow solid in 96% yields.

10.3 The effect of the loading of VEC on the regioisomeric ratio



1a **2a** **3a** **4a**

Four reactions were parallelly carried out under the similar operational procedure:

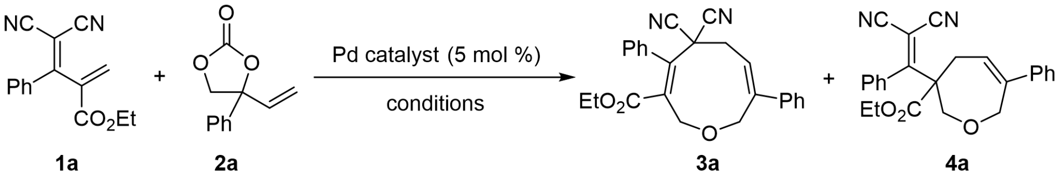
To over-dried Schlenk tubes was added $Pd(PPh_3)_4$ (5 mol %), after which the tube was evacuated and back-filled with argon three times. Subsequently, under the protection of argon, a solution of allylidenemalononitrile **1a** (0.10 mmol) and vinylethylene carbonate **2a** in dry THF (1.0 mL) was added.

The amounts of **2a** in the four reactions respectively refer to 0.15 mmol, 0.25 mmol, 0.35 mmol and 0.45 mmol. Then, the four reactions were stirred at 60 °C for 12 hours, respectively. After then, the reaction mixture was cooled to room temperature, filtered through a plug of silica (eluting with ethyl acetate) and concentrated, which were dried under vacuum and further analyzed by ^1H NMR with CH_2Br_2 as the internal standard. The results were listed as follow:

Table S6. The results of the control experiments.

The ratio of **1a**:**2a**	1:1.5	1:2.5	1:3.5	1:4.5
NMR yield of **3a** (%)	<1	72	85	92
NMR yield of **4a** (%)	91	21	6	<1

10.4 The effect of the loading of ligand on the regioisomeric ratio



I. Condition: THF, 20 °C

Five reactions were parallelly carried out under the similar operational procedure:

To over-dried Schlenk tubes was added $Pd_2(dba)_3 \cdot CHCl_3$ (2.5 mol %) and PPh_3, after which the tube was evacuated and back-filled with argon three times. Then under the protection of argon, dry THF (0.5 mL) was added and stirred at 20 °C for 1 hour. The amounts of PPh_3 in the five reactions respectively refer to 5 mol %, 10 mol %, 20 mol %, 40 mol %, and 80 mol %.

Subsequently, under the protection of argon, a solution of allylidenemalononitrile **1a** (0.10 mmol) and vinylethylene carbonate **2a** in dry THF (0.5 mL) was added respectively. Then, the five reactions were stirred at 20 °C for 12 hours. After then, the reaction mixture was filtered through a plug of silica (eluting with ethyl acetate) and concentrated, which were dried under vacuum and further analyzed by ^{1}H NMR with CH_2Br_2 as the internal standard.

II. Condition: THF, 60 °C

Four reactions were parallelly carried out under the similar operational procedure:

To over-dried Schlenk tubes was added $Pd_2(dba)_3{\cdot}CHCl_3$ (2.5 mol %) and PPh_3, after which the tube was evacuated and back-filled with argon three times. Then under the protection of argon, dry THF (0.5 mL) was added and stirred at 20 °C for 1 hour. The amounts of PPh_3 in the four reactions respectively refer to 5 mol %, 10 mol %, 20 mol % and 40 mol %.

Subsequently, under the protection of argon, a solution of allylidenemalononitrile **1a** (0.10 mmol) and vinylethylene carbonate **2a** in dry THF (0.5 mL) was added respectively. Then, the four reactions were stirred at 60 °C for 12 hours. After then, the reaction mixture was cooled to room temperature, filtered through a plug of silica (eluting with ethyl acetate) and concentrated, which were dried under vacuum and further analyzed by ^{1}H NMR with CH_2Br_2 as the internal standard.

III. Condition: MeCN, 60 °C

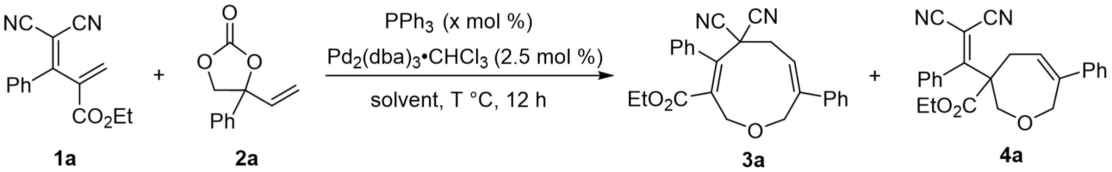
Four reactions were parallelly carried out under the similar operational procedure:

To over-dried Schlenk tubes was added $Pd_2(dba)_3{\cdot}CHCl_3$ (2.5 mol %) and PPh_3, after which the tube was evacuated and back-filled with argon three times. Then under the protection of argon, dry MeCN (0.5 mL) was added and stirred at 20 °C for 1 hour. The amounts of PPh_3 in the four reactions respectively refer to 5 mol %, 10 mol %, 20 mol % and 40 mol %.

Subsequently, under the protection of argon, a solution of allylidenemalononitrile **1a** (0.10 mmol) and vinylethylene carbonate **2a** in dry MeCN (0.5 mL) was added respectively. Then, the four reactions were stirred at 60 °C for 12 hours. After then, the reaction mixture was cooled to room temperature, filtered through a plug of silica (eluting with ethyl acetate) and concentrated, which were dried under vacuum and further analyzed by ^{1}H NMR with CH_2Br_2 as the internal standard.

The results were listed as follow:

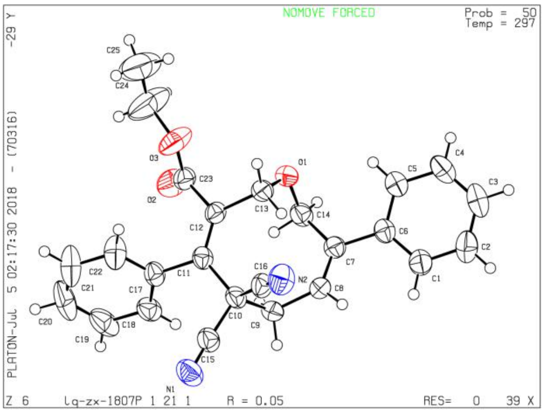
Table S7. The results of effect of the loading of ligand.[a]



entry	PPh_3 (x mol%)	solvent	T (°C)	yield (%)[b]	**3a**:**4a**[c]
1	5	THF	20	18	>20:1
2	10	THF	20	66	>20:1
3	20	THF	20	82	10.5:1
4	40	THF	20	79	5.7:1
5	80	THF	20	54	1:1.7
6	5	THF	60	39	>20:1
7	10	THF	60	96	1.9:1
8	20	THF	60	89	2.2:1
9	40	THF	60	96	<1:20
10	5	MeCN	60	69	>20:1
11	10	MeCN	60	90	11.9:1
12	20	MeCN	60	57	8.2:1
13	40	MeCN	60	45	2.3:1

[a] Unless noted otherwise, the reactions were carried out with **1a** (0.10 mmol), **2a** (0.15 mmol), and Pd catalyst (5 mol %) in solvent (1.0 mL) for 12 h. And the Pd/ligand complex was pre-prepared with $Pd_2(dba)_3{\cdot}CHCl_3$ and PPh_3 in solvent at rt for 1 h. [b] Yield was determined by ^{1}H-NMR analysis with CH_2Br_2 as the internal standard. [c] The ratio of **3a**:**4a** was determined by ^{1}H-NMR analysis of the crude reaction mixture. [d]

11. Crystal Data and Structure Refinement



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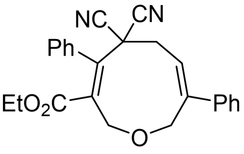
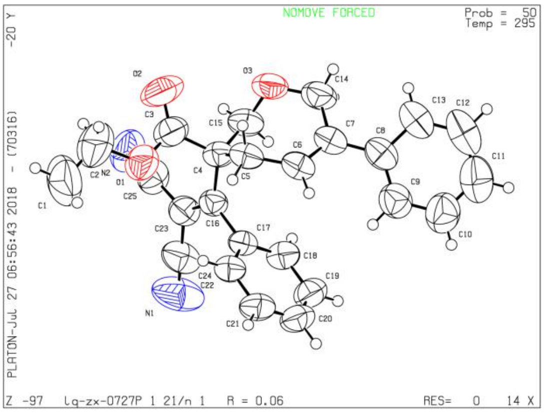


3a
CCDC 1943770

Identification code	**3a**
Empirical formula	$C_{25}H_{22}N_2O_3$
Formula weight	398.44
Temperature/K	296.6(3)
Crystal system	monoclinic
Space group	$P2_1$
a/Å	9.0919(5)
b/Å	9.9836(5)
c/Å	11.7719(5)
α/°	90
β/°	95.822(5)
γ/°	90
Volume/Å^3	1063.02(10)
Z	2
ρ_{calc}g/cm^3	1.245
μ/mm^{-1}	0.662
F(000)	420.0
Crystal size/mm^3	0.6 × 0.4 × 0.2
Radiation	CuKα (λ = 1.54184)
2Θ range for data collection/°	7.548 to 145.832
Index ranges	$-9 \le h \le 11$, $-7 \le k \le 12$, $-14 \le l \le 14$
Reflections collected	6415
Independent reflections	3358 [R_{int} = 0.0288, R_{sigma} = 0.0365]
Data/restraints/parameters	3358/1/272
Goodness-of-fit on F^2	1.042
Final R indexes [I>=2σ (I)]	R_1 = 0.0549, wR_2 = 0.1433
Final R indexes [all data]	R_1 = 0.0573, wR_2 = 0.1472
Largest diff. peak/hole / e Å^{-3}	0.24/-0.29



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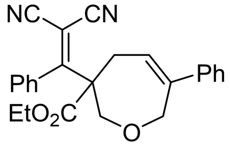
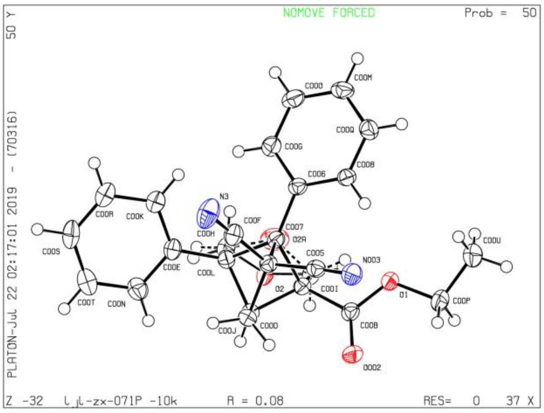


4a
CCDC 1943771

Identification code	**4a**
Empirical formula	$C_{25}H_{22}N_2O_3$
Formula weight	398.44
Temperature/K	295.4(4)
Crystal system	monoclinic
Space group	$P2_1/n$
a/Å	9.6576(5)
b/Å	13.2796(9)
c/Å	17.3578(10)
α/°	90
β/°	99.745(5)
γ/°	90
Volume/Å^3	2194.0(2)
Z	4
ρ_{calc}g/cm^3	1.206
μ/mm^{-1}	0.642
F(000)	840.0
Crystal size/mm^3	0.6 × 0.4 × 0.3
Radiation	CuKα (λ = 1.54184)
2Θ range for data collection/°	8.43 to 146.126
Index ranges	$-11 \le h \le 11$, $-16 \le k \le 16$, $-21 \le l \le 21$
Reflections collected	12330
Independent reflections	4284 [R_{int} = 0.0225, R_{sigma} = 0.0183]
Data/restraints/parameters	4284/0/272
Goodness-of-fit on F^2	1.044
Final R indexes [I>=2σ (I)]	R_1 = 0.0608, wR_2 = 0.1748
Final R indexes [all data]	R_1 = 0.0752, wR_2 = 0.1940
Largest diff. peak/hole / e Å^{-3}	0.18/-0.22



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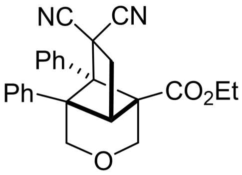


12a
CCDC 1943772

Identification code	**12a**
Empirical formula	$C_{25}H_{22}N_2O_3$
Formula weight	398.44
Temperature/K	225(100)
Crystal system	triclinic
Space group	P-1
a/Å	7.8691(9)
b/Å	9.8641(8)
c/Å	13.1840(9)
α/°	87.285(6)
β/°	85.531(8)
γ/°	74.852(9)
Volume/Å^3	984.42(16)
Z	2
ρ_{calc}g/cm^3	1.344
μ/mm^{-1}	0.715
F(000)	420.0
Crystal size/mm^3	0.6 × 0.2 × 0.1
Radiation	CuKα (λ = 1.54184)
2Θ range for data collection/°	6.728 to 144.716
Index ranges	$-7 \leq h \leq 9$, $-12 \leq k \leq 12$, $-16 \leq l \leq 16$
Reflections collected	10529
Independent reflections	3791 [R_{int} = 0.0750, R_{sigma} = 0.0560]
Data/restraints/parameters	3791/0/282
Goodness-of-fit on F^2	1.040
Final R indexes [I>=2σ (I)]	R_1 = 0.0793, wR_2 = 0.2132
Final R indexes [all data]	R_1 = 0.0877, wR_2 = 0.2314
Largest diff. peak/hole / e Å^{-3}	0.71/-0.47

12. References and Notes

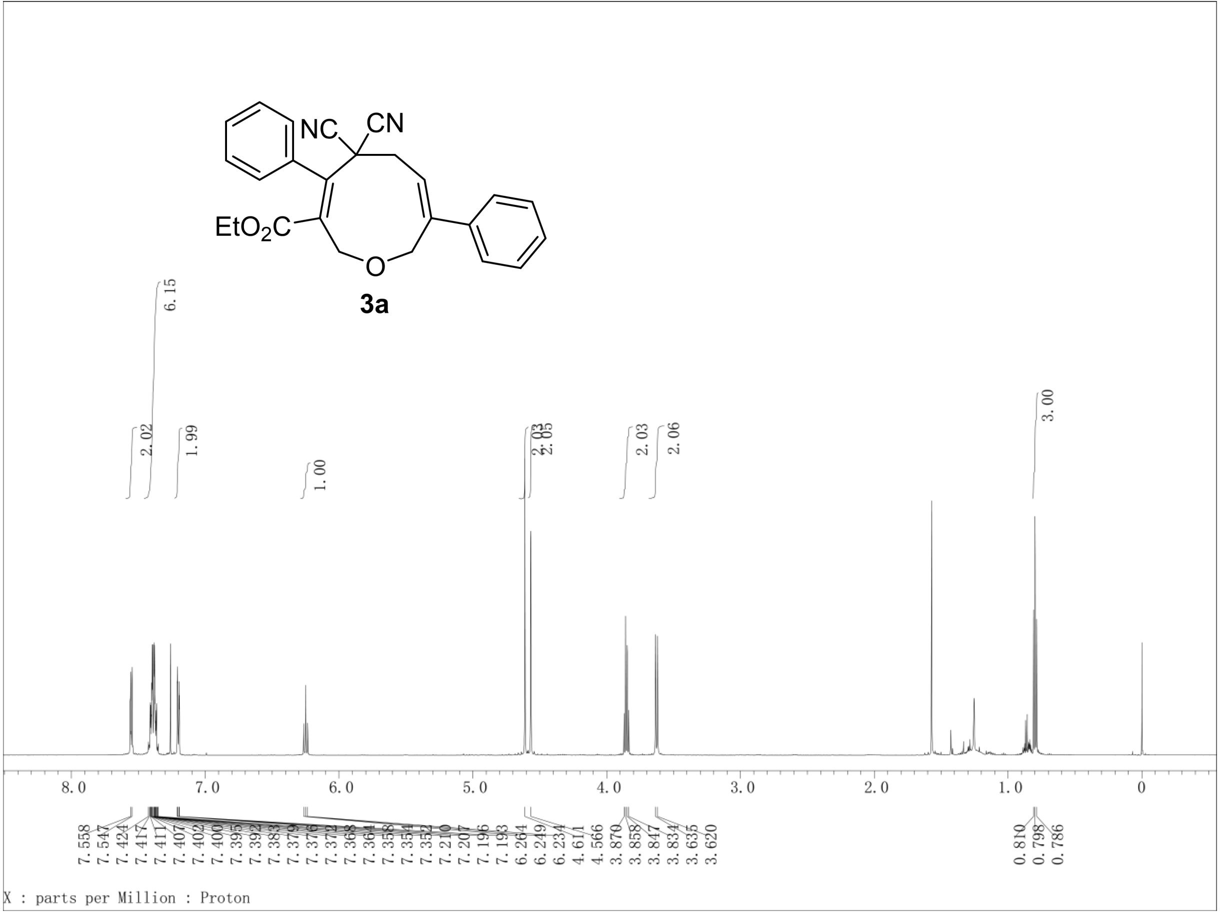
1 (a) E. Krell, *Handbook of Laboratory Distillation*, Elseriver Publishing Company, Amsterdam-London-New York. 1963; (b) M. J. Rosengart, *The Technique of Distillation and Rectification in the Laboratory*, VEB Verlag Technik, Berlin, 1954; (c) F. Stage, *Angew. Chem.*, 1947, **19**, 175.

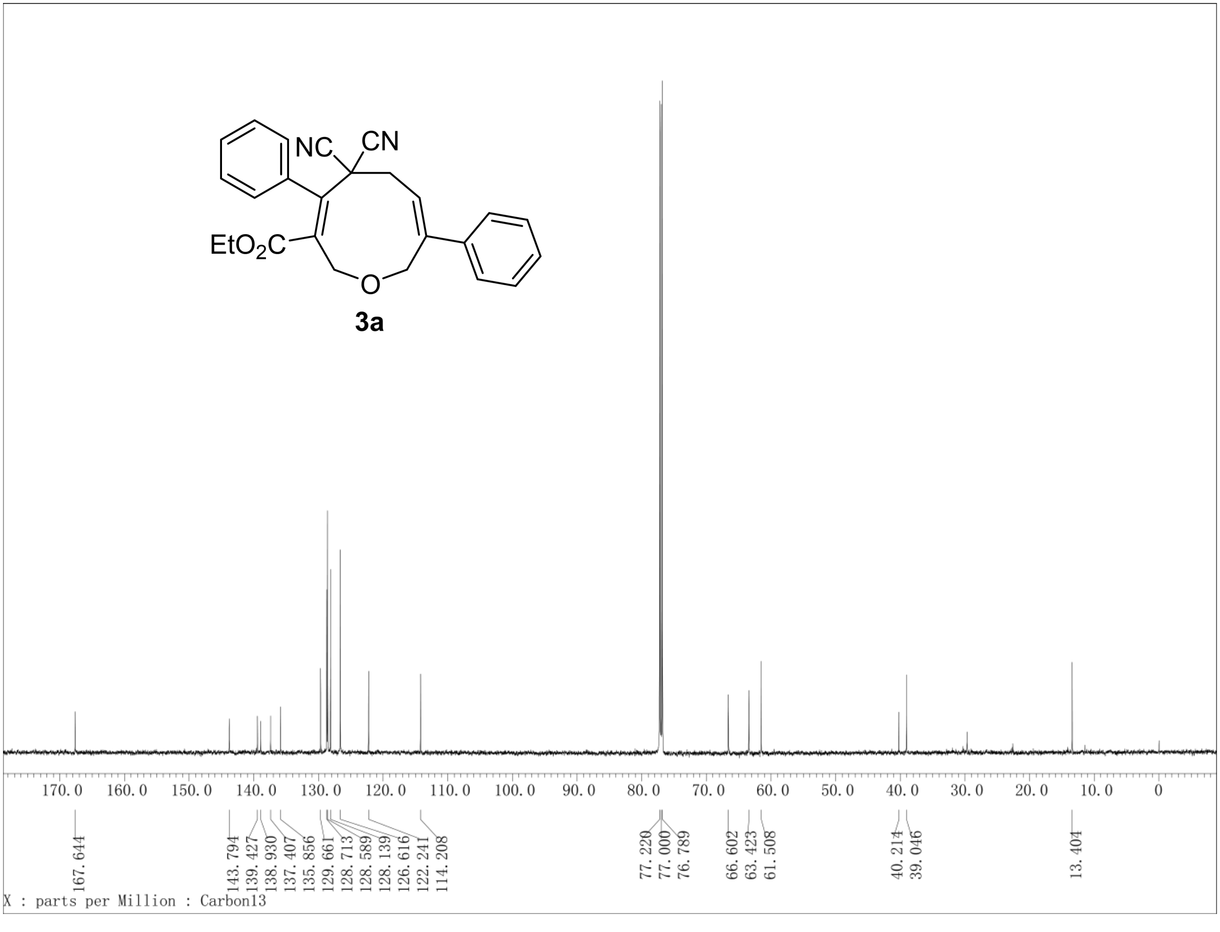
2 X. Jiang, D. Fu, X. Shi, S.; Wang and R. Wang, *Chem. Commun.*, 2011, **47**, 8289.

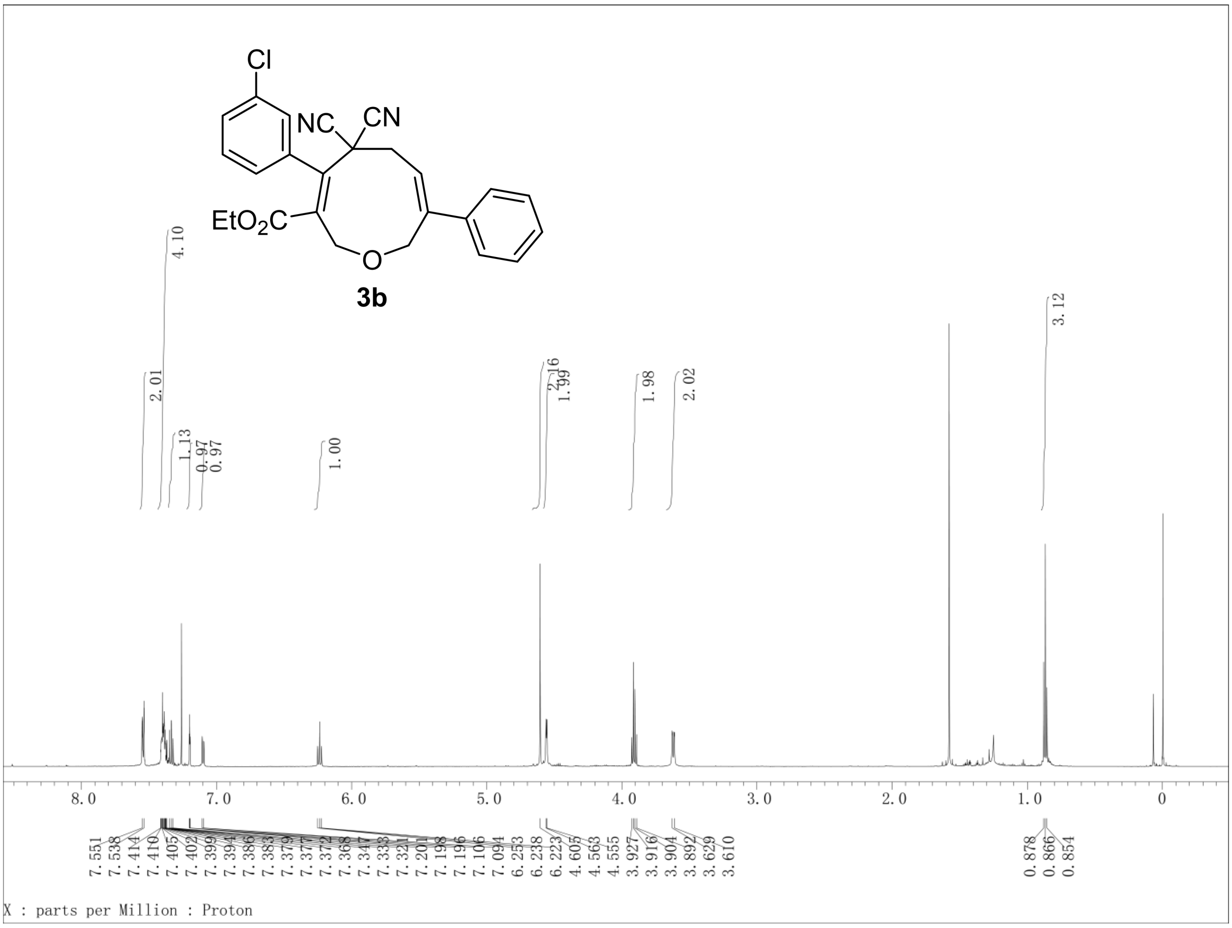
3 A. Khan, R. Zheng, Y. Kan, J. Ye, J. Xing and Y. J. Zhang, *Angew. Chem.*, *Int. Ed.*, 2014, **53**, 6439.

