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− Electronic Supplementary Information −

Oxidative cross-dehydrogenative [2+3] annulation of α-amino ketones with α-keto esters: concise synthesis of clausenamide analogues

Vinod Bhajammanavar, Sumitava Mallik, and Mahiuddin Baidya*

Department of Chemistry, Indian Institute of Technology Madras,
Chennai 600 036, Tamil Nadu, India
E-mail: mbaidya@iitm.ac.in

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General information

All non-aqueous reactions were carried out under an atmosphere of nitrogen in flame-dried glassware and were stirred using a magnetic stir plate. All reactions were carried out using commercial grade solvent unless otherwise noted. CH_3CN, toluene, and DCE were dried over calcium hydride. Dry THF was prepared by distilling over sodium ketyl.

All reactions were monitored by thin layer chromatography (TLC) on WhatmanPartisil® K6F TLC plates (silica gel 60 Å, 0.25 mm thickness) and visualized using a UV lamp (366 or 254 nm) or by use of one of the following visualization reagents: PMA: 10 g phosphomolybdic acid/ 100 mL ethanol; $KMnO_4$: 0.75 g potassium permanganate, 5 g K_2CO_3, / 100mL water. Products were isolated by column chromatography (Merck silica gel 100-200μm). Yields refer to chromatographically and spectroscopically homogenous materials unless noted otherwise. ^{13}C and ^{1}H NMR spectra were recorded on a Bruker 400 or 500 MHz spectrometers. Chemical shift values (δ) are reported in ppm and calibrated to the residual solvent peak $CDCl_3$ δ = 7.2600 ppm for ^{1}H, δ = 77.16 for ^{13}C, DMSO-d_6 δ = 2.500 ppm for ^{1}H, δ = 39.500 ppm for ^{13}C; or calibrated to tetramethylsilane (δ = 0.00). All NMR spectra were recorded at ambient temperature (290 K) unless otherwise noted. ^{1}H NMR spectra are reported as follows: chemical shift (multiplicity, coupling constant, integration). The following abbreviations are used to indicate multiplicities: s, singlet; d, doublet; t, triplet; q, quartet; quint, quintet; sext, sextet; sept, septet; m, multiplet; dd, doublet of doublet; dt, doublet of triplet; dq, doublet of quartet; td, triplet of doublet; tt, triplet of triplet; dq, doublet of quartet; br, broad; app, apparent.

Mass spectra were recorded by electrospray ionization (ESI) method on a Q-TOF Micro with lock spray source. The crystal data were collected and integrated using a BrukerAxs kappa apex2 CCD diffractometer, with graphite monochromated Mo-Kα radiation.

The 1,2-diketoesters[1-3] and 1-phenyl-2-(phenylamino)ethan-1-one[4] were synthesized following literature procedures published previously.

Amine catalysts quinidine, quinine, 3-quinuclidinol, DABCO, and DBU were bought from Sigma-Aldrich.

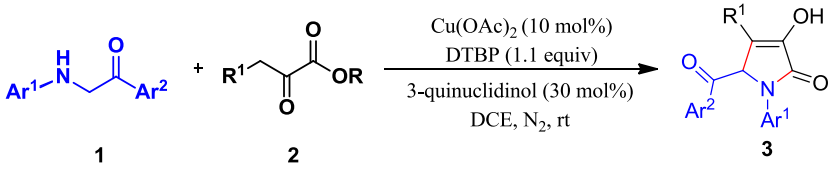
(1) K. Nakamura, K. Inoue, K. Ushio, S. Oka and A. Ohno, *J. Org. Chem.*, 1988, **53**, 2589.

(2) A. Nakamura, S. Lectard, D. Hashizume and Y. Hamashima, *J. Am. Chem. Soc.*, 2010, **132**, 4036.

(3) W. Raimondi, O. Baslé, D. Bonne, T. Constantieux and J. Rodriguez, *Adv. Synth. Catal.*, 2012, **354**, 563.

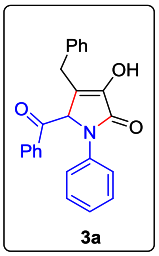
(4) F. J. Lakner, M. A. Parker, B. Rogovoy and A. Khvat, *Synthesis*, 2009, **12**, 1987.

General procedure of oxidative cross-dehydrogenative [2+3] annulation reaction

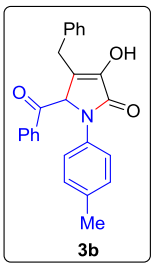


The α-amino ketones **1** (0.22 mmol, 1.2 equiv.), α-keto esters **2** (0.2 mmol, 1 equiv.), copper(II) acetate (10 mol%) and 3-quinuclidinol (30 mol%) were taken in a 16x100 mm oven dried reaction tube equipped with a magnetic stir. The reaction tube was capped with a septum, and purged nitrogen gas. Then, di-tert-butyl peroxide (DTBP, 1.1 equiv.) and dry DCE (4 mL) were added sequentially via syringe. The mixture was allowed to stir at room temperature for 14 h. The completion (TLC monitored), the crude reaction mixture was loaded directly onto silica gel column and purified with a gradient eluent of hexane and ethyl acetate to provide pure pyrrolones **3**.

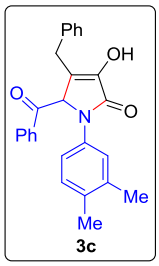
*It is worth noting that, except **3f**, the peak for the hydroxyl proton (OH) of compounds **3a**–**c**, **3g**–**h**, **3j**–**n**, and **3q**–**x** was not observed when ^{1}H NMR spectra were recorded in $CDCl_3$. However, the peak for the hydroxyl proton of compound **3q** was observed when ^{1}H NMR spectrum of **3q** was recorded using DMSO-d_6 solvent (see the comparison in page S31). Similarly, the peak for the hydroxyl proton of compounds **3d**, **3e**, **3i**, **3o**, and **3p** was also observed in ^{1}H NMR spectra in DMSO-d_6. The specific nature of these compounds in two different solvents, which likely arises from the higher acidic nature of the hydroxyl proton, is possibly responsible for this phenomenon. Nevertheless, HRMS data of all the compounds fully corroborate to the presence of hydroxyl group in these compounds. Crystal structure of compound **3a** also supports the analysis.*



Compound 3a was prepared following the general procedure of oxidative cross-dehydrogenative [2+3] annulation described above and purified by silica gel column chromatography (10→ 15% EtOAc : hexane) to provide pure compound as white solid (55 mg, 74%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.66 (dd, *J* = 8.2, 1.0 Hz, 2H), 7.56 (t, *J* = 7.5 Hz, 1H), 7.47 (d, *J* = 7.7 Hz, 2H), 7.36 (t, *J* = 7.8 Hz, 2H), 7.27 – 7.17 (m, 5H), 7.06 (dd, *J* = 11.0, 4.1 Hz, 3H), 5.79 (s, 1H), 3.95 (d, *J* = 15.4 Hz, 1H), 3.23 (d, *J* = 15.4 Hz, 1H). **^{13}C NMR** (125 MHz, DMSO) δ 195.4, 166.3, 145.1, 138.1, 137.5, 135.7, 134.4, 129.0 (2×C), 128.4, 128.2 (2×C), 126.1, 124.2, 119.9, 119.3, 63.4, 29.8. **HRMS** (ESI/TOF-Q) m/z: $[M+H]^+$ Calcd for $C_{24}H_{20}NO_3^+$ 370.1443; Found 370.1429.

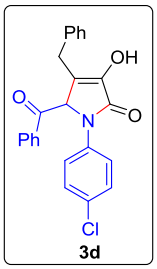


Compound 3b was prepared following the general procedure of oxidative cross-dehydrogenative [2+3] annulation described above and purified by silica gel column chromatography (10→ 15% EtOAc : hexane) to provide pure compound as white solid (48 mg, 63%). mp 158- 160 ^{0}C. **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.66 (d, *J* = 8.1 Hz, 2H), 7.56 – 7.53 (m, 1H), 7.39 – 7.31 (m, 4H), 7.26 – 7.18 (m, 3H), 7.08 – 7.03 (m, 4H), 5.75 (s, 1H), 3.94 (d, *J* = 15.3 Hz, 1H), 3.23 (d, *J* = 15.3 Hz, 1H), 2.23 (s, 3H).**^{13}C NMR** (125 MHz, $CDCl_3$) δ 195.1, 166.9, 144.1, 137.6, 135.7, 135.2, 135.0, 134.1, 130.0, 129.0 (2×C), 128.8 (2×C), 128.4, 126.9, 120.3, 66.2, 30.4, 21.0. **HRMS** (ESI/TOF-Q) m/z: $[M+K]^+$ Calcd for $C_{25}H_{21}NO_3K^+$ 422.1159; Found 422.1137.



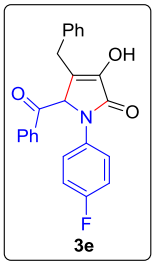
3c

Compound 3c was prepared following the general procedure of oxidative cross-dehydrogenative [2+3] annulation described above and purified by silica gel column chromatography (10→ 15% EtOAc : hexane) to provide pure compound as white solid (60 mg, 75%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.70 – 7.63 (m, 2H), 7.54 (t, *J* = 7.4 Hz, 1H), 7.35 (t, *J* = 7.8 Hz, 2H), 7.28 (d, *J* = 1.7 Hz, 1H), 7.26 – 7.17 (m, 3H), 7.12 (dd, *J* = 8.2, 2.1 Hz, 1H), 7.08 (d, *J* = 6.6 Hz, 2H), 6.97 (d, *J* = 8.2 Hz, 1H), 5.75 (s, 1H), 3.96 (d, *J* = 15.3 Hz, 1H), 3.22 (d, *J* = 15.3 Hz, 1H), 2.14 (s, 3H), 2.12 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 195.1, 167.2, 144.4, 137.7 (2×C), 135.8, 135.1, 134.1, 134.0, 130.3, 128.9 (2×C), 128.7, 128.4, 126.8, 122.0, 120.2, 118.0, 66.3, 30.3, 20.1, 19.3. **HRMS** (ESI/TOF-Q) m/z: $[M+Na]^+$ Calcd for $C_{26}H_{23}NO_3Na^+$ 420.1576; Found 420.1585.



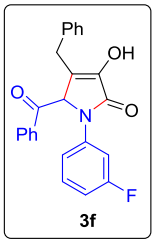
3d

Compound 3d was prepared following the general procedure of oxidative cross-dehydrogenative [2+3] annulation described above and purified by silica gel column chromatography (10→ 15% EtOAc : hexane) to provide pure compound as white solid (55 mg, 68%). **^{1}H NMR** (500 MHz, DMSO–d_6) δ 10.22 (s, 1H), 7.88 (d, *J* = 7.4 Hz, 2H), 7.69 (t, *J* = 7.4 Hz, 1H), 7.63 (d, *J* = 9.0 Hz, 2H), 7.48 (t, *J* = 7.8 Hz, 2H), 7.37 – 7.34 (m, 2H), 7.14 – 7.10 (m, 3H), 6.84 – 6.81 (m, 2H), 6.66 (s, 1H), 3.58 (d, *J* = 15.5 Hz, 1H), 3.30 (d, *J* = 15.5 Hz, 1H). **^{13}C NMR** (125 MHz, DMSO–d_6) δ 195.3, 166.3, 145.0, 137.5, 137.0, 135.6, 134.6, 129.1, 128.9, 128.4, 128.3, 128.2, 128.1, 126.2, 121.0, 120.3, 63.5, 29.8. **HRMS** (ESI/TOF-Q) m/z: $[M+H]^+$ Calcd for $C_{24}H_{19}NO_3Cl^+$ 404.1053; Found 404.1069.



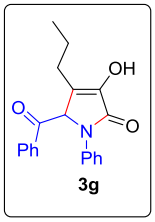
3e

Compound 3e was prepared following the general procedure of oxidative cross-dehydrogenative [2+3] annulation described above and purified by silica gel column chromatography (10→ 15% EtOAc : hexane) to provide pure compound as white solid (56 mg, 72%). **^{1}H NMR** (400 MHz, DMSO–d_6) δ 10.16 (s, 1H), 7.89 (d, *J* = 7.7 Hz, 2H), 7.68 (t, *J* = 7.3 Hz, 1H), 7.60 (d, *J* = 8.0 Hz, 2H), 7.47 (t, *J* = 7.6 Hz, 2H), 7.28 (t, *J* = 7.8 Hz, 2H), 7.12 (d, *J* = 5.8 Hz, 2H), 7.04 (t, *J* = 7.3 Hz, 1H), 6.83 (d, *J* = 5.9 Hz, 2H), 6.65 (s, 1H), 3.58 (d, *J* = 15.5 Hz, 1H), 3.32 (d, *J* = 15.6 Hz, 1H).**^{13}C NMR** (125 MHz, $CDCl_3$) δ 194.8, 166.9, 160.1 (d, *J* = 245.6 Hz), 144.0, 137.5, 135.7, 134.3, 133.5, 129.1, 128.9, 128.8, 128.3, 126.9, 122.3 (d, *J* = 8.2 Hz), 120.3, 116.2 (d, *J* = 22.7 Hz), 66.2, 30.4. **^{19}F NMR**(500 MHz, DMSO) δ –110.1. **HRMS** (ESI/TOF-Q) m/z: $[M+Na]^+$ Calcd for $C_{24}H_{18}NO_3FNa^+$ 410.1168; Found 410.1180.

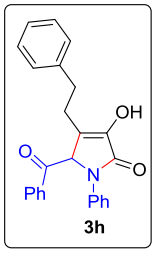


3f

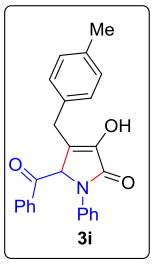
Compound 3f was prepared following the general procedure of oxidative cross-dehydrogenative [2+3] annulation described above and purified by silica gel column chromatography (10→ 15% EtOAc : hexane) to provide pure compound as white solid (60 mg, 77%). mp 166-168 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.68 (d, *J* = 7.6 Hz, 2H), 7.59 (t, *J* = 7.2 Hz, 1H), 7.48 (d, *J* = 11.2 Hz, 1H), 7.39 (t, *J* = 7.4 Hz, 2H), 7.31 – 7.14 (m, 4H), 7.08 (dd, *J* = 18.7, 7.3 Hz, 3H), 6.76 (t, *J* = 7.9 Hz, 1H), 6.42 (s, 1H), 5.77 (s, 1H), 3.95 (d, *J* = 15.4 Hz, 1H), 3.22 (d, *J* = 15.4 Hz, 1H).**^{13}C NMR** (125 MHz, DMSO) δ 195.2, 166.5, 162.2 (d, *J* = 242.1 Hz), 145.0, 139.7 (d, *J* = 10.8 Hz), 137.4, 135.6, 134.6, 130.7 (d, *J* = 9.5 Hz), 129.1, 128.5, 128.3, 128.2, 126.2, 120.4, 114.7, 110.7 (d, *J* = 21.0 Hz), 106.2 (d, *J* = 26.6 Hz), 63.4, 29.8. **^{19}F NMR** (500 MHz, DMSO–d_6) δ -111.5. **HRMS** (ESI/TOF-Q) m/z: $[M+H]^+$ Calcd for $C_{24}H_{19}NO_3F^+$ 388.1349; Found 388.1322.



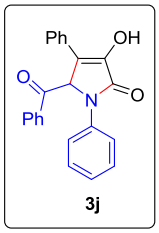
Compound 3g was prepared following the general procedure of oxidative cross-dehydrogenative [2+3] annulation described above and purified by silica gel column chromatography (10→ 15% EtOAc : hexane) to provide pure compound as yellow solid (36 mg, 56%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.72 (dd, *J* = 8.3, 1.2 Hz, 2H), 7.43 (dd, *J* = 8.6, 1.0 Hz, 3H), 7.34 (dd, *J* = 10.6, 4.9 Hz, 3H), 7.24 – 7.18 (m, 2H), 5.66 (s, 1H), 2.42 – 2.24 (m, 1H), 2.15 – 1.93 (m, 1H), 1.53 – 1.31 (m, 2H), 0.82 (t, *J* = 7.3 Hz, 3H). **^{13}C NMR** (125 MHz, $CDCl_3$) δ 195.6, 167.1, 143.2, 137.6, 134.1, 129.4, 129.2, 129.1, 128.1, 125.3, 121.5, 119.9, 67.8, 26.6, 21.4, 14.1. **HRMS** (ESI/TOF-Q) m/z: $[M+K]^+$ Calcd for $C_{20}H_{19}NO_3K^+$ 360.1002; Found 360.1028.



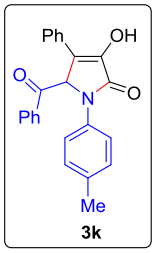
Compound 3h was prepared following the general procedure of oxidative cross-dehydrogenative [2+3] annulation described above and purified by silica gel column chromatography (10→ 15% EtOAc : hexane) to provide pure compound as yellow solid (54 mg, 70%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.71 (d, *J* = 7.9 Hz, 2H), 7.57 (t, *J* = 7.5 Hz, 1H), 7.46 (d, *J* = 8.0 Hz, 2H), 7.41 (t, *J* = 7.6 Hz, 2H), 7.29 – 7.24 (m, 5H), 7.20 (d, *J* = 6.9 Hz, 1H), 7.11 – 7.05 (m, 2H), 5.66 (s, 1H), 2.96 – 2.85 (m, 1H), 2.83 – 2.72 (m, 2H), 2.40 – 2.29 (m, 1H). **^{13}C NMR** (125 MHz, $CDCl_3$) δ 195.3, 167.0, 143.6, 140.8, 137.5, 135.8, 134.2, 129.5, 129.2, 128.6 (3×C), 128.3, 126.5, 125.4, 120.1, 67.3, 34.0, 26.6. **HRMS** (ESI/TOF-Q) m/z: $[M+Na]^+$ Calcd for $C_{25}H_{21}NO_3Na^+$ 406.1419; Found 406.1447.



Compound 3i was prepared following the general procedure oxidative cross-dehydrogenative [2+3] annulation described above and purified by silica gel column chromatography (10→ 15% EtOAc : hexane) to provide pure compound as white solid (48 mg, 63%). **^{1}H NMR** (400 MHz, DMSO–d_6) δ 10.10 (s, 1H), 7.83 – 7.73 (m, 2H), 7.67 – 7.57 (m, 3H), 7.40 (t, *J* = 7.6 Hz, 2H), 7.28 (t, *J* = 7.9 Hz, 2H), 7.08 – 6.90 (m, 4H), 6.80 (dd, *J* = 7.3, 1.7 Hz, 1H), 6.58 (s, 1H), 3.54 (d, *J* = 16.2 Hz, 1H), 3.27 (d, *J* = 16.2 Hz, 1H), 1.87 (s, 3H). **^{13}C NMR** (125 MHz, DMSO–d_6) δ 195.6, 166.2, 145.3, 138.0, 135.8, 135.7, 135.0, 134.2, 128.9, 128.8, 128.1, 126.3, 125.7, 124.2, 119.5, 119.1, 63.4, 27.3, 18.9. **HRMS** (ESI/TOF-Q) m/z: $[M+H]^+$ Calcd for $C_{25}H_{22}NO_3^+$ 384.1600; Found 384.1627.

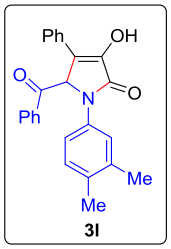


Compound 3j was prepared following the general procedure of oxidative cross-dehydrogenative [2+3] annulation described above and purified by silica gel column chromatography (10→ 15% EtOAc : hexane) to provide pure compound as white solid (55 mg, 77%). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.82 (d, *J* = 7.8 Hz, 2H), 7.57 (d, *J* = 7.8 Hz, 2H), 7.53 (d, *J* = 8.0 Hz, 2H), 7.42 (t, *J* = 7.5 Hz, 1H), 7.33 (dt, *J* = 16.6, 7.7 Hz, 4H), 7.26 (dd, *J* = 9.0, 6.1 Hz, 3H), 7.14 (t, *J* = 7.4 Hz, 1H), 6.11 (s, 1H).**^{13}C NMR** (125 MHz, $CDCl_3$) δ 196.6, 166.8, 143.5, 136.8, 135.7, 133.4, 130.4, 129.5, 128.9, 128.8, 128.6, 127.9, 127.6, 126.1, 121.4, 118.7, 68.3. **HRMS** (ESI/TOF-Q) m/z: $[M+H]^+$ Calcd for $C_{23}H_{18}NO_3^+$ 356.1287; Found 356.1295.



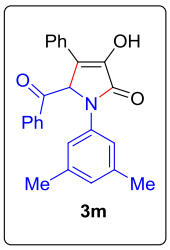
Compound 3k was prepared following the general procedure of oxidative cross-dehydrogenative [2+3] annulation described above and purified by silica gel column chromatography (10→ 15% EtOAc : hexane) to provide pure compound as white solid (58 mg, 78%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.80 (d, *J* = 7.6 Hz, 2H), 7.58 (d, *J* = 7.8 Hz, 2H), 7.43 (t, *J* = 7.4 Hz, 1H), 7.39 – 7.33 (m 4H), 7.29 – 7.24 (m, 3H), 7.11 (d, *J* = 7.5 Hz, 2H), 6.07 (s, 1H), 2.28 (s, 3H). **^{13}C NMR** (100 MHz, DMSO) δ 196.8, 166.0, 144.8,

135.6, 134.8, 134.5, 134.0, 130.9, 129.4, 128.9, 128.3, 128.2, 127.6, 127.1, 121.3, 118.6, 63.1, 20.4. **HRMS** (ESI/TOF-Q) m/z: $[M+Na]^+$ Calcd for $C_{24}H_{19}NO_3Na^+$ 392.1263; Found 392.1271.



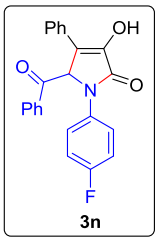
3l

Compound 3l was prepared following the general procedure of oxidative cross-dehydrogenative [2+3] annulation described above and purified by silica gel column chromatography (10→ 15% EtOAc : hexane) to provide pure compound as white solid (53 mg, 68%). mp 177- 179 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.83 – 7.75 (m, 2H), 7.59 (dd, *J* = 8.4, 1.2 Hz, 2H), 7.49 – 7.40 (m, 1H), 7.35 (t, *J* = 7.6 Hz, 2H), 7.31 – 7.23 (m, 3H), 7.18 (dd, *J* = 8.2, 2.3 Hz, 1H), 7.06 (d, *J* = 8.2 Hz, 1H), 7.00 (s, 1H), 6.07 (s, 1H), 2.20 (s, 3H), 2.19 (s, 3H). **^{13}C NMR** (125 MHz, DMSO) δ 196.8, 166.0, 144.8, 136.8, 135.7, 135.0, 134.1, 133.3, 130.9, 129.9, 129.0, 128.4, 128.3, 127.6, 127.1, 122.5, 118.8, 118.6, 62.8, 19.6, 18.8. **HRMS** (ESI/TOF-Q) m/z: $[M+Na]^+$ Calcd for $C_{25}H_{21}NO_3Na^+$ 406.1419; Found 406.1407.



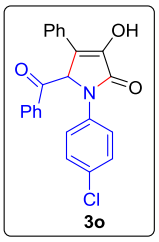
3m

Compound 3m was prepared following the general procedure of oxidative cross-dehydrogenative [2+3] annulation described above and purified by silica gel column chromatography (10→ 15% EtOAc : hexane) to provide pure compound as white solid (51 mg, 66%). mp 169- 171 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.84 – 7.76 (m, 2H), 7.62 – 7.53 (m, 2H), 7.47 – 7.40 (m, 1H), 7.35 (dd, *J* = 10.5, 4.7 Hz, 2H), 7.31 – 7.24 (m, 3H), 7.11 (s, 2H), 6.78 (s, 1H), 6.07 (s, 1H), 2.25 (s, 6H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 196.7, 166.7, 143.4, 139.2, 136.6, 135.9, 133.4, 130.5, 128.9, 128.8, 128.6, 128.0 (2×C), 127.6, 119.5, 118.4, 68.4, 21.5. **HRMS** (ESI/TOF-Q) m/z: $[M+H]^+$ Calcd for $C_{25}H_{22}NO_3^+$ 384.1600; Found 384.1592.



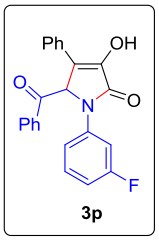
3n

Compound 3n was prepared following the general procedure of oxidative cross-dehydrogenative [2+3] annulation described above and purified by silica gel column chromatography (10→ 15% EtOAc : hexane) to provide pure compound as white solid (61 mg, 82%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.80 (d, *J* = 5.6 Hz, 2H), 7.58 (d, *J* = 7.0 Hz, 2H), 7.46 (s, 3H), 7.40 – 7.22 (m, 5H), 7.01 (s, 2H), 6.06 (s, 1H). **^{13}C NMR** (100 MHz, DMSO) δ 196.7, 166.1, 159.3 (d, *J* = 242.8 Hz), 144.6, 135.6, 134.1, 133.6, 130.8, 129.0, 128.3, 128.2, 127.7, 127.1, 123.6 (d, *J* = 8.3 Hz), 118.9, 115.8 (d, *J* = 22.6 Hz), 63.2. **^{19}F NMR** (500 MHz, $CDCl_3$) δ -115.2. **HRMS** (ESI/TOF-Q) m/z: $[M+H]^+$ Calcd for $C_{23}H_{17}NO_3F^+$ 396.1012; Found 396.1005.

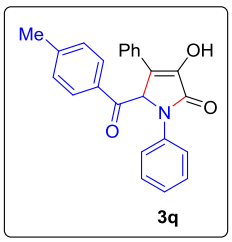


3o

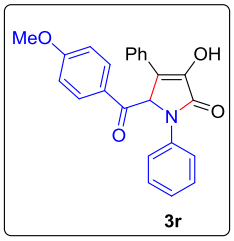
Compound 3o was prepared following the general procedure of oxidative cross-dehydrogenative [2+3] annulation described above and purified by silica gel column chromatography (10→ 15% EtOAc : hexane) to provide pure compound as white solid (54 mg, 70%). mp 155- 157 °C. **^{1}H NMR** (500 MHz, DMSO–d_6) δ 10.93 (s, 1H), 7.95 – 7.91 (m, 3H), 7.71–7.67 (m, 4H), 7.62 (t, *J* = 7.3 Hz, 1H), 7.50–7.42 (m, 4H), 7.28 (t, *J* = 7.6 Hz, 2H), 7.20 (s, 1H). **^{13}C NMR** (125 MHz, DMSO–d_6) δ 196.7, 166.2, 144.5, 136.3, 135.6, 134.2, 130.6, 129.1, 129.0, 128.4, 128.3, 127.9, 127.3, 122.5, 119.2, 114.2, 62.9. **HRMS** (ESI/TOF-Q) m/z: $[M+H]^+$ Calcd for $C_{23}H_{17}NO_3Cl^+$ 390.0897; Found 390.0899.



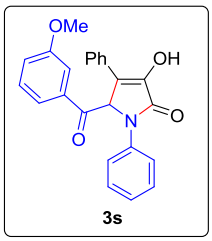
Compound 3p was prepared following the general procedure of oxidative cross-dehydrogenative [2+3] annulation described above and purified by silica gel column chromatography (10→ 15% EtOAc : hexane) to provide pure compound as white solid (54 mg, 73%). mp 168- 170 °C. **^{1}H NMR** (500 MHz, DMSO–d_6) δ 10.95 (s, 1H), 7.97 (d, J = 7.8 Hz, 2H), 7.72 – 7.65 (m, 3H), 7.61 (t, J = 7.5 Hz, 1H), 7.47 (t, J = 7.4 Hz, 3H), 7.39 (q, J = 7.8 Hz, 1H), 7.27 (t, J = 7.6 Hz, 2H), 7.23 (s, 1H), 7.18 (t, J = 7.4 Hz, 1H), 6.96 (td, J = 8.5, 2.3 Hz, 1H). **^{13}C NMR** (125 MHz, DMSO) δ 196.6, 166.4, 162.2 (d, J = 243.0 Hz), 144.5, 139.1 (d, J = 10.7 Hz), 135.5, 134.3, 130.9 (d, J = 9.4 Hz), 130.5, 129.0, 128.4, 128.3, 128.0, 127.4, 119.4, 116.1, 111.7 (d, J = 21.0 Hz), 107.5 (d, J = 25.9 Hz), 62.9. **^{19}F NMR** (500 MHz, DMSO–d_6) δ -111.2. **HRMS** (ESI/TOF-Q) m/z: $[M+Na]^+$ Calcd for $C_{23}H_{16}NO_3FNa^+$ 396.1012; Found 396.1036.



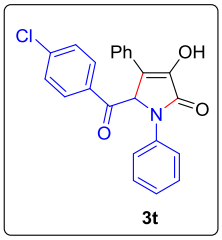
Compound 3q was prepared following the general procedure of oxidative cross-dehydrogenative [2+3] annulation described above and purified by silica gel column chromatography (10→ 15% EtOAc : hexane) to provide pure compound as white solid (58 mg, 78%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.80 (d, J = 7.7 Hz, 2H), 7.59 – 7.50 (m, 4H), 7.38 – 7.30 (m, 4H), 7.27 (d, J = 6.7 Hz, 2H), 7.14 (t, J = 7.5 Hz, 1H), 7.07 (s, 1H), 6.12 (s, 1H), 2.30 (s, 3H). **^{1}H NMR** (400 MHz, DMSO–d_6) δ 10.81 (s, 1H), 7.92 (d, J = 7.9 Hz, 2H), 7.70 – 7.62 (m, 4H), 7.34 (t, J = 7.8 Hz, 2H), 7.29–7.25 (m, 4H), 7.20 – 7.14 (m, 2H), 7.11 (t, J = 7.4 Hz, 1H), 2.32 (s, 3H). **^{13}C NMR** (100 MHz, DMSO) δ 195.9, 166.2, 145.0, 144.7, 137.3, 133.0, 130.9, 129.6, 129.1, 128.6, 128.4, 127.7, 127.1, 125.1, 121.1, 119.1, 62.3, 21.2. **HRMS** (ESI/TOF-Q) m/z: $[M+H]^+$ Calcd for $C_{24}H_{20}NO_3^+$ 370.1443; Found 370.1432.



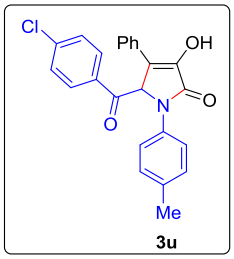
Compound 3r was prepared following the general procedure of oxidative cross-dehydrogenative [2+3] annulation described above and purified by silica gel column chromatography (10→ 15% EtOAc : hexane) to provide pure compound as white solid (56 mg, 73%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.80 (d, J = 7.7 Hz, 2H), 7.71 (d, J = 8.5 Hz, 2H), 7.55 (d, J = 7.9 Hz, 2H), 7.37 – 7.27 (m, 5H), 7.14 (t, J = 7.6 Hz, 1H), 6.77 (d, J = 8.5 Hz, 2H), 6.12 (s, 1H), 3.78 (s, 3H). **^{13}C NMR** (125 MHz, $CDCl_3$) δ 193.9, 166.6, 164.0, 142.9, 137.0, 130.7, 130.5, 129.5, 128.9, 128.6, 128.3, 127.7, 126.0, 121.5, 119.2, 114.2, 68.1, 55.6. **HRMS** (ESI/TOF-Q) m/z: $[M+H]^+$ Calcd for $C_{24}H_{22}NO_4^+$ 388.1549; Found 388.1561.



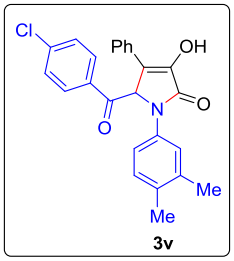
Compound 3s was prepared following the general procedure of oxidative cross-dehydrogenative [2+3] annulation described above and purified by silica gel column chromatography (10→ 15% EtOAc : hexane) to provide pure compound as white solid (55 mg, 71%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.87 – 7.78 (m, 2H), 7.53 (d, J = 8.0 Hz, 2H), 7.40 – 7.32 (m, 4H), 7.28 (d, J = 7.3 Hz, 1H), 7.22 – 7.15 (m, 3H), 7.09 – 7.04 (m, 1H), 7.07– 6.97 (m, 1H), 6.13 (s, 1H), 3.68 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 196.3, 166.9, 159.6, 143.6, 136.7, 130.4, 129.9, 129.6, 129.5, 128.9, 128.7, 127.6, 126.1, 121.5, 120.4, 120.2, 118.9, 112.1, 68.2, 55.4. **HRMS** (ESI/TOF-Q) m/z: $[M+H]^+$ Calcd for $C_{24}H_{22}NO_4^+$ 388.1549; Found 388.1546.



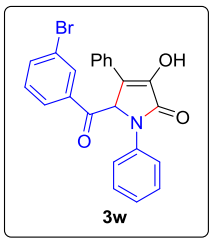
Compound 3t was prepared following the general procedure of oxidative cross-dehydrogenative [2+3] annulation described above and purified by silica gel column chromatography (10→ 15% EtOAc : hexane) to provide pure compound as white solid (48 mg, 62%). mp 177- 179 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.84 – 7.78 (m, 2H), 7.53 – 7.50 (m, 5H), 7.40 – 7.29 (m, 5H), 7.24 (s, 1H), 7.17 (t, *J* = 7.4 Hz, 1H), 6.08 (s, 1H). **^{13}C NMR** (125 MHz, $CDCl_3$) δ 196.0, 166.1, 144.8, 139.2, 137.3, 134.2, 130.7, 130.1, 129.2, 128.4, 127.8, 127.3, 125.3, 121.1, 121.0, 118.8, 63.0. **HRMS** (ESI/TOF-Q) m/z: $[M+Na]^+$ Calcd for $C_{23}H_{17}NO_3Cl^+$ 390.0897; Found 380.0882.



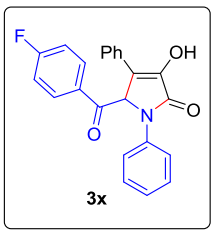
Compound 3u was prepared following the general procedure of oxidative cross-dehydrogenative [2+3] annulation described above and purified by silica gel column chromatography (10→ 15% EtOAc : hexane) to provide pure compound as white solid (47 mg, 58%). mp 155- 157 °C. **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.79 (d, *J* = 7.5 Hz, 2H), 7.52 (d, *J* = 8.6 Hz, 2H), 7.40 – 7.34 (m, 4H), 7.29 (d, *J* = 7.4 Hz, 2H), 7.24 (s, 1H), 7.13 (d, *J* = 8.0 Hz, 2H), 6.04 (s, 1H), 2.29 (s, 3H). **^{13}C NMR** (125 MHz, $CDCl_3$) δ 195.4, 166.3, 143.4, 140.0, 136.2, 134.0, 133.8, 131.8, 130.2, 129.4, 129.2, 129.0, 128.8, 127.5, 121.5, 118.4, 68.6, 21.1. **HRMS** (ESI/TOF-Q) m/z: $[M+H]^+$ Calcd for $C_{24}H_{19}NO_3Cl^+$ 404.1053; Found 404.1040.



Compound 3v was prepared following the general procedure of oxidative cross-dehydrogenative [2+3] annulation described above and purified by silica gel column chromatography (10→ 15% EtOAc : hexane) to provide pure compound as white solid (48 mg, 58%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.05 (d, *J* = 8.2 Hz, 2H), 7.79 (d, *J* = 7.7 Hz, 2H), 7.54 (d, *J* = 8.3 Hz, 2H), 7.46 (d, *J* = 8.1 Hz, 2H), 7.37 (t, *J* = 7.6 Hz, 2H), 7.29 (d, *J* = 7.4 Hz, 1H), 7.08 (d, *J* = 8.2 Hz, 1H), 6.05 (s, 1H), 2.22 (s, 3H), 2.20 (s, 3H). **^{13}C NMR** (125 MHz, DMSO) δ 196.0, 166.5, 144.8, 139.2, 137.8, 136.9, 134.9, 134.3, 133.4, 131.2, 129.7, 129.9, 128.8, 128.7, 128.4, 127.1, 118.8, 118.4, 62.9, 19.6, 18.8. **HRMS** (ESI/TOF-Q) m/z: $[M+H]^+$ Calcd for $C_{25}H_{21}Cl^+$ 418.1210; Found 418.1205.



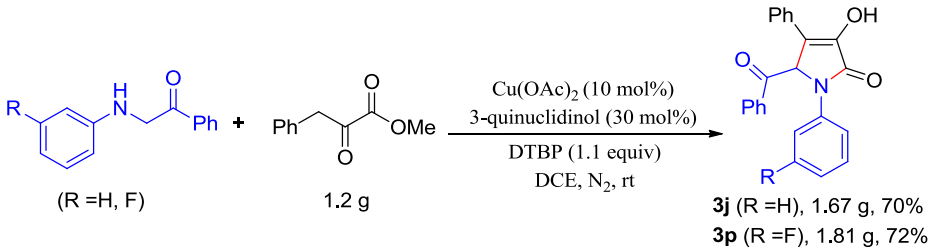
Compound 3w was prepared following the general procedure of oxidative cross-dehydrogenative [2+3] annulation described above and purified by silica gel column chromatography (10→ 15% EtOAc : hexane) to provide pure compound as white solid (56 mg, 65%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.81 (d, *J* = 7.4 Hz, 2H), 7.63 (s, 1H), 7.57 – 7.54 (m, 1H), 7.54 – 7.34 (m, 3H), 7.41 – 7.33 (m, 4H), 7.31 (d, *J* = 7.5 Hz, 1H), 7.18 (dd, *J* = 10.4, 7.7 Hz, 2H), 6.09 (s, 1H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 195.3, 166.4, 143.3, 136.9, 136.5, 136.2, 131.1, 130.2, 130.0, 129.5, 128.9, 128.8, 127.4, 126.2, 125.8, 122.9, 121.1, 118.2, 68.2. **HRMS** (ESI/TOF-Q) m/z: $[M+H]^+$ Calcd for $C_{23}H_{17}NO_3Br^+$ 434.0392; Found 434.0384.