4 K. Ohmatsu, N. Imagawa and T. Ooi, *Nat. Chem.*, 2014, **6**, 47.

13. NMR Spectra



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2.02
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7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
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7.538
7.414
7.410
7.405
7.402
7.399
7.394
7.386
7.383
7.379
7.377
7.372
7.368
7.347
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7.321
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7.198
7.196
7.106
7.094
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6.238
6.223
4.605
4.563
4.555
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3.892
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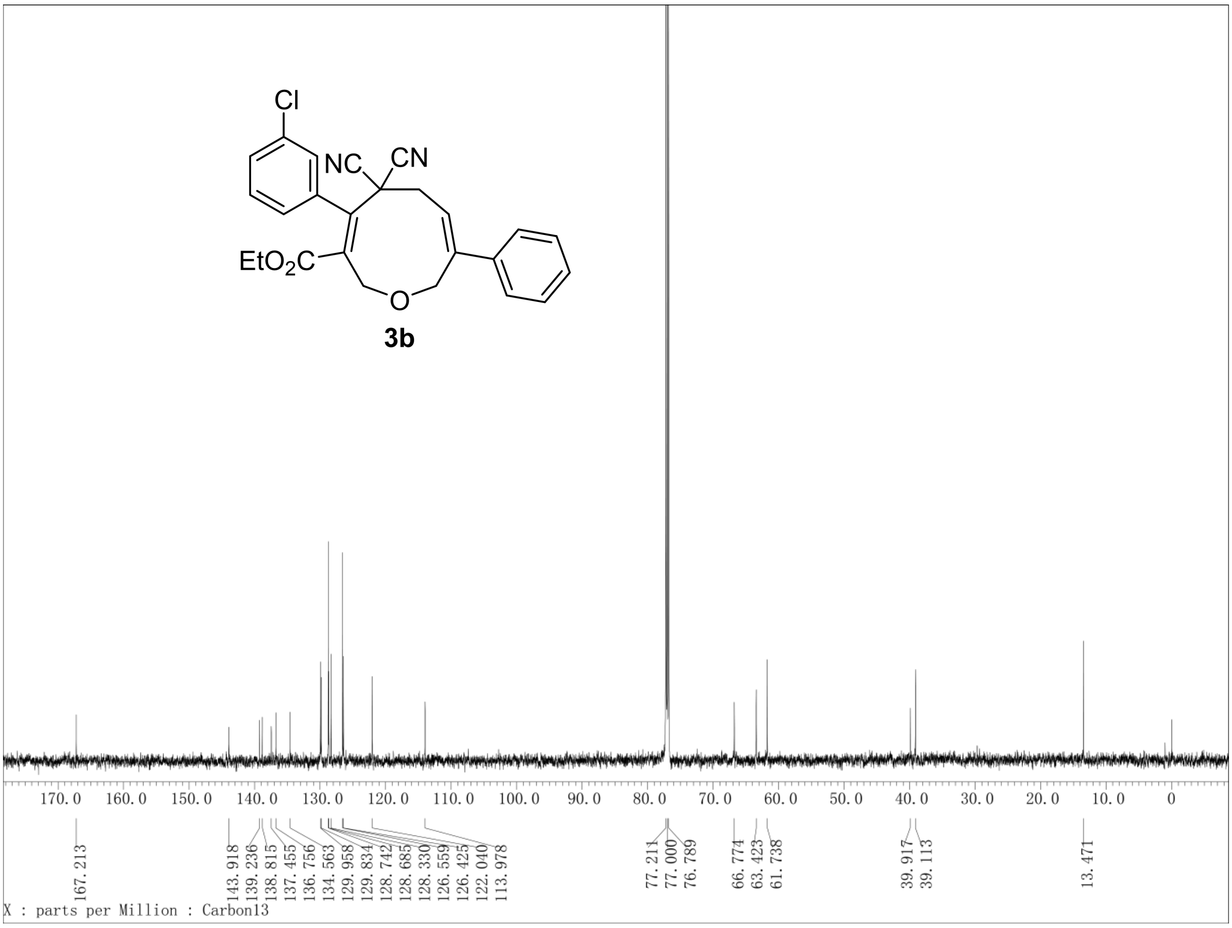
0.878
0.866
0.854
X : parts per Million : Proton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80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
167.213
143.918
139.236
138.815
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136.756
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126.425
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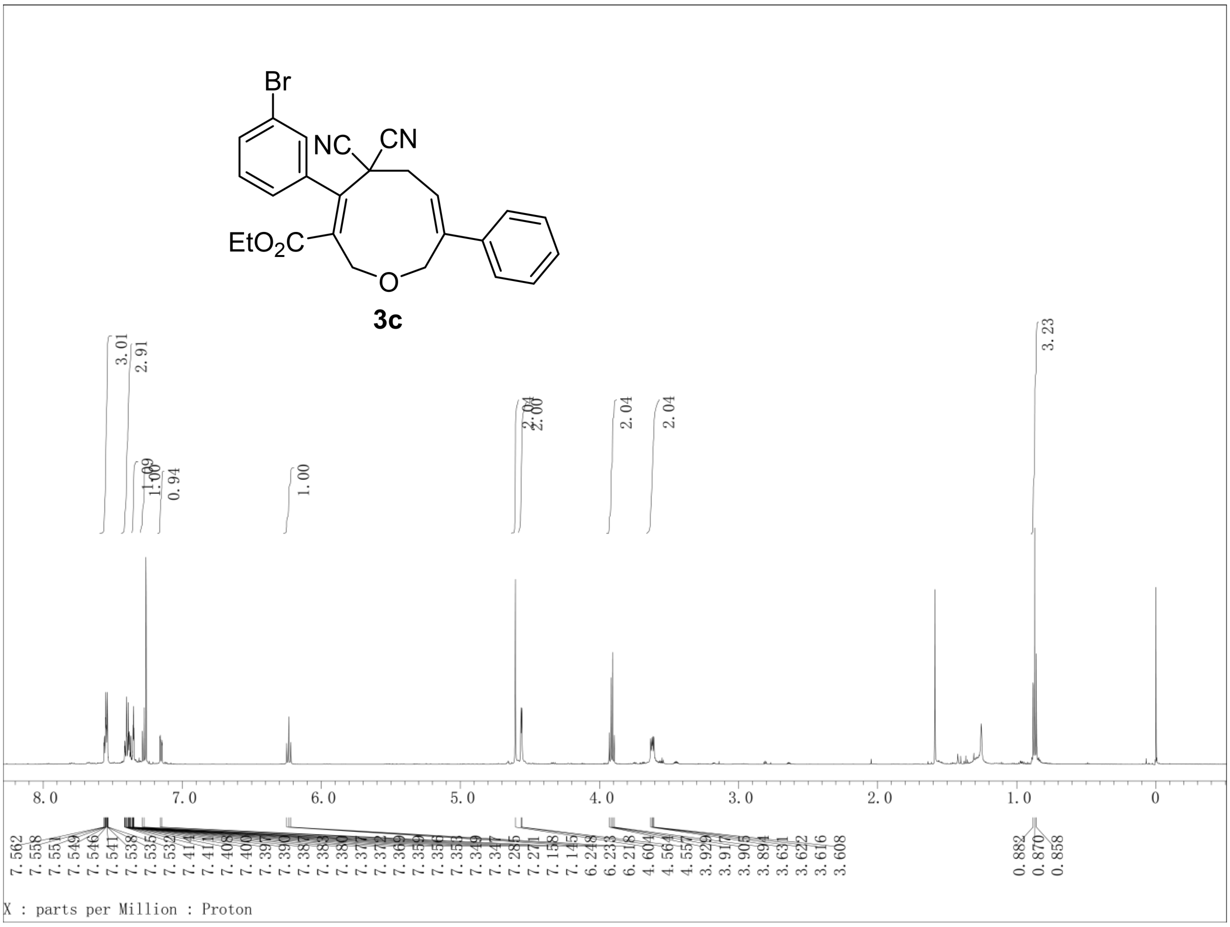
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2.04
2.04
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7.0
6.0
5.0
4.0
3.0
2.0
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0
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7.411
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7.380
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7.158
7.145
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6.233
6.218
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4.557
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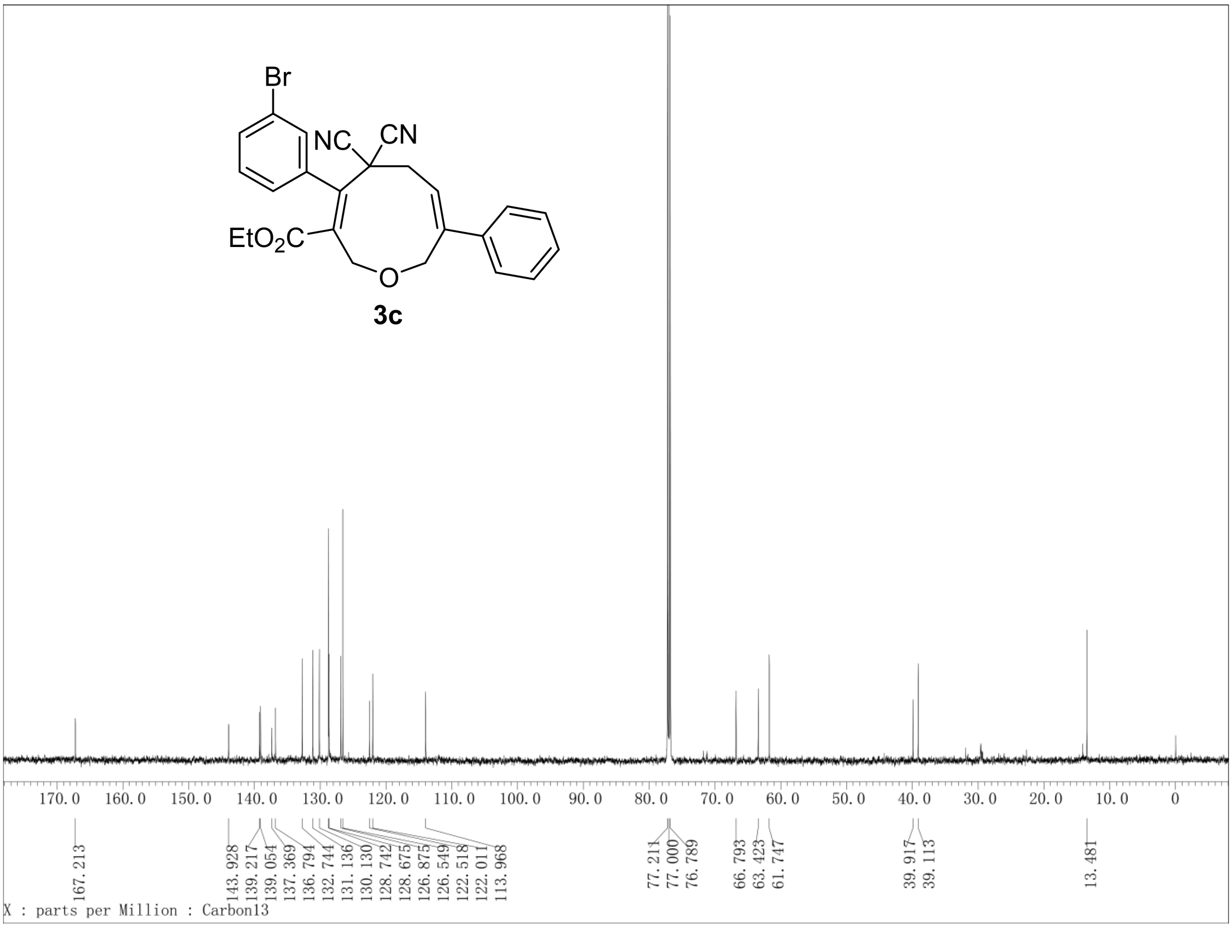
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40.0
30.0
20.0
10.0
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126.549
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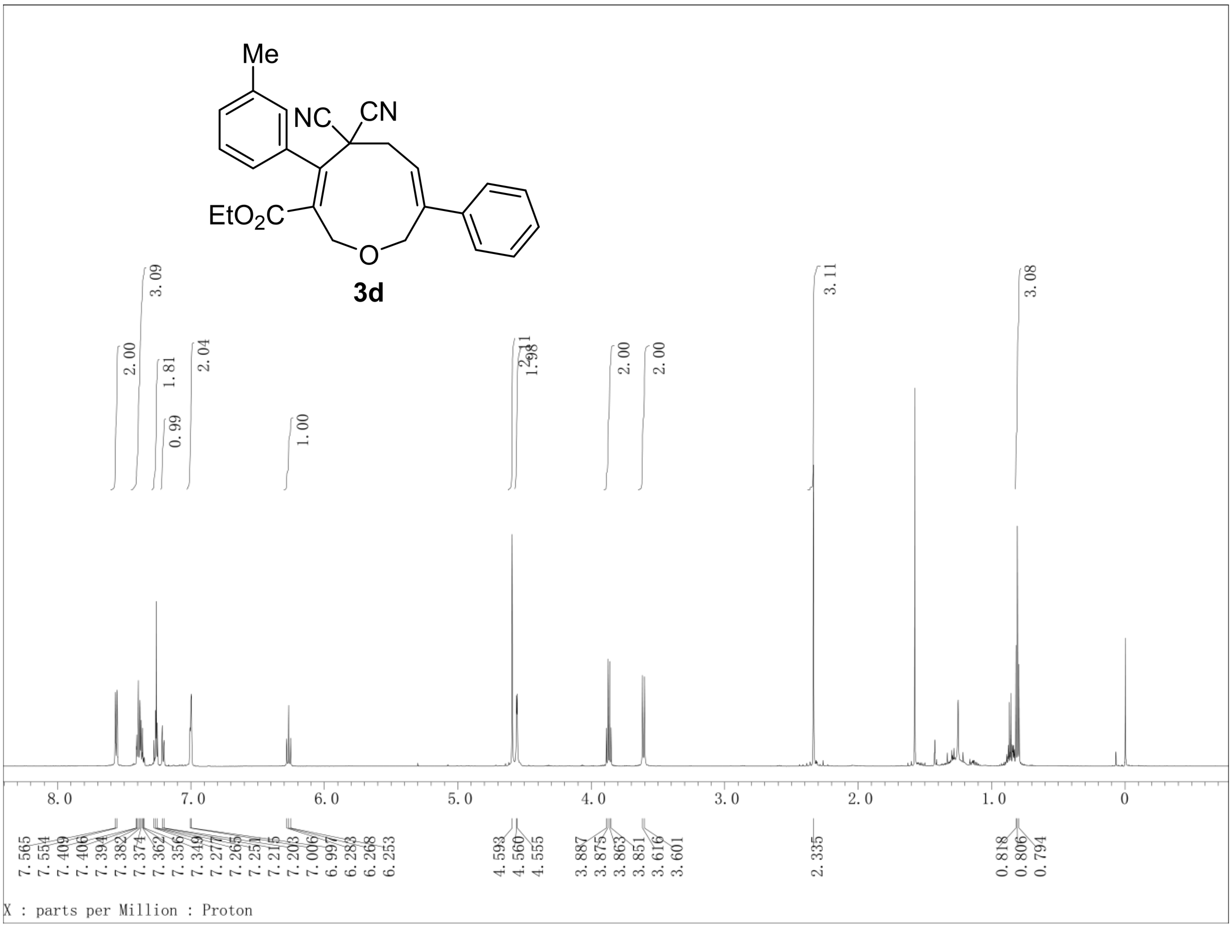
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CN
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2.00
2.00
3.11
3.08
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7.0
6.0
5.0
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7.382
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7.356
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7.203
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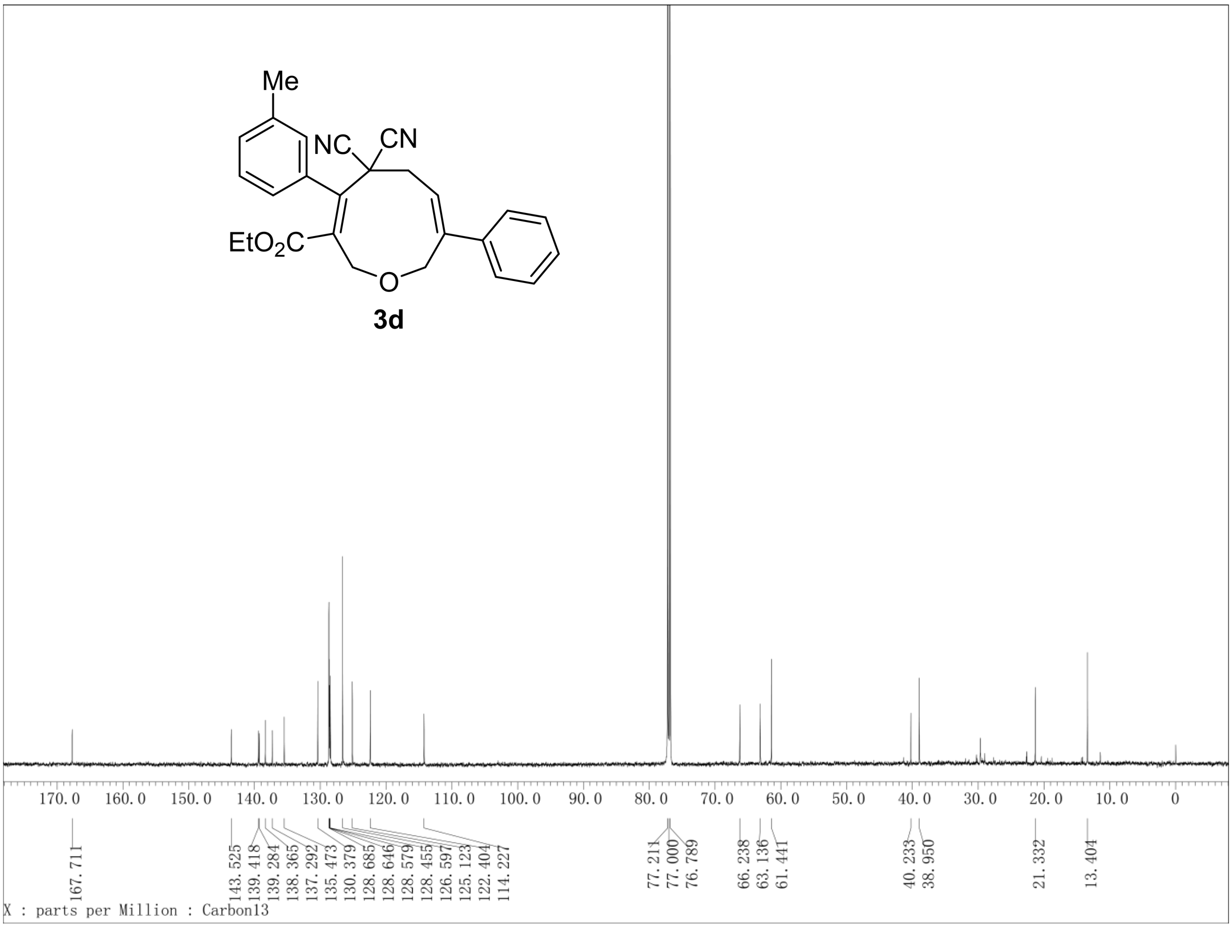
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120.0
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138.365
137.292
135.473
130.379
128.685
128.646
128.579
128.455
126.597
125.123
122.404
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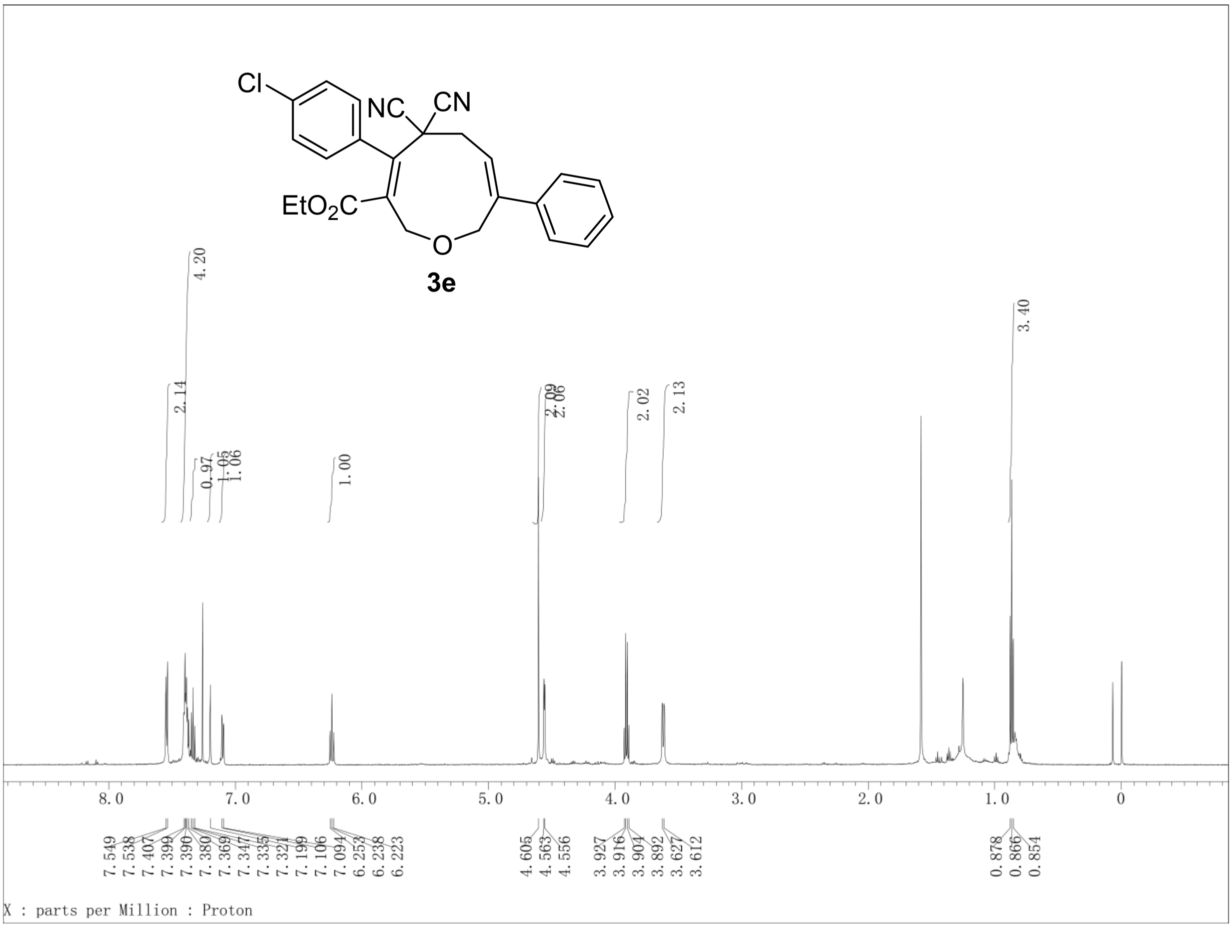
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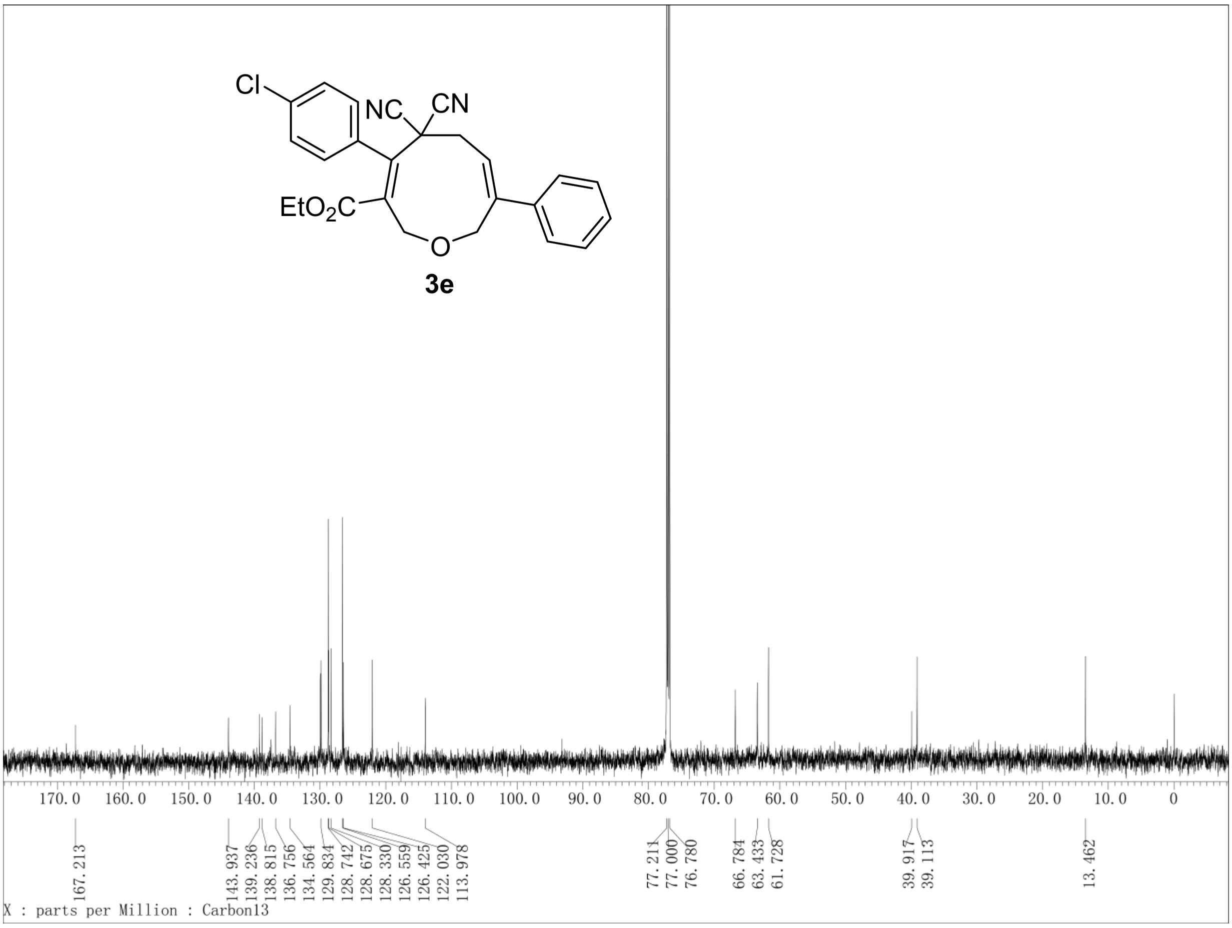
X : parts per Million : Proton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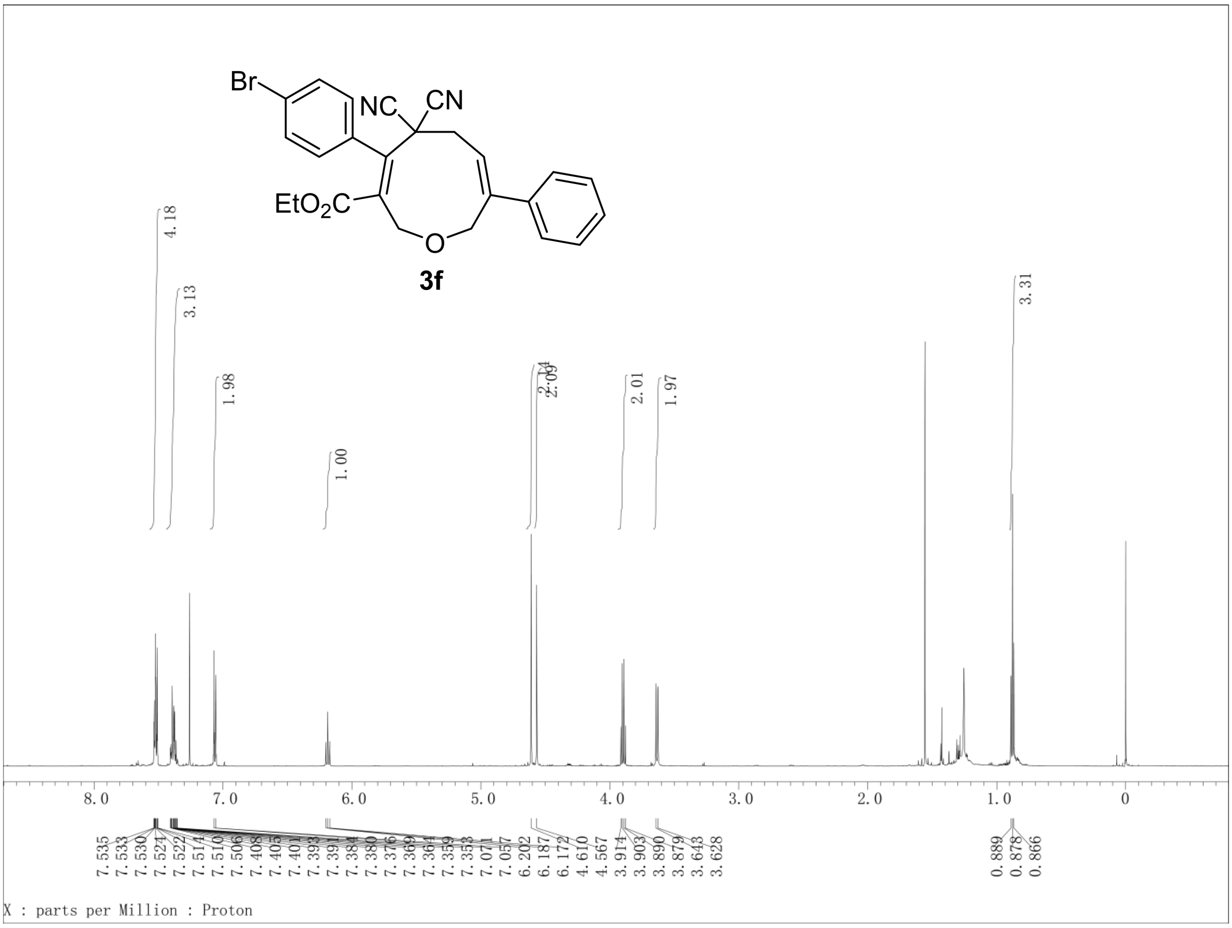
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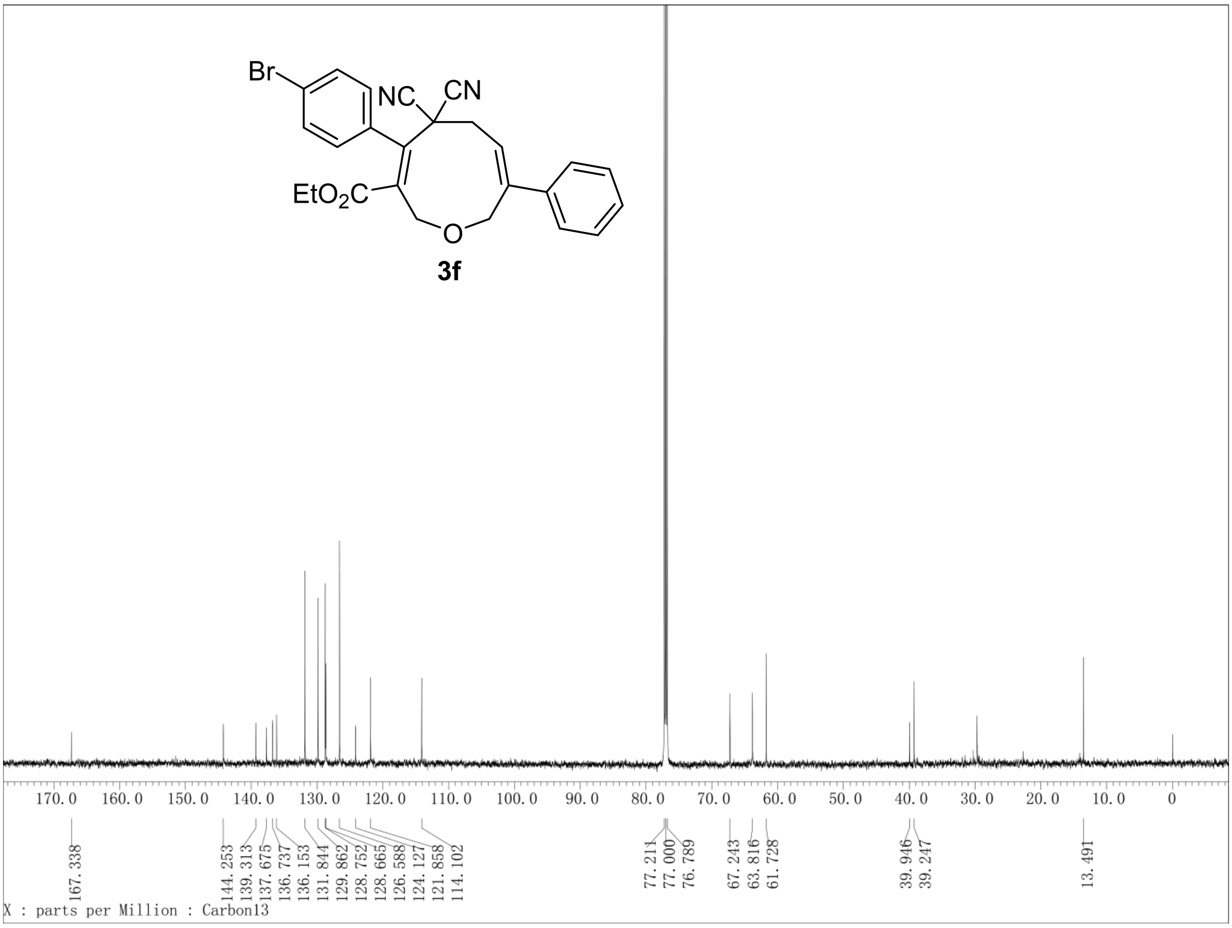
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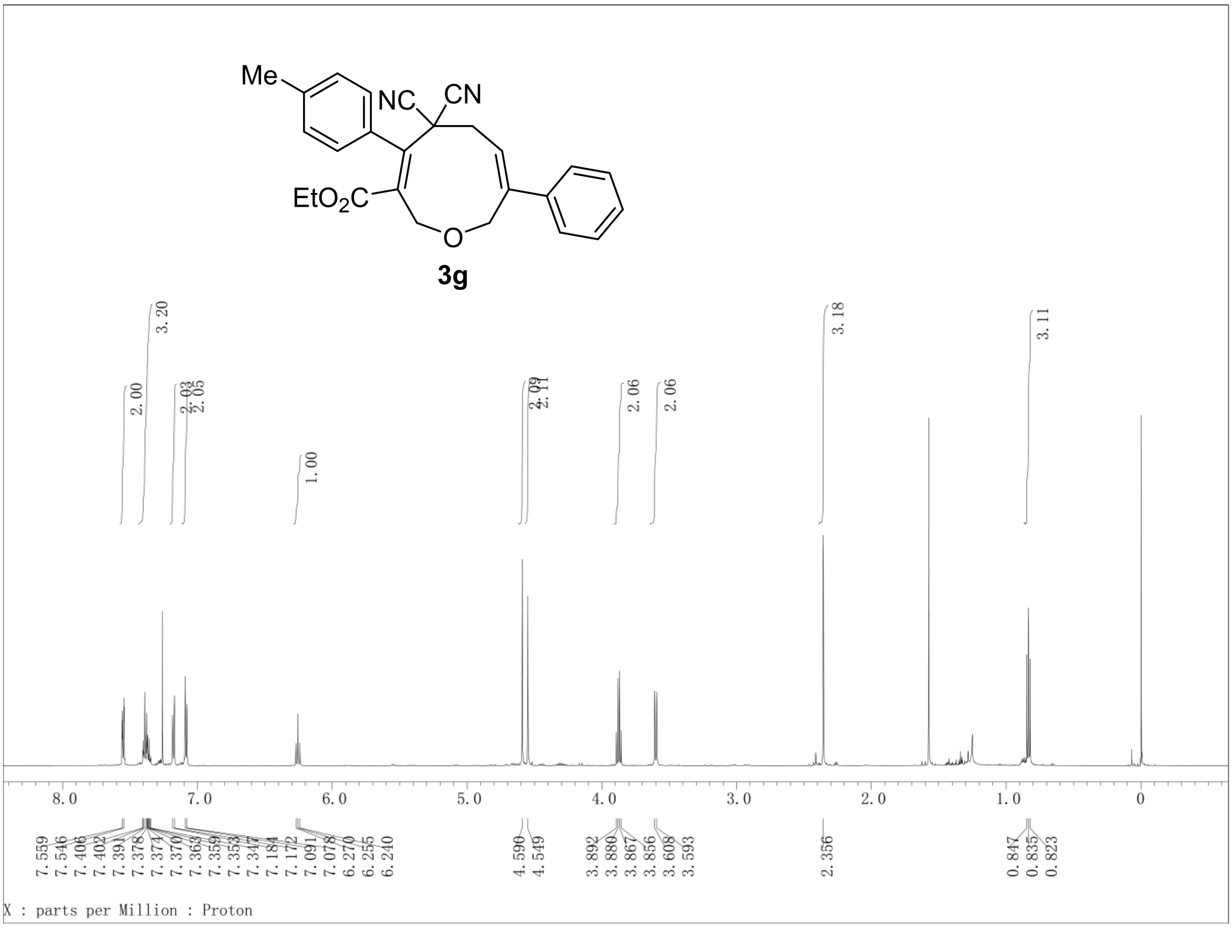
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2.06
3.18
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5.0
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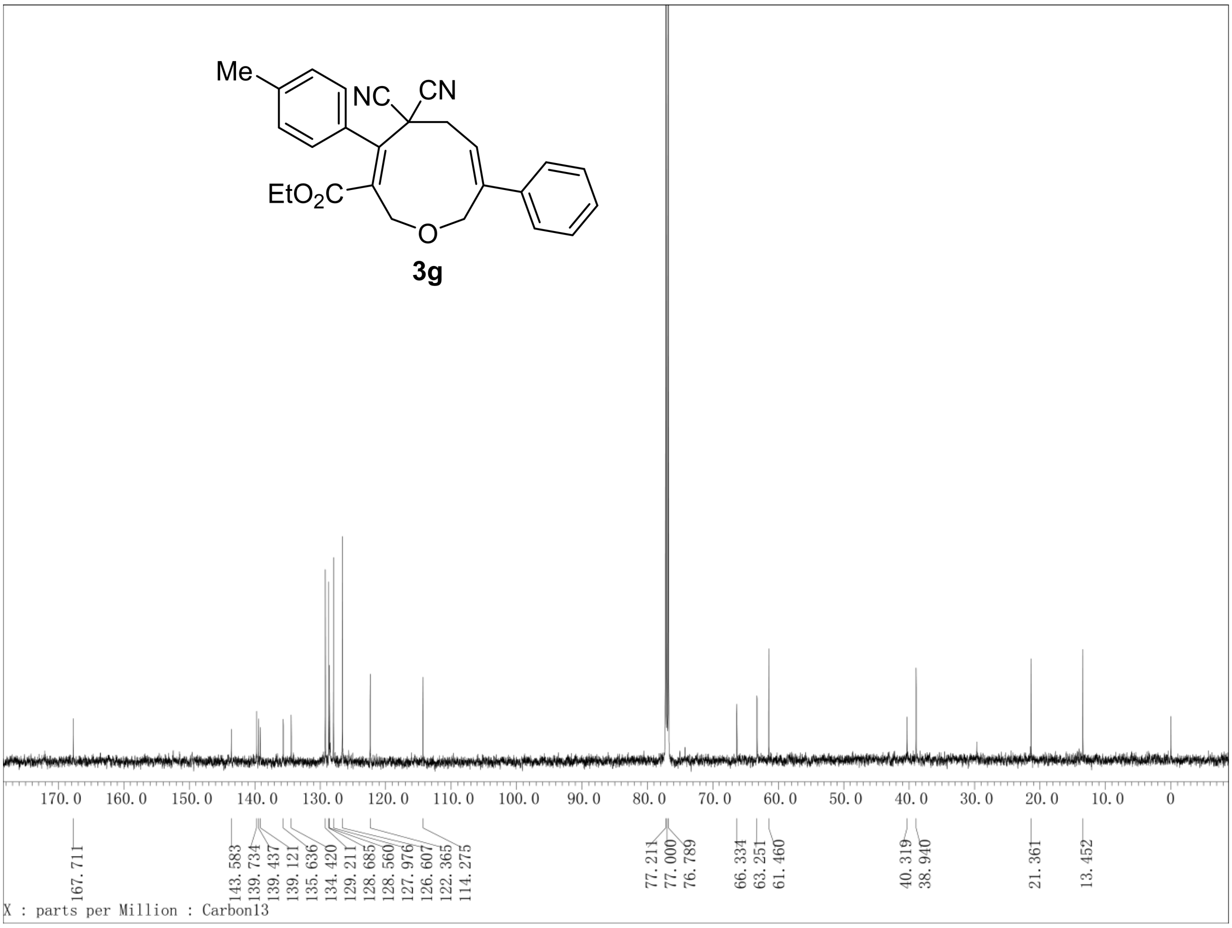
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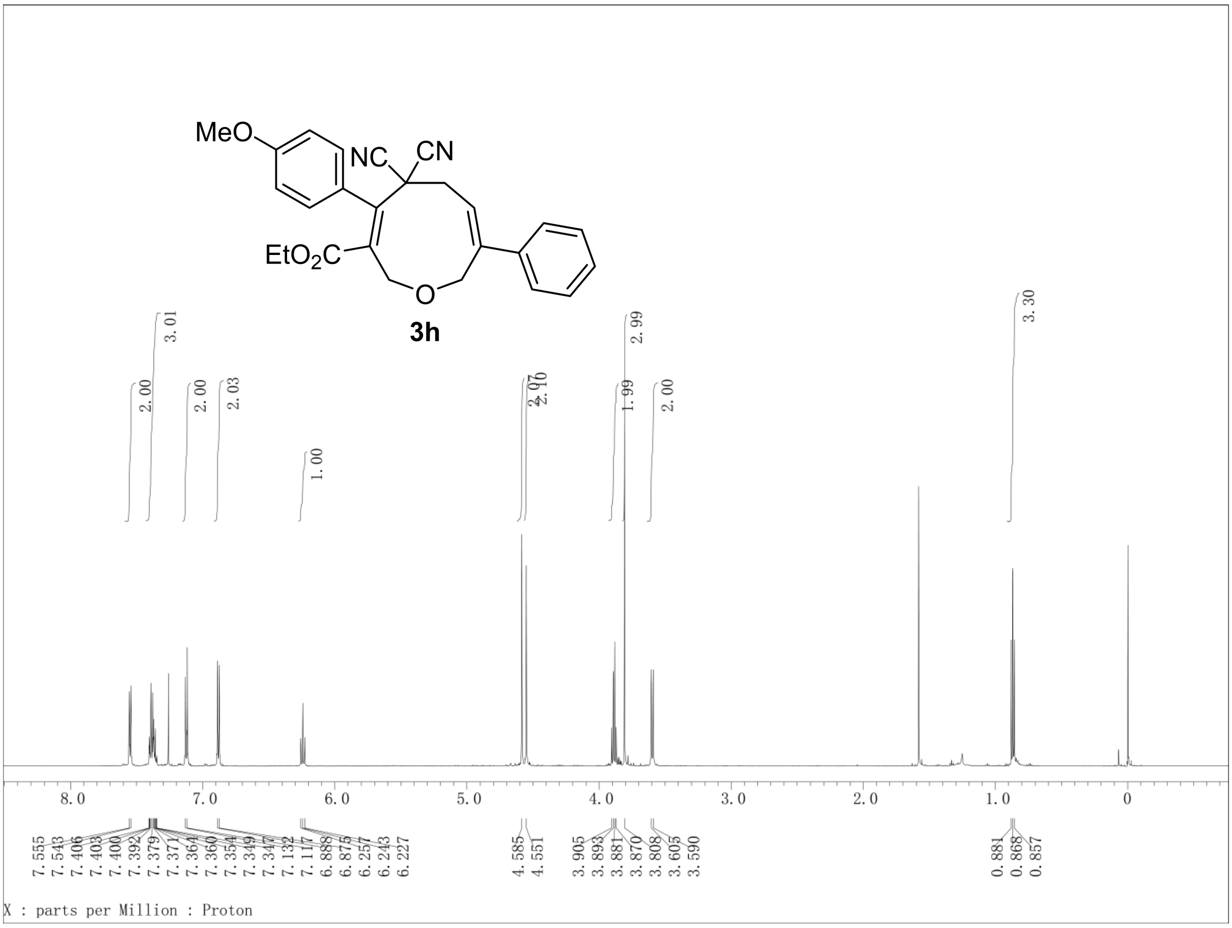
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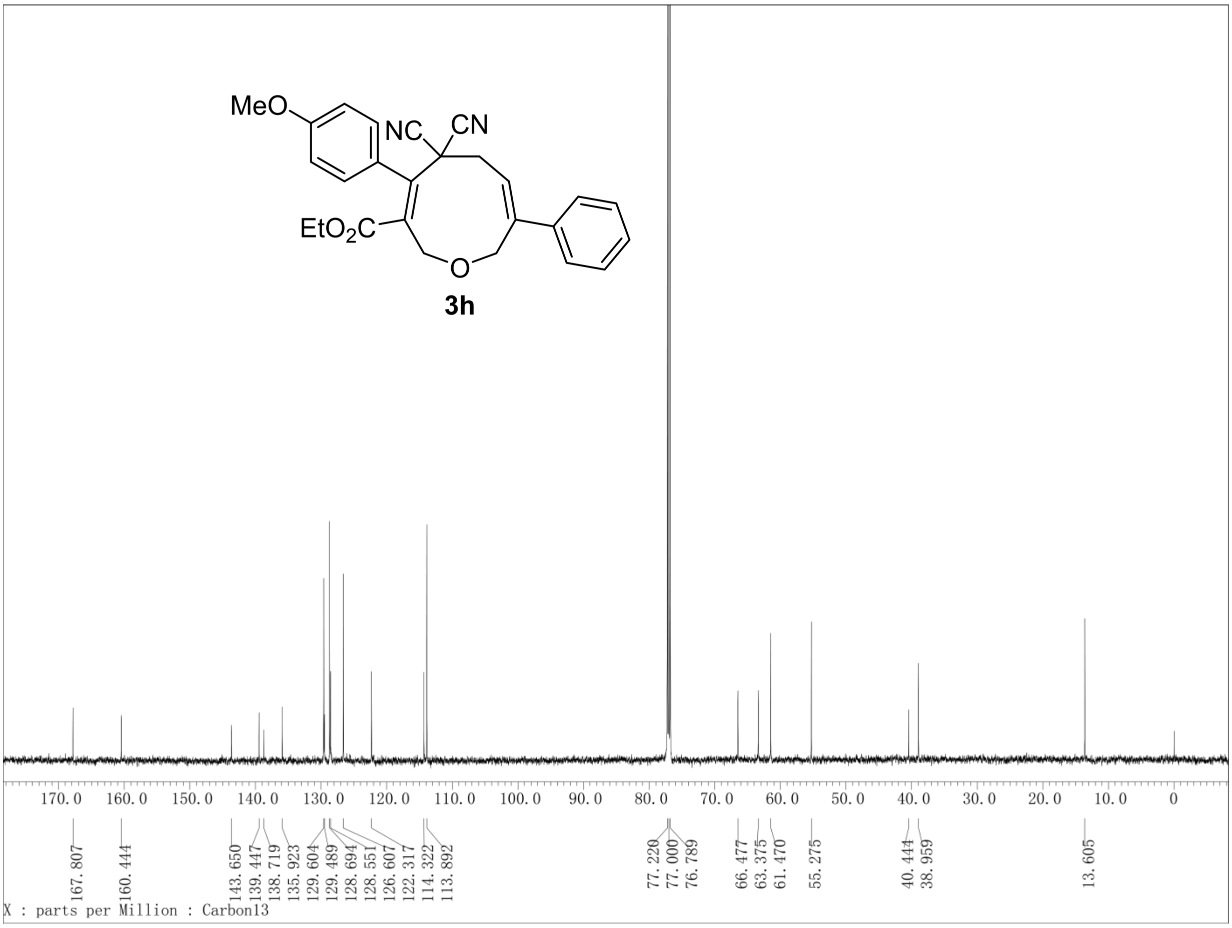
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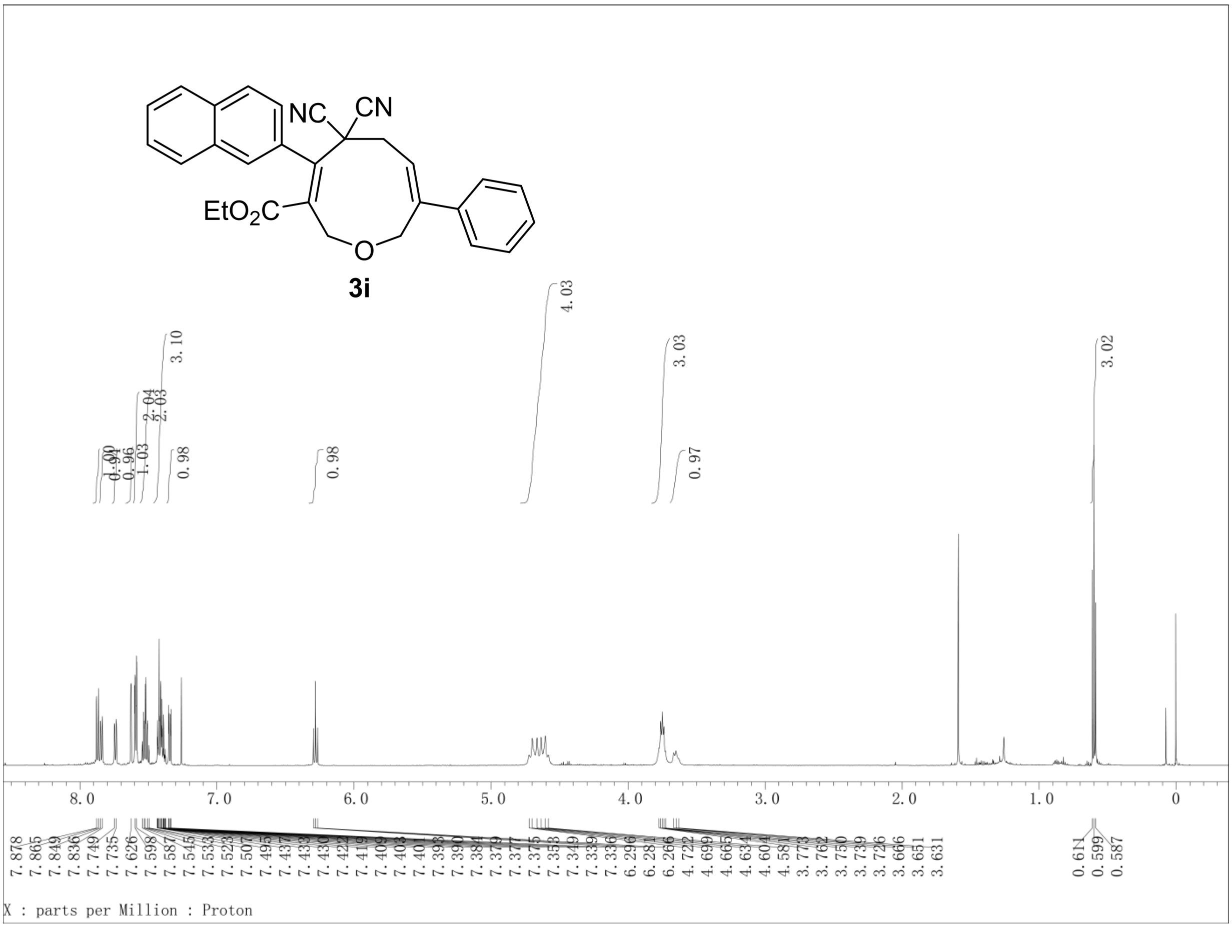
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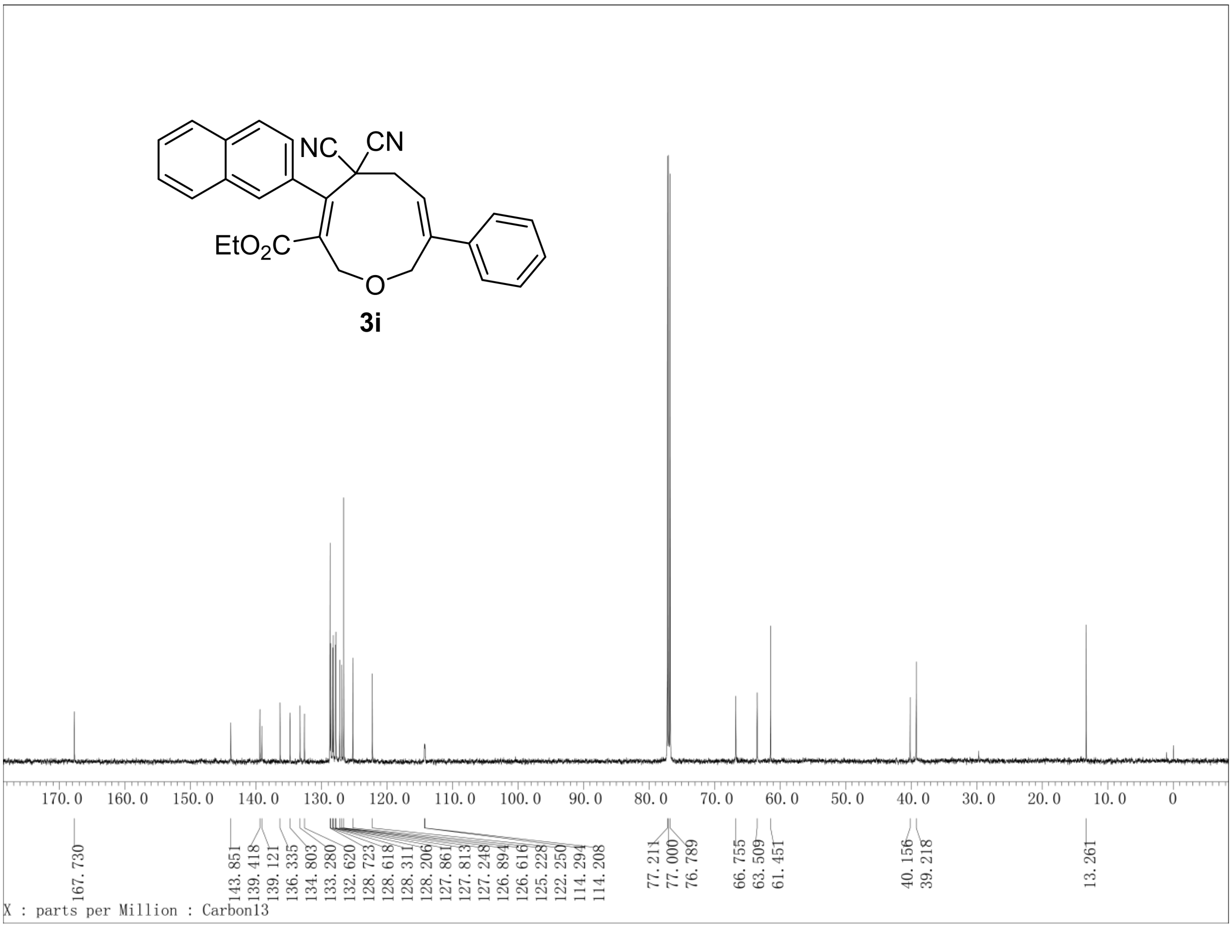
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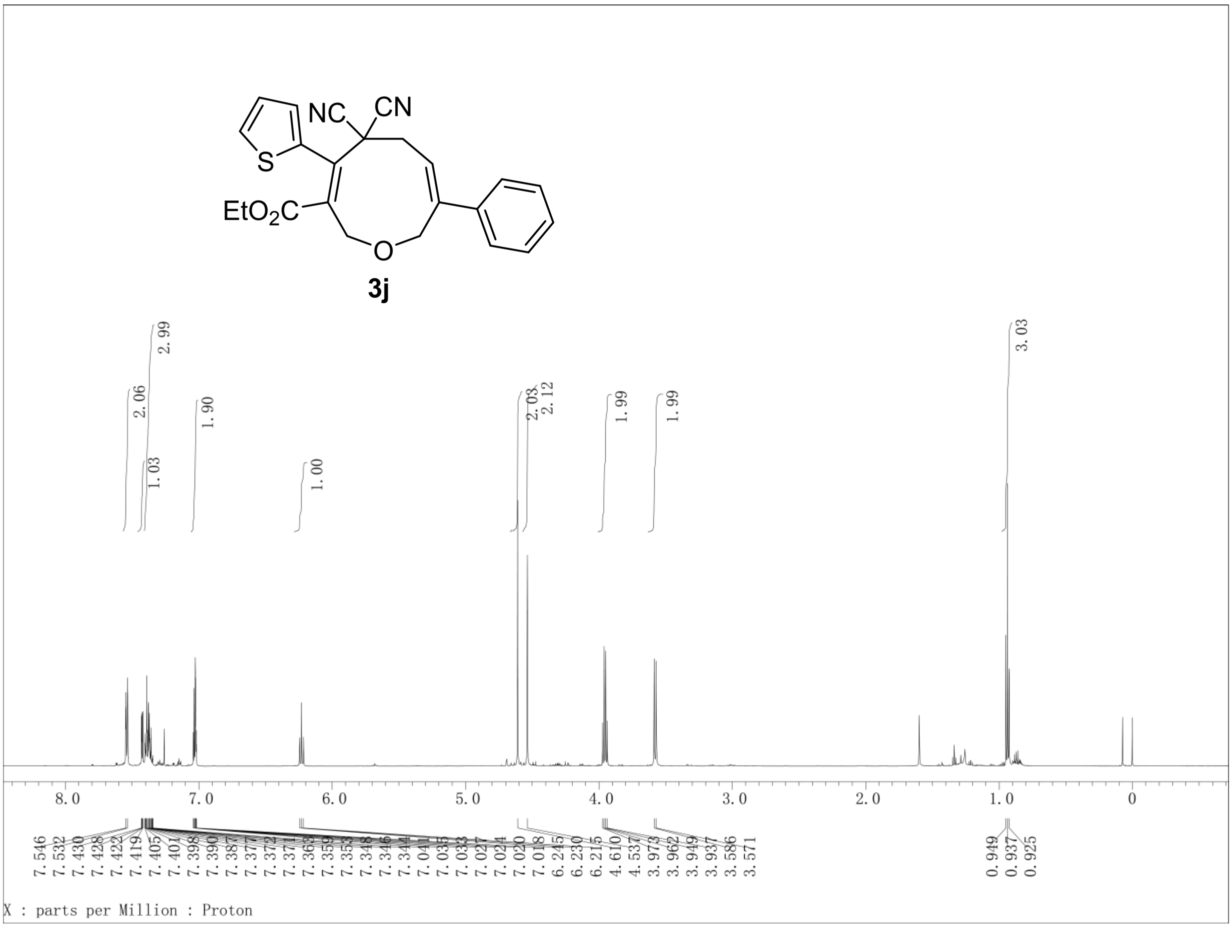
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1.0
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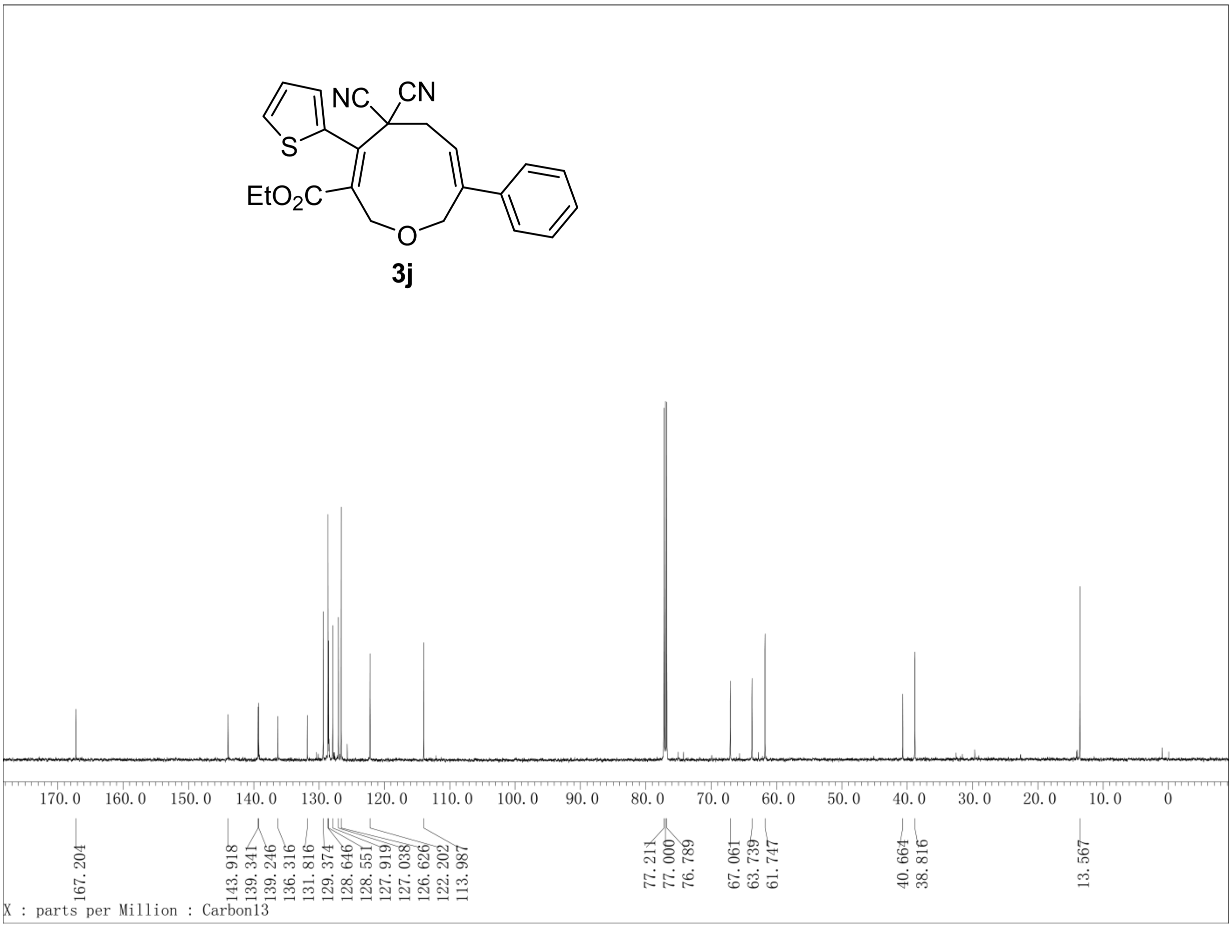
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O
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20.0
10.0
0
167.204
143.918
139.341
139.246
136.316
131.816
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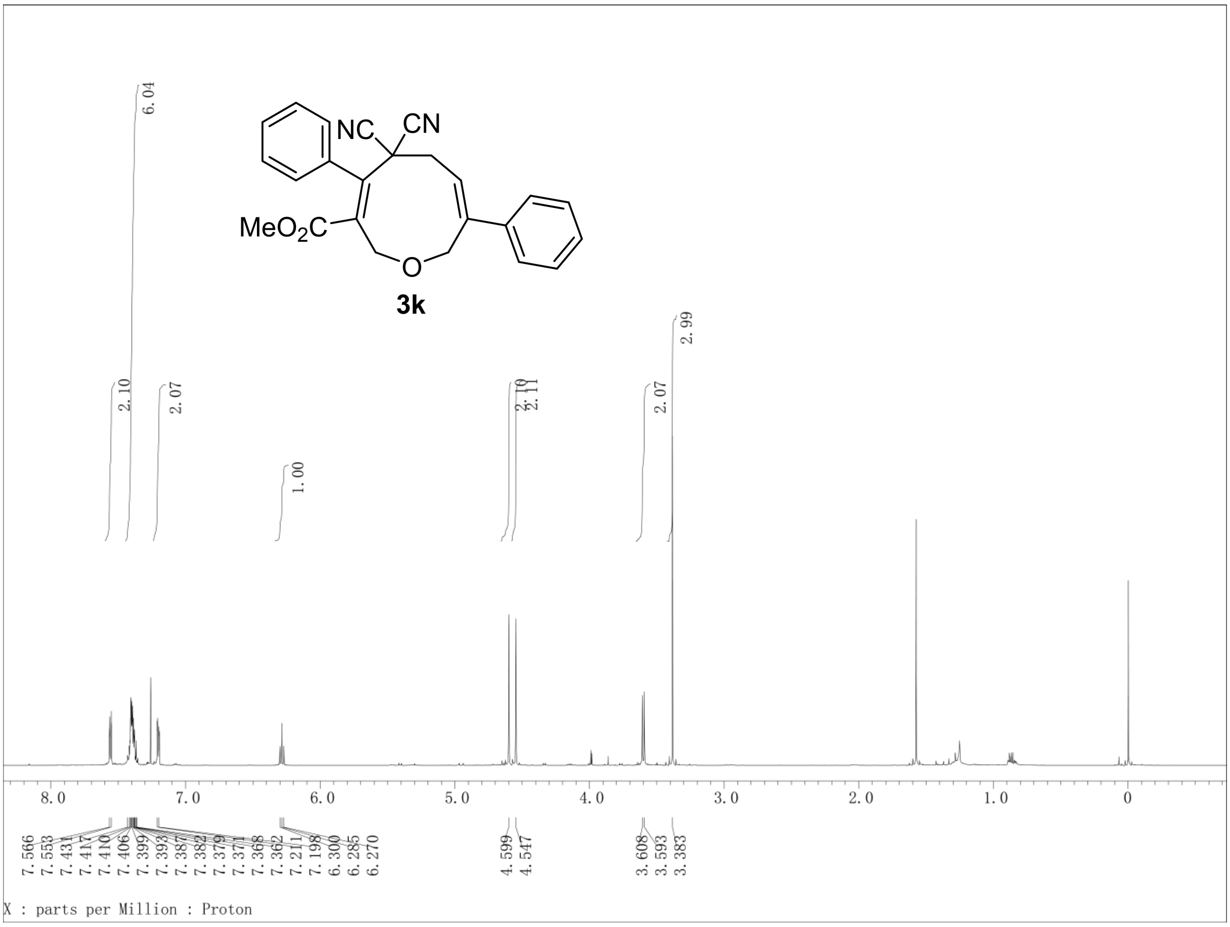
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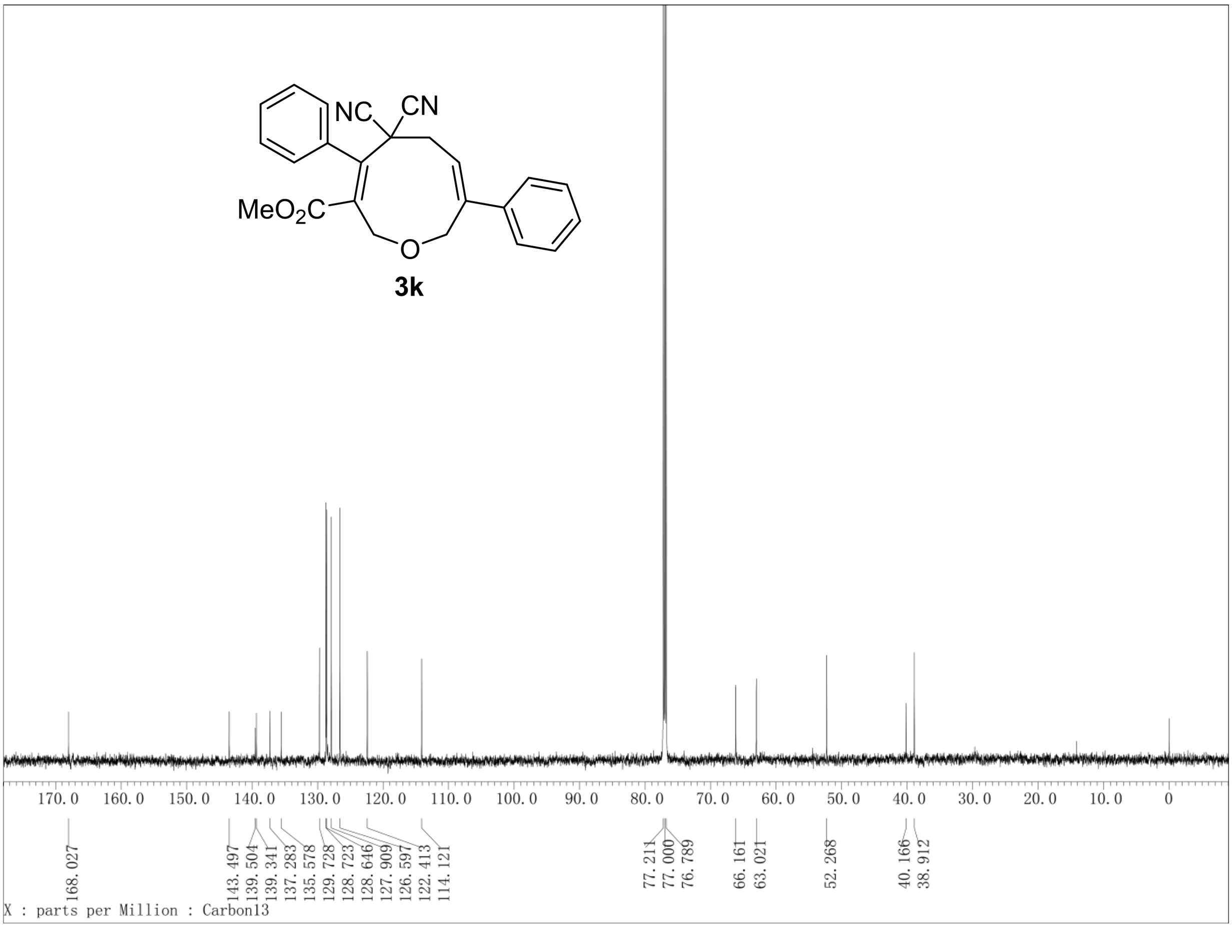
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MeO$_2$C
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60.0
50.0
40.0
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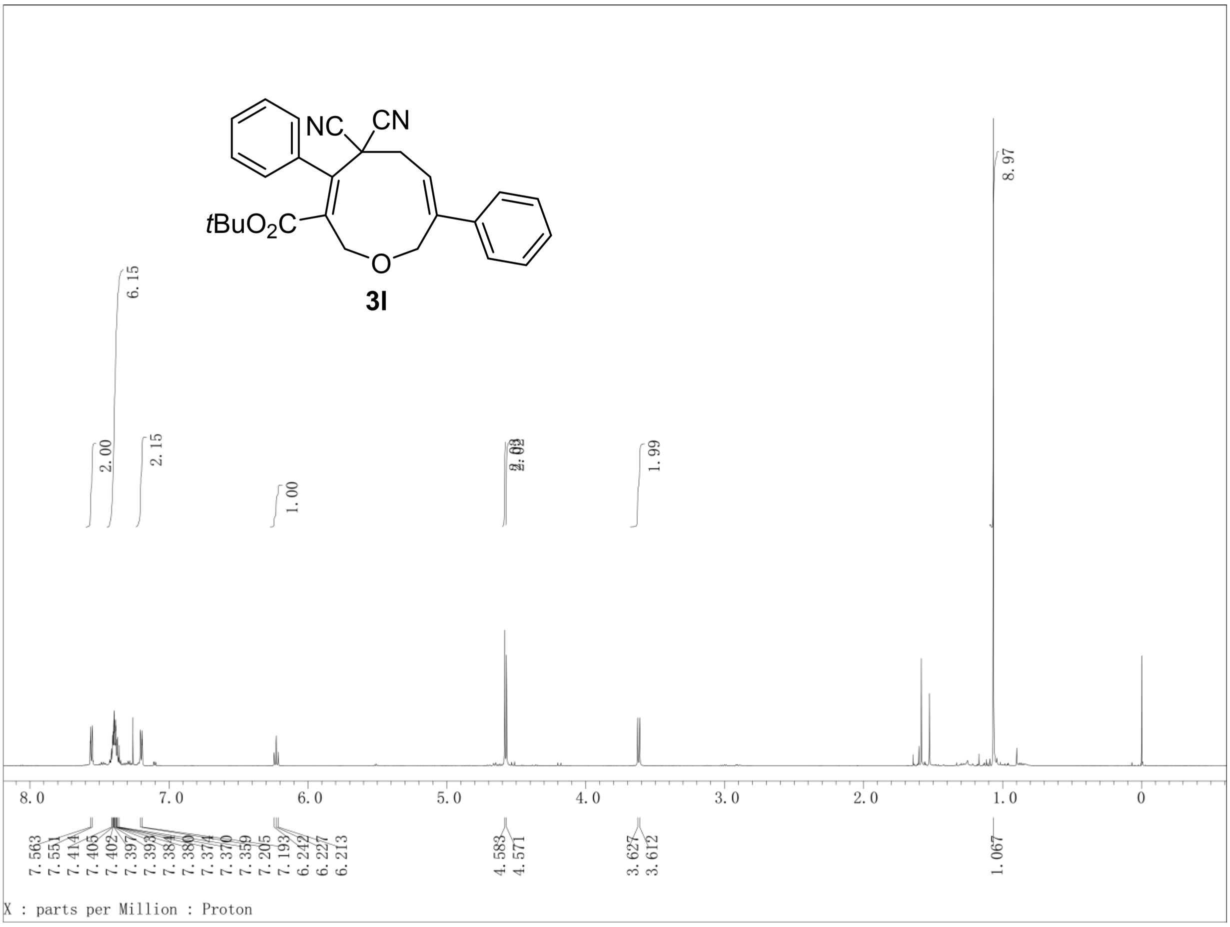
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2.02
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6.0
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3.0
2.0
1.0
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7.551
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7.402
7.397
7.393
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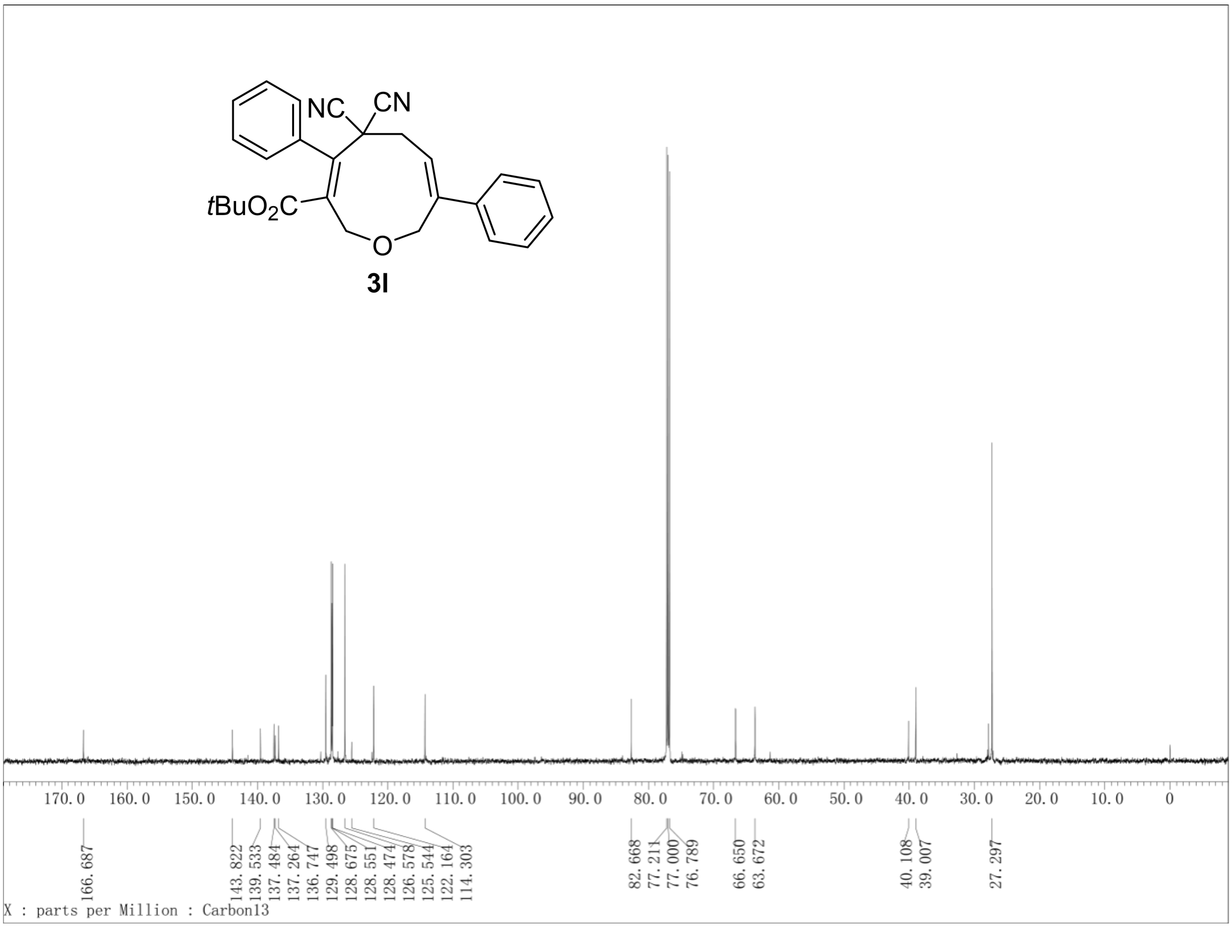
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70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
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143.822
139.533
137.484
137.264
136.747
129.498
128.675
128.551
128.474
126.578
125.544
122.164
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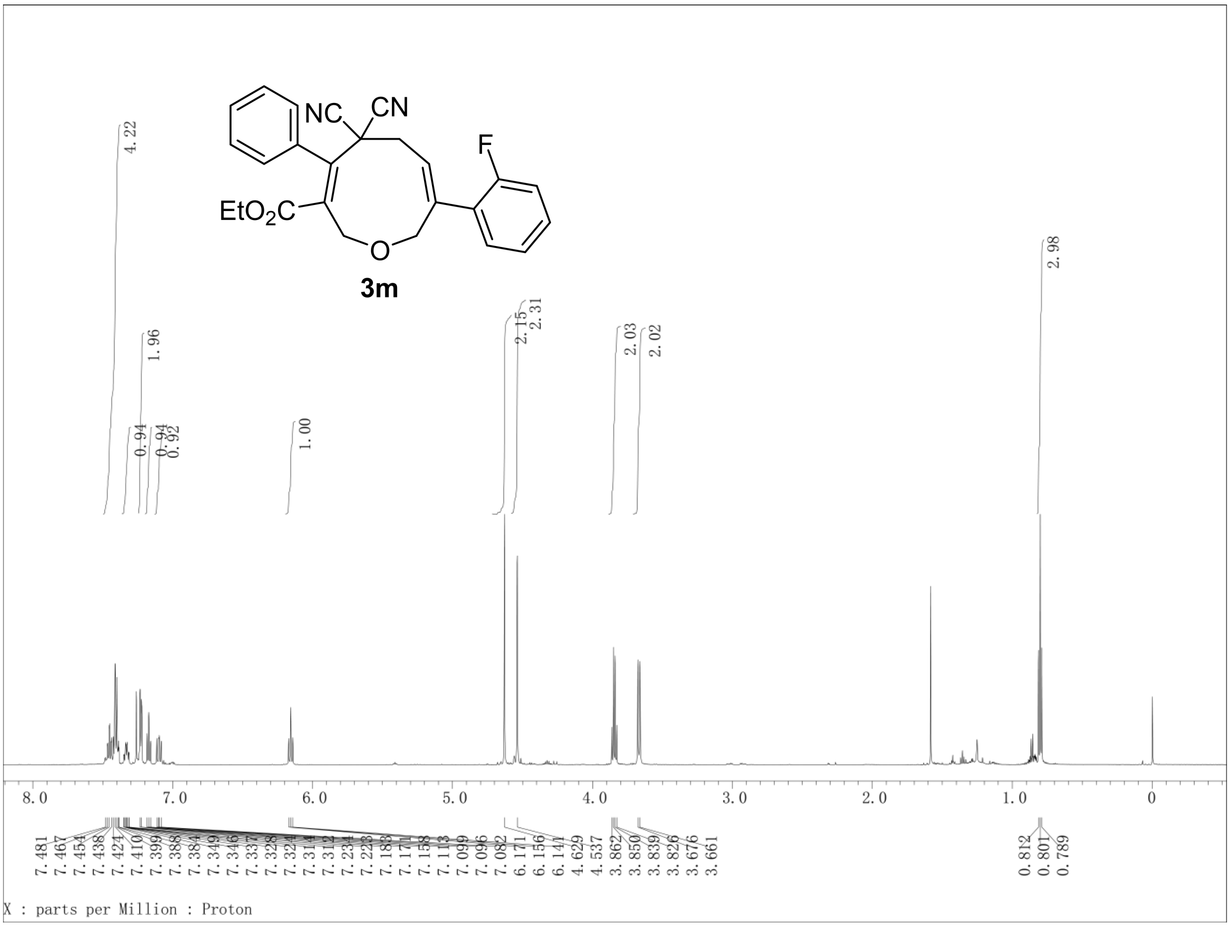
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2.03
2.02
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4.0
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2.0
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7.384
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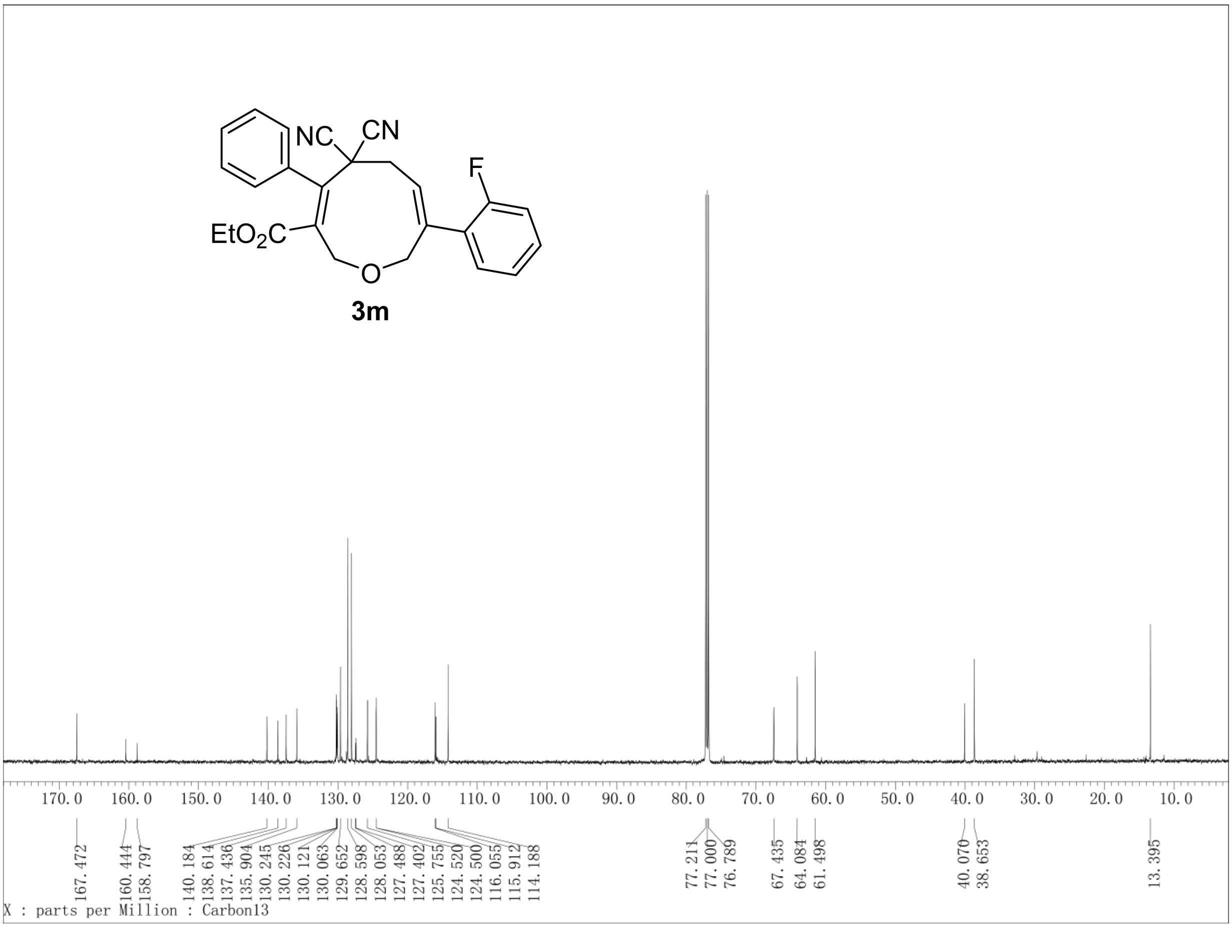
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20.0
10.0
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158.797
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138.614
137.436
135.904
130.245
130.226
130.121
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128.598
128.053
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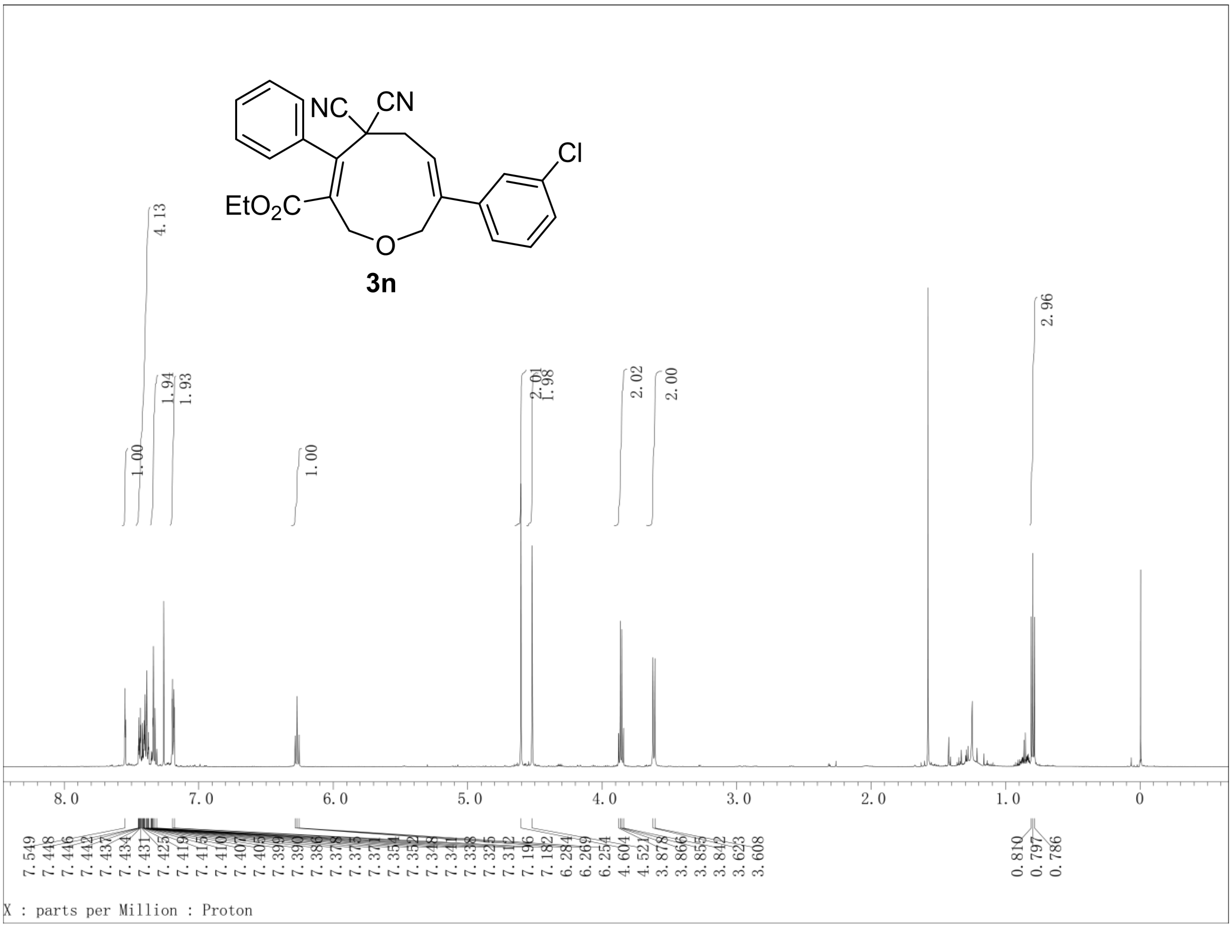
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7.446
7.442
7.437
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7.431
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7.415
7.410
7.407
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7.378
7.375
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7.325
7.312
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7.182
6.284
6.269
6.254
4.604
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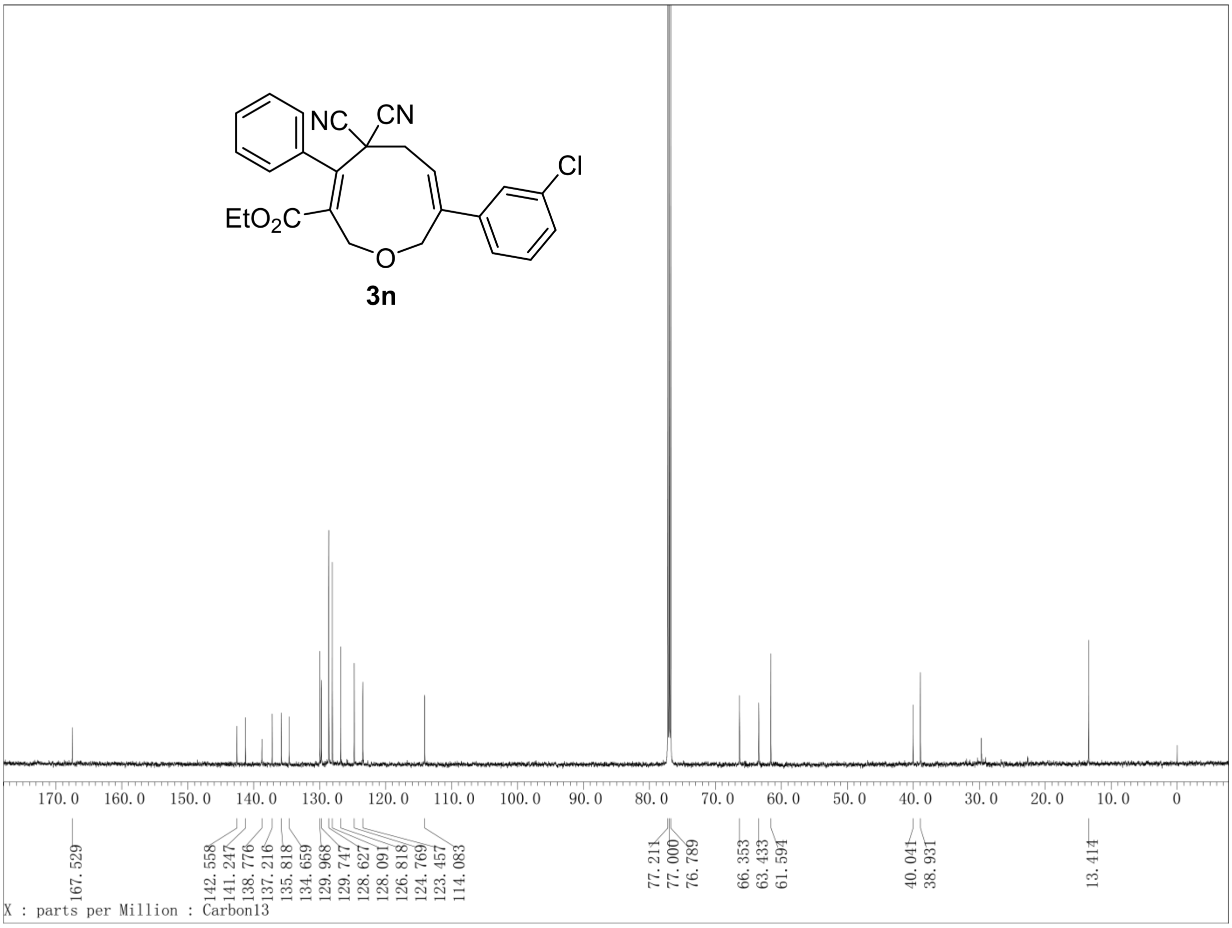
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80.0
70.0
60.0
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40.0
30.0
20.0
10.0
0
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141.247
138.776
137.216
135.818
134.659
129.968
129.747
128.627
128.091
126.818
124.769
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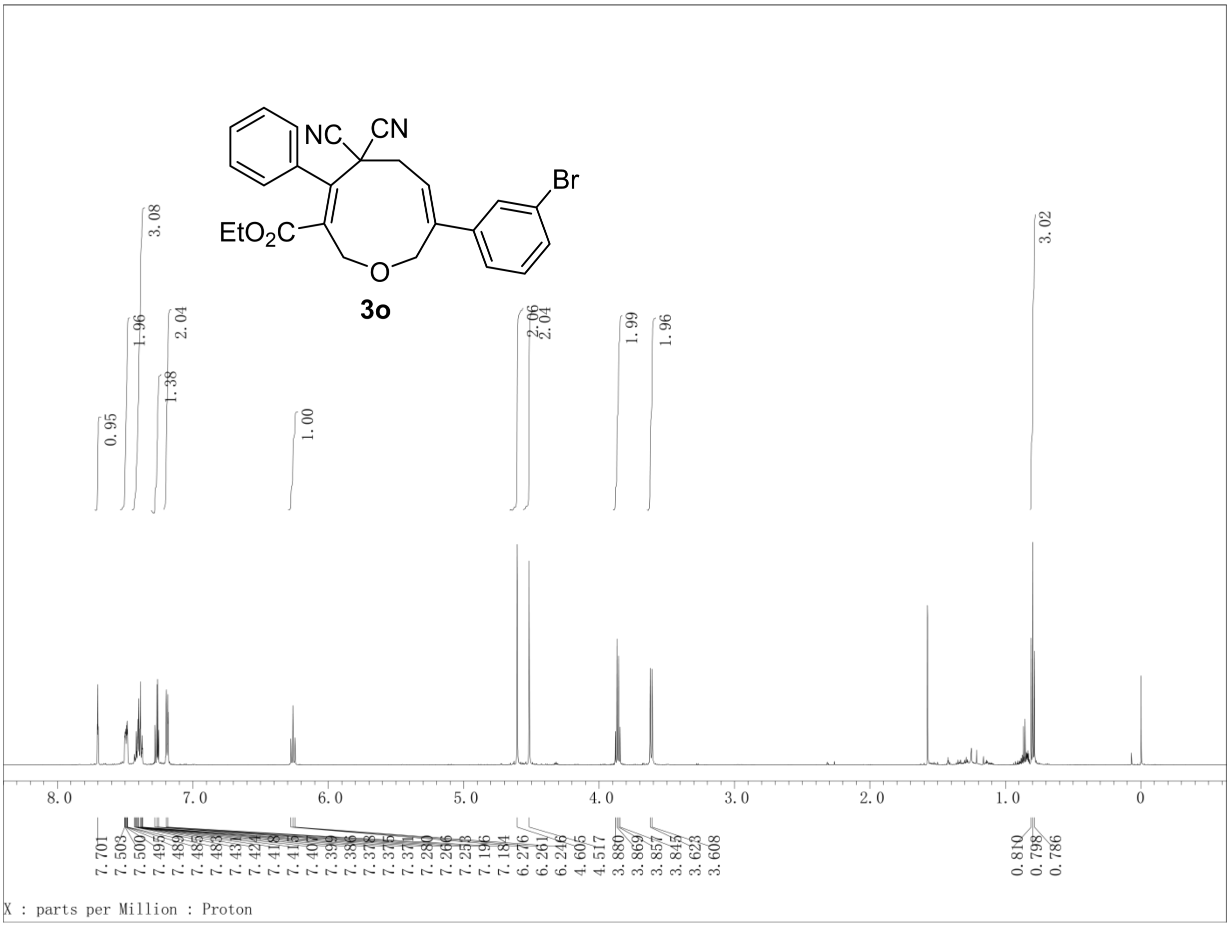
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EtO2C
O
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7.500
7.495
7.489
7.485
7.483
7.431
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7.418
7.415
7.407
7.399
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7.378
7.375
7.371
7.280
7.266
7.253
7.196
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6.261
6.246
4.605
4.517
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3.608
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0.786
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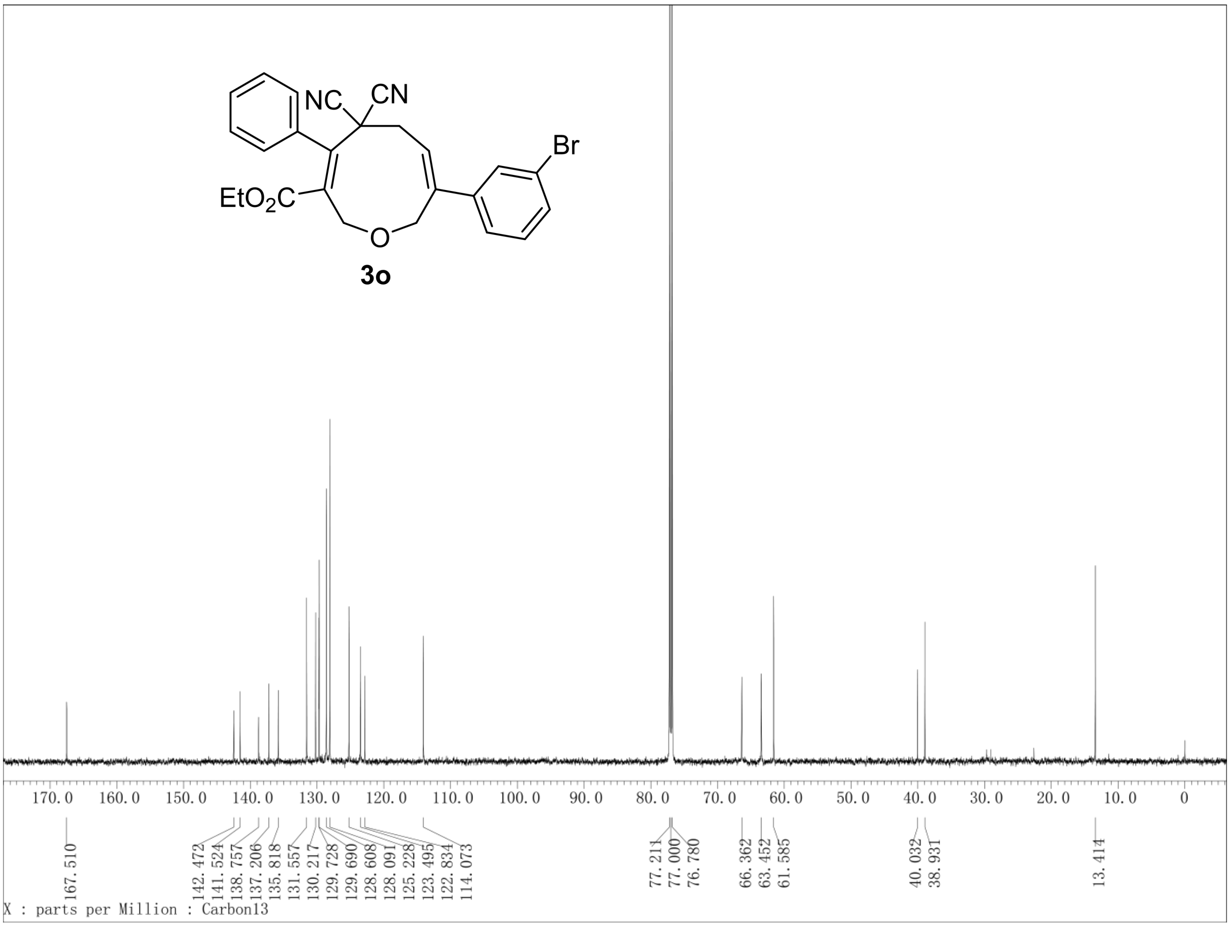
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O
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110.0
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130.217
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128.608
128.091
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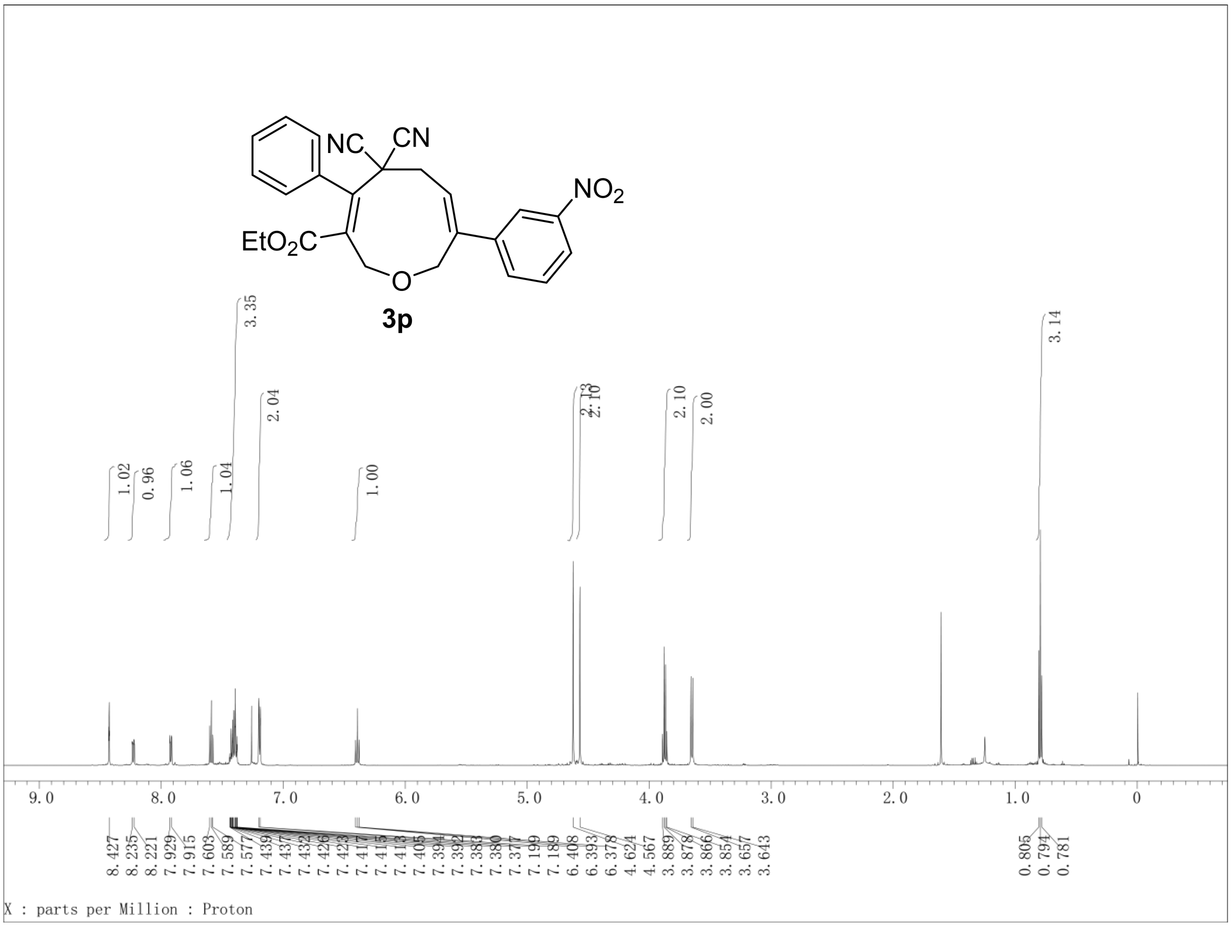
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2.10
2.00
3.14
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7.0
6.0
5.0
4.0
3.0
2.0
1.0
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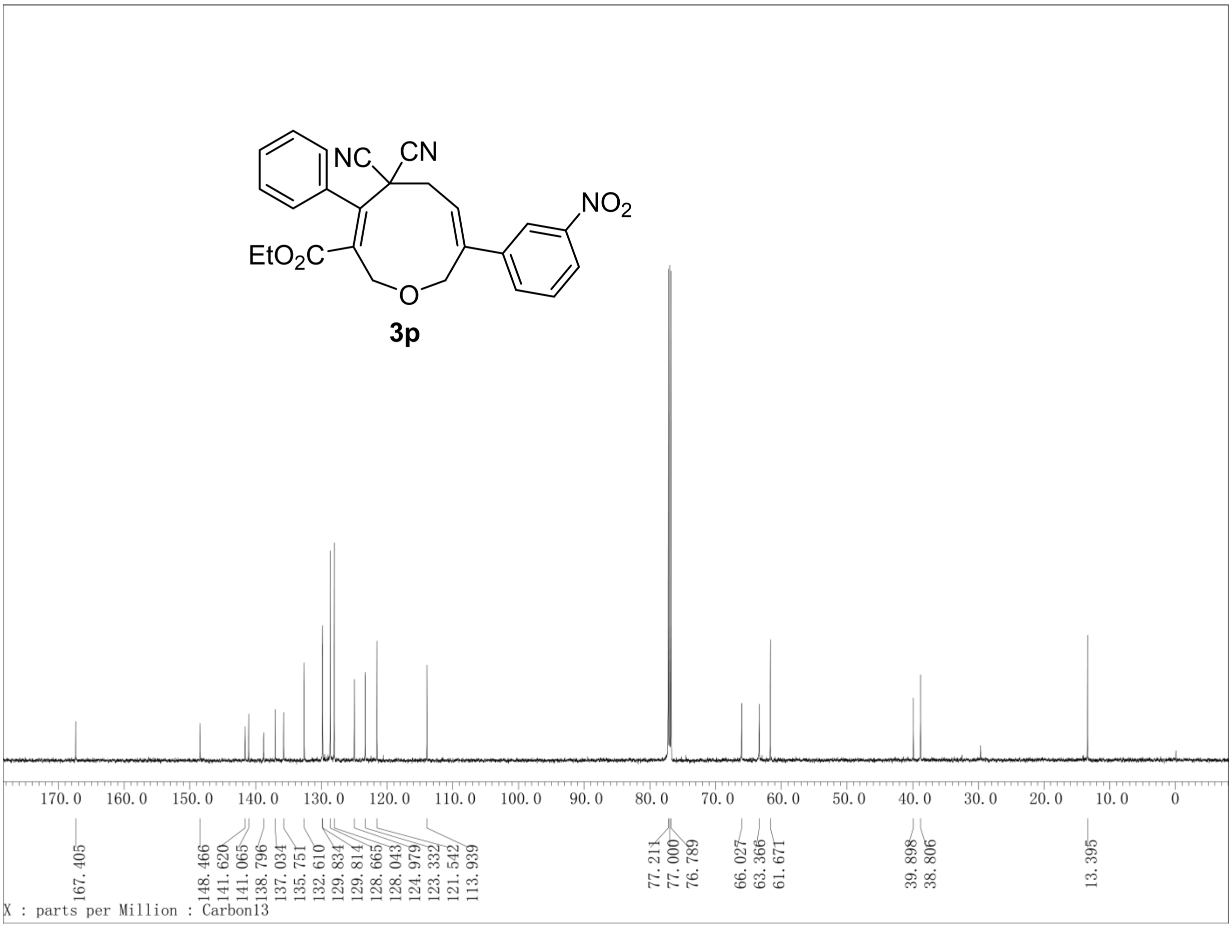
X : parts per Million : Proton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20.0
10.0
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167.405
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141.065
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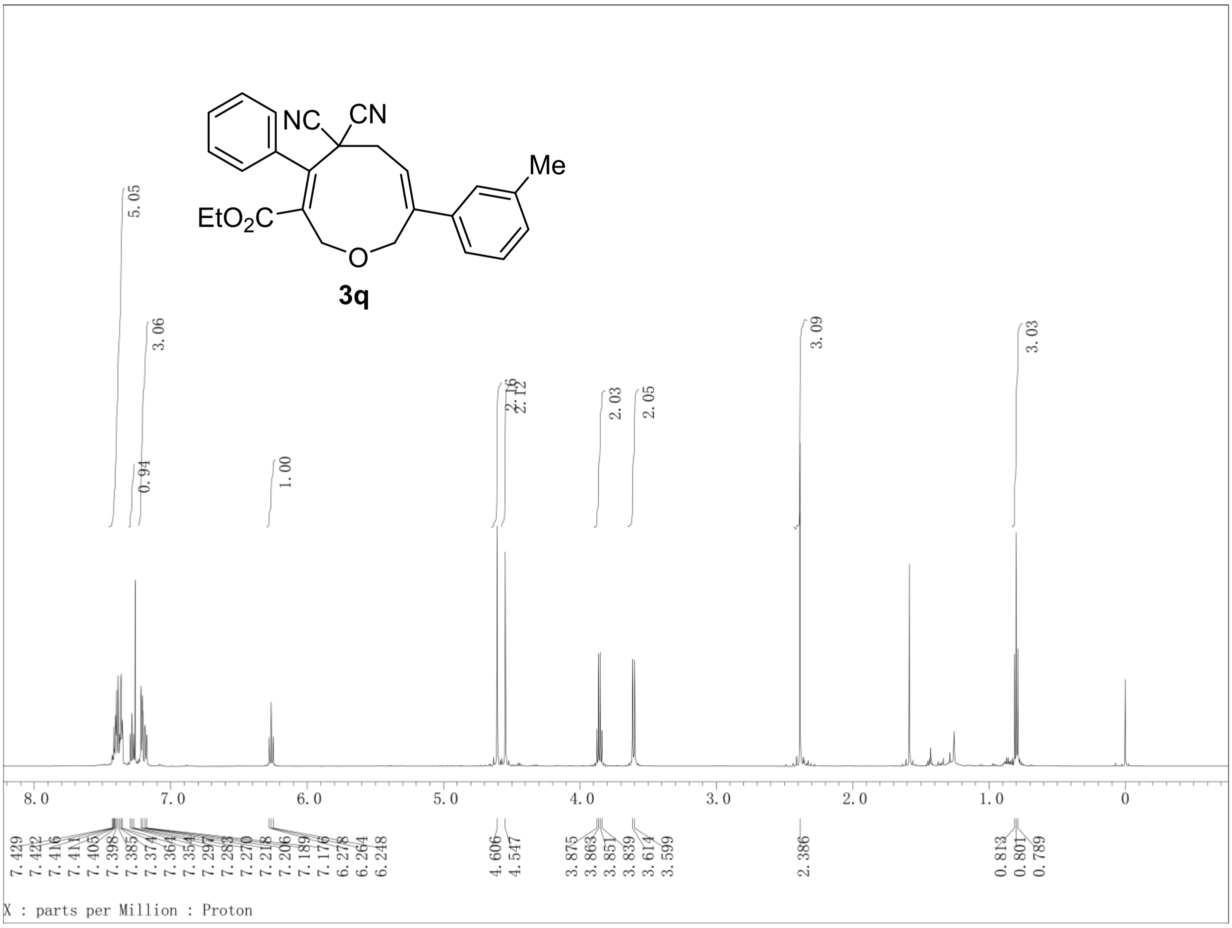
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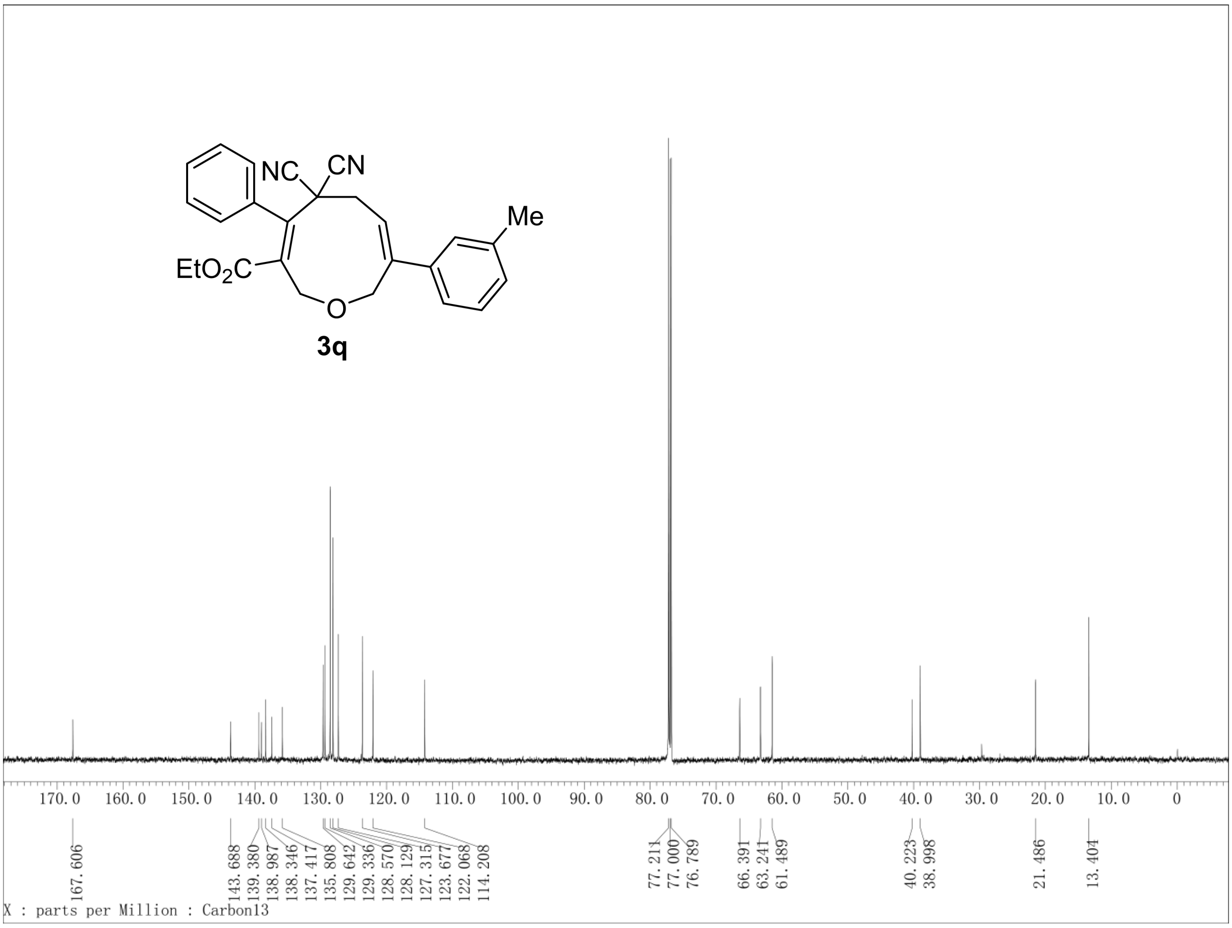
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90.0
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70.0
60.0
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40.0
30.0
20.0
10.0
0
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138.987
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129.336
128.570
128.129
127.315
123.677
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114.208
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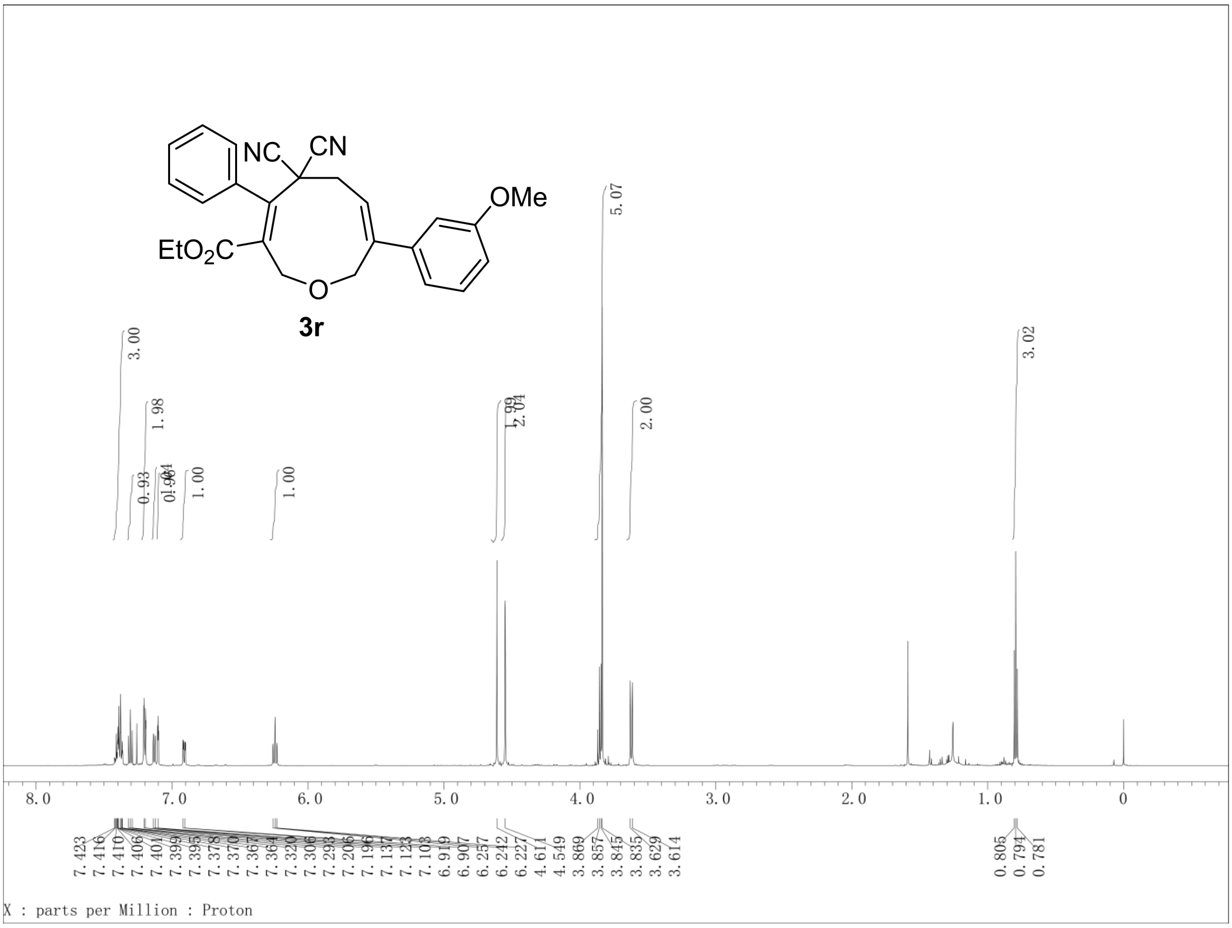
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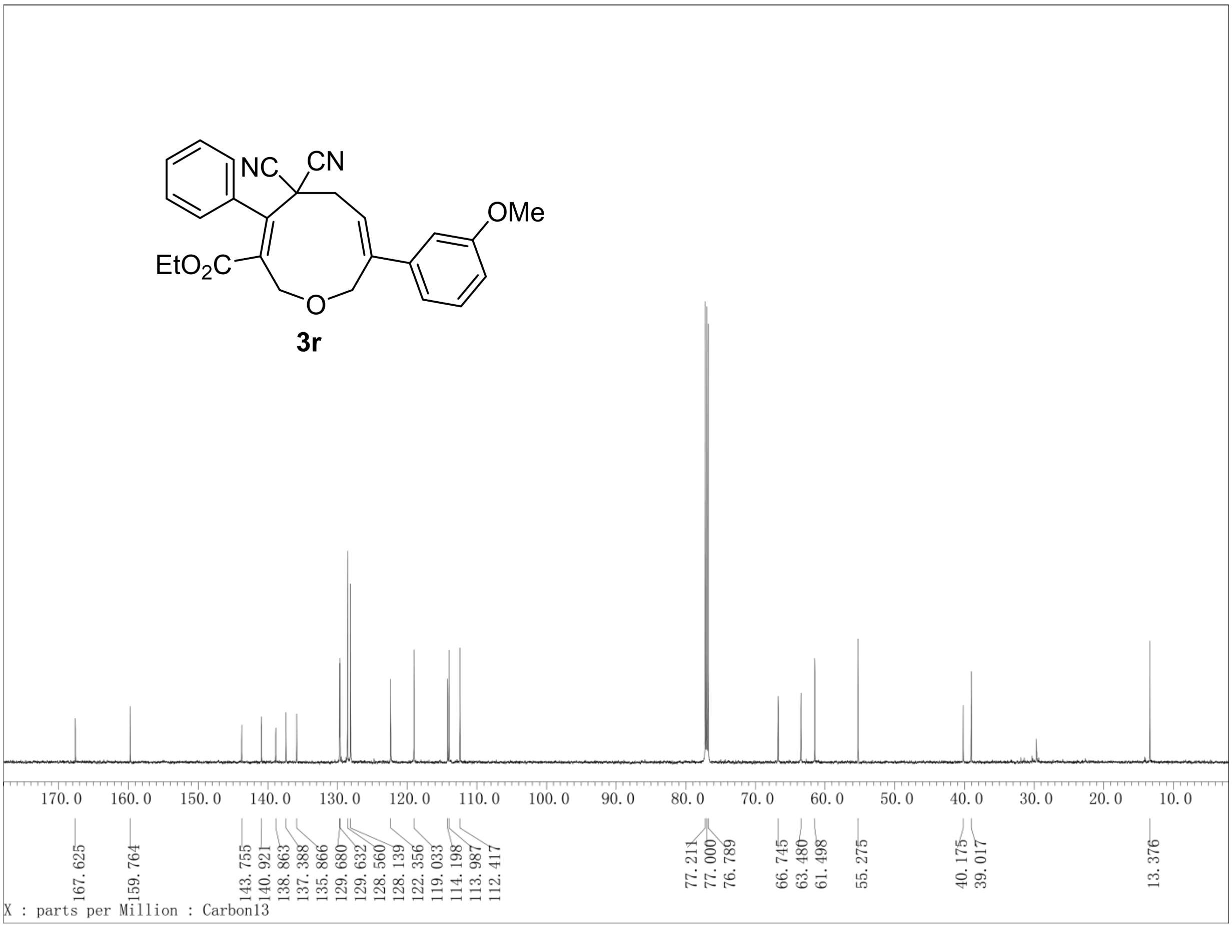
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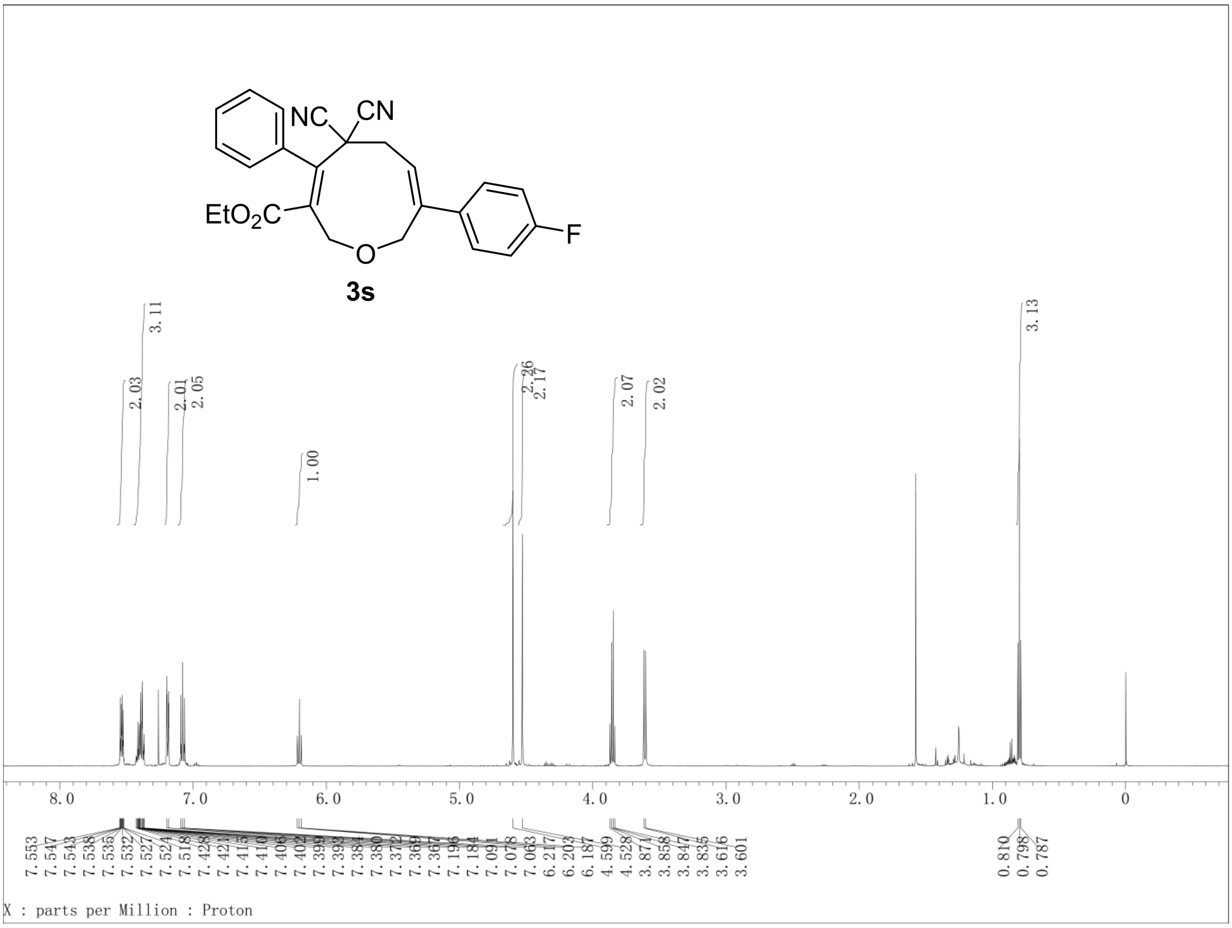
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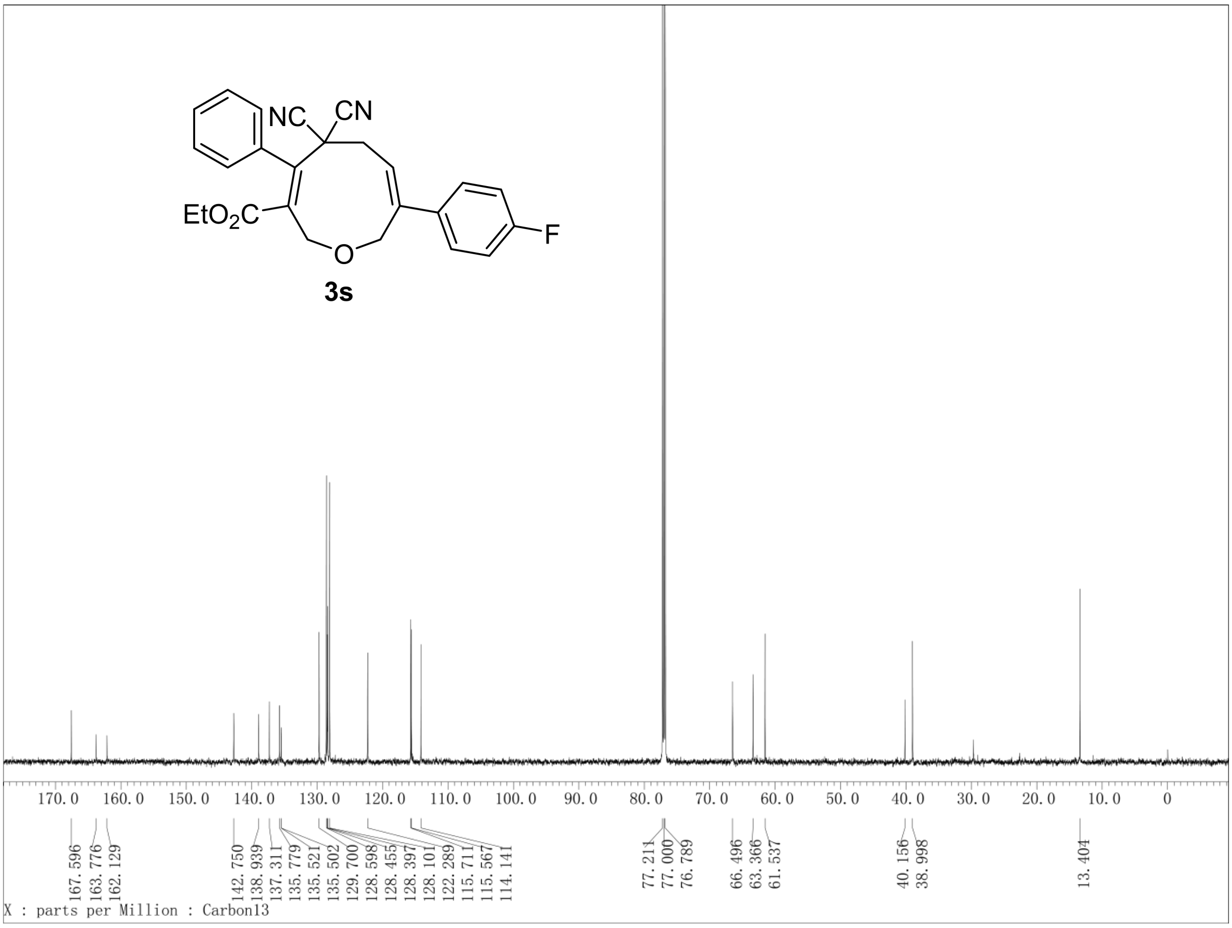
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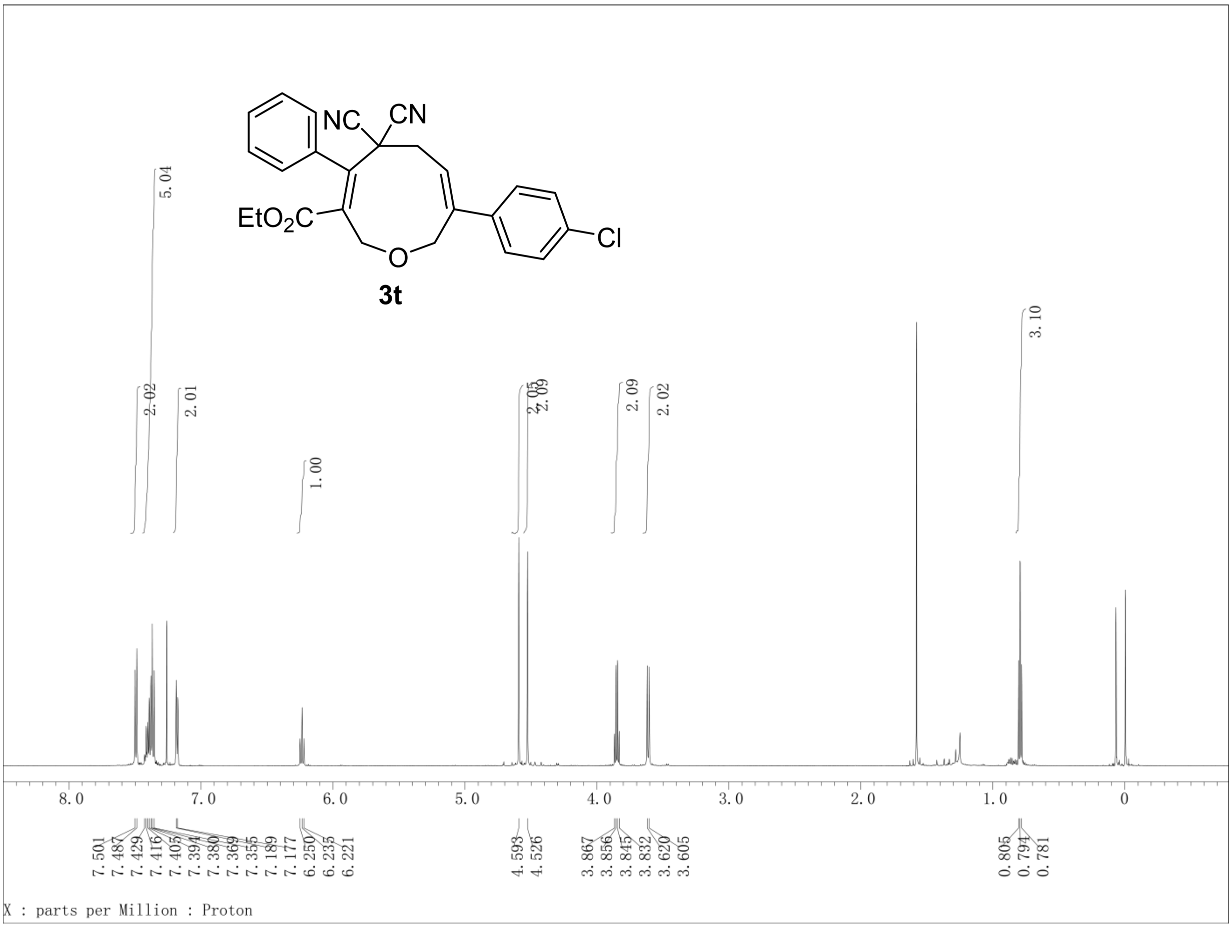
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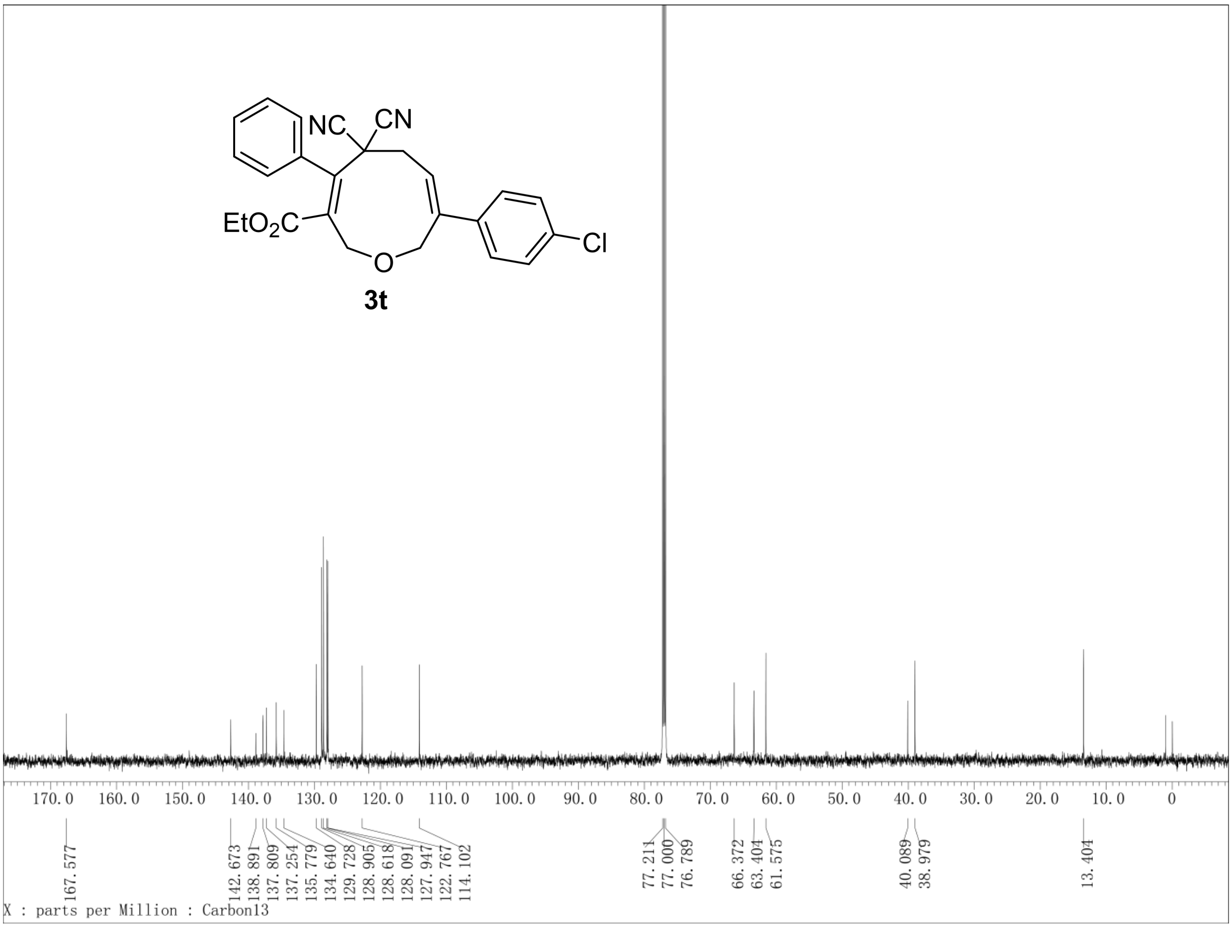
0.781
X : parts per Million : Proton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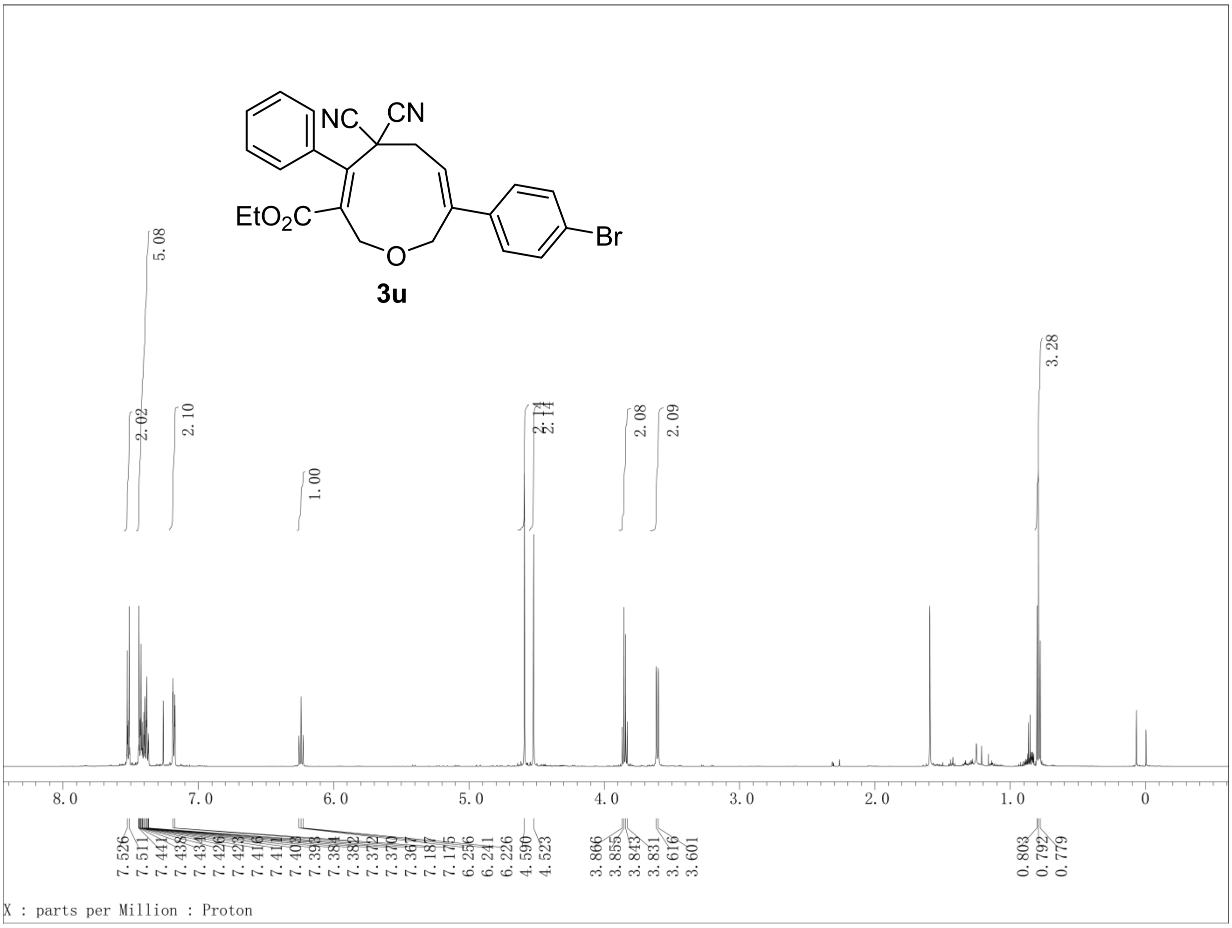
X : parts per Million : Carbon13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3.0
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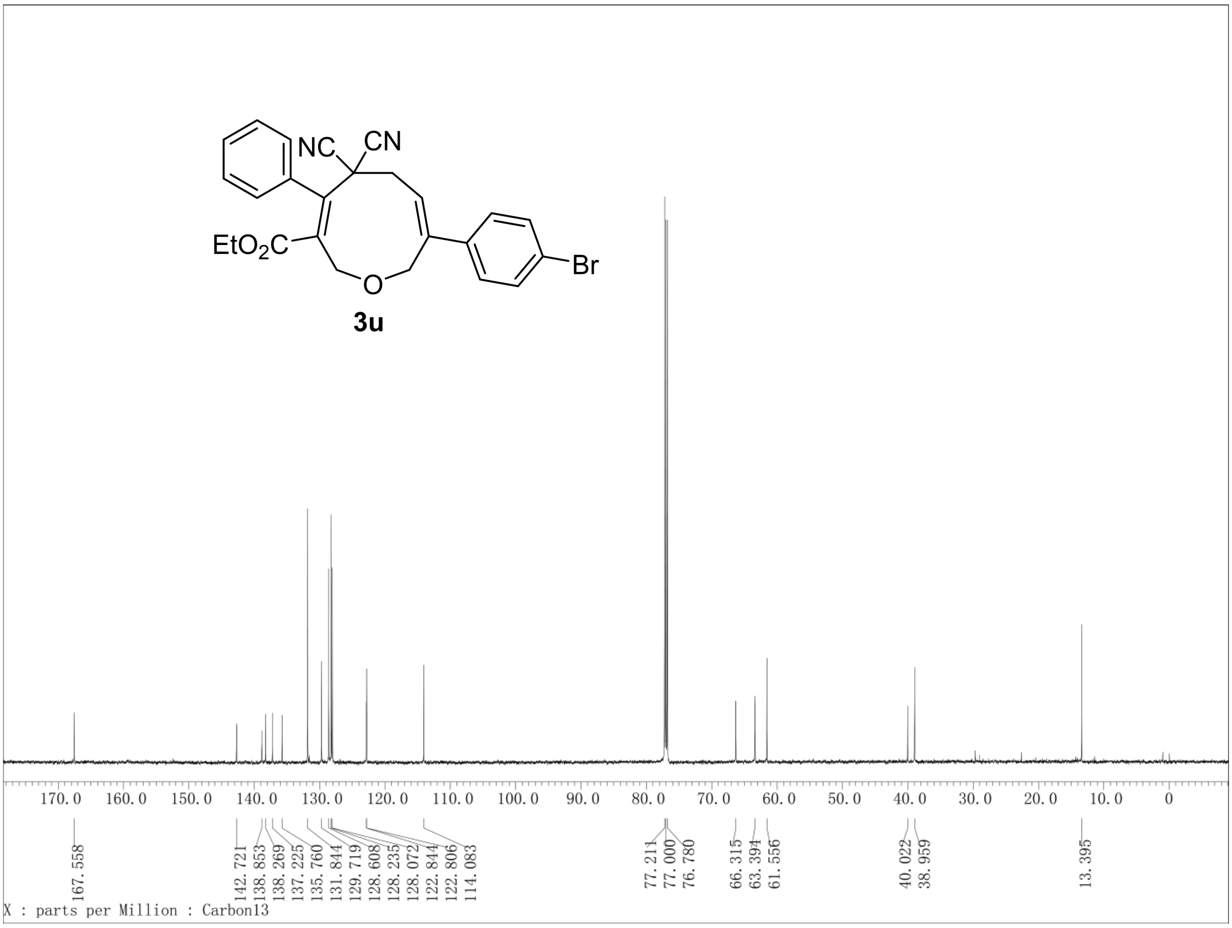
X : parts per Million : Proton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O
Br
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120.0
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100.0
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80.0
70.0
60.0
50.0
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20.0
10.0
0
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137.225
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128.072
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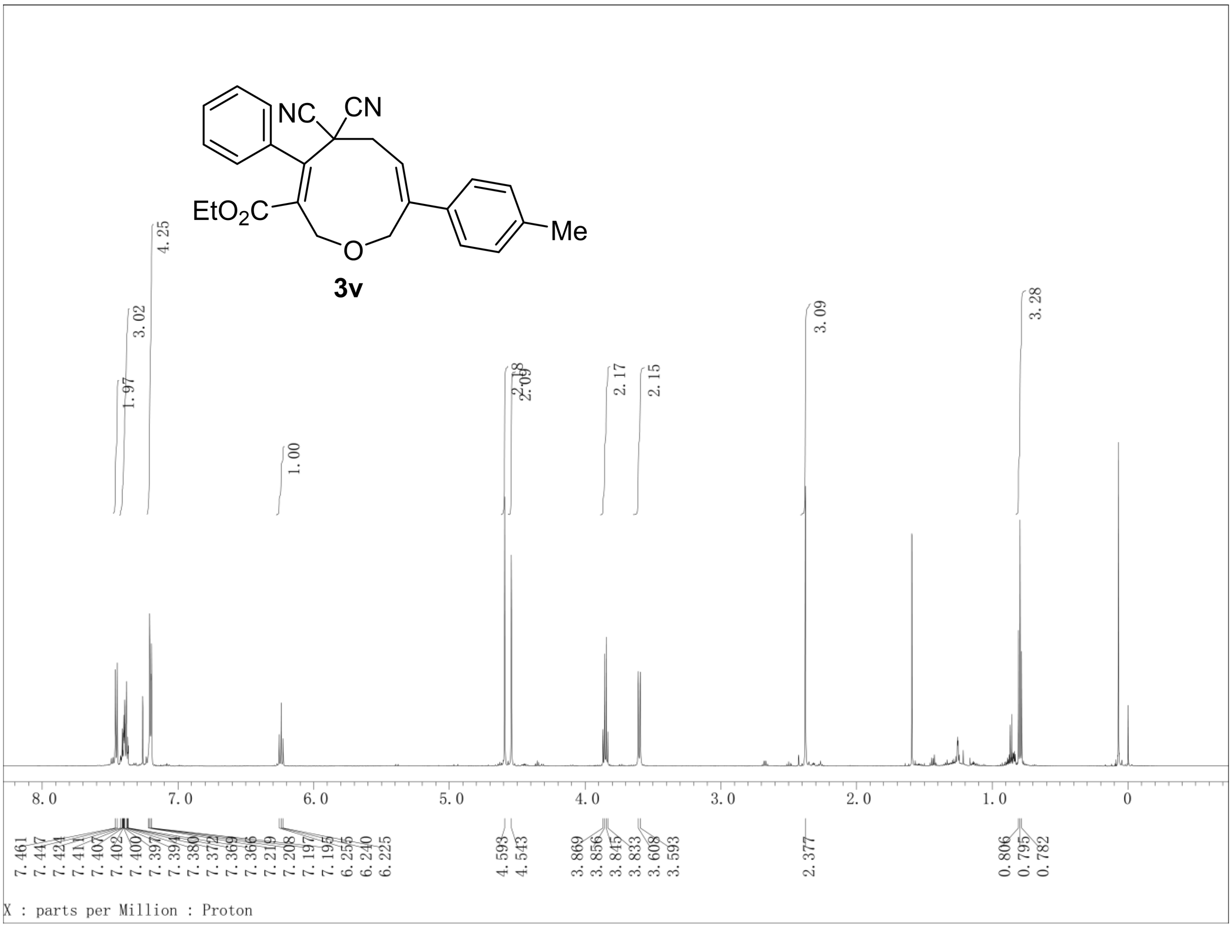
X : parts per Million : Carbon13