Compound 3x was prepared following the general procedure of oxidative cross-dehydrogenative [2+3] annulation described above and purified by silica gel column chromatography (10→ 15% EtOAc : hexane) to provide pure compound as white solid (53 mg, 70%). mp 151- 153 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.85 – 7.77 (m, 2H), 7.64 (dd, *J* = 8.9, 5.4 Hz, 2H), 7.52 (d, *J* = 7.9 Hz, 2H), 7.41 – 7.28 (m, 5H), 7.16 (t, *J* = 7.4 Hz, 1H), 6.95 (t, *J* = 8.6 Hz, 2H), 6.09 (s, 1H).**^{13}C NMR** (100 MHz,

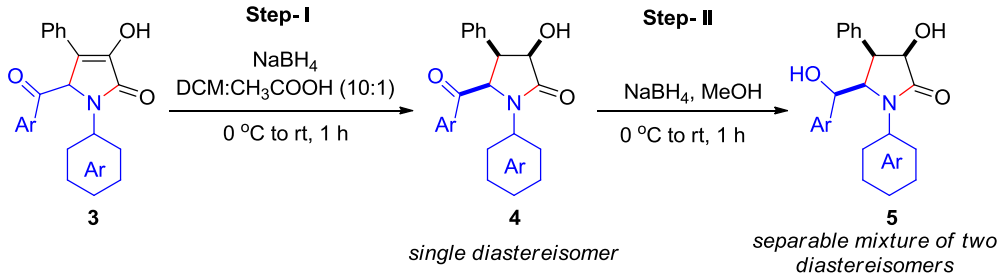
DMSO) δ 194.8, 166.5, 165.9 (d, *J* = 256.4 Hz), 143.2, 136.7, 131.8 (d, *J* = 3.6 Hz), 130.7 (d, *J* = 9.4 Hz), 130.2, 129.6, 129.0, 128.8, 127.6, 126.2, 121.3, 118.7, 116.1 (d, *J* = 21.9 Hz), 68.4. **^{19}F NMR** (500 MHz, $CDCl_3$) δ -103.5. **HRMS** (ESI/TOF-Q) m/z: $[M+H]^+$ Calcd for $C_{23}H_{20}NO_3F^+$ 374.1192; Found 374.1187.

Gram scale synthesis of compounds 3j and 3p:



The methyl 3-phenylpyruvate (1.2 g, 1 equiv.), α-amino ketones **1** (R = H or F) (1.2 equiv.), and copper(II) acetate (113 mg, 10 mol%) and 3-quinuclidinol (226 mg, 30 mol%) were taken in a 100 mL round bottom flask equipped with a magnetic stir. The round bottom flask was capped with a septum and purged with nitrogen gas. Then, di-tert-butyl peroxide (DTBP, 1.26 mL, 1.1 equiv.) and dry DCE (15 mL) were successively added via syringe. The mixture was allowed to stir at room temperature for 20 h. After completion (TLC monitored), volatiles were carefully evaporated and the crude reaction mixture was loaded directly onto silica gel column and purified with a gradient eluent of hexane and ethyl acetate to get pure **3j** or **3p**.

General procedure for synthesis of clausenamide analogues:



Step-I

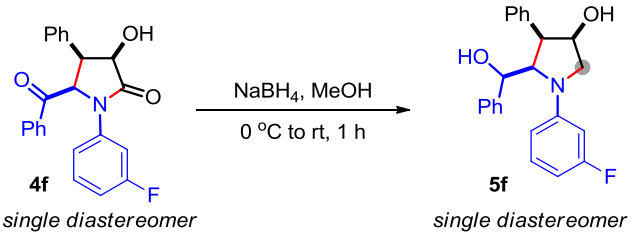
To a solution of pyrrolone **3** (0.30 mmol) in DCM: CH_3COOH (10:1, v/v, 6 mL), sodium borohydride (0.6 mmol) was added portion wise with stirring at 0 °C. After the addition, the reaction mixture was allowed to stir at room temperature for 1 h. Then, a saturated aqueous solution of $NaHCO_3$ (6 mL) was added and extracted with DCM (3x10 mL). The combined organic layer was washed with brine, dried over anhydrous $MgSO_4$ and concentrated in vacuo. The resulting residue was purified by silica gel column chromatography (hexane/ethyl acetate) to get pure pyrrolidinone **4** as a single diastereomer.

Step-II

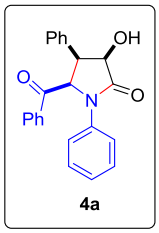
Sodium borohydride (0.4 mmol) was added portion wise to the solution of **4** (0.2 mmol) in methanol (5 mL) at 0 °C. After addition, the reaction mixture was allowed to stir for 1 h at room temperature. Methanol was evaporated and residue was diluted with ethyl acetate (5 mL). A saturated aqueous solution of $NaHCO_3$ (5 mL) was added into it and extracted with ethyl acetate (3x10 mL). The combined organic layer was washed with brine, dried over anhydrous $MgSO_4$ and concentrated in vacuo. The resulting

residue was purified by silica gel column chromatography (hexane/ethyl acetate) to get clausenamide analogues **5** (as a separated two diastereomers).

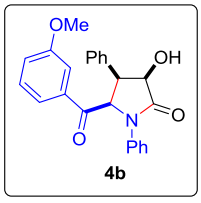
Under the same conditions (**step-II**), reduction of amide functionality was also occurred specifically for the compound **4f** and in this case, pyrrolidine **5f** was isolated as a single diastereomer.



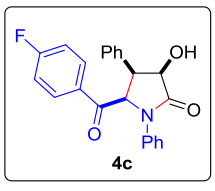
*It is worth noting that peak for the hydroxyl proton (OH) of compounds **4a**, **4c**, **4e**, and **4f** was not observed in ^{1}H NMR spectra. However, HRMS data are in agreement with the presence of hydroxyl group for these compounds. Interestingly, the peak for the hydroxyl proton of the reduced products **5a-f** was visible in the ^{1}H NMR spectra, which is in line with our preceding discussion.*



Compound 4a was prepared following the general procedure for synthesis of clausenamide analogues described above and purified by silica gel column chromatography (25→ 30% EtOAc : hexane) to provide pure compound as white solid (101 mg, 93%). **^{1}H NMR** (500 MHz, DMSO–d_6) δ 7.78 (d, *J* = 7.4 Hz, 2H), 7.62 (t, *J* = 7.3 Hz, 1H), 7.49 – 7.42 (m, 3H), 7.34 (d, *J* = 7.5 Hz, 2H), 7.23 – 7.11 (m, 2H), 7.03 (d, *J* = 8.4 Hz, 2H), 6.85 (d, *J* = 7.5 Hz, 2H), 6.58 (d, *J* = 6.8 Hz, 1H), 5.94 – 5.85 (m, 1H), 4.85 (dd, *J* = 8.1, 5.3 Hz, 1H), 4.33 (t, *J* = 7.6 Hz, 1H). **^{13}C NMR** (100 MHz, DMSO–d_6) δ 193.2, 173.9, 139.0, 135.4, 134.3, 133.6, 130.0, 128.7, 128.3, 127.9, 127.2,126.8, 124.5, 121.8, 70.9, 63.5, 47.5. **HRMS** (ESI/TOF-Q) m/z: $[M+K]^+$ Calcd for $C_{23}H_{19}NO_3K^+$ 396.1002; Found 396.0994.

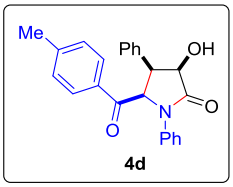


Compound 4b was prepared following the general procedure for synthesis of clausenamide analogues described above and purified by silica gel column chromatography (25→ 30% EtOAc : hexane) to provide pure compound as white solid (103 mg, 89%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.34 (d, *J* = 8.0 Hz, 2H), 7.27 – 7.21 (m, 4H), 7.13 – 7.01 (m, 5H), 6.96 – 6.89 (m, 3H), 6.05 (d, *J* = 7.0 Hz, 1H), 4.80 – 4.71 (m, 1H), 4.14 (t, *J* = 7.5 Hz, 1H), 3.68 (d, *J* = 12.1 Hz, 1H), 3.61 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 193.9, 174.3, 159.9, 138.1, 137.1, 132.4, 130.0, 129.9, 129.0, 128.3, 128.0, 126.0, 122.4, 120.6, 120.4, 112.3, 72.1, 64.8, 55.5, 48.0. **HRMS** (ESI/TOF-Q) m/z: $[M+H]^+$ Calcd for $C_{24}H_{22}NO_4^+$ 388.1549; Found 388.1546.



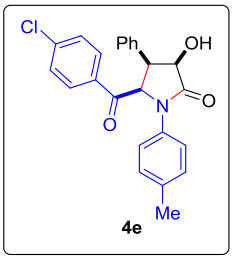
Compound 4c was prepared following the general procedure for synthesis of clausenamide analogues above and purified by silica gel column chromatography (25→ 30% EtOAc : hexane) to provide pure compound as white solid (104 mg, 92%). **^{1}H NMR** (400 MHz, DMSO–d_6) δ 7.87 (dd, *J* = 8.7, 5.6 Hz, 2H), 7.47 – 7.41 (m, 2H), 7.36 – 7.26 (m, 4H), 7.17 – 7.11 (m, 1H), 7.05 (d, *J* = 7.1 Hz, 2H), 6.89 – 6.84 (m, 2H), 6.58 (d, *J* = 7.0 Hz, 1H), 5.95 (d, *J* = 5.5 Hz, 1H), 4.85 (dd, *J* = 8.2, 5.5 Hz, 1H), 4.33 (t, *J* = 7.7 Hz, 1H). **^{13}C NMR** (100 MHz, DMSO–d_6) δ 191.9, 173.9, 165.2 (d, *J* = 252.9 Hz), 139.0, 134.3,

132.2 (d, *J* = 3.0 Hz), 131.0 (d, *J* = 9.5 Hz), 130.0, 128.3, 127.3, 126.9, 124.6, 121.8, 115.9 (d, *J* = 21.8 Hz), 70.8, 63.5, 47.4. **HRMS** (ESI/TOF-Q) m/z: $[M+Na]^+$ Calcd for $C_{23}H_{18}NO_3FNa^+$ 398.1168; Found 398.1162.



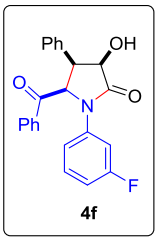
4d

Compound 4d was prepared following the general procedure for synthesis of clausenamide analogues described above and purified by silica gel column chromatography (25→ 30% EtOAc : hexane) to provide pure compound as white solid (100 mg, 90%). **^{1}H NMR** (400 MHz, $CDCl_3$+DMSO–d_6) δ 7.64 – 7.52 (m, 2H), 7.37 (d, *J* = 7.5 Hz, 2H), 7.23 (t, *J* = 7.6 Hz, 2H), 7.14 (d, *J* = 7.7 Hz, 2H), 7.05 (s, 1H), 6.97 (d, *J* = 8.5 Hz, 3H), 6.85 (d, *J* = 7.4 Hz, 2H), 6.29 (d, *J* = 6.7 Hz, 1H), 5.60 (d, *J* = 5.6 Hz, 1H), 4.84 (t, *J* = 6.8 Hz, 1H), 4.21 (t, *J* = 7.3 Hz, 1H), 2.33 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$+DMSO–d_6) δ 191.4, 173.0, 143.2, 137.7, 132.6, 132.1, 129.0, 128.2, 127.2, 126.8, 126.3, 126.0, 123.7, 120.8, 70.2, 62.5, 47.0, 20.4. **HRMS** (ESI/TOF-Q) m/z: $[M+Na]^+$ Calcd for $C_{24}H_{22}NO_3^+$ 372.1600; Found 372.1601.



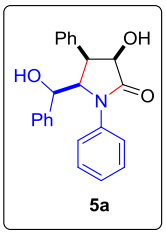
4e

Compound 4e was prepared following the general procedure for synthesis of clausenamide analogues described above and purified by silica gel column chromatography (25→ 30% EtOAc : hexane) to provide pure compound as white solid (102 mg, 84%). mp 210- 212 ^{0}C. **^{1}H NMR** (400 MHz, DMSO–d_6) δ 7.77 (d, *J* = 8.6 Hz, 2H), 7.51 (s, 1H), 7.30 (d, *J* = 8.1 Hz, 2H), 7.12 (d, *J* = 8.2 Hz, 2H), 7.04 (d, *J* = 6.6 Hz, 3H), 6.88 – 6.84 (m, 2H), 6.52 (d, *J* = 7.0 Hz, 1H), 5.91 (d, *J* = 5.5 Hz, 1H), 4.81 (dd, *J* = 8.2, 5.5 Hz, 1H), 4.31 (t, *J* = 7.7 Hz, 1H), 2.25 (s, 3H). **^{13}C NMR** (100 MHz, DMSO–d_6) δ 192.5, 173.8, 138.6, 136.4, 134.3, 134.0, 133.8, 130.0, 129.8, 128.9, 128.8, 127.3, 127.0, 121.9, 70.8, 63.7, 47.4, 20.5. **HRMS** (ESI/TOF-Q) m/z: $[M+Na]^+$ Calcd for $C_{25}H_{20}NO_3ClNa^+$ 4258.1029; Found 425.1031.



4f

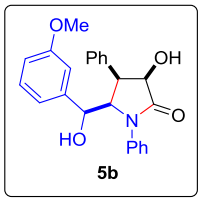
Compound 4f was prepared following the general procedure for synthesis of clausenamide analogues described above and purified by silica gel column chromatography (25→ 30% EtOAc : hexane) to provide pure compound as white solid (106 mg, 94%). mp 153- 155 ^{0}C. **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.83 – 7.72 (m, 2H), 7.67 – 7.60 (m, 1H), 7.47 (t, *J* = 7.8 Hz, 2H), 7.46– 7.40 (m, 1H), 7.36 (s, 1H), 7.16 (dd, *J* = 8.2, 2.1 Hz, 1H), 7.06 – 6.97 (m, 3H), 6.86 – 6.78 (m, 2H), 6.58 (d, *J* = 7.0 Hz, 1H), 5.97 (d, *J* = 5.6 Hz, 1H), 4.87 (dd, *J* = 8.3, 5.5 Hz, 1H), 4.42 – 4.30 (m, 1H). **^{13}C NMR** (125 MHz, DMSO) δ 193.1, 174.1, 161.8 (d, *J* = 242.1 Hz), 140.7 (d, *J* = 10.4 Hz), 135.3, 134.2, 133.8, 130.0, 129.9, 128.8, 128.0, 127.3, 126.9, 117.4, 111.2 (d, *J* = 20.9 Hz), 109.0 (d, *J* = 25.0 Hz), 70.8, 63.7, 47.3. **HRMS** (ESI/TOF-Q) m/z: $[M+Na]^+$ Calcd for $C_{23}H_{18}NO_3FNa^+$ 398.1168; Found 398.1173.



5a

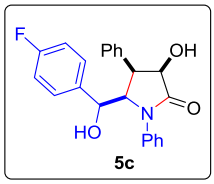
Compound 5a was prepared following the general procedure for synthesis of clausenamide analogues described above and purified by silica gel column chromatography (20→ 25% EtOAc : hexane) to provide pure compound as white solid (63 mg, 88%; dr = 1:1). For major isomer: **^{1}H NMR** (500 MHz, DMSO–d_6) δ 7.37 – 7.35 (m, 2H), 7.21– 7.20 (m, 2H), 7.13 – 7.09 (m, 5H), 6.94 – 6.87 (m, 4H), 6.83 – 6.80 (m, 2H), 5.90 (d, *J* = 7.5 Hz, 1H), 5.77 (d, *J* = 4.4 Hz, 1H), 4.97 (t, *J* = 6.0 Hz, 1H), 4.51 – 4.45 (m, 2H), 3.88 (t, *J* = 6.5 Hz, 1H). **^{13}C NMR** (125 MHz, DMSO–d_6) δ 174.1, 142.0, 137.5, 136.1, 130.2, 128.3, 127.2, 127.1, 126.2, 126.1 (2×C), 125.7, 125.5, 71.6, 70.2, 65.7, 46.5.

HRMS (ESI/TOF-Q) m/z: $[M+H]^+$ Calcd for $C_{23}H_{22}NO_3^+$ 360.1600; Found 360.1577; For other isomer: **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.64 (d, *J* = 8.0 Hz, 2H), 7.45 (t, *J* = 7.8 Hz, 2H), 7.32 (qt, *J* = 6.6, 3.7 Hz, 8H), 7.24 (d, *J* = 7.4 Hz, 1H), 7.21 – 7.15 (m, 2H), 5.10 – 5.02 (m, 1H), 4.79 (d, *J* = 4.1 Hz, 1H), 3.85 (d, *J* = 8.7 Hz, 1H), 3.63 (dd, *J* = 8.8, 4.3 Hz, 1H), 2.27 – 2.19 (m, 1H), 2.05 (d, *J* = 6.4 Hz, 1H). **^{13}C NMR** (125 MHz, $CDCl_3$) δ 174.0, 139.3, 138.6, 137.5, 129.6, 129.2, 128.9, 128.8, 128.1, 127.8, 126.1, 126.0, 122.0, 72.4, 71.1, 68.7, 44.0. **HRMS** (ESI/TOF-Q) m/z: $[M+H]^+$ Calcd for $C_{23}H_{22}NO_3^+$ 360.1600; Found 360.1590.



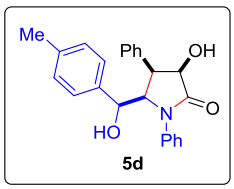
5b

Compound 5b was prepared following the general procedure for synthesis of synthesis of clausenamide analogues described above and purified by silica gel column chromatography (20→ 25% EtOAc : hexane) to provide pure compound as white solid (70 mg, 90%, dr = 1:5). For major isomer: mp 122 - 124 ^{0}C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.36 – 7.24 (m, 6H), 7.25 – 7.08 (m, 5H), 6.94 (t, *J* = 7.9 Hz, 1H), 6.55 (dd, *J* = 8.1, 2.7 Hz, 1H), 6.45 (d, *J* = 7.5 Hz, 1H), 6.26 (s, 1H), 4.85 (dd, *J* = 6.6, 4.6 Hz, 1H), 4.73 (d, *J* = 4.6 Hz,1H), 4.64 (d, *J* = 6.6 Hz, 1H), 3.93 (t, *J* = 6.6 Hz, 1H), 3.78 (s, 1H), 3.58 (s, 3H). **^{13}C NMR** (125 MHz, $CDCl_3$) δ 174.7, 159.4, 141.9, 136.5, 134.3, 130.0, 129.3, 129.0, 128.2, 127.4, 127.2, 125.8, 118.0, 113.0, 111.4, 72.3, 71.0, 67.7, 55.1, 46.6. **HRMS** (ESI/TOF-Q) m/z: $[M+Na]^+$ Calcd for $C_{24}H_{23}NO_4Na^+$ 412.1525; Found 412.1520.



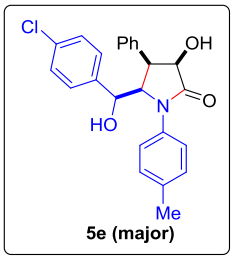
5c

Compound 5c was prepared following the general procedure for synthesis of synthesis of clausenamide analogues described above and purified by silica gel column chromatography (20→ 25% EtOAc : hexane) to provide pure compound as white solid (69 mg, 92%, dr = 1:5).For major isomer: **^{1}H NMR** (400 MHz,$CDCl_3$) δ 7.41 – 7.18 (m, 10H), 6.76 (t, *J* = 6.9 Hz, 2H), 6.65 (t, *J* = 8.5 Hz, 2H), 4.79 (t, *J* = 5.9 Hz, 1H), 4.71 (t, *J* = 6.9 Hz, 2H), 4.26 (d, *J* = 6.9 Hz, 1H), 3.99 (t, *J* = 6.6 Hz, 1H), 2.96 (s, 1H). **^{13}C NMR** (125 MHz, $CDCl_3$) δ 174.6, 162.0 (d, *J* = 246.3 Hz), 136.6, 136.1 (d, *J* = 3.2 Hz), 134.3, 130.1, 129.3, 128.6, 127.9, 127.8 (d, *J* = 8.2 Hz), 127.3, 126.0, 115.0 (d, *J* = 21.6 Hz), 72.4, 71.3, 67.2, 47.0. **^{19}F NMR** (500 MHz, $CDCl_3$) δ -115.2. **HRMS** (ESI/TOF-Q) m/z: $[M+H]^+$ Calcd for $C_{23}H_{21}NO_3F^+$ 378.1505; Found 378.1505.



5d

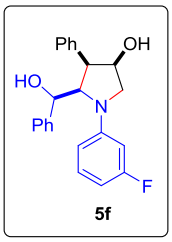
Compound 5d was prepared following the general procedure for synthesis of synthesis of clausenamide analogues described above and purified by silica gel column chromatography (20→ 25% EtOAc : hexane) to provide pure compound as white solid (71 mg, 95%, dr = 1:4). For major isomer: **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.36 – 7.32 (m, 2H), 7.26 – 7.17 (m, 8H), 6.81 (d, *J* = 7.7 Hz, 2H), 6.70 (d, *J* = 7.7 Hz, 2H), 4.79 (t, *J* = 5.9 Hz, 1H), 4.70 (q, *J* = 8.0, 6.4 Hz, 2H), 3.98 (t, *J* = 6.6 Hz, 1H), 3.70 (s, 1H), 2.22 (s, 4H). **^{13}C NMR** (125 MHz, $CDCl_3$) δ 174.8, 137.2, 137.0, 136.6, 134.3, 130.2, 129.1, 128.8, 128.5, 127.7, 127.1, 126.1, 125.9, 72.4, 71.5, 66.7, 47.1, 21.1. **HRMS** (ESI/TOF-Q) m/z: $[M+H]^+$ Calcd for $C_{24}H_{24}NO_3^+$ 374.1756; Found 374.1756.



5e (major)

Compound 5e was prepared following the general procedure for synthesis of synthesis of clausenamide analogues described above and purified by silica gel column chromatography (20→ 25% EtOAc : hexane) to provide pure compound as white solid (73 mg, 89%, dr = 1:5). For major isomer: mp 218-220 ^{0}C. **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.29 – 7.25 (m, 2H), 7.20 – 7.15 (m, 4H), 7.02 (d, *J* = 2.2 Hz,

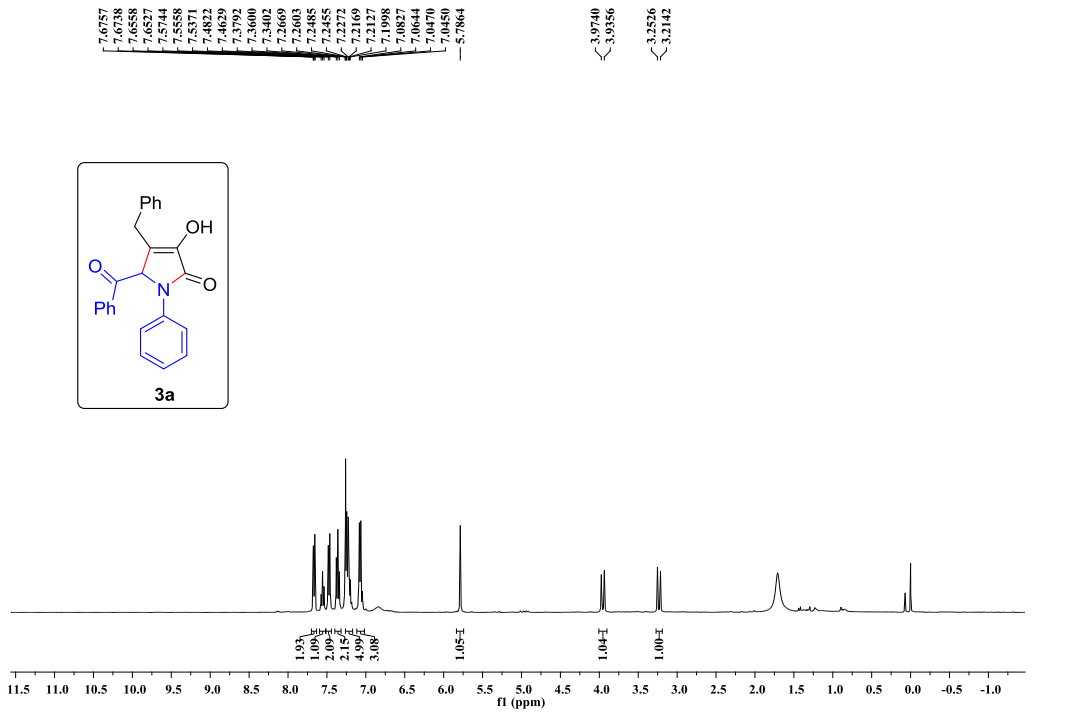
3H), 6.88 (d, *J* = 8.2 Hz, 2H), 6.67 (d, *J* = 8.2 Hz, 2H), 4.64 (dt, *J* = 11.0, 6.1 Hz, 3H), 3.91 (t, *J* = 6.5 Hz, 1H), 3.80 (s, 1H), 2.60 (s, 1H), 2.26 (s, 3H). **^{13}C NMR** (125 MHz, $CDCl_3$) δ 174.6, 138.9, 137.5, 134.2, 133.8, 130.4, 130.1, 130.0, 129.1, 129.0, 128.6, 128.1, 127.8, 127.4, 127.1, 125.9, 123.5, 72.3, 71.1, 67.3, 46.9, 21.2.**HRMS** (ESI/TOF-Q) m/z: $[M+Na]^+$ Calcd for $C_{24}H_{22}NO_3ClNa^+$ 430.1186; Found 430.1189; For minor isomer: mp 210-212 ^{0}C. **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.39 (d, *J* = 8.5 Hz, 2H), 7.27 – 7.20 (m, 5H), 7.18 – 7.14 (m, 4H), 7.12 – 7.08 (m, 2H), 4.97 (t, *J* = 3.5 Hz, 1H), 4.65 (d, *J* = 4.1 Hz, 1H), 4.61 (s, 1H), 3.73 – 3.67 (m, 2H), 2.30 (s, 3H), 2.06 (d, *J* = 4.8 Hz, 1H). **^{13}C NMR** (125 MHz, $CDCl_3$) δ 173.8, 138.5, 137.9, 136.1, 134.9, 134.7, 130.2, 130.0, 129.3, 129.2, 129.1, 128.1, 127.9, 127.5, 127.2, 125.0, 122.0, 72.1, 71.1, 68.9, 44.2, 21.1. **HRMS** (ESI/TOF-Q) m/z: $[M+Na]^+$ Calcd for $C_{24}H_{22}NO_3ClNa^+$ 430.1186; Found 430.1187.

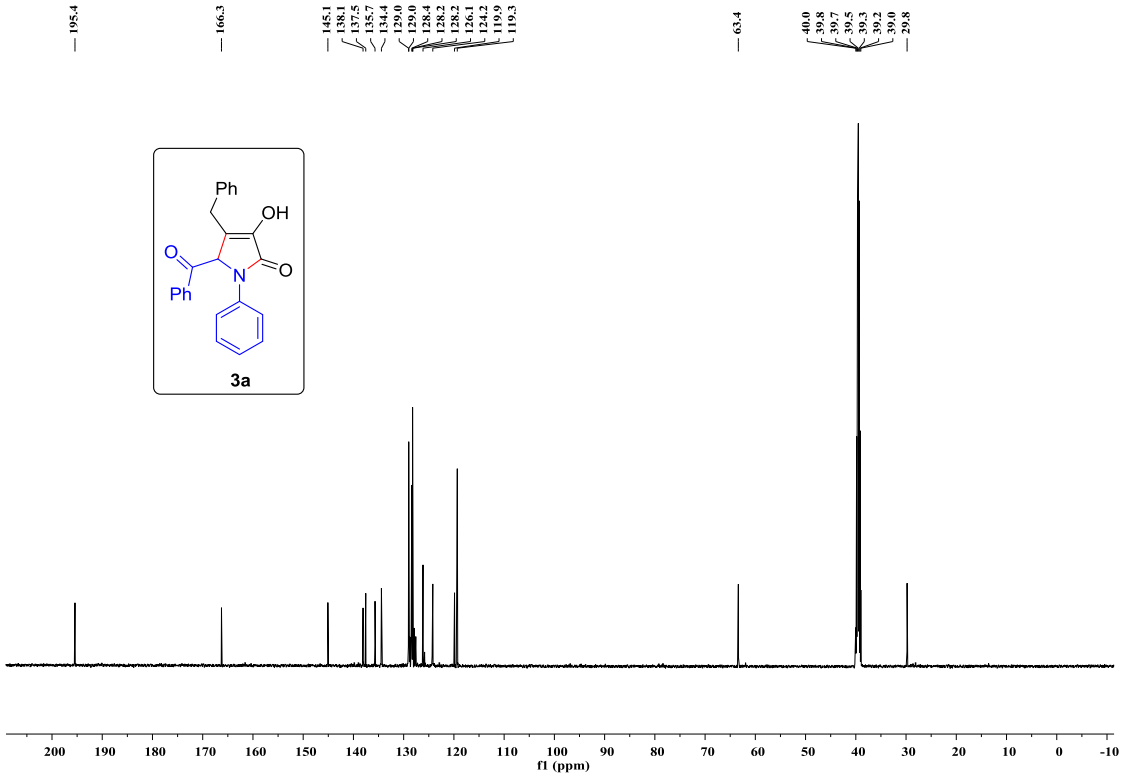


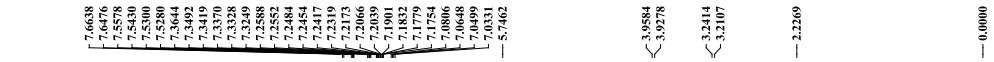
5f

Compound 5f was prepared following the general procedure for synthesis of synthesis of clausenamide analogues described above and purified by silica gel column chromatography (20→ 25% EtOAc : hexane) to provide pure compound as white solid (60 mg, 84%, single diastereomer). **^{1}H NMR** (500 MHz, DMSO–d_6) δ 7.35 (t, *J* = 7.4 Hz, 2H), 7.33 – 7.23 (m, 5H), 7.10 (dd, *J* = 8.2, 6.8 Hz, 2H), 7.06 – 6.97 (m, 1H), 6.80 (q, *J* = 7.8 Hz, 1H), 6.45 – 6.37 (m, 2H), 6.05 (td, *J* = 7.8, 7.3, 2.1 Hz, 1H), 5.43 (d, *J* = 4.3 Hz, 1H), 4.76 – 4.68 (m, 1H), 4.65 (d, *J* = 5.4 Hz, 1H), 4.31 (t, *J* = 5.5 Hz, 1H), 4.25 (td, *J* = 10.1, 2.2 Hz, 1H), 3.86 (dd, *J* = 9.7, 4.2 Hz, 1H), 3.48 (dd, *J* = 10.9, 2.2 Hz, 1H), 3.15 – 3.11 (m,1H). **^{13}C NMR** (125 MHz, DMSO–d_6) δ 163.1 (d, *J* = 237.8 Hz), 151.4 (d, *J* = 11.5 Hz), 144.7, 138.8, 130.1, 129.4 (d, *J* = 10.4 Hz), 127.9, 127.3, 127.1, 126.6, 126.2, 108.8, 100.8 (d, *J* = 21.4 Hz), 98.5 (d, *J* = 25.1 Hz), 73.4, 71.1, 64.7, 57.8, 48.4. **Dept NMR** (125 MHz, DMSO–d_6) δ 130.1, 129.4 (d, *J* = 10.4 Hz), 127.9, 127.3, 127.1, 126.6, 126.2, 108.8, 100.8 (d, *J* = 21.4 Hz), 98.5 (d, *J* = 25.1 Hz), 73.4, 71.1, 64.7, 57.8, 48.4. **^{19}F NMR** (500 MHz, DMSO–d_6) δ -113.9. **HRMS** (ESI/TOF-Q) m/z: $[M+Na]^+$ Calcd for $C_{23}H_{23}NO_3F^+$ 364.1713; Found 364.1702.

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



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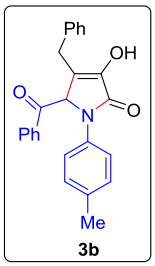
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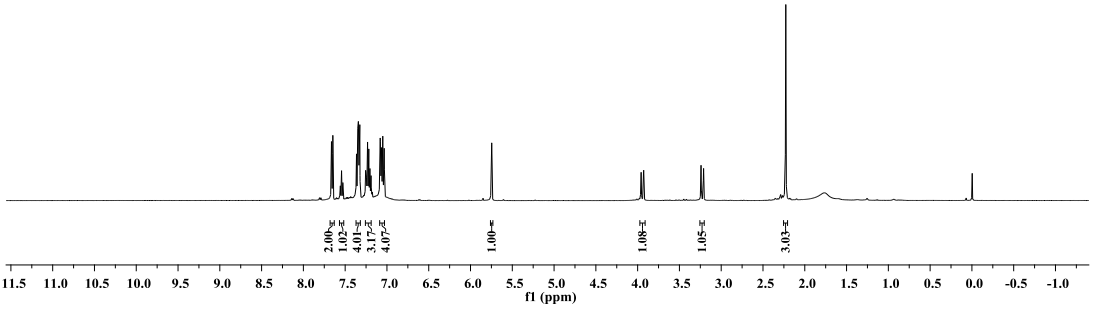
O
Ph
N
O
Me

3b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3.03
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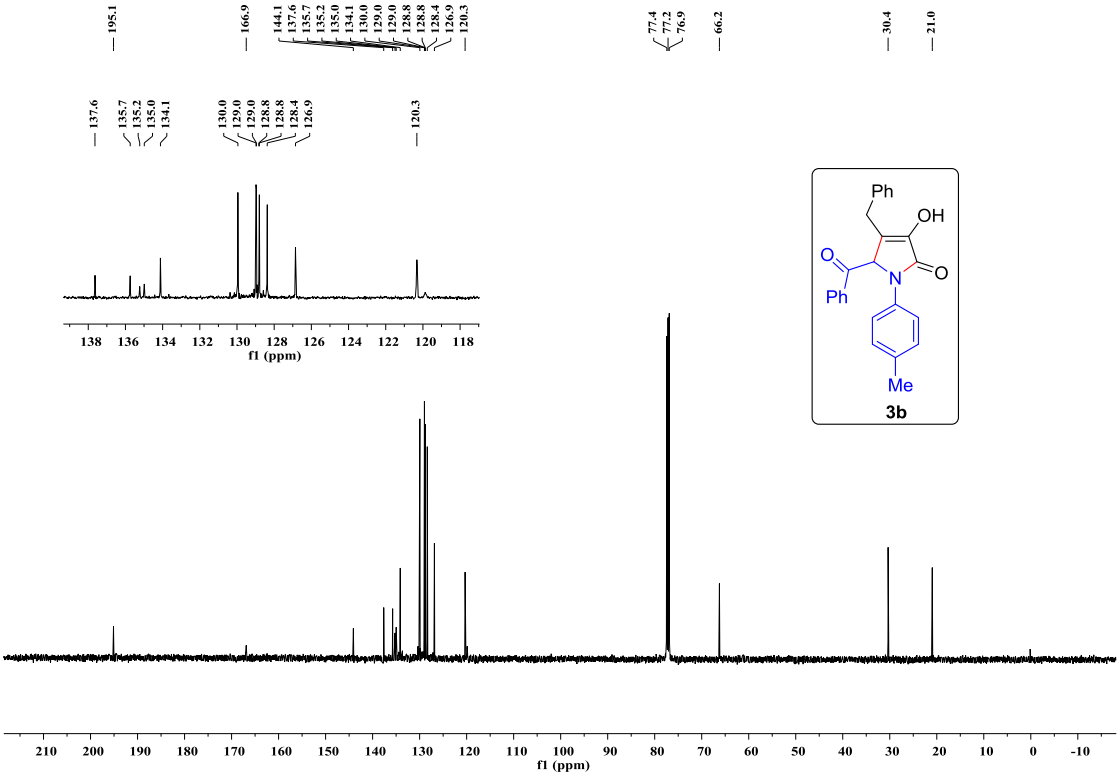
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21.0
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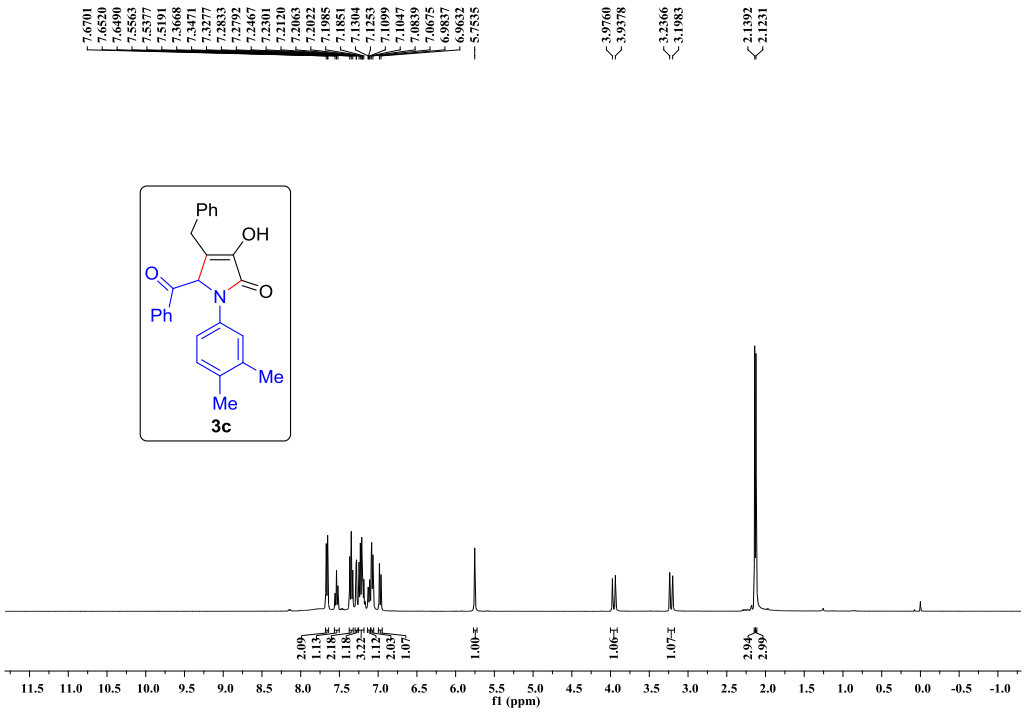
f1 (ppm)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