3v

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4.0
3.0
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1.0
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7.424
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6.255
6.240
6.225
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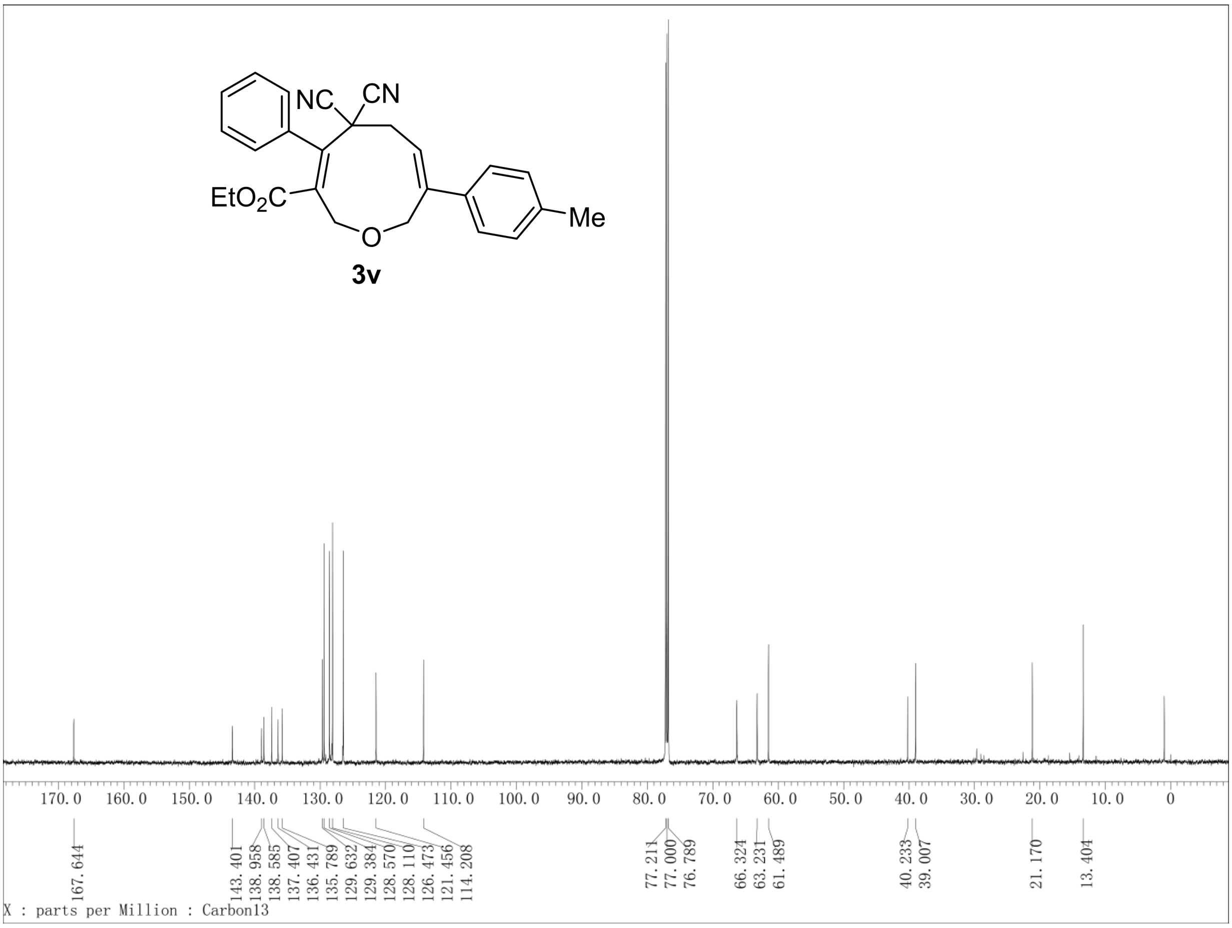

3v

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CN
EtO2C
O
Me
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150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
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143.401
138.958
138.585
137.407
136.431
135.789
129.632
129.384
128.570
128.110
126.473
121.456
114.208
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63.231
61.489
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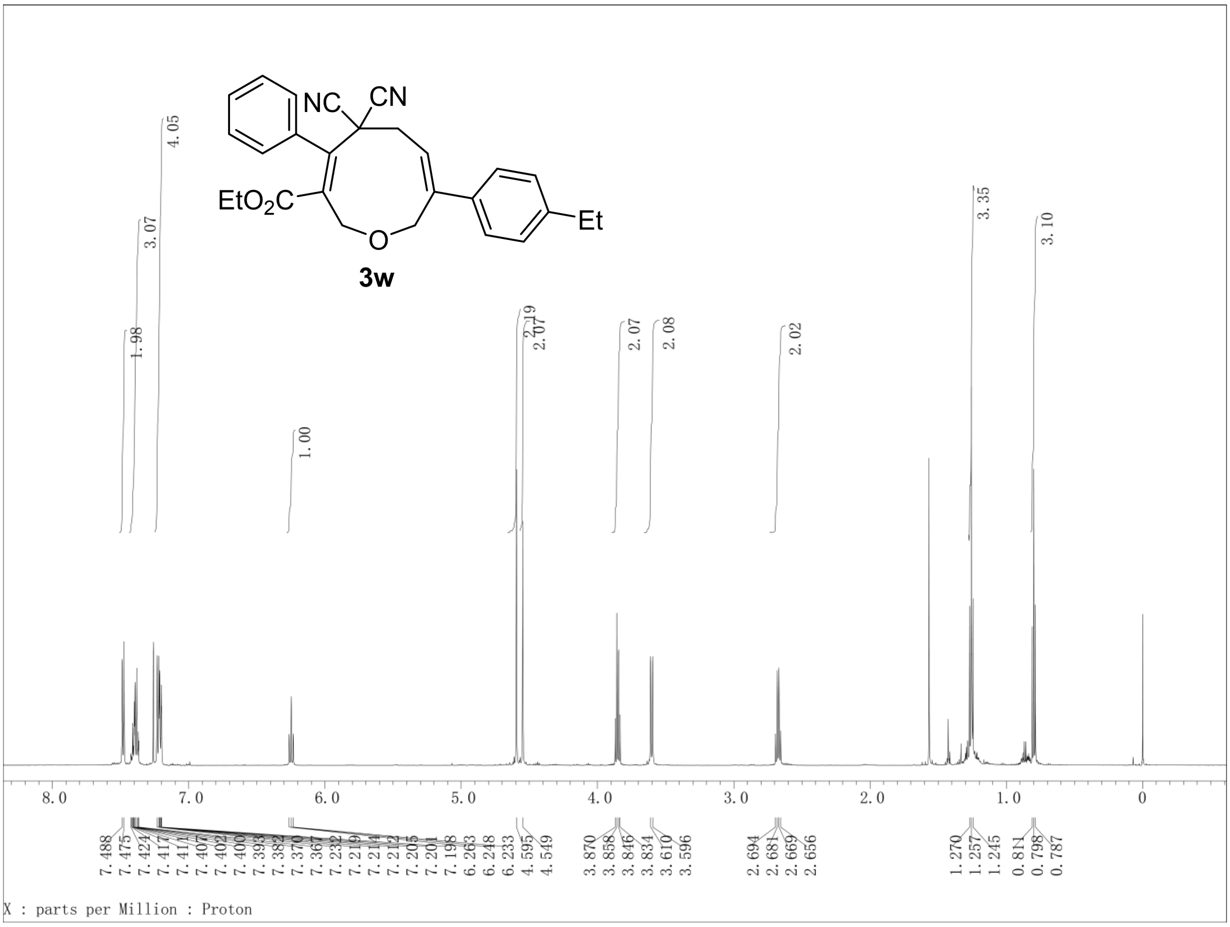
13.404
X : parts per Million : Carbon13


3w

NC
CN
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2.07
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2.08
2.02
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3.10
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7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
7.488
7.475
7.424
7.417
7.411
7.407
7.402
7.400
7.393
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7.367
7.232
7.219
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7.212
7.205
7.201
7.198
6.263
6.248
6.233
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4.549
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3.846
3.834
3.610
3.596
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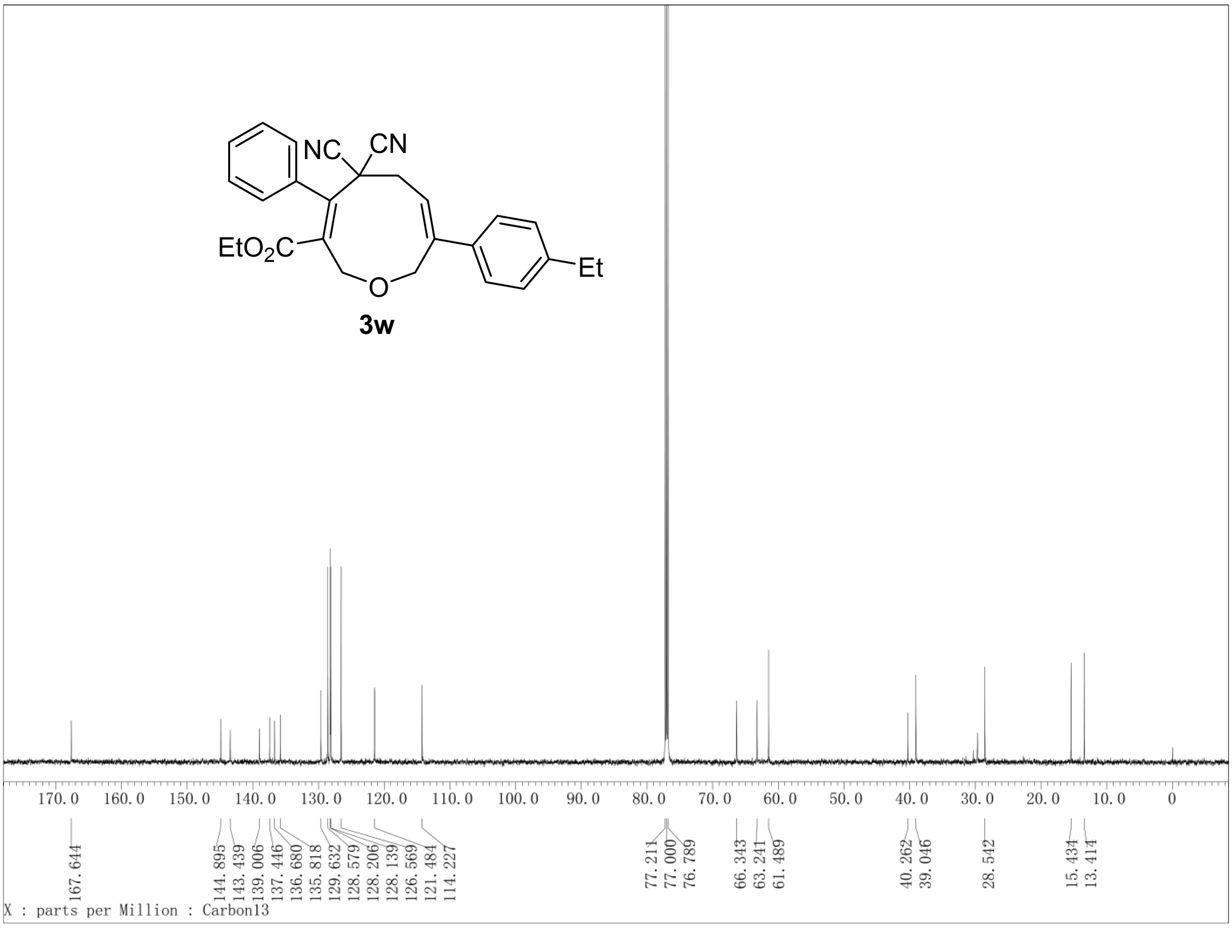
3w

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70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
167.644
144.895
143.439
139.006
137.446
136.680
135.818
129.632
128.579
128.206
128.139
126.569
121.484
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77.211
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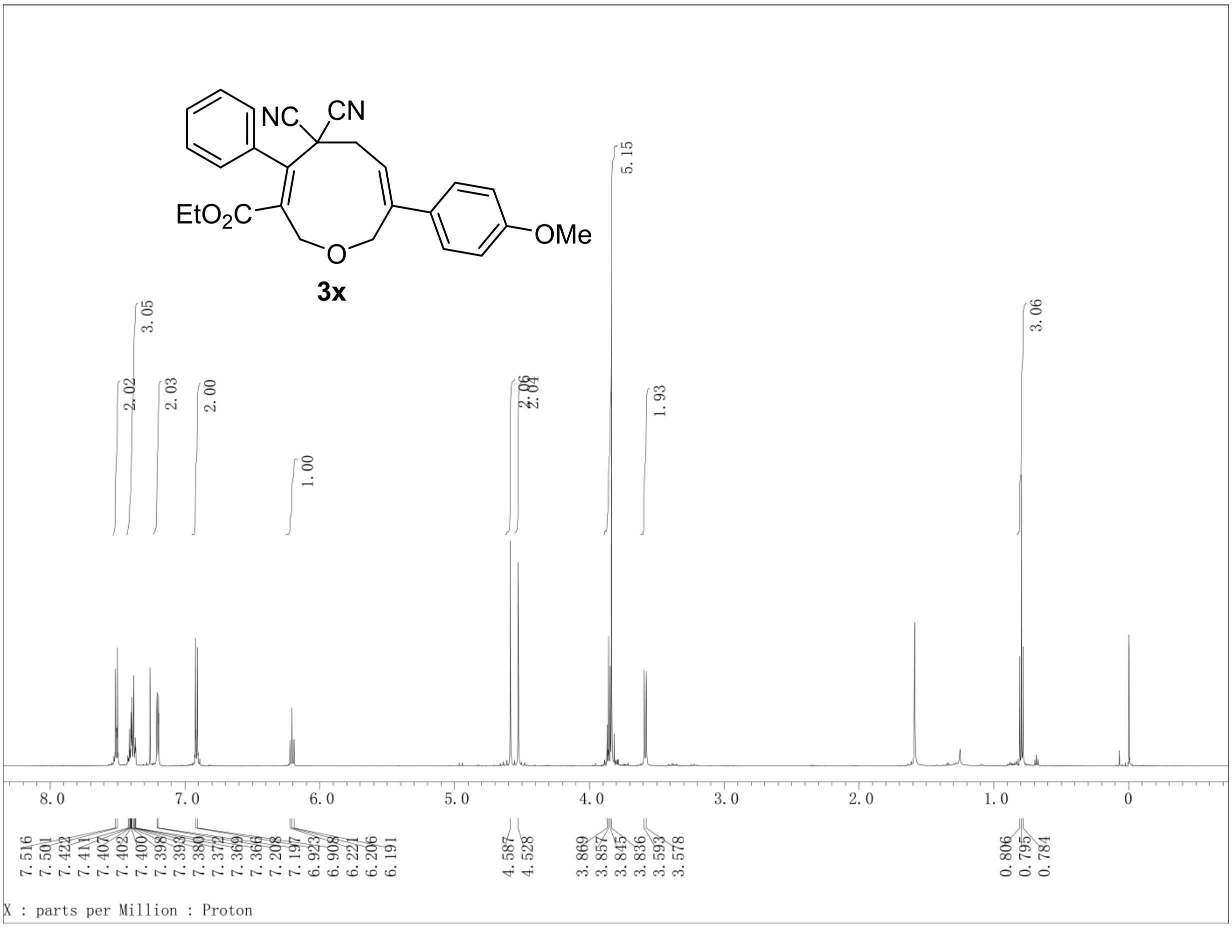
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O
OMe
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2.03
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1.00
2.06
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3.06
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
7.516
7.501
7.422
7.411
7.407
7.402
7.400
7.398
7.393
7.380
7.372
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7.366
7.208
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6.923
6.908
6.221
6.206
6.191
4.587
4.528
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0.795
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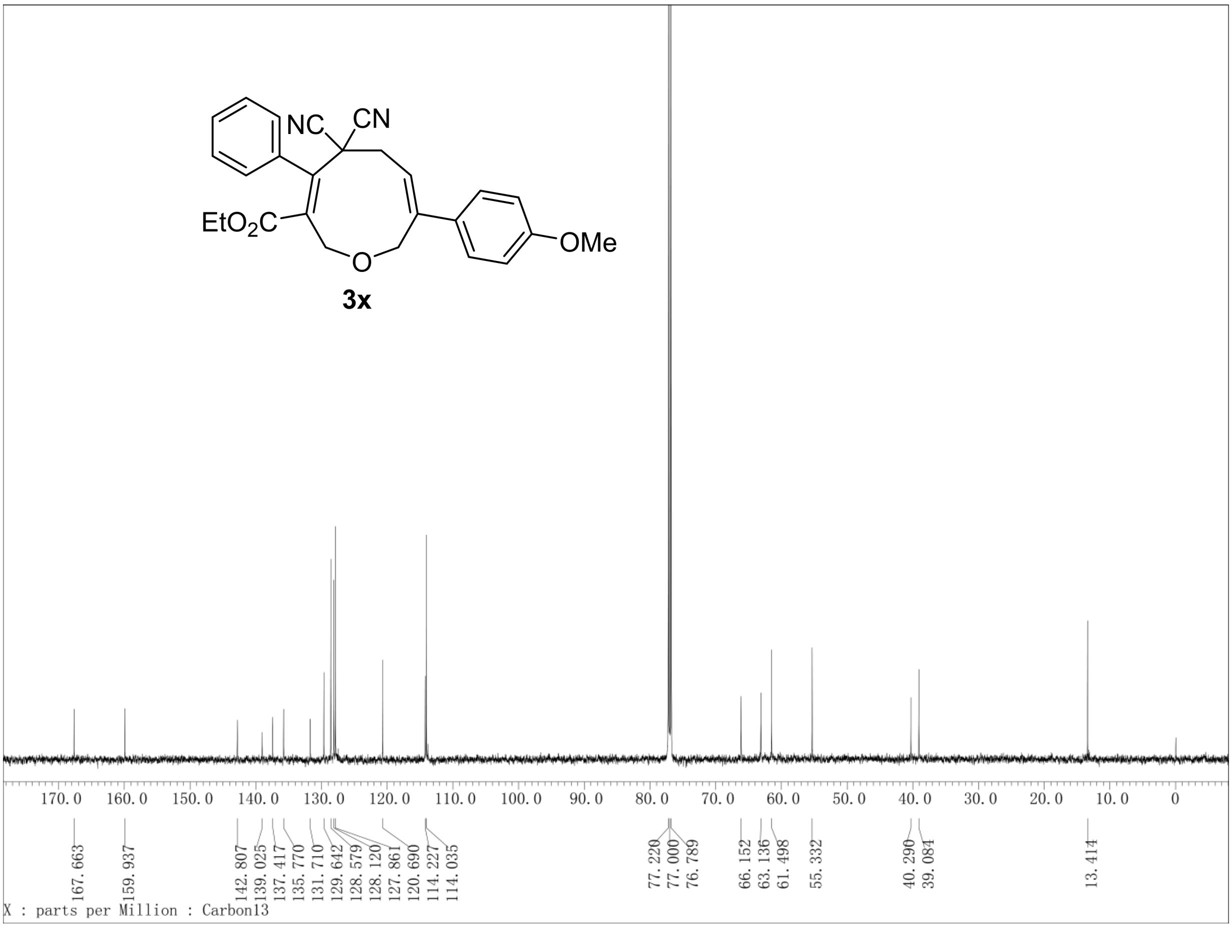
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EtO2C
O
OMe
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140.0
130.0
120.0
110.0
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50.0
40.0
30.0
20.0
10.0
0
167.663
159.937
142.807
139.025
137.417
135.770
131.710
129.642
128.579
128.120
127.861
120.690
114.227
114.035
77.220
77.000
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66.152
63.136
61.498
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40.290
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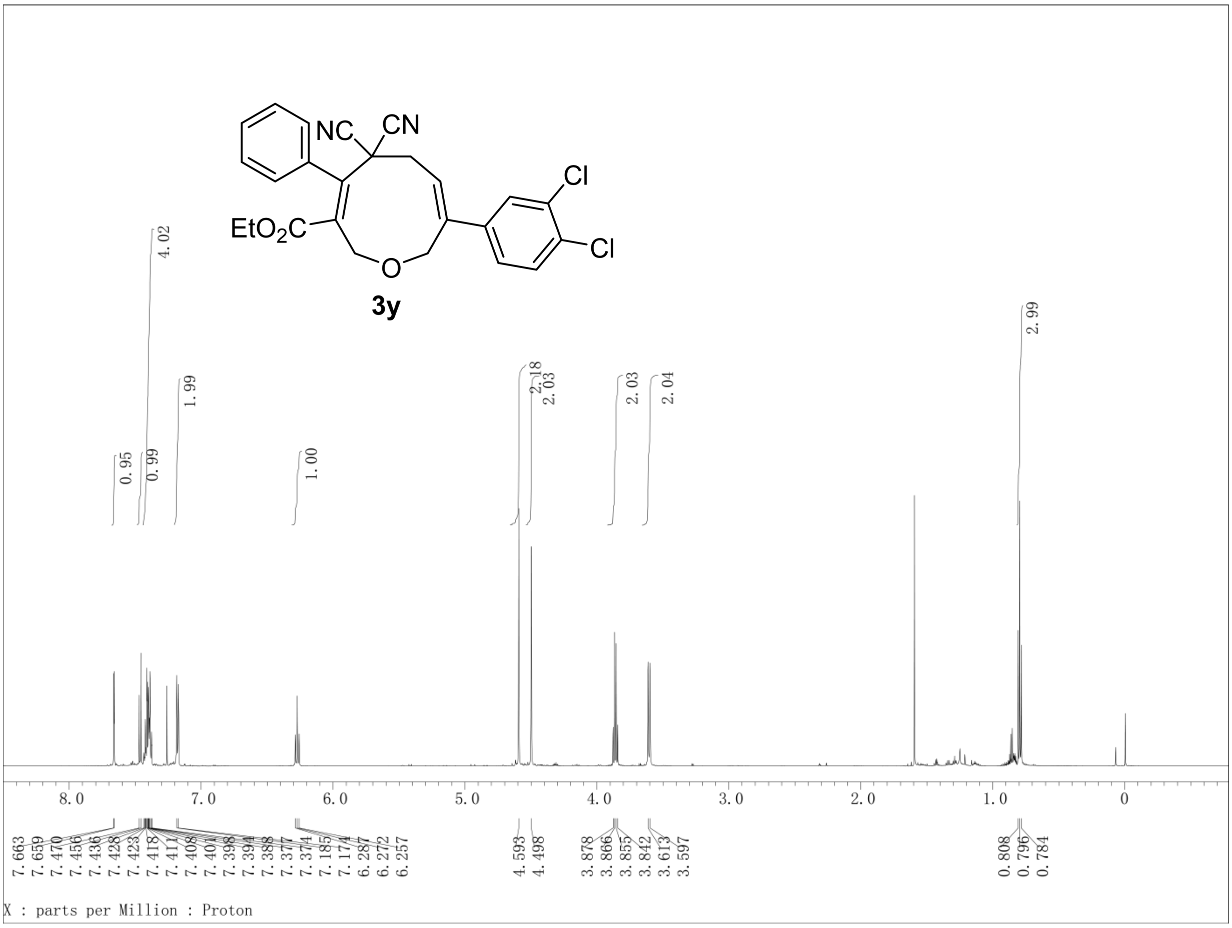
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Cl
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1.00
2.18
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2.03
2.04
2.99
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7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
7.663
7.659
7.470
7.456
7.436
7.428
7.423
7.418
7.411
7.408
7.401
7.398
7.394
7.388
7.377
7.374
7.185
7.174
6.287
6.272
6.257
4.593
4.498
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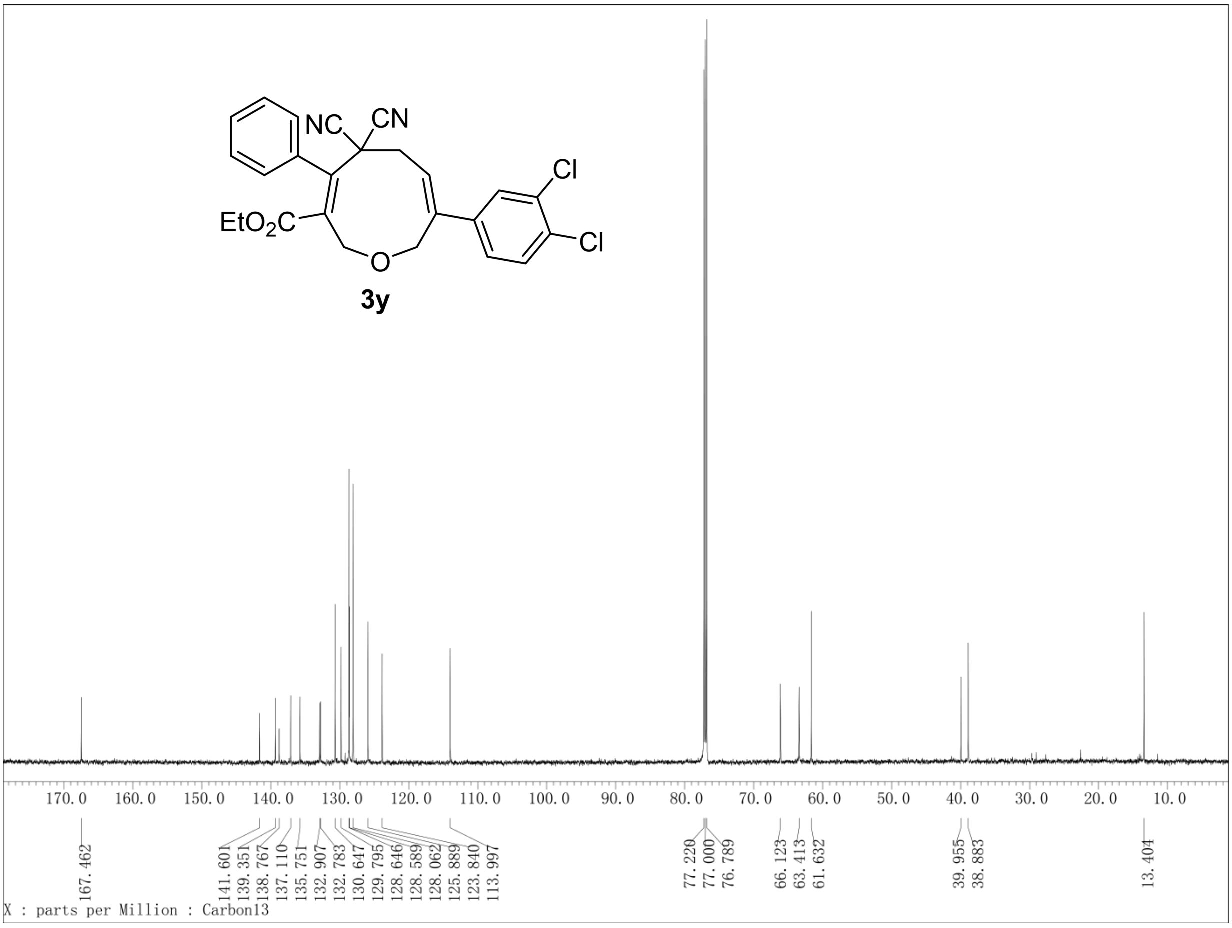
0.784
X : parts per Million : Proton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Cl
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O
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140.0
130.0
120.0
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50.0
40.0
30.0
20.0
10.0
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141.601
139.351
138.767
137.110
135.751
132.907
132.783
130.647
129.795
128.646
128.589
128.062
125.889
123.840
113.997
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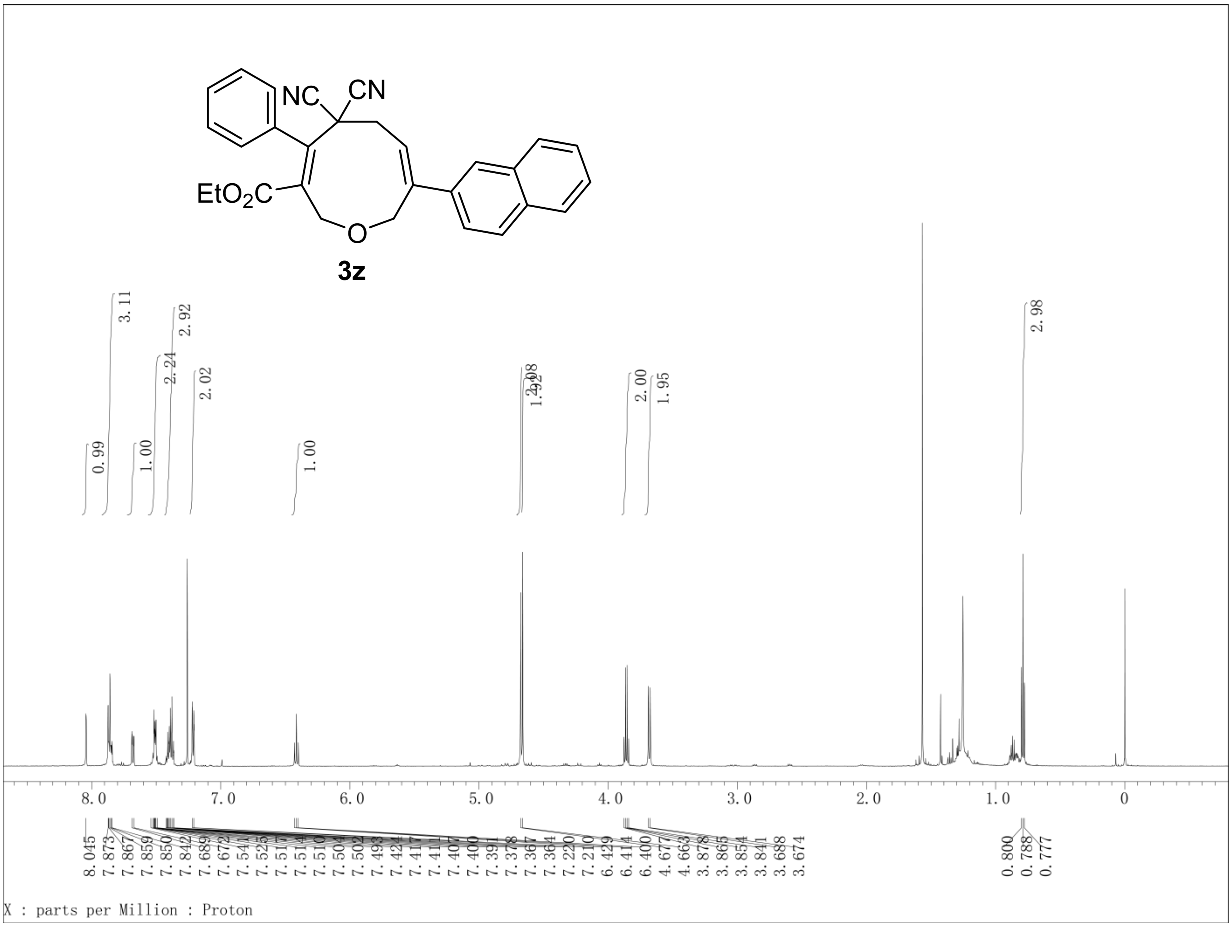
77.000
76.789
66.123
63.413
61.632
39.955
38.883
13.404
X : parts per Million : Carbon13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O
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3.11
1.00
2.24
2.92
2.02
1.00
2.08
1.92
2.00
1.95
2.98
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
8.045
7.873
7.867
7.859
7.850
7.842
7.689
7.672
7.541
7.525
7.517
7.514
7.510
7.504
7.502
7.493
7.424
7.417
7.411
7.407
7.400
7.391
7.378
7.367
7.364
7.220
7.210
6.429
6.414
6.400
4.677
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3.688
3.674
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0.788
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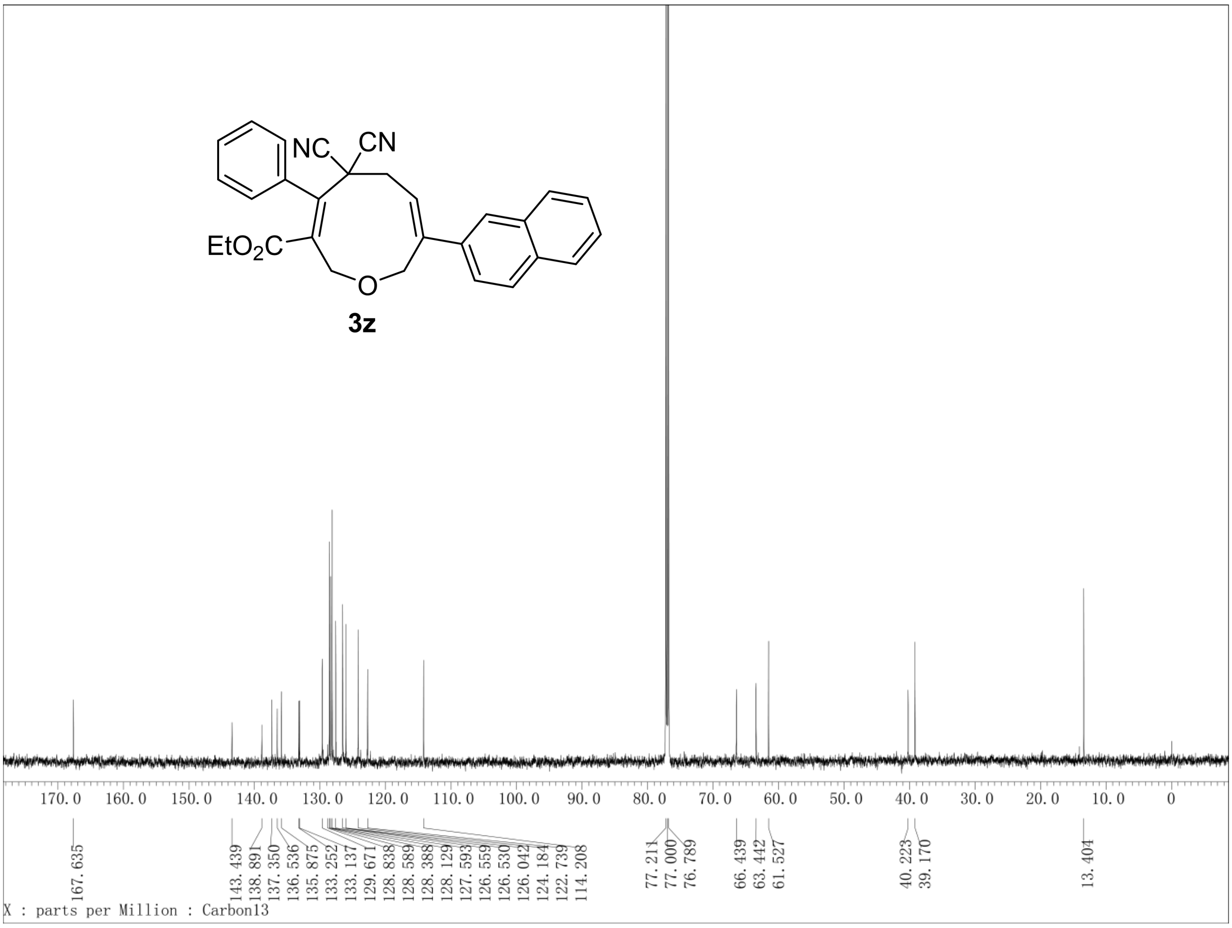
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EtO2C
O
3z
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130.0
120.0
110.0
100.0
90.0
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70.0
60.0
50.0
40.0
30.0
20.0
10.0
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135.875
133.252
133.137
129.671
128.838
128.589
128.388
128.129
127.593
126.559
126.530
126.042
124.184
122.739
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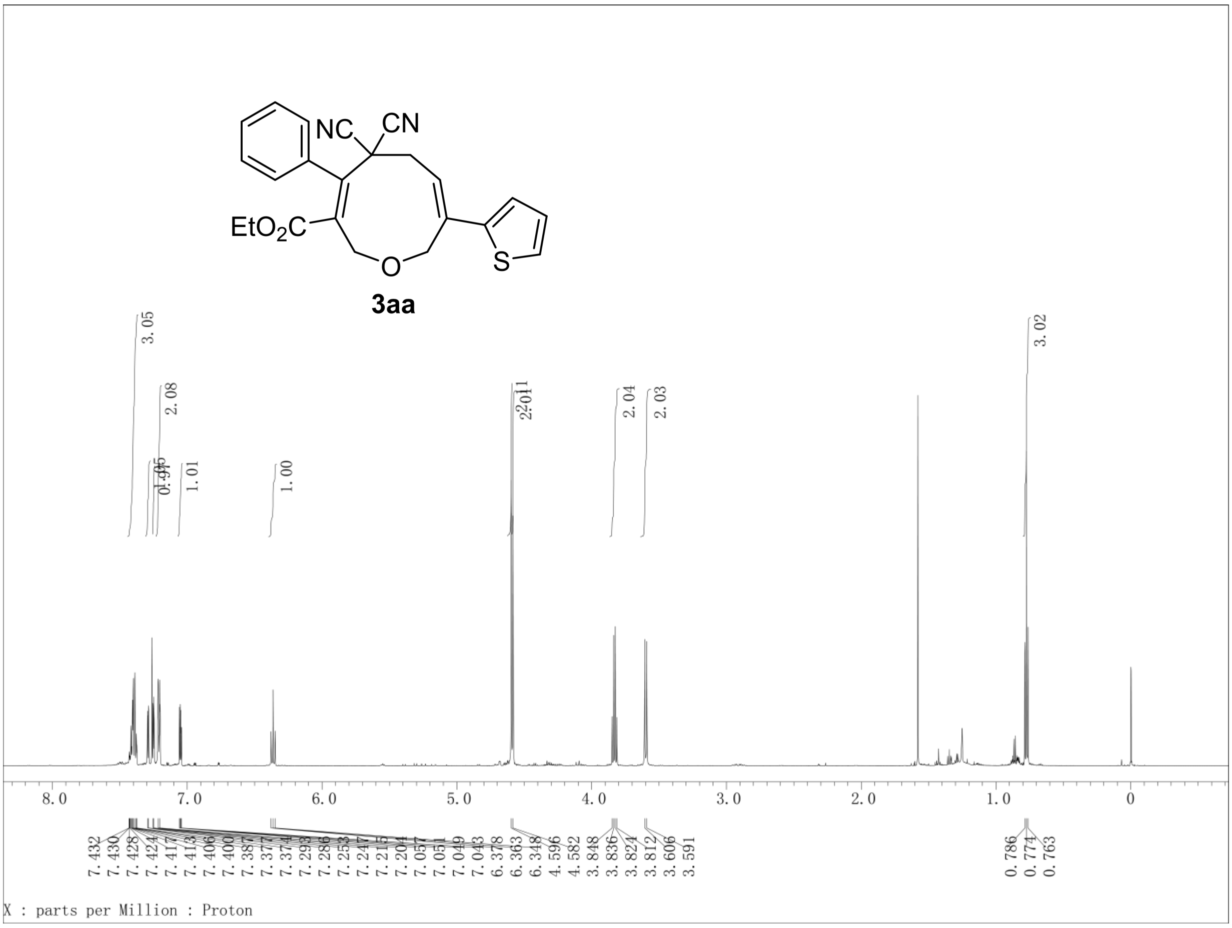
76.789
66.439
63.442
61.527
40.223
39.170
13.404
X : parts per Million : Carbon13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O
S
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2.08
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1.00
2.11
2.01
2.04
2.03
3.02
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
7.432
7.430
7.428
7.424
7.417
7.413
7.406
7.400
7.387
7.377
7.374
7.293
7.286
7.253
7.247
7.215
7.204
7.057
7.051
7.049
7.043
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6.363
6.348
4.596
4.582
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3.824
3.812
3.606
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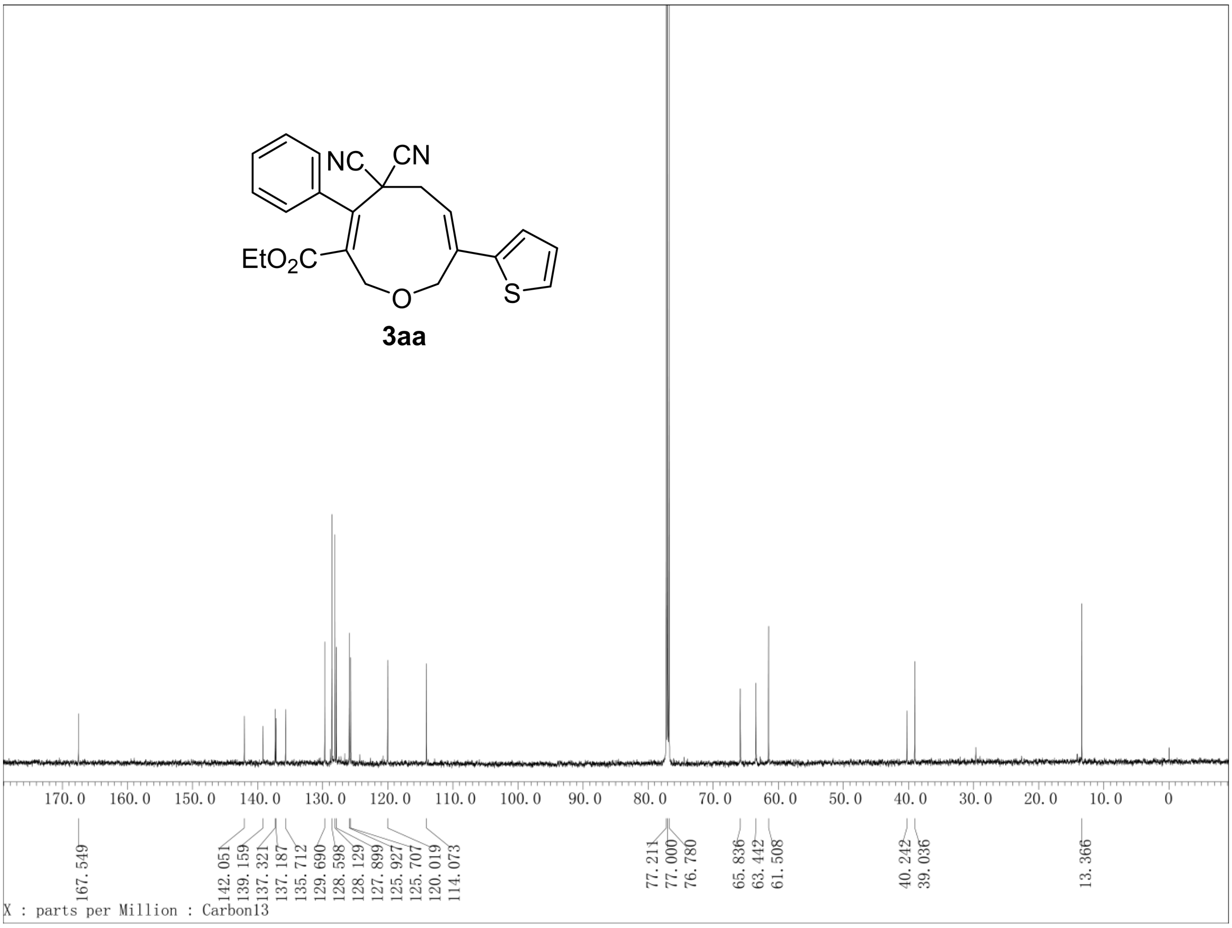
0.786
0.774
0.763
X : parts per Million : Proton