Ph
OH
O
Ph
N
O
Me

3b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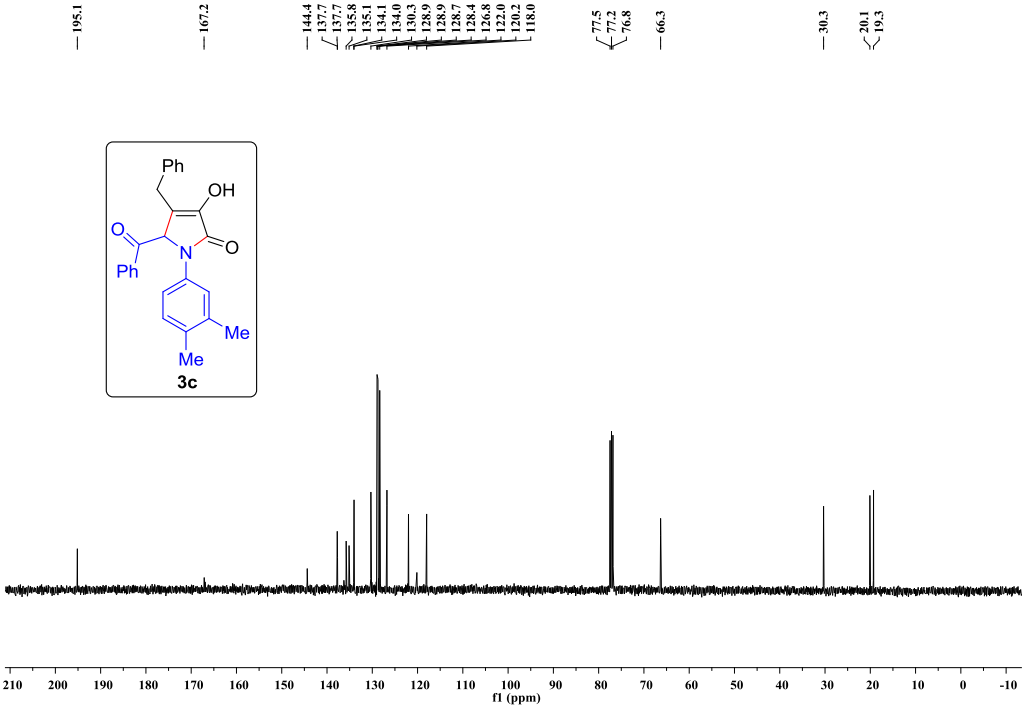
7.3471
7.3277
7.2833
7.2792
7.2467
7.2301
7.2120
7.2063
7.2022
7.1985
7.1851
7.1304
7.1253
7.1099
7.1047
7.0839
7.0675
6.9837
6.9632
5.7535
3.9760
3.9378
3.2366
3.1983
2.1392
2.1231
Ph
OH
O
N
O
Ph
Me
Me
3c
2.09
1.13
2.18
1.18
3.22
1.12
2.03
1.07
1.00
1.06
1.07
2.94
2.99
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)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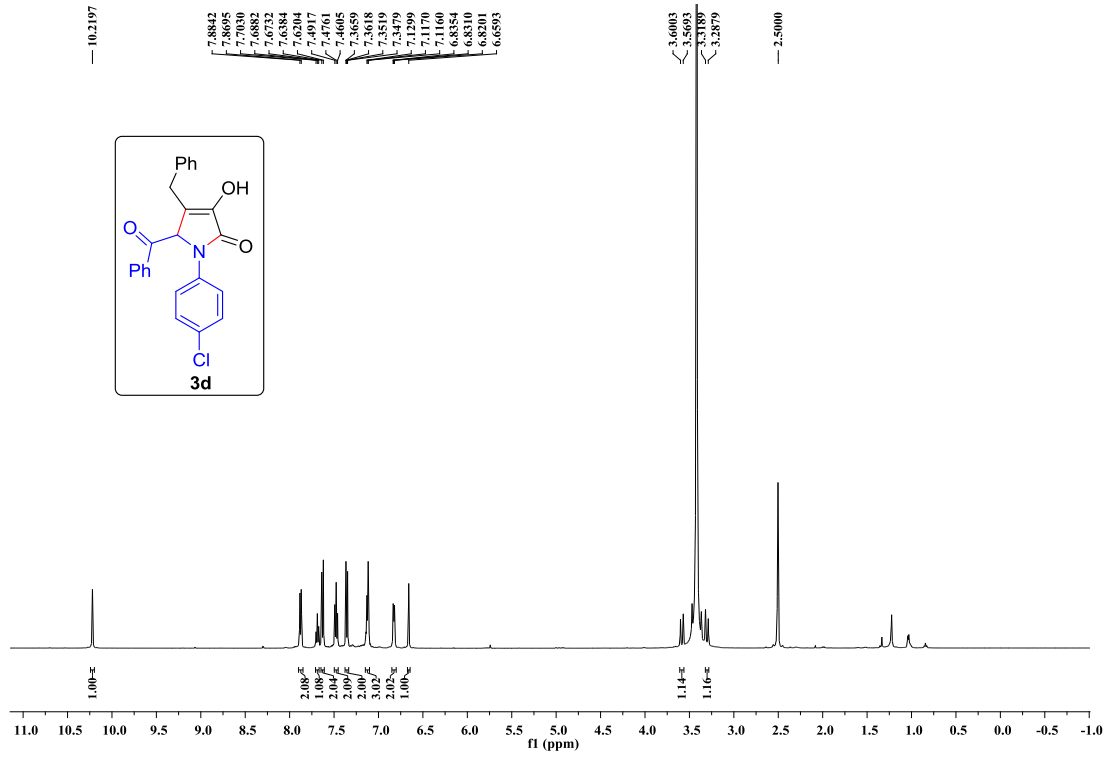
167.2
144.4
137.7
137.7
135.8
135.1
134.1
134.0
130.3
128.9
128.9
128.7
128.4
126.8
122.0
120.2
118.0
77.5
77.2
76.8
66.3
30.3
20.1
19.3
Ph
OH
O
N
O
Ph
Me
Me
3c
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)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7.6384
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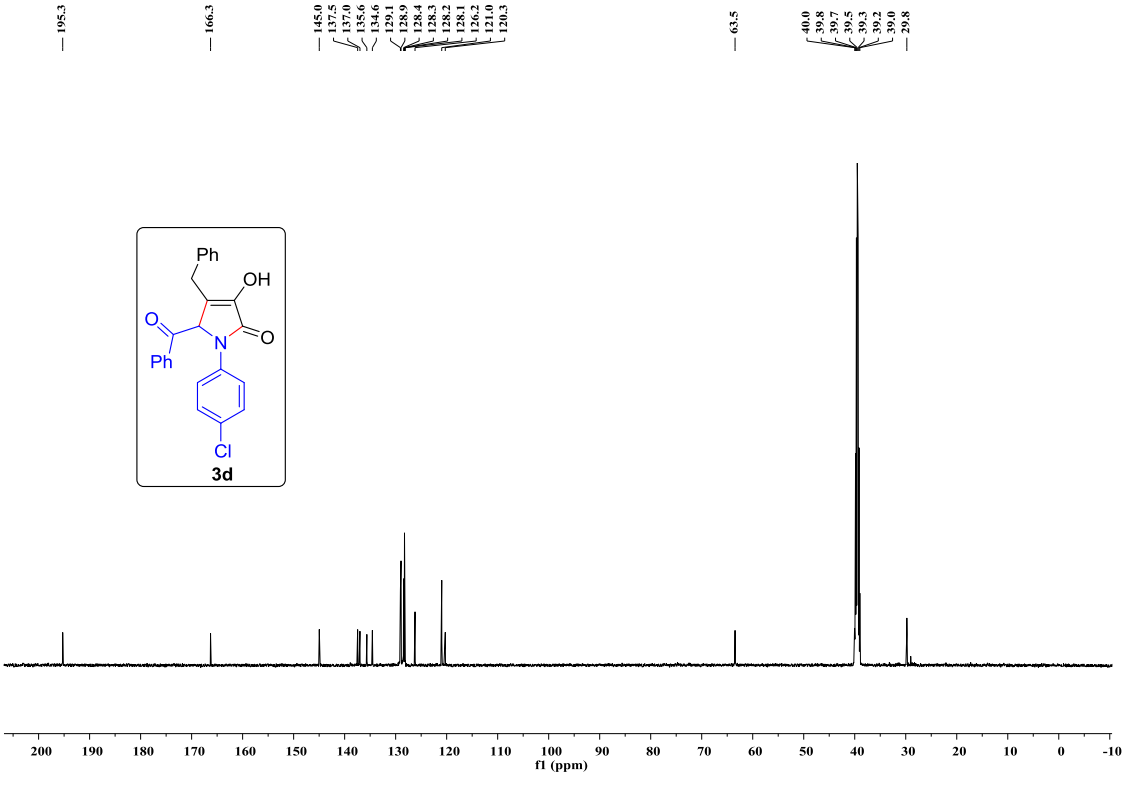
7.4761
7.4605
7.3659
7.3618
7.3519
7.3479
7.1299
7.1170
7.1160
6.8354
6.8310
6.8201
6.6593
3.6003
3.5693
3.3189
3.2879
2.5000
Ph
OH
O
Ph
N
O
Cl
3d
1.00
2.08
1.08
2.04
2.09
2.00
3.02
2.02
1.00
1.14
1.16
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)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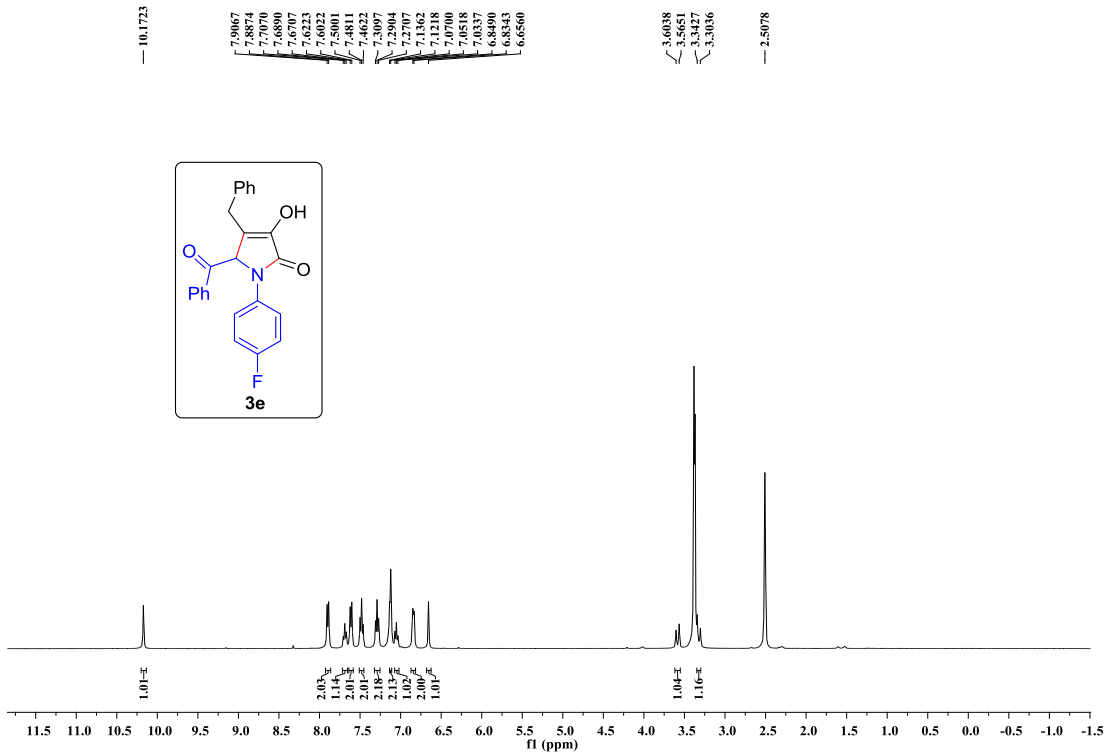
135.6
134.6
129.1
128.9
128.4
128.3
128.2
128.1
126.2
121.0
120.3
63.5
40.0
39.8
39.7
39.5
39.3
39.2
39.0
29.8
Ph
OH
O
Ph
N
O
Cl
3d
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)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7.7070
7.6890
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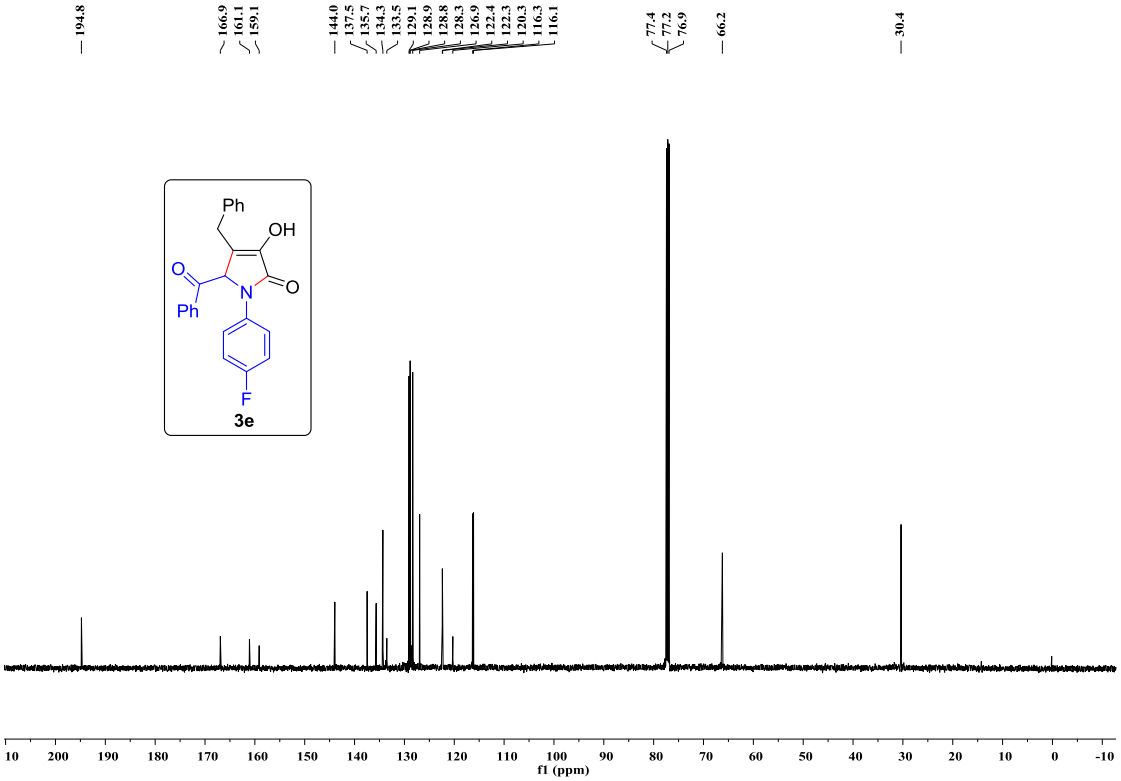
7.6223
7.6022
7.5001
7.4811
7.4622
7.3097
7.2904
7.2707
7.1362
7.1218
7.0700
7.0518
7.0337
6.8490
6.8343
6.6560
3.6038
3.5651
3.5427
3.3036
2.5078
Ph
OH
O
N
O
Ph
F
3e
1.01
2.05
1.14
2.01
2.01
2.18
2.13
1.02
2.00
1.01
1.04
1.16
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0 -1.5
f1 (ppm)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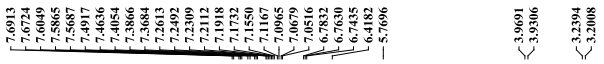
166.9
161.1
159.1
144.0
137.5
135.7
134.3
133.5
129.1
128.9
128.8
128.3
126.9
122.4
122.3
120.3
116.3
116.1
77.4
77.2
76.9
66.2
30.4
Ph
OH
O
N
O
Ph
F
3e
10 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)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7.6049
7.5865
7.5687
7.4917
7.4636
7.4054
7.3866
7.3684
7.2613
7.2492
7.2309
7.2112
7.1918
7.1732
7.1550
7.1167
7.0965
7.0679
7.0516
6.7832
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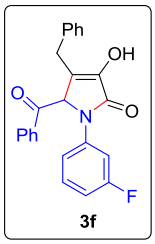
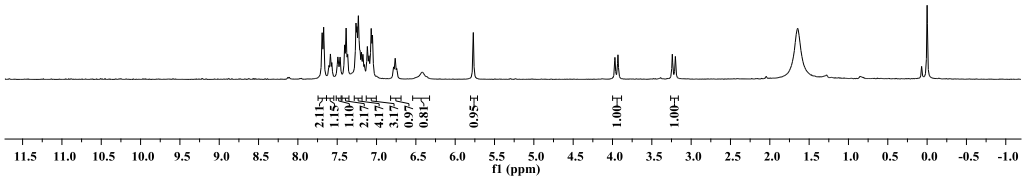
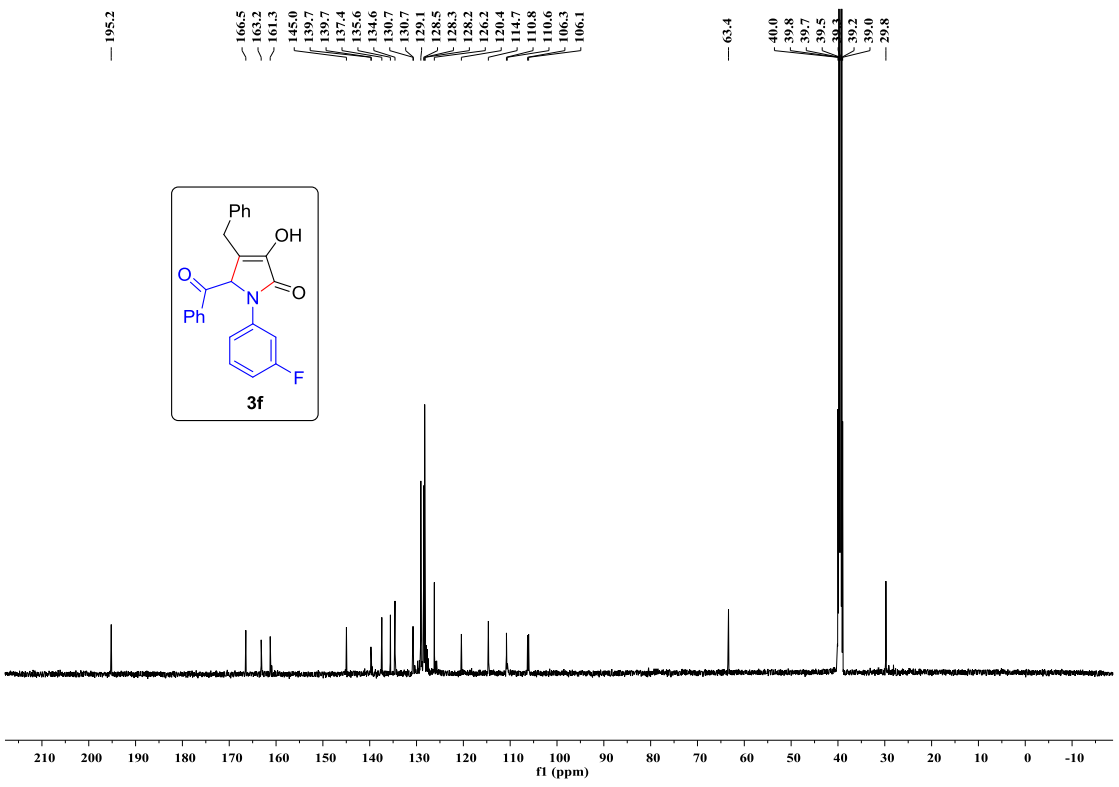
5.7696
3.9691
3.9306
3.2394
3.2008


Ph
OH
O
N
O
Ph
F

3f


2.11
1.15
1.10
2.17
4.17
3.17
0.97
0.81
0.95
1.00
1.00
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)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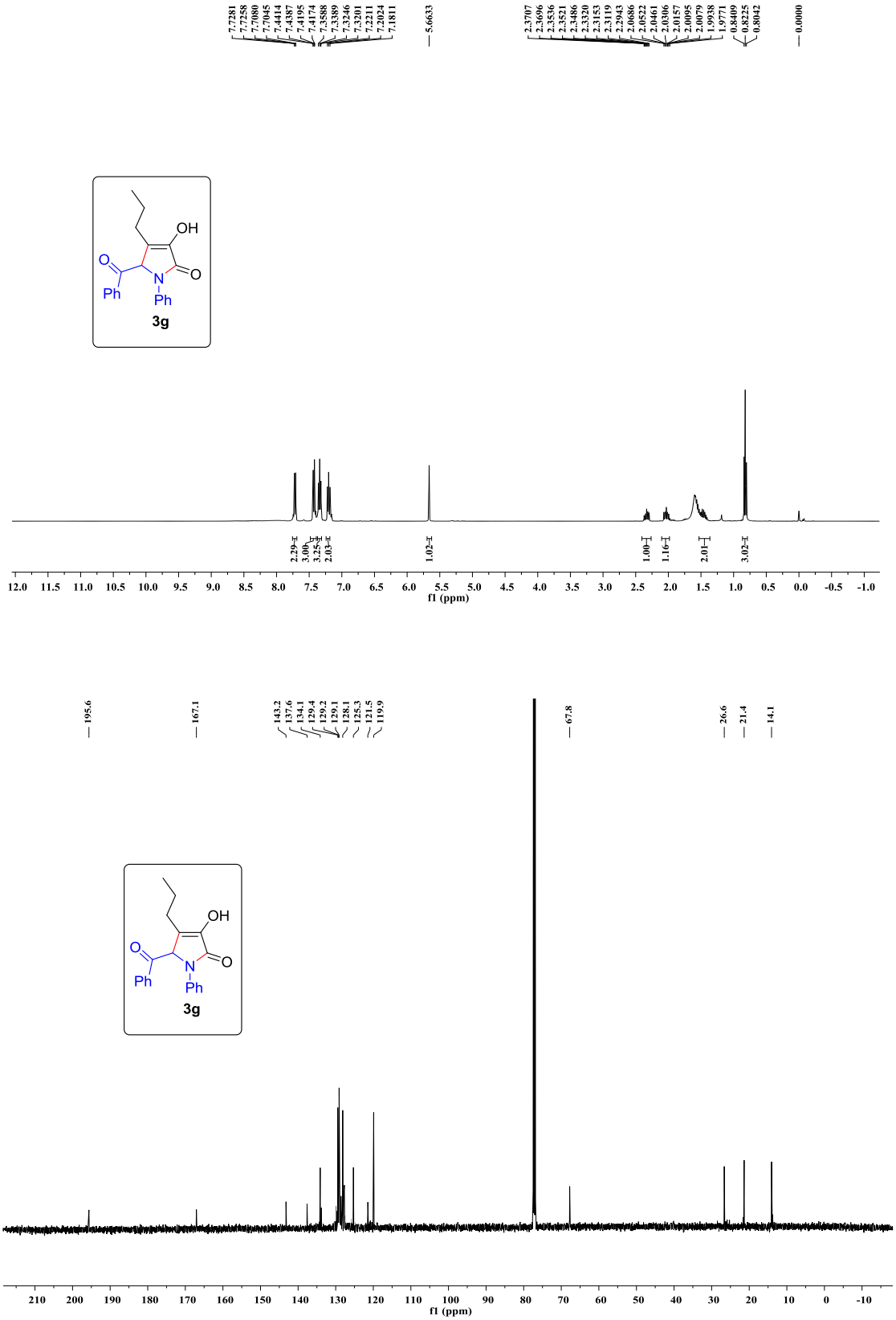
166.5
163.2
161.3
145.0
139.7
139.7
137.4
135.6
134.6
130.7
130.7
129.1
128.5
128.3
128.2
126.2
120.4
114.7
110.8
110.6
106.3
106.1
63.4
40.0
39.8
39.7
39.5
39.2
39.0
29.8
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

Ph
OH
O
N
O
Ph
F

3f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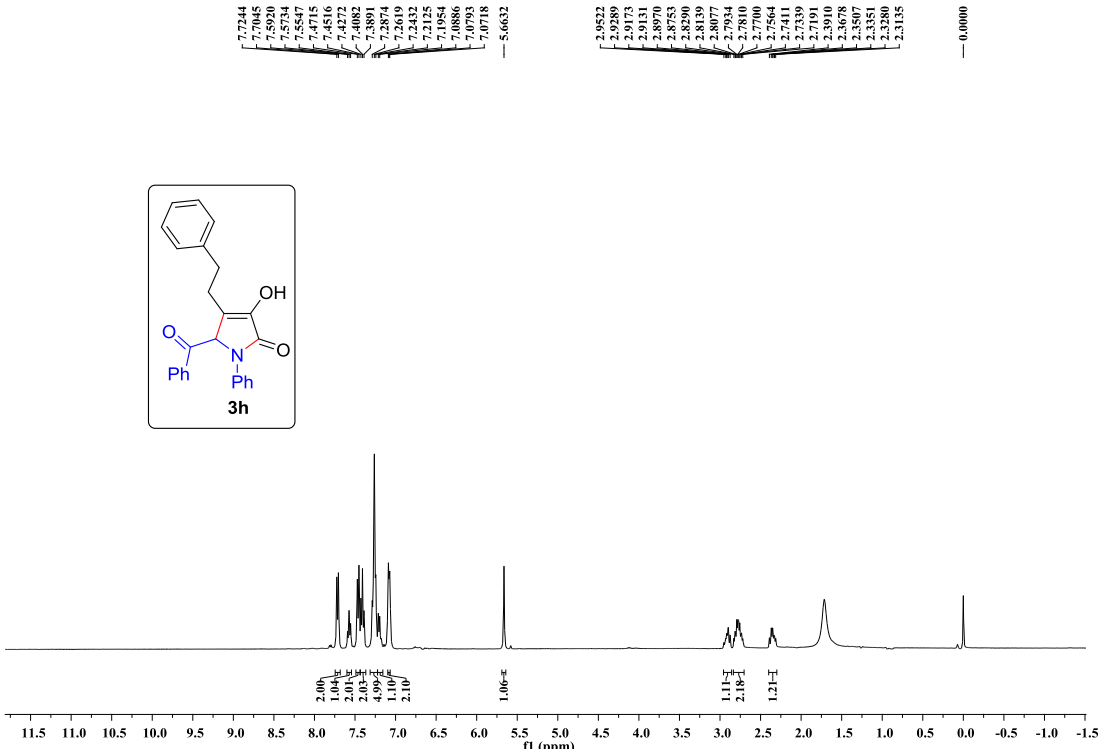
7.7080
7.7045
7.4414
7.4387
7.4195
7.4174
7.3588
7.3389
7.3246
7.3201
7.2211
7.2024
7.1811
5.6633
2.3707
2.3696
2.3536
2.3521
2.3486
2.3320
2.3153
2.3119
2.2943
2.0686
2.0522
2.0461
2.0306
2.0157
2.0095
2.0079
1.9938
1.9771
0.8409
0.8225
0.8042
0.0000
OH
O
N
O
Ph
Ph
3g
2.29
3.00
3.25
2.03
1.02
1.00
1.16
2.01
3.02
12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)
195.6
167.1
143.2
137.6
134.1
129.4
129.2
129.1
128.1
125.3
121.5
119.9
67.8
26.6
21.4
14.1
OH
O
N
O
Ph
Ph
3g
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)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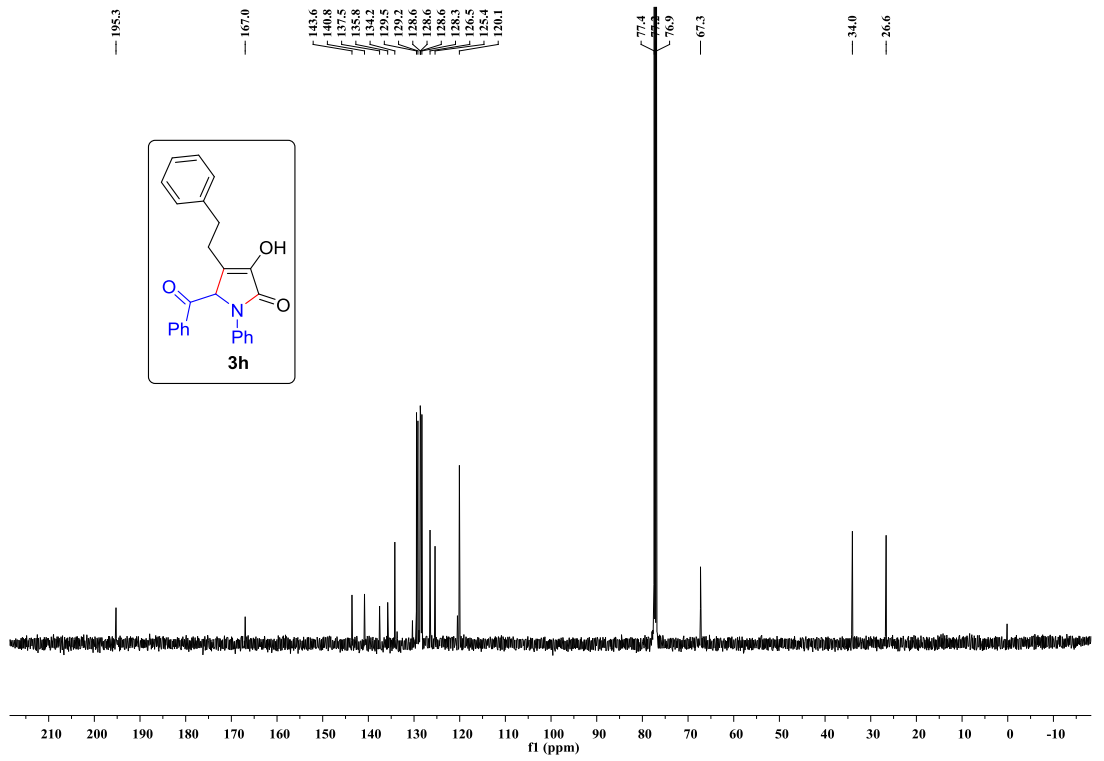
7.5920
7.5734
7.5547
7.4715
7.4516
7.4272
7.4082
7.3891
7.2874
7.2619
7.2432
7.2125
7.1954
7.0886
7.0793
7.0718
5.6632
2.9522
2.9289
2.9173
2.9131
2.8970
2.8753
2.8290
2.8139
2.8077
2.7934
2.7810
2.7700
2.7564
2.7411
2.7339
2.7191
2.3910
2.3678
2.3507
2.3351
2.3280
2.3135
0.0000
OH
O
N
O
Ph
Ph
3h
2.00
1.04
2.01
2.03
4.99
1.10
2.10
1.06
1.11
2.18
1.21
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0 -1.5
f1 (ppm)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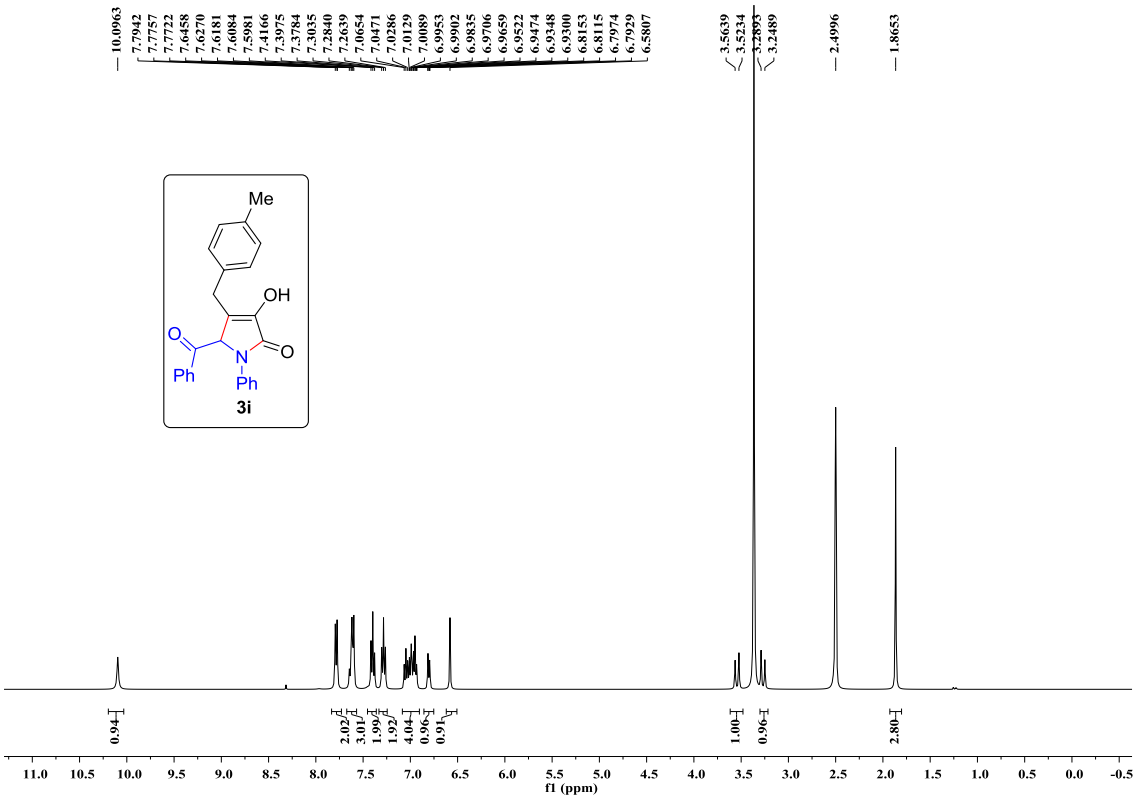
167.0
143.6
140.8
137.5
135.8
134.2
129.5
129.2
128.6
128.6
128.6
128.3
126.5
125.4
120.1
77.4
77.2
76.9
67.3
34.0
26.6
OH
O
N
O
Ph
Ph
3h
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)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7.7722
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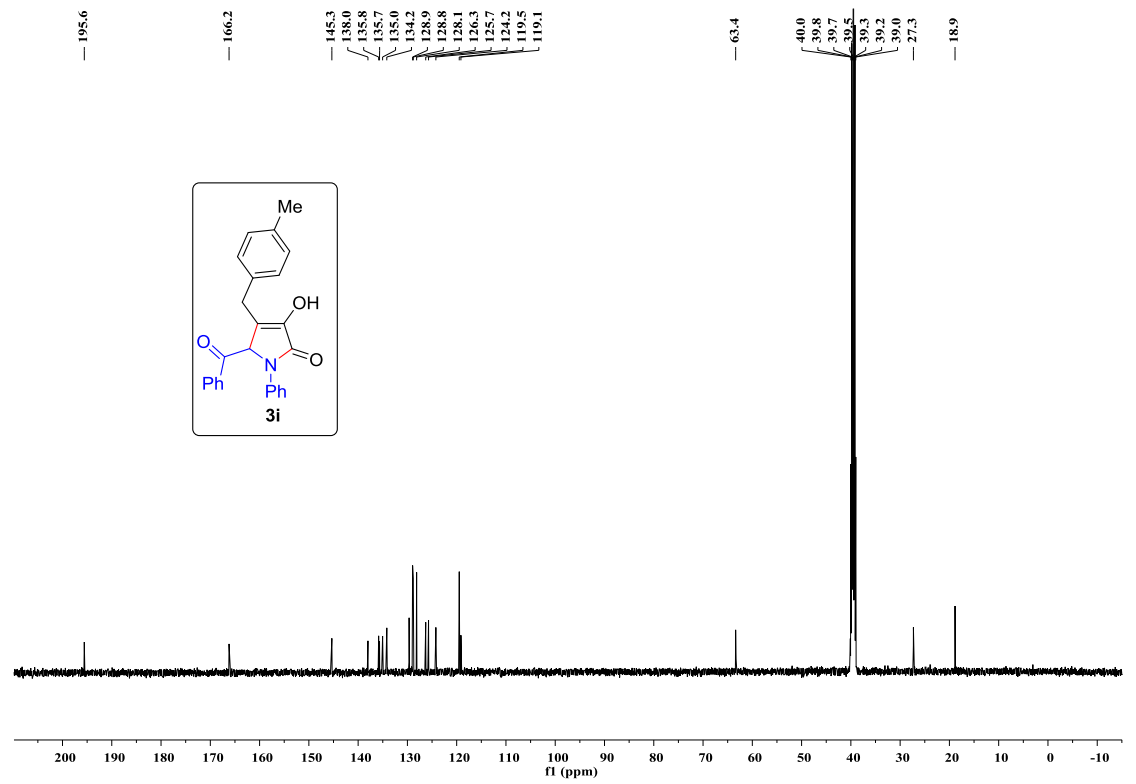
7.6270
7.6181
7.6084
7.5981
7.4166
7.3975
7.3784
7.3035
7.2840
7.2639
7.0654
7.0471
7.0286
7.0129
7.0089
6.9953
6.9902
6.9835
6.9706
6.9659
6.9522
6.9474
6.9348
6.9300
6.8153
6.8115
6.7974
6.7929
6.5807
3.5639
3.5234
3.2893
3.2489
2.4996
1.8653
Me
OH
O
N
O
Ph
Ph
3i
0.94
2.02
3.01
1.99
1.92
4.04
0.96
0.91
1.00
0.96
2.80
f1 (ppm)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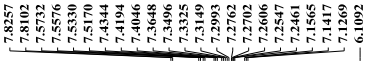
145.3
138.0
135.8
135.7
135.0
134.2
128.9
128.8
128.1
126.3
125.7
124.2
119.5
119.1
63.4
40.0
39.8
39.7
39.5
39.3
39.2
39.0
27.3
18.9
Me
OH
O
N
O
Ph
Ph
3i
f1 (ppm)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7.4344
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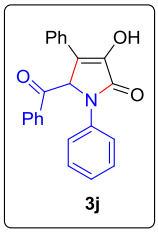
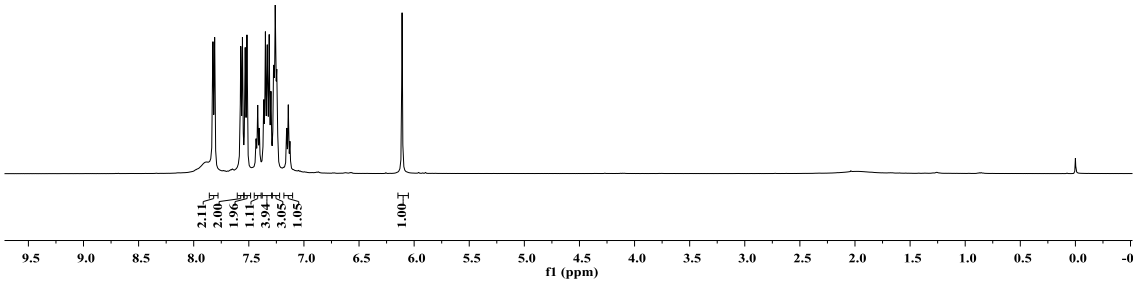
7.3648
7.3496
7.3325
7.3149
7.2993
7.2762
7.2702
7.2606
7.2547
7.2461
7.1565
7.1417
7.1269
6.1092


Ph
OH
O
N
O
Ph

3j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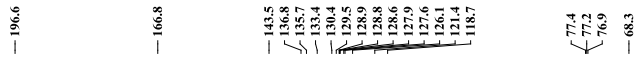
1.96
1.11
3.94
3.05
1.05
1.00
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0
f1 (ppm)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133.4
130.4
129.5
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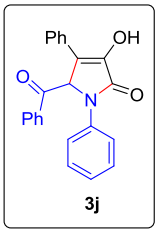
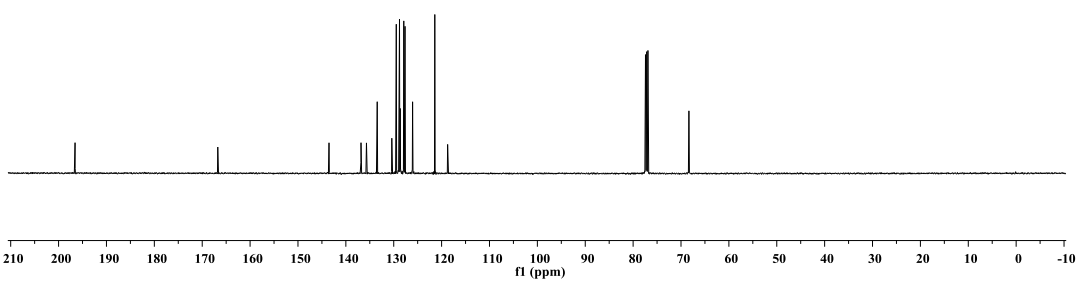
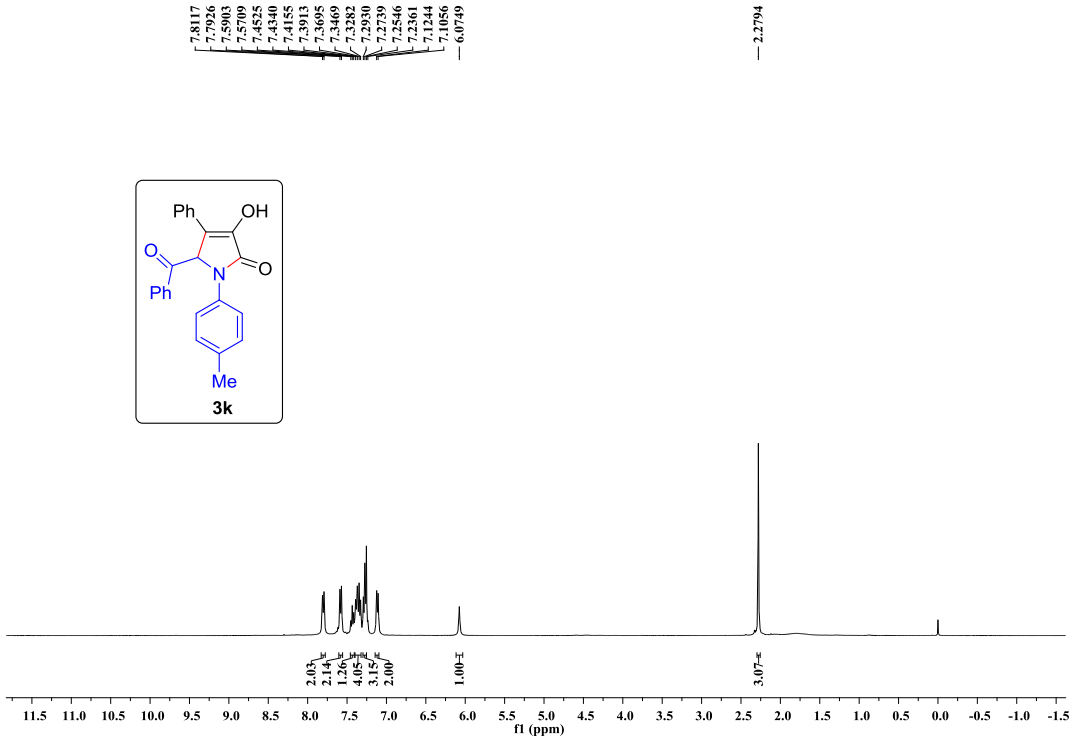
128.8
128.6
127.9
127.6
126.1
121.4
118.7
77.4
77.2
76.9
68.3


Ph
OH
O
N
O
Ph

3j


210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)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7.5709
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7.3695
7.3469
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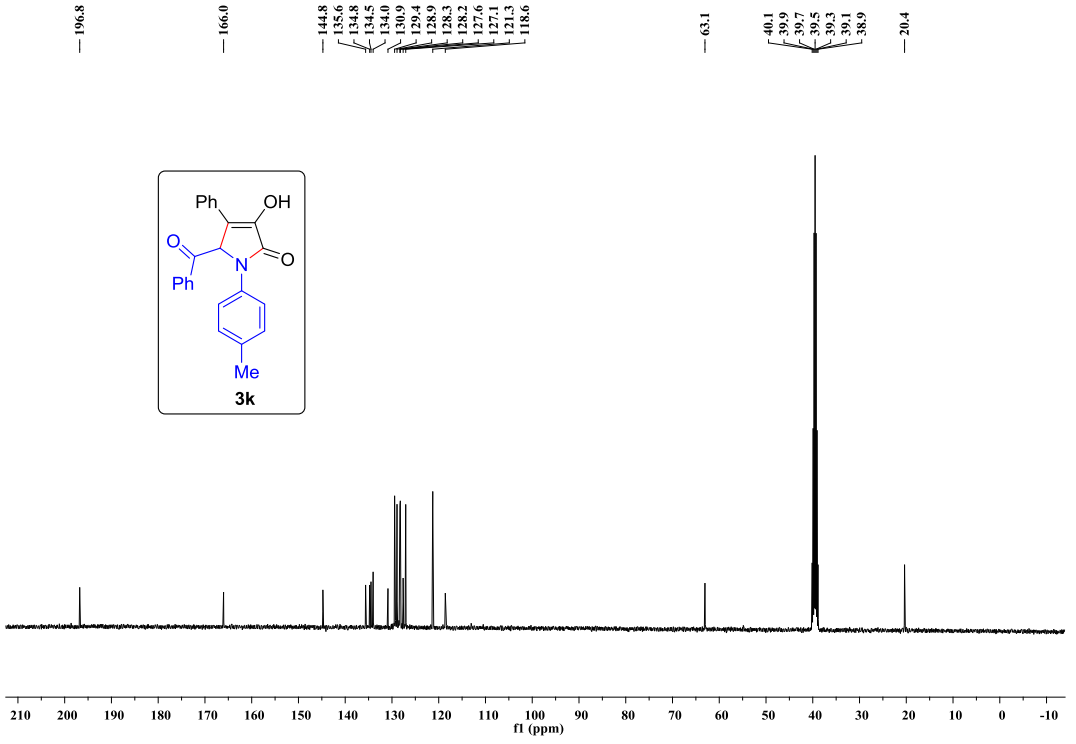
7.2930
7.2739
7.2546
7.2361
7.1244
7.1056
6.0749
2.2794
Ph
OH
O
N
O
Ph
Me
3k
2.03
2.14
1.26
4.05
3.15
2.00
1.00
3.07
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0 -1.5
f1 (ppm)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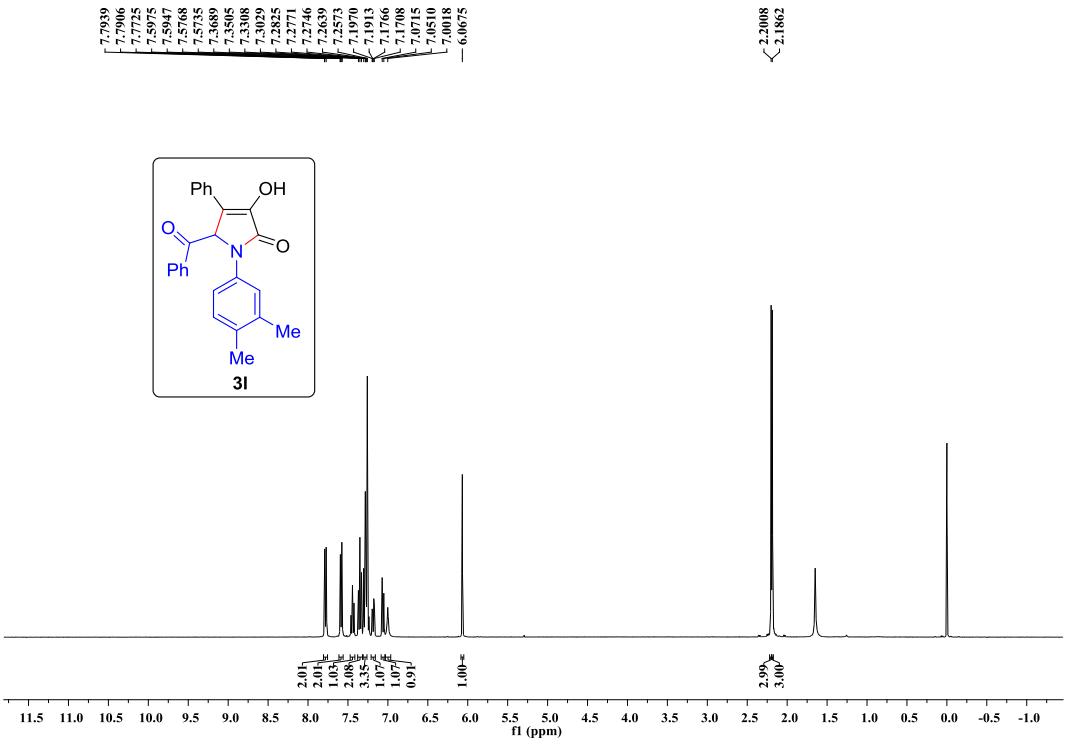
144.8
135.6
134.8
134.5
134.0
130.9
129.4
128.9
128.3
128.2
127.6
127.1
121.3
118.6
63.1
40.1
39.9
39.7
39.5
39.3
39.1
38.9
20.4
Ph
OH
O
N
O
Ph
Me
3k
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)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7.7725
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7.5768
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7.3505
7.3308
7.3029
7.2825
7.2771
7.2746
7.2639
7.2573
7.1970
7.1913
7.1766
7.1708
7.0715
7.0510
7.0018
6.0675
2.2008
2.1862
Ph
OH
O
N
O
Ph
Me
Me
3l
2.01
2.01
1.03
2.06
3.35
1.07
1.07
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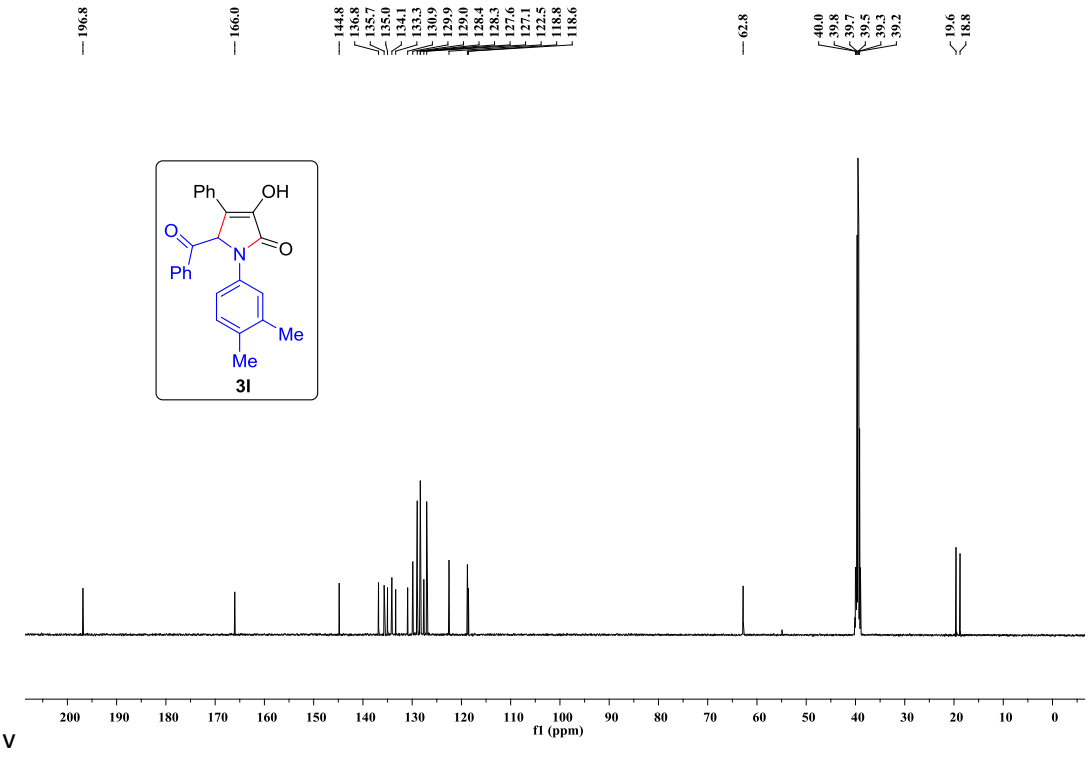
1.00
2.99
3.00
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)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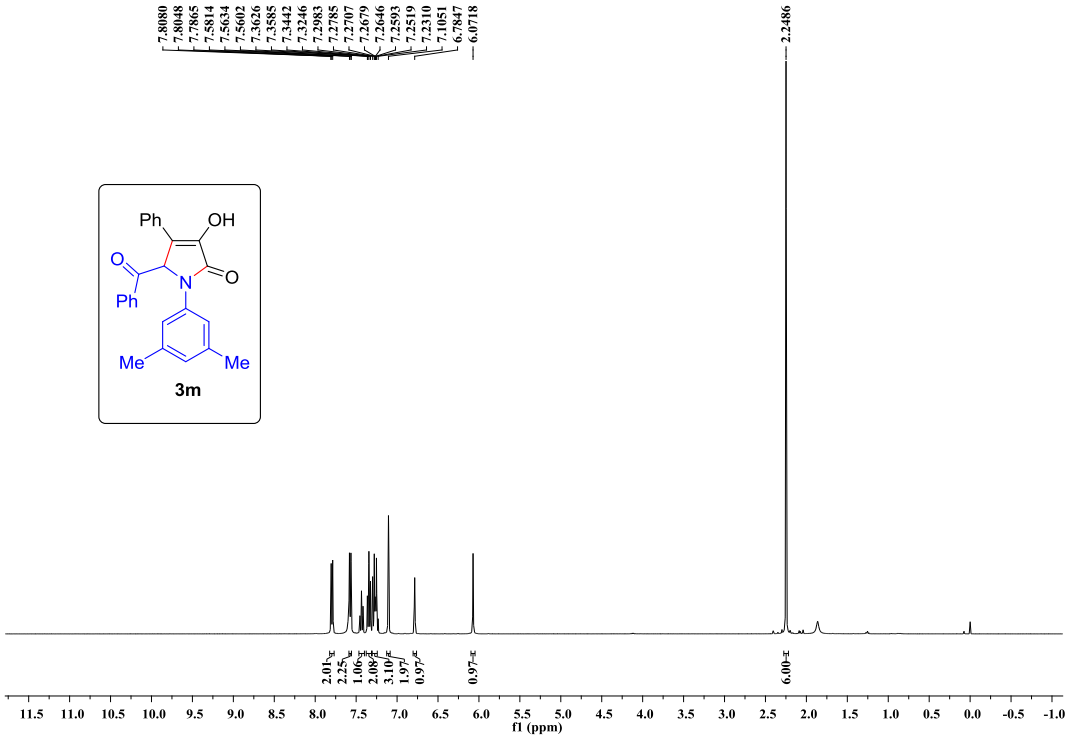
166.0
144.8
136.8
135.7
135.0
134.1
133.3
130.9
129.9
129.0
128.4
128.3
127.6
127.1
122.5
118.8
118.6
62.8
40.0
39.8
39.7
39.5
39.3
39.2
19.6
18.8
Ph
OH
O
N
O
Ph
Me
Me
3l
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

V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7.7865
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7.3626
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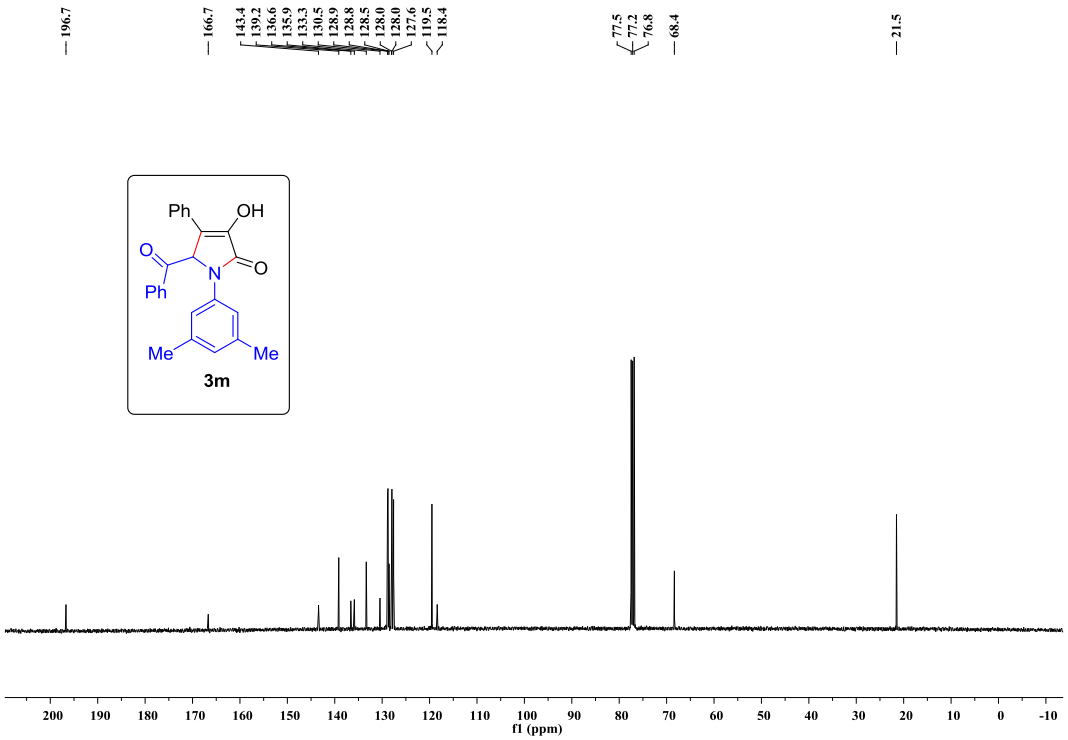
7.3246
7.2983
7.2785
7.2707
7.2679
7.2646
7.2593
7.2519
7.2310
7.1051
6.7847
6.0718
2.2486
Ph
OH
O
N
O
Ph
Me
Me
3m
2.01
2.25
1.06
2.08
3.10
1.97
0.97
0.97
6.00
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)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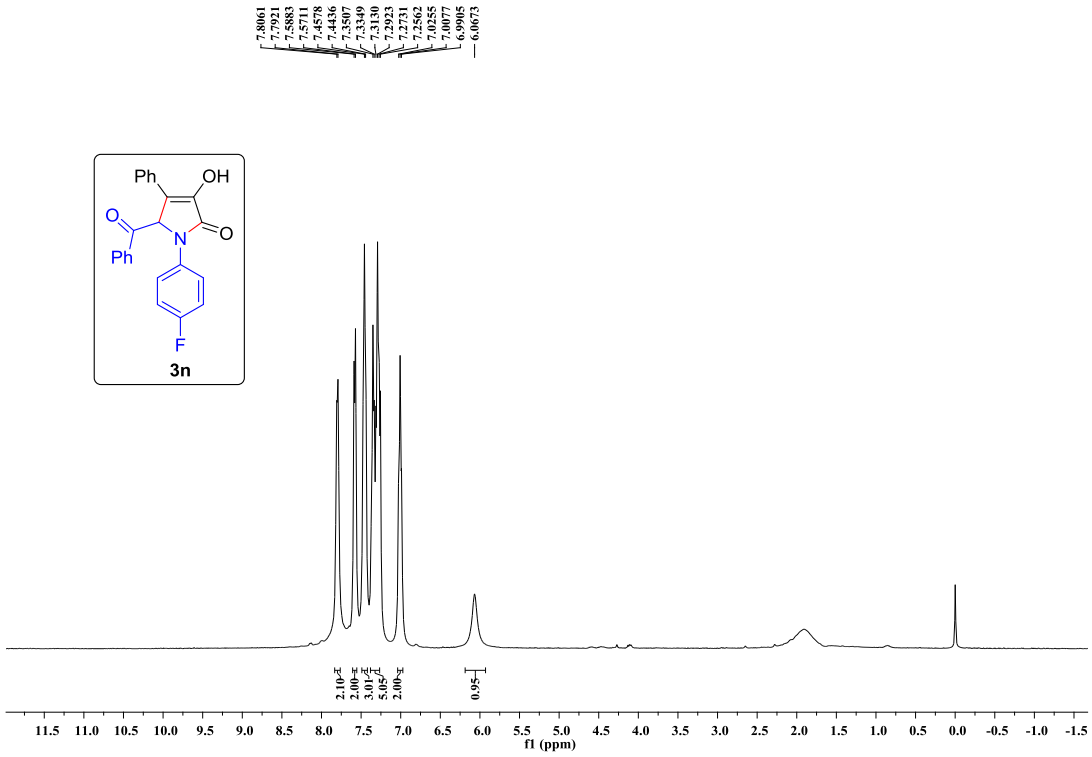
166.7
143.4
139.2
136.6
135.9
133.3
130.5
128.9
128.8
128.5
128.0
128.0
127.6
119.5
118.4
77.5
77.2
76.8
68.4
21.5
Ph
OH
O
N
O
Ph
Me
Me
3m
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)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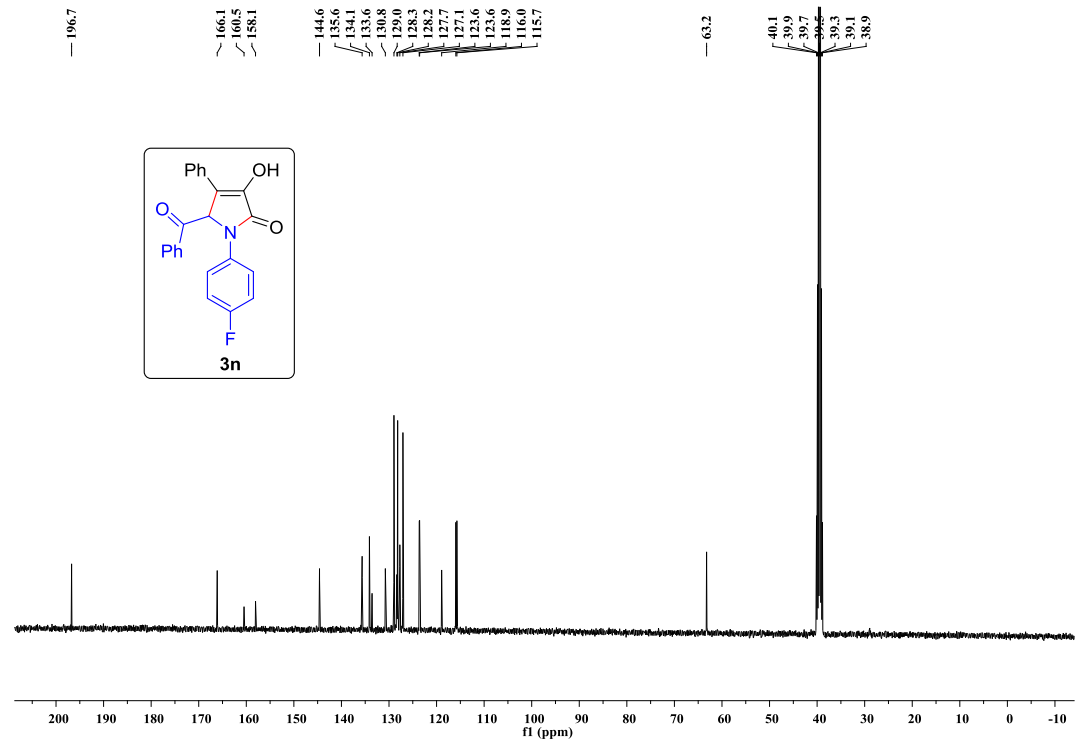
7.7921
7.5883
7.5711
7.4578
7.4436
7.3507
7.3349
7.3130
7.2923
7.2731
7.2562
7.0255
7.0077
6.9905
6.6673
Ph
OH
O
N
O
Ph
F
3n
2.10
2.00
3.01
5.05
2.00
0.95
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0 -1.5
f1 (ppm)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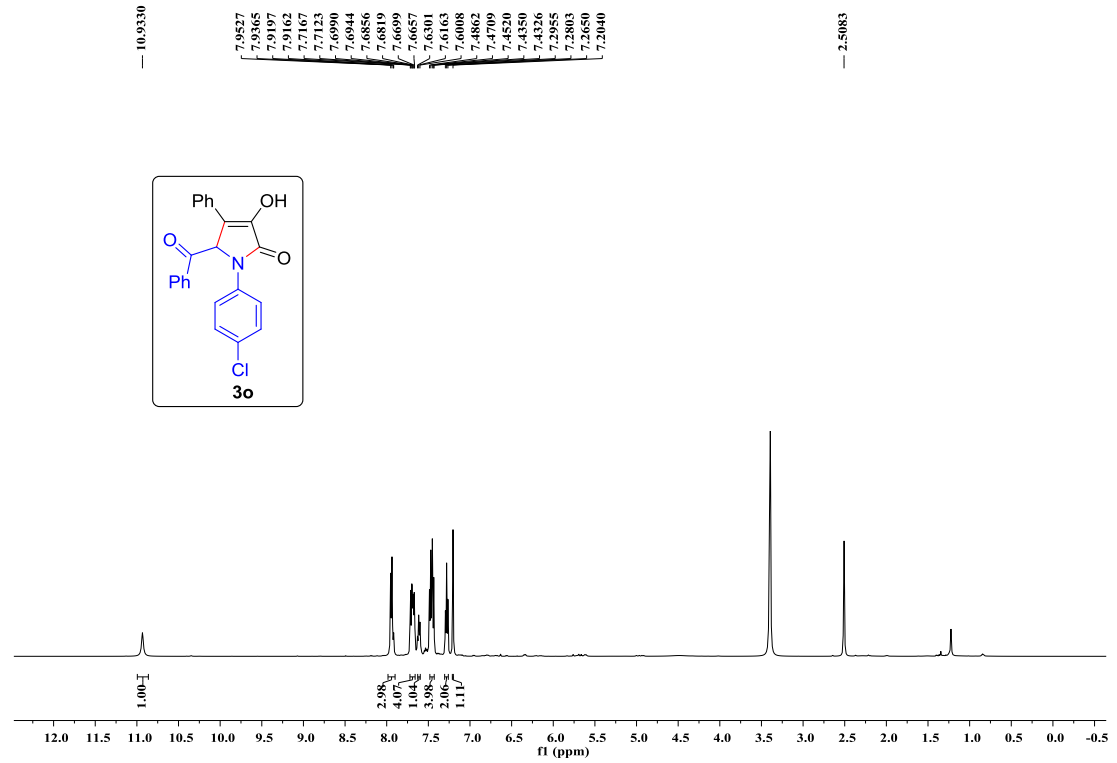
166.1
160.5
158.1
144.6
135.6
134.1
133.6
130.8
129.0
128.3
128.2
127.7
127.1
123.6
123.6
118.9
116.0
115.7
63.2
40.1
39.9
39.7
39.5
39.3
39.1
38.9
Ph
OH
O
N
O
Ph
F
3n
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)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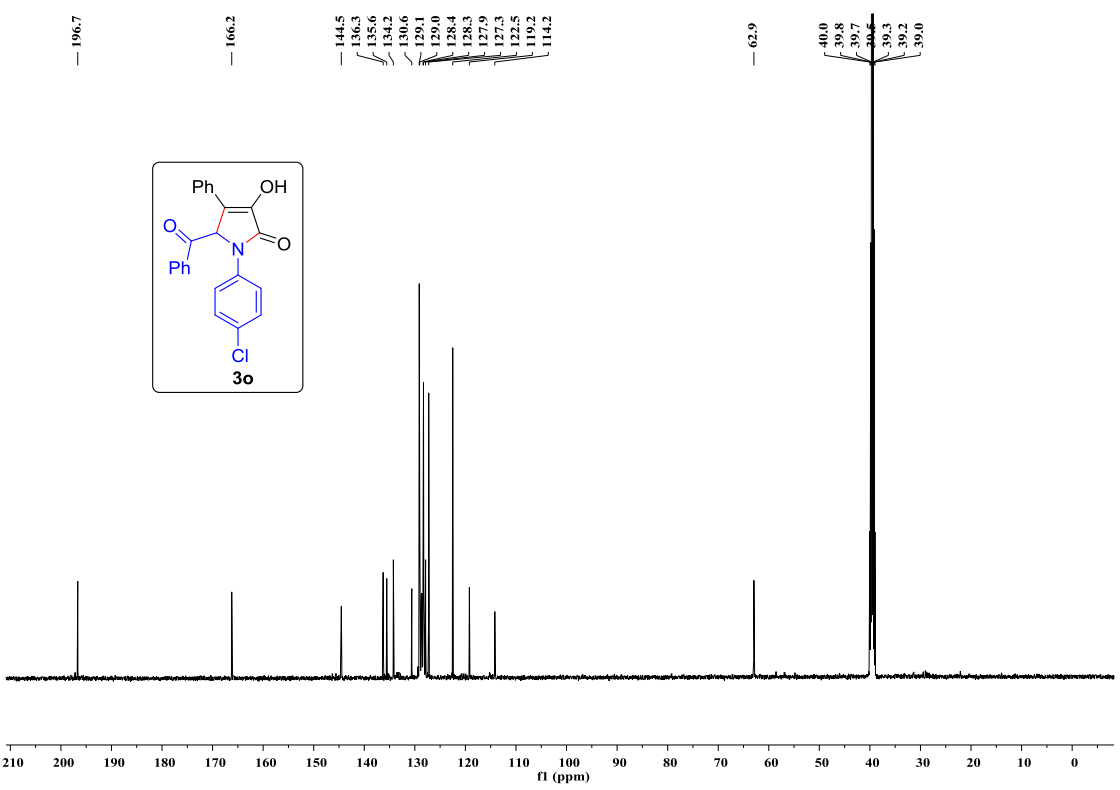
7.9527
7.9365
7.9197
7.9162
7.7167
7.7123
7.6990
7.6944
7.6856
7.6819
7.6699
7.6657
7.6301
7.6163
7.6008
7.4862
7.4709
7.4520
7.4350
7.4326
7.2955
7.2803
7.2650
7.2040
2.5083
Ph
OH
O
N
O
Ph
Cl
3o
1.00
2.98
4.07
1.04
3.98
2.06
1.11
12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)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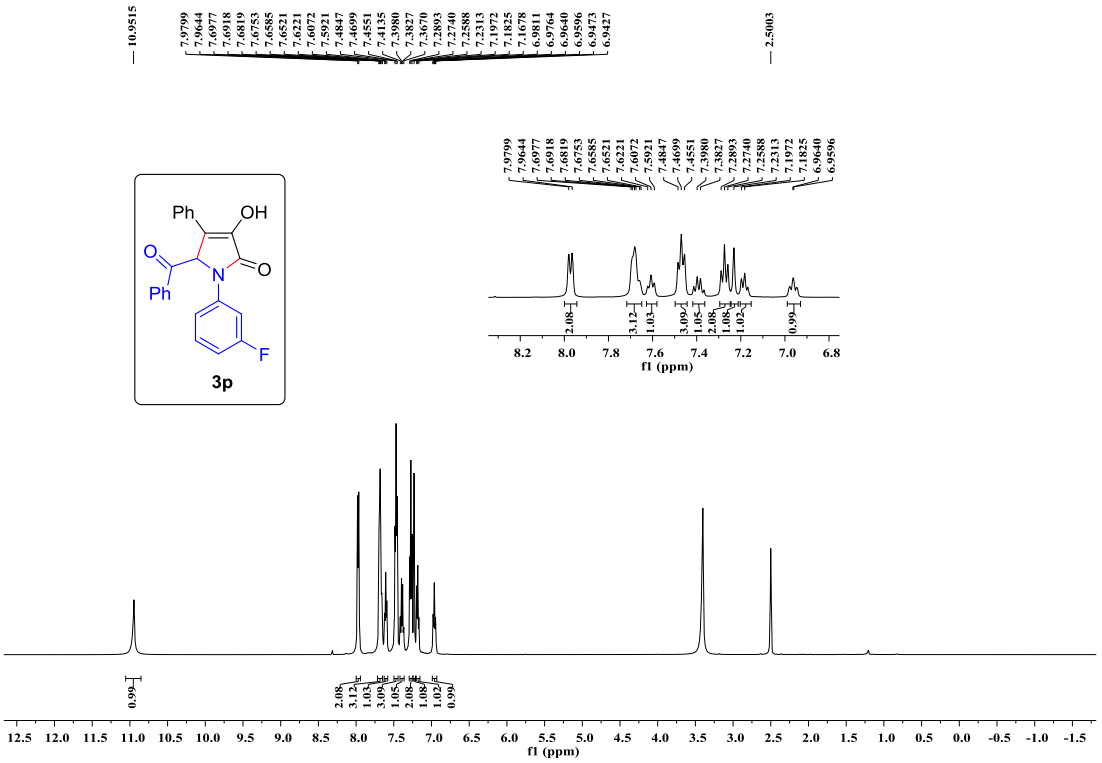
166.2
144.5
136.3
135.6
134.2
130.6
129.1
129.0
128.4
128.3
127.9
127.3
122.5
119.2
114.2
62.9
40.0
39.8
39.7
39.3
39.2
39.0
Ph
OH
O
N
O
Ph
Cl
3o
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)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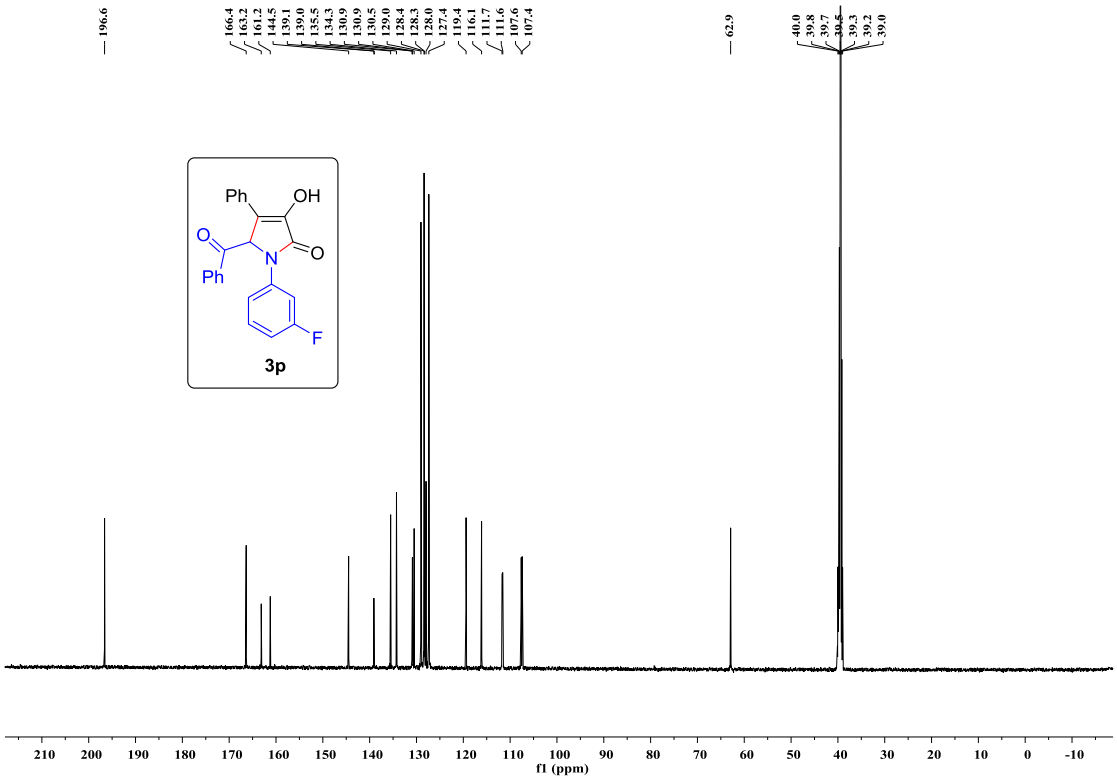
7.9799
7.9644
7.6977
7.6918
7.6819
7.6753
7.6585
7.6521
7.6221
7.6072
7.5921
7.4847
7.4699
7.4551
7.4135
7.3980
7.3827
7.3670
7.2893
7.2740
7.2588
7.2313
7.1972
7.1825
7.1678
6.9811
6.9764
6.9640
6.9596
6.9473
6.9427
2.5003
Ph
OH
O
N
O
Ph
F
3p
2.08
3.12
1.03
3.09
1.05
2.08
1.08
1.02
0.99
f1 (ppm)
0.99
2.08
3.12
1.03
3.09
1.05
2.08
1.08
1.02
0.99
f1 (ppm)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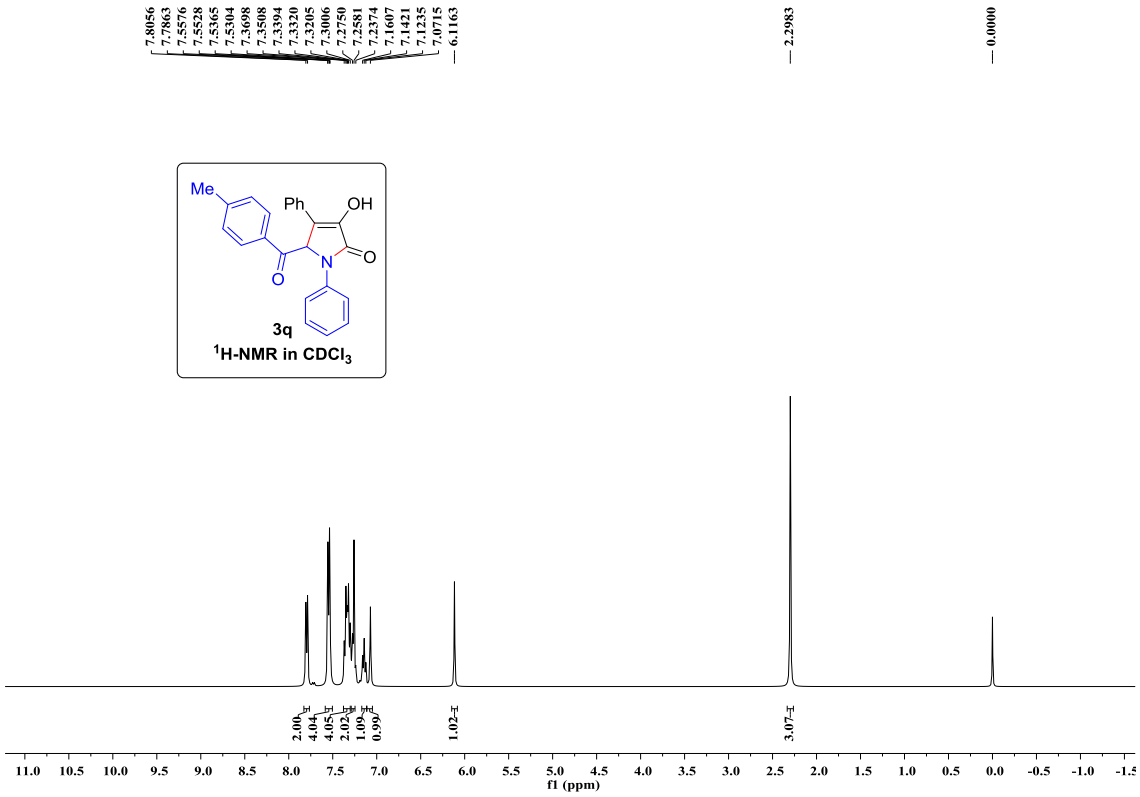
166.4
163.2
161.2
144.5
139.1
139.0
135.5
134.3
130.9
130.9
130.5
129.0
128.4
128.3
128.0
127.4
119.4
116.1
111.7
111.6
107.6
107.4
62.9
40.0
39.8
39.7
39.5
39.3
39.2
39.0
Ph
OH
O
N
O
Ph
F
3p
f1 (ppm)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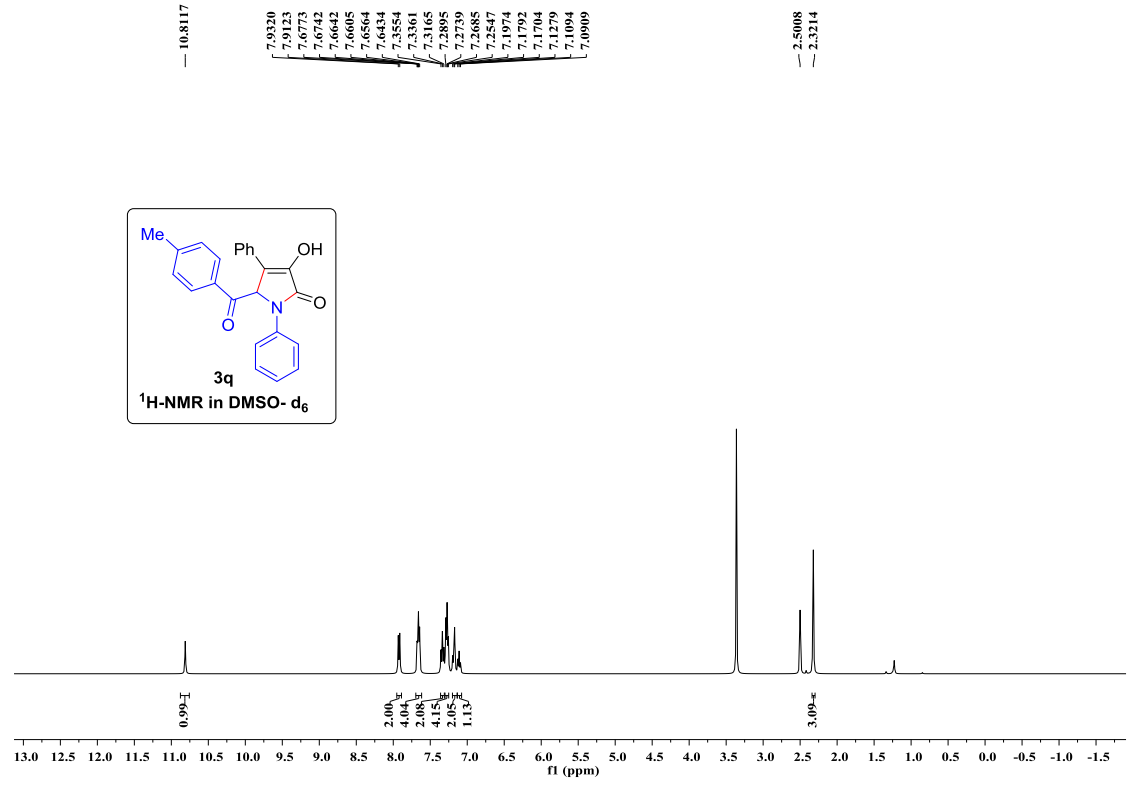
7.7863
7.5576
7.5528
7.5365
7.5304
7.3698
7.3508
7.3394
7.3320
7.3205
7.3006
7.2750
7.2581
7.2374
7.1607
7.1421
7.1235
7.0715
6.1163
2.2983
0.0000
Me
Ph
OH
O
N
O
3q
1H-NMR in CDCl3
2.00
4.04
4.05
2.02
1.09
0.99
1.02
3.07
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)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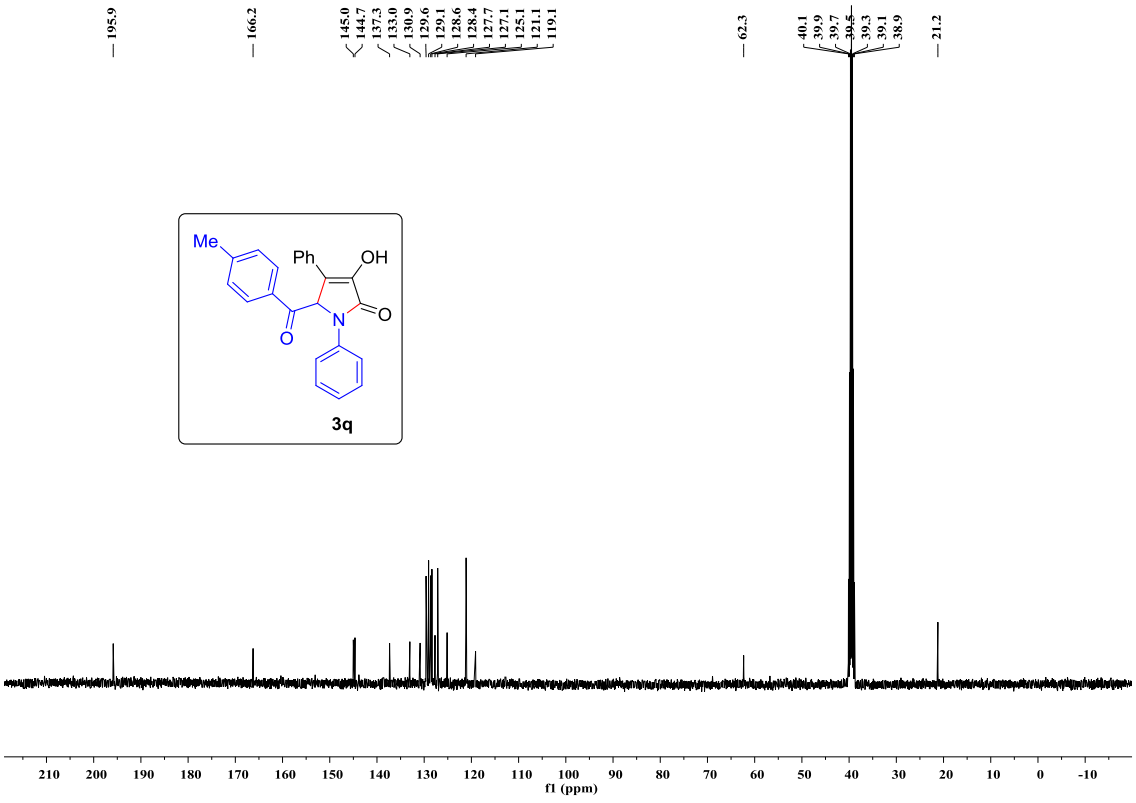
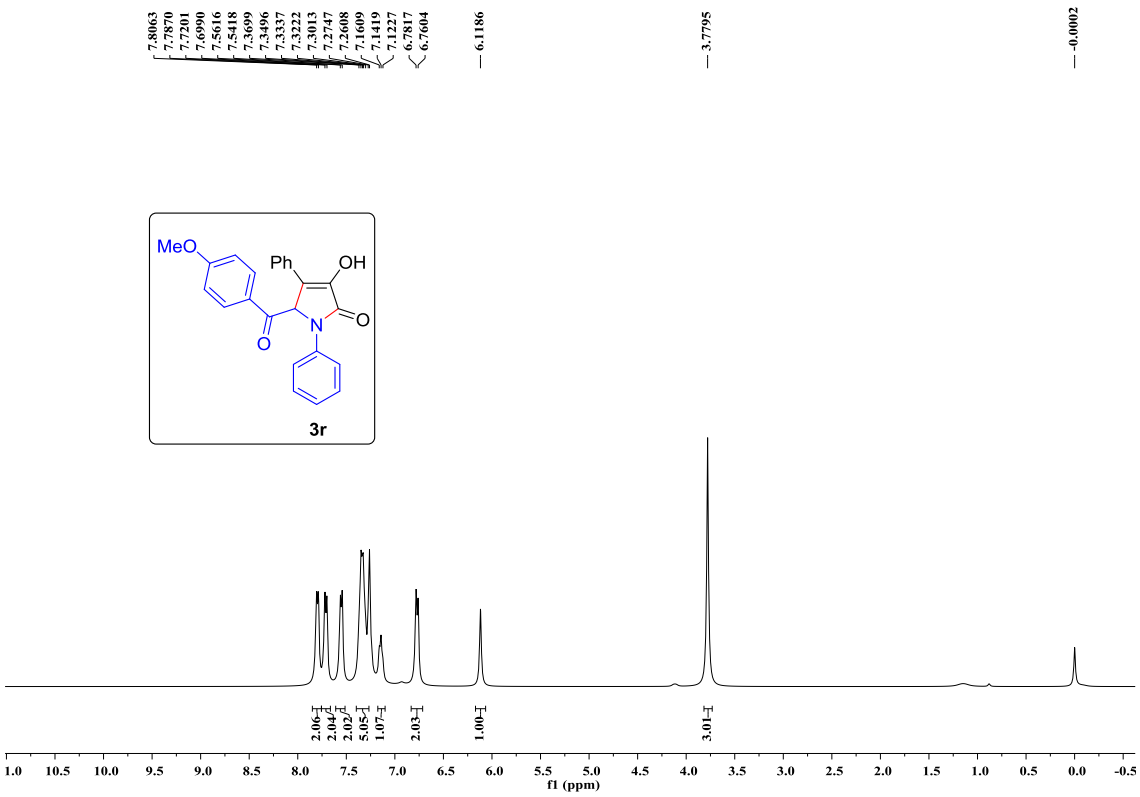
7.9320
7.9123
7.6773
7.6742
7.6642
7.6605
7.6564
7.6434
7.3554
7.3361
7.3165
7.2895
7.2739
7.2685
7.2547
7.1974
7.1792
7.1704
7.1279
7.1094
7.0909
2.5008
2.3214
Me
Ph
OH
O
N
O
3q
1H-NMR in DMSO- d6
0.99
2.00
4.04
2.08
4.15
2.05
1.13
3.09
13.0 12.5 12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0 -1.5
f1 (ppm)