NC
CN
EtO_2C
O
S
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150.0
140.0
130.0
120.0
110.0
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30.0
20.0
10.0
0
167.549
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139.159
137.321
137.187
135.712
129.690
128.598
128.129
127.899
125.927
125.707
120.019
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77.000
76.780
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63.442
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40.242
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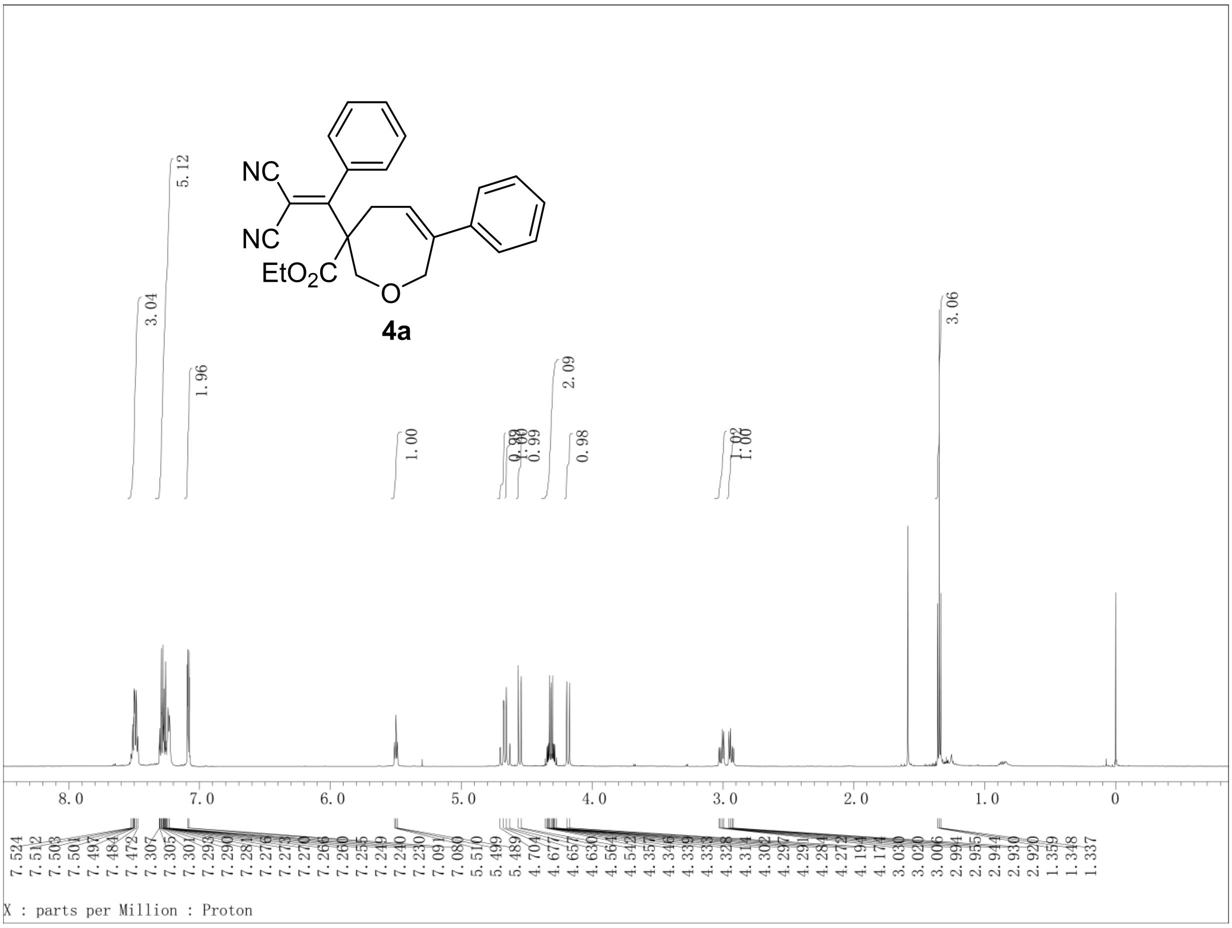
NC
NC
EtO2C
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0.98
1.00
0.99
2.09
0.98
1.02
1.00
3.06
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
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7.512
7.503
7.501
7.497
7.484
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7.307
7.305
7.301
7.293
7.290
7.281
7.276
7.273
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7.266
7.260
7.255
7.249
7.240
7.230
7.091
7.080
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5.499
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4.677
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4.564
4.542
4.357
4.346
4.339
4.333
4.328
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4.302
4.297
4.291
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1.337
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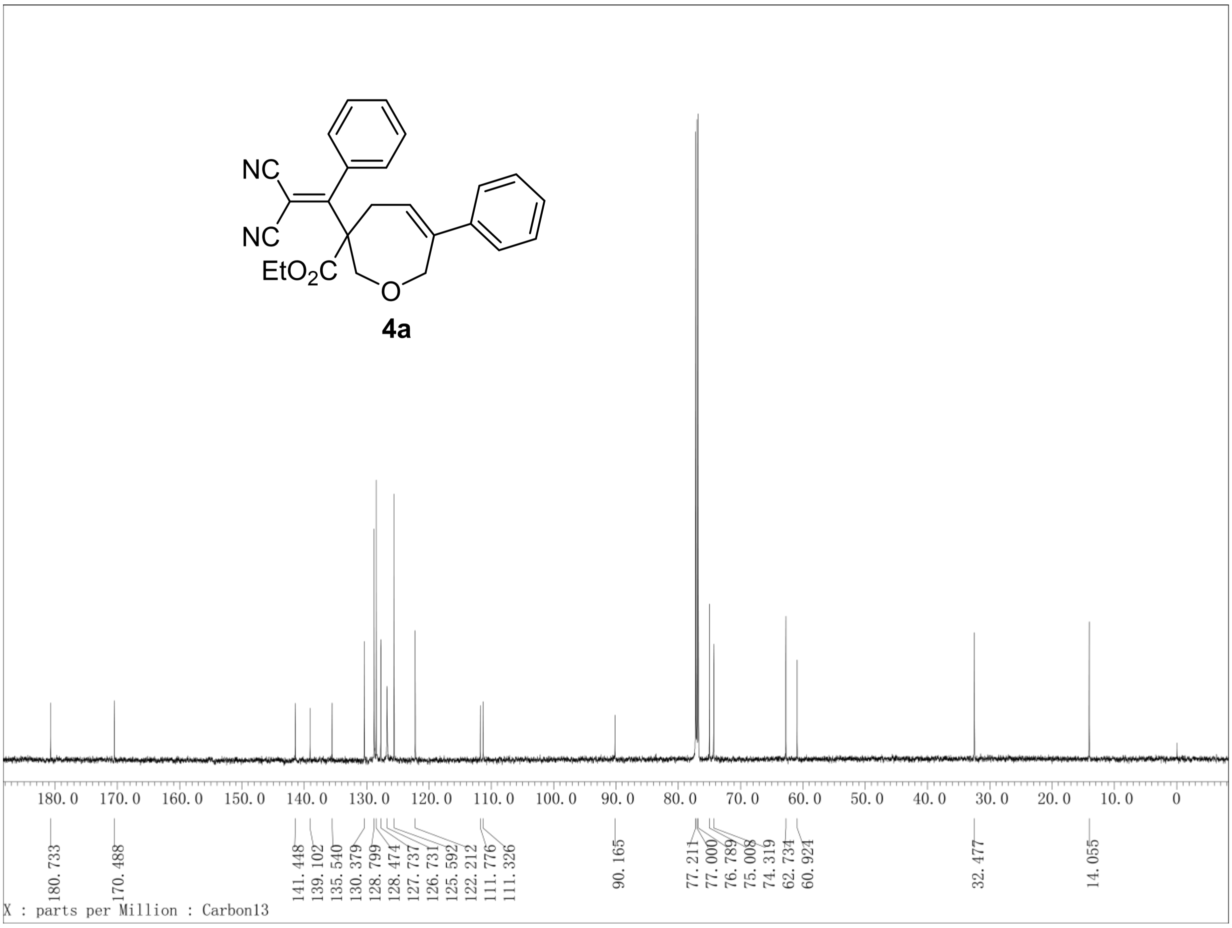
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NC
EtO2C
O
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150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
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170.488
141.448
139.102
135.540
130.379
128.799
128.474
127.737
126.731
125.592
122.212
111.776
111.326
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76.789
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62.734
60.921
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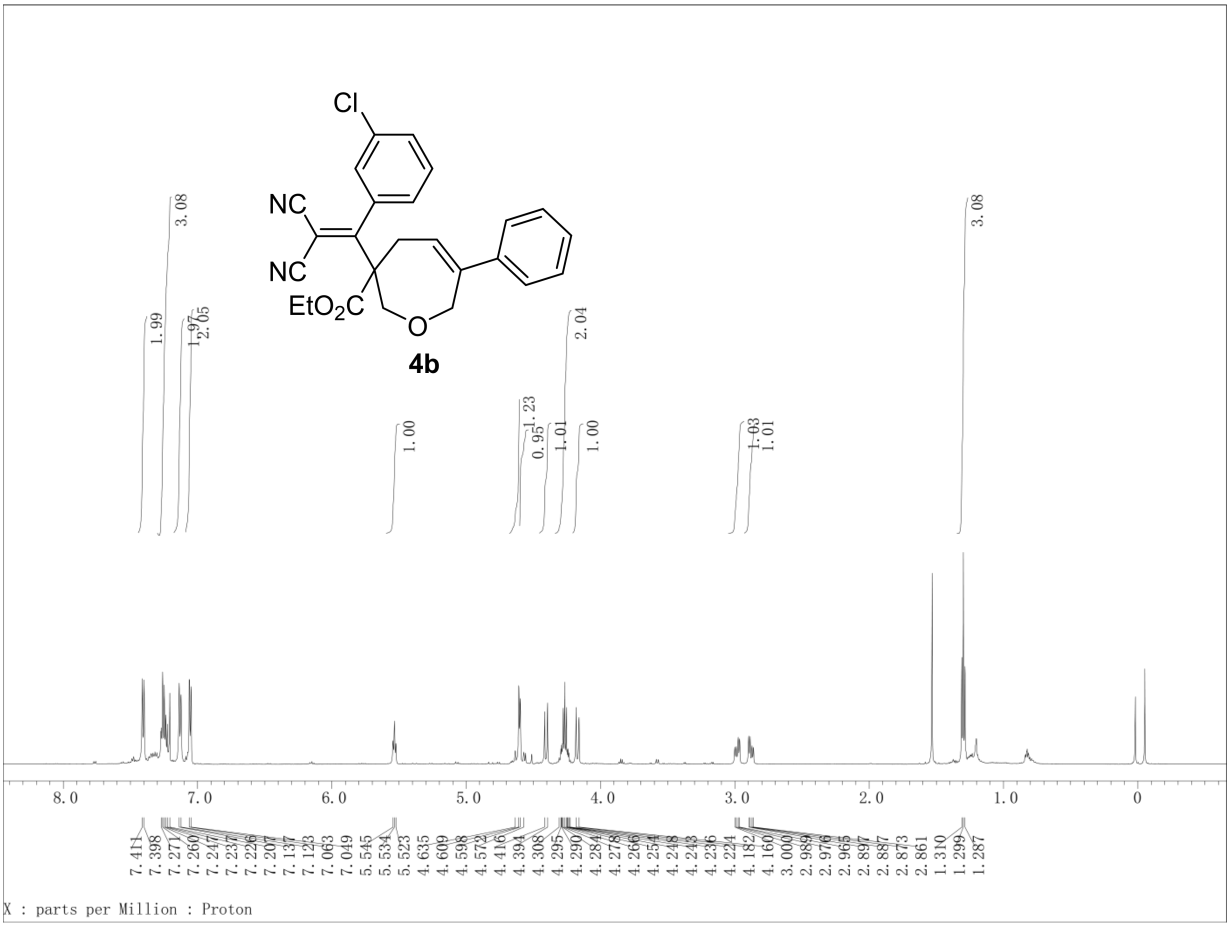
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NC
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O
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2.05
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1.23
0.95
1.01
2.04
1.00
1.03
1.01
3.08
8.0
7.0
6.0
5.0
4.0
3.0
2.0
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7.398
7.271
7.260
7.247
7.237
7.226
7.207
7.137
7.123
7.063
7.049
5.545
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5.523
4.635
4.609
4.598
4.572
4.416
4.394
4.308
4.295
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4.284
4.278
4.266
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4.248
4.243
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4.224
4.182
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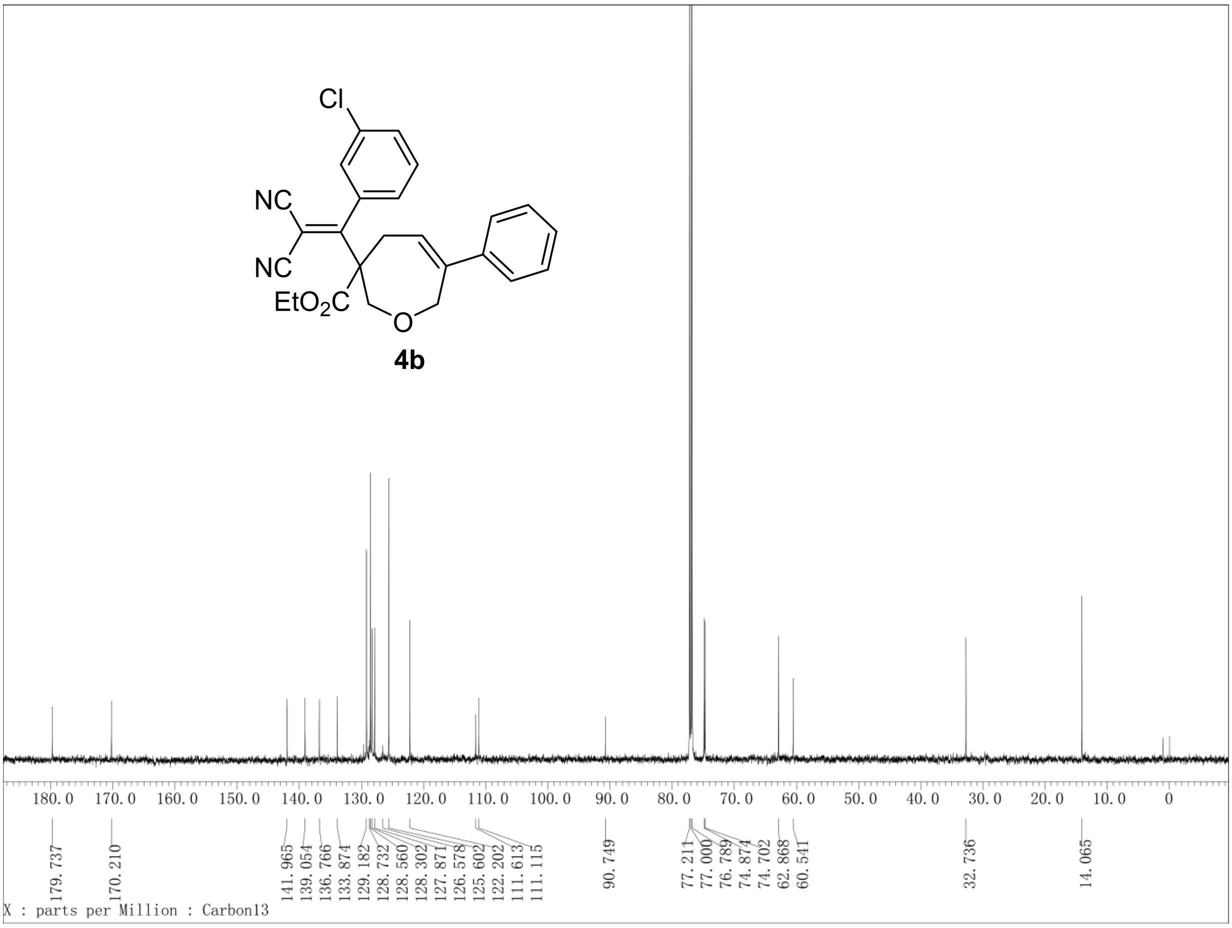
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NC
EtO2C
O
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150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
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170.210
141.965
139.054
136.766
133.874
129.182
128.732
128.560
128.302
127.871
126.578
125.602
122.202
111.613
111.115
90.749
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76.789
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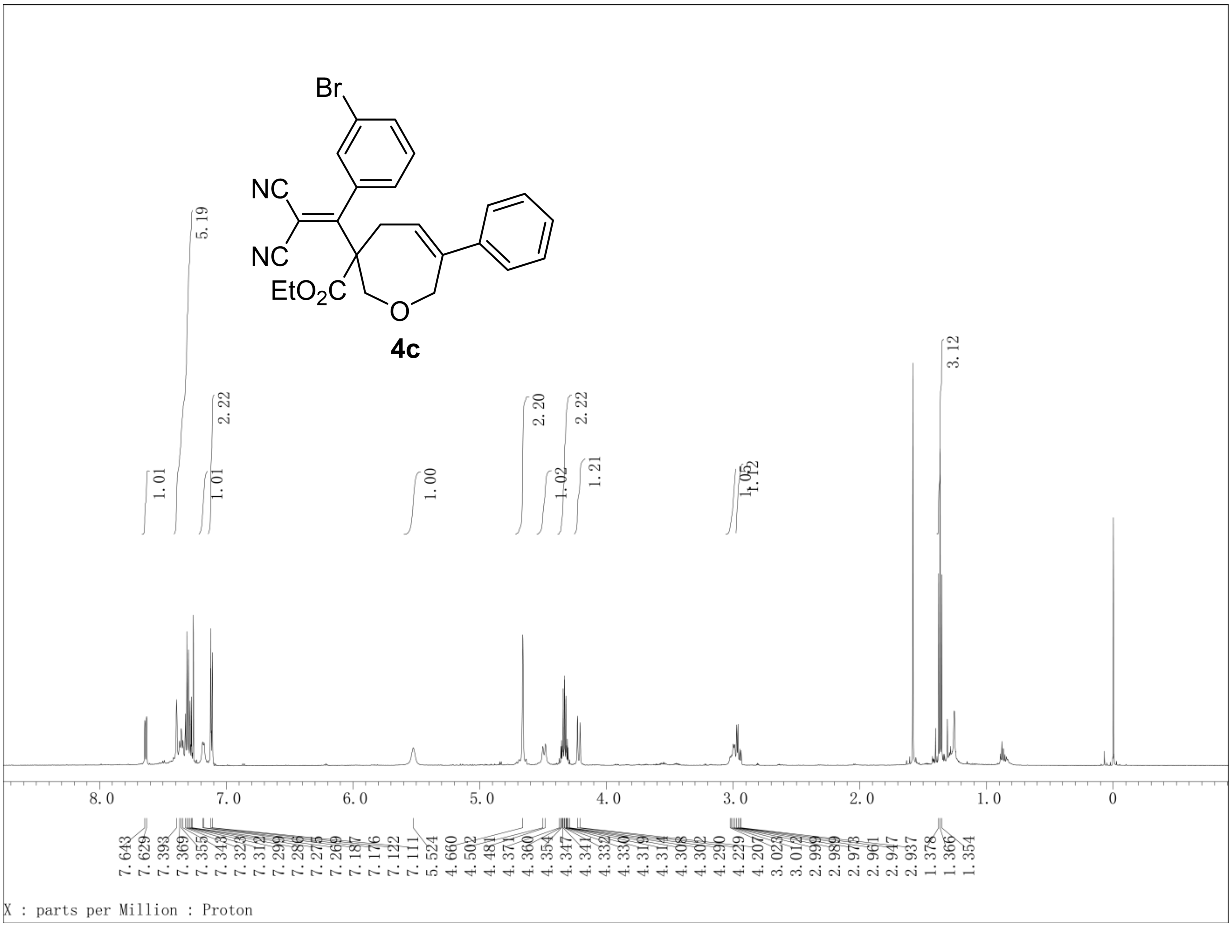
Br
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NC
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O
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2.20
1.02
2.22
1.21
1.05
1.12
3.12
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
7.643
7.629
7.393
7.369
7.355
7.343
7.323
7.312
7.299
7.286
7.275
7.269
7.187
7.176
7.122
7.111
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4.502
4.481
4.371
4.360
4.354
4.347
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4.332
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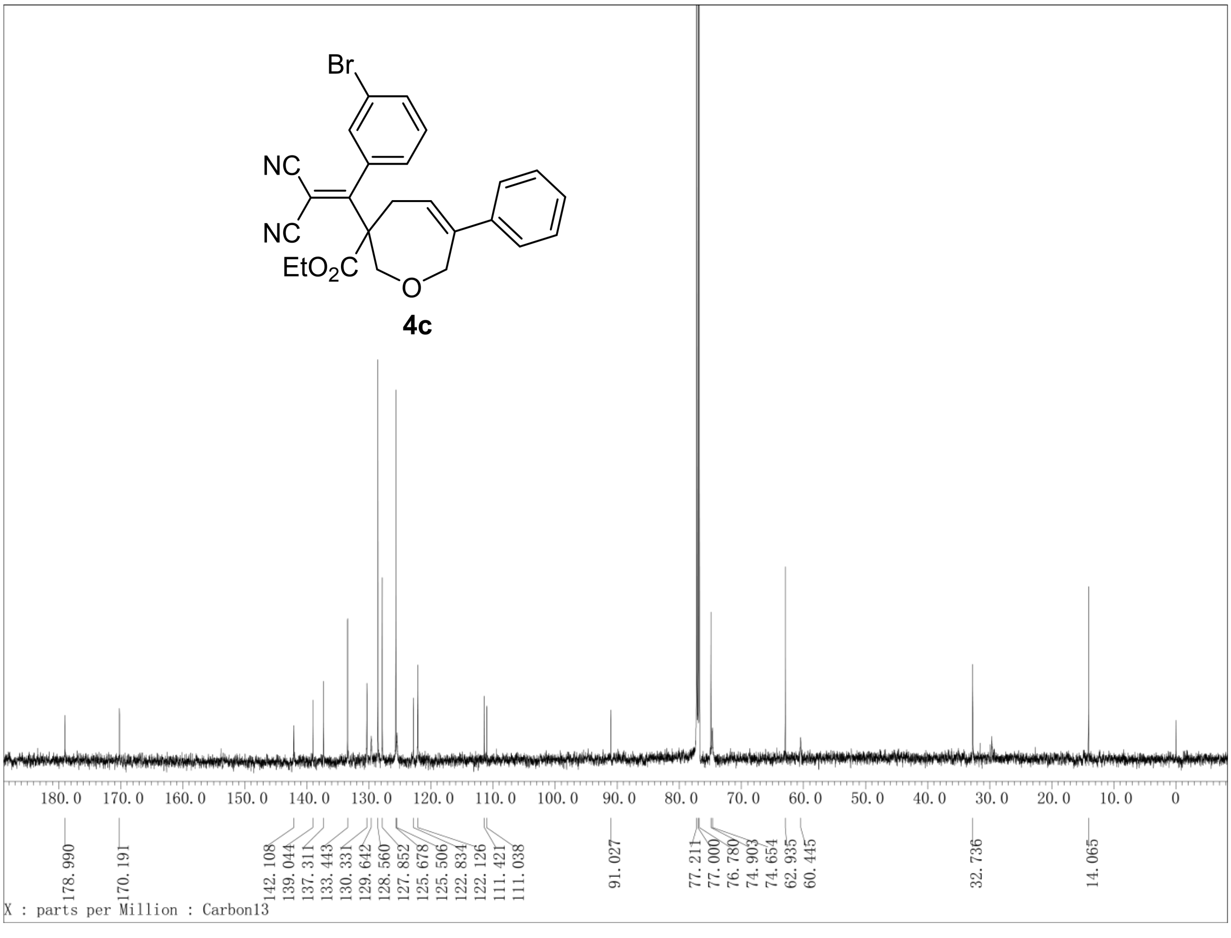
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NC
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O
4c
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150.0
140.0
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120.0
110.0
100.0
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70.0
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50.0
40.0
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20.0
10.0
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170.191
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139.044
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133.443
130.331
129.642
128.560
127.852
125.678
125.506
122.834
122.126
111.421
111.038
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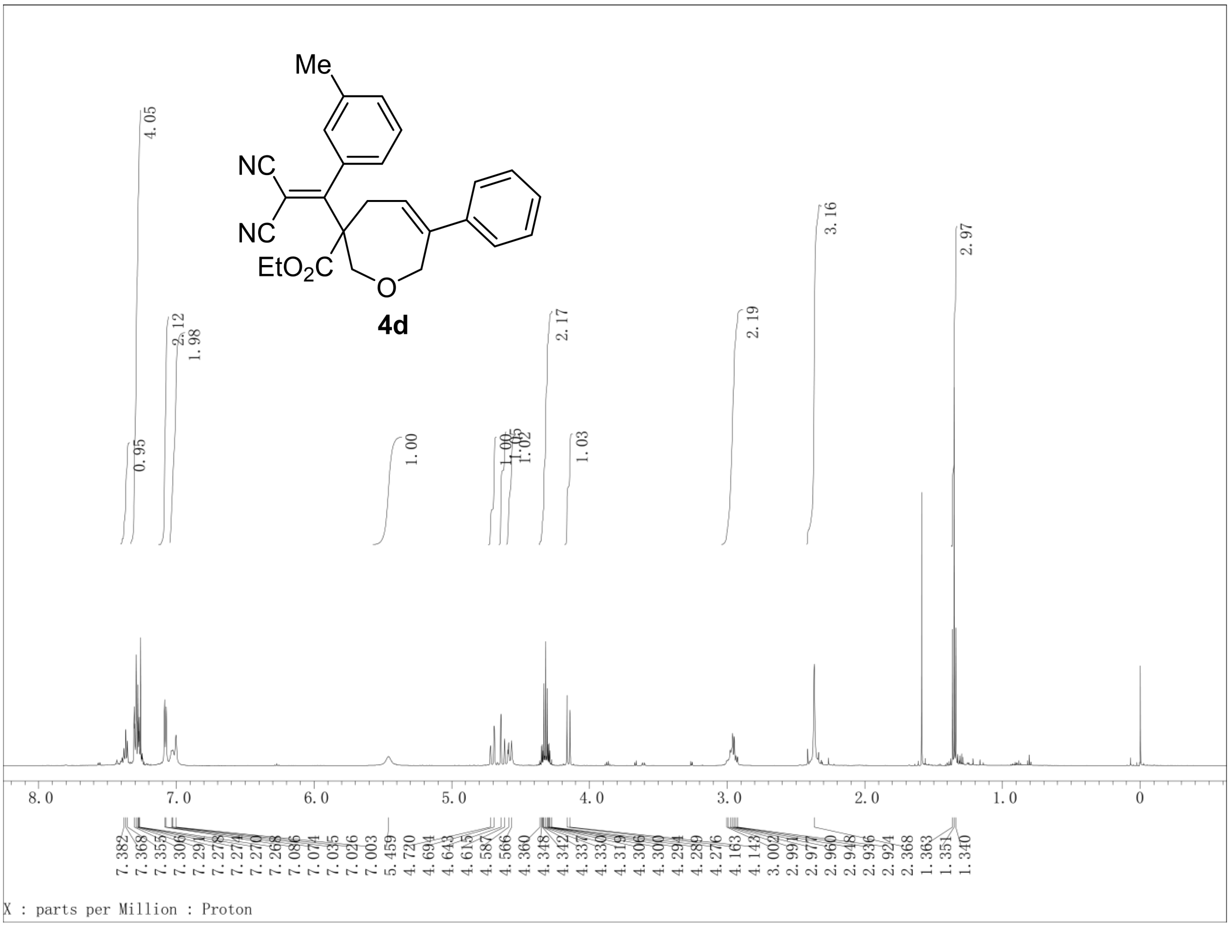
60.445
32.736
14.065
X : parts per Million : Carbon13


Me
NC
NC
EtO2C
O
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1.00
1.05
1.02
2.17
1.03
2.19
3.16
2.97
8.0
7.0
6.0
5.0
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7.278
7.274
7.270
7.268
7.086
7.074
7.035
7.026
7.003
5.459
4.720
4.694
4.643
4.615
4.587
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4.319
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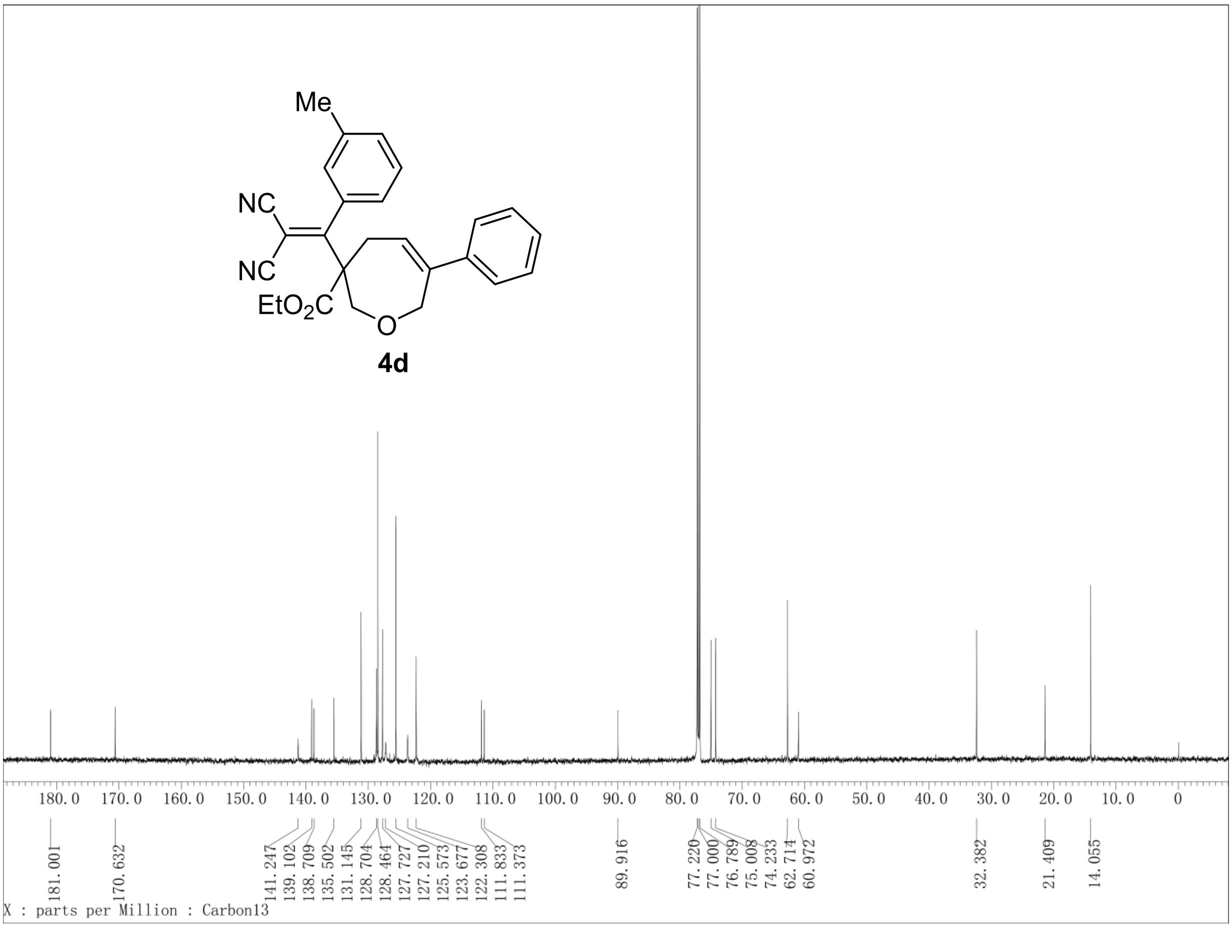
Me
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NC
EtO2C
O
4d
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150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
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141.247
139.102
138.709
135.502
131.145
128.704
128.464
127.727
127.210
125.573
123.677
122.308
111.833
111.373
89.916
77.220
77.000
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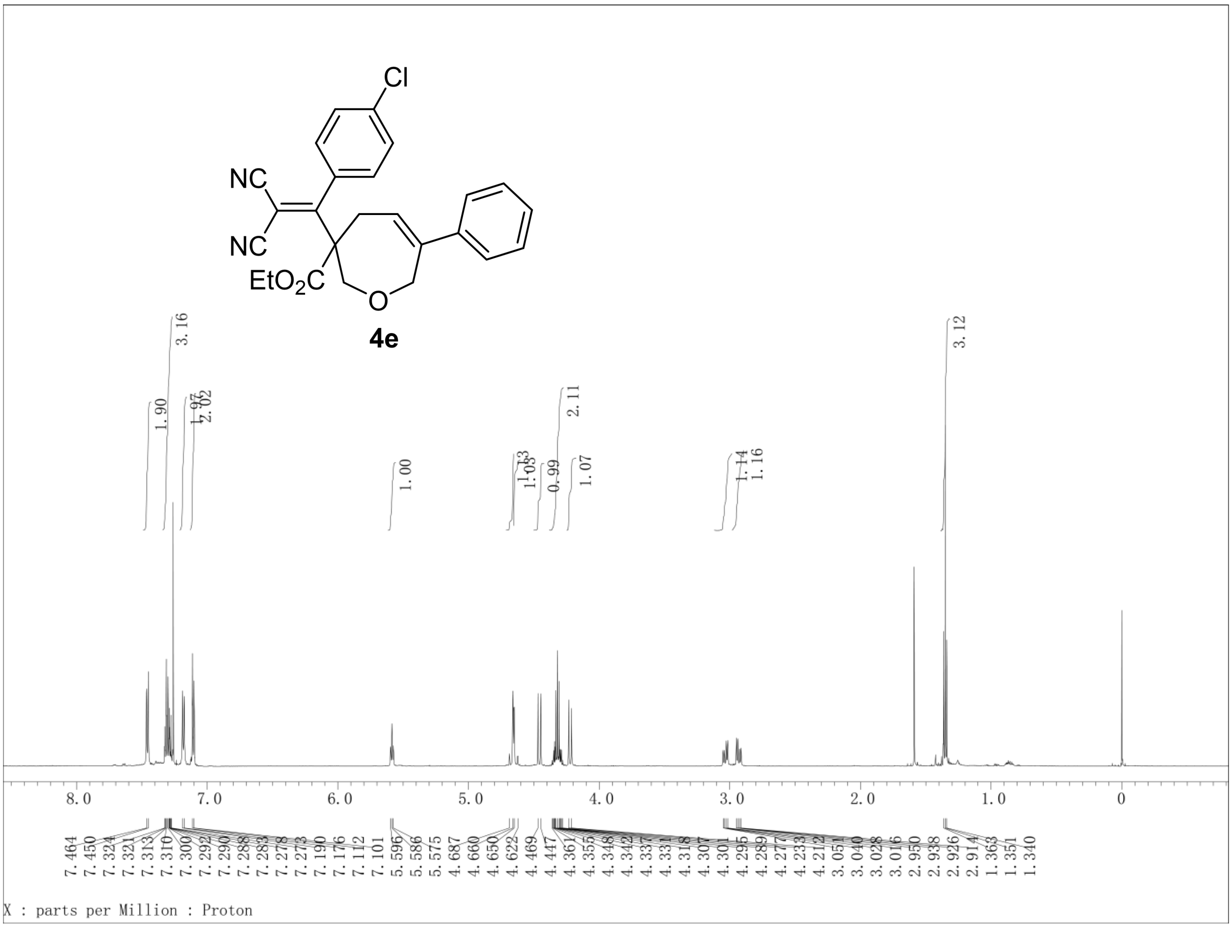
74.233
62.714
60.972
32.382
21.409
14.055
X : parts per Million : Carbon13


Cl
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NC
EtO2C
O
4e
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1.13
1.05
0.99
2.11
1.07
1.14
1.16
3.12
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
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7.464
7.450
7.324
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7.273
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5.586
5.575
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4.650
4.622
4.469
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4.361
4.355
4.348
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4.337
4.331
4.318
4.307
4.301
4.295
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4.277
4.233
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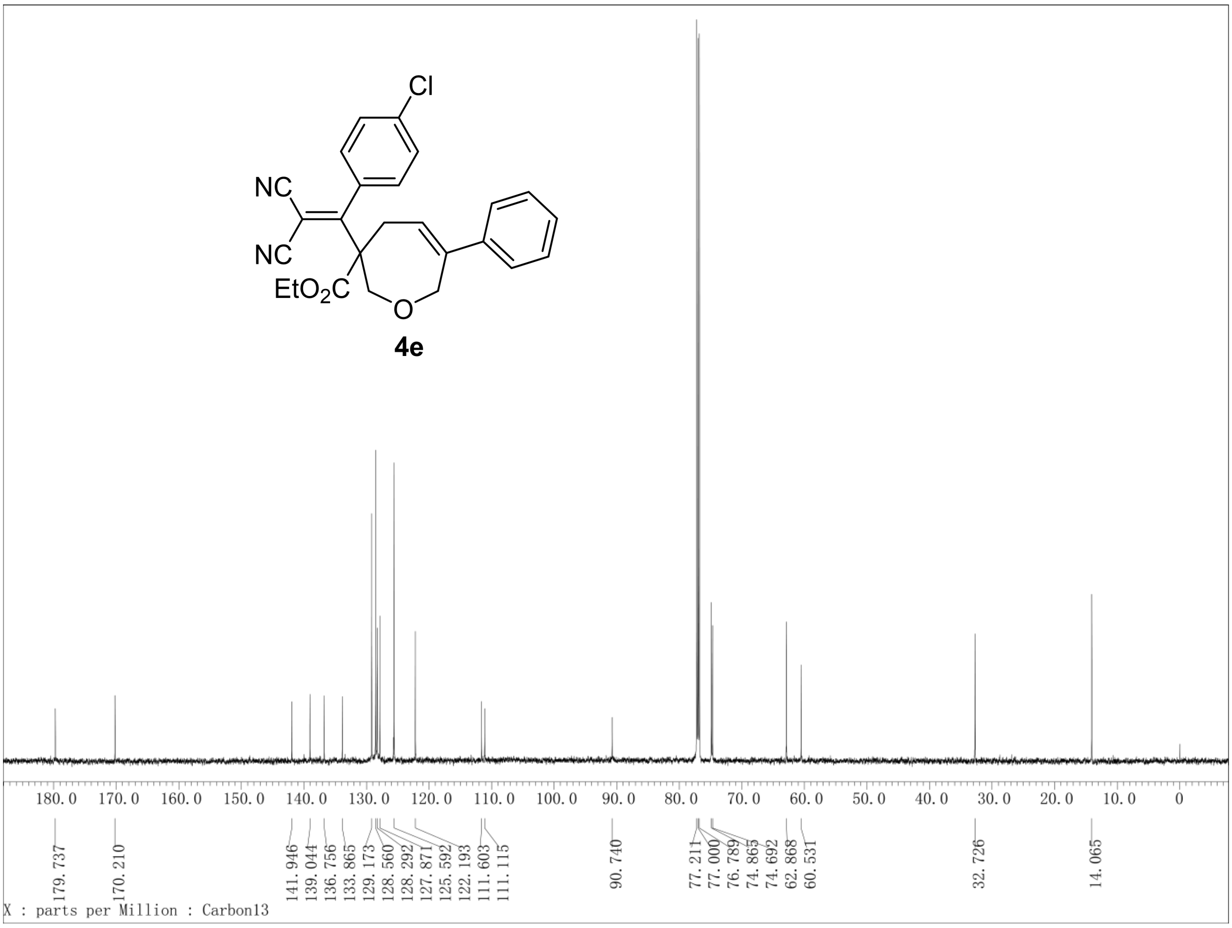
Cl
NC
NC
EtO2C
O
4e
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170.0
160.0
150.0
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130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
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40.0
30.0
20.0
10.0
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170.210
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139.044
136.756
133.865
129.173
128.560
128.292
127.871
125.592
122.193
111.603
111.115
90.740
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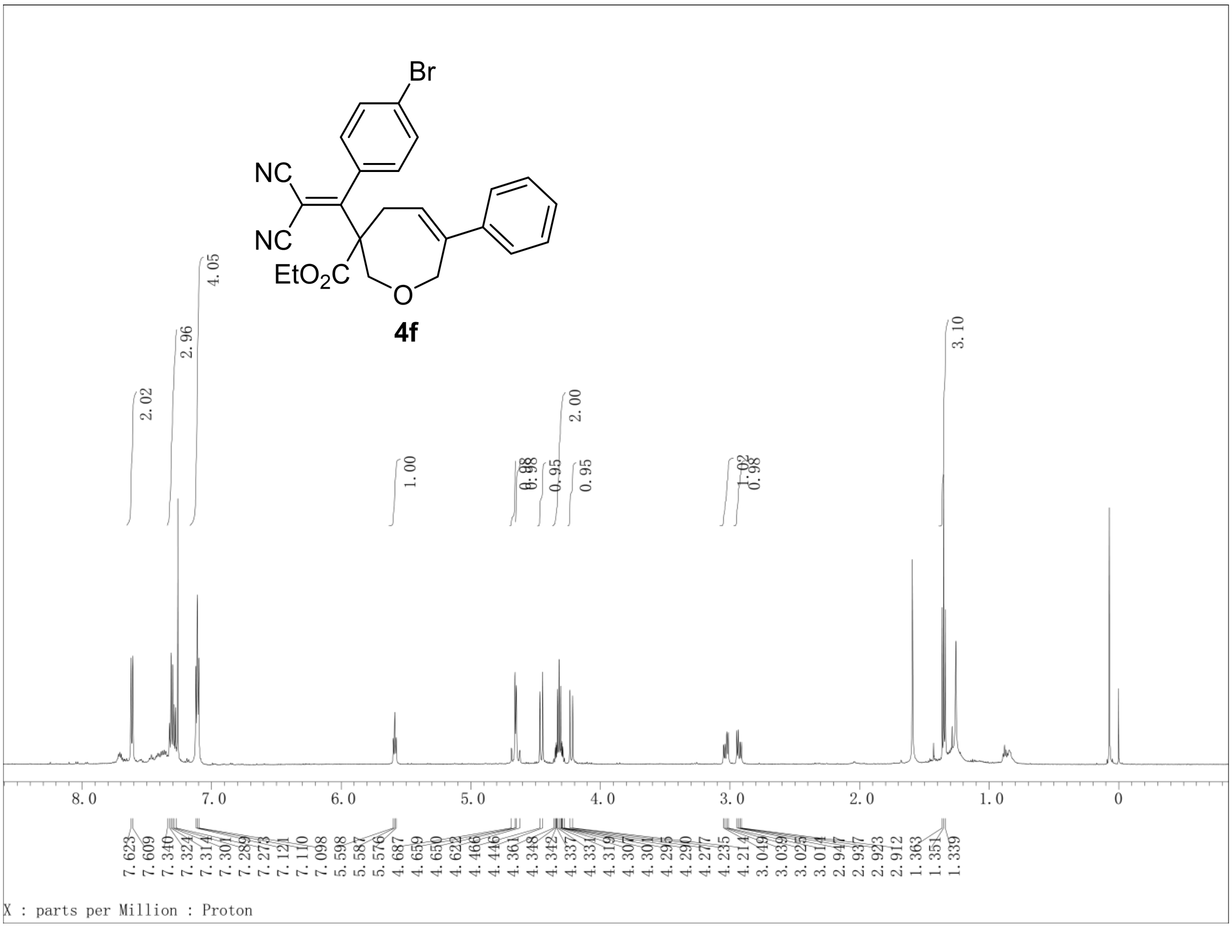
76.789
74.865
74.692
62.868
60.531
32.726
14.065
X : parts per Million : Carbon13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0.98
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2.00
0.95
1.02
0.98
3.10
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7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
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7.609
7.340
7.324
7.314
7.301
7.289
7.273
7.121
7.110
7.098
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5.587
5.576
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4.650
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4.214
3.049
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2.923
2.912
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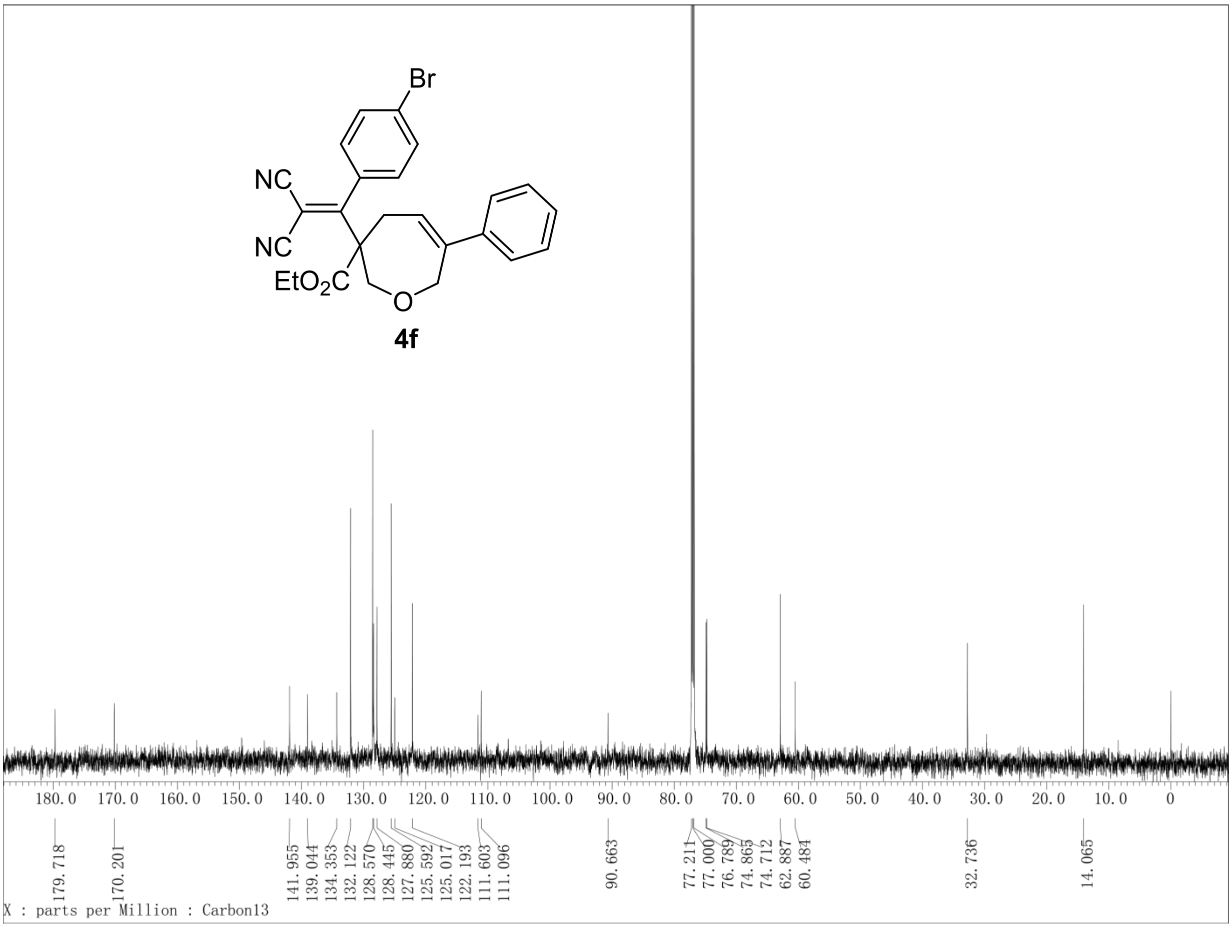
X : parts per Million : Proton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NC
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80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
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170.201
141.955
139.044
134.353
132.122
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128.445
127.880
125.592
125.017
122.193
111.603
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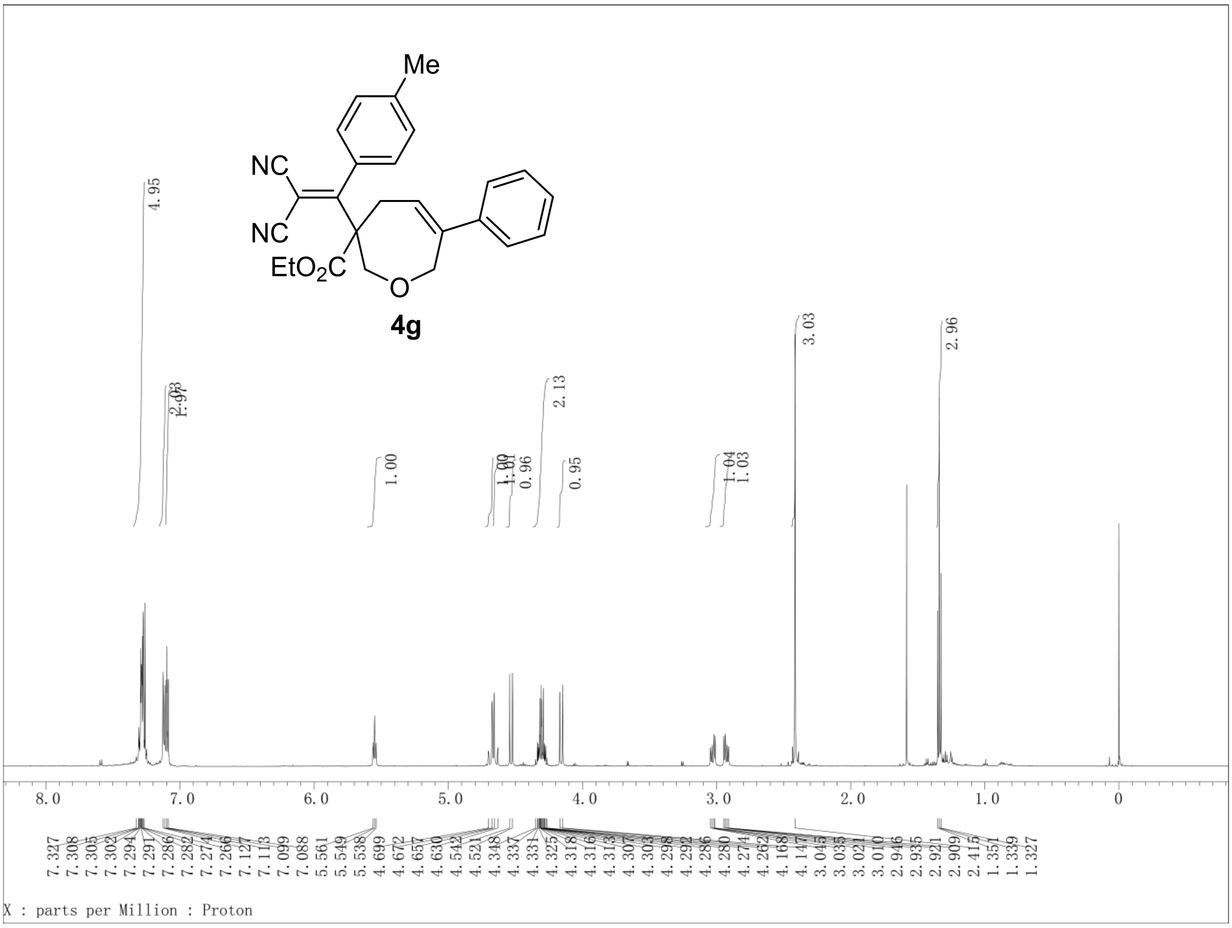
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NC
EtO2C
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1.00
1.01
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0.95
1.04
1.03
3.03
2.96
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7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
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7.308
7.305
7.302
7.294
7.291
7.286
7.282
7.274
7.266
7.127
7.113
7.099
7.088
5.561
5.549
5.538
4.699
4.672
4.657
4.630
4.542
4.521
4.348
4.337
4.331
4.325
4.318
4.316
4.313
4.307
4.303
4.298
4.292
4.286
4.280
4.274
4.262
4.168
4.147
3.045
3.035
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2.909
2.415
1.351
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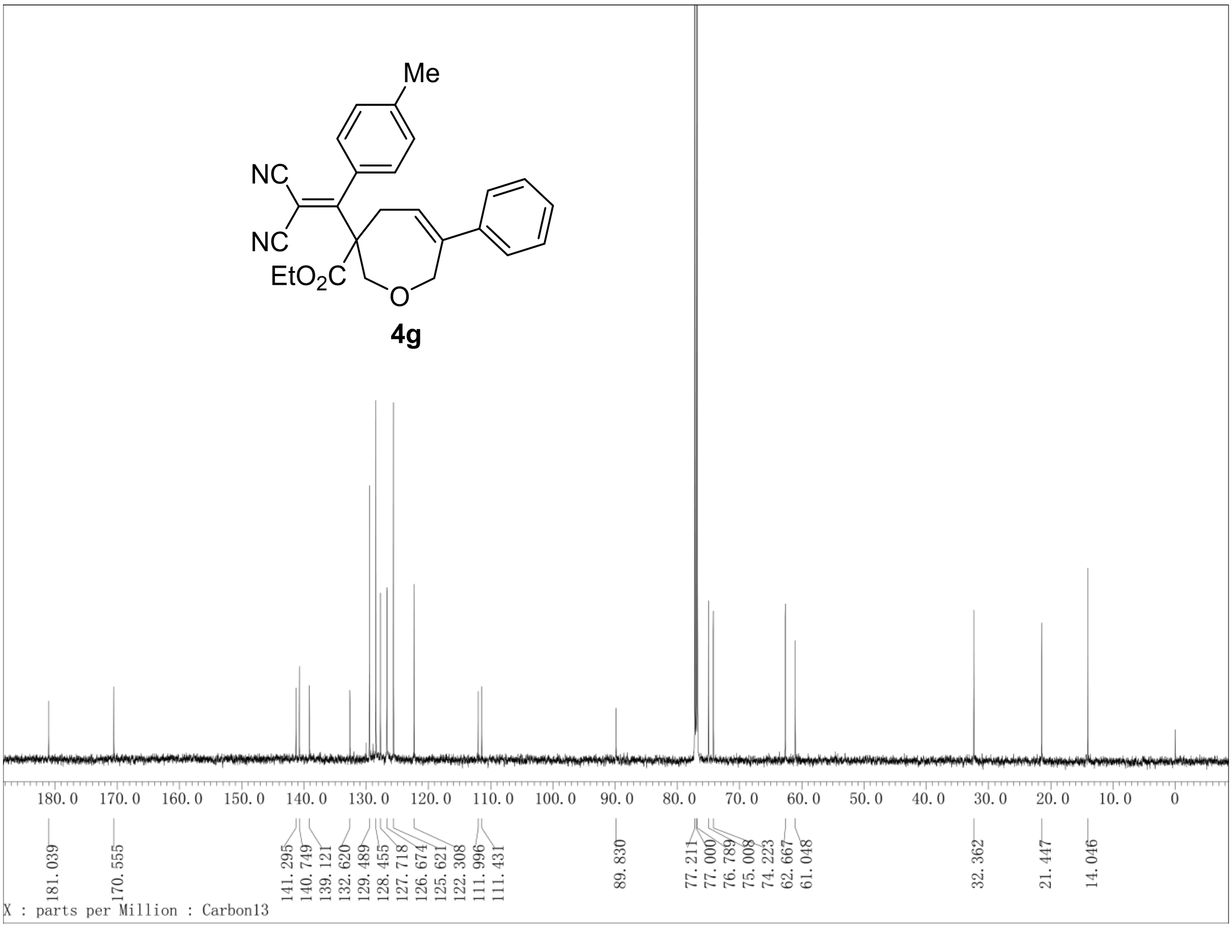
1.327
X : parts per Million : Proton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NC
EtO2C
O
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100.0
90.0
80.0
70.0
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30.0
20.0
10.0
0
181.039
170.555
141.295
140.749
139.121
132.620
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128.455
127.718
126.674
125.621
122.308
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111.431
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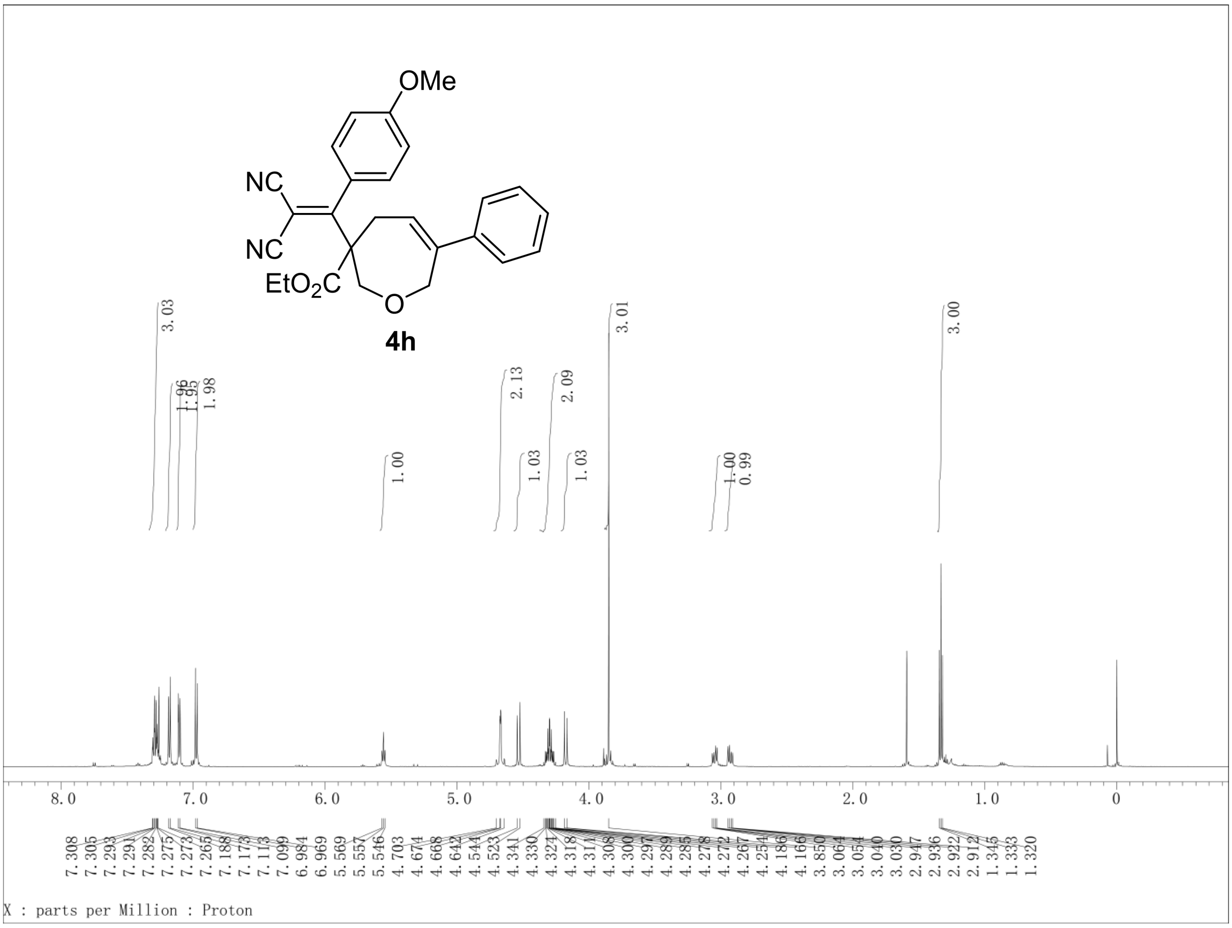
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NC
EtO2C
O
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1.95
1.98
1.00
2.13
1.03
2.09
1.03
3.01
1.00
0.99
3.00
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
7.308
7.305
7.293
7.291
7.282
7.275
7.273
7.265
7.188
7.173
7.113
7.099
6.984
6.969
5.569
5.557
5.546
4.703
4.674
4.668
4.642
4.544
4.523
4.341
4.330
4.327
4.318
4.317
4.308
4.300
4.297
4.289
4.285
4.278
4.272
4.267
4.254
4.186
4.166
3.850
3.064
3.054
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2.922
2.912
1.345
1.333
1.320
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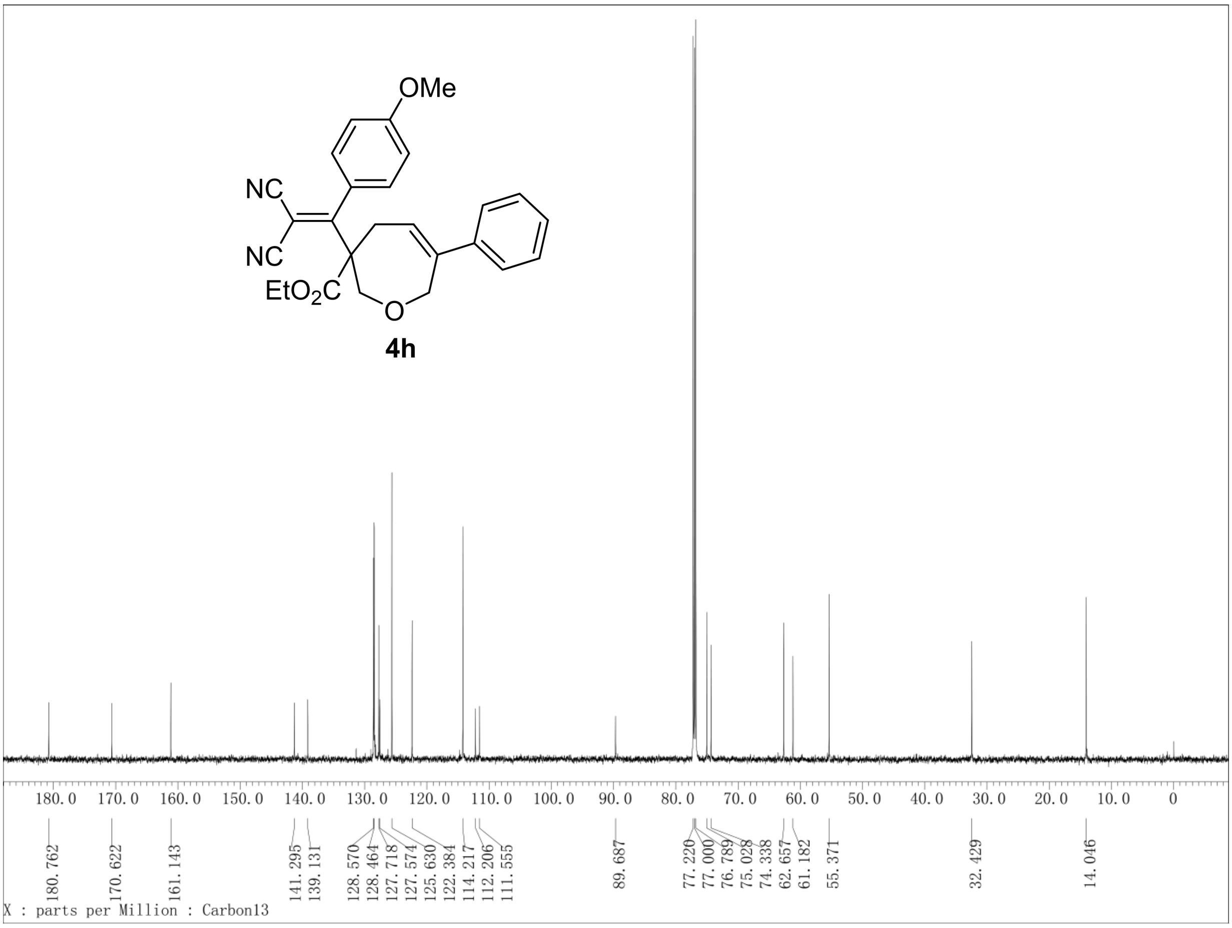
OMe
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NC
EtO2C
O
4h
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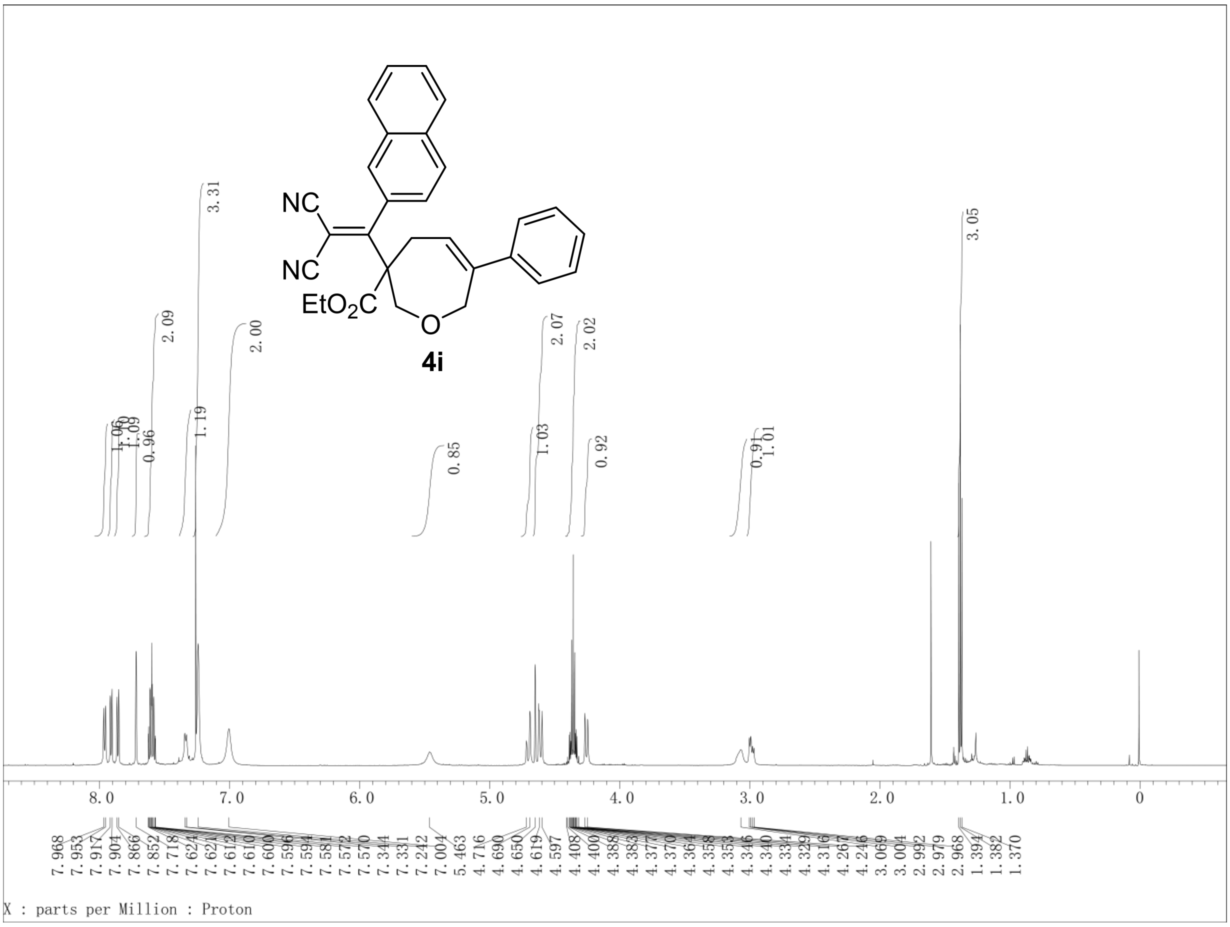
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
180.762
170.622
161.143
141.295
139.131
128.570
128.464
127.718
127.574
125.630
122.384
114.217
112.206
111.555
89.687
77.220
77.000
76.789
75.028
74.338
62.657
61.182
55.371
32.429
14.046
X : parts per Million : Carbon13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NC
NC
EtO2C
O
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3.05
2.09
2.00
2.07
2.02
1.06
1.00
1.09
0.96
1.19
0.85
1.03
0.92
0.91
1.01
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
7.968
7.953
7.917
7.904
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7.852
7.718
7.624
7.621
7.612
7.610
7.600
7.596
7.594
7.581
7.572
7.570
7.344
7.331
7.242
7.004
5.463
4.716
4.690
4.650
4.619
4.597
4.408
4.400
4.388
4.383
4.377
4.370
4.364
4.358
4.353
4.346
4.340
4.334
4.329
4.316
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4.246
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3.004
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2.979
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1.382
1.370
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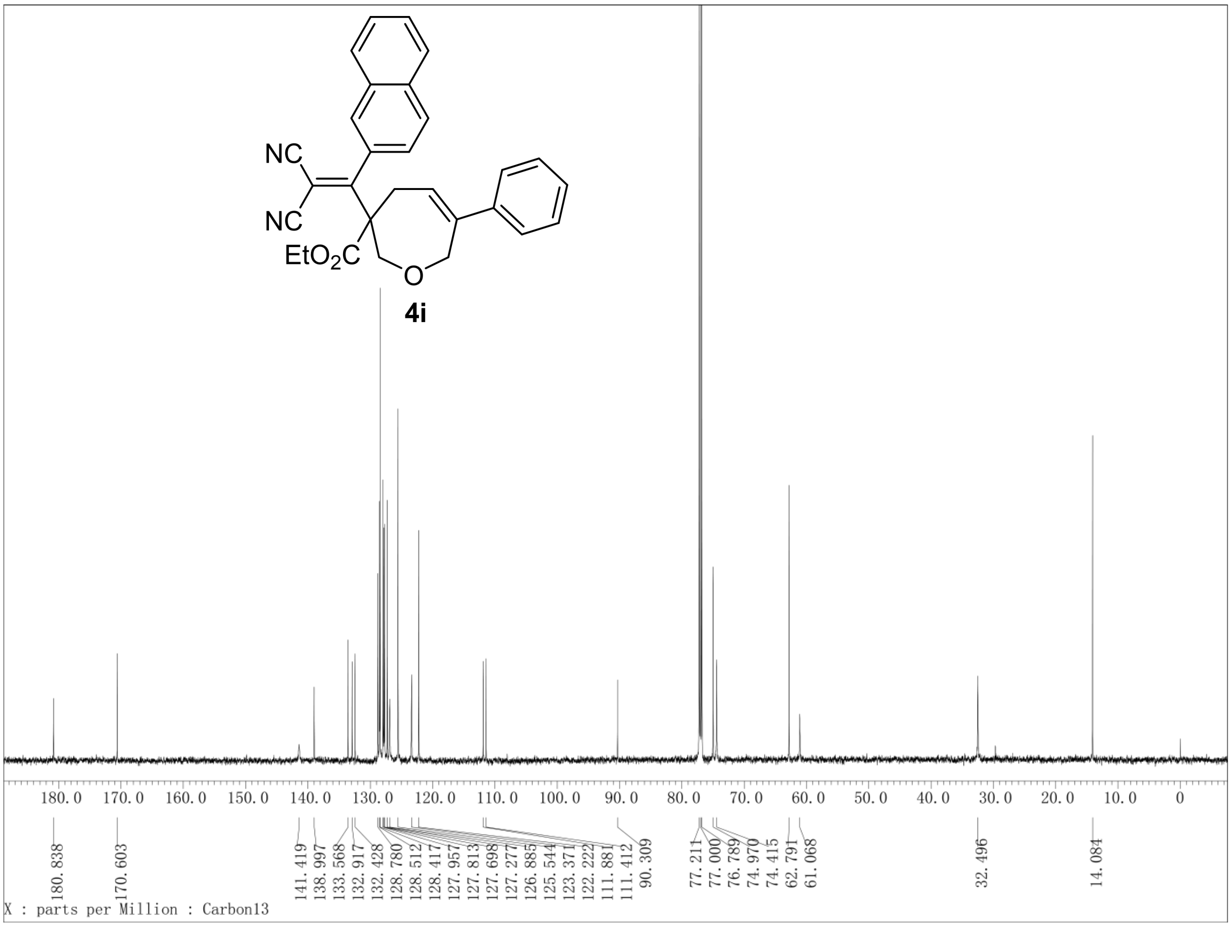
4i
NC
NC
EtO2C
O
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170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
180.838
170.603
141.419
138.997
133.568
132.917
132.428
128.780
128.512
128.417
127.957
127.813
127.698
127.277
126.885
125.544
123.371
122.222
111.881
111.412
90.309
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77.000
76.789
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74.415
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14.084
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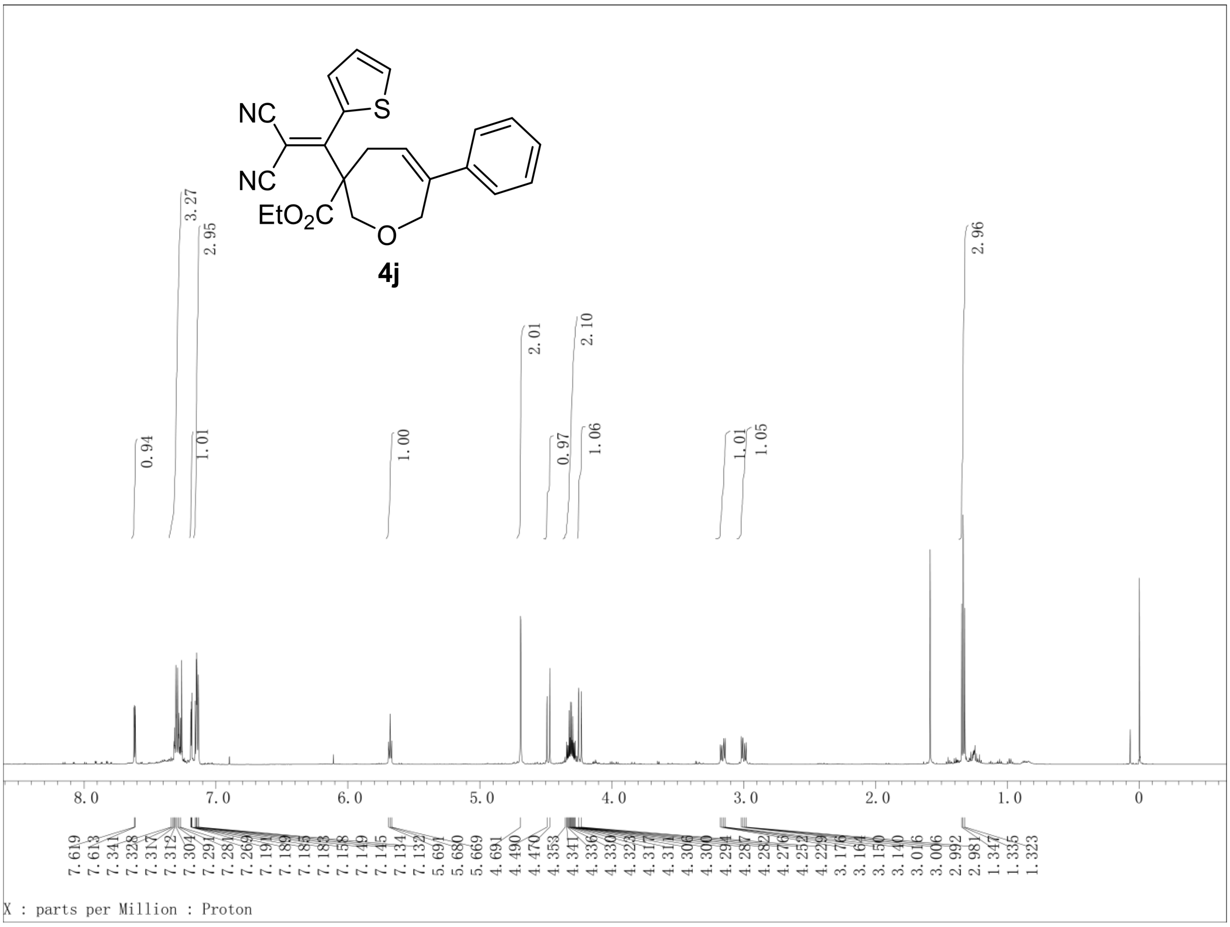
NC
NC
S
EtO2C
O
4j
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3.27
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1.01
1.00
2.01
0.97
2.10
1.06
1.01
1.05
2.96
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
7.619
7.613
7.341
7.328
7.317
7.312
7.304
7.297
7.281
7.269
7.191
7.189
7.185
7.183
7.158
7.149
7.145
7.134
7.132
5.691
5.680
5.669
4.691
4.490
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4.330
4.323
4.317
4.311
4.306
4.300
4.294
4.287
4.282
4.276
4.252
4.229
3.176
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3.006
2.992
2.981
1.347
1.335
1.323
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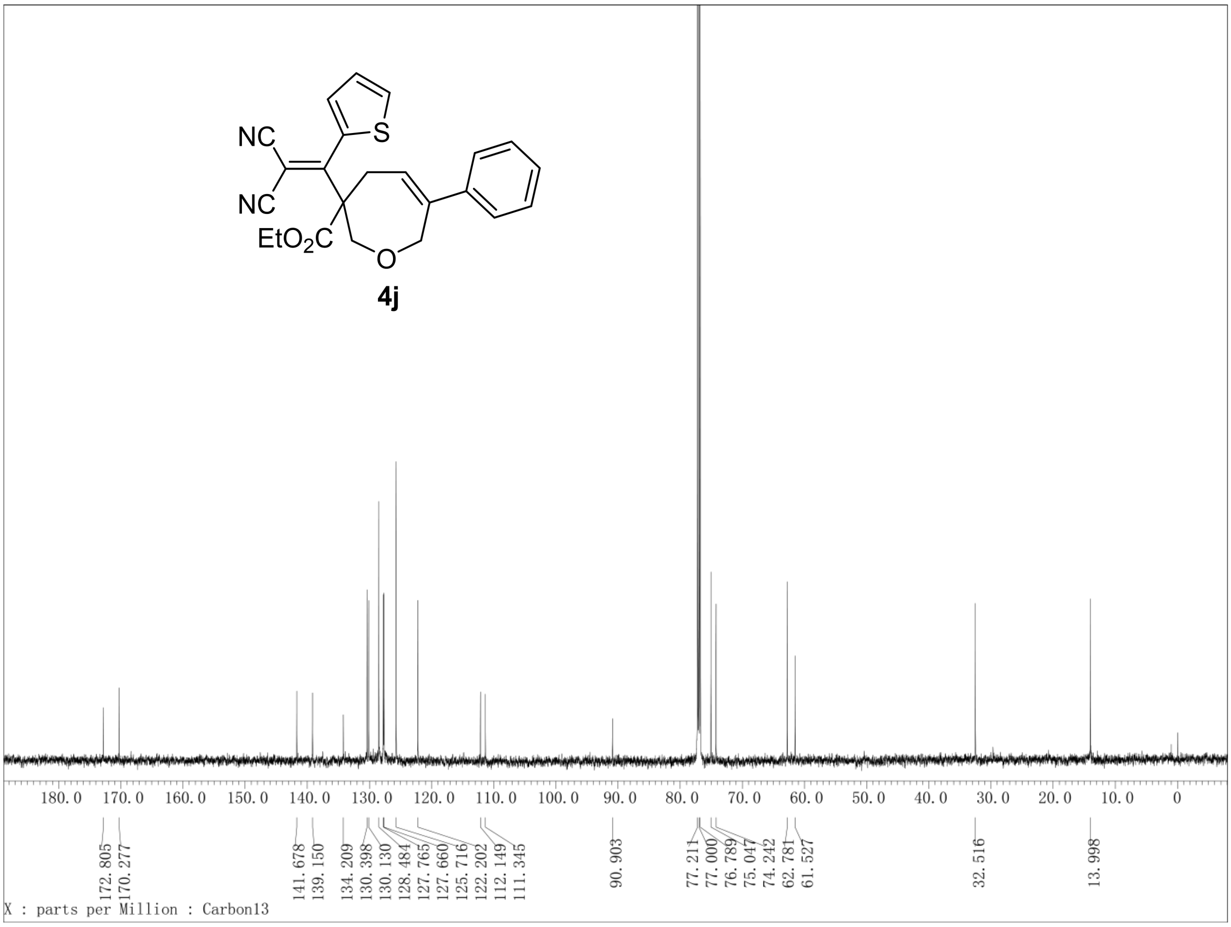
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NC
S
EtO2C
O
4j
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170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
172.805
170.277
141.678
139.150
134.209
130.398
130.130
128.484
127.765
127.660
125.716
122.202
112.149
111.345
90.903
77.211
77.000
76.789
75.047
74.242
62.781
61.527
32.516
13.998
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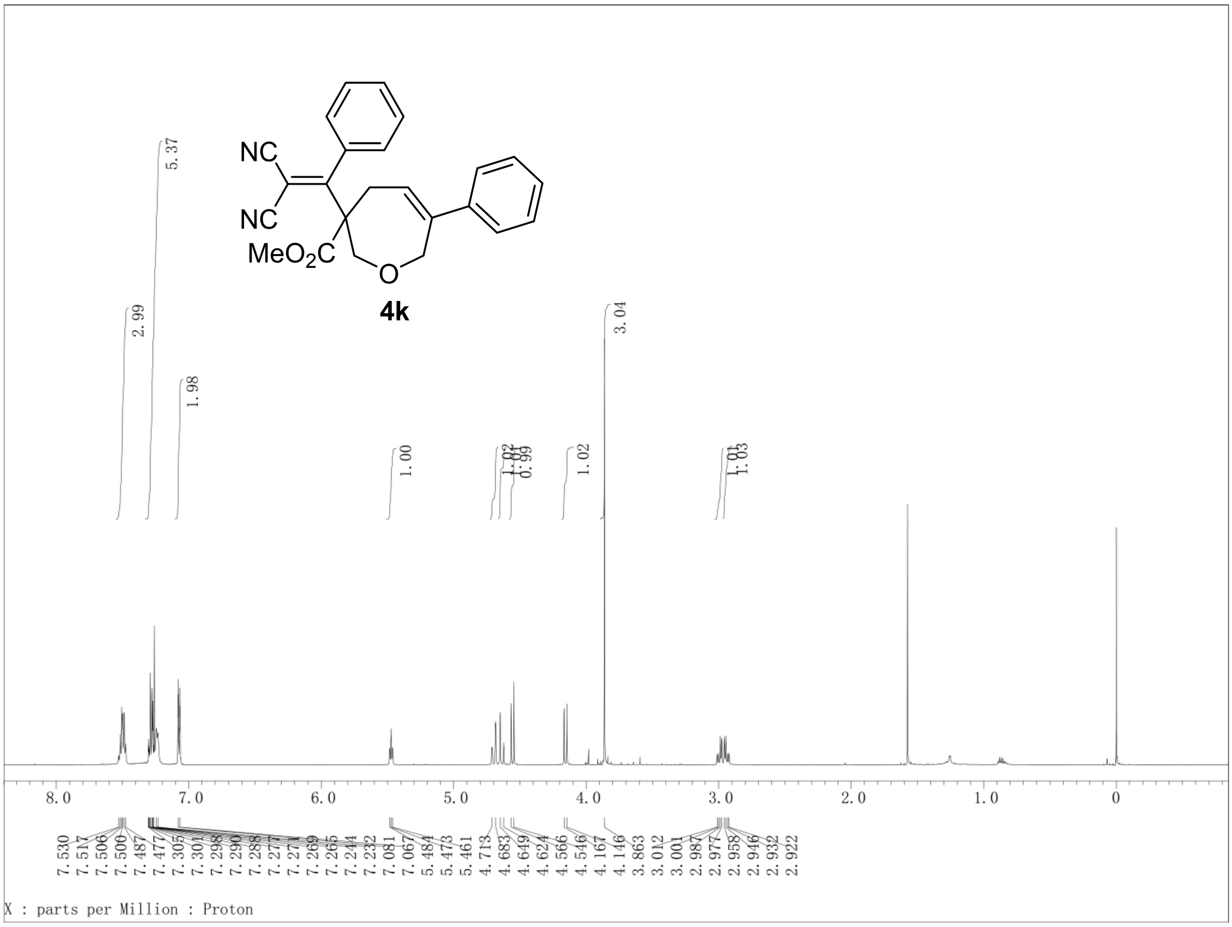
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NC
MeO2C
O
4k
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1.98
1.00
1.02
1.01
0.99
1.02
3.04
1.01
1.03
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
7.530
7.517
7.506
7.500
7.487
7.477
7.305
7.301
7.298
7.290
7.288
7.277
7.271
7.269
7.265
7.244
7.232
7.081
7.067
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5.473
5.461
4.713
4.683
4.649
4.624
4.566
4.546
4.167
4.146
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3.001
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2.932
2.922
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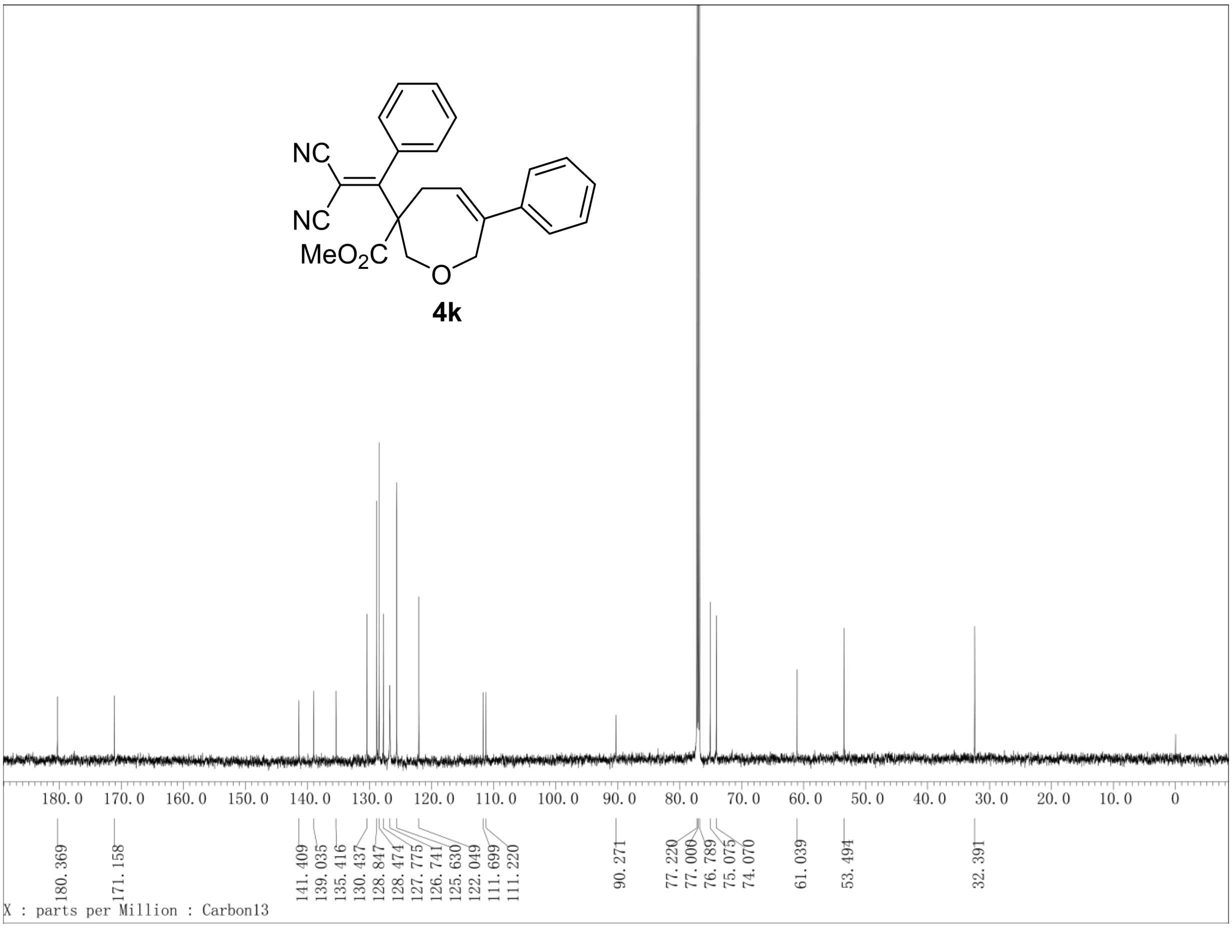
NC
NC
MeO2C
O
4k
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160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
180.369
171.158
141.409
139.035
135.416
130.437
128.847
128.474
127.775
126.741
125.630
122.049
111.699
111.220
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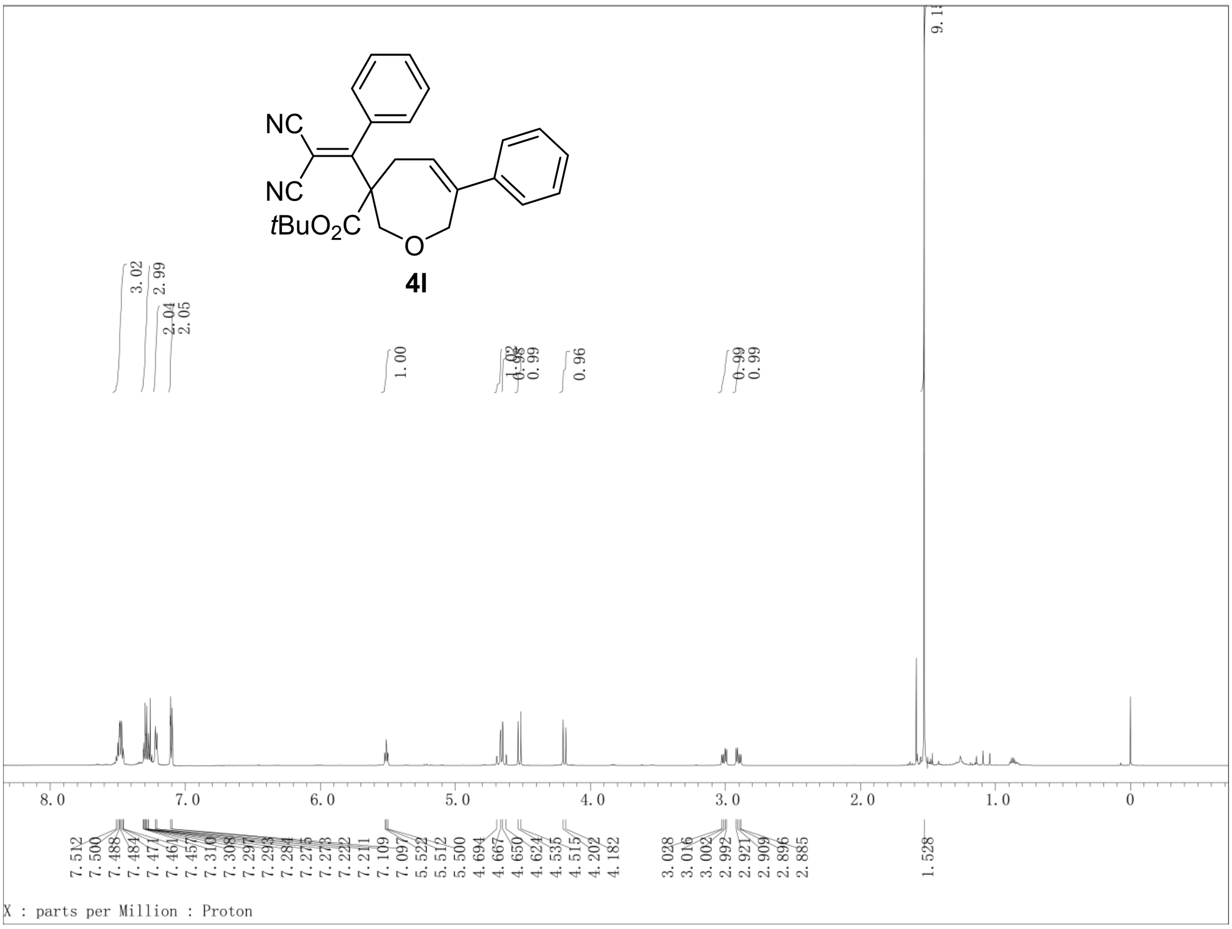
77.220
77.000
76.789
75.075
74.070
61.039
53.494
32.391
X : parts per Million : Carbon13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NC
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O
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2.04
2.05
1.00
1.02
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0.99
0.96
0.99
0.99
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
7.512
7.500
7.488
7.484
7.471
7.461
7.457
7.310
7.308
7.297
7.293
7.284
7.275
7.273
7.222
7.211
7.109
7.097
5.522
5.512
5.500
4.694
4.667
4.650
4.624
4.535
4.515
4.202
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2.896
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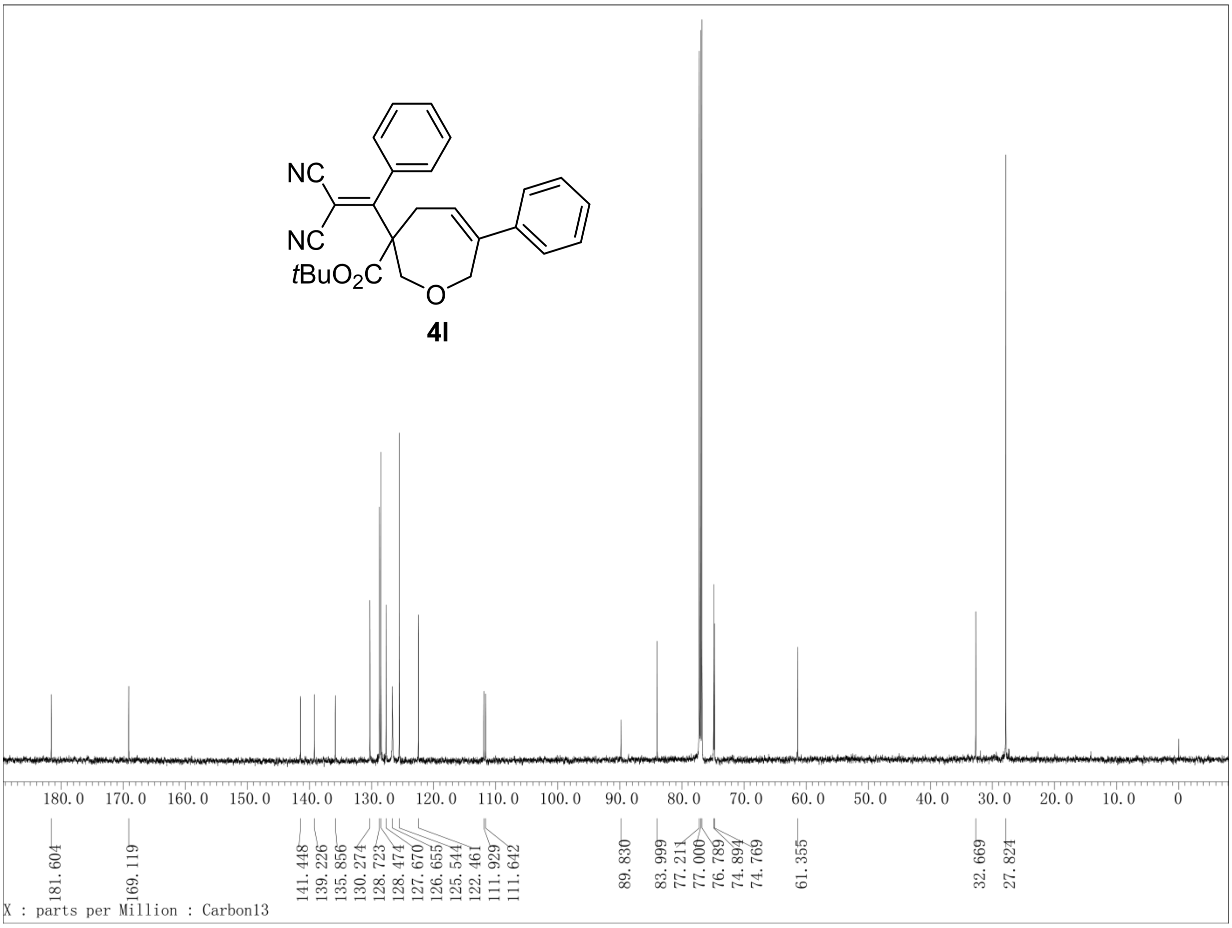
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NC
tBuO2C
O
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150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
181.604
169.119
141.448
139.226
135.856
130.274
128.723
128.474
127.670
126.655
125.544
122.461
111.929
111.642
89.830
83.999
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77.000
76.789
74.894
74.769
61.355
32.669
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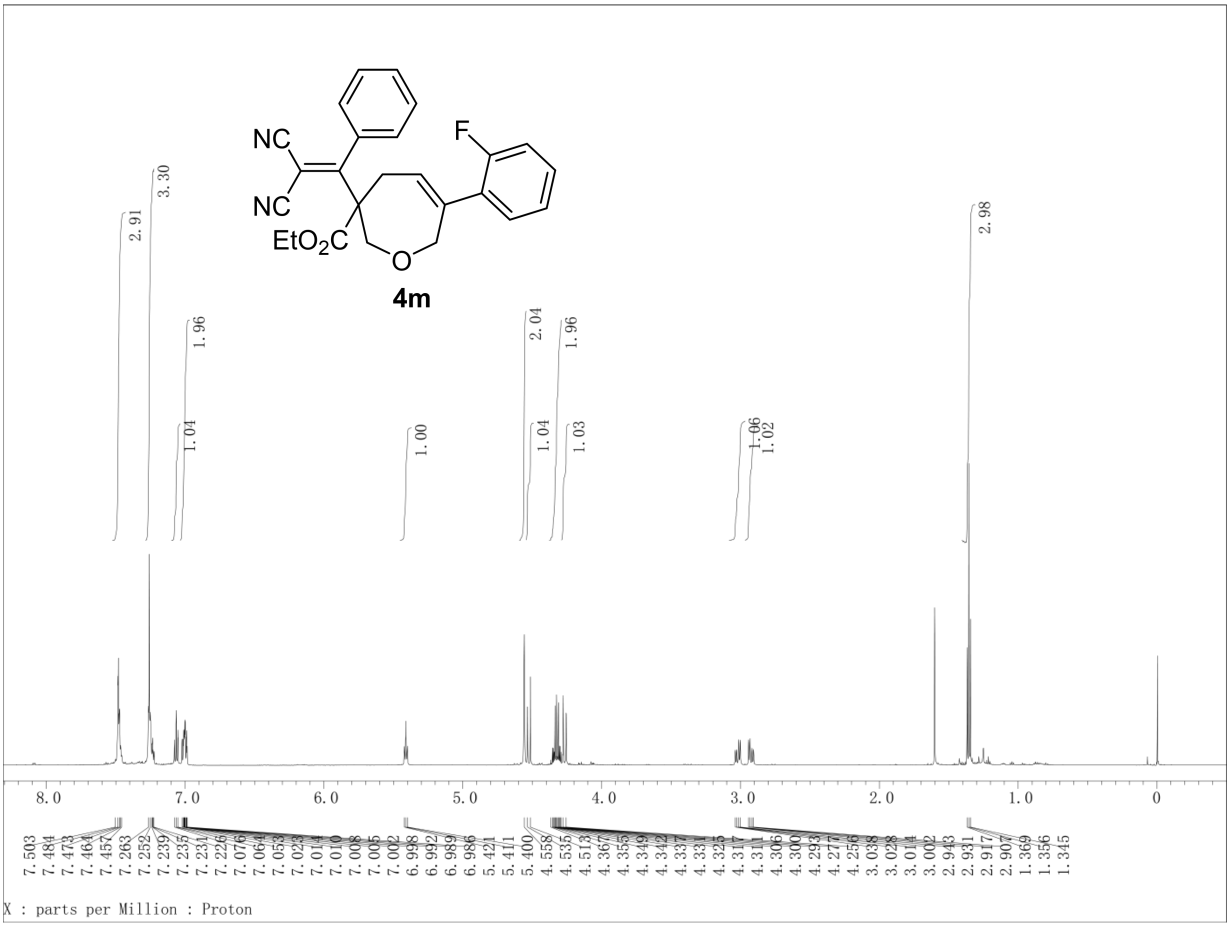
NC
NC
EtO2C
O
F
4m
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1.96
1.00
2.04
1.04
1.96
1.03
1.06
1.02
2.98
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
7.503
7.484
7.473
7.464
7.457
7.263
7.252
7.239
7.235
7.231
7.226
7.076
7.064
7.053
7.023
7.014
7.010
7.008
7.005
7.002
6.998
6.992
6.989
6.986
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5.411
5.400
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4.535
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4.367
4.355
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4.337
4.331
4.325
4.317
4.311
4.306
4.300
4.293
4.277
4.256
3.038
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2.917
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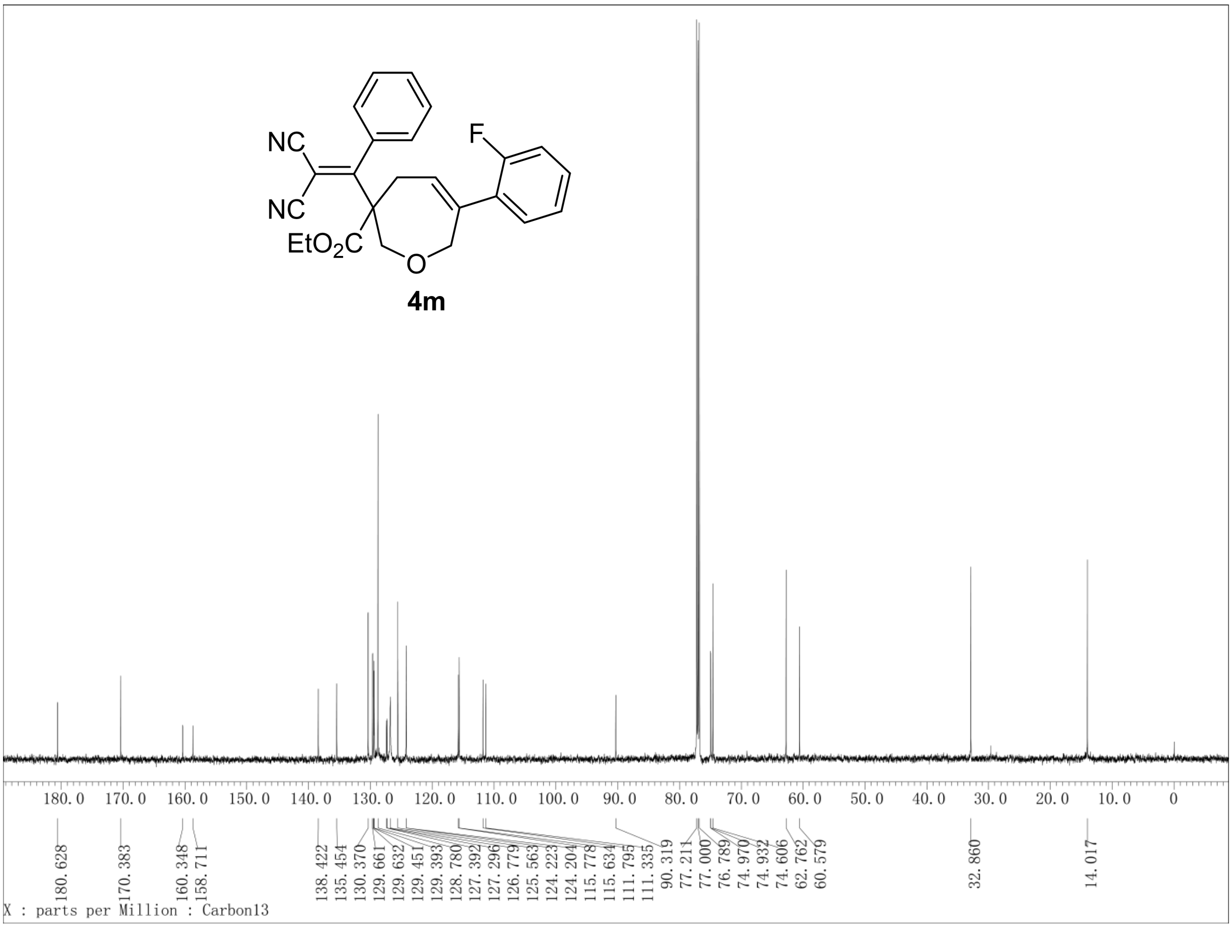
1.369
1.356
1.345
X : parts per Million : Proton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NC
EtO2C
O
F
4m
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160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
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170.383
160.348
158.711
138.422
135.454
130.370
129.661
129.632
129.451
129.393
128.780
127.392
127.296
126.779
125.563
124.223
124.204
115.778
115.634
111.795
111.335
90.319
77.211
77.000
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74.970
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74.606
62.762
60.579
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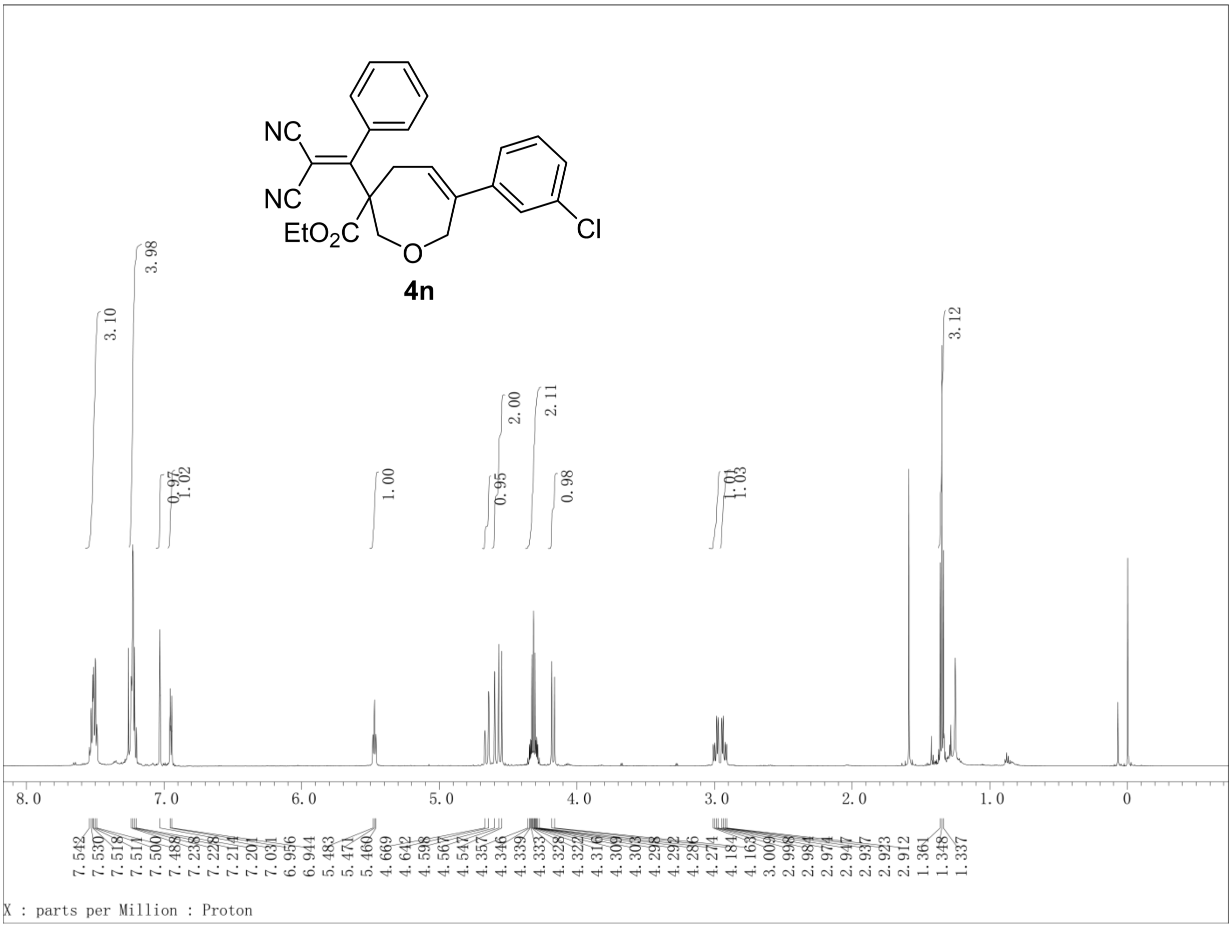
NC
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O
Cl
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0.95
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0.98
1.01
1.03
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6.0
5.0
4.0
3.0
2.0
1.0
0
7.542
7.530
7.518
7.511
7.500
7.488
7.238
7.228
7.214
7.201
7.031
6.956
6.944
5.483
5.471
5.460
4.669
4.642
4.598
4.567
4.547
4.357
4.346
4.339
4.333
4.328
4.322
4.316
4.309
4.303
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4.292
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4.274
4.184
4.163
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2.912
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1.348
1.337
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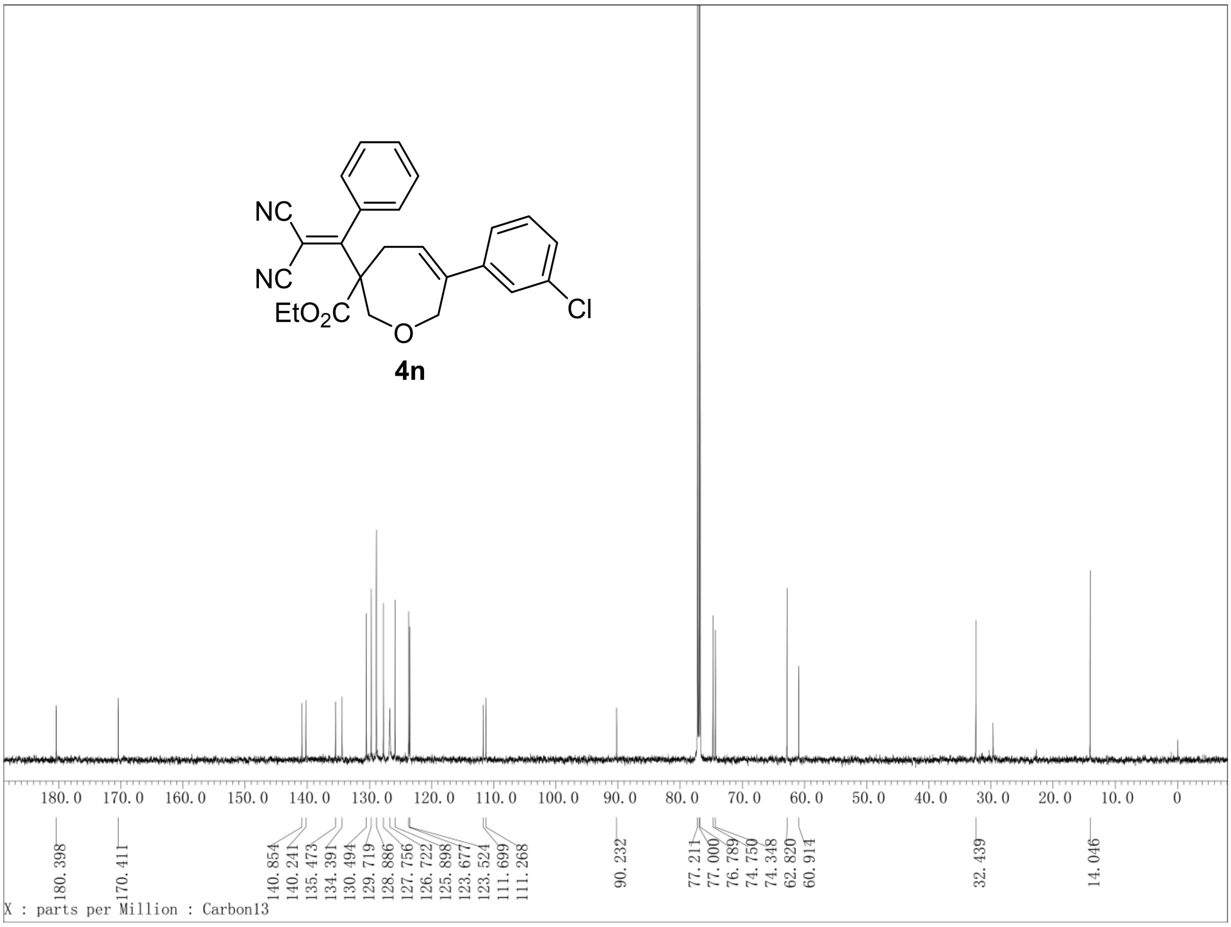
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NC
EtO2C
O
Cl
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150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
180.398
170.411
140.854
140.241
135.473
134.391
130.494
129.719
128.886
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126.722
125.898
123.677
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111.699
111.268
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32.439
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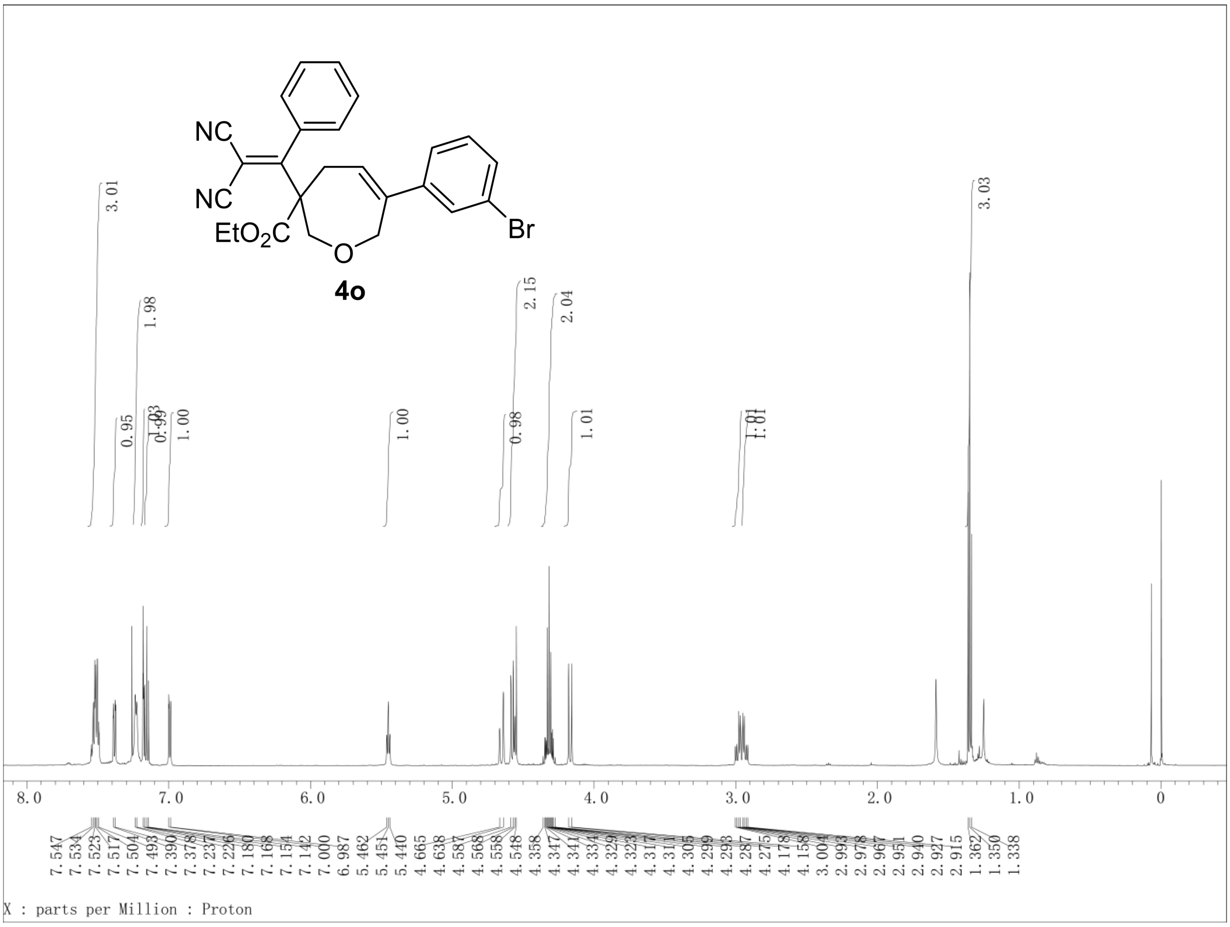
X : parts per Million : Carbon13


NC
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EtO$_2$C
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Br
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1.00
1.00
0.98
2.15
2.04
1.01
1.01
1.01
3.03
8.0
7.0
6.0
5.0
4.0
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2.0
1.0
0
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7.493
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7.237
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7.180
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7.154
7.142
7.000
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4.317
4.311
4.305
4.299
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4.275
4.178
4.158
3.004
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2.940
2.927
2.915
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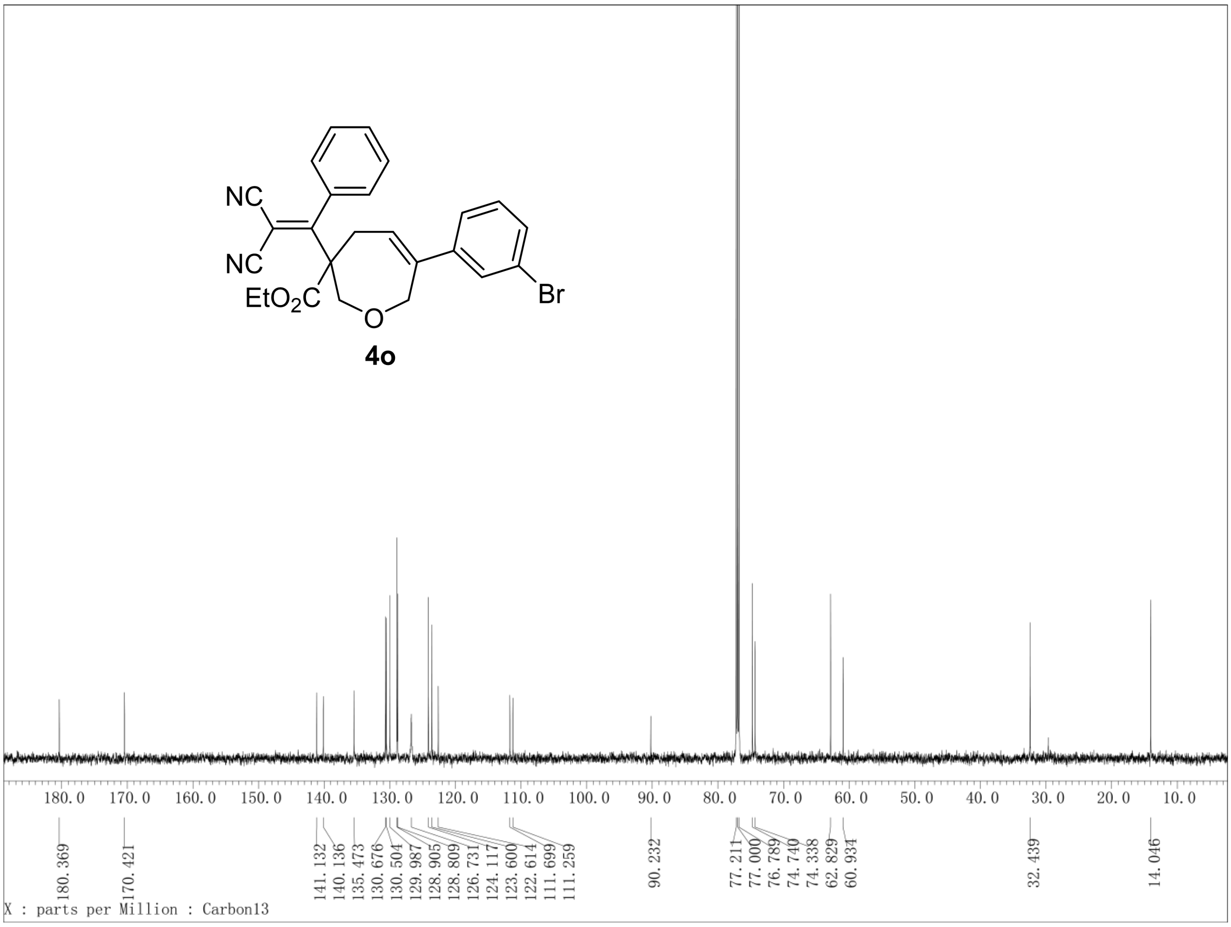
1.350
1.338
X : parts per Million : Proton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NC
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Br
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80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
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140.136
135.473
130.676
130.504
129.987
128.905
128.809
126.731
124.117
123.600
122.614
111.699
111.259
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76.789
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60.934
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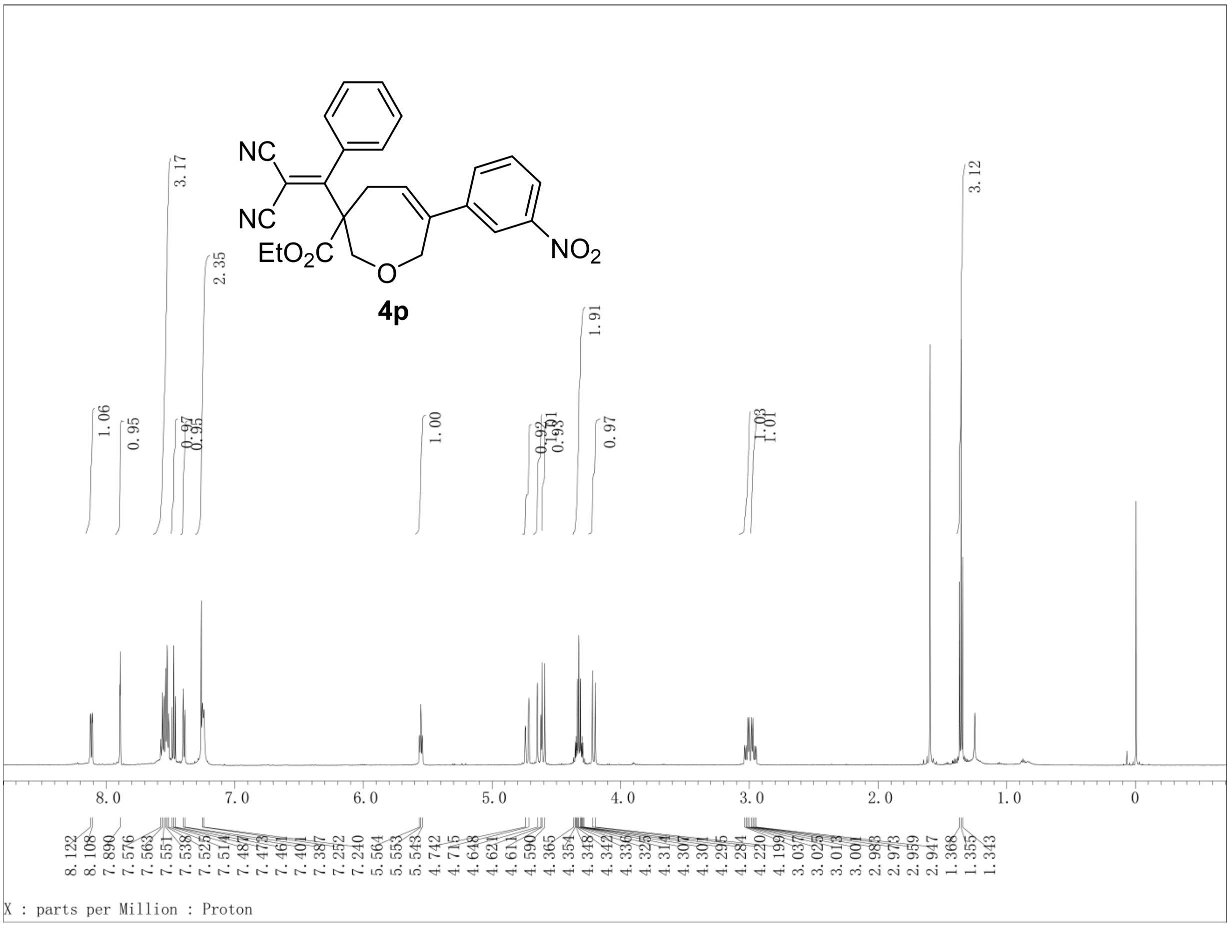
X : parts per Million : Carbon13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NO2
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1.01
0.93
1.91
0.97
1.03
1.01
3.12
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
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7.576
7.563
7.551
7.538
7.525
7.514
7.487
7.473
7.461
7.401
7.387
7.252
7.240
5.564
5.553
5.543
4.742
4.715
4.648
4.621
4.611
4.590
4.365
4.354
4.348
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4.336
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4.301
4.295
4.284
4.220
4.199
3.037
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2.959
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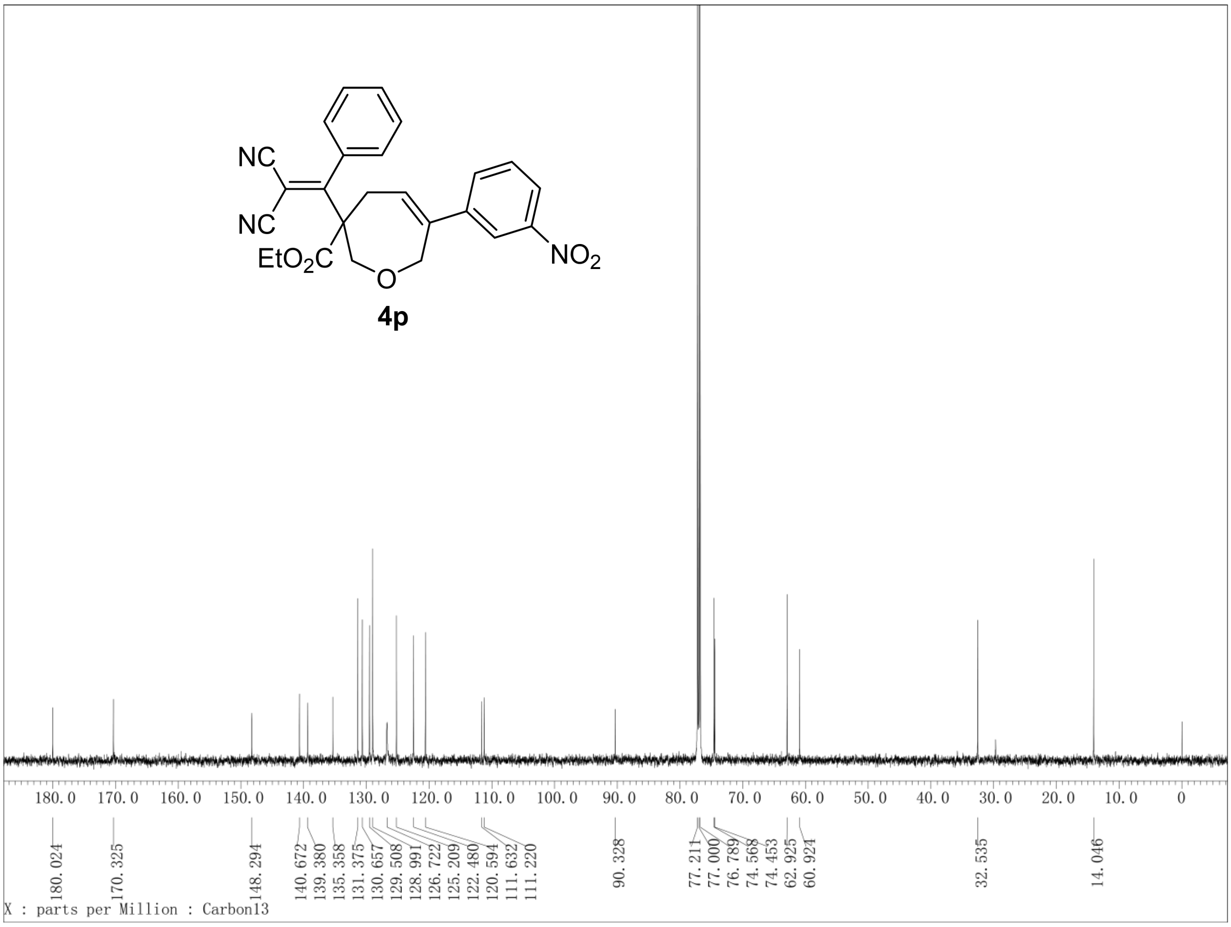
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NO2
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80.0
70.0
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50.0
40.0
30.0
20.0
10.0
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135.358
131.375
130.657
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128.991
126.722
125.209
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60.924
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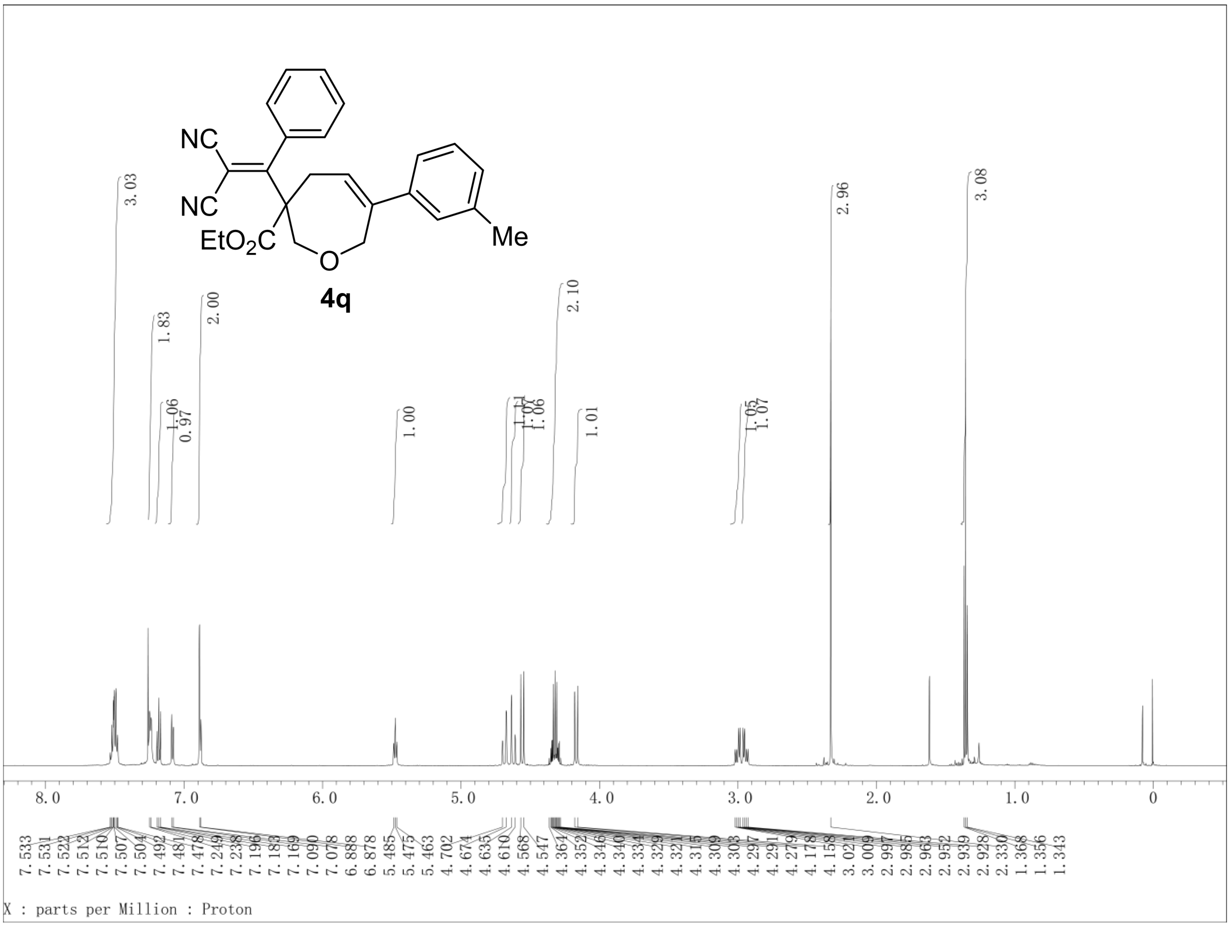
X : parts per Million : Carbon13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O
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1.00
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1.06
2.10
1.01
1.05
1.07
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3.08
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7.0
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5.0
4.0
3.0
2.0
1.0
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7.531
7.522
7.513
7.510
7.507
7.504
7.492
7.481
7.478
7.249
7.238
7.196
7.183
7.169
7.090
7.078
6.888
6.878
5.485
5.475
5.463
4.702
4.674
4.635
4.610
4.568
4.547
4.361
4.352
4.346
4.340
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4.309
4.303
4.297
4.291
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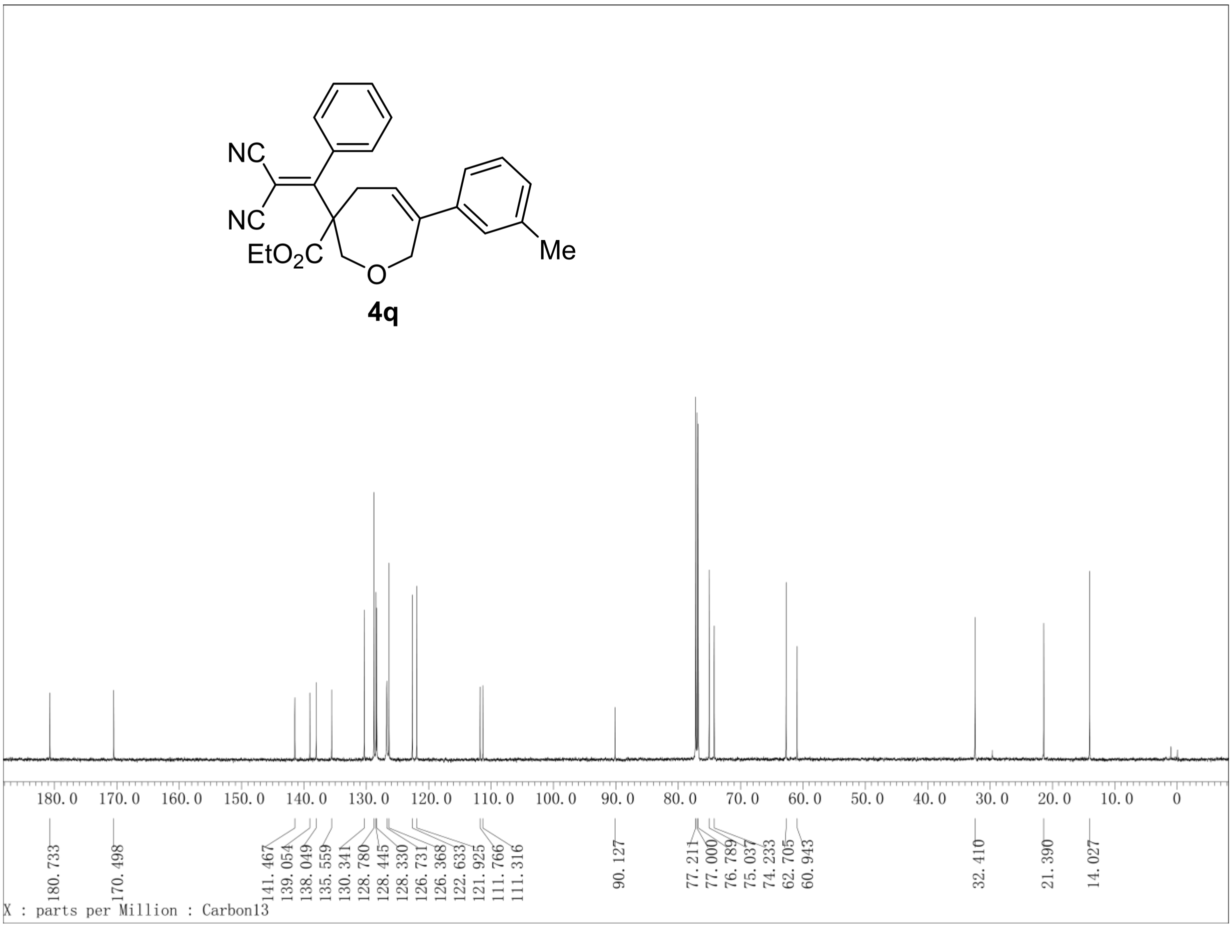
1.343
X : parts per Million : Proton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Me
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90.0
80.0
70.0
60.0
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40.0
30.0
20.0
10.0
0
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170.498
141.467
139.054
138.049
135.559
130.341
128.780
128.445
128.330
126.731
126.368
122.633
121.925
111.766
111.316
90.127
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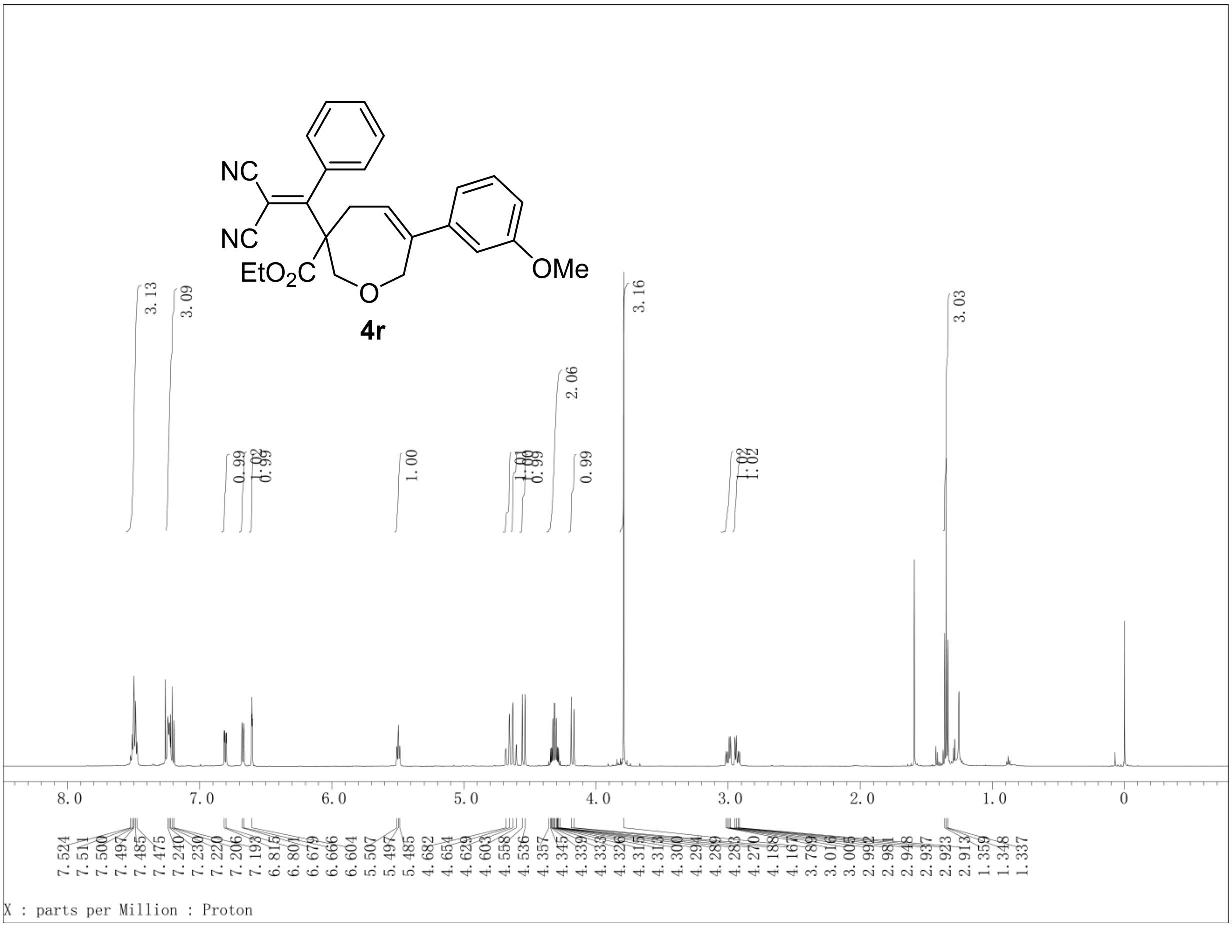
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EtO2C
O
OMe
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0.99
1.00
1.01
1.00
0.99
2.06
0.99
3.16
1.02
1.02
3.03
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
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7.511
7.500
7.497
7.485
7.475
7.240
7.230
7.220
7.206
7.193
6.815
6.801
6.679
6.666
6.604
5.507
5.497
5.485
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4.654
4.629
4.603
4.558
4.536
4.357
4.345
4.339
4.333
4.326
4.315
4.313
4.300
4.294
4.289
4.283
4.270
4.188
4.167
3.789
3.016
3.005
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2.948
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2.923
2.913
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1.337
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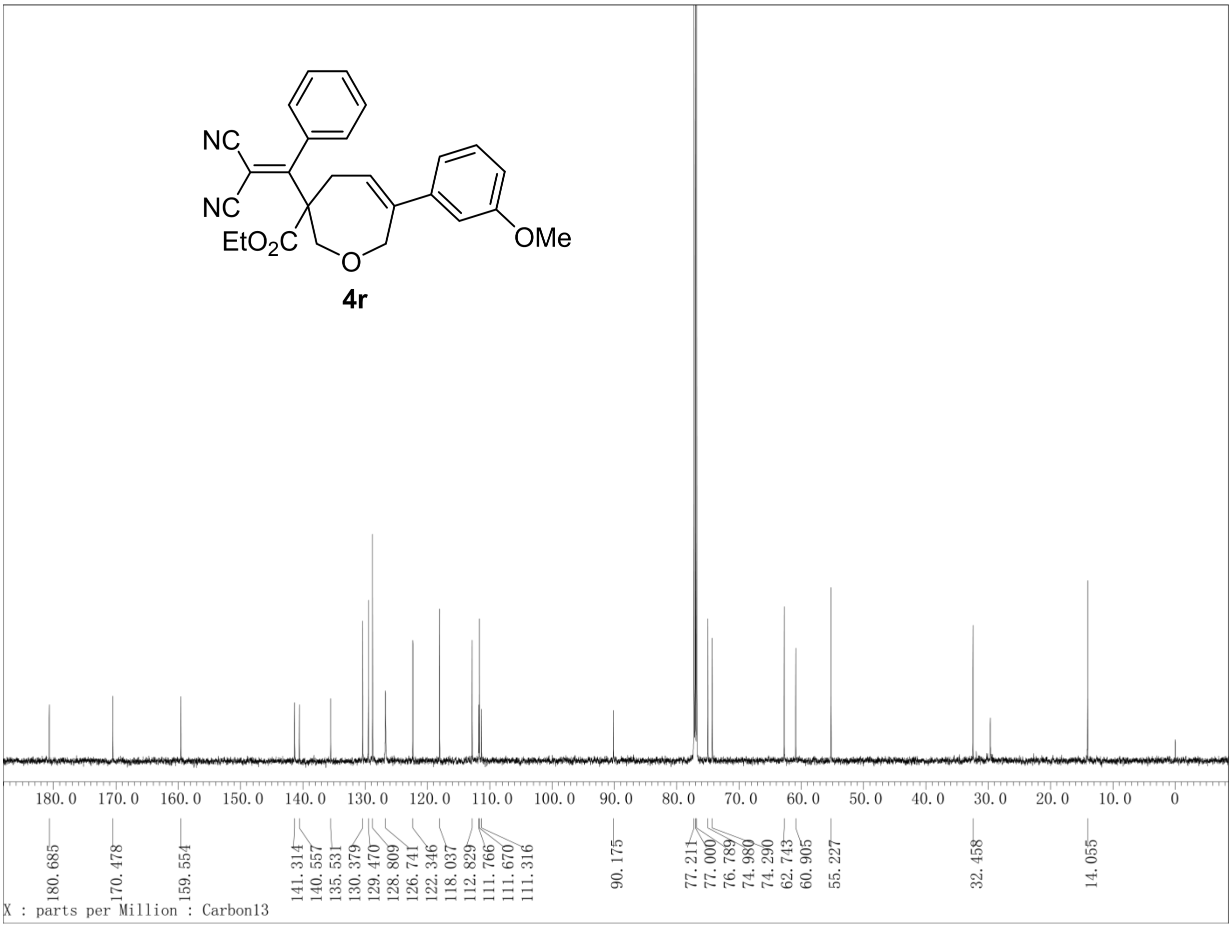
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NC
EtO2C
O
OMe
4r
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150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
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170.478
159.554
141.314
140.557
135.531
130.379
129.470
128.809
126.741
122.346
118.037
112.829
111.766
111.670
111.316
90.175
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74.980
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62.743
60.905
55.227
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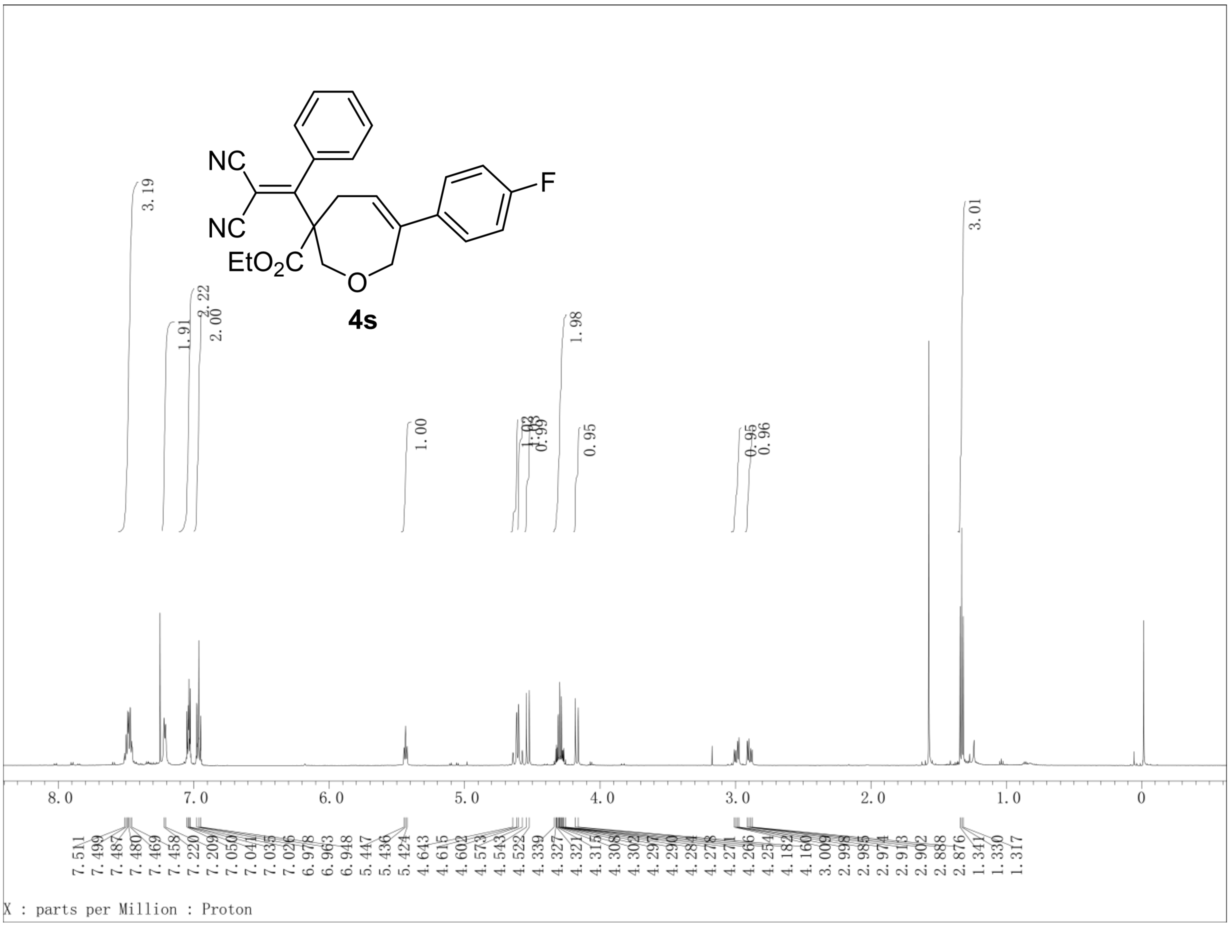
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NC
EtO2C
O
F
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2.00
1.00
1.02
1.03
0.99
1.98
0.95
0.95
0.96
3.01
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
7.511
7.499
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7.209
7.050
7.041
7.035
7.026
6.978
6.963
6.948
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5.436
5.424
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4.615
4.602
4.573
4.543
4.522
4.339
4.327
4.321
4.315
4.308
4.302
4.297
4.290
4.284
4.278
4.271
4.266
4.254
4.182
4.160
3.009
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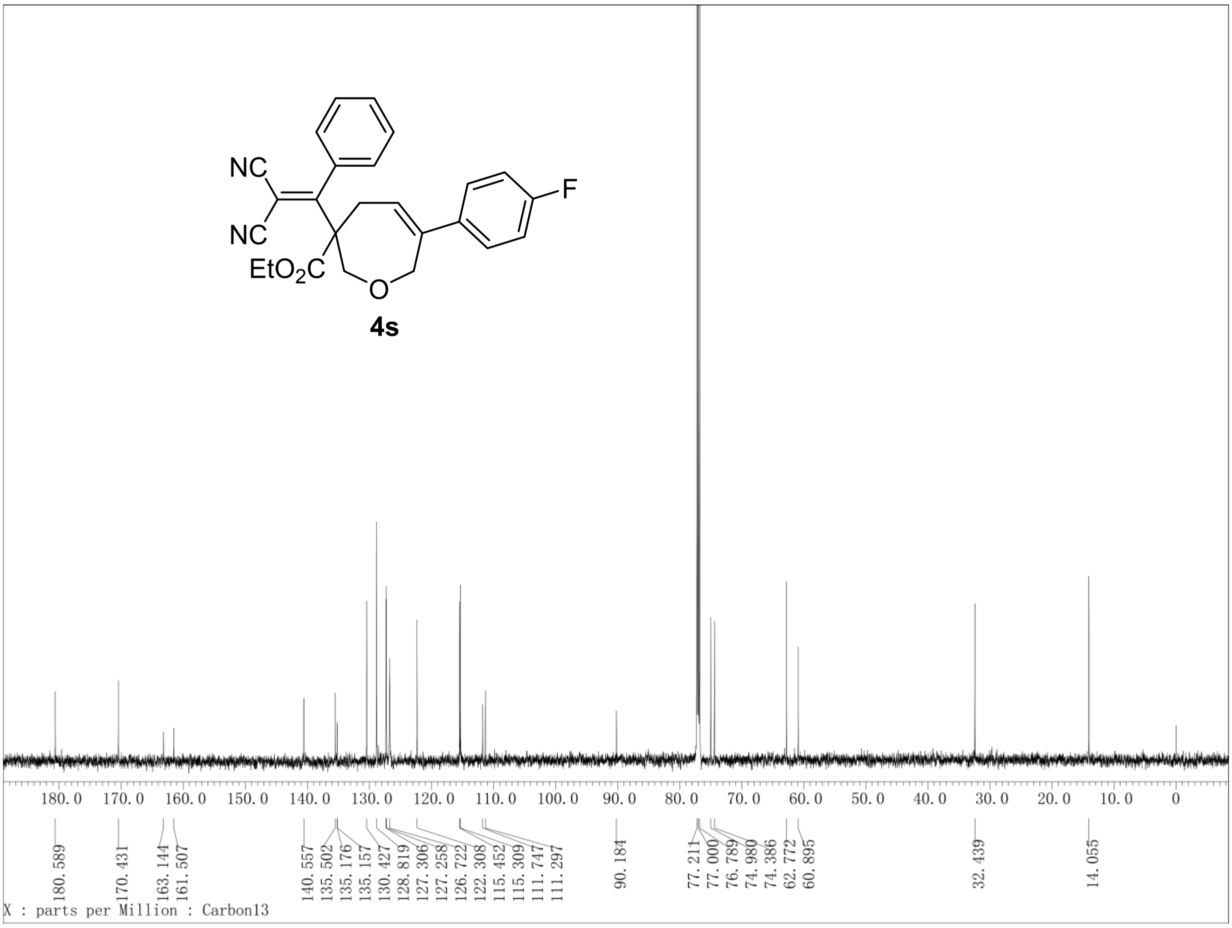
X : parts per Million : Proton