195.9
166.2
145.0
144.7
137.3
133.0
130.9
129.6
129.1
128.6
128.4
127.7
127.1
125.1
121.1
119.1
62.3
40.1
39.9
39.7
39.5
39.3
39.1
38.9
21.2
Me
Ph
OH
O
N
O
3q
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)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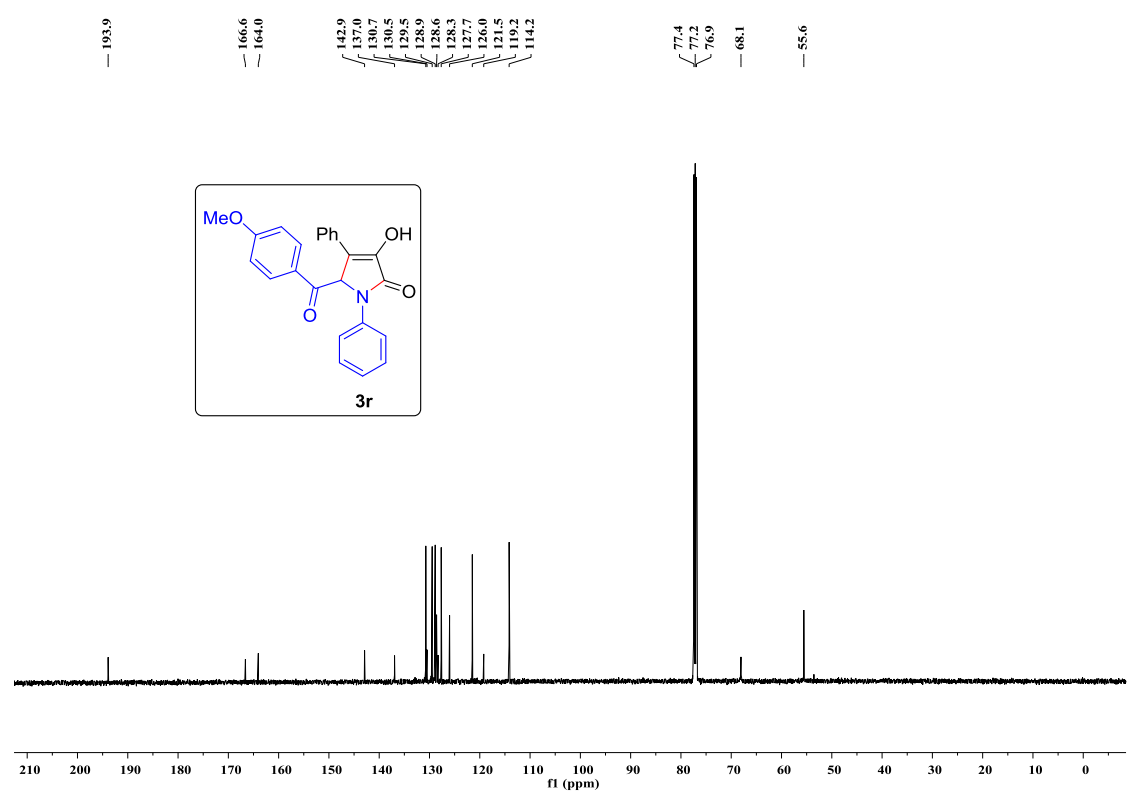
7.7201
7.6990
7.5616
7.5418
7.3699
7.3496
7.3337
7.3222
7.3013
7.2747
7.2608
7.1609
7.1419
7.1227
6.7817
6.7604
6.1186
3.7795
-0.0002
MeO
Ph
OH
O
N
O
3r
2.06
2.04
2.02
5.05
1.07
2.03
1.00
3.01
f1 (ppm)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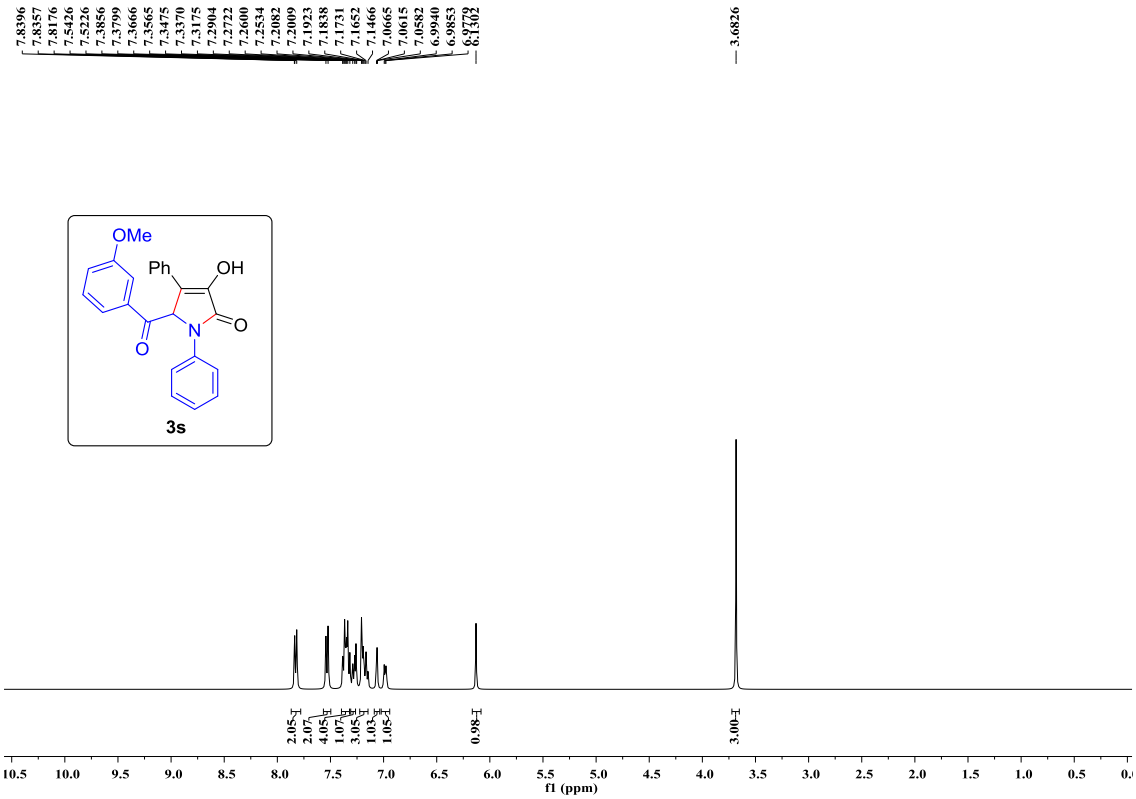
166.6
164.0
142.9
137.0
130.7
130.5
129.5
128.9
128.6
128.3
127.7
126.0
121.5
119.2
114.2
77.4
77.2
76.9
68.1
55.6
MeO
Ph
OH
O
N
O
3r
f1 (ppm)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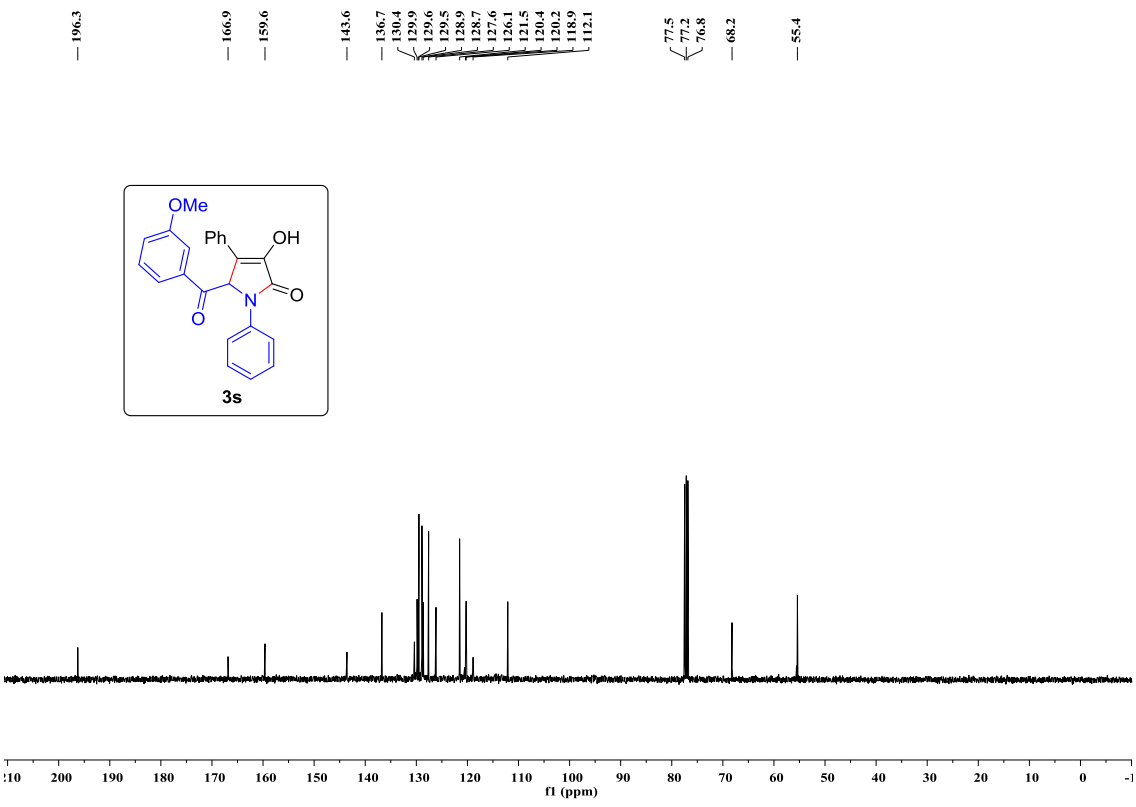
7.8357
7.8176
7.5426
7.5226
7.3856
7.3799
7.3666
7.3565
7.3475
7.3370
7.3175
7.2904
7.2722
7.2600
7.2534
7.2082
7.2009
7.1923
7.1838
7.1731
7.1652
7.1466
7.0665
7.0615
7.0582
6.9940
6.9853
6.9729
6.9302
3.6826
OMe
Ph
OH
O
N
O
3s
2.05
2.07
4.05
1.07
3.05
1.03
1.05
0.98
3.00
f1 (ppm)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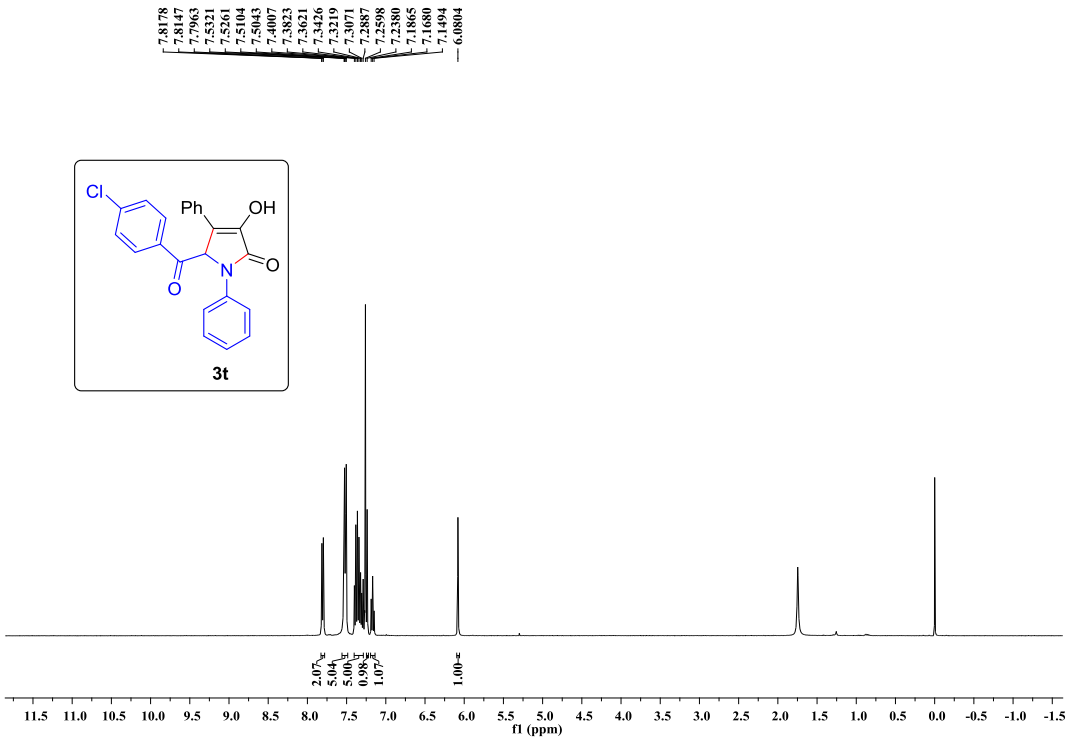
159.6
143.6
136.7
130.4
129.9
129.6
129.5
128.9
128.7
127.6
126.1
121.5
120.4
120.2
118.9
112.1
77.5
77.2
76.8
68.2
55.4
OMe
Ph
OH
O
N
O
3s
f1 (ppm)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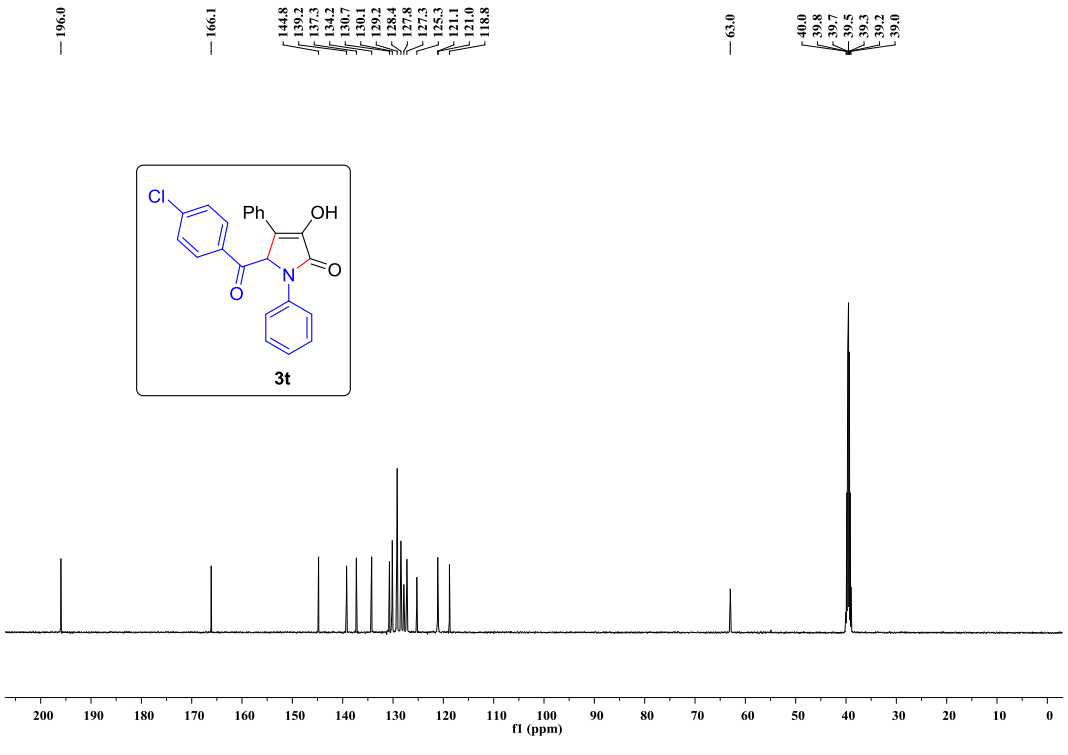
7.8147
7.7963
7.5321
7.5261
7.5104
7.5043
7.4007
7.3823
7.3621
7.3426
7.3219
7.3071
7.2887
7.2598
7.2380
7.1865
7.1680
7.1494
6.0804
Cl
Ph
OH
O
N
O
3t
2.07
5.04
5.00
0.98
1.07
1.00
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0 -1.5
f1 (ppm)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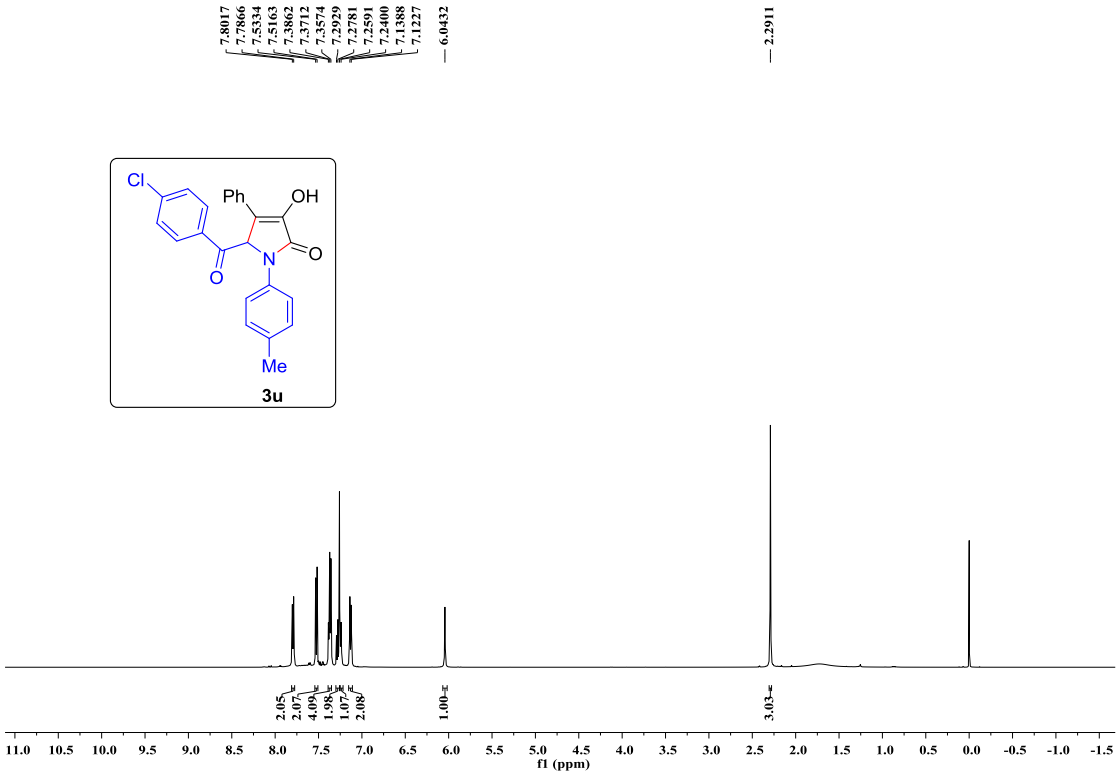
144.8
139.2
137.3
134.2
130.7
130.1
129.2
128.4
127.8
127.3
125.3
121.1
121.0
118.8
63.0
40.0
39.8
39.7
39.5
39.3
39.2
39.0
Cl
Ph
OH
O
N
O
3t
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)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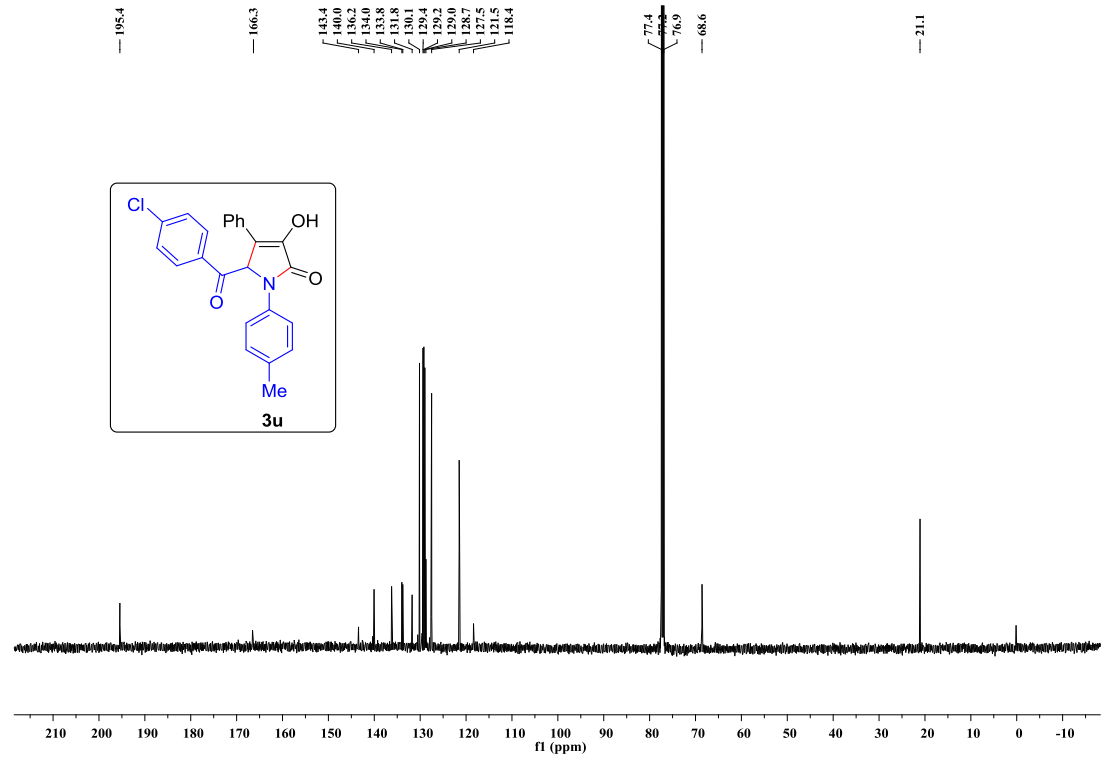
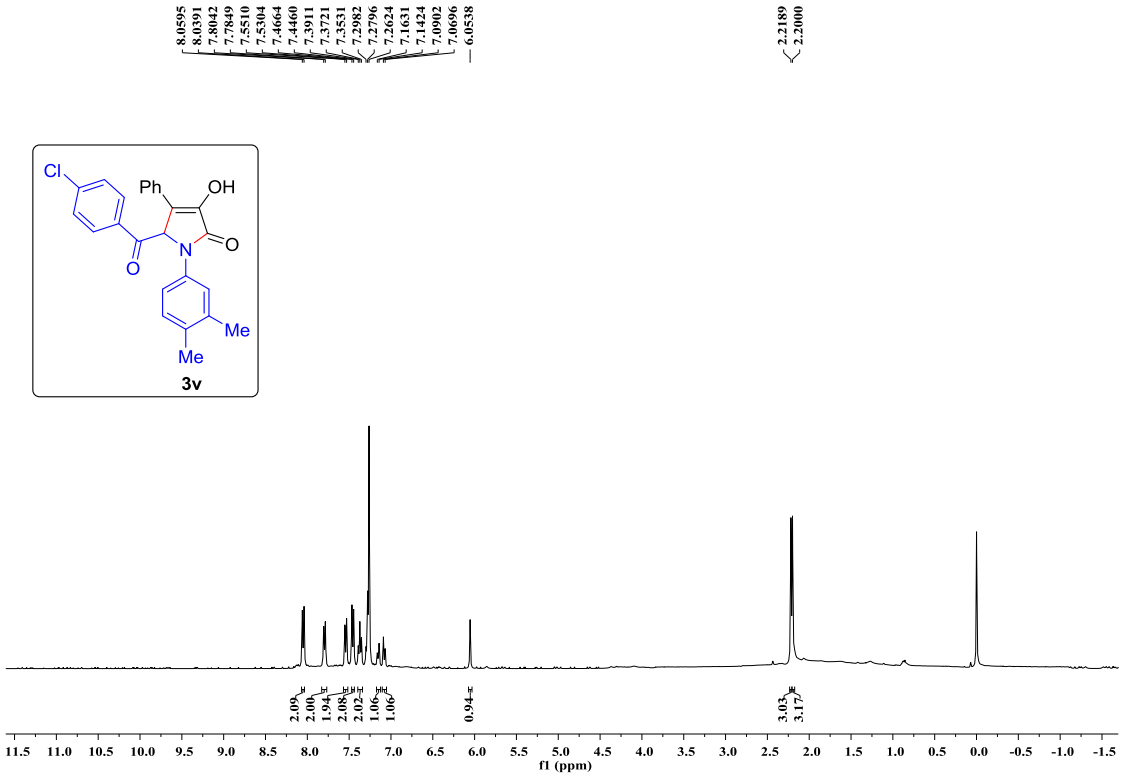
7.5163
7.3862
7.3712
7.3574
7.2929
7.2781
7.2591
7.2400
7.1388
7.1227
6.0432
2.2911
Cl
Ph
OH
O
N
O
Me
3u
2.05
2.07
4.09
1.98
1.07
2.08
1.00
3.03
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0 -1.5
f1 (ppm)