NC
NC
EtO2C
O
F
4s
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160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
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163.144
161.507
140.557
135.502
135.176
135.157
130.427
128.819
127.306
127.258
126.722
122.308
115.452
115.309
111.747
111.297
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32.439
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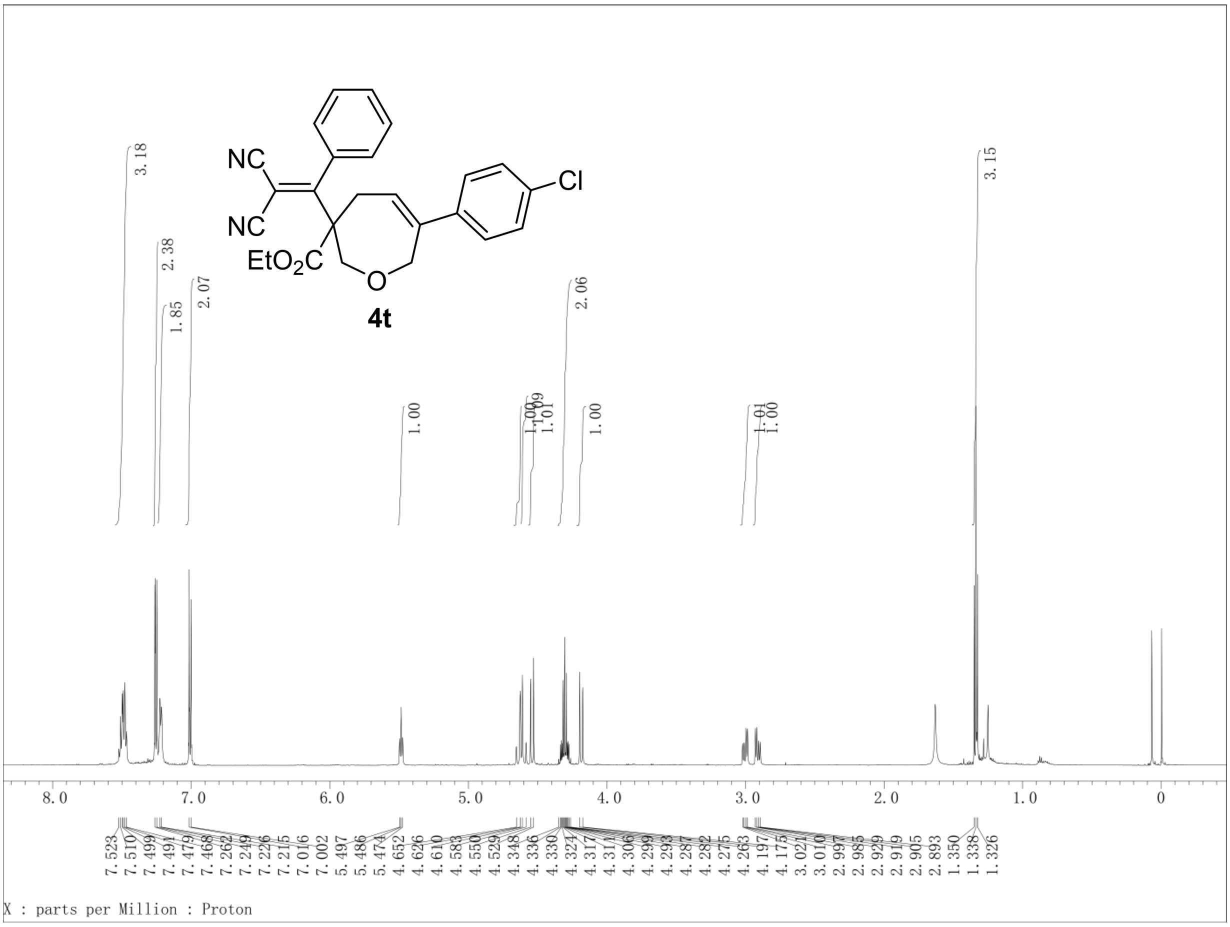
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NC
EtO$_2$C
O
Cl
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1.85
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1.00
1.00
1.09
1.01
1.00
2.06
1.01
1.00
3.15
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
7.523
7.510
7.499
7.491
7.479
7.468
7.262
7.249
7.226
7.215
7.016
7.002
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4.583
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4.306
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4.293
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4.282
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4.175
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3.010
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1.338
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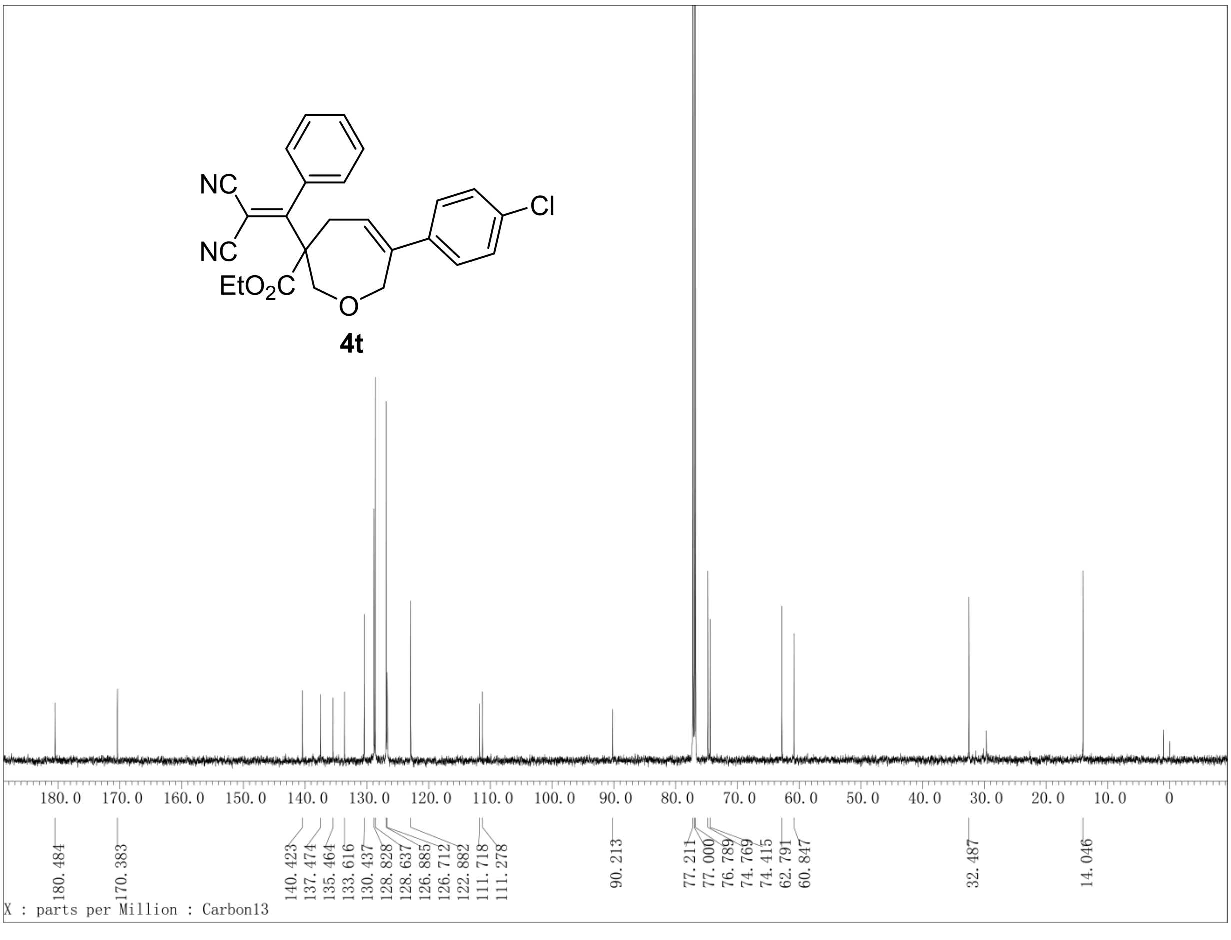
X : parts per Million : Proton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NC
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O
Cl
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160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
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170.383
140.423
137.474
135.464
133.616
130.437
128.828
128.637
126.885
126.712
122.882
111.718
111.278
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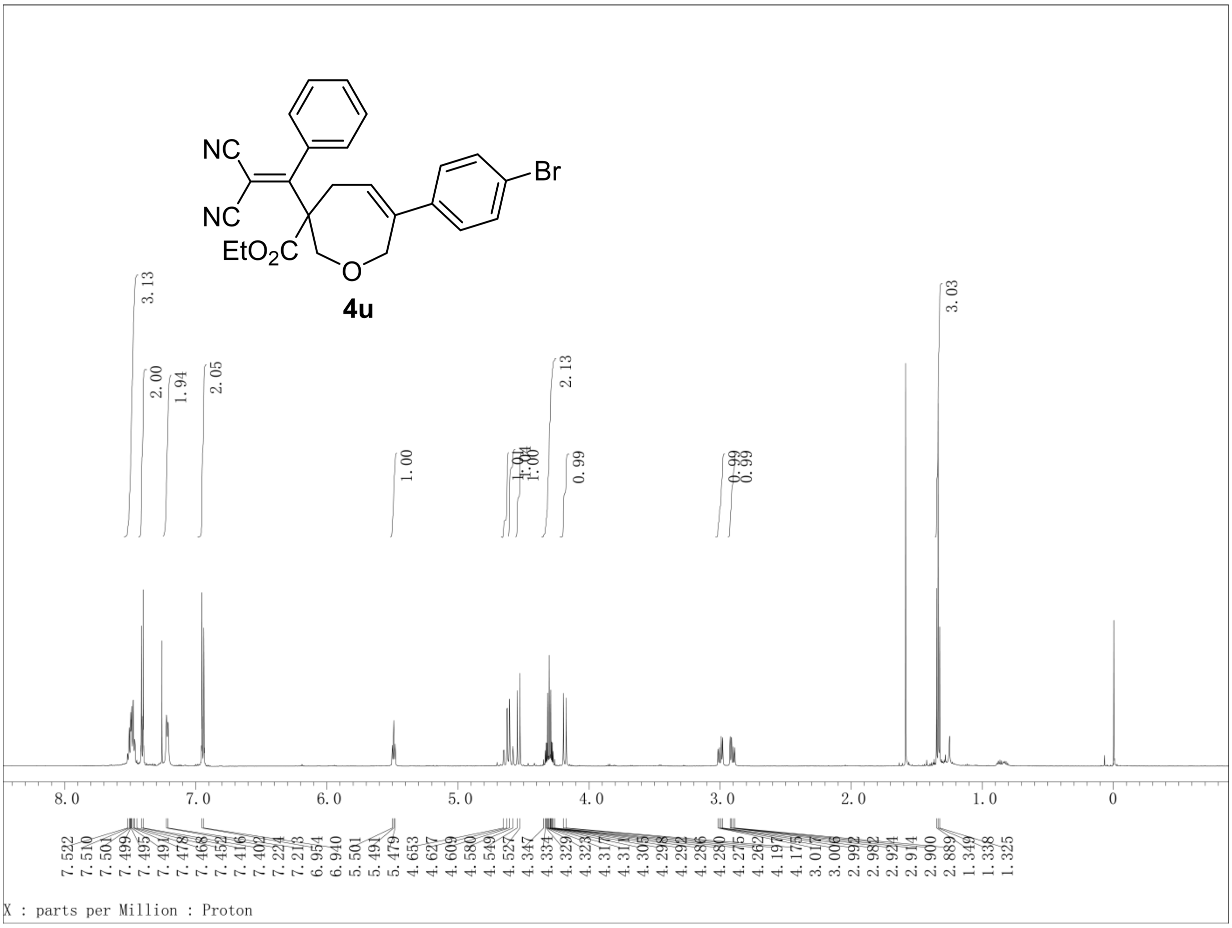
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NC
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O
Br
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1.01
1.04
1.00
2.13
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0.99
0.99
3.03
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7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
7.522
7.510
7.501
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7.495
7.491
7.478
7.468
7.452
7.416
7.402
7.224
7.213
6.954
6.940
5.501
5.491
5.479
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4.292
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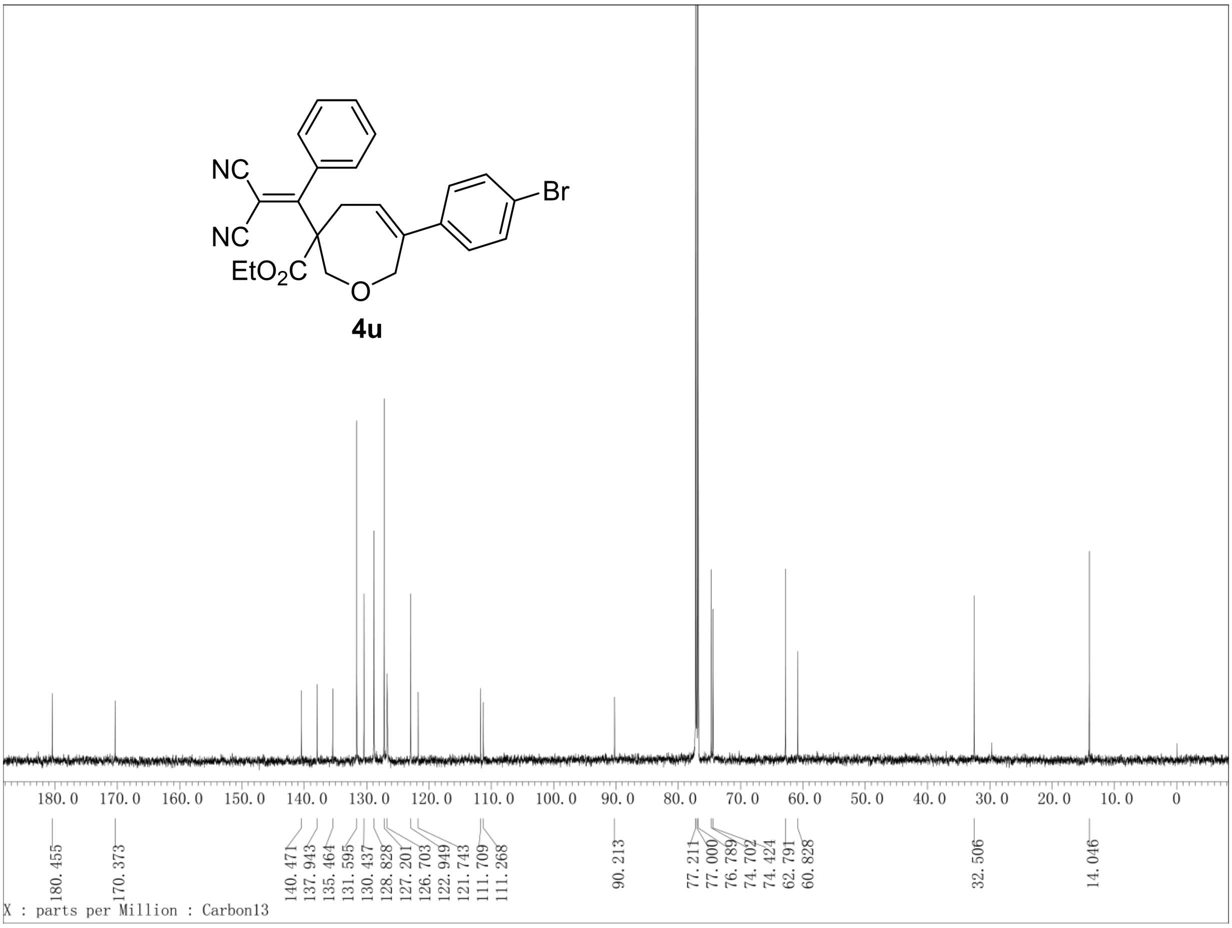
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NC
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O
Br
4u
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130.0
120.0
110.0
100.0
90.0
80.0
70.0
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50.0
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20.0
10.0
0
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140.471
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135.464
131.595
130.437
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127.201
126.703
122.949
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111.709
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62.791
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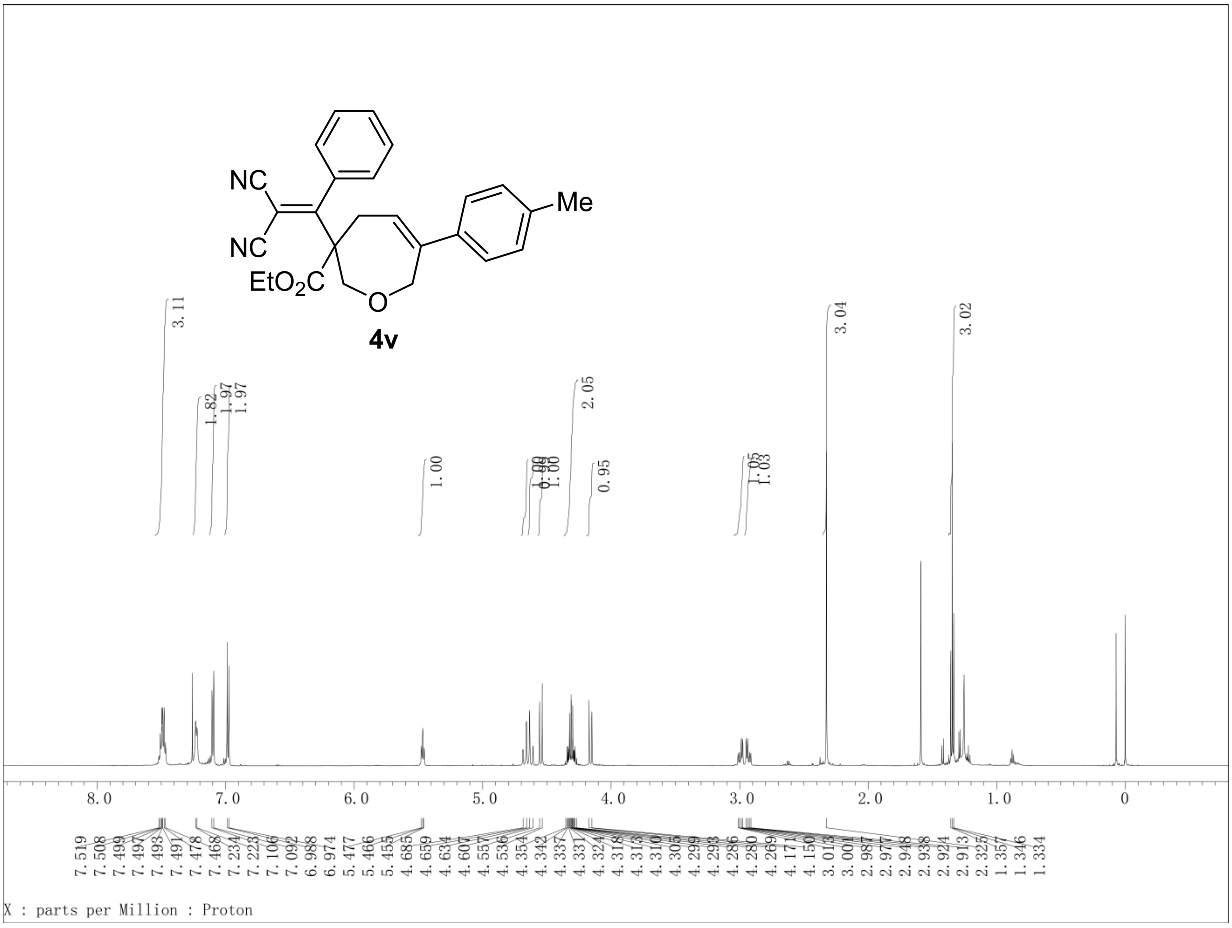
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O
Me
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1.00
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2.05
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1.05
1.03
3.04
3.02
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7.0
6.0
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4.0
3.0
2.0
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0
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6.974
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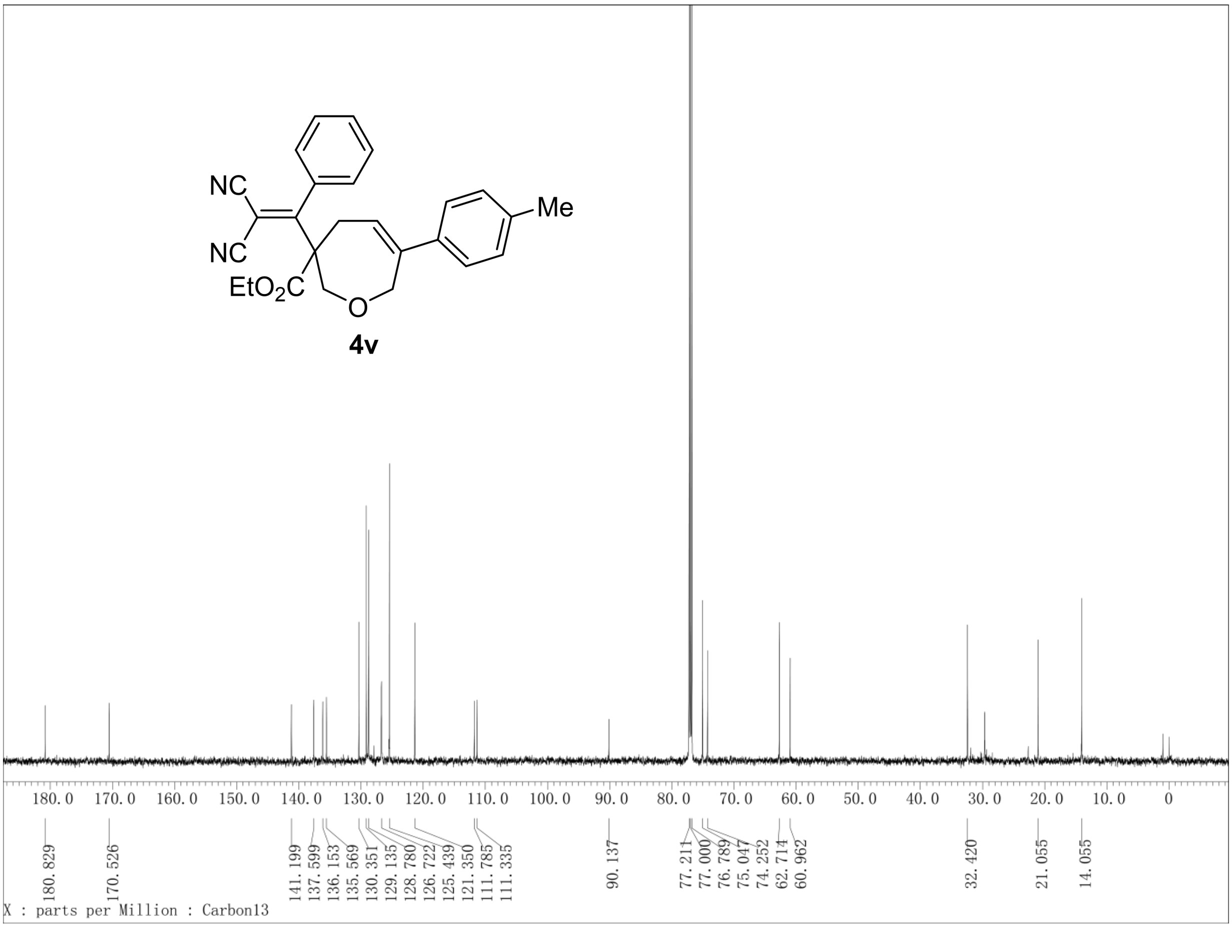
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NC
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O
Me
4v
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130.0
120.0
110.0
100.0
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80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
180.829
170.526
141.199
137.599
136.153
135.569
130.351
129.135
128.780
126.722
125.439
121.350
111.785
111.335
90.137
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62.714
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32.420
21.055
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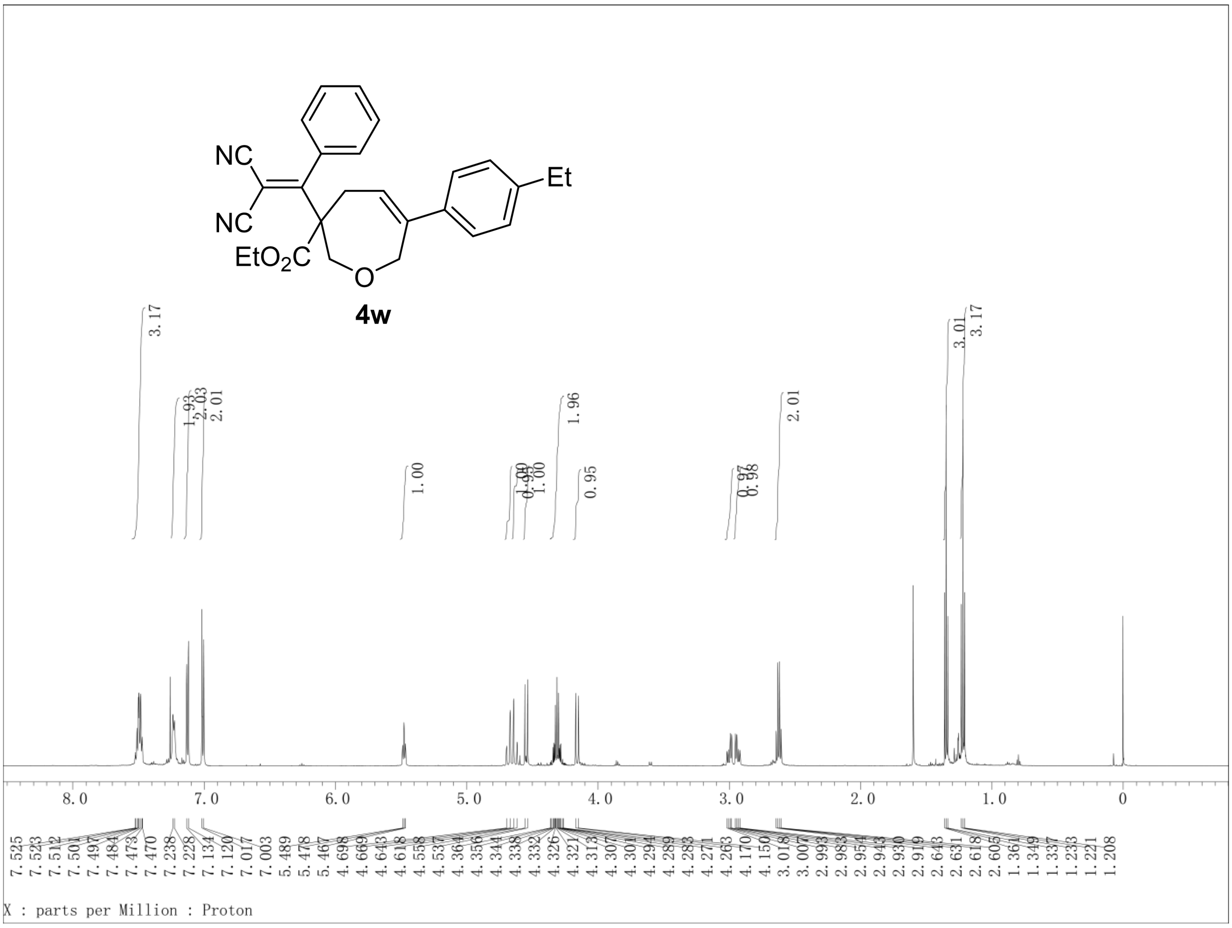
X : parts per Million : Carbon13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O
Et
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1.00
1.96
0.95
0.97
0.98
2.01
3.01
3.17
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
7.525
7.523
7.512
7.501
7.497
7.484
7.473
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7.228
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7.120
7.017
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5.478
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4.618
4.558
4.537
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4.356
4.344
4.338
4.332
4.326
4.321
4.313
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4.301
4.294
4.289
4.283
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3.018
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2.983
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1.337
1.233
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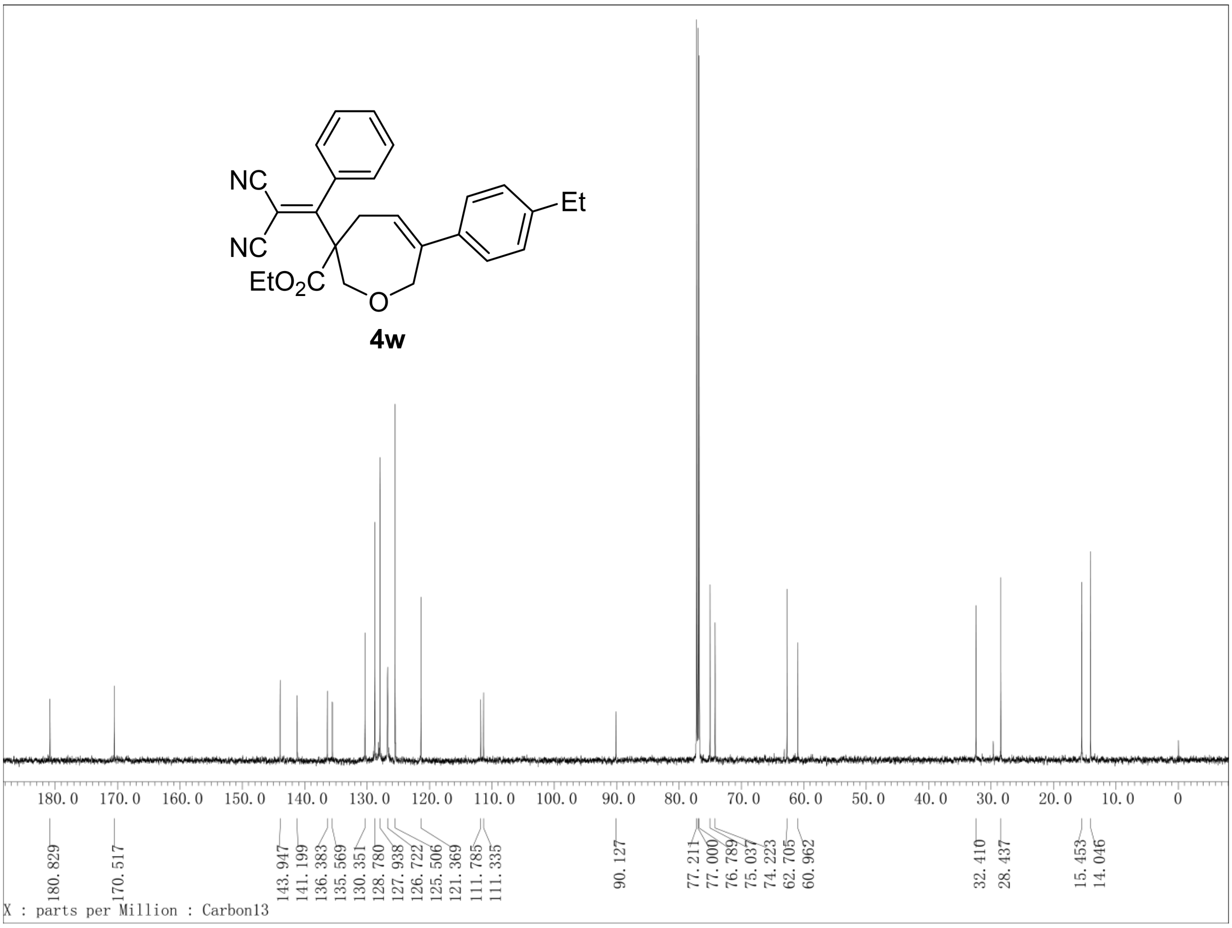
NC
NC
EtO2C
O
Et
4w
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160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
180.829
170.517
143.947
141.199
136.383
135.569
130.351
128.780
127.938
126.722
125.506
121.369
111.785
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90.127
77.211
77.000
76.789
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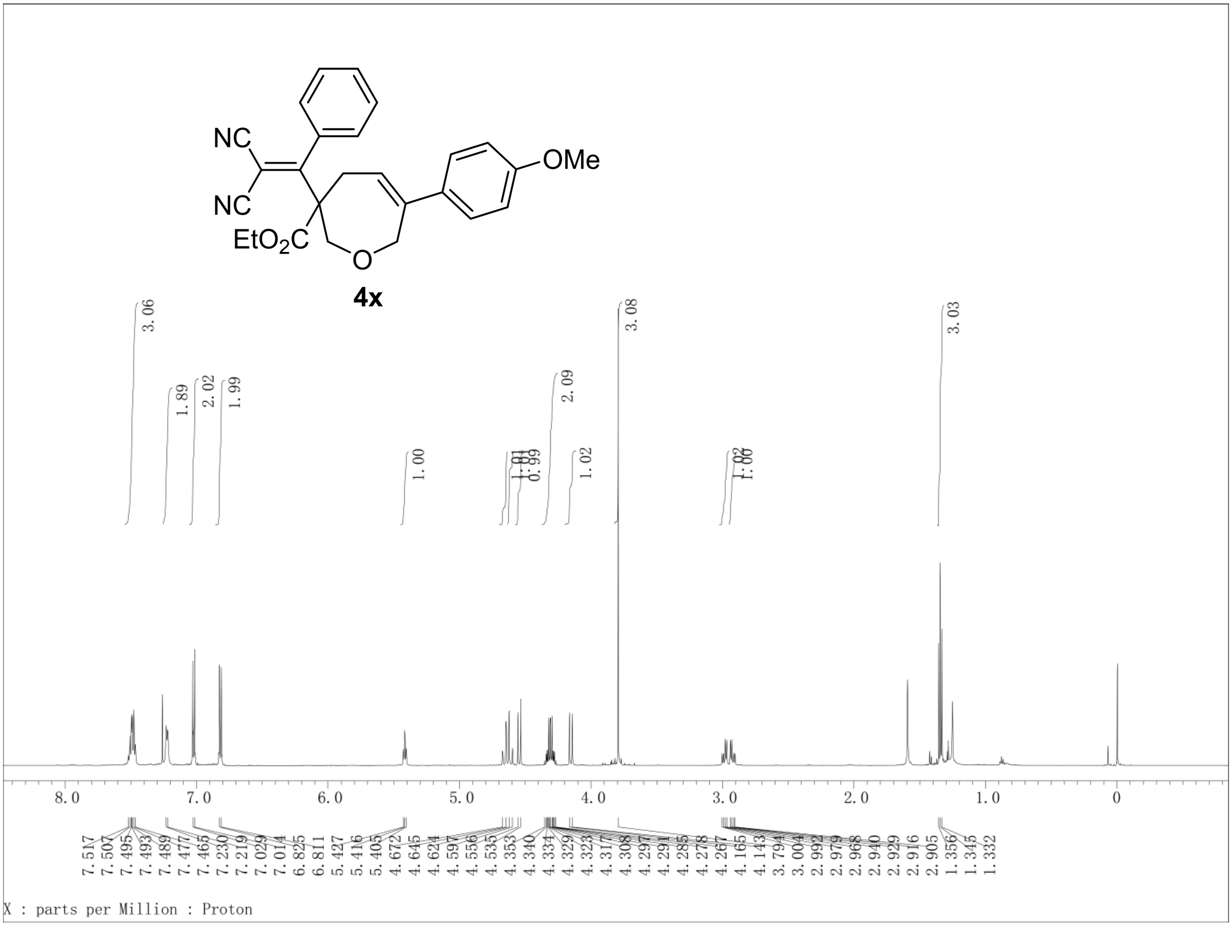
74.223
62.705
60.962
32.410
28.437
15.453
14.046
X : parts per Million : Carbon13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EtO2C
O
OMe
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1.01
1.01
0.99
2.09
1.02
3.08
1.02
1.00
3.03
8.0
7.0
6.0
5.0
4.0
3.0
2.0
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4.535
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4.317
4.308
4.297
4.291
4.285
4.278
4.267
4.165
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3.794
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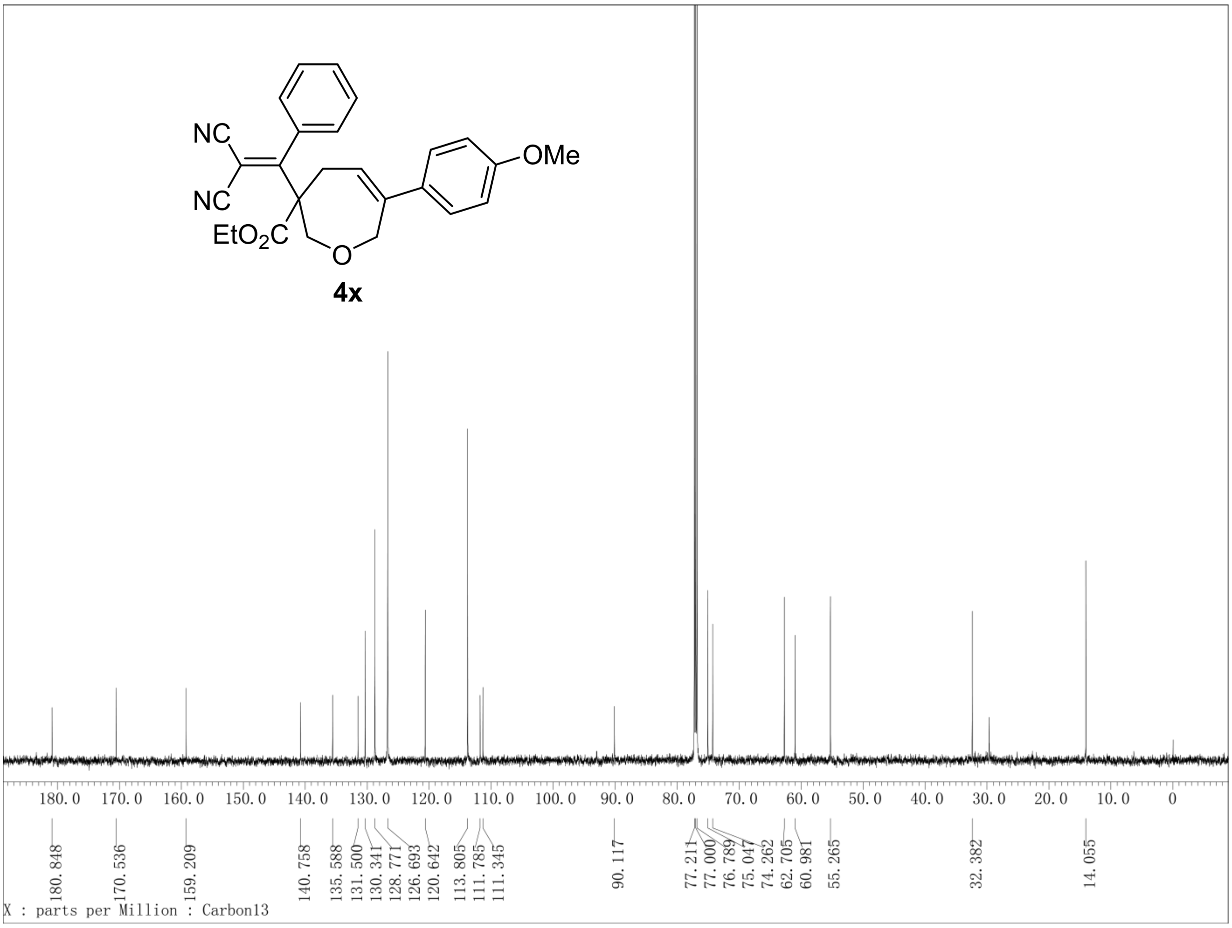
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NC
EtO2C
O
OMe
4x
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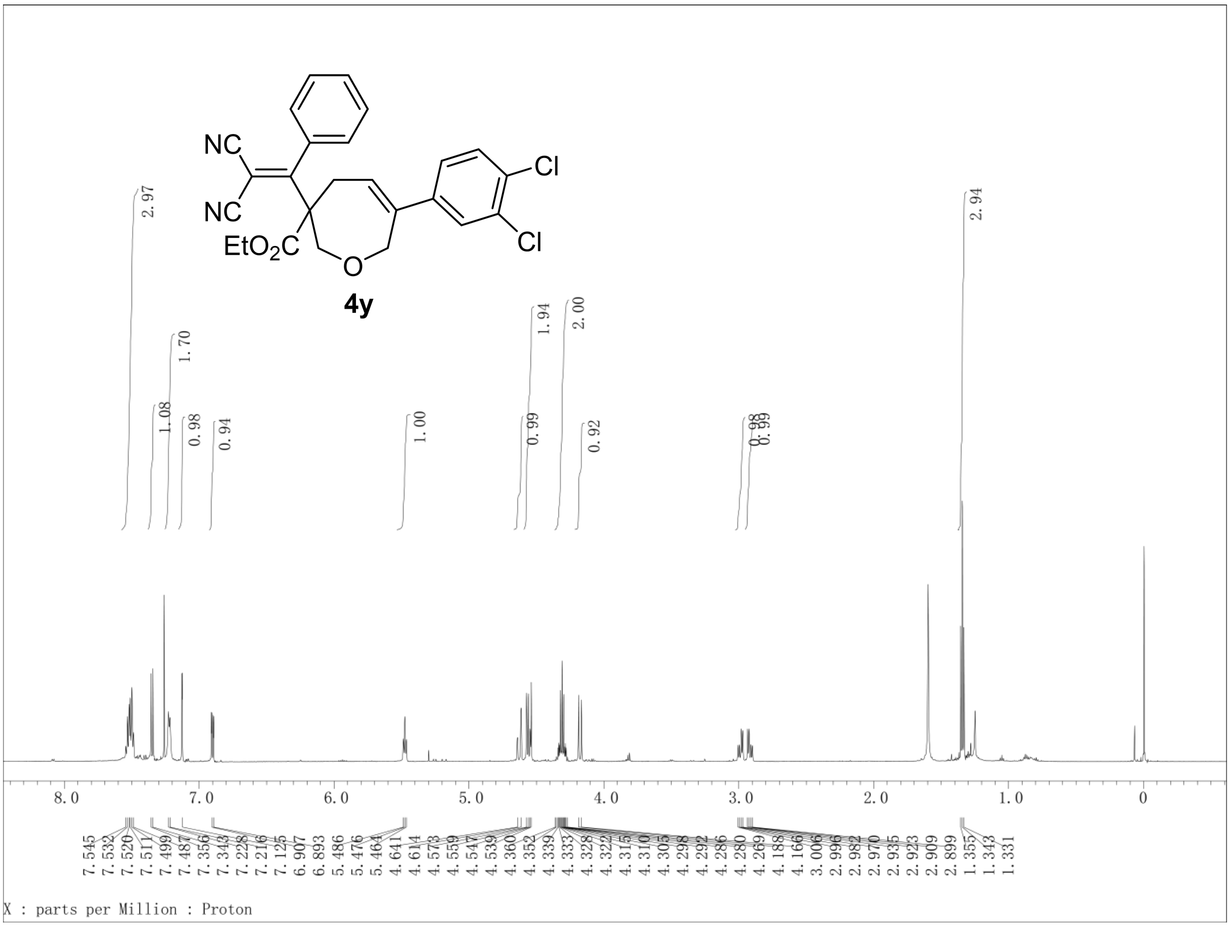
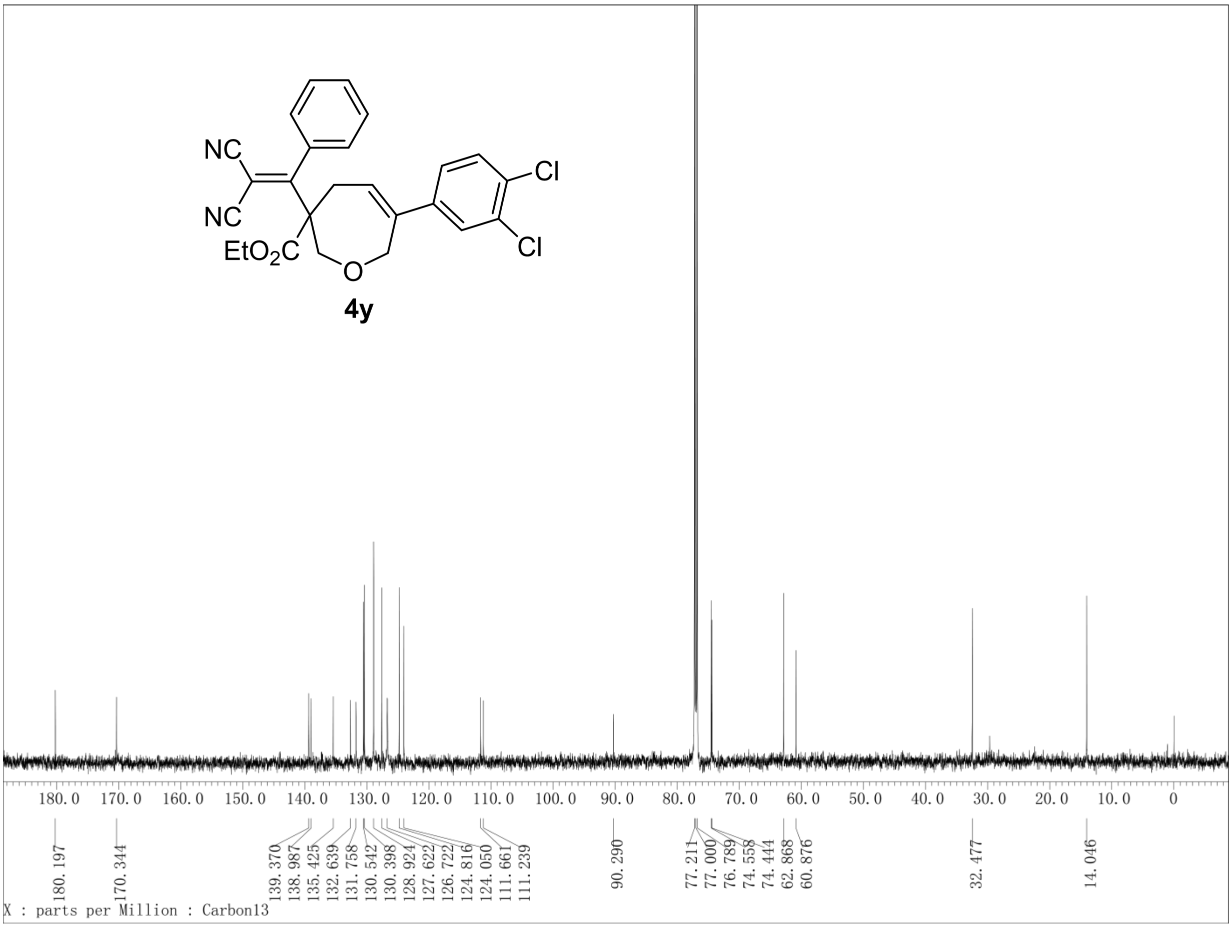
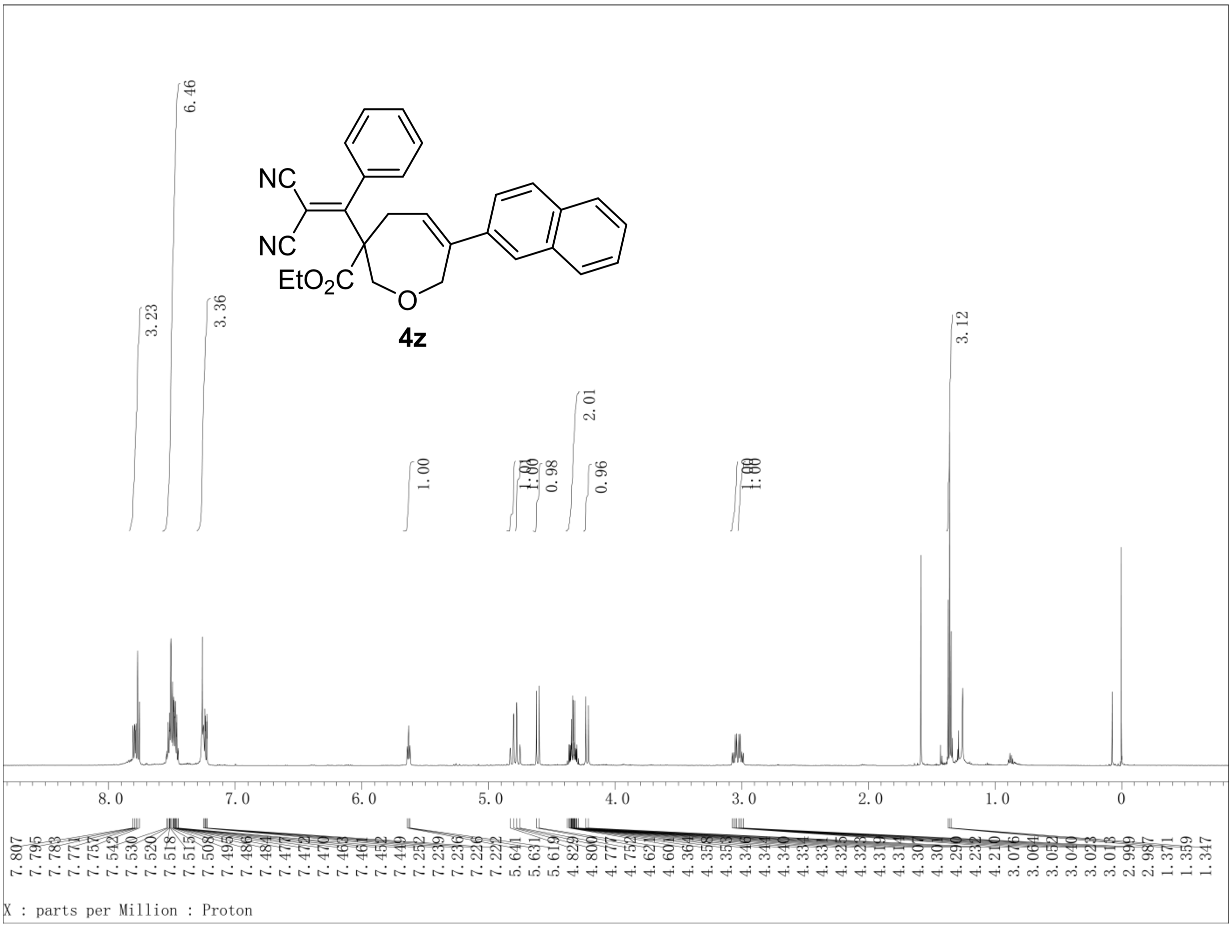
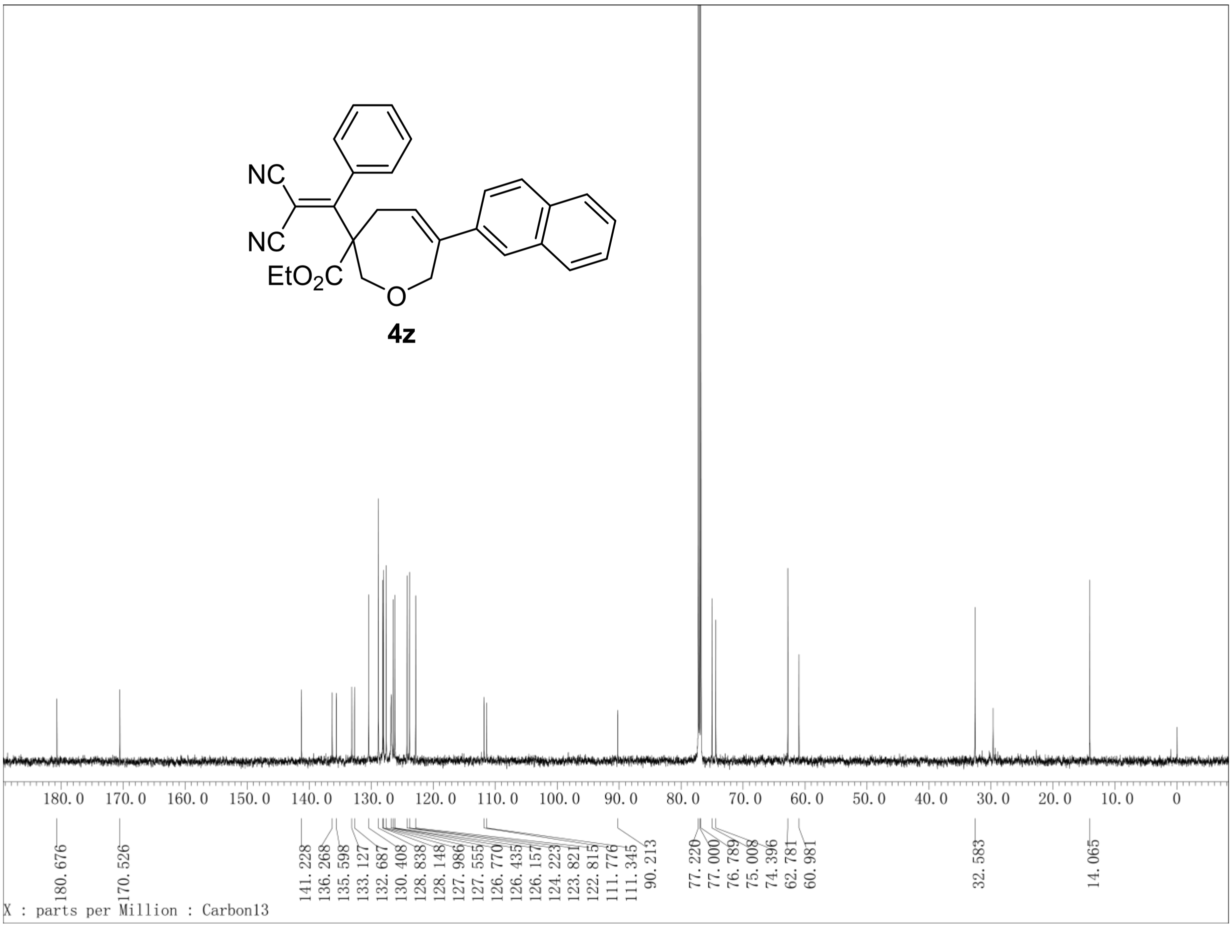
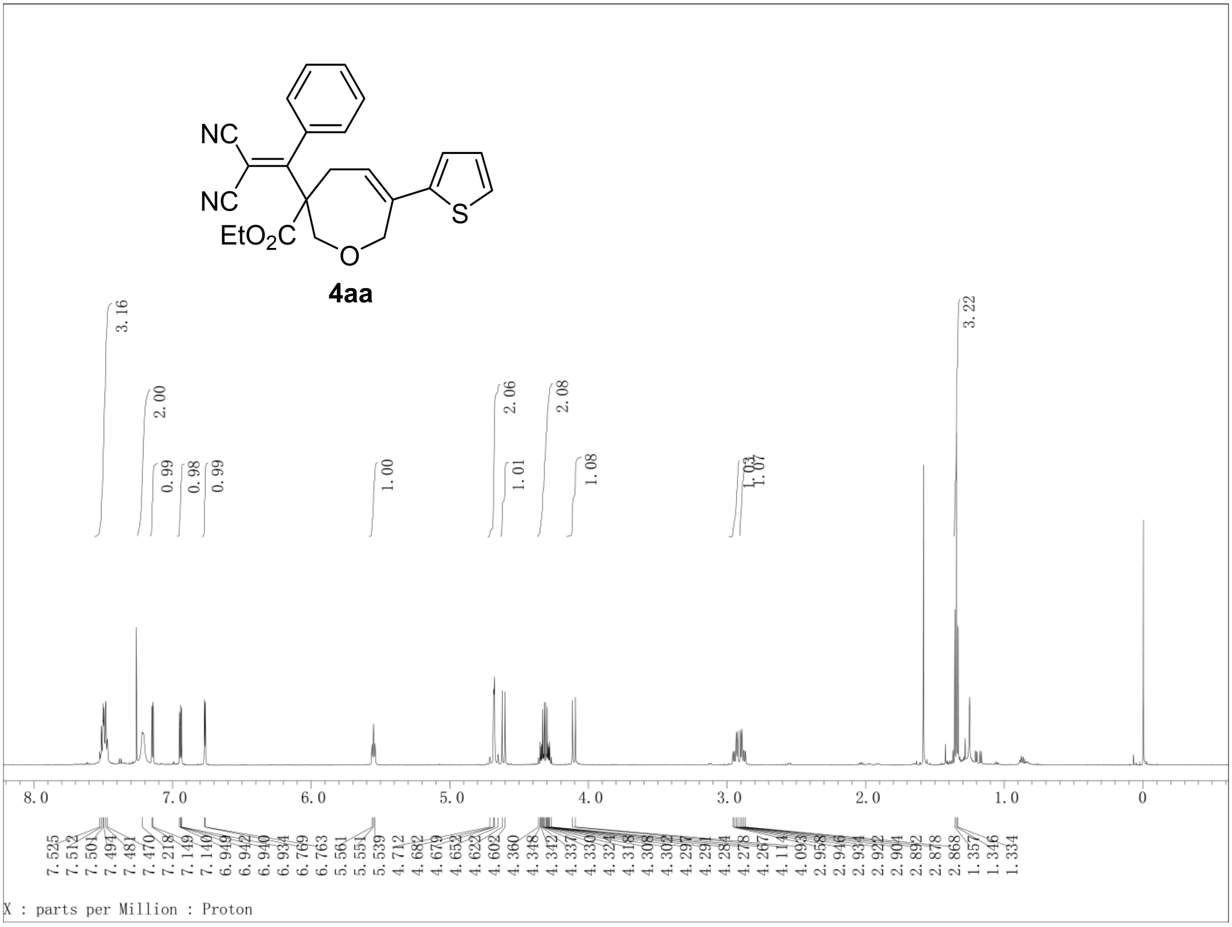
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
180.848
170.536
159.209
140.758
135.588
131.500
130.341
128.771
126.693
120.642
113.805
111.785
111.345
90.117
77.211
77.000
76.789
75.047
74.262
62.705
60.981
55.265
32.382
14.055
X : parts per Million : Carbon13


NC
NC
EtO2C
O
Cl
Cl
4y
2.97
1.08
1.70
0.98
0.94
1.00
0.99
1.94
2.00
0.92
0.98
0.99
2.94
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
7.545
7.532
7.520
7.511
7.499
7.487
7.356
7.343
7.228
7.216
7.125
6.907
6.893
5.486
5.476
5.464
4.641
4.614
4.573
4.559
4.547
4.539
4.360
4.352
4.339
4.333
4.328
4.322
4.315
4.310
4.305
4.298
4.292
4.286
4.280
4.269
4.188
4.166
3.006
2.996
2.982
2.970
2.935
2.923
2.909
2.899
1.355
1.343
1.331
X : parts per Million : Proton


NC
NC
EtO2C
O
Cl
Cl
4y
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
180.197
170.344
139.370
138.987
135.425
132.639
131.758
130.542
130.398
128.924
127.622
126.722
124.816
124.050
111.661
111.239
90.290
77.211
77.000
76.789
74.558
74.444
62.868
60.876
32.477
14.046
X : parts per Million : Carbon13

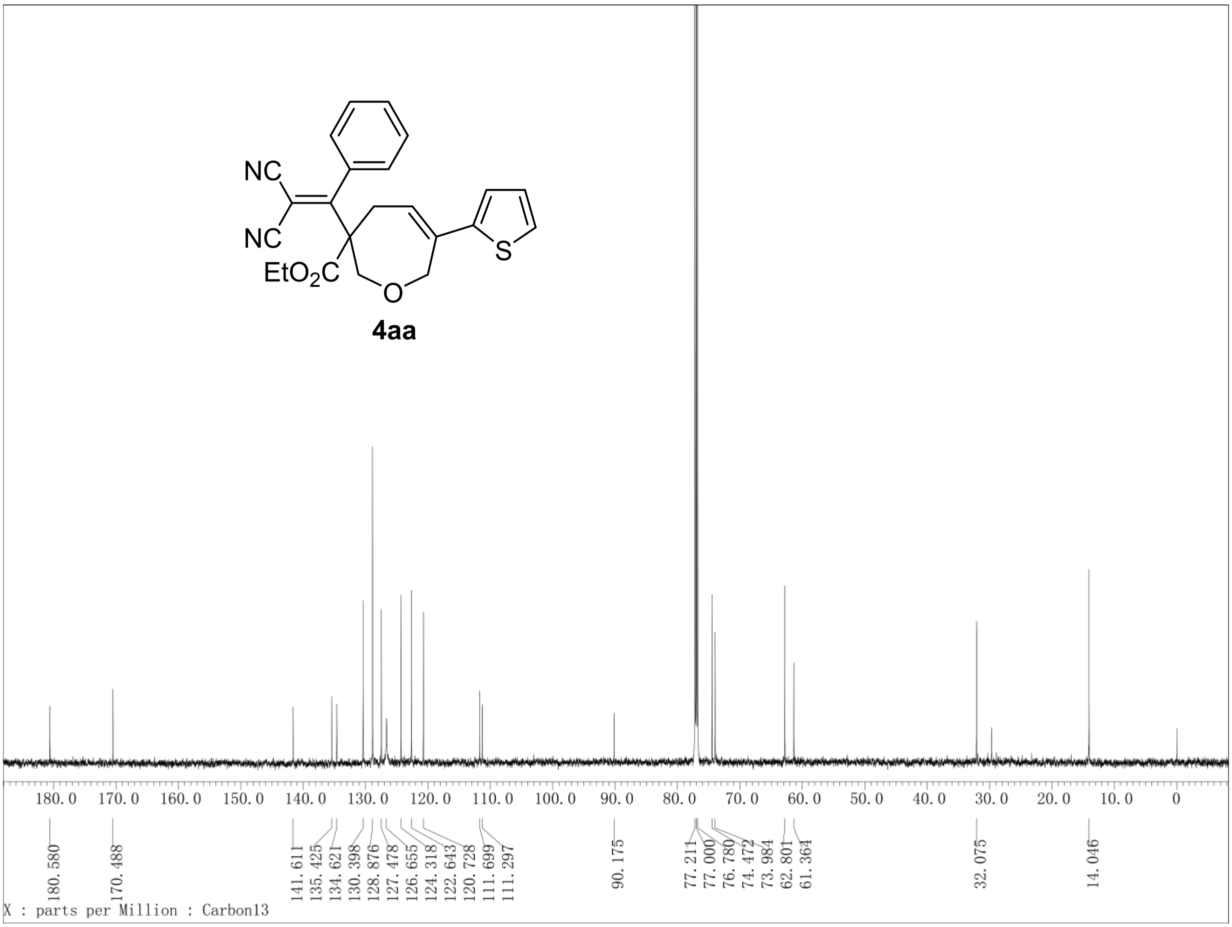

NC
NC
EtO2C
O
4z
3.23
6.46
3.36
1.00
1.01
1.00
0.98
2.01
0.96
1.00
1.00
3.12
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
7.807
7.795
7.783
7.771
7.757
7.542
7.530
7.520
7.518
7.515
7.508
7.495
7.486
7.484
7.477
7.472
7.470
7.463
7.461
7.452
7.449
7.252
7.239
7.236
7.226
7.222
5.641
5.631
5.619
4.829
4.800
4.777
4.752
4.621
4.601
4.364
4.358
4.353
4.346
4.344
4.340
4.334
4.331
4.325
4.323
4.319
4.314
4.307
4.301
4.290
4.232
4.210
3.076
3.064
3.052
3.040
3.023
3.013
2.999
2.987
1.371
1.359
1.347
X : parts per Million : Proton


NC
NC
EtO2C
O
4z
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
180.676
170.526
141.228
136.268
135.598
133.127
132.687
130.408
128.838
128.148
127.986
127.555
126.770
126.435
126.157
124.223
123.821
122.815
111.776
111.345
90.213
77.220
77.000
76.789
75.008
74.396
62.781
60.981
32.583
14.065
X : parts per Million : Carbon13



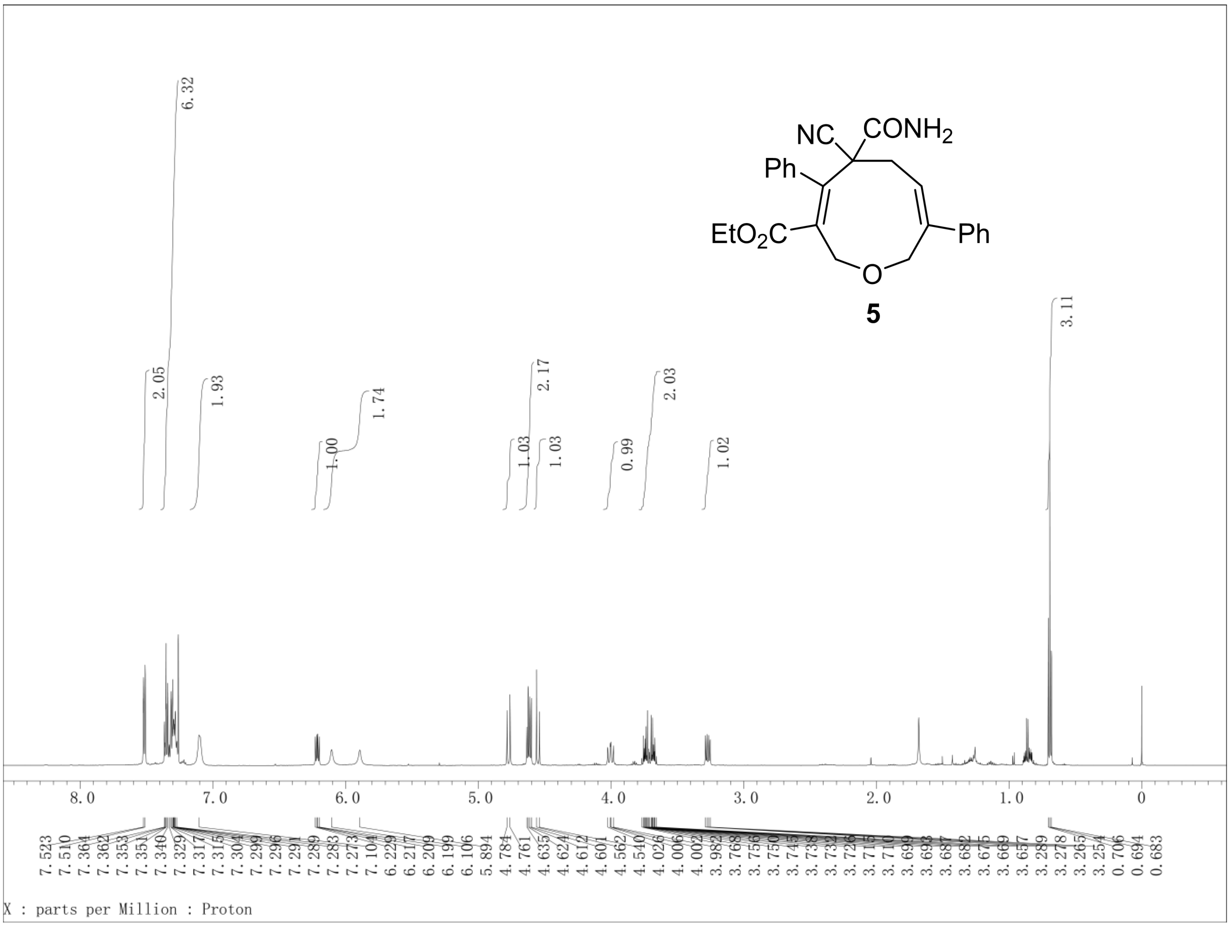
4aa

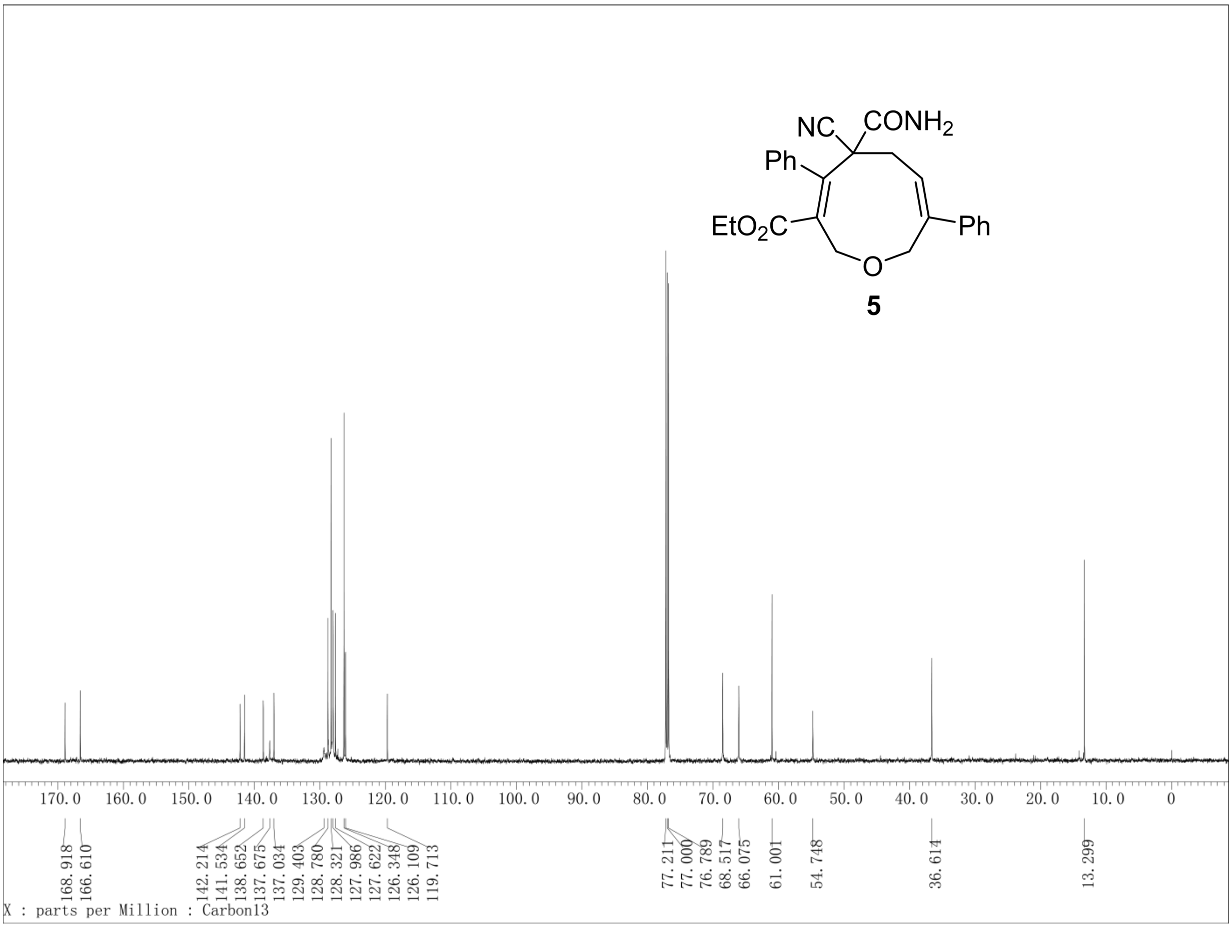
NC
NC
EtO2C
O
S
3.16
2.00
0.99
0.98
0.99
1.00
2.06
1.01
2.08
1.08
1.03
1.07
3.22
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
7.525
7.512
7.501
7.494
7.481
7.470
7.218
7.149
7.140
6.949
6.942
6.940
6.934
6.769
6.763
5.561
5.551
5.539
4.712
4.682
4.679
4.652
4.622
4.602
4.360
4.348
4.342
4.337
4.330
4.324
4.318
4.308
4.302
4.297
4.291
4.284
4.278
4.267
4.114
4.093
2.958
2.946
2.934
2.922
2.904
2.892
2.878
2.868
1.357
1.346
1.334
X : parts per Million : Proton

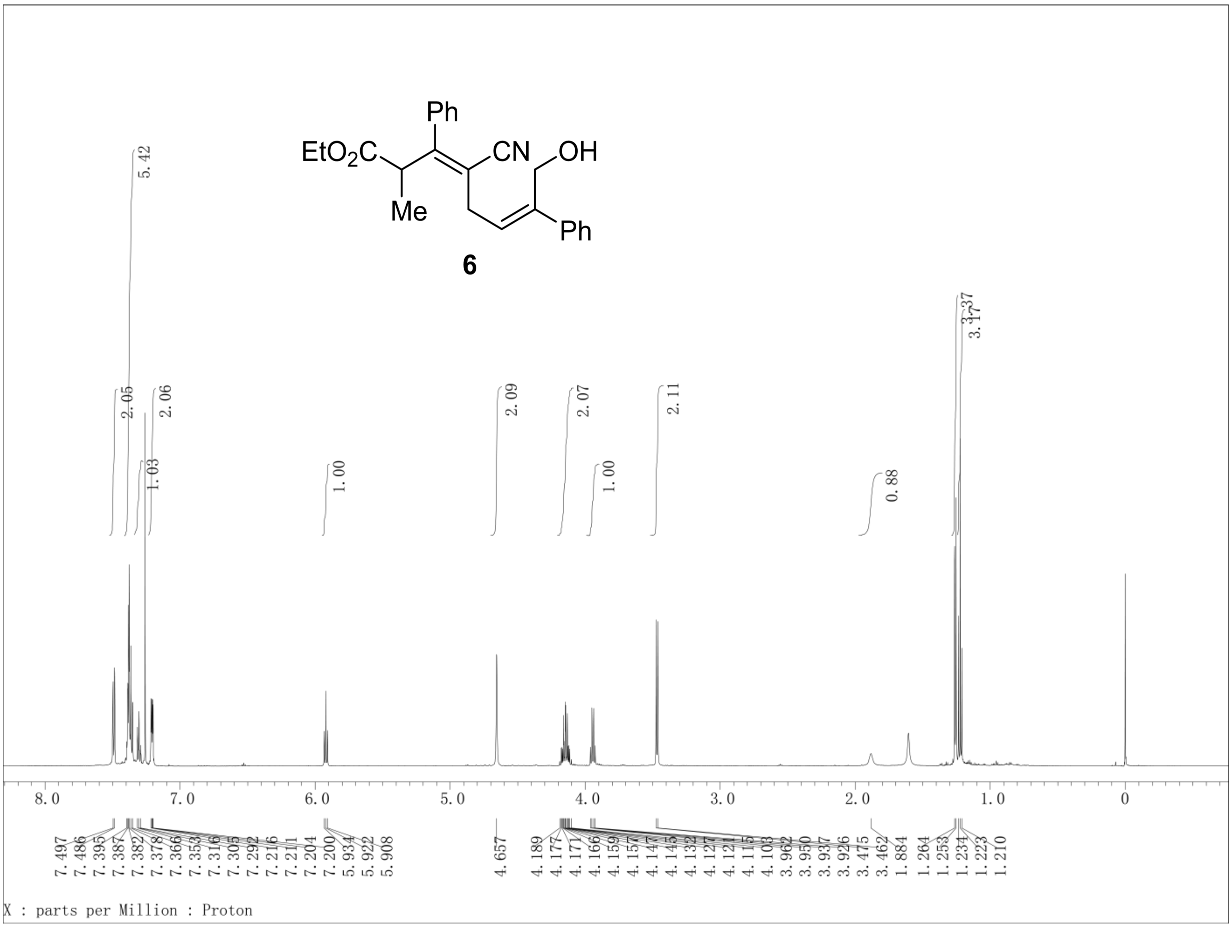


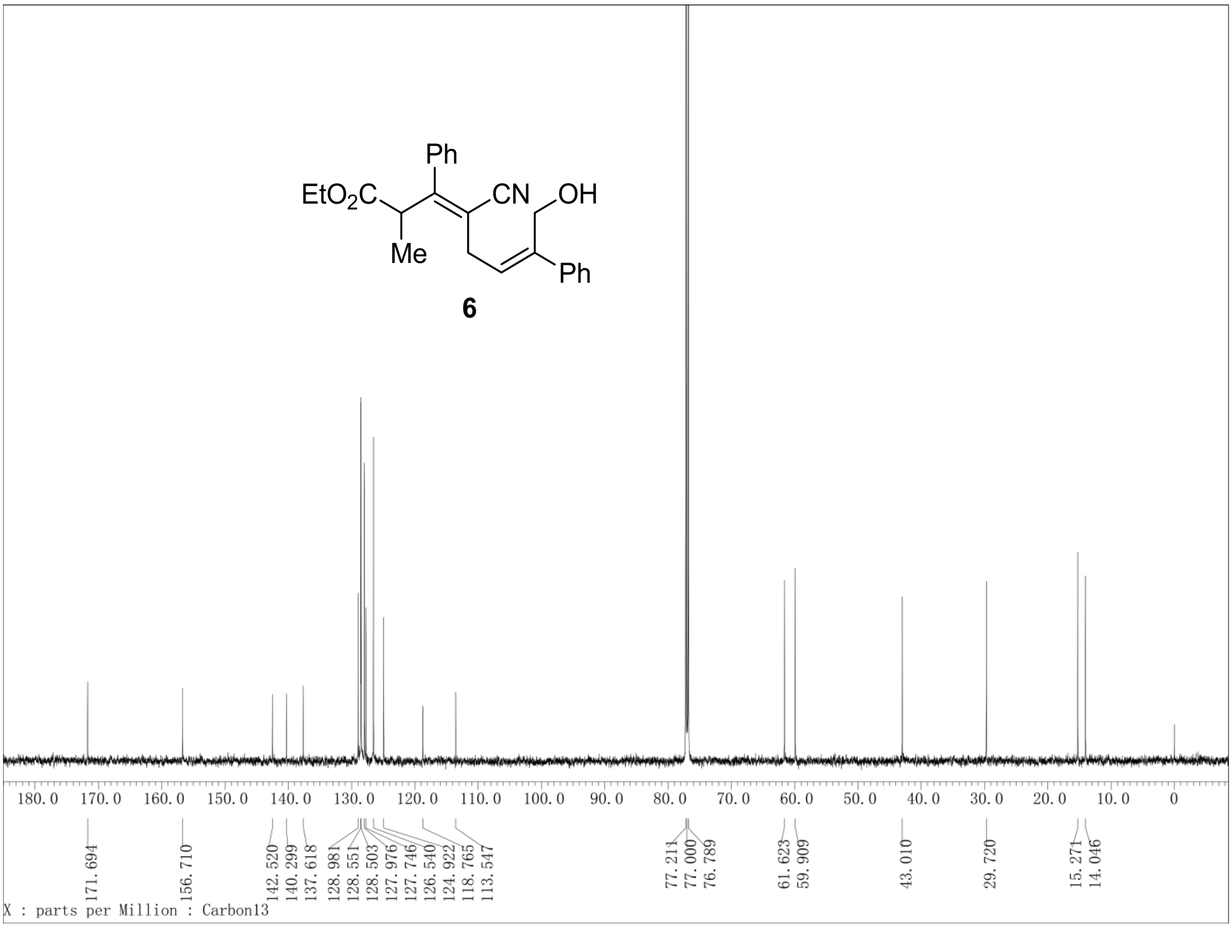
4aa

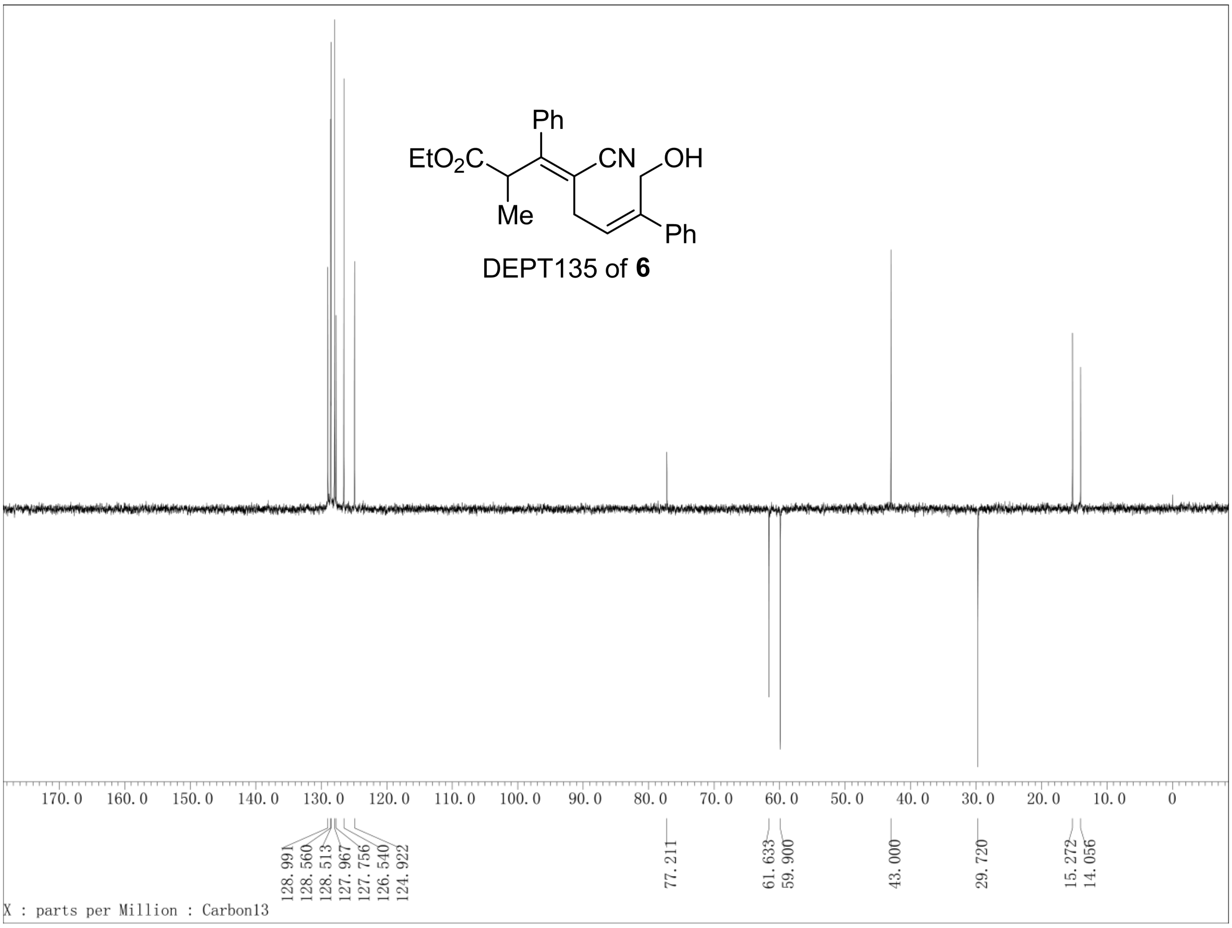
NC
NC
EtO2C
O
S
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
180.580
170.488
141.611
135.425
134.621
130.398
128.876
127.478
126.655
124.318
122.643
120.728
111.699
111.297
90.175
77.211
77.000
76.780
74.472
73.984
62.801
61.364
32.075
14.046
X : parts per Million : Carbon13

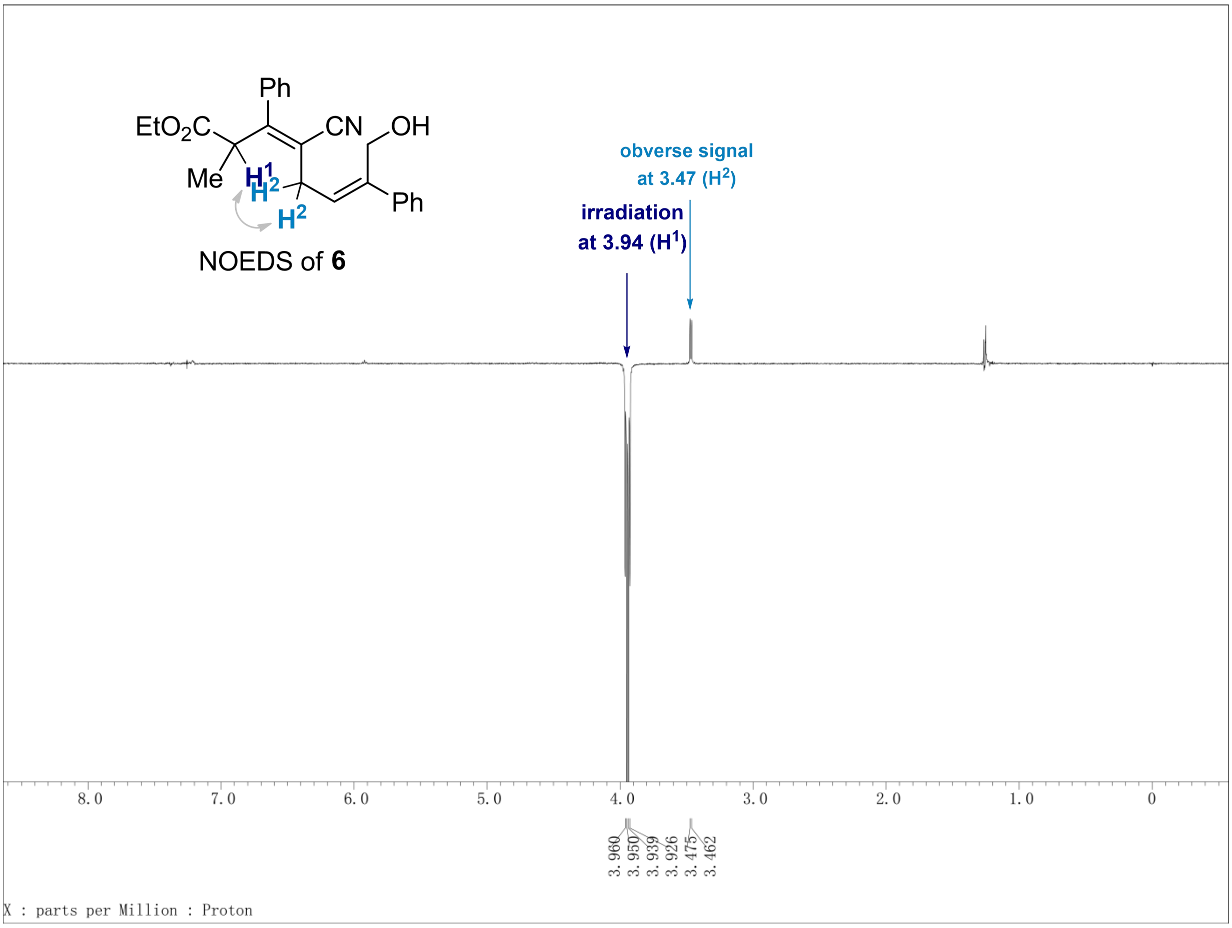

NC
CONH2
Ph
EtO2C
Ph
O
5
6.32
2.05
1.93
1.00
1.74
1.03
2.17
1.03
0.99
2.03
1.02
3.11
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
7.523
7.510
7.364
7.362
7.353
7.351
7.340
7.329
7.317
7.315
7.304
7.299
7.296
7.291
7.289
7.283
7.273
7.104
6.229
6.217
6.209
6.199
6.106
5.894
4.784
4.761
4.635
4.624
4.612
4.601
4.562
4.540
4.026
4.006
4.002
3.982
3.768
3.756
3.750
3.745
3.738
3.732
3.726
3.715
3.710
3.699
3.693
3.687
3.682
3.675
3.669
3.657
3.289
3.278
3.265
3.254
0.706
0.694
0.683
X : parts per Million : Proton

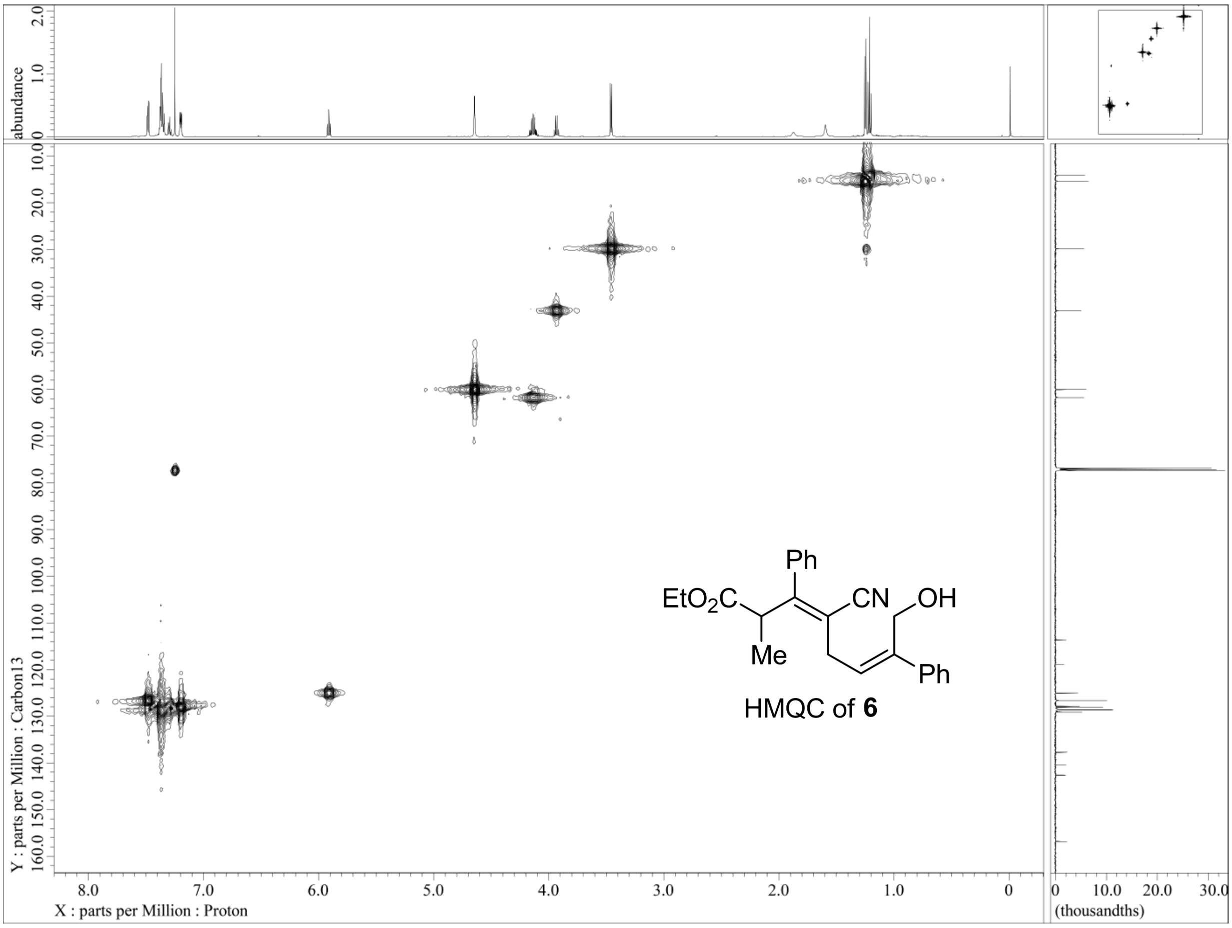

NC
CONH2
Ph
EtO2C
Ph
O
5
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
168.918
166.610
142.214
141.534
138.652
137.675
137.034
129.403
128.780
128.321
127.986
127.622
126.348
126.109
119.713
77.211
77.000
76.789
68.517
66.075
61.001
54.748
36.614
13.299
X : parts per Million : Carbon13


EtO2C
Ph
CN
OH
Me
Ph
6
5.42
2.05
1.03
2.06
1.00
2.09
2.07
1.00
2.11
0.88
3.37
3.17
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
7.497
7.486
7.395
7.387
7.382
7.378
7.366
7.353
7.316
7.305
7.292
7.216
7.211
7.204
7.200
5.934
5.922
5.908
4.657
4.189
4.177
4.171
4.166
4.159
4.157
4.147
4.145
4.132
4.127
4.121
4.115
4.103
3.962
3.950
3.937
3.926
3.475
3.462
1.884
1.264
1.253
1.234
1.223
1.210
X : parts per Million : Proton

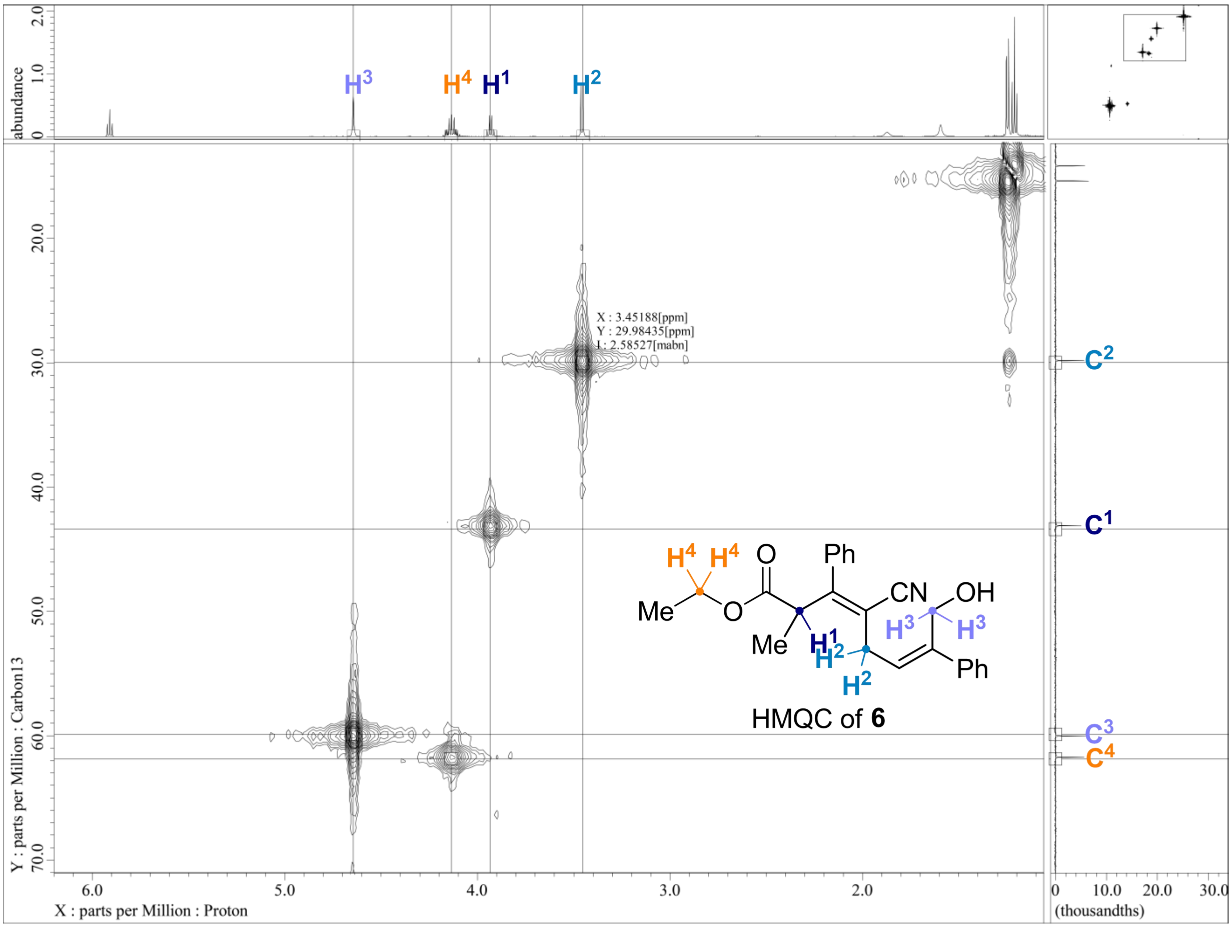

EtO2C
Ph
CN
OH
Me
Ph
6
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
171.694
156.710
142.520
140.299
137.618
128.981
128.551
128.503
127.976
127.746
126.540
124.922
118.765
113.547
77.211
77.000
76.789
61.623
59.909
43.010
29.720
15.271
14.046
X : parts per Million : Carbon13


Ph
EtO$_2$C
CN
OH
Me
Ph
DEPT135 of **6**
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
128.991
128.560
128.513
127.967
127.756
126.540
124.922
77.211
61.633
59.900
43.000
29.720
15.272
14.056
X : parts per Million : Carbon13

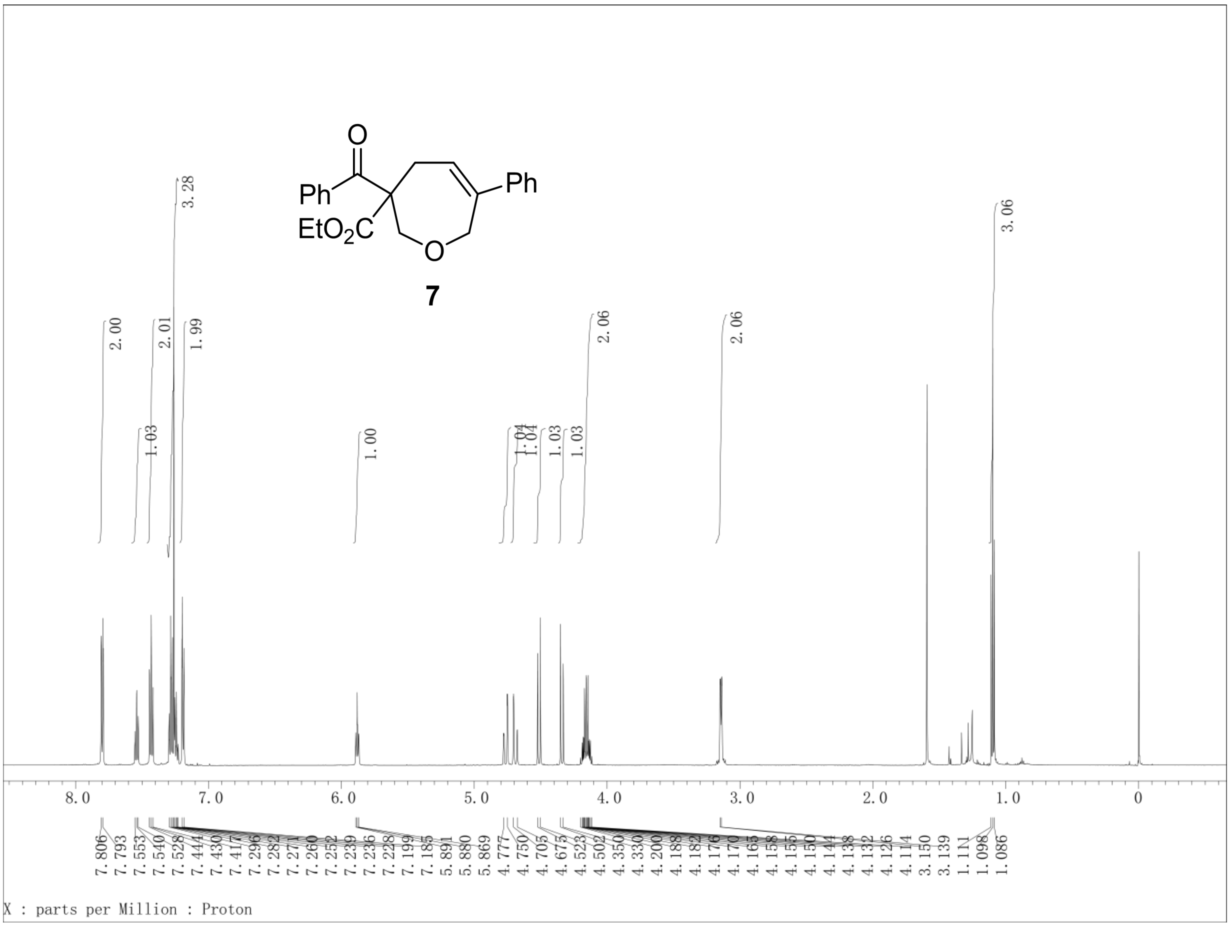

Ph
EtO$_2$C
CN
OH
Me
H^1
H^2
H^2
Ph
NOEDS of **6**
obverse signal at 3.47 (H^2)
irradiation at 3.94 (H^1)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
3.960
3.950
3.939
3.926
3.475
3.462
X : parts per Million : Proton

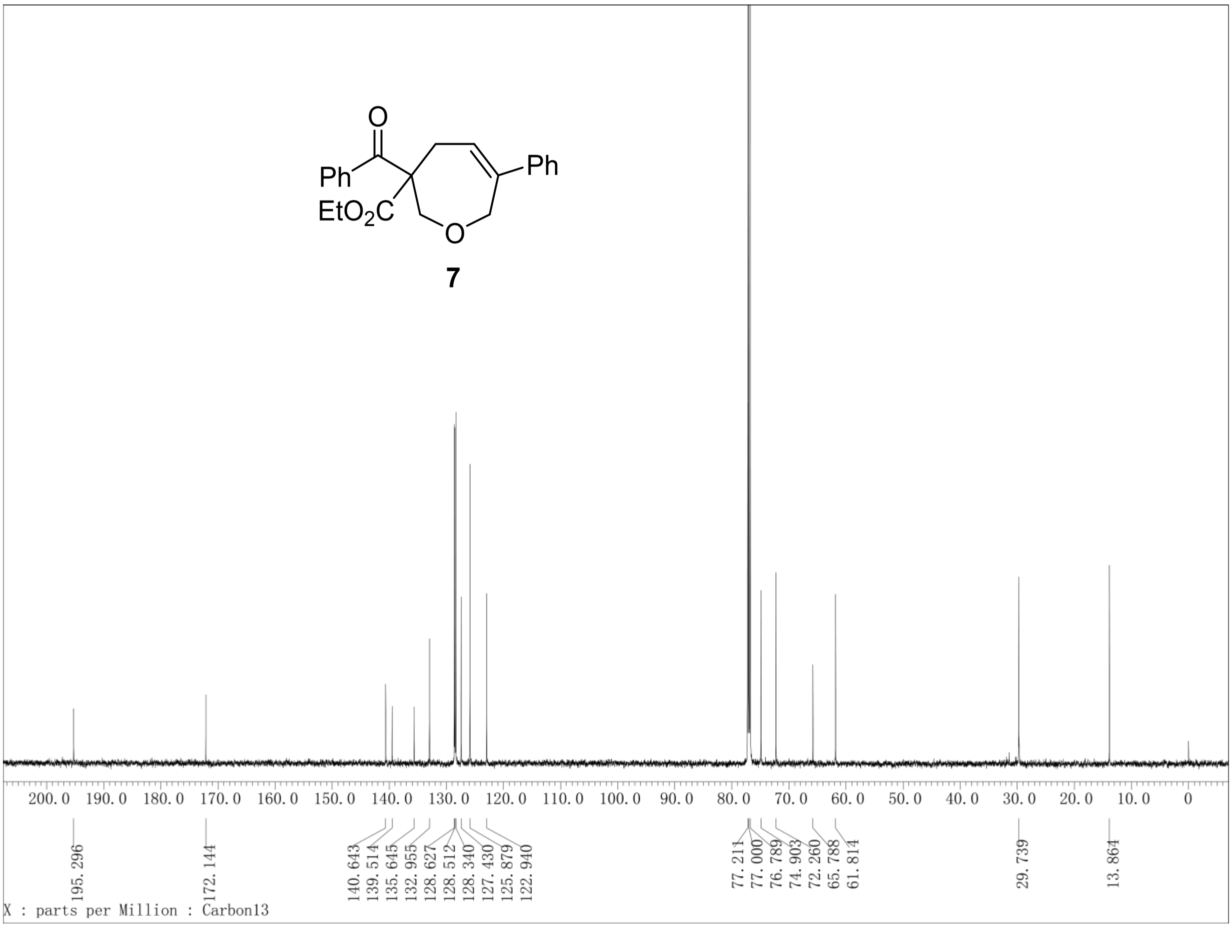


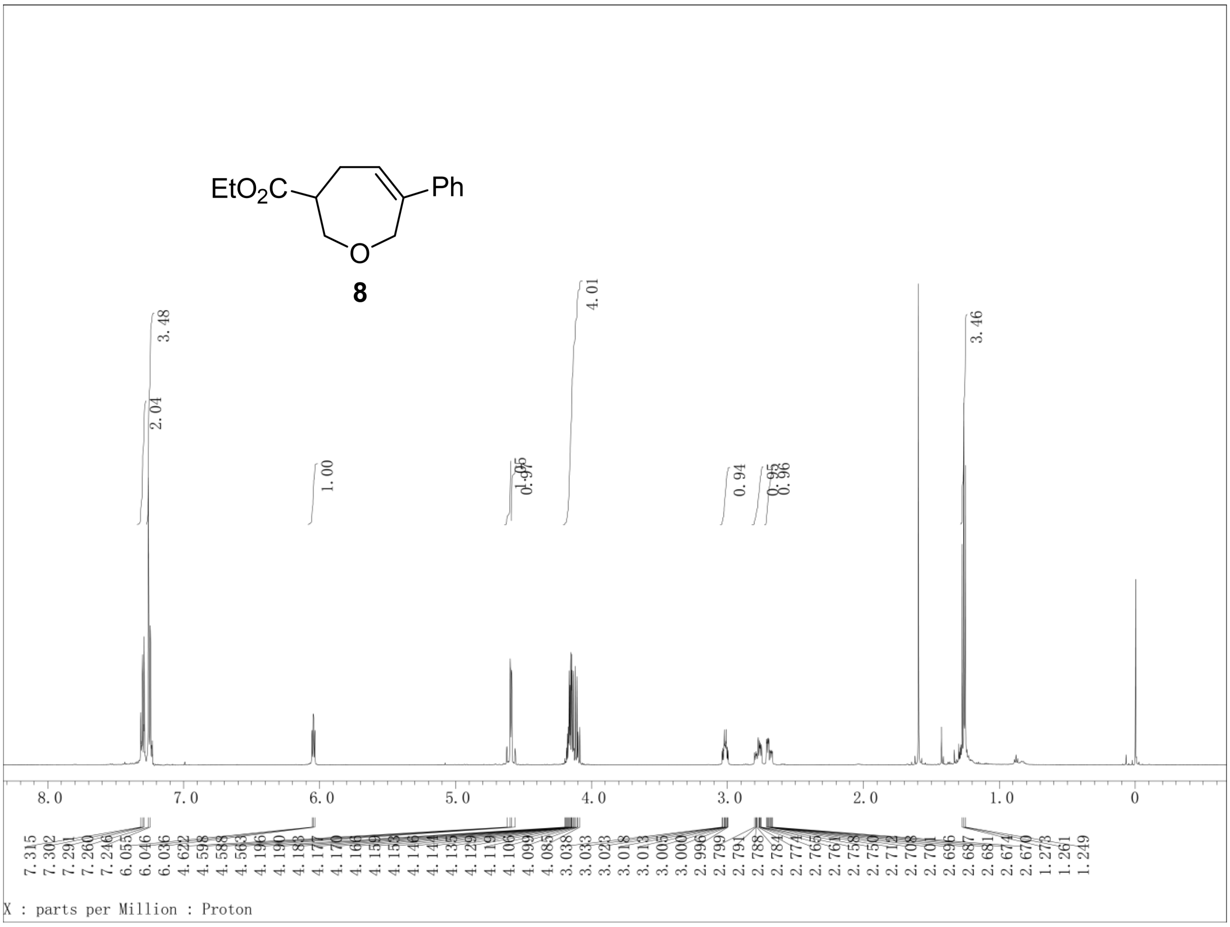
HMQC of **6**

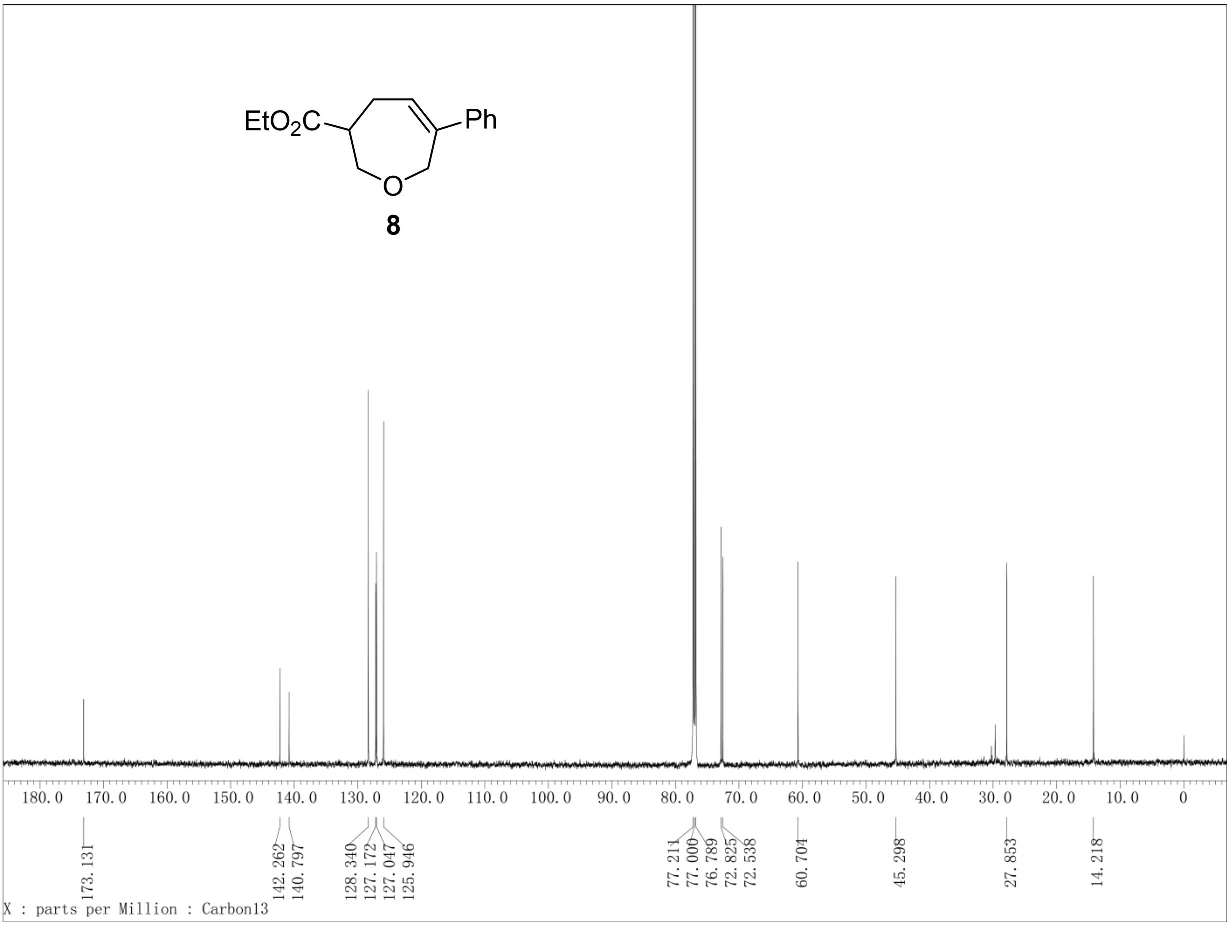


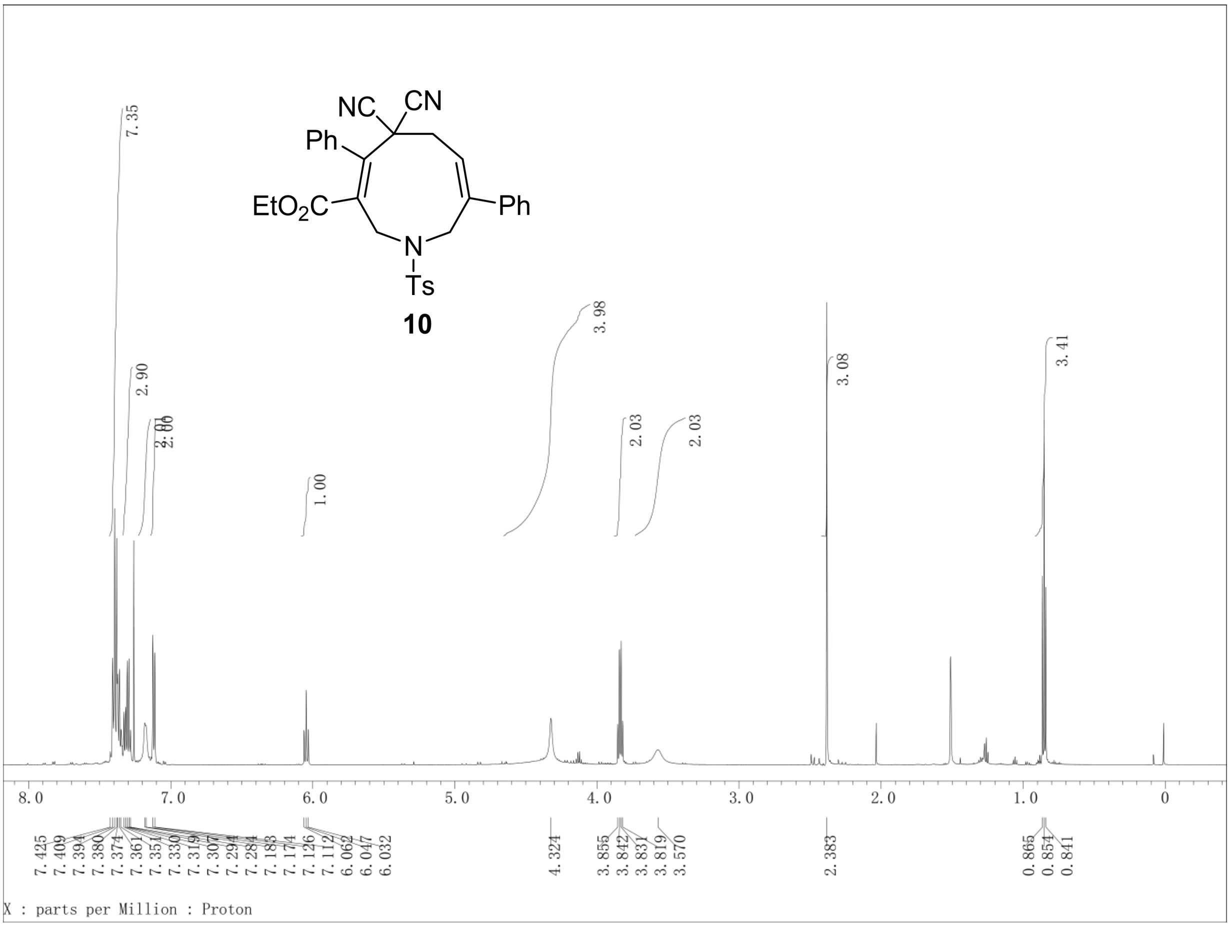
HMQC of **6**

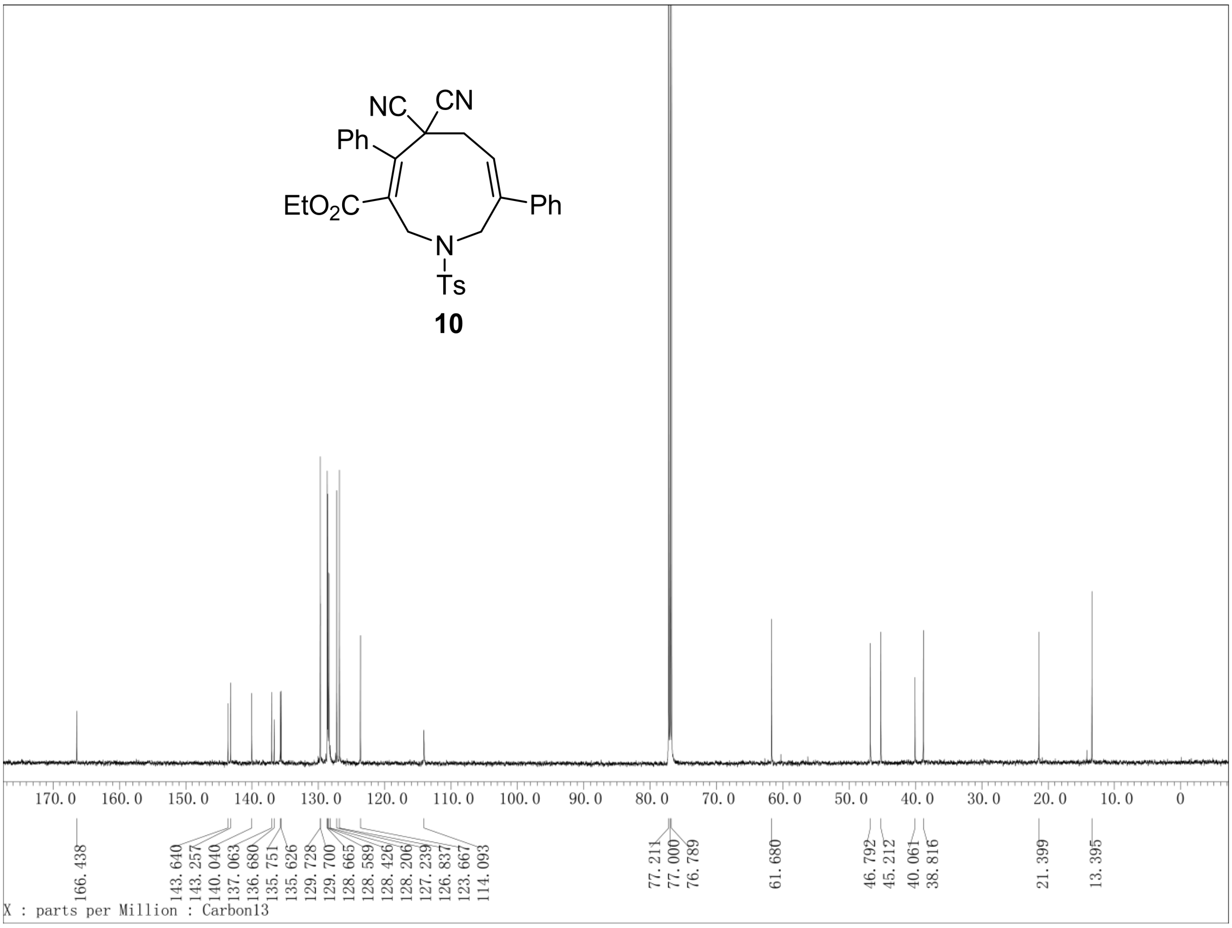

O
Ph
EtO2C
O
Ph
7
2.00
1.03
2.01
3.28
1.99
1.00
1.04
1.04
1.03
1.03
2.06
2.06
3.06
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
7.806
7.793
7.553
7.540
7.528
7.444
7.430
7.417
7.296
7.282
7.271
7.260
7.252
7.239
7.236
7.228
7.199
7.185
5.891
5.880
5.869
4.777
4.750
4.705
4.675
4.523
4.502
4.350
4.330
4.200
4.188
4.182
4.176
4.170
4.165
4.158
4.155
4.150
4.144
4.138
4.132
4.126
4.114
3.150
3.139
1.111
1.098
1.086
X : parts per Million : Proton

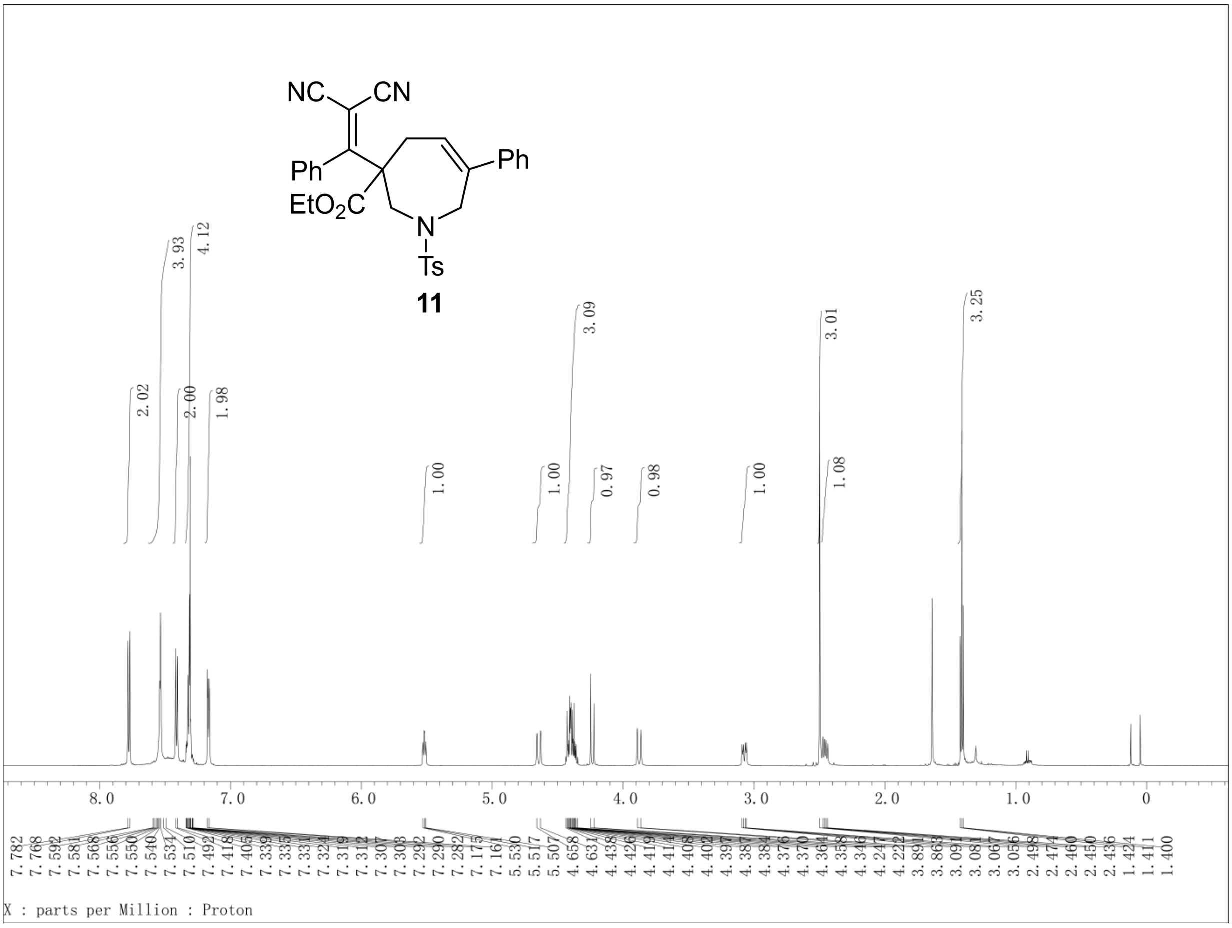

O
Ph
EtO2C
O
Ph
7
200.0
190.0
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
195.296
172.144
140.643
139.514
135.645
132.955
128.627
128.512
128.340
127.430
125.879
122.940
77.211
77.000
76.789
74.903
72.260
65.788
61.814
29.739
13.864
X : parts per Million : Carbon13

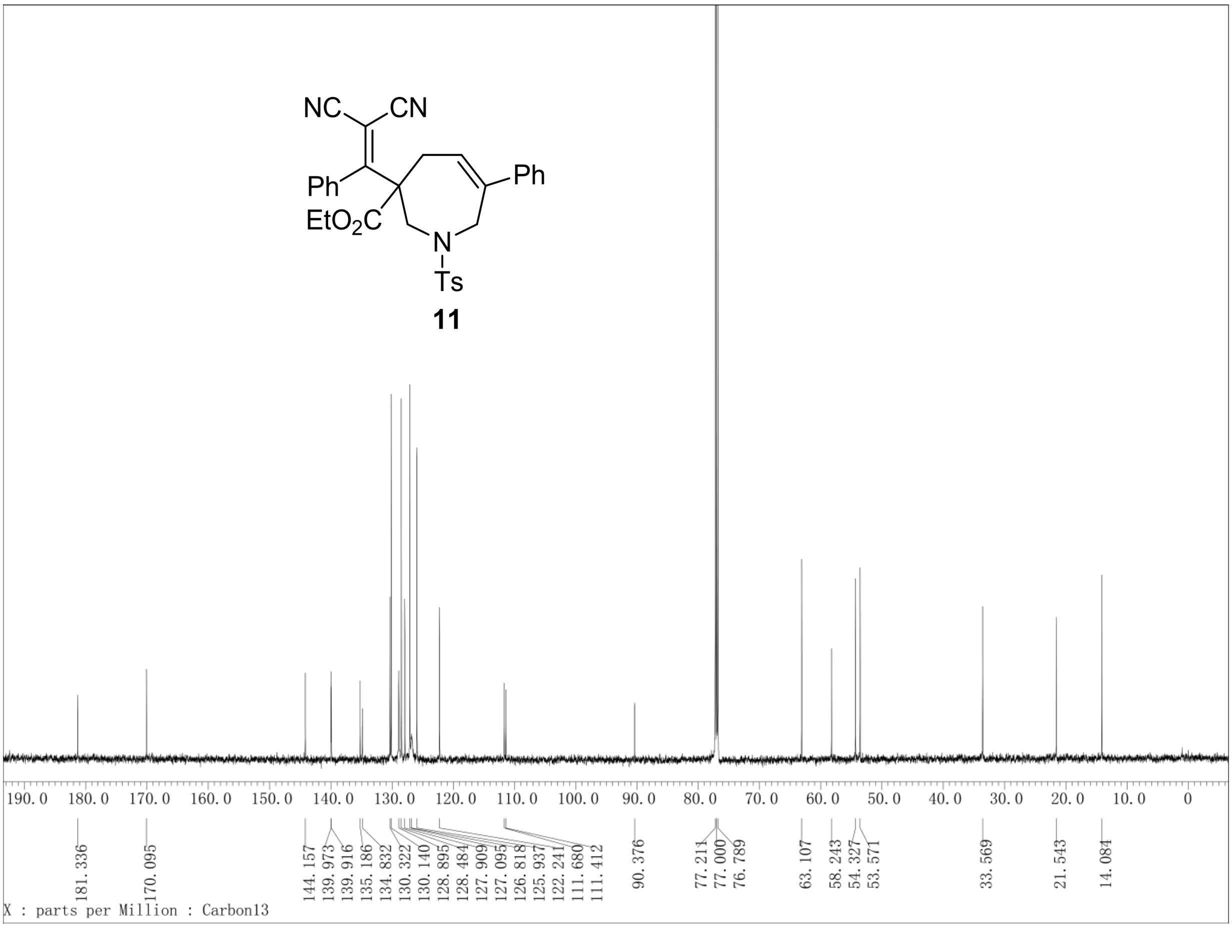

EtO2C
Ph
O
8
3.48
2.04
1.00
1.05
0.97
4.01
0.94
0.95
0.96
3.46
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
7.315
7.302
7.291
7.260
7.246
6.055
6.046
6.036
4.622
4.598
4.588
4.563
4.196
4.190
4.183
4.177
4.170
4.166
4.159
4.153
4.146
4.144
4.135
4.129
4.119
4.106
4.099
4.085
3.038
3.033
3.023
3.018
3.013
3.005
3.000
2.996
2.799
2.791
2.788
2.784
2.774
2.765
2.761
2.758
2.750
2.712
2.708
2.701
2.696
2.687
2.681
2.674
2.670
1.273
1.261
1.249
X : parts per Million : Proton


EtO2C
Ph
O
8
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
173.131
142.262
140.797
128.340
127.172
127.047
125.946
77.211
77.000
76.789
72.825
72.538
60.704
45.298
27.853
14.218
X : parts per Million : Carbon13


NC
CN
Ph
EtO2C
Ph
N
Ts
10
7.35
2.90
2.01
2.00
1.00
3.98
2.03
2.03
3.08
3.41
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
7.425
7.409
7.394
7.380
7.374
7.361
7.351
7.330
7.319
7.307
7.294
7.284
7.183
7.174
7.126
7.112
6.062
6.047
6.032
4.324
3.855
3.842
3.831
3.819
3.570
2.383
0.865
0.854
0.841
X : parts per Million : Proton


NC
CN
Ph
EtO2C
Ph
N
Ts
10
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
166.438
143.640
143.257
140.040
137.063
136.680
135.751
135.626
129.728
129.700
128.665
128.589
128.426
128.206
127.239
126.837
123.667
114.093
77.211
77.000
76.789
61.680
46.792
45.212
40.061
38.816
21.399
13.395
X : parts per Million : Carbon13


NC
CN
Ph
Ph
EtO$_2$C
N
Ts
11
2.02
3.93
2.00
4.12
1.98
1.00
1.00
3.09
0.97
0.98
1.00
3.01
1.08
3.25
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
7.782
7.768
7.592
7.581
7.568
7.556
7.550
7.540
7.531
7.510
7.492
7.418
7.405
7.339
7.335
7.331
7.324
7.319
7.312
7.307
7.303
7.292
7.290
7.282
7.175
7.161
5.530
5.517
5.507
4.658
4.631
4.438
4.426
4.419
4.414
4.408
4.402
4.397
4.387
4.384
4.376
4.370
4.364
4.358
4.346
4.247
4.222
3.891
3.863
3.091
3.081
3.067
3.056
2.498
2.471
2.460
2.450
2.436
1.424
1.411
1.400
X : parts per Million : Proton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CN
Ph
Ph
EtO$_2$C
N
Ts
11
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150.0
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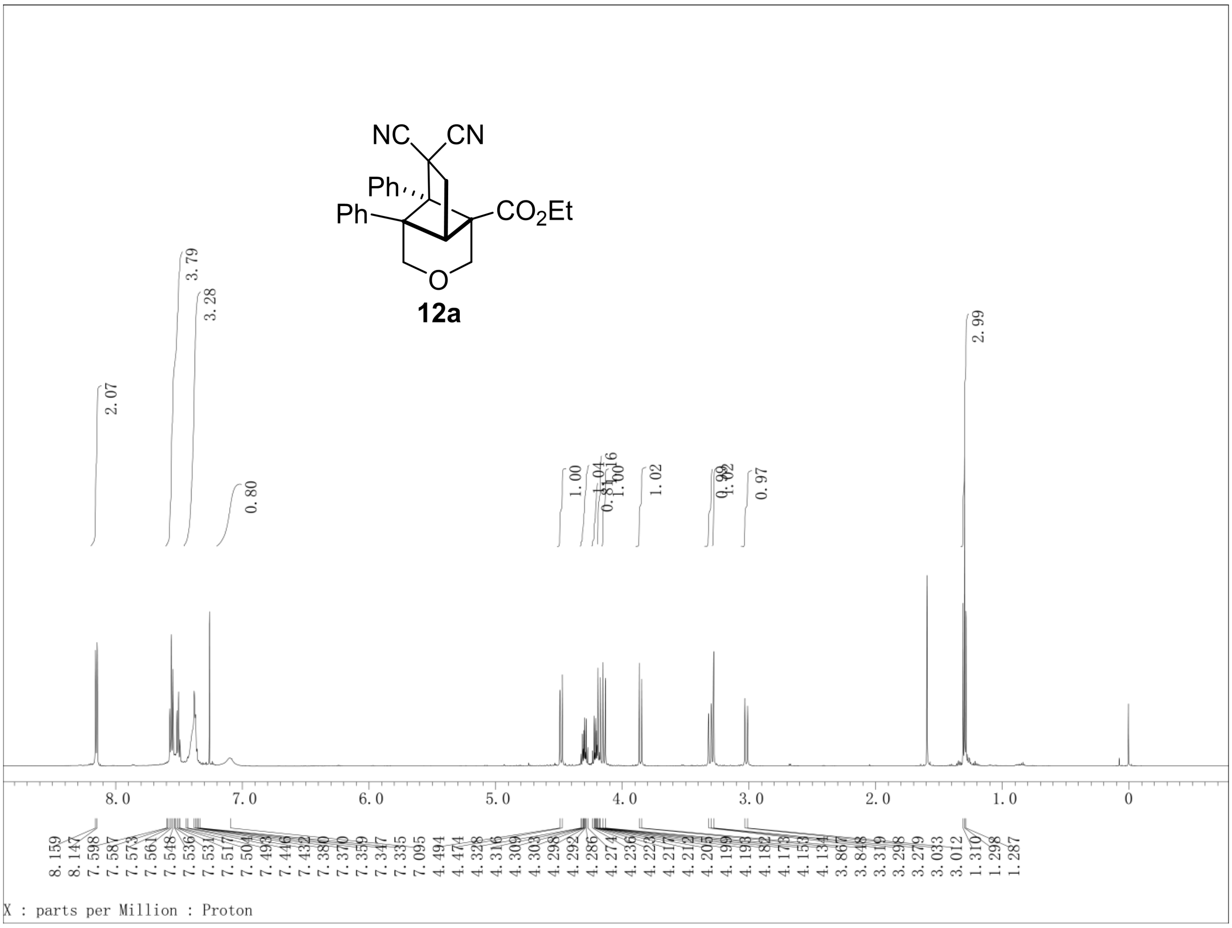
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
181.336
170.095
144.157
139.973
139.916
135.186
134.832
130.322
130.140
128.895
128.484
127.909
127.095
126.818
125.937
122.241
111.680
111.412
90.376
77.211
77.000
76.789
63.107
58.243
54.327
53.571
33.569
21.543
14.084
X : parts per Million : Carbon13


NC
CN
Ph
Ph
CO$_2$Et
O
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3.79
3.28
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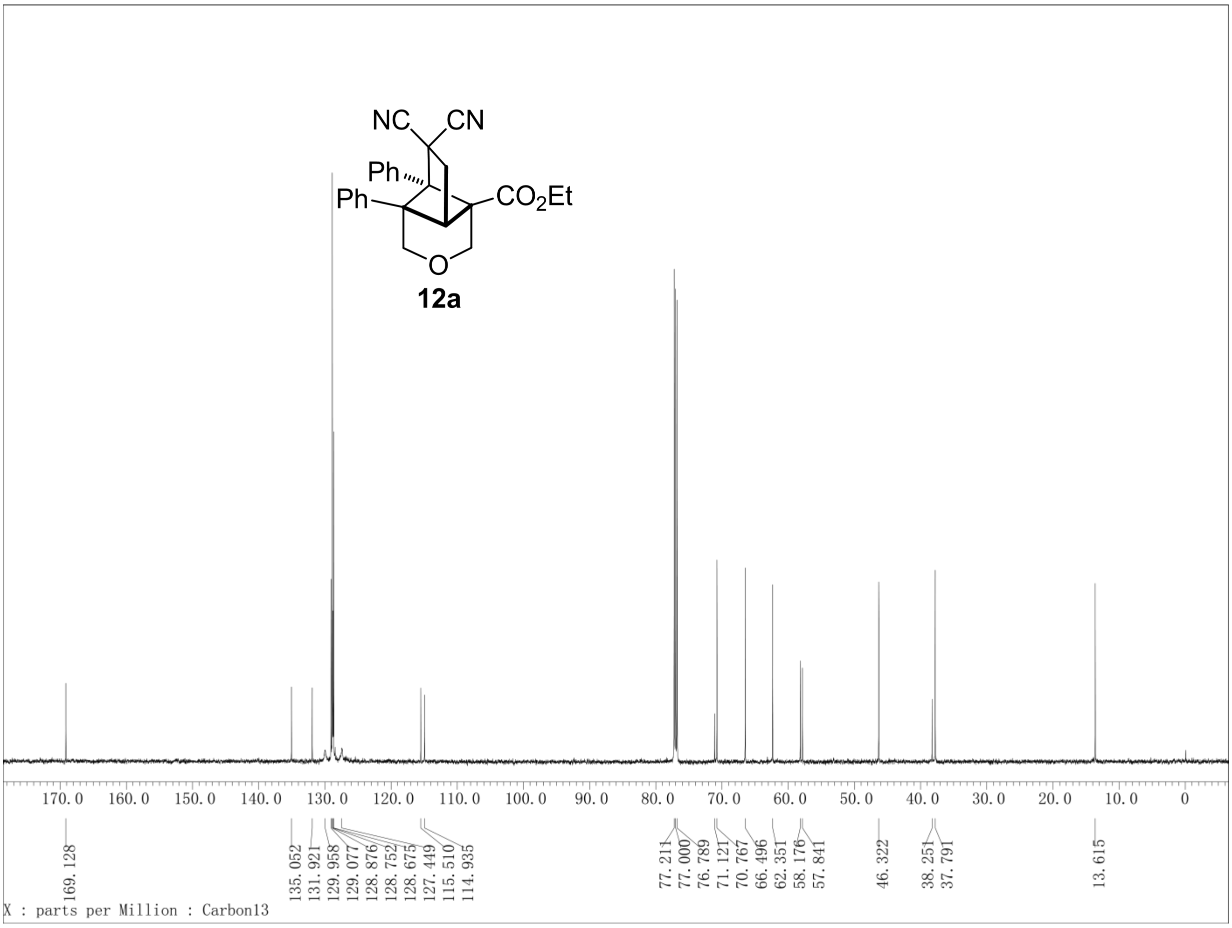
1.00
1.04
0.81
1.16
1.00
1.02
0.99
1.02
0.97
2.99
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
8.159
8.147
7.598
7.587
7.573
7.561
7.548
7.536
7.531
7.517
7.504
7.493
7.446
7.432
7.380
7.370
7.359
7.347
7.335
7.095
4.494
4.474
4.328
4.316
4.309
4.303
4.298
4.292
4.286
4.274
4.236
4.223
4.217
4.212
4.205
4.199
4.193
4.182
4.173
4.153
4.134
3.867
3.848
3.319
3.298
3.279
3.033
3.012
1.310
1.298
1.287
X : parts per Million : Proton


NC
CN
Ph
Ph
CO$_2$Et
O
12a
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130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
169.128
135.052
131.921
129.958
129.077
128.876
128.752
128.675
127.449
115.510
114.935
77.211
77.000
76.789
71.121
70.767
66.496
62.351
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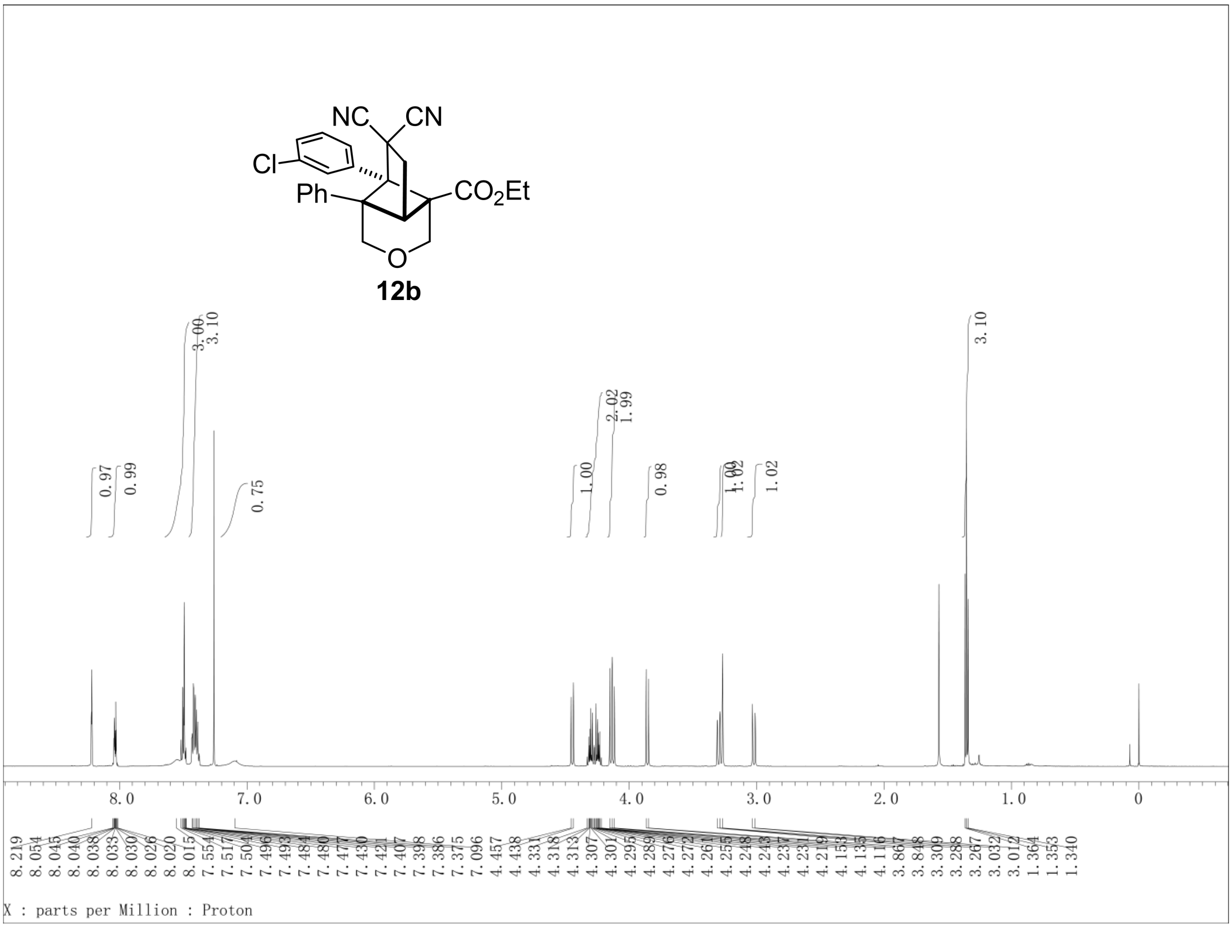
57.841
46.322
38.251
37.791
13.615
X : parts per Million : Carbon13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CN
Cl
Ph
CO2Et
O
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0.99
3.00
3.10
0.75
1.00
2.02
1.99
0.98
1.00
1.02
1.02
3.10
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
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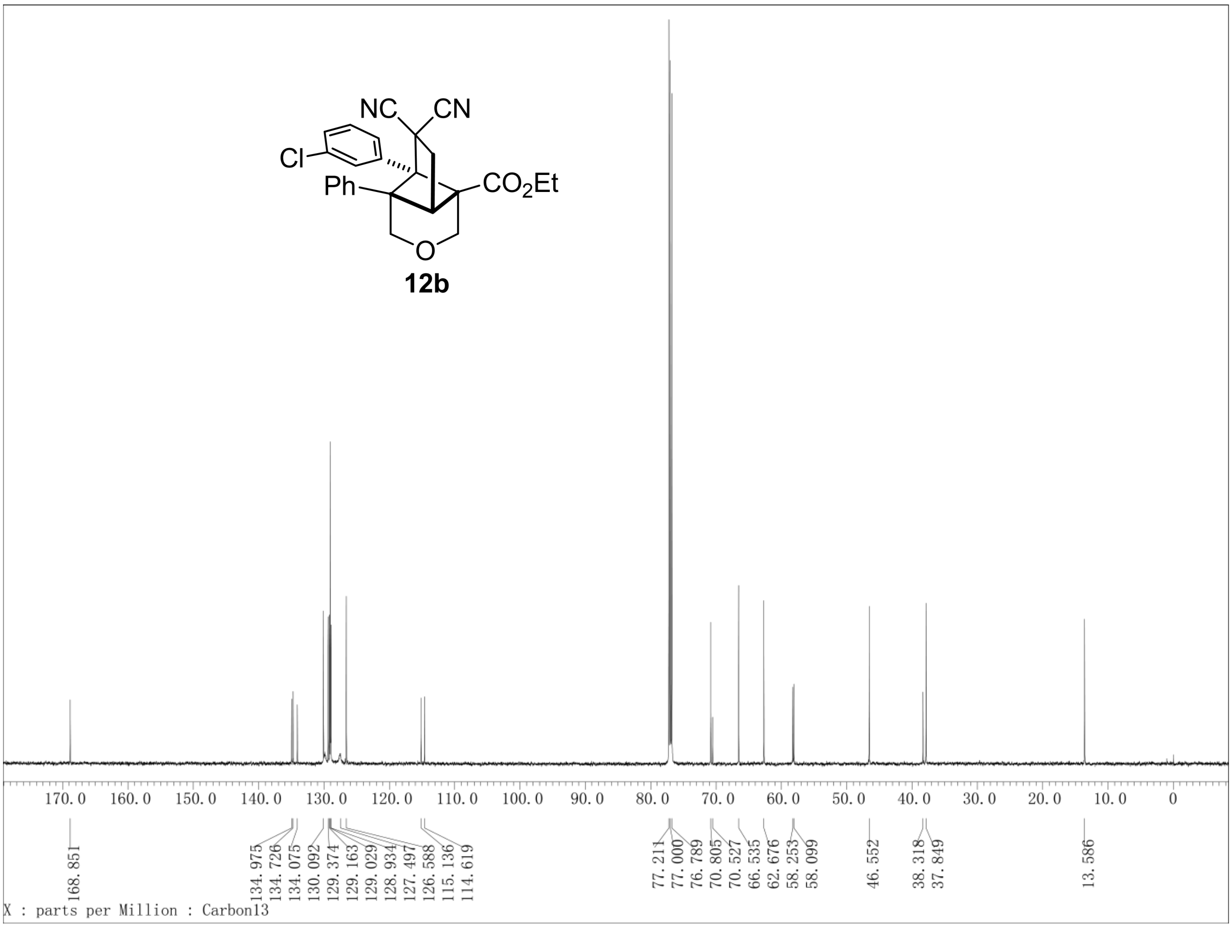
8.054
8.045
8.040
8.038
8.033
8.030
8.026
8.020
8.015
7.554
7.517
7.504
7.496
7.493
7.484
7.480
7.477
7.430
7.421
7.407
7.398
7.386
7.375
7.096
4.457
4.438
4.331
4.318
4.313
4.307
4.301
4.295
4.289
4.276
4.272
4.261
4.255
4.248
4.243
4.237
4.231
4.219
4.153
4.135
4.116
3.867
3.848
3.309
3.288
3.267
3.032
3.012
1.364
1.353
1.340
X : parts per Million : Proton

12b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Ph
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140.0
130.0
120.0
110.0
100.0
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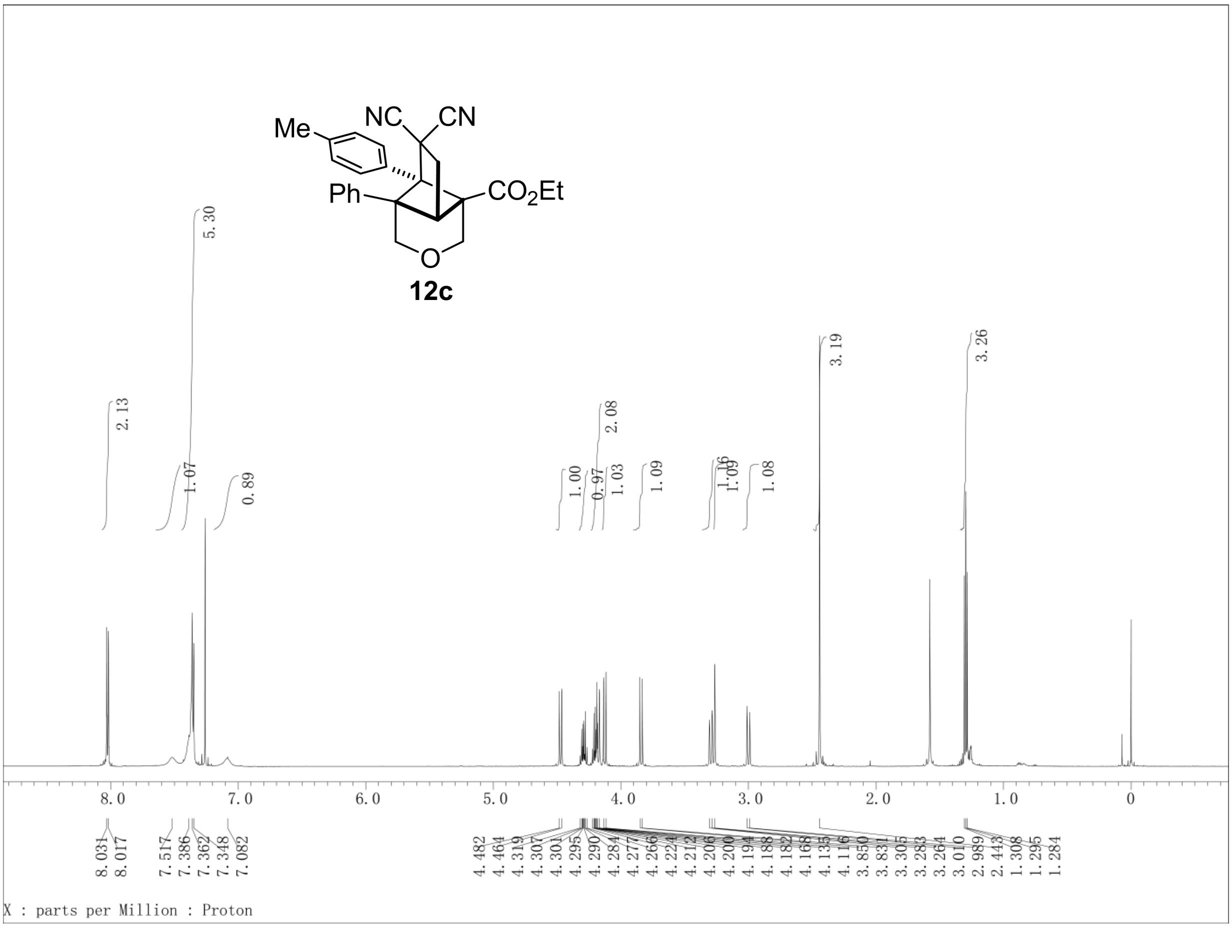
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
168.851
134.975
134.726
134.075
130.092
129.374
129.163
129.029
128.934
127.497
126.588
115.136
114.619
77.211
77.000
76.789
70.805
70.527
66.535
62.676
58.253
58.099
46.552
38.318
37.849
13.586
X : parts per Million : Carbon13