195.4
166.3
143.4
140.0
136.2
134.0
133.8
131.8
130.1
129.4
129.2
129.0
128.7
127.5
121.5
118.4
77.4
77.2
76.9
68.6
21.1
Cl
Ph
OH
O
N
O
Me
3u
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)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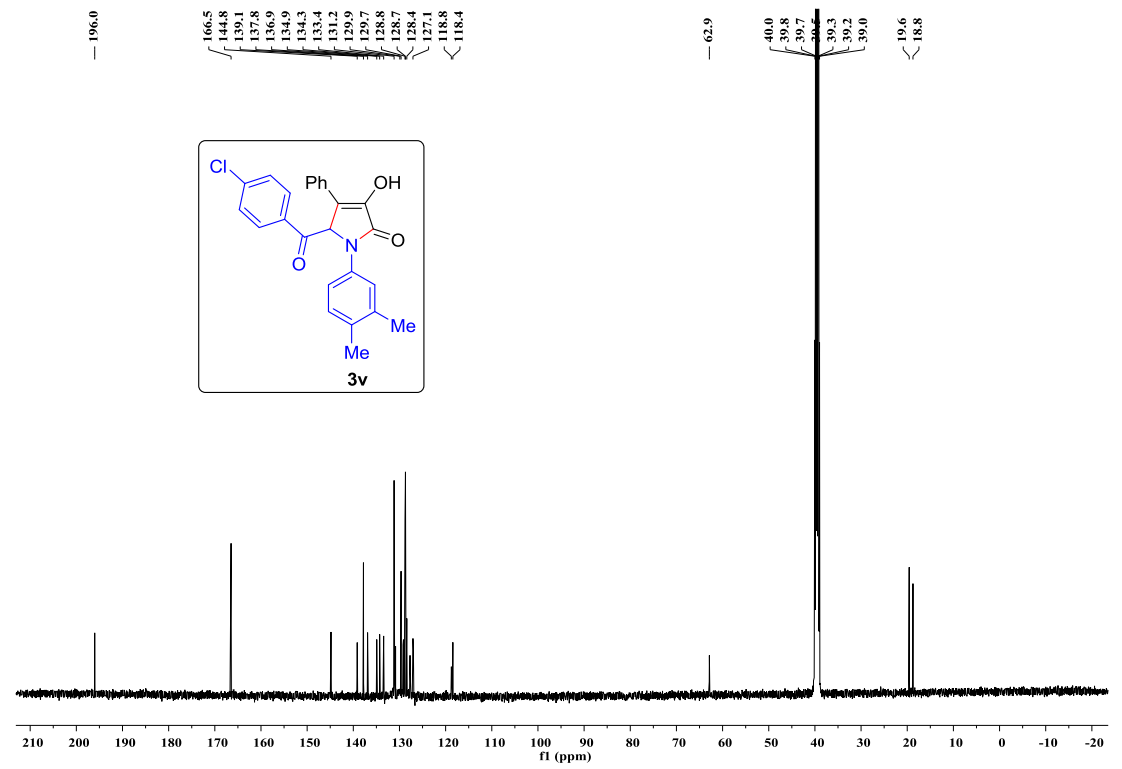
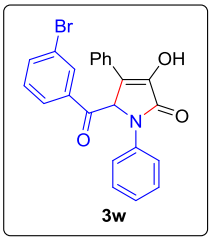
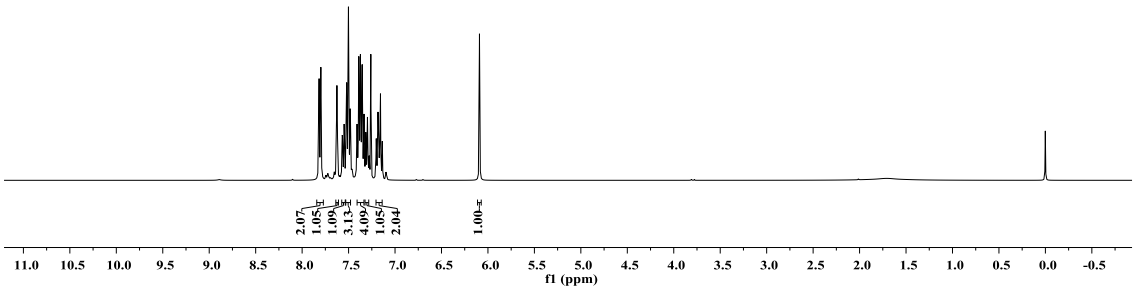
7.8042
7.7849
7.5510
7.5304
7.4664
7.4460
7.3911
7.3721
7.3531
7.2982
7.2796
7.2624
7.1631
7.1424
7.0902
7.0696
6.0538
2.2189
2.2000
Cl
Ph
OH
O
O
N
O
Me
Me
3v
2.09
2.00
1.94
2.08
2.02
1.06
1.06
0.94
3.03
3.17
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0 -1.5
f1 (ppm)


196.0
166.5
144.8
139.1
137.8
136.9
134.9
134.3
133.4
131.2
129.9
129.7
128.8
128.7
128.4
127.1
118.8
118.4
62.9
40.0
39.8
39.7
39.3
39.2
39.0
19.6
18.8
Cl
Ph
OH
O
O
N
O
Me
Me
3v
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
f1 (ppm)


7.8171
7.7986
7.6302
7.6254
7.6206
7.5699
7.5652
7.5509
7.5469
7.5243
7.5206
7.5057
7.5011
7.4858
7.4816
7.4090
7.3902
7.3865
7.3737
7.3701
7.3539
7.3377
7.3337
7.3155
7.2967
7.2605
7.1836
7.1766
7.0913
0.0010


Br
Ph
OH
O
N
O

3w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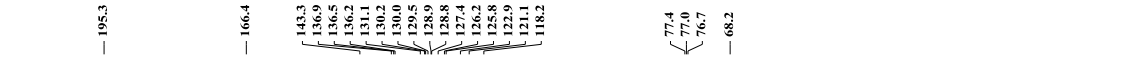
1.05
1.09
3.13
4.09
1.05
2.04
1.00
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)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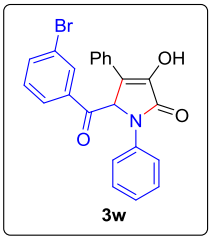
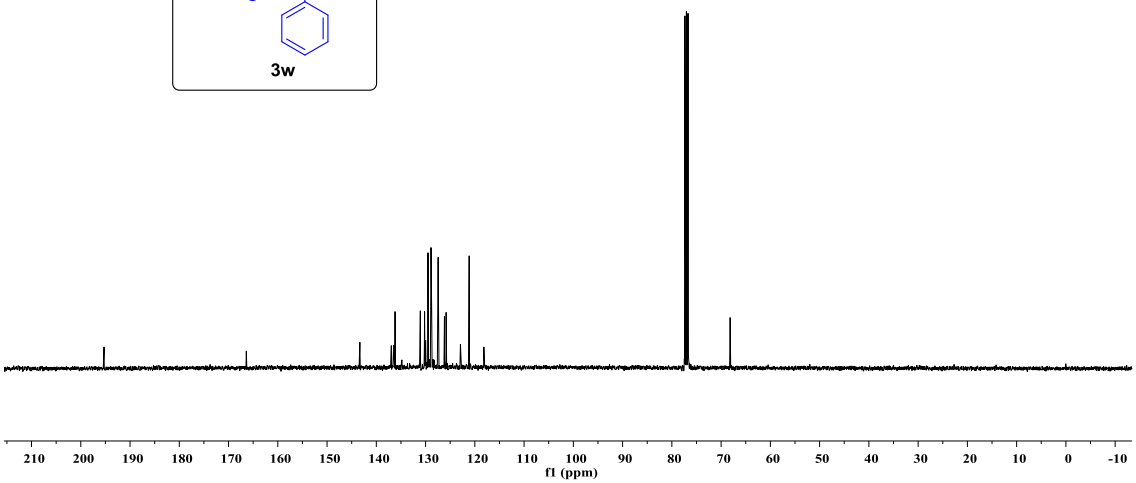
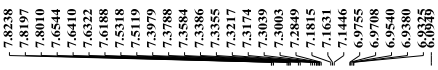
166.4
143.3
136.9
136.5
136.2
131.1
130.2
130.0
129.5
128.9
128.8
127.4
126.2
125.8
122.9
121.1
118.2
77.4
77.0
76.7
68.2


Br
Ph
OH
O
N
O

3w


210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)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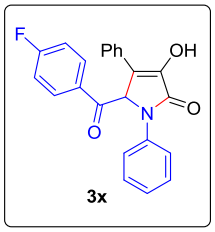
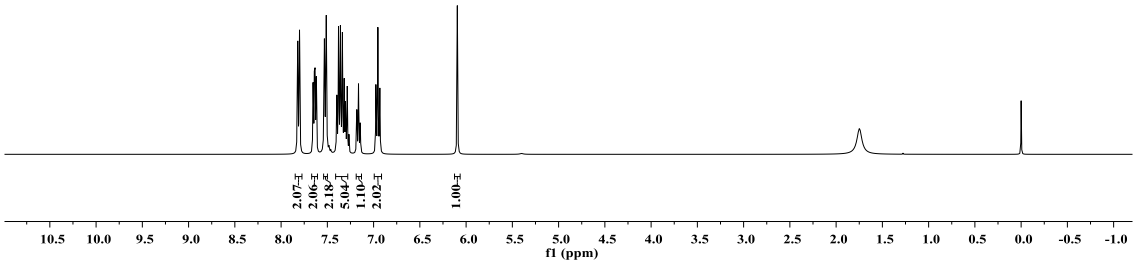
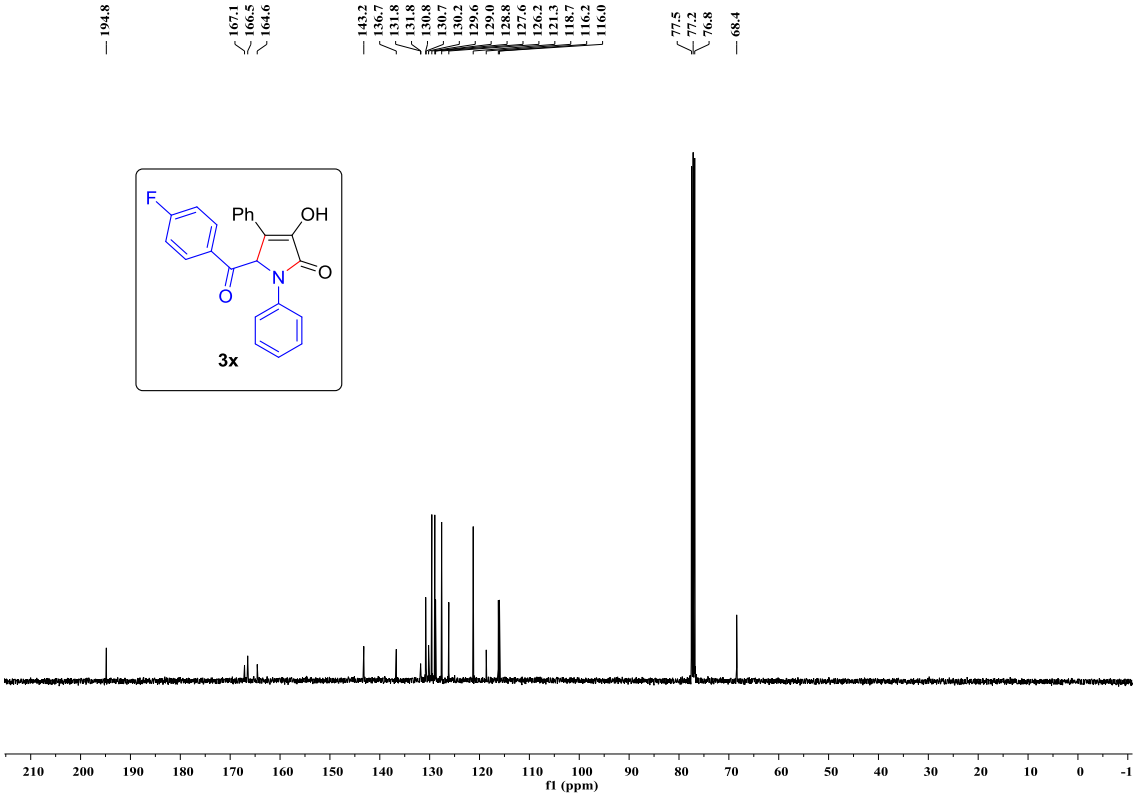
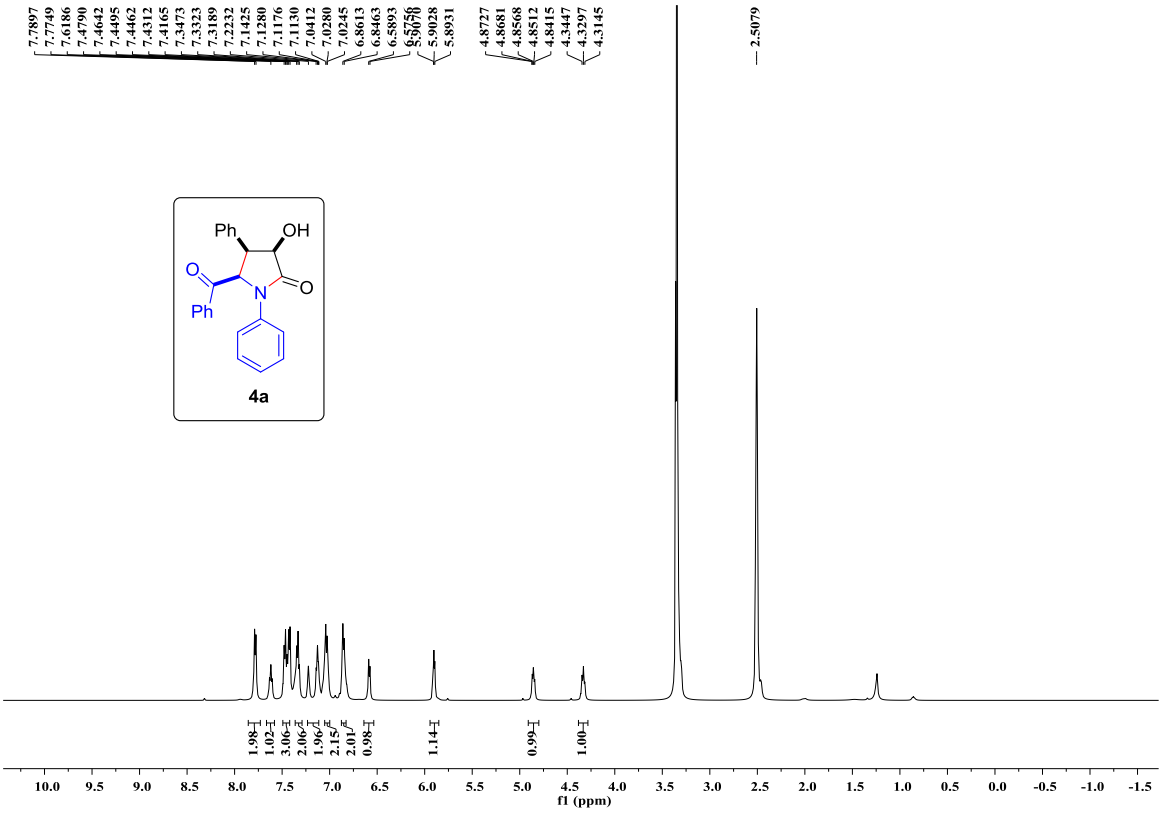
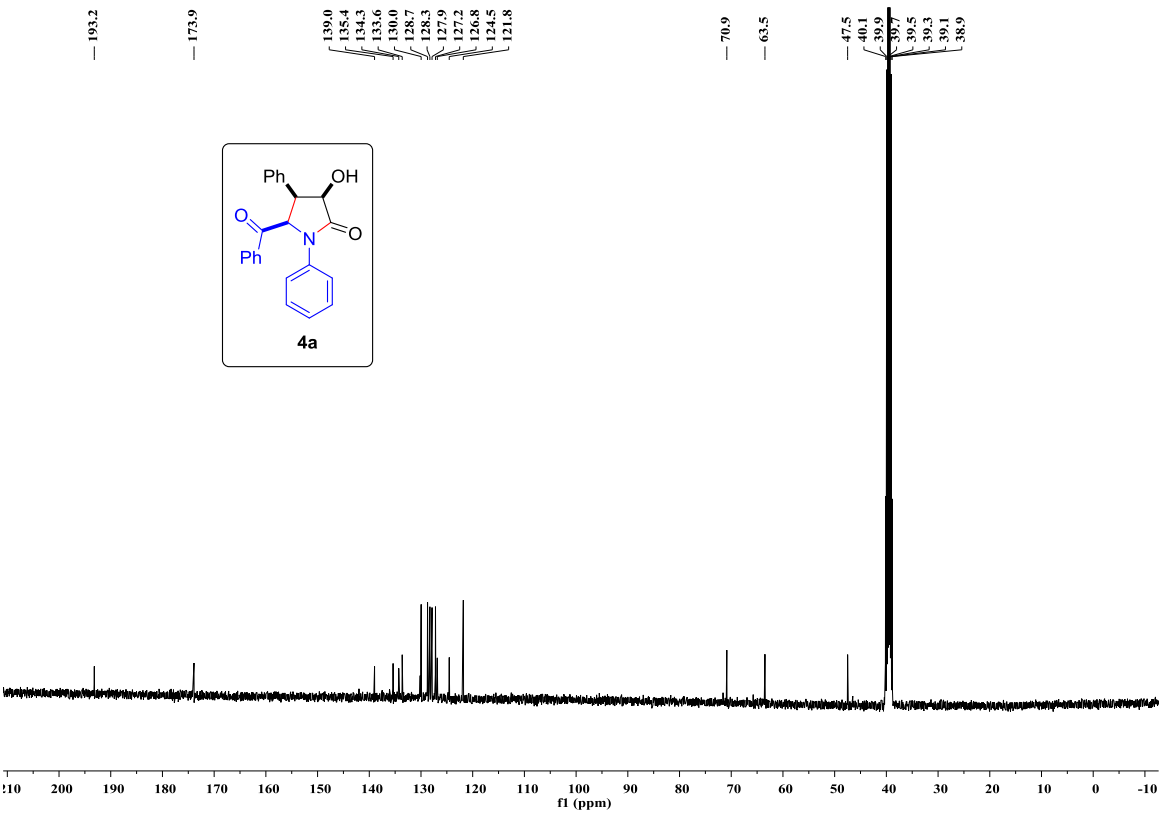
7.8197
7.8010
7.6544
7.6410
7.6322
7.6188
7.5318
7.5119
7.3979
7.3788
7.3584
7.3386
7.3355
7.3217
7.3174
7.3039
7.3003
7.2849
7.1815
7.1631
7.1446
6.9755
6.9708
6.9540
6.9380
6.9325
6.0039
-0.0002

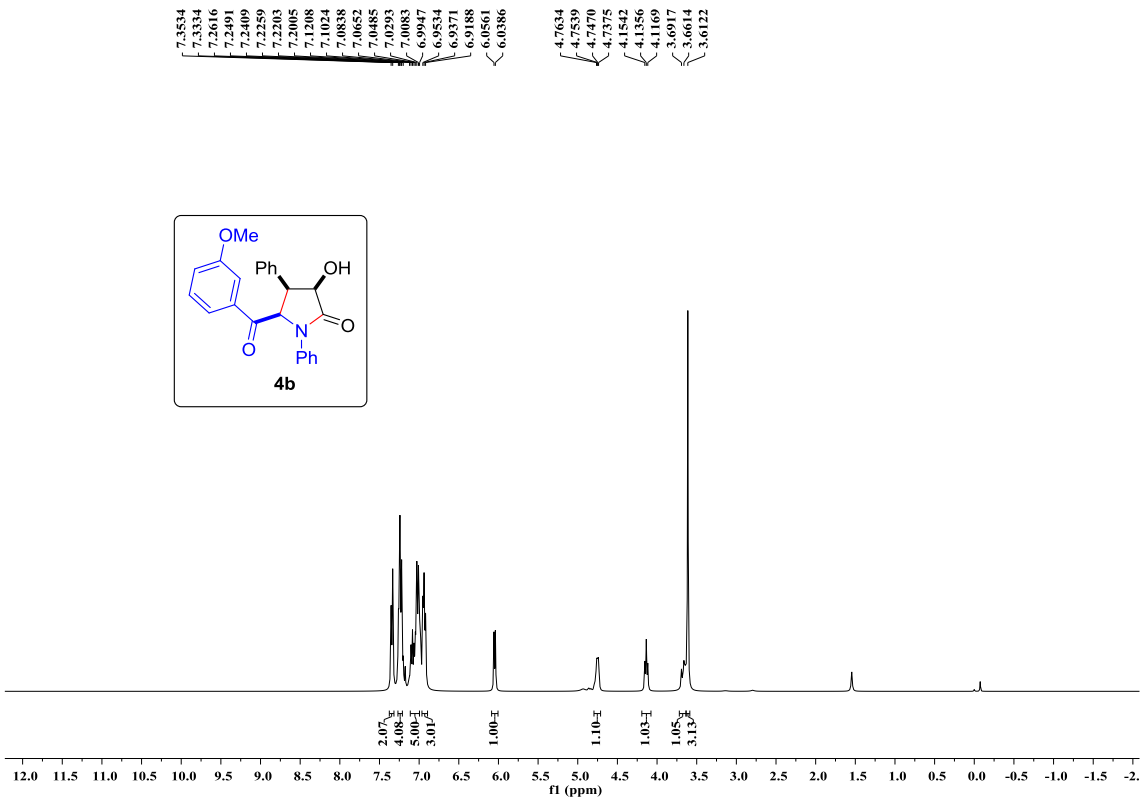

F
Ph
OH
O
N
O
3x


2.07
2.06
2.18
5.04
1.10
2.02
1.00
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)


194.8
167.1
166.5
164.6
143.2
136.7
131.8
131.8
130.8
130.7
130.2
129.6
129.0
128.8
127.6
126.2
121.3
118.7
116.2
116.0
77.5
77.2
76.8
68.4
F
Ph
OH
O
N
O
3x
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -1
f1 (ppm)


7.7897
7.7749
7.6186
7.4790
7.4642
7.4495
7.4462
7.4312
7.4165
7.3473
7.3323
7.3189
7.2232
7.1425
7.1280
7.1176
7.1130
7.0412
7.0280
7.0245
6.8613
6.8463
6.5893
6.5756
5.9070
5.9028
5.8931
4.8727
4.8681
4.8568
4.8512
4.8415
4.3447
4.3397
4.3145
2.5079
Ph
OH
O
N
O
Ph
4a
1.98
1.02
3.06
2.06
1.96
2.15
2.01
0.98
1.14
0.99
1.00
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0 -1.5
f1 (ppm)


193.2
173.9
139.0
135.4
134.3
133.6
130.0
128.7
128.3
127.9
127.2
126.8
124.5
121.8
70.9
63.5
47.5
40.1
39.9
39.7
39.5
39.3
39.1
38.9
Ph
OH
O
N
O
Ph
4a
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)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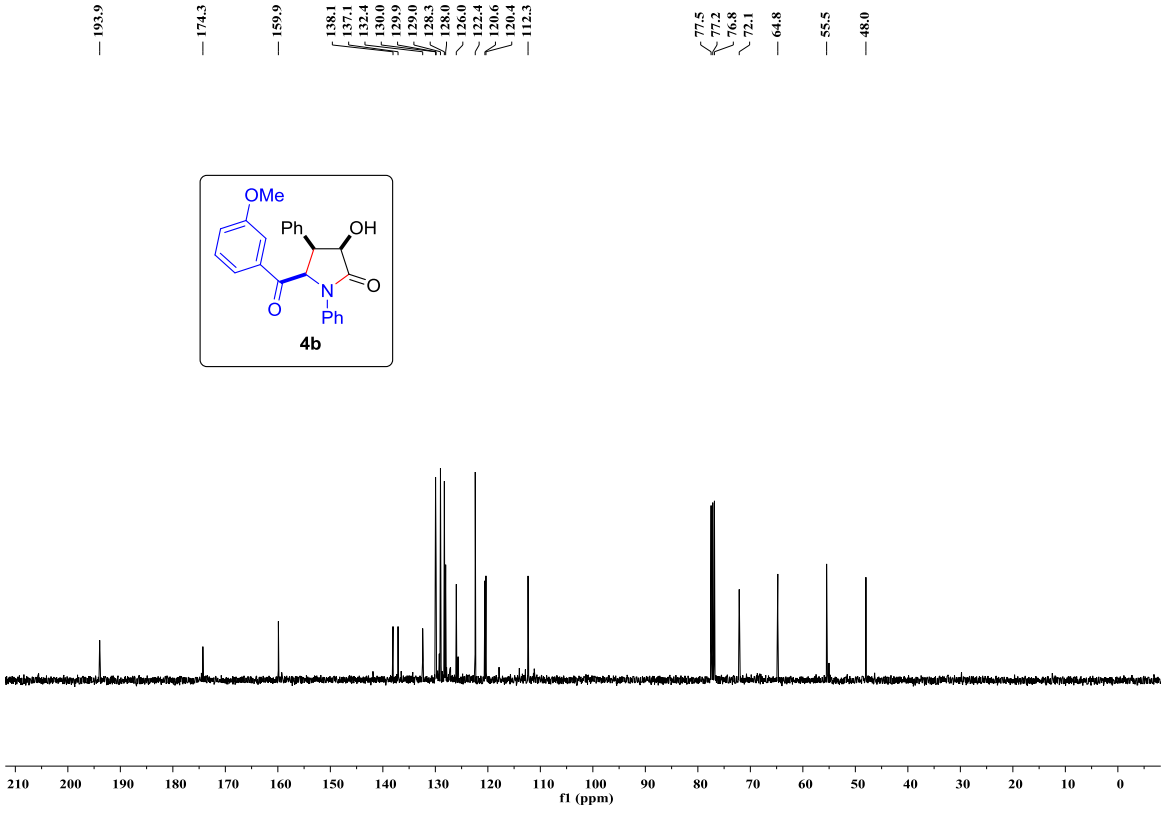
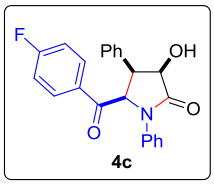
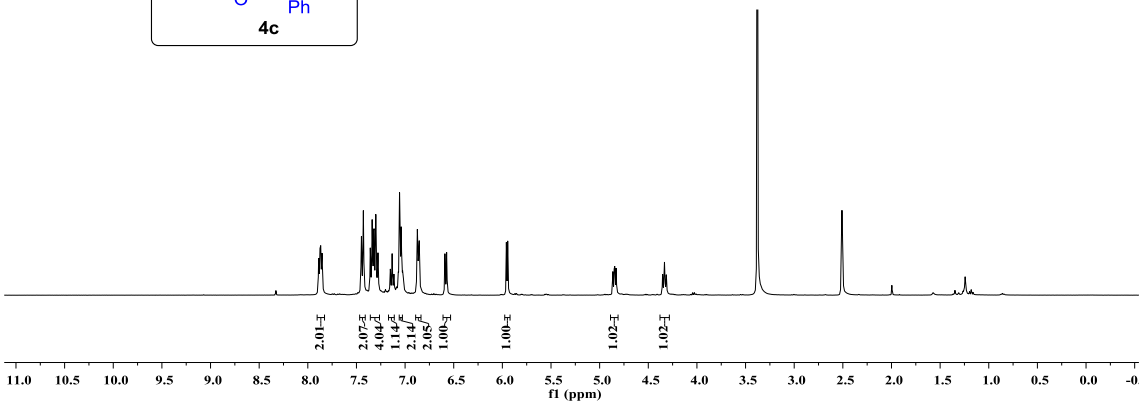
7.3334
7.2616
7.2491
7.2409
7.2259
7.2203
7.2005
7.1208
7.1024
7.0838
7.0652
7.0485
7.0293
7.0083
6.9947
6.9534
6.9371
6.9188
6.0561
6.0386
4.7634
4.7539
4.7470
4.7375
4.1542
4.1356
4.1169
3.6917
3.6614
3.6122
OMe
Ph
OH
N
O
O
Ph
4b
2.07
4.08
5.00
3.01
1.00
1.10
1.03
1.05
3.13
f1 (ppm)

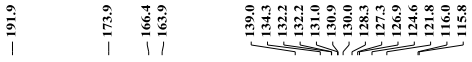

193.9
174.3
159.9
138.1
137.1
132.4
130.0
129.9
129.0
128.3
128.0
126.0
122.4
120.6
120.4
112.3
77.5
77.2
76.8
72.1
64.8
55.5
48.0
OMe
Ph
OH
N
O
O
Ph
4b
f1 (ppm)

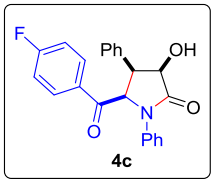

7.8891
7.8752
7.8674
7.8532
7.4524
7.4486
7.4302
7.4276
7.3578
7.3381
7.3229
7.3183
7.3008
7.2790
7.1548
7.1518
7.1487
7.1329
7.1182
7.1151
7.1121
7.0571
7.0521
7.0395
6.8780
6.8740
6.8693
6.8593
6.8538
6.5903
6.5729
5.9588
5.9450
4.8647
4.8510
4.8441
4.8304
4.3528
4.3336
4.3145


F
Ph
OH
O
N
O
Ph

4c

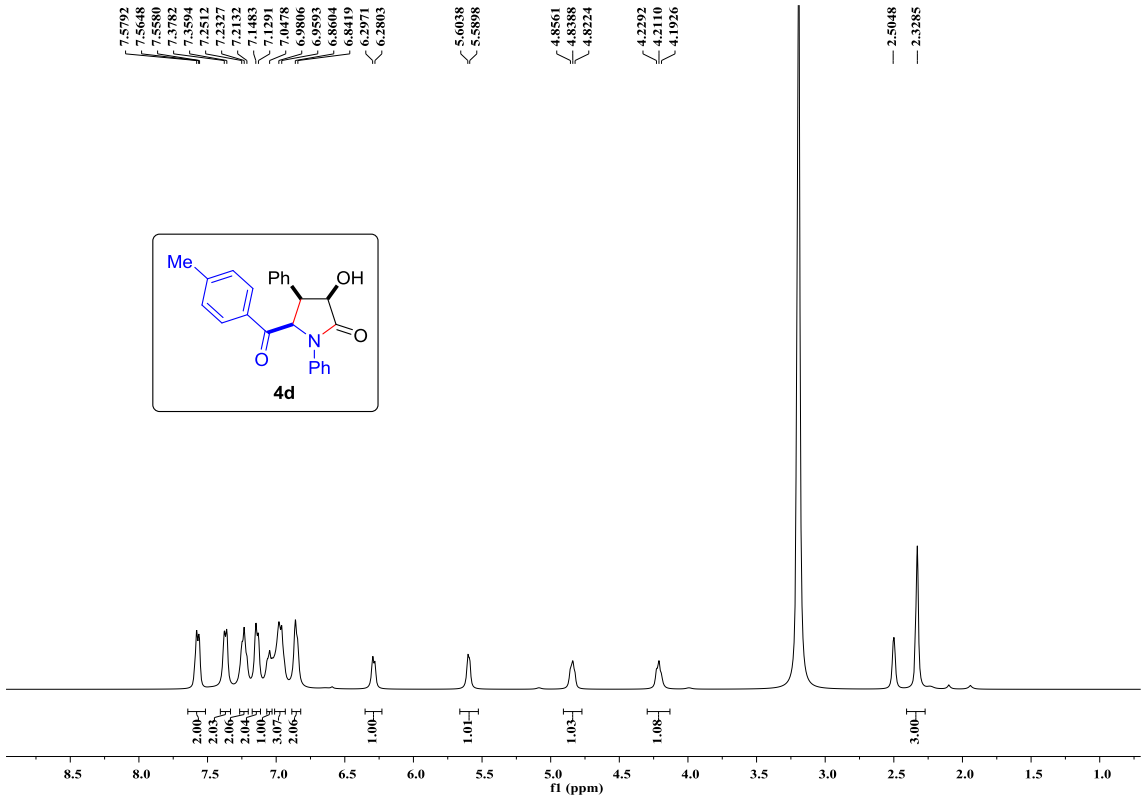

2.01
2.07
4.04
1.14
2.14
2.05
1.00
1.00
1.02
1.02
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0
f1 (ppm)


191.9
173.9
166.4
163.9
139.0
134.3
132.2
132.2
131.0
130.9
130.0
128.3
127.3
126.9
124.6
121.8
116.0
115.8
70.8
63.5
47.4
40.1
39.9
39.7
39.5
39.3
39.1
38.9


F
Ph
OH
O
N
O
Ph

4c

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


7.5792
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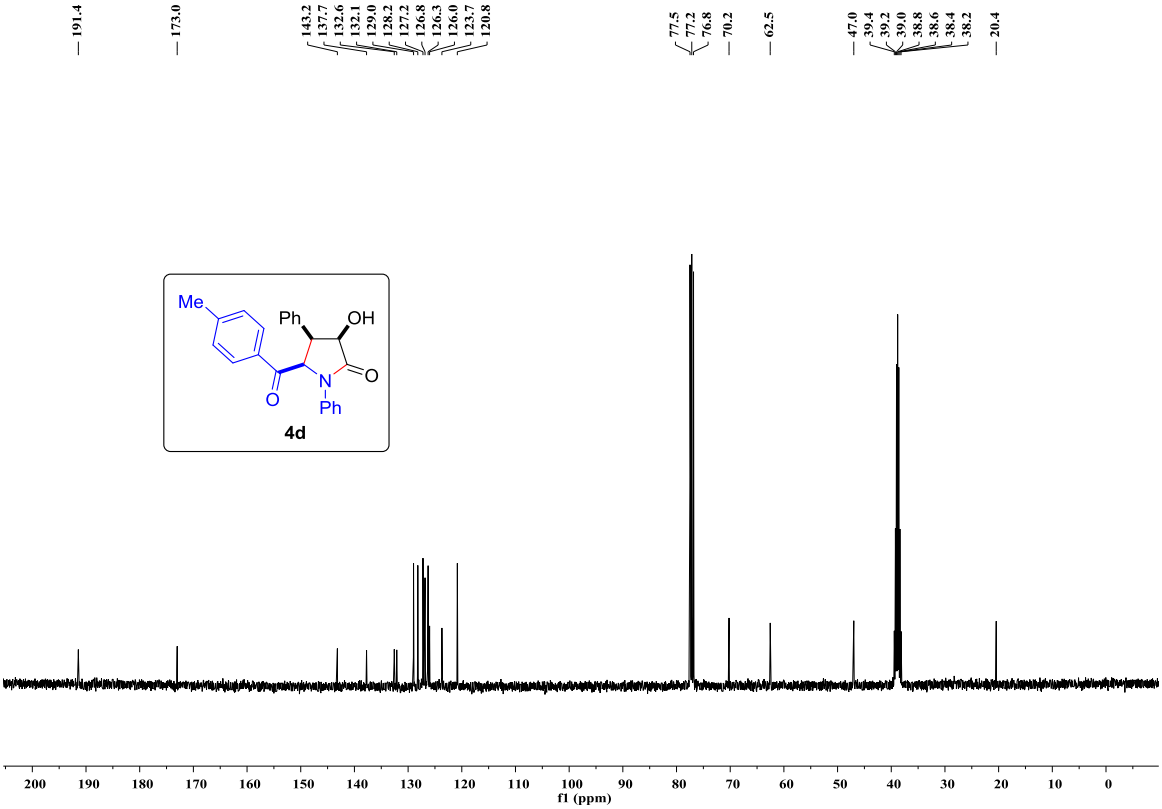
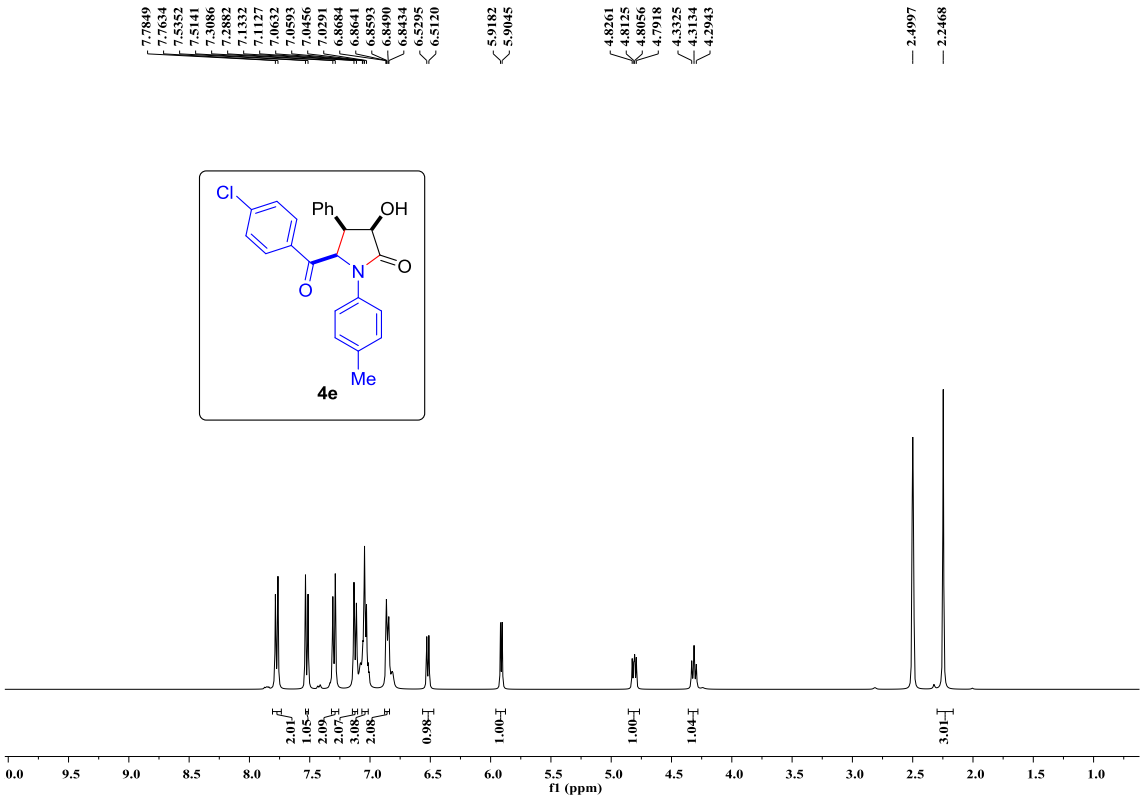
7.5580
7.3782
7.3594
7.2512
7.2327
7.2132
7.1483
7.1291
7.0478
6.9806
6.9593
6.8604
6.8419
6.2971
6.2803
5.6038
5.5898
4.8561
4.8388
4.8224
4.2292
4.2110
4.1926
2.5048
2.3285
Me
Ph
OH
O
N
Ph
O
4d
2.00
2.03
2.06
2.04
1.00
3.07
2.06
1.00
1.01
1.03
1.08
3.00
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
f1 (ppm)