12b


Me
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CN
Ph
CO2Et
O
12c
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1.07
0.89
1.00
0.97
2.08
1.03
1.09
1.16
1.09
1.08
3.19
3.26
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
8.031
8.017
7.517
7.386
7.362
7.348
7.082
4.482
4.464
4.319
4.307
4.301
4.295
4.290
4.284
4.277
4.266
4.224
4.212
4.206
4.200
4.194
4.188
4.182
4.168
4.135
4.116
3.850
3.831
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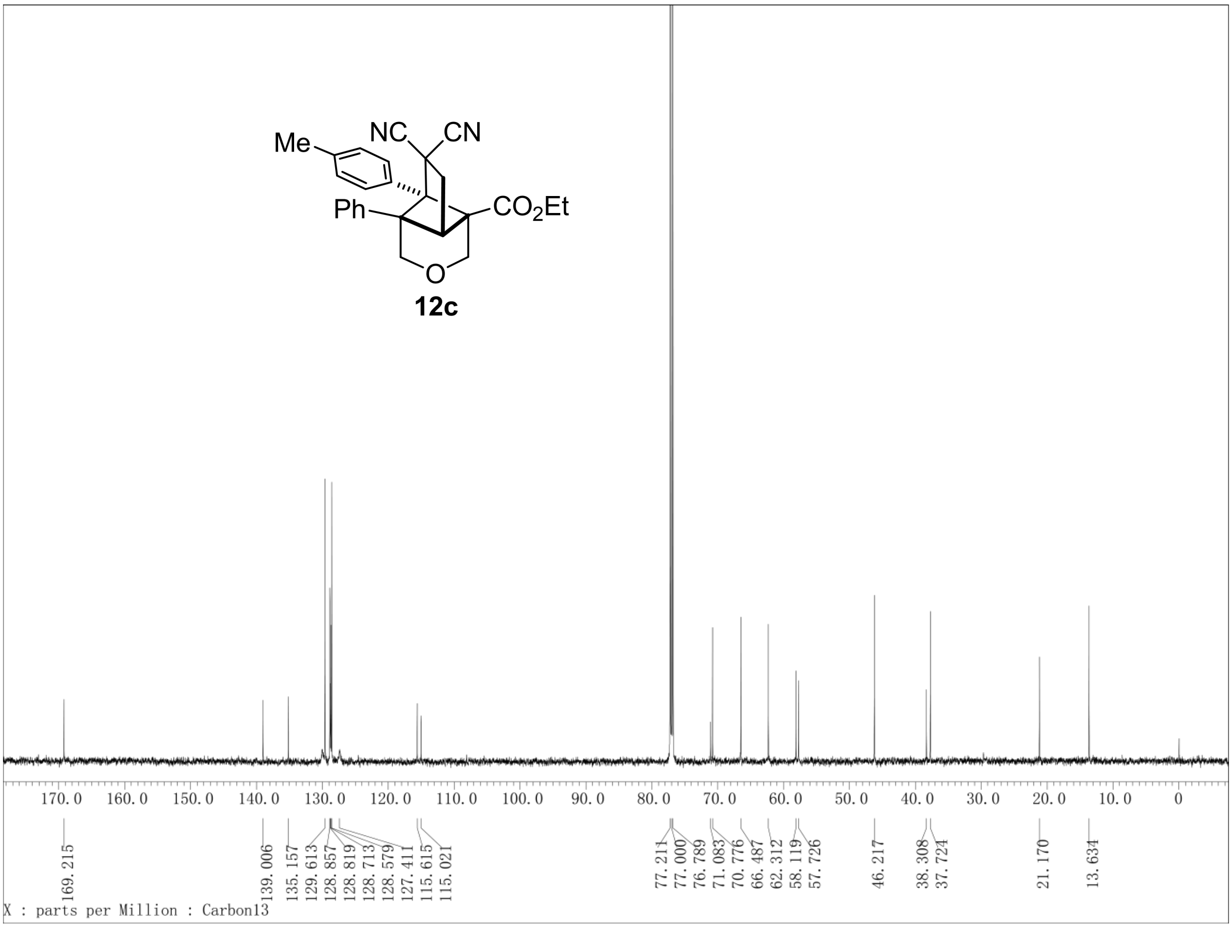
3.283
3.264
3.010
2.989
2.443
1.308
1.295
1.284
X : parts per Million : Proton


Me
NC
CN
Ph
CO2Et
O
12c
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150.0
140.0
130.0
120.0
110.0
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70.0
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20.0
10.0
0
169.215
139.006
135.157
129.613
128.857
128.819
128.713
128.579
127.411
115.615
115.021
77.211
77.000
76.789
71.083
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58.119
57.726
46.217
38.308
37.724
21.170
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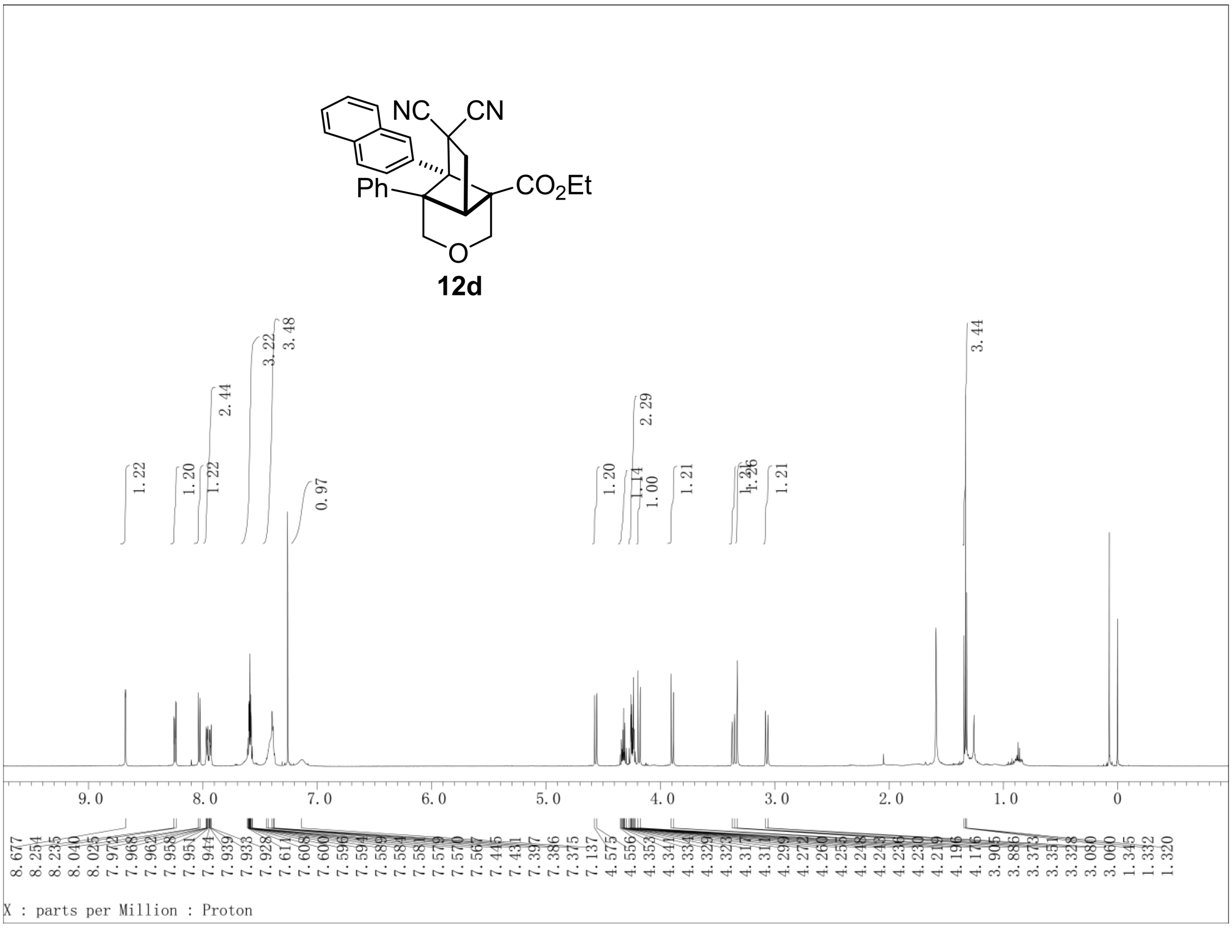
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Ph
CO2Et
O
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1.20
1.22
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3.48
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1.20
1.14
2.29
1.00
1.21
1.21
1.26
1.21
3.44
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
8.677
8.254
8.235
8.040
8.025
7.972
7.968
7.962
7.958
7.951
7.944
7.939
7.933
7.928
7.611
7.608
7.600
7.596
7.594
7.589
7.584
7.581
7.579
7.570
7.567
7.445
7.431
7.397
7.386
7.375
7.137
4.575
4.556
4.353
4.347
4.334
4.329
4.323
4.317
4.311
4.299
4.272
4.260
4.255
4.248
4.243
4.236
4.230
4.219
4.196
4.176
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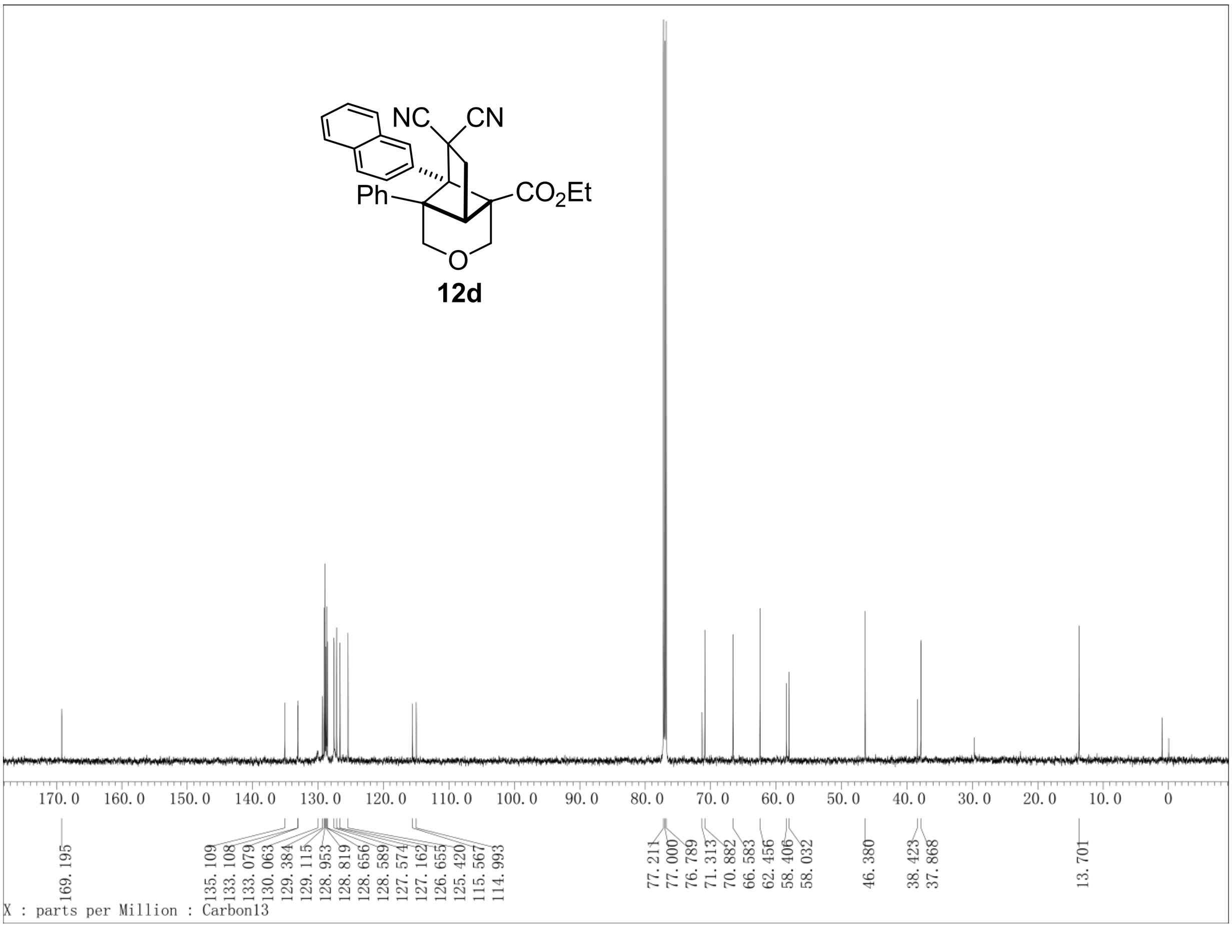
3.351
3.328
3.080
3.060
1.345
1.332
1.320
X : parts per Million : Proton


12d
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CN
Ph
CO2Et
O
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160.0
150.0
140.0
130.0
120.0
110.0
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80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
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135.109
133.108
133.079
130.063
129.384
129.115
128.953
128.819
128.656
128.589
127.574
127.162
126.655
125.420
115.567
114.993
77.211
77.000
76.789
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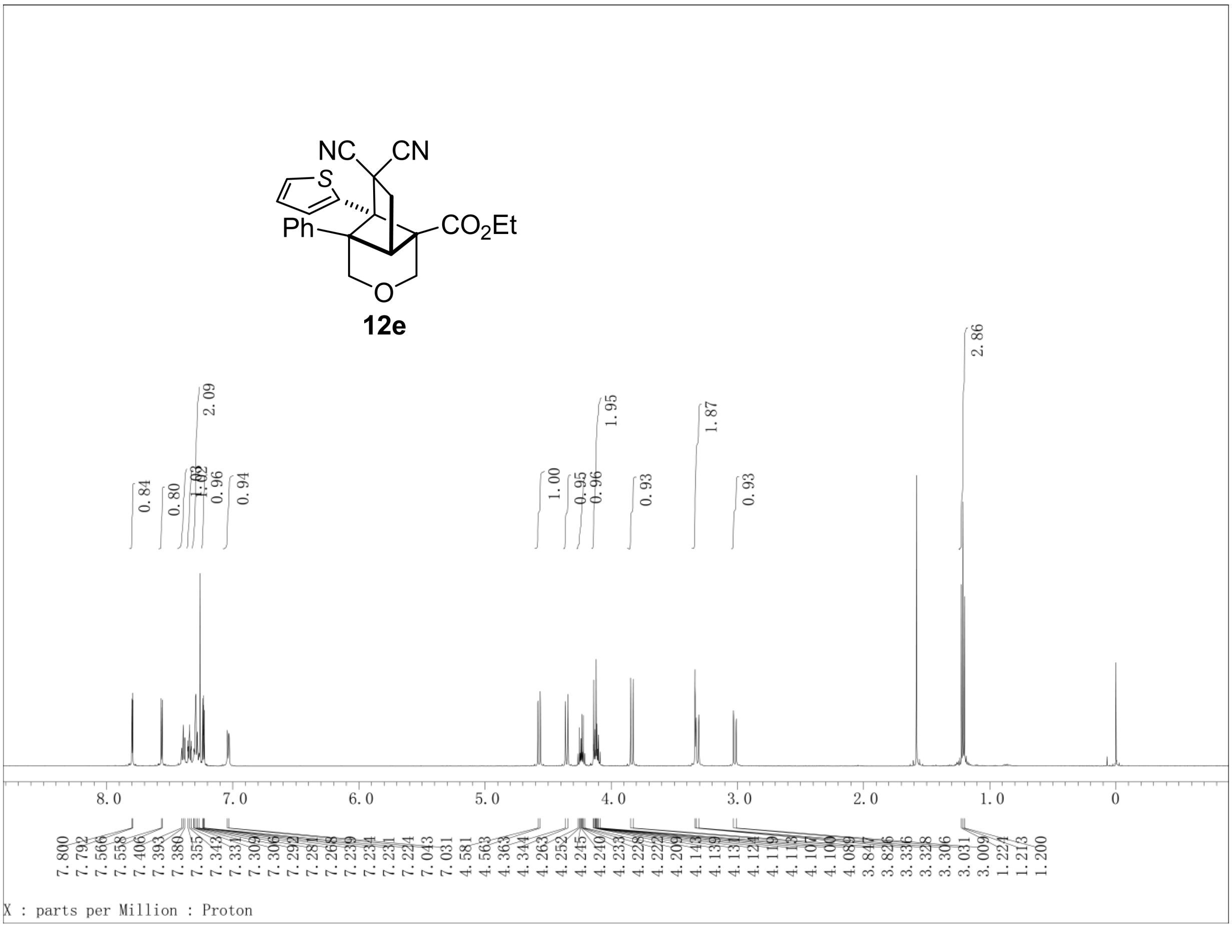
62.456
58.406
58.032
46.380
38.423
37.868
13.701
X : parts per Million : Carbon13



12e

NC
CN
S
Ph
CO2Et
O
0.84
0.80
1.03
1.02
2.09
0.96
0.94
1.00
0.95
0.96
1.95
0.93
1.87
0.93
2.86
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
7.800
7.792
7.566
7.558
7.406
7.393
7.380
7.355
7.343
7.331
7.309
7.306
7.292
7.281
7.268
7.239
7.234
7.231
7.224
7.043
7.031
4.581
4.563
4.363
4.344
4.263
4.252
4.245
4.240
4.233
4.228
4.222
4.209
4.143
4.139
4.131
4.124
4.119
4.113
4.107
4.100
4.089
3.847
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3.336
3.328
3.306
3.031
3.009
1.224
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1.200
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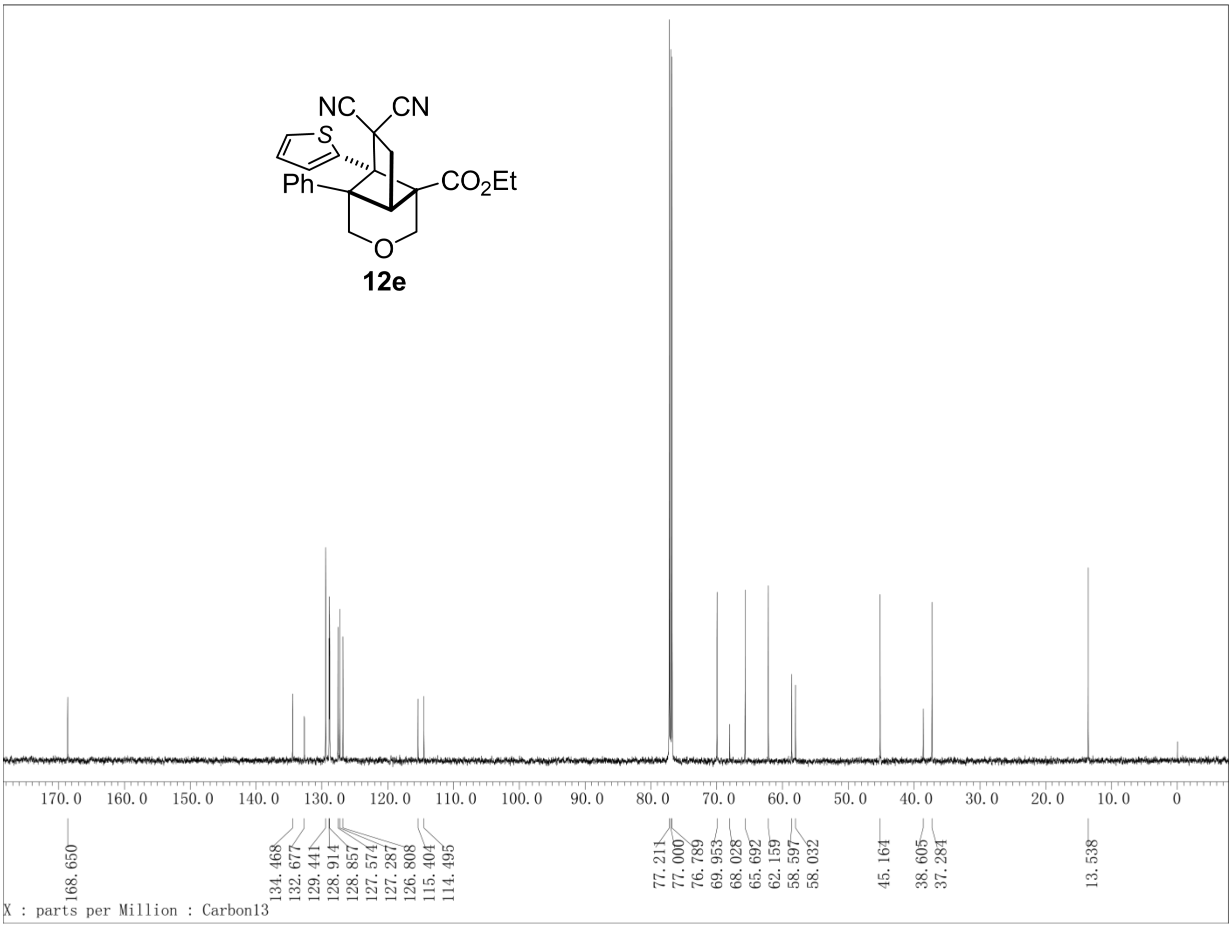

12e

NC
CN
S
Ph
CO2Et
O
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
168.650
134.468
132.677
129.441
128.914
128.857
127.574
127.287
126.808
115.404
114.495
77.211
77.000
76.789
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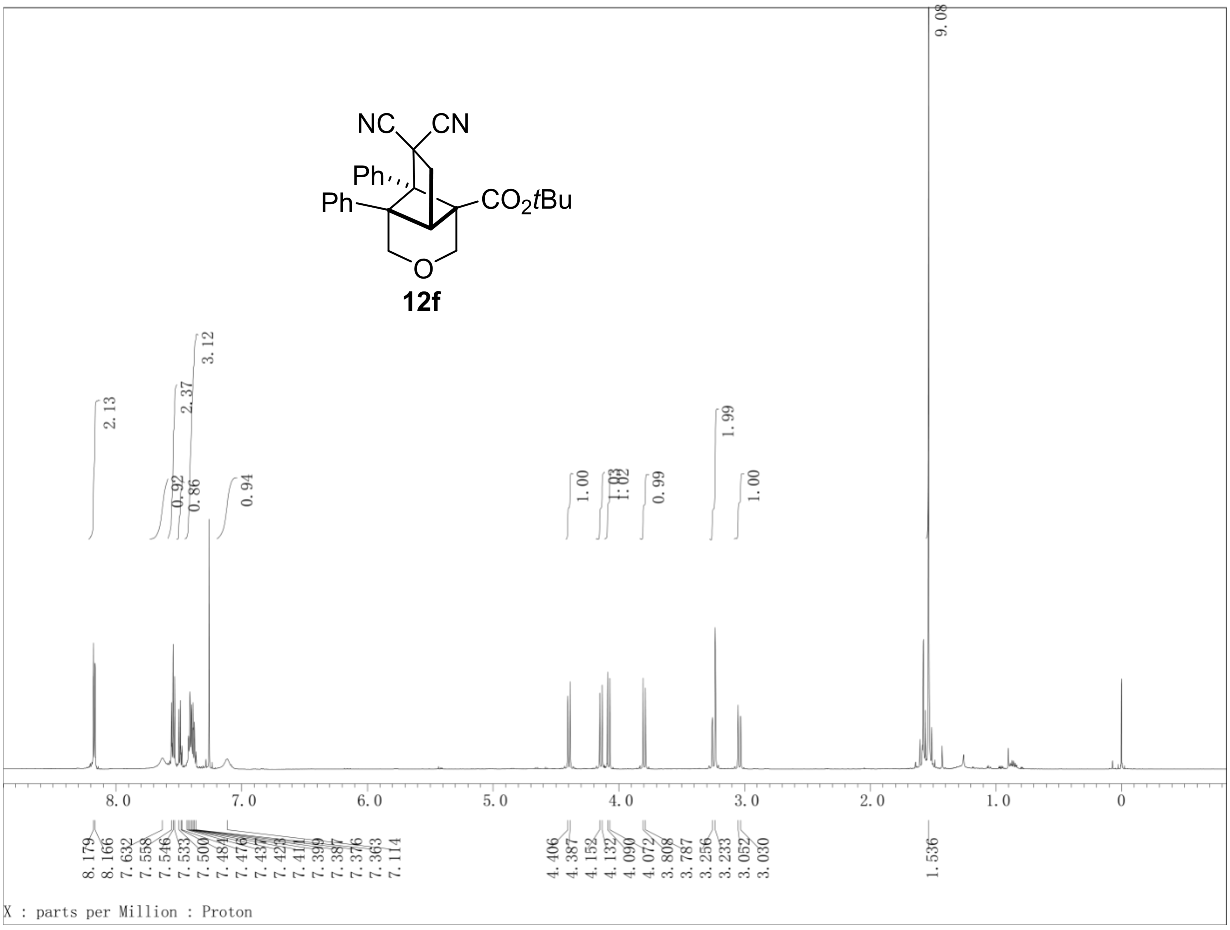
68.028
65.692
62.159
58.597
58.032
45.164
38.605
37.284
13.538
X : parts per Million : Carbon13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CN
Ph
Ph
CO2tBu
O
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2.37
0.86
3.12
0.94
1.00
1.03
1.02
0.99
1.99
1.00
9.08
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
8.179
8.166
7.632
7.558
7.546
7.533
7.500
7.484
7.476
7.437
7.423
7.411
7.399
7.387
7.376
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7.114
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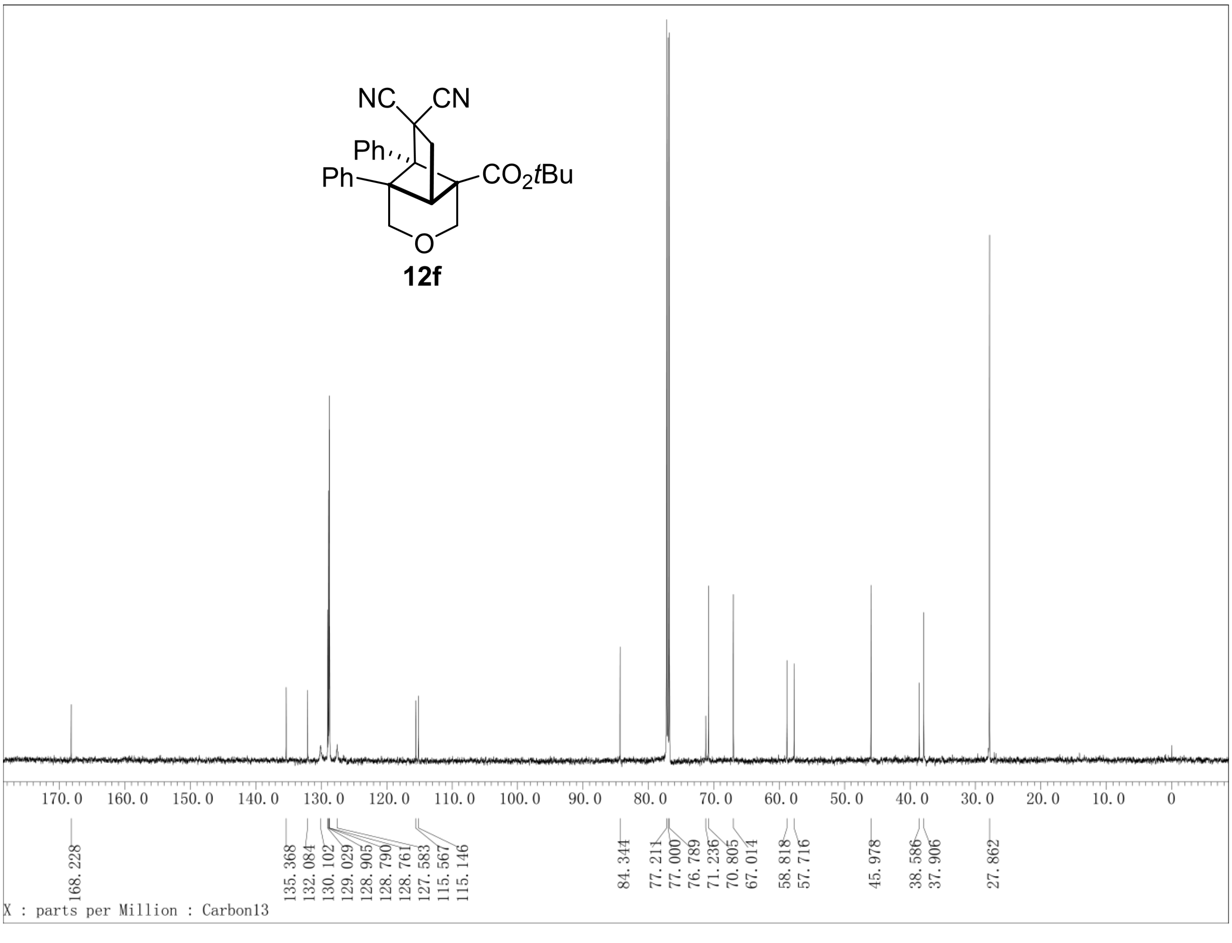
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CN
Ph
Ph
CO2tBu
O
12f
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150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
168.228
135.368
132.084
130.102
129.029
128.905
128.790
128.761
127.583
115.567
115.146
84.344
77.211
77.000
76.789
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57.716
45.978
38.586
37.906
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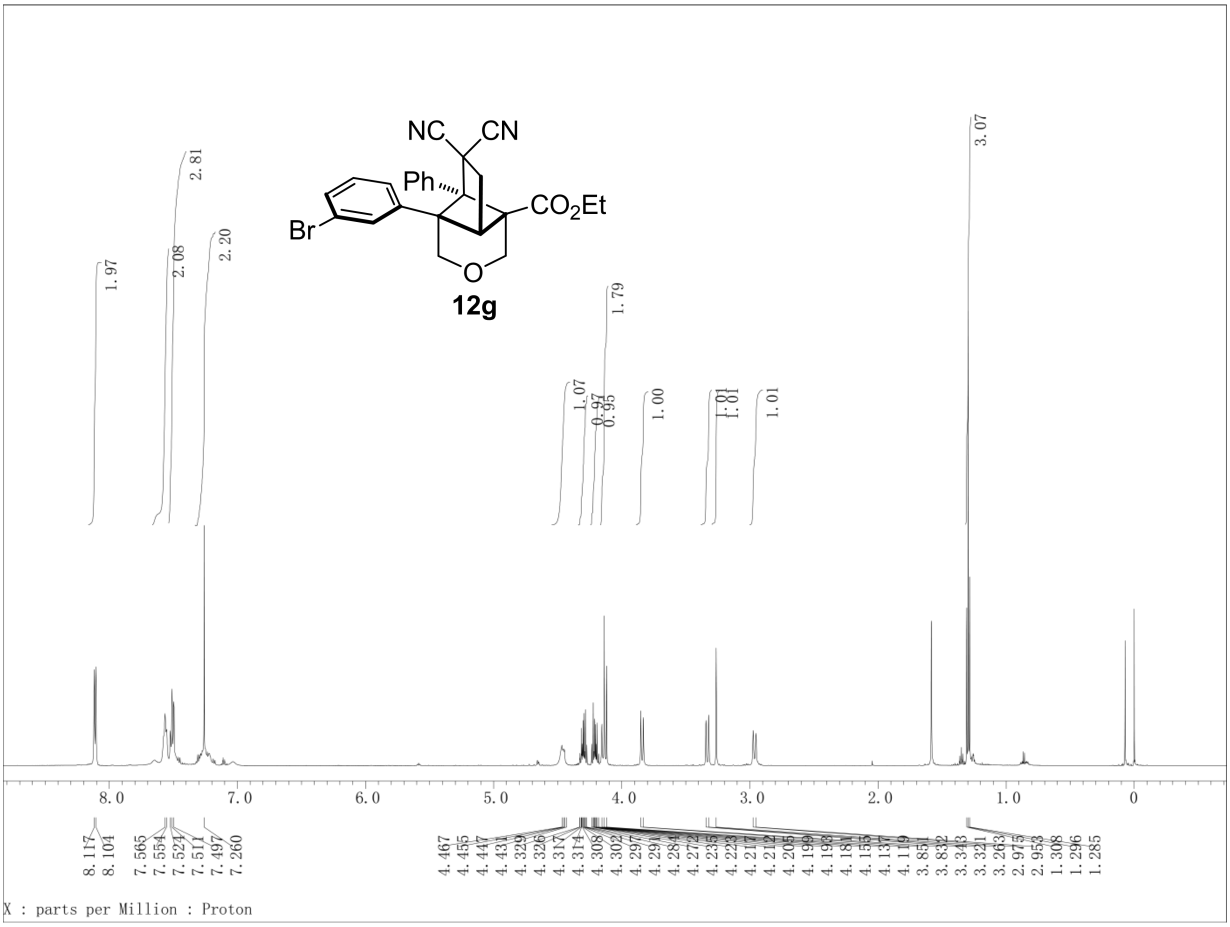
NC
CN
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CO2Et
Br
O
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1.07
0.97
0.95
1.79
1.00
1.01
1.01
1.01
3.07
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
8.117
8.104
7.565
7.554
7.524
7.511
7.497
7.260
4.467
4.455
4.447
4.431
4.329
4.326
4.317
4.314
4.308
4.302
4.297
4.291
4.284
4.272
4.235
4.223
4.217
4.212
4.205
4.199
4.193
4.181
4.155
4.137
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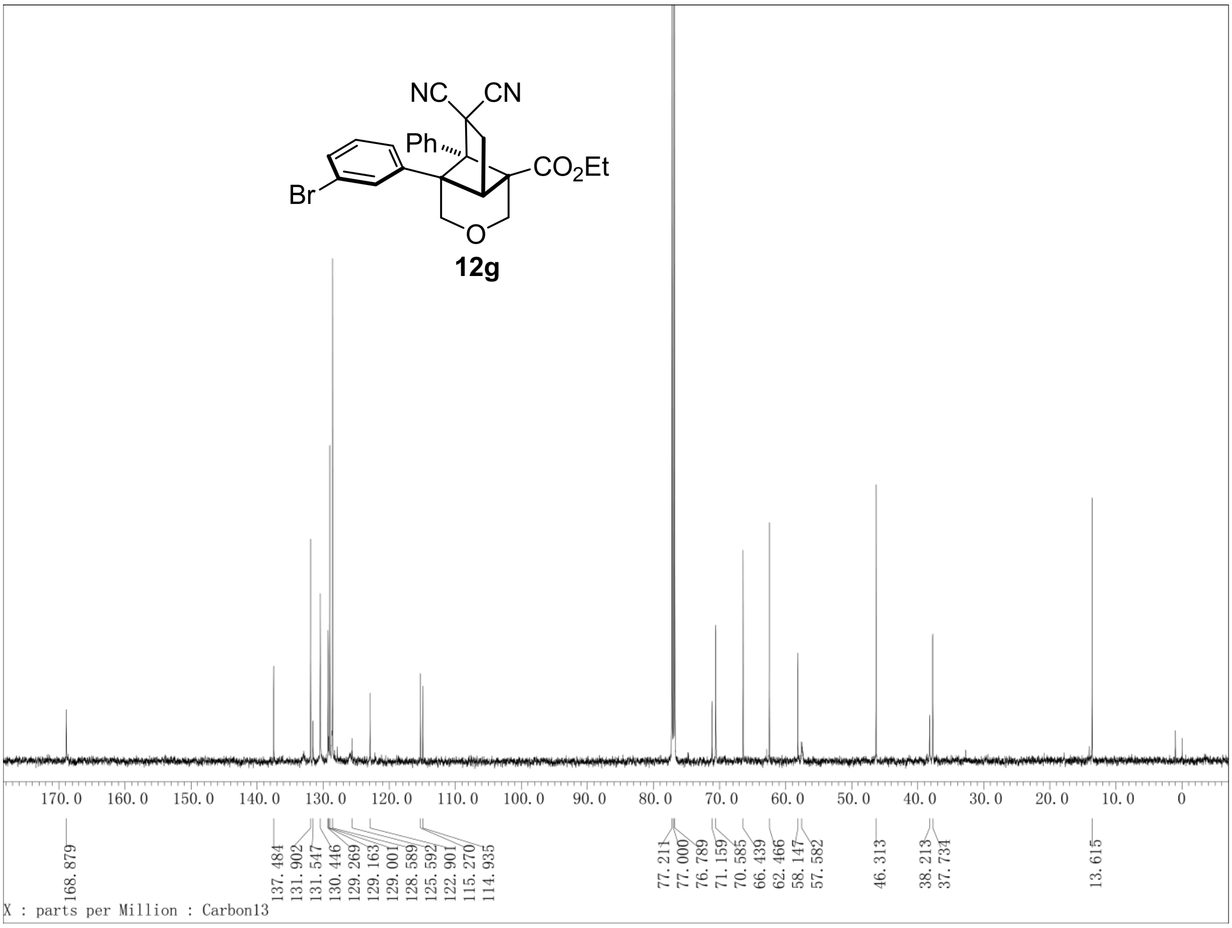
X : parts per Million : Proton


NC
CN
Ph
CO2Et
Br
O
12g
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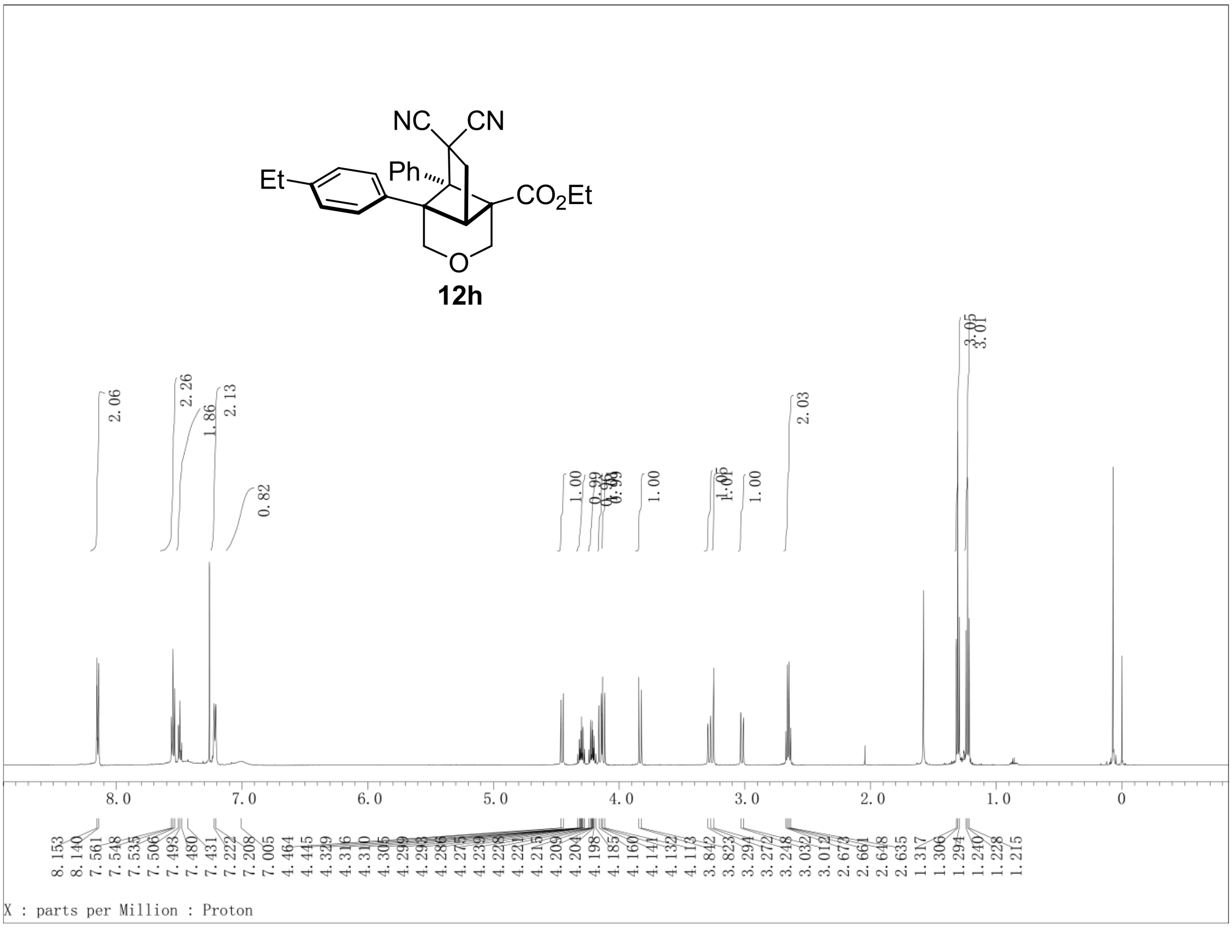
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
168.879
137.484
131.902
131.547
130.446
129.269
129.163
129.001
128.589
125.592
122.901
115.270
114.935
77.211
77.000
76.789
71.159
70.585
66.439
62.466
58.147
57.582
46.313
38.213
37.734
13.615
X : parts per Million : Carbon13


12h

NC
CN
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Et
CO2Et
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2.13
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0.99
1.00
1.00
1.05
1.01
1.00
2.03
3.05
3.01
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
8.153
8.140
7.561
7.548
7.535
7.506
7.493
7.480
7.431
7.222
7.208
7.005
4.464
4.445
4.329
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4.310
4.305
4.299
4.293
4.286
4.275
4.239
4.228
4.221
4.215
4.209
4.204
4.198
4.185
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4.141
4.132
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3.248
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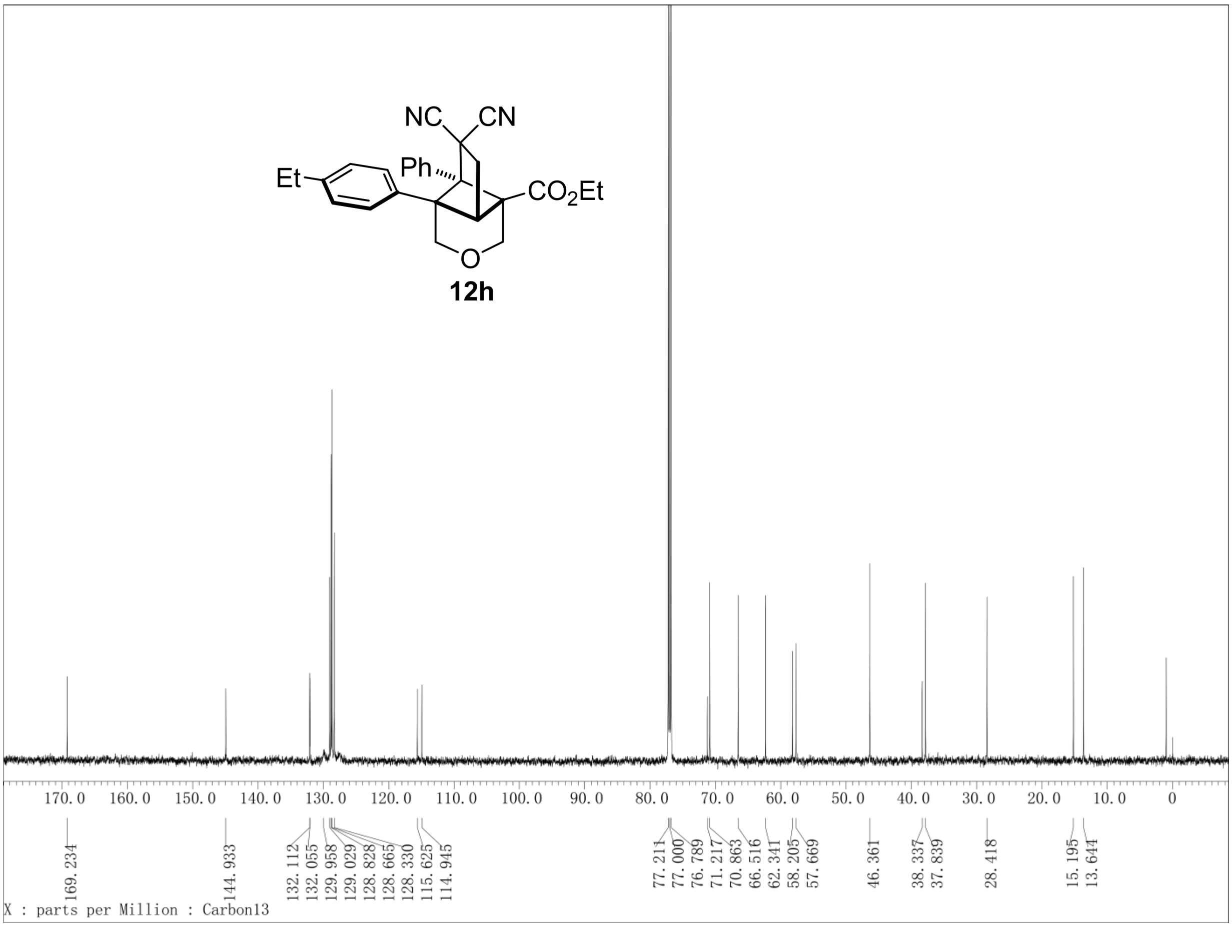
1.240
1.228
1.215
X : parts per Million : Proton


12h

NC
CN
Ph
Et
CO2Et
O
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150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
169.234
144.933
132.112
132.055
129.958
129.029
128.828
128.665
128.330
115.625
114.945
77.211
77.000
76.789
71.217
70.863
66.516
62.341
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57.669
46.361
38.337
37.839
28.418
15.195
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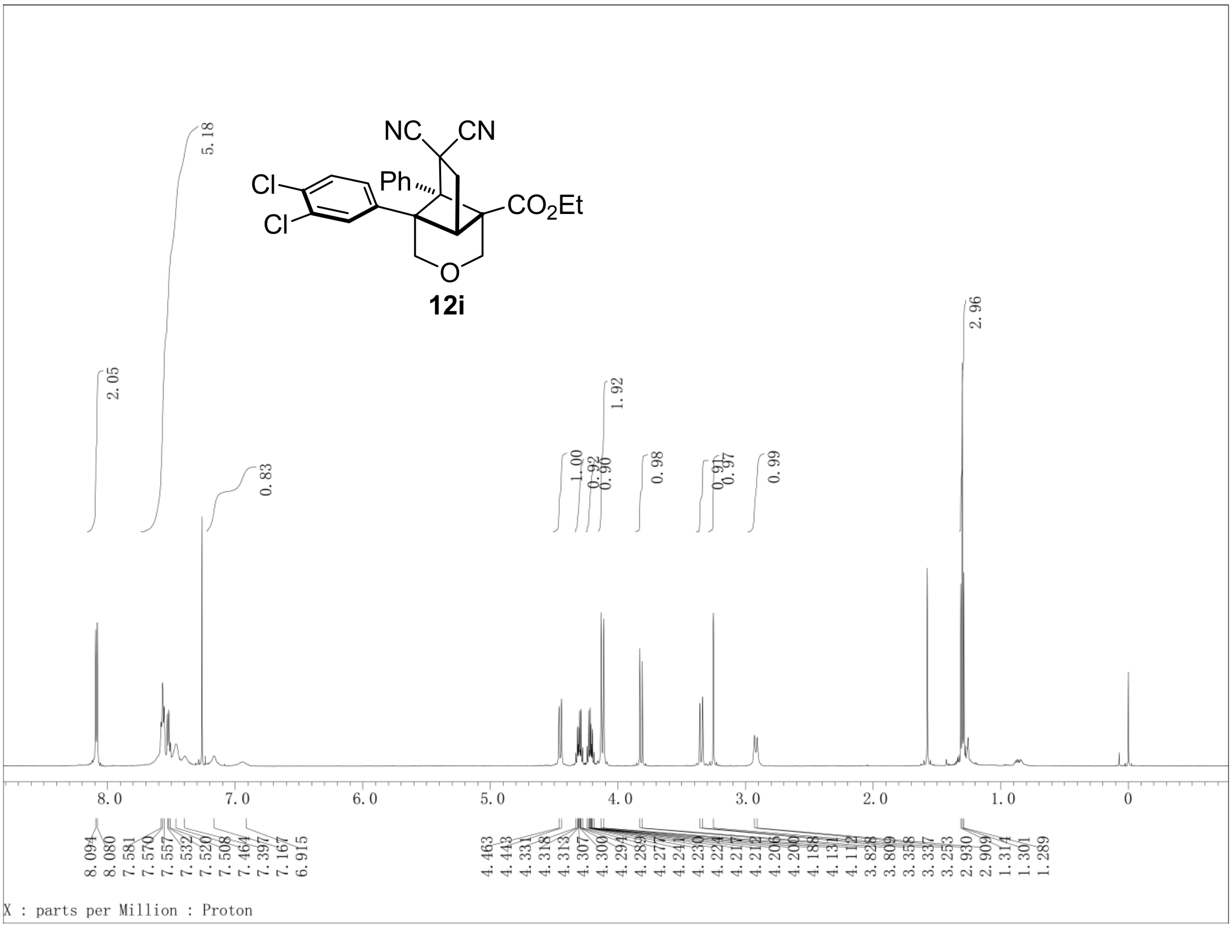
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Cl
Ph
CO2Et
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1.92
0.98
0.91
0.97
0.99
2.96
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
8.094
8.080
7.581
7.570
7.557
7.532
7.520
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4.443
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4.313
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4.300
4.294
4.289
4.277
4.241
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4.224
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4.206
4.200
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4.131
4.112
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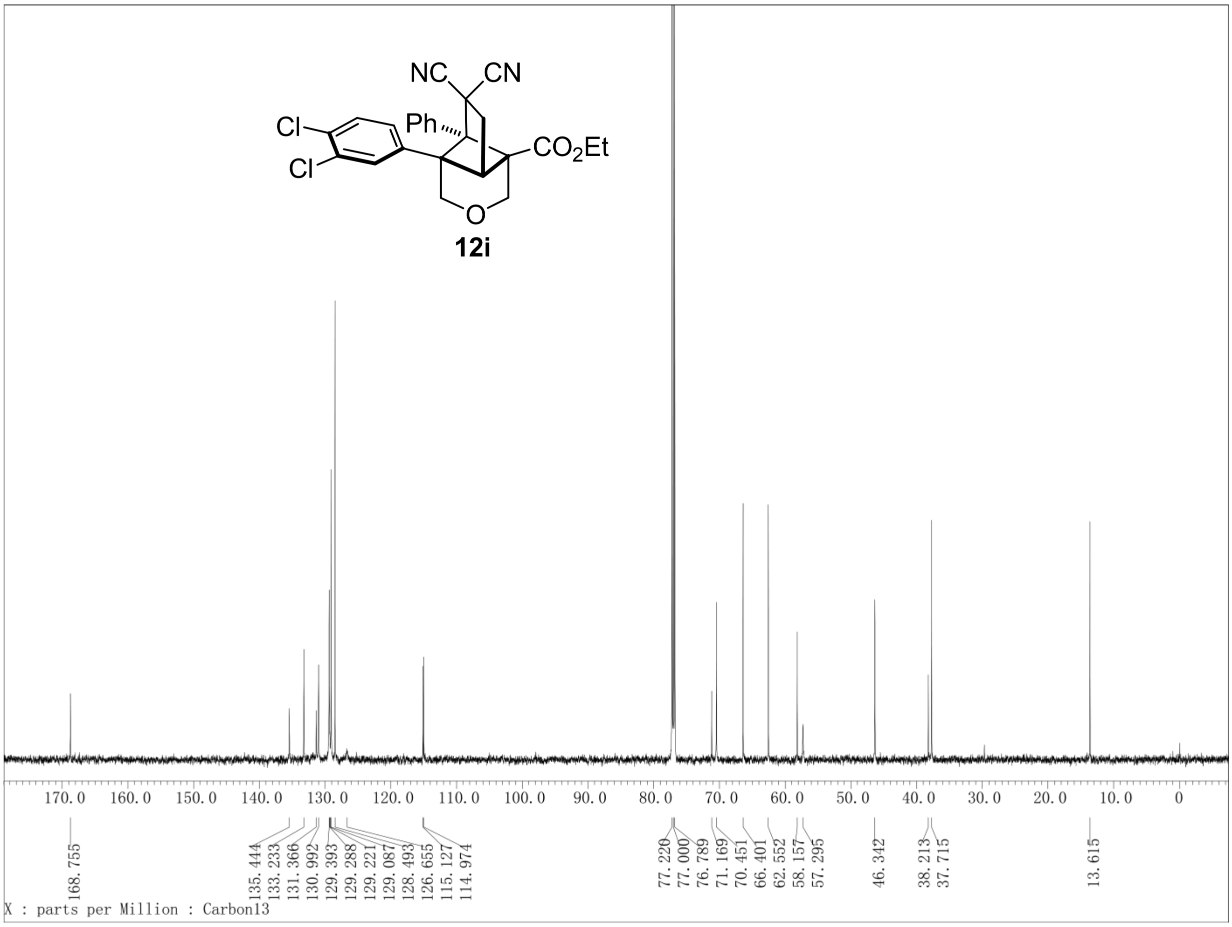
2.909
1.314
1.301
1.289
X : parts per Million : Proton


NC
CN
Cl
Cl
Ph
CO2Et
O
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150.0
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100.0
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80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
168.755
135.444
133.233
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130.992
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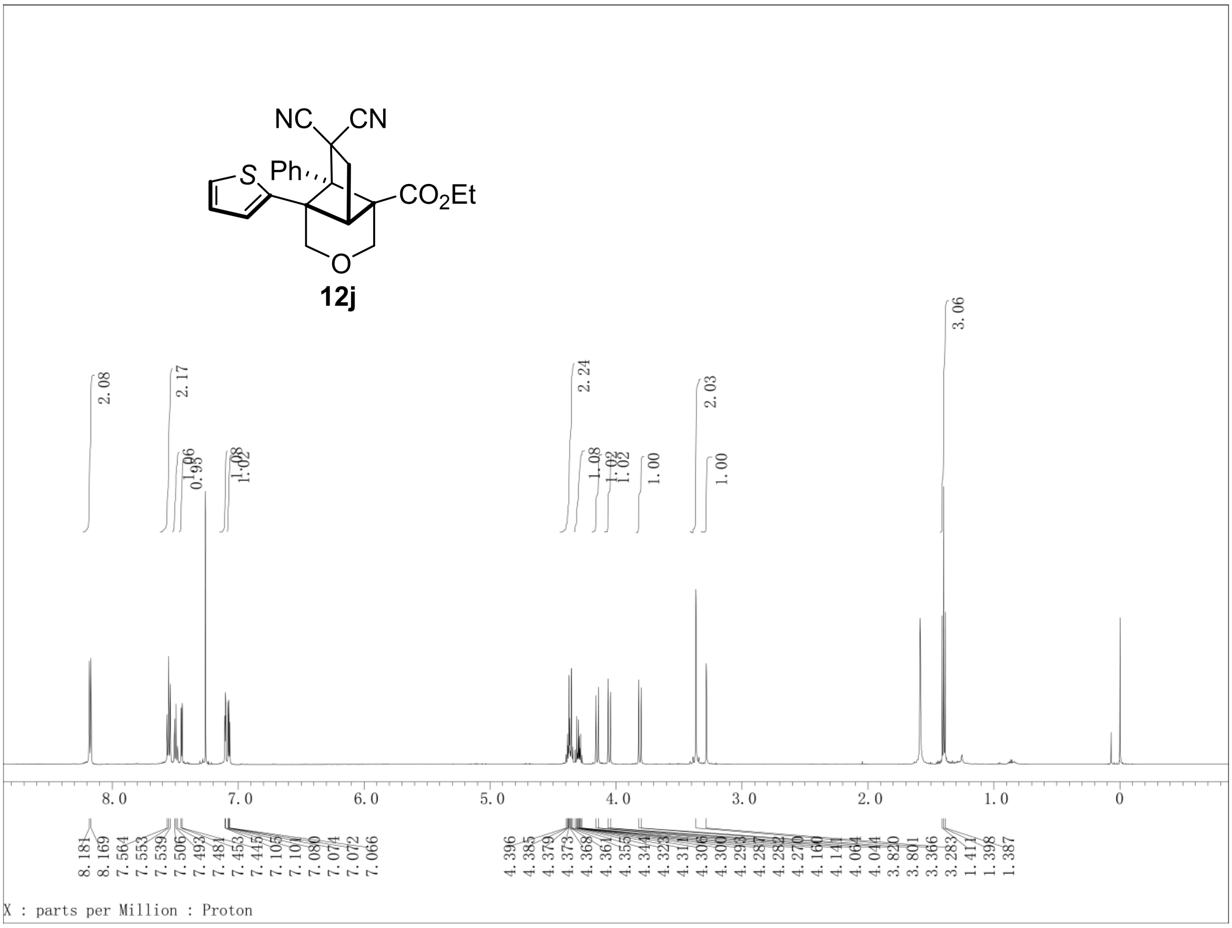
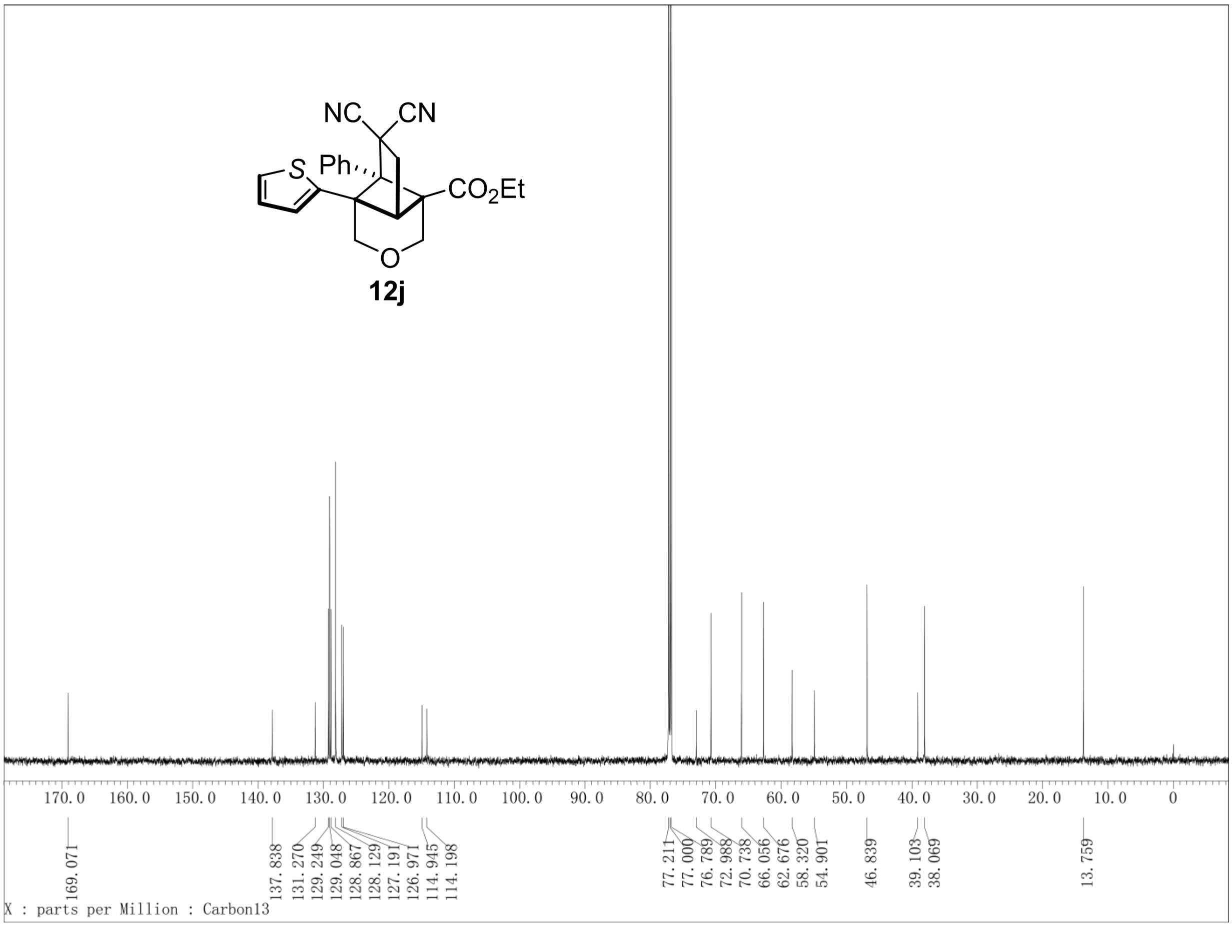
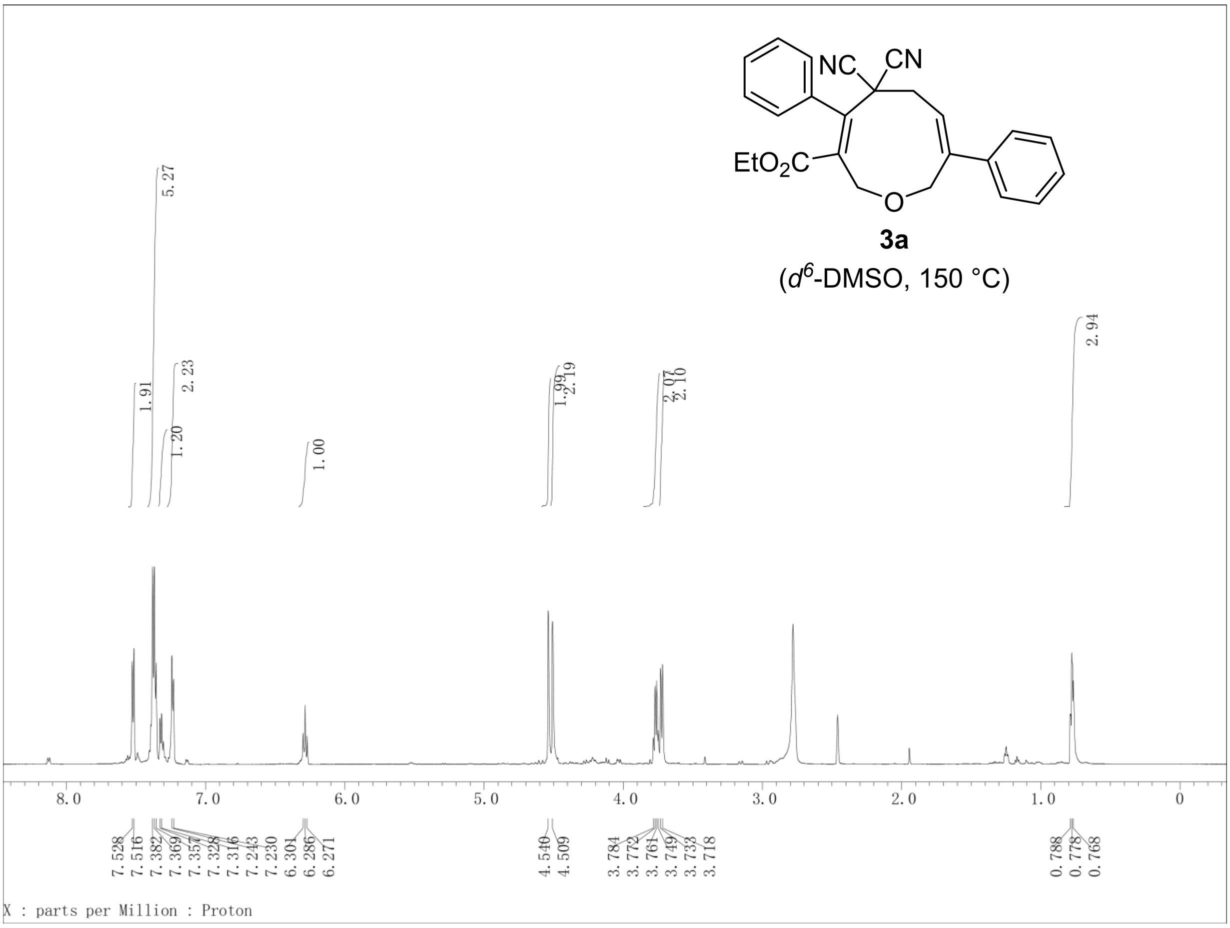
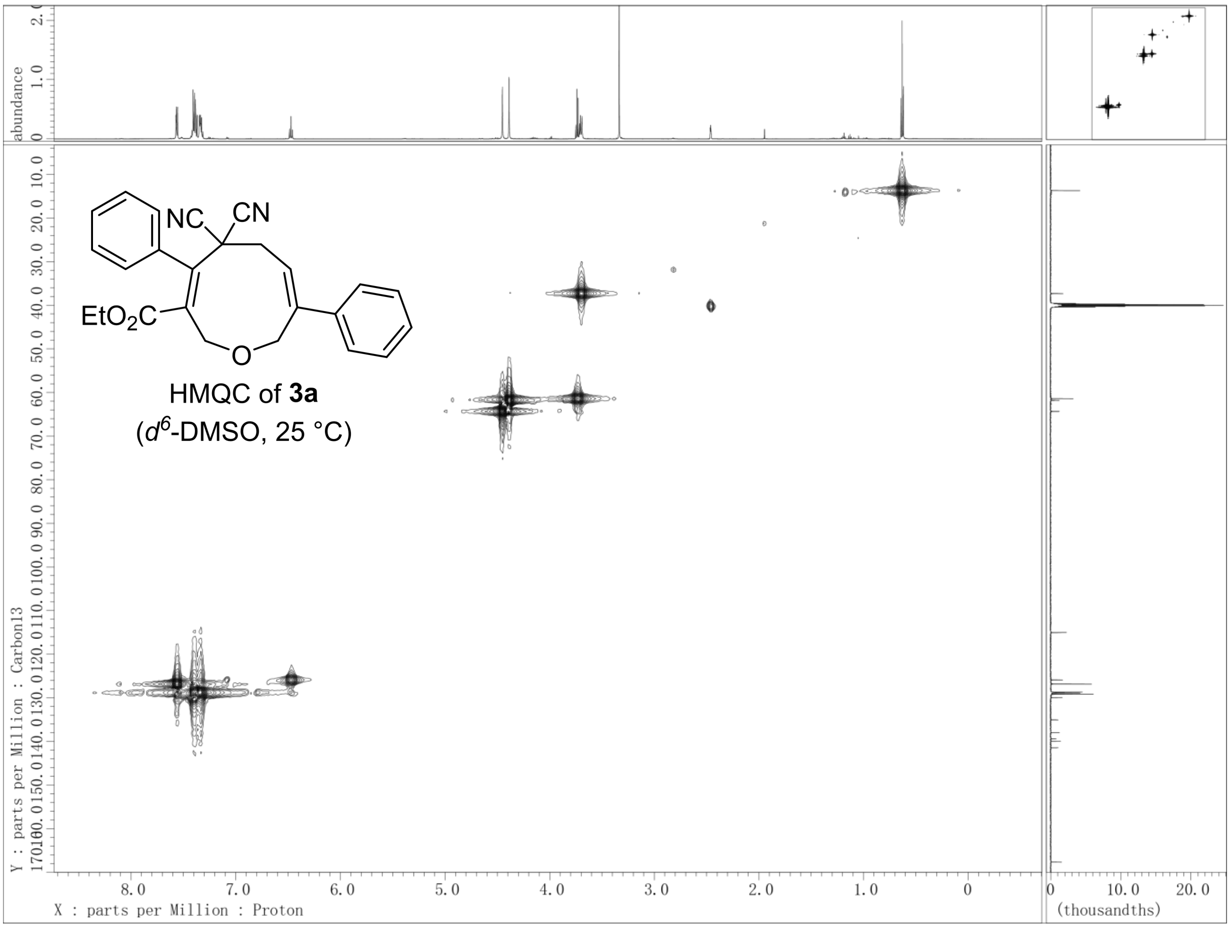
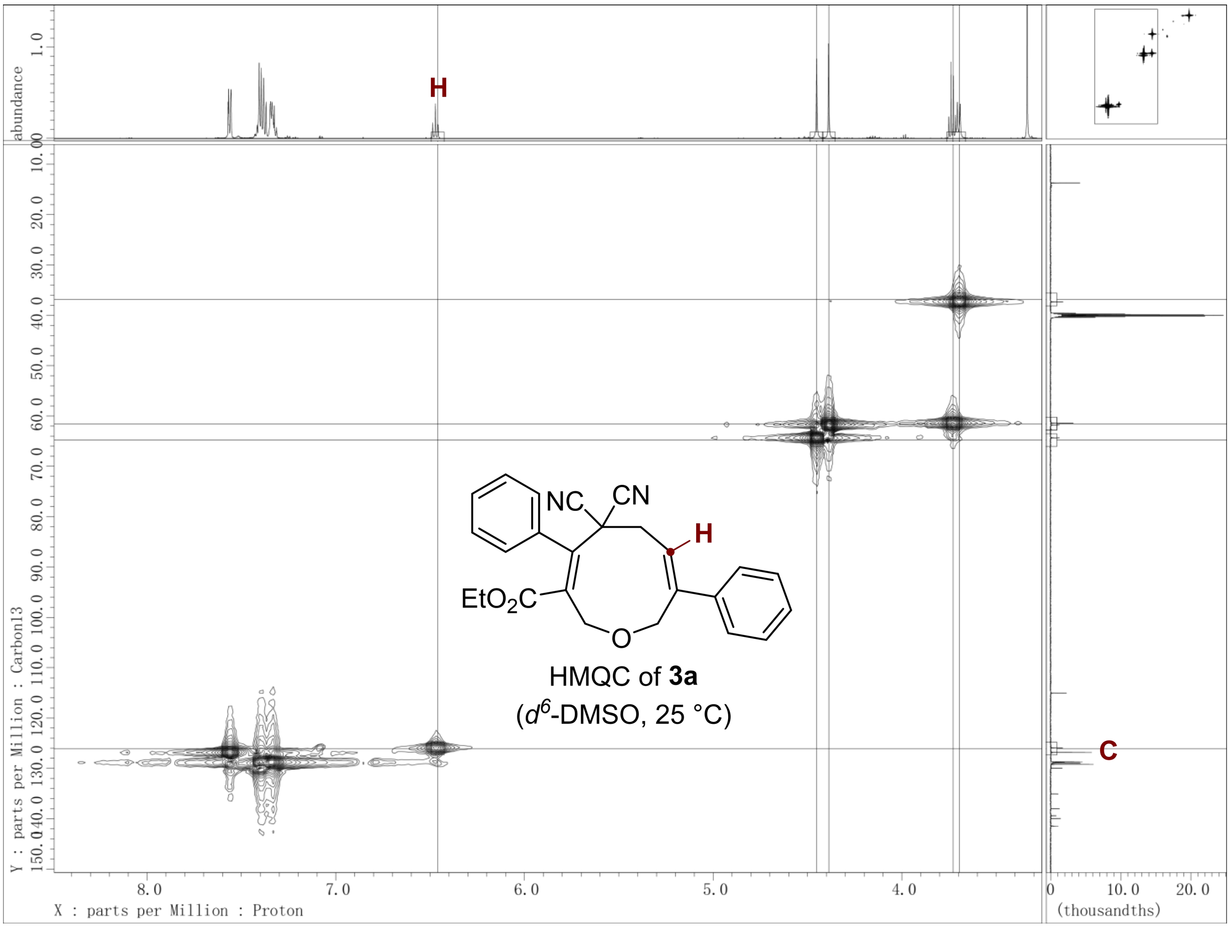
129.288
129.221
129.087
128.493
126.655
115.127
114.974
77.220
77.000
76.789
71.169
70.451
66.401
62.552
58.157
57.295
46.342
38.213
37.715
13.615
X : parts per Million : Carbon13


NC
CN
S
Ph
CO2Et
O
12j
2.08
2.17
1.06
0.95
1.08
1.02
2.24
1.08
1.02
1.02
1.00
2.03
1.00
3.06
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
8.181
8.169
7.564
7.553
7.539
7.506
7.493
7.481
7.453
7.445
7.105
7.101
7.080
7.074
7.072
7.066
4.396
4.385
4.379
4.373
4.368
4.361
4.355
4.344
4.323
4.311
4.306
4.300
4.293
4.287
4.282
4.270
4.160
4.141
4.064
4.044
3.820
3.801
3.366
3.283
1.411
1.398
1.387
X : parts per Million : Proton


NC
CN
S
Ph
CO2Et
O
12j
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
169.071
137.838
131.270
129.249
129.048
128.867
128.129
127.191
126.971
114.945
114.198
77.211
77.000
76.789
72.988
70.738
66.056
62.676
58.320
54.901
46.839
39.103
38.069
13.759
X : parts per Million : Carbon13


NC
CN
EtO$_2$C
O
3a
(d^6-DMSO, 150 °C)
5.27
1.91
2.23
1.20
1.00
1.99
2.19
2.07
2.10
2.94
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
7.528
7.516
7.382
7.369
7.357
7.328
7.316
7.243
7.230
6.301
6.286
6.271
4.540
4.509
3.784
3.772
3.761
3.749
3.733
3.718
0.788
0.778
0.768
X : parts per Million : Proton


abundance
0
1.0
2.0
NC
CN
EtO$_2$C
O
HMQC of 3a
(d^6-DMSO, 25 °C)
Y : parts per Million : Carbon13
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
120.0
130.0
140.0
150.0
160.0
170.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
X : parts per Million : Proton
0
10.0
20.0
(thousandths)



HMQC of **3a**
(d^6-DMSO, 25 °C)