191.4
173.0
143.2
137.7
132.6
132.1
129.0
128.2
127.2
126.8
126.3
126.0
123.7
120.8
77.5
77.2
76.8
70.2
62.5
47.0
39.4
39.2
39.0
38.8
38.6
38.4
38.2
20.4
Me
Ph
OH
O
N
Ph
O
4d
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)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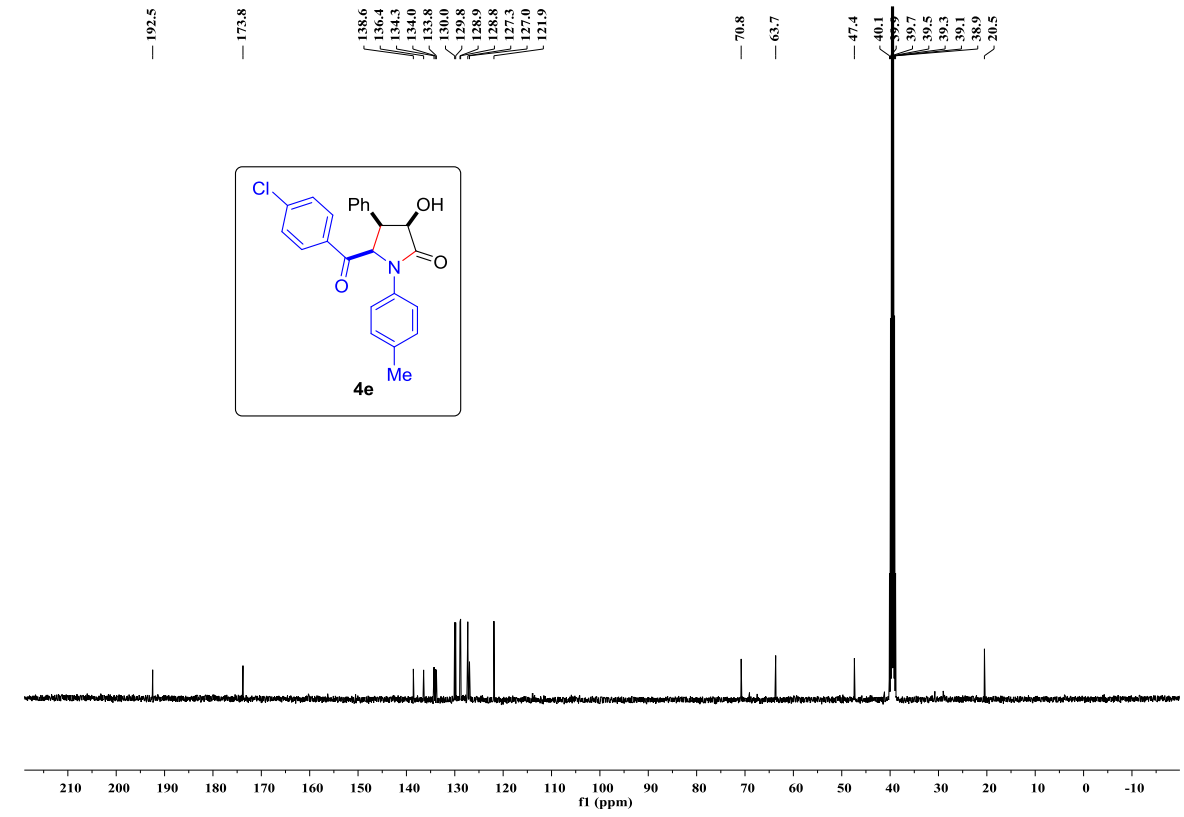
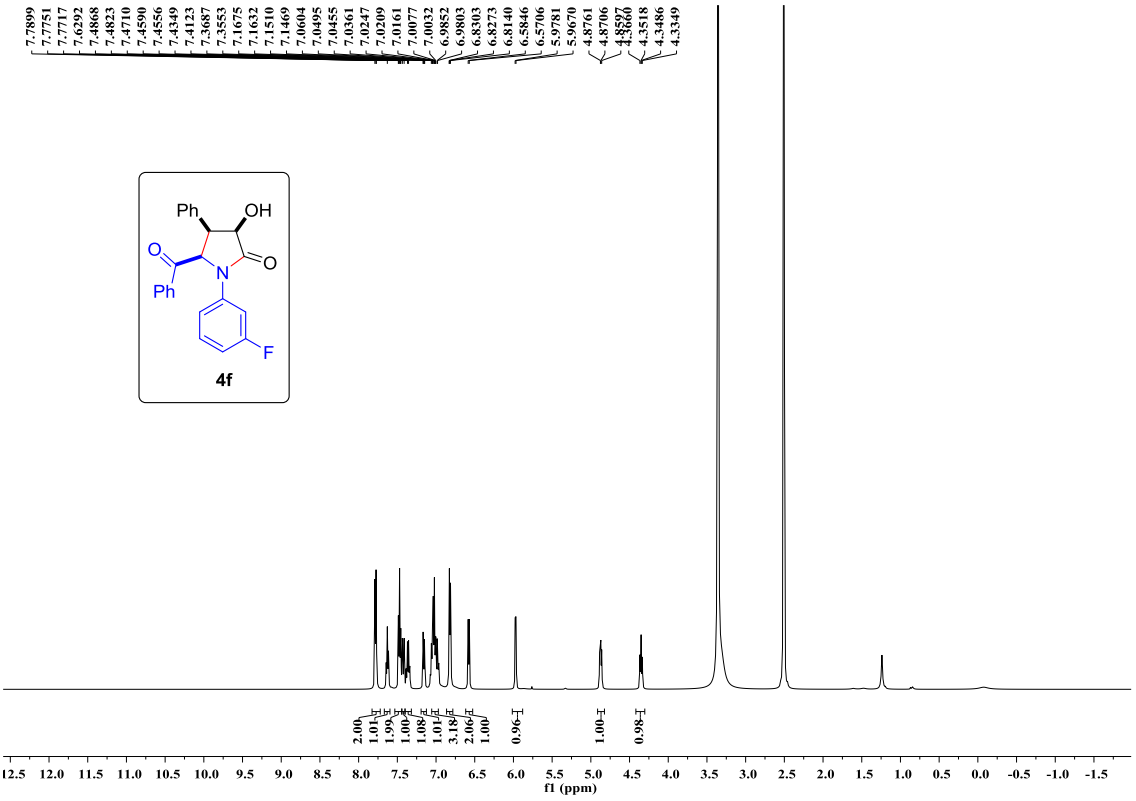
7.5141
7.3086
7.2882
7.1332
7.1127
7.0632
7.0593
7.0456
7.0291
6.8684
6.8641
6.8593
6.8490
6.8434
6.5295
6.5120
5.9182
5.9045
4.8261
4.8125
4.8056
4.7918
4.3325
4.3134
4.2943
2.4997
2.2468
Cl
Ph
OH
O
N
O
Me
4e
2.01
1.05
2.09
2.07
3.08
2.08
0.98
1.00
1.00
1.04
3.01
f1 (ppm)


192.5
173.8
138.6
136.4
134.3
134.0
133.8
130.0
129.8
128.9
128.8
127.3
127.0
121.9
70.8
63.7
47.4
40.1
39.9
39.7
39.5
39.3
39.1
38.9
20.5
Cl
Ph
OH
O
N
O
Me
4e
f1 (ppm)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7.4868
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7.4710
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7.4556
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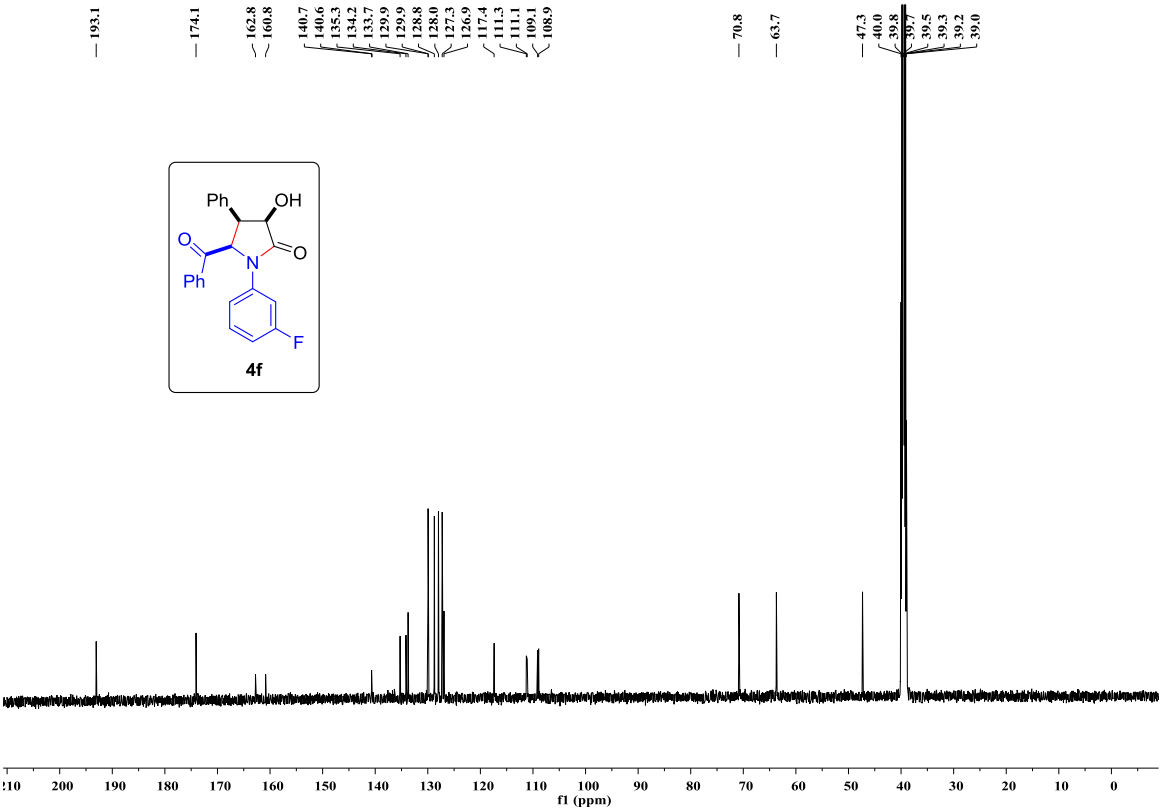
7.4123
7.3687
7.3553
7.1675
7.1632
7.1510
7.1469
7.0604
7.0495
7.0455
7.0361
7.0247
7.0209
7.0161
7.0077
7.0032
6.9852
6.9803
6.8303
6.8273
6.8140
6.5846
6.5706
5.9781
5.9670
4.8761
4.8706
4.8597
4.3660
4.3518
4.3486
4.3349
Ph
OH
O
O
N
Ph
F
4f
2.00
1.01
1.99
1.00
1.08
1.01
3.18
2.06
1.00
0.96
1.00
0.98
f1 (ppm)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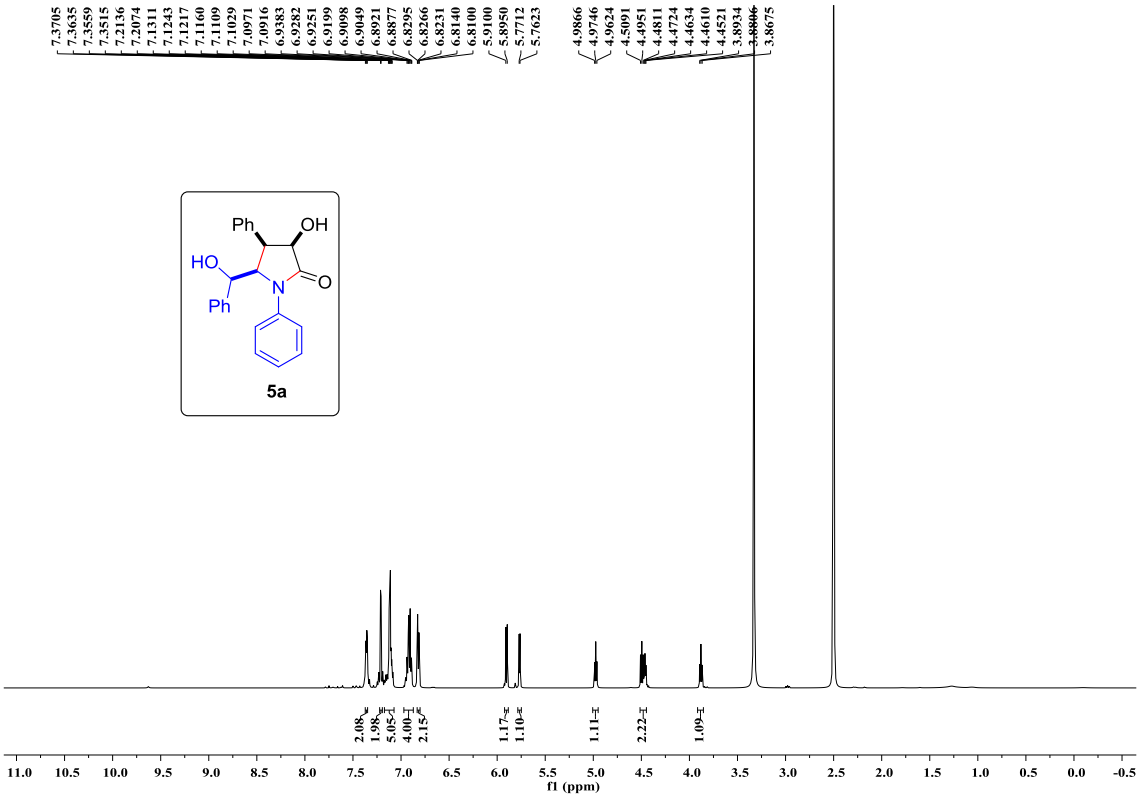
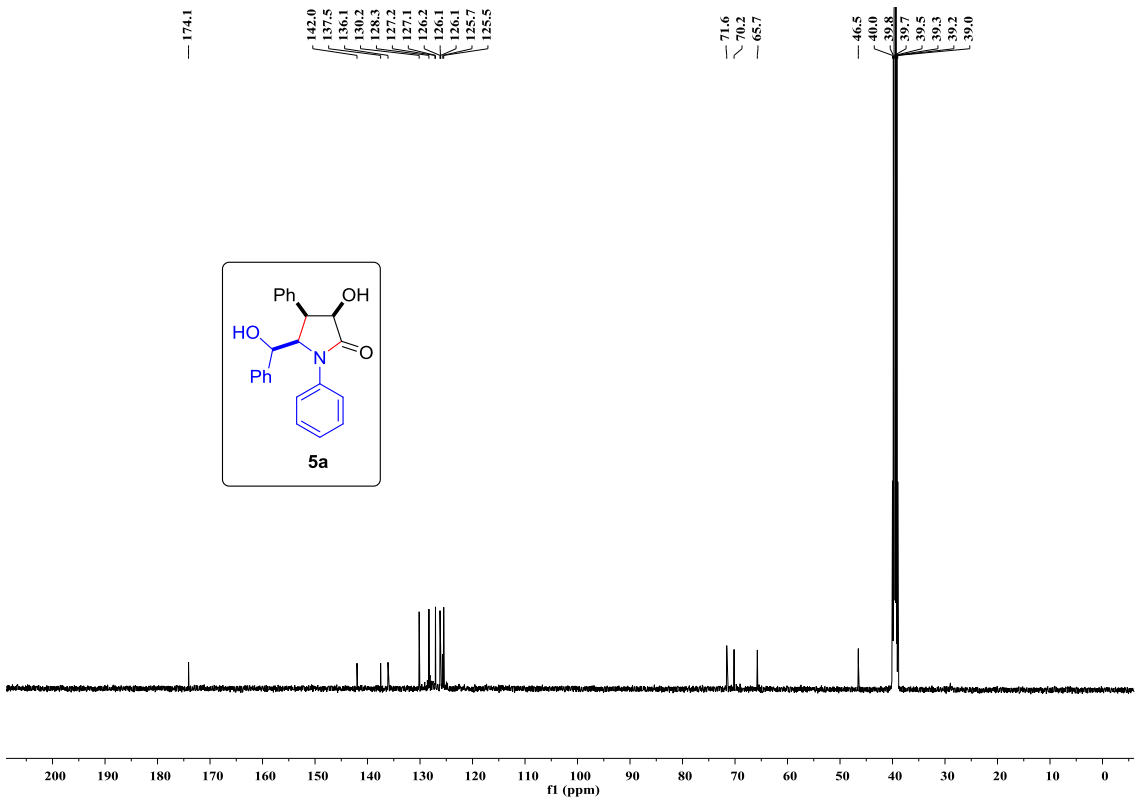
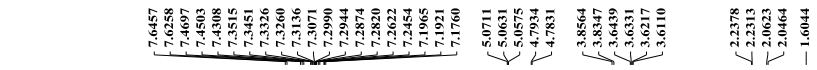
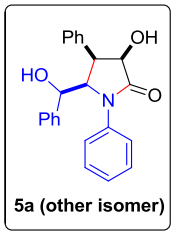
174.1
162.8
160.8
140.7
140.6
135.3
134.2
133.7
129.9
129.9
128.8
128.0
127.3
126.9
117.4
111.3
111.1
109.1
108.9
70.8
63.7
47.3
40.0
39.8
39.7
39.5
39.3
39.2
39.0
Ph
OH
O
O
N
Ph
F
4f
f1 (ppm)

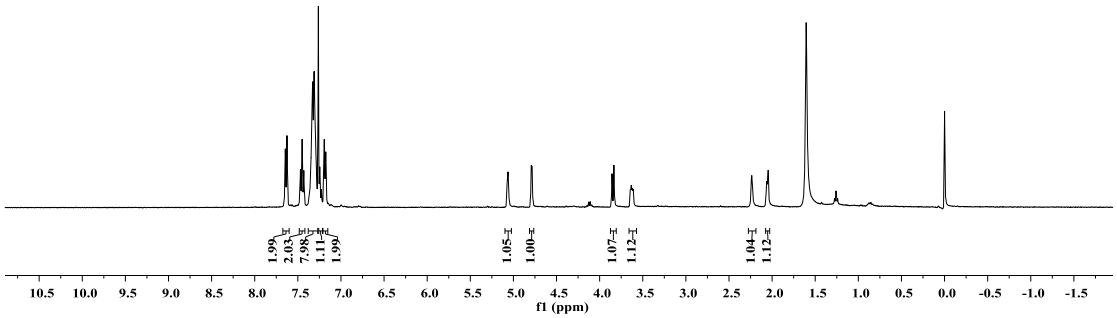

7.3705
7.3635
7.3559
7.3515
7.2136
7.2074
7.1311
7.1243
7.1217
7.1160
7.1109
7.1029
7.0971
7.0916
6.9383
6.9282
6.9251
6.9199
6.9098
6.9049
6.8921
6.8877
6.8295
6.8266
6.8231
6.8140
6.8100
5.9100
5.8950
5.7712
5.7623
4.9866
4.9746
4.9624
4.5091
4.4951
4.4811
4.4724
4.4634
4.4610
4.4521
3.8934
3.8886
3.8675
Ph
OH
HO
N
O
Ph
5a
2.08
1.98
5.05
4.00
2.15
1.17
1.10
1.11
2.22
1.09
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

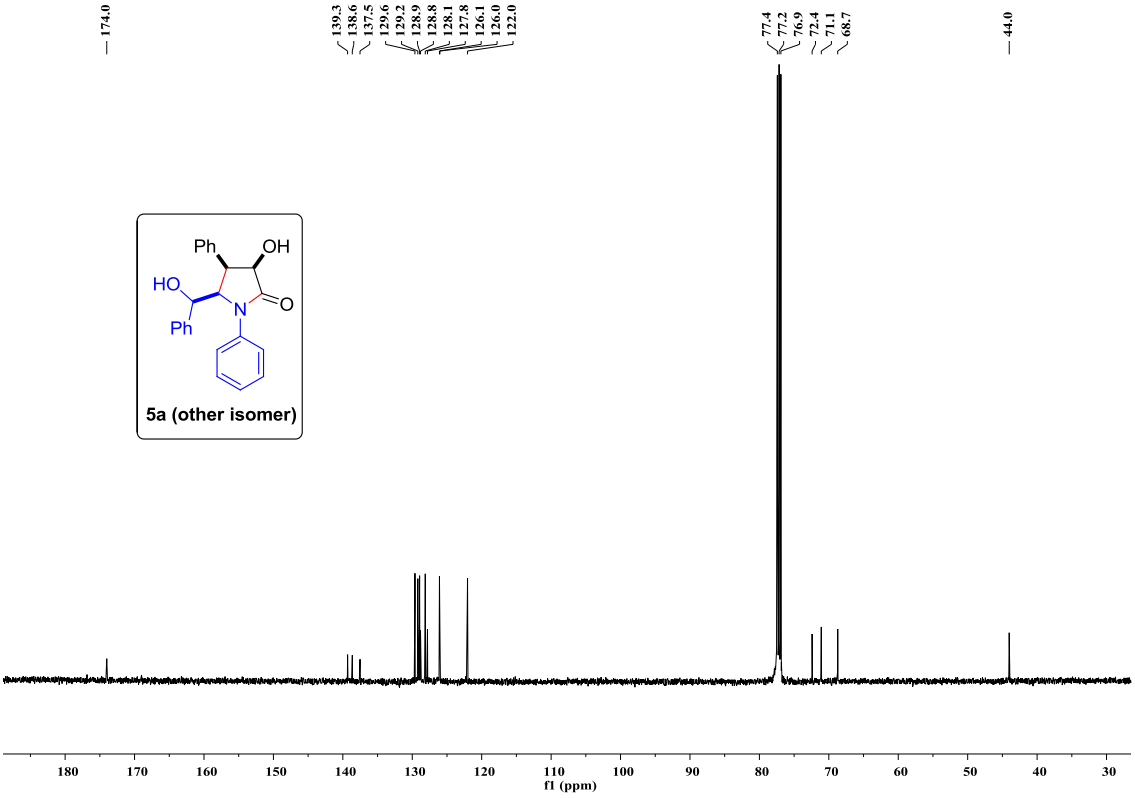

174.1
142.0
137.5
136.1
130.2
128.3
127.2
127.1
126.2
126.1
126.1
125.7
125.5
71.6
70.2
65.7
46.5
40.0
39.8
39.7
39.5
39.3
39.2
39.0
Ph
OH
HO
N
O
Ph
5a
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)



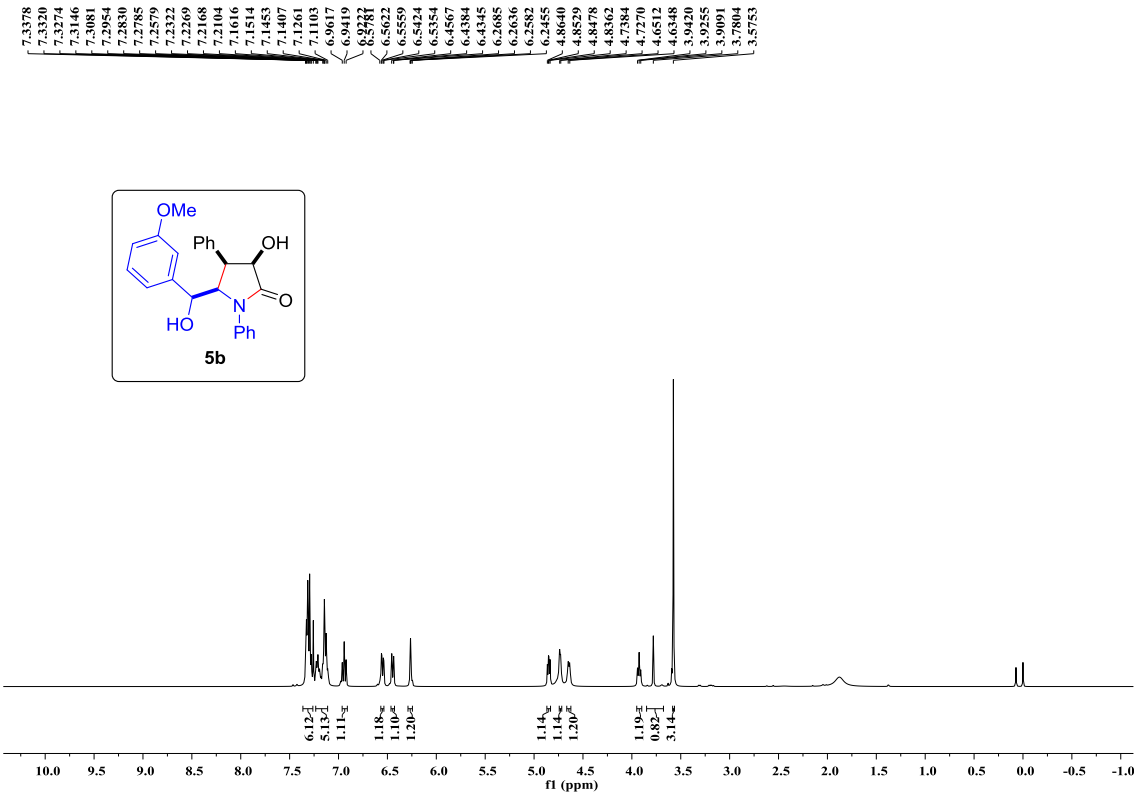


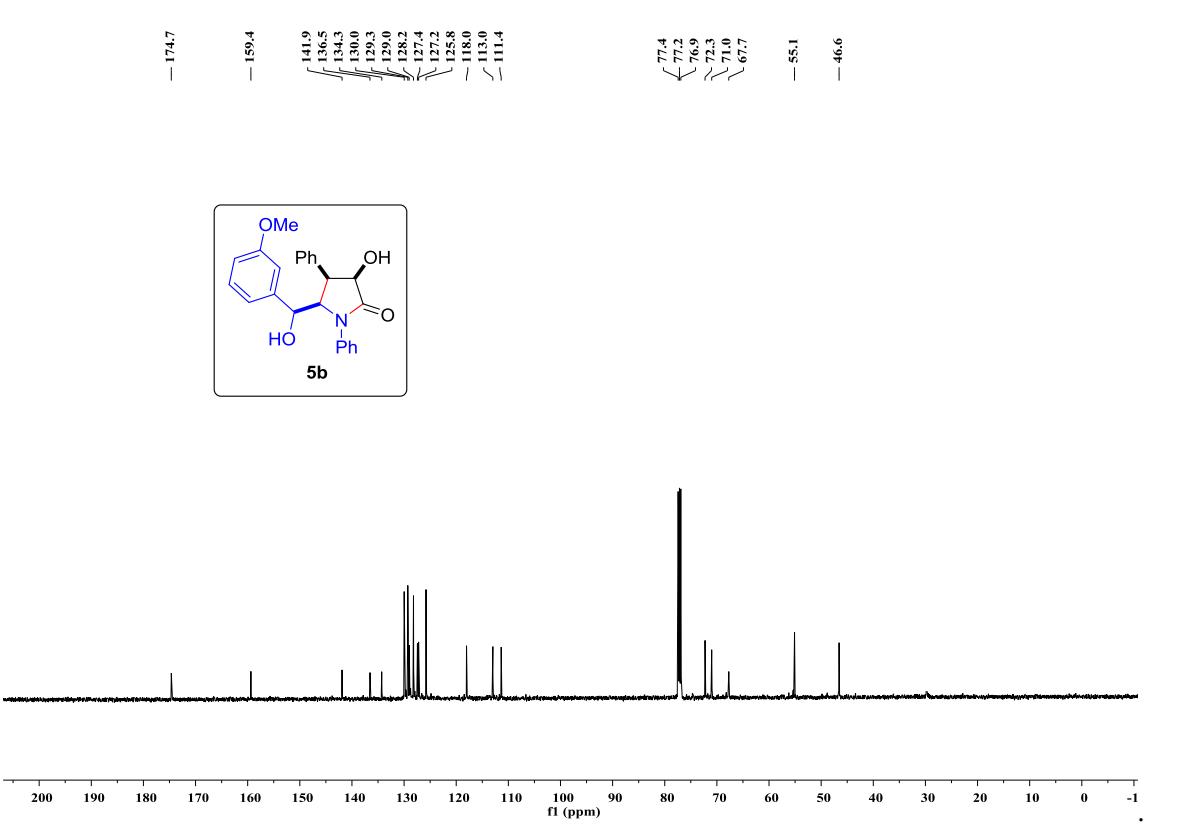
5a (other isomer)

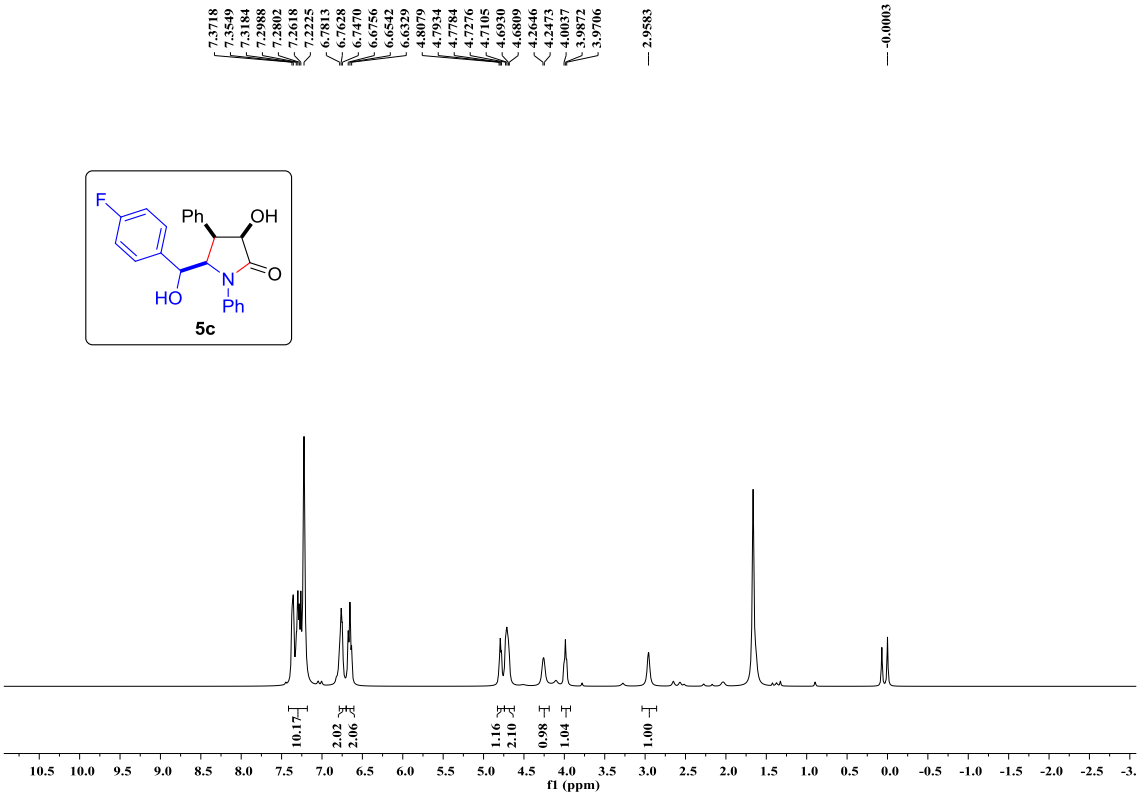


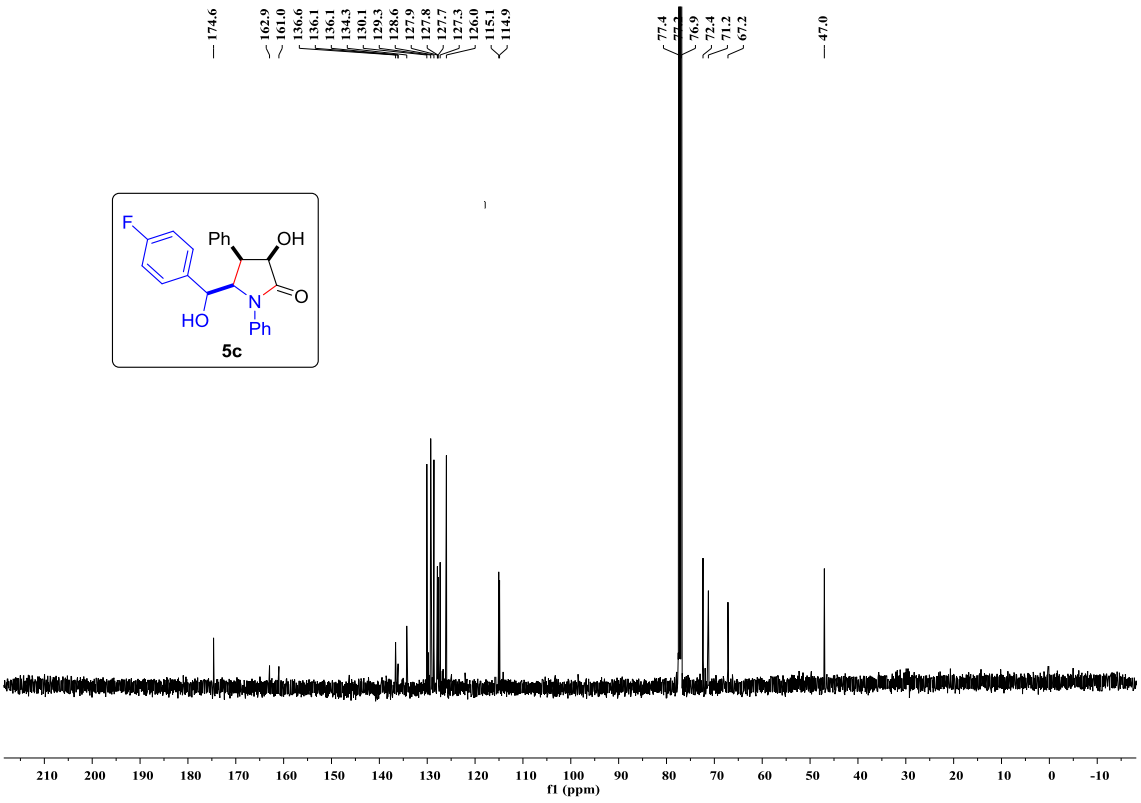


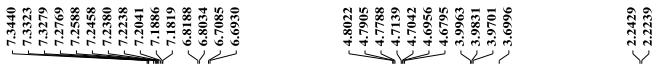
5a (other isomer)

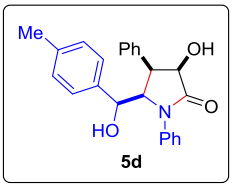

7.3378
7.3320
7.3274
7.3146
7.3081
7.2954
7.2830
7.2785
7.2579
7.2322
7.2269
7.2168
7.2104
7.1616
7.1514
7.1453
7.1407
7.1261
7.1103
6.9617
6.9419
6.9222
6.5781
6.5622
6.5559
6.5424
6.5354
6.4567
6.4384
6.4345
6.2685
6.2636
6.2582
6.2455
4.8640
4.8529
4.8478
4.8362
4.7384
4.7270
4.6512
4.6348
3.9420
3.9255
3.9091
3.7804
3.5753
OMe
Ph
OH
HO
N
Ph
O
5b
6.12
5.13
1.11
1.18
1.10
1.20
1.14
1.14
1.20
1.19
0.82
3.14
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
f1 (ppm)


174.7
159.4
141.9
136.5
134.3
130.0
129.3
129.0
128.2
127.4
127.2
125.8
118.0
113.0
111.4
77.4
77.2
76.9
72.3
71.0
67.7
55.1
46.6
OMe
Ph
OH
HO
N
Ph
O
5b
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-1
f1 (ppm)

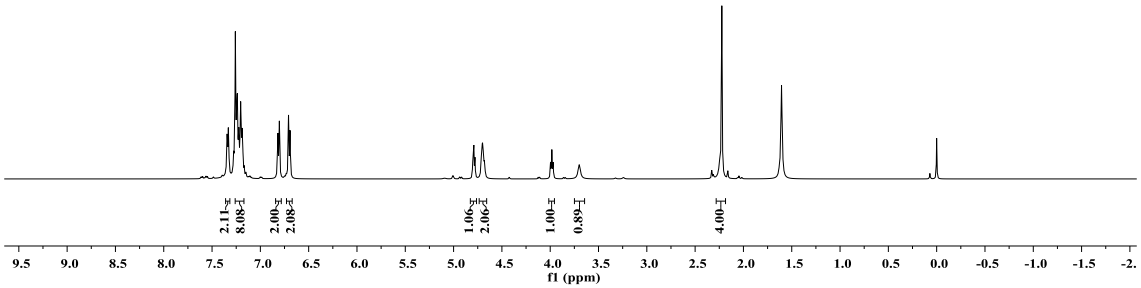

7.3718
7.3549
7.3184
7.2988
7.2802
7.2618
7.2225
6.7813
6.7628
6.7470
6.6756
6.6542
6.6329
4.8079
4.7934
4.7784
4.7276
4.7105
4.6930
4.6809
4.2646
4.2473
4.0037
3.9872
3.9706
2.9583
-0.0003
F
Ph
OH
O
N
HO
Ph
5c
10.17
2.02
2.06
1.16
2.10
0.98
1.04
1.00
f1 (ppm)

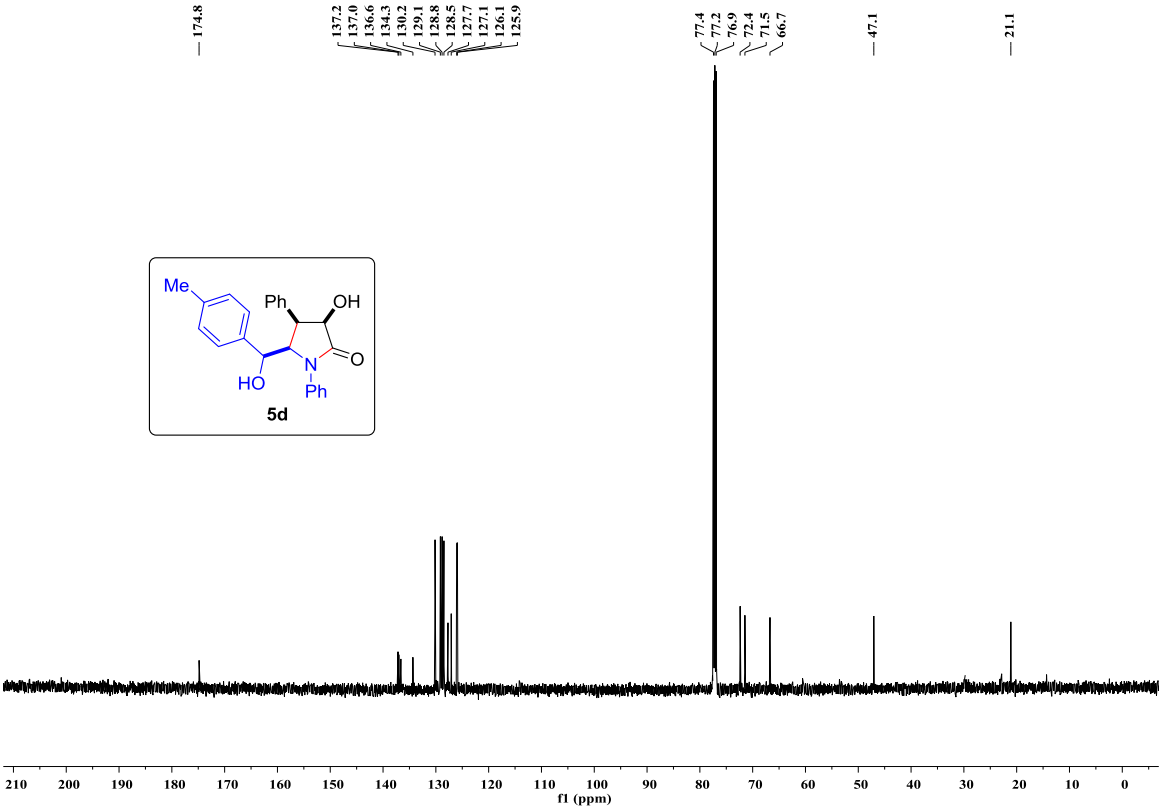

174.6
162.9
161.0
136.6
136.1
136.1
134.3
130.1
129.3
128.6
127.9
127.8
127.7
127.3
126.0
115.1
114.9
77.4
76.9
72.4
71.2
67.2
47.0
F
Ph
OH
O
N
HO
Ph
5c
f1 (ppm)


7.3440
7.3323
7.3279
7.2769
7.2588
7.2458
7.2380
7.2238
7.2041
7.1886
7.1819
6.8188
6.8034
6.7085
6.6930
4.8022
4.7905
4.7788
4.7139
4.7042
4.6956
4.6795
3.9963
3.9831
3.9701
3.6996
2.2429
2.2239


Me
Ph
OH
O
N
HO
Ph

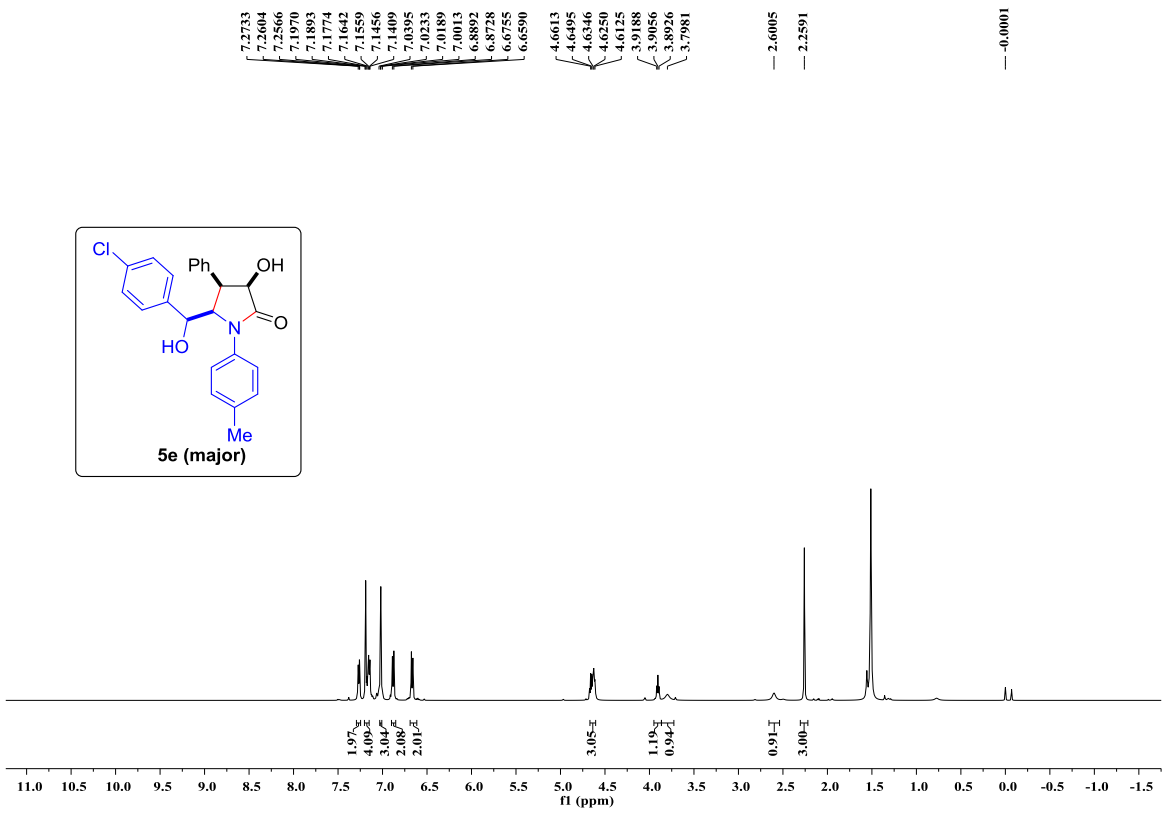
5d

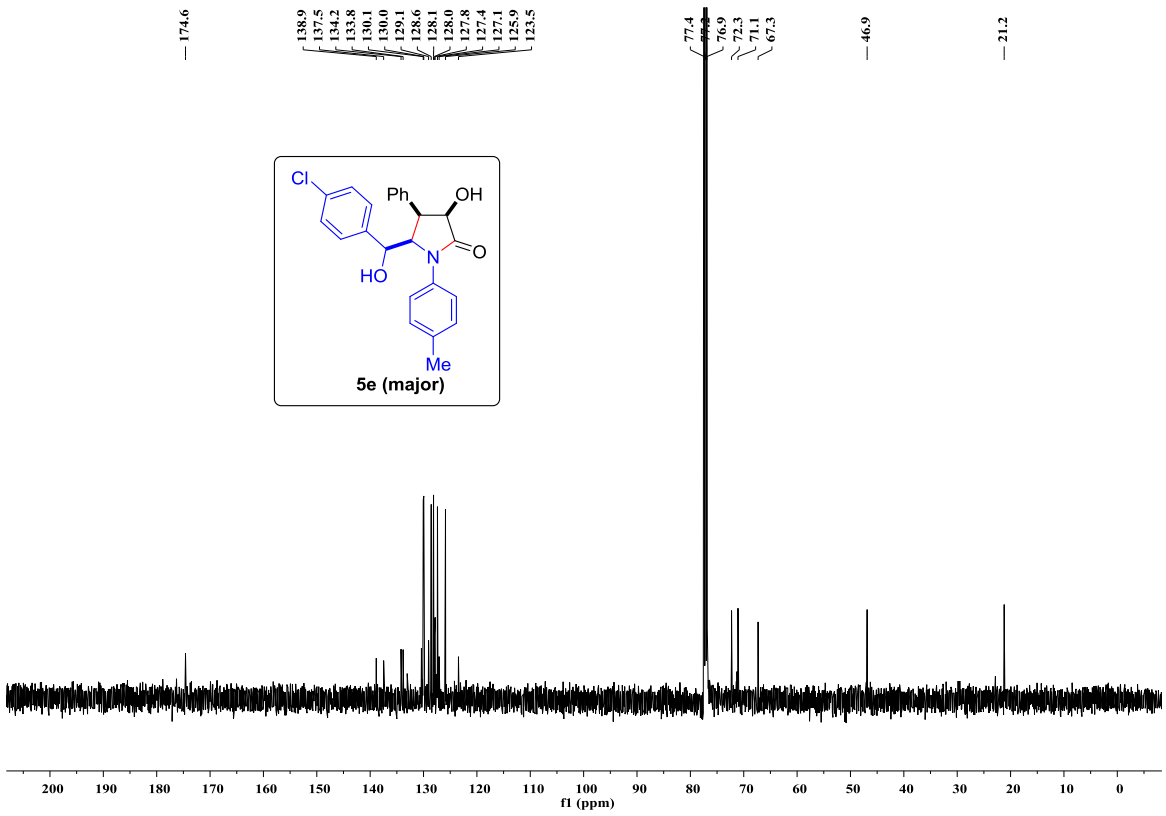

2.11
8.08
2.00
2.08
1.06
2.06
1.00
0.89
4.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0 -1.5 -2.
f1 (ppm)

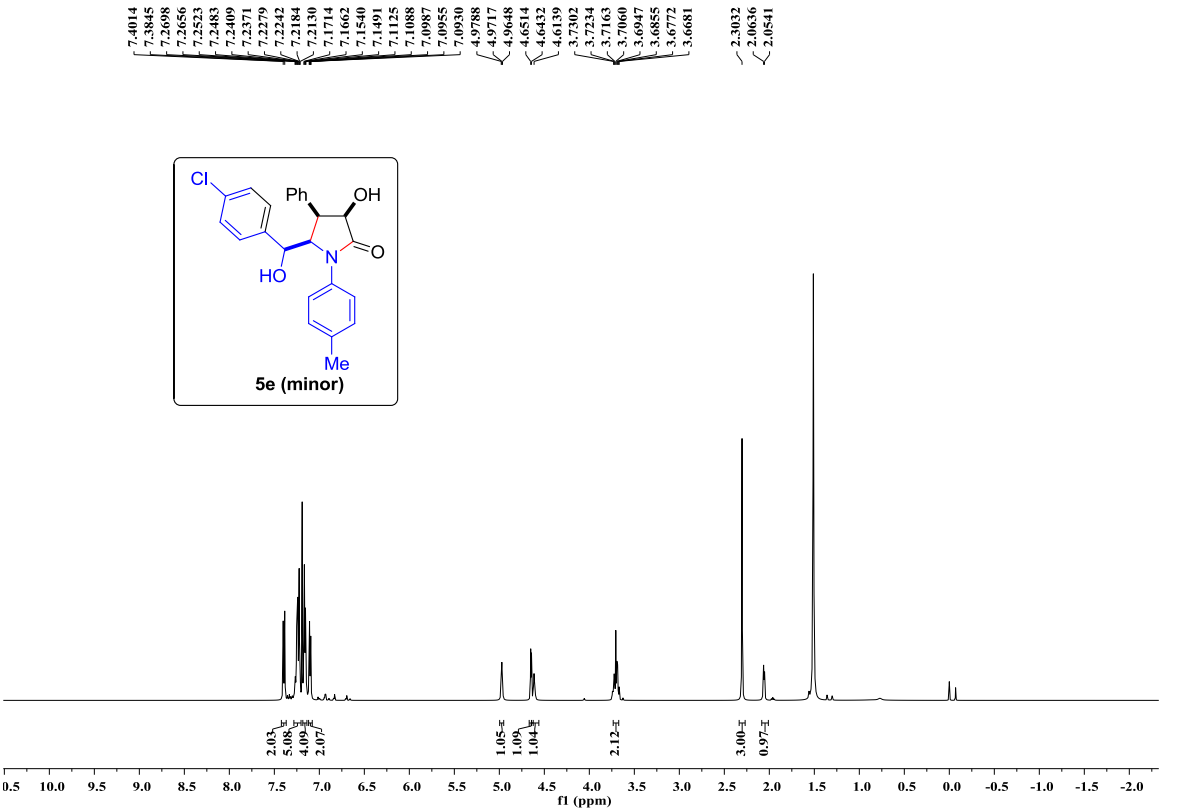

174.8
137.2
137.0
136.6
134.3
130.2
129.1
128.8
128.5
127.7
127.1
126.1
125.9
77.4
77.2
76.9
72.4
71.5
66.7
47.1
21.1
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

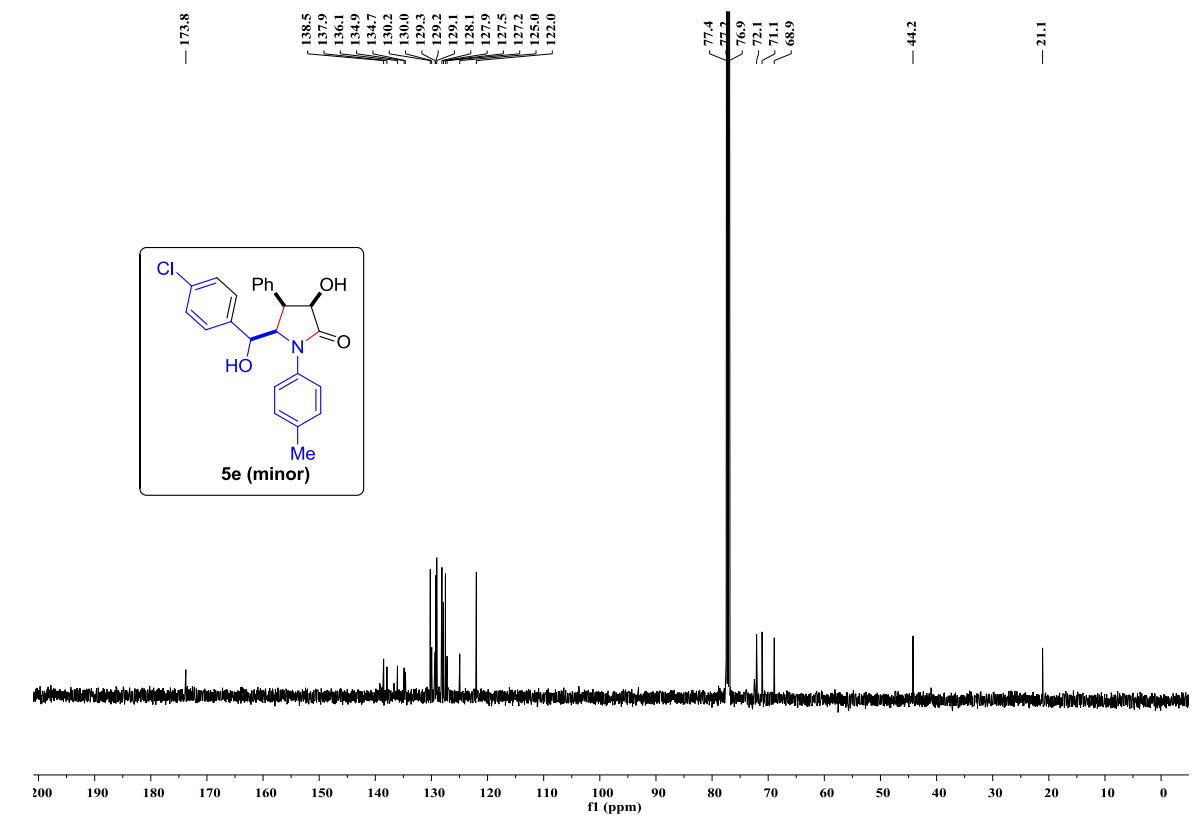
Me
Ph
OH
O
N
HO
Ph

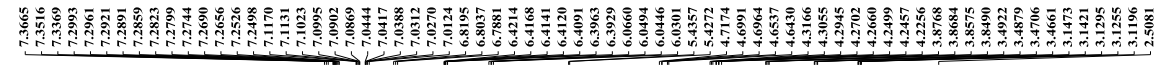
5d

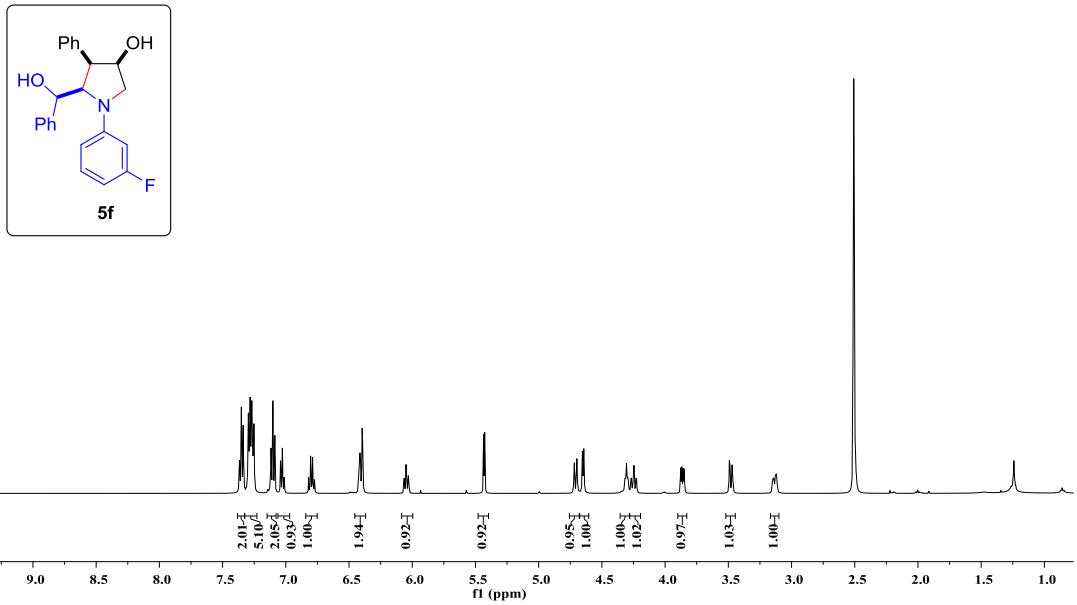

7.2733
7.2604
7.2566
7.1970
7.1893
7.1774
7.1642
7.1559
7.1456
7.1409
7.0395
7.0233
7.0189
7.0013
6.8892
6.8728
6.6755
6.6590
4.6613
4.6495
4.6346
4.6250
4.6125
3.9188
3.9056
3.8926
3.7981
2.6005
2.2591
-0.0001
Cl
Ph
OH
HO
N
O
Me
5e (major)
1.97
4.09
3.04
2.08
2.01
3.05
1.19
0.94
0.91
3.00
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0 -1.5
f1 (ppm)

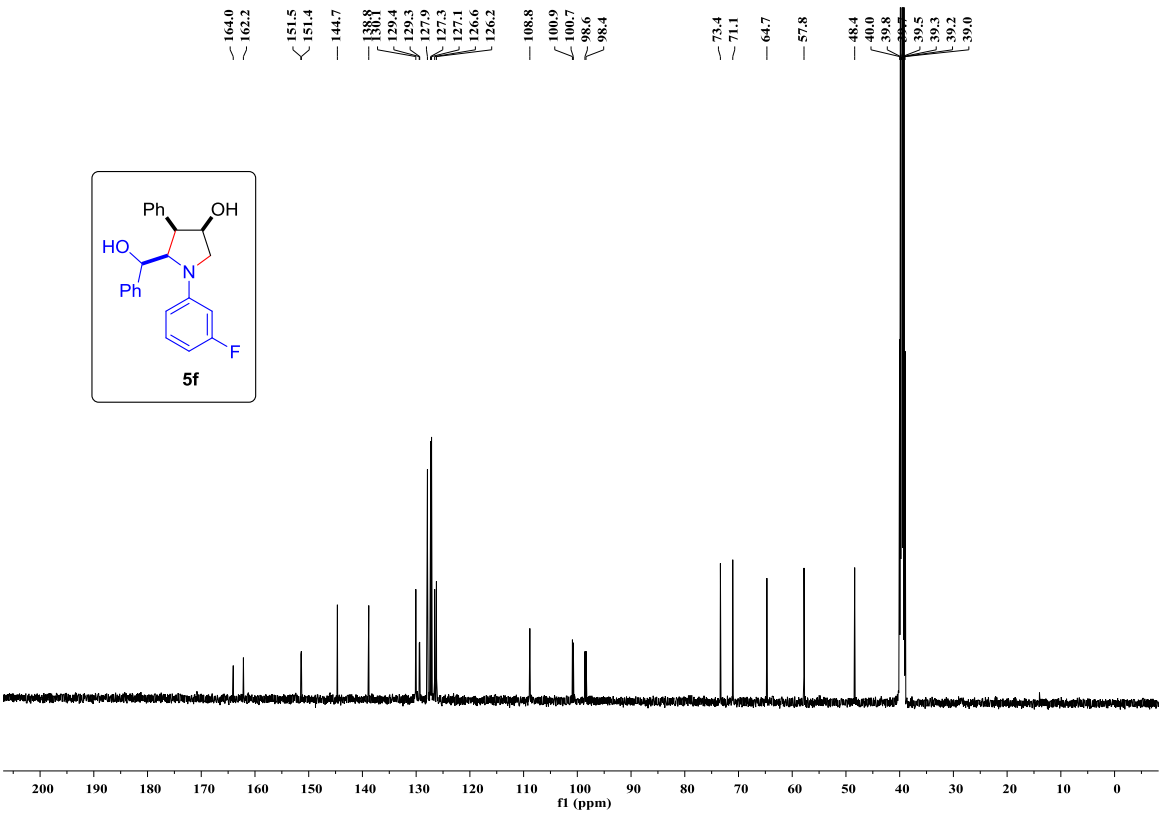

174.6
138.9
137.5
134.2
133.8
130.1
130.0
129.1
128.6
128.1
128.0
127.8
127.4
127.1
125.9
123.5
77.4
76.9
72.3
71.1
67.3
46.9
21.2
Cl
Ph
OH
HO
N
O
Me
5e (major)
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

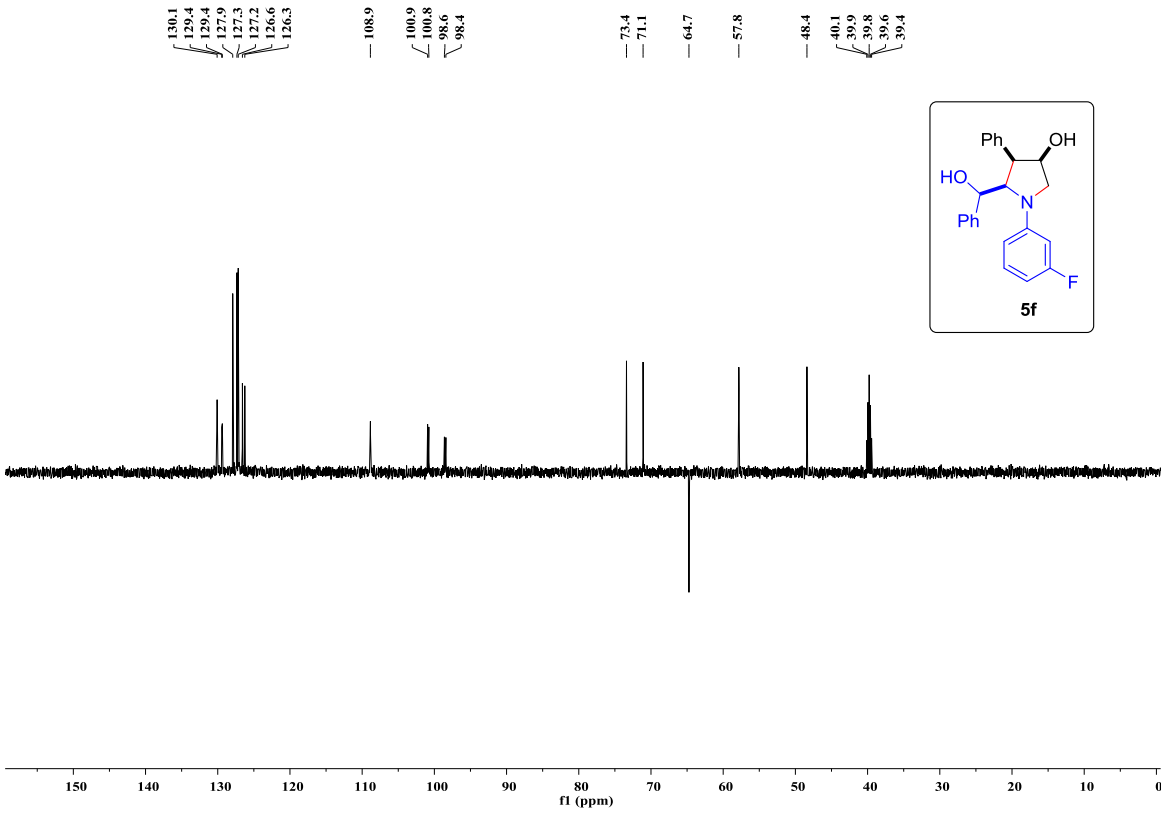

7.4014
7.3845
7.2698
7.2656
7.2523
7.2483
7.2409
7.2371
7.2279
7.2242
7.2184
7.2130
7.1714
7.1662
7.1540
7.1491
7.1125
7.1088
7.0987
7.0955
7.0930
4.9788
4.9717
4.9648
4.6514
4.6432
4.6139
3.7302
3.7234
3.7163
3.7060
3.6947
3.6855
3.6772
3.6681
2.3032
2.0636
2.0541
Cl
Ph
OH
HO
N
O
Me
5e (minor)
2.03
5.08
4.09
2.07
1.05
1.09
1.04
2.12
3.00
0.97
f1 (ppm)


173.8
138.5
137.9
136.1
134.9
134.7
130.2
130.0
129.3
129.2
129.1
128.1
127.9
127.5
127.2
125.0
122.0
77.4
77.2
76.9
72.1
71.1
68.9
44.2
21.1
Cl
Ph
OH
HO
N
O
Me
5e (minor)
f1 (ppm)

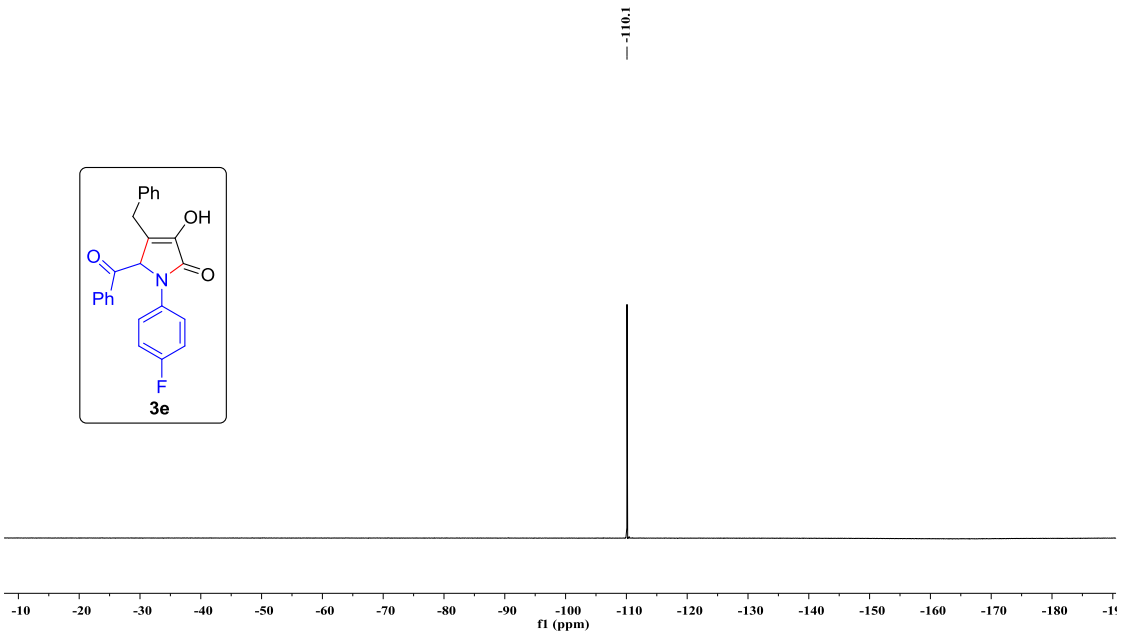


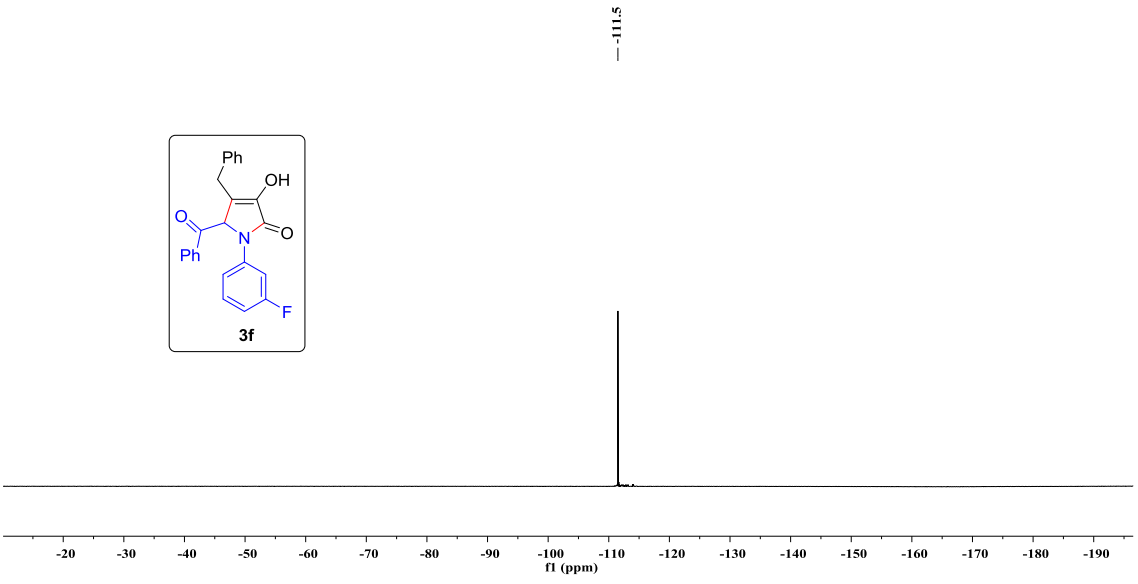

Ph
OH
HO
Ph
N
F
5f
2.01
5.10
2.05
0.93
1.00
1.94
0.92
0.92
0.95
1.00
1.00
1.02
0.97
1.03
1.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0
f1 (ppm)

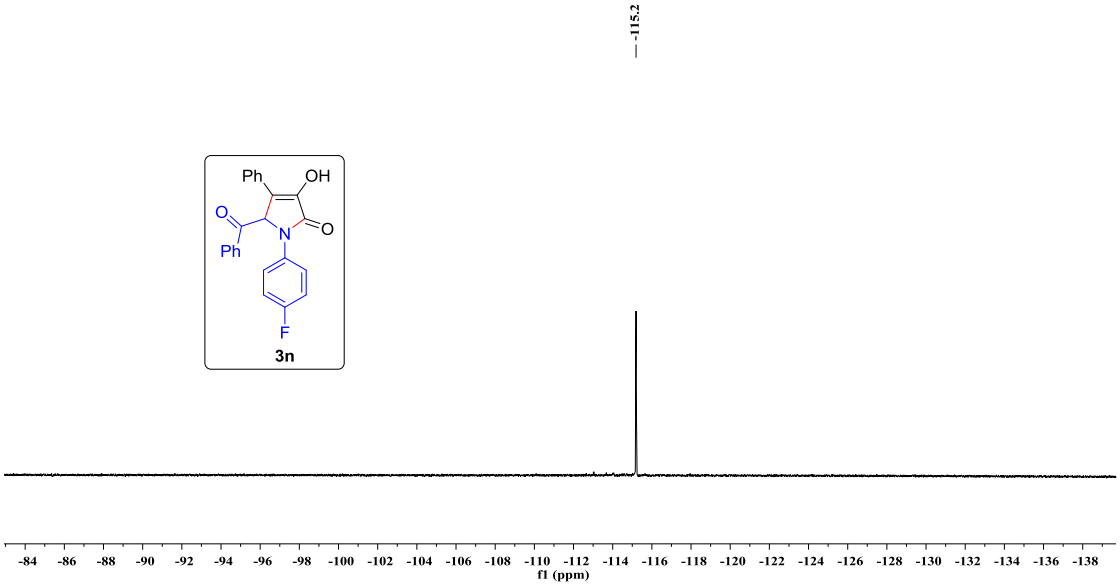

164.0
162.2
151.5
151.4
144.7
138.8
130.1
129.4
129.3
127.9
127.3
127.1
126.6
126.2
108.8
100.9
100.7
98.6
98.4
73.4
71.1
64.7
57.8
48.4
40.0
39.8
39.5
39.3
39.2
39.0
Ph
OH
HO
Ph
N
F
5f
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

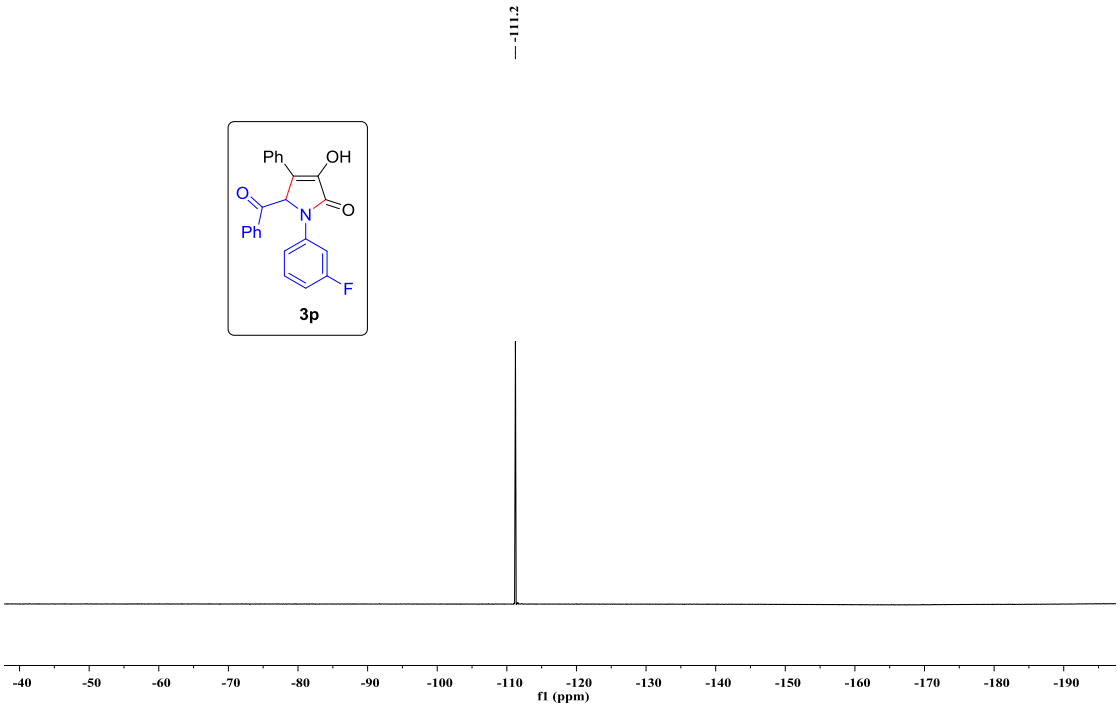

130.1
129.4
129.4
127.9
127.3
127.2
126.6
126.3
108.9
100.9
100.8
98.6
98.4
73.4
71.1
64.7
57.8
48.4
40.1
39.9
39.8
39.6
39.4
Ph
OH
HO
Ph
N
F
5f
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

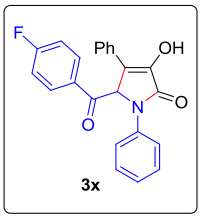
^{19}F spectra


-110.1
Ph
OH
O
N
O
Ph
F
3e
-10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180
f1 (ppm)


-111.5
Ph
OH
O
N
O
Ph
F
3f
-20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190
f1 (ppm)

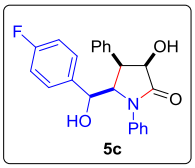

-115.2
Ph
OH
O
N
O
Ph
F
3n
-84 -86 -88 -90 -92 -94 -96 -98 -100 -102 -104 -106 -108 -110 -112 -114 -116 -118 -120 -122 -124 -126 -128 -130 -132 -134 -136 -138
f1 (ppm)


-111.2
Ph
OH
O
N
O
Ph
F
3p
-40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190
f1 (ppm)


F
Ph
OH
O
N
O
O

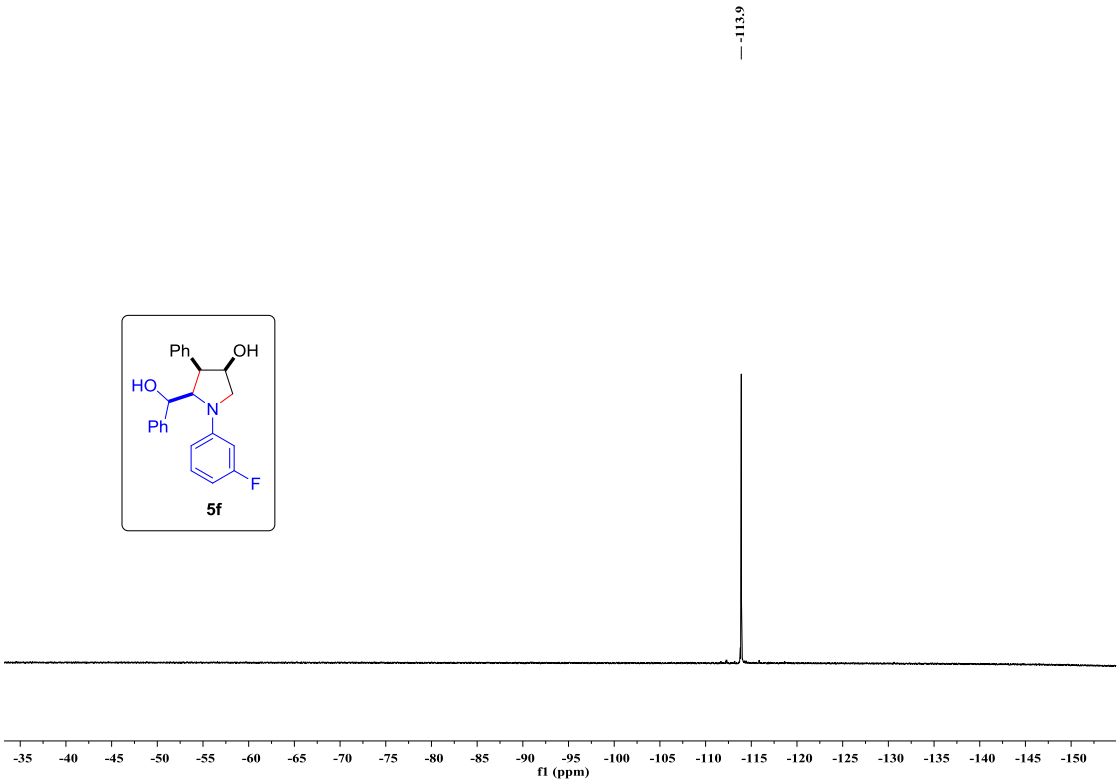
3x

-103.5
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
f1 (ppm)


F
Ph
OH
HO
N
Ph
O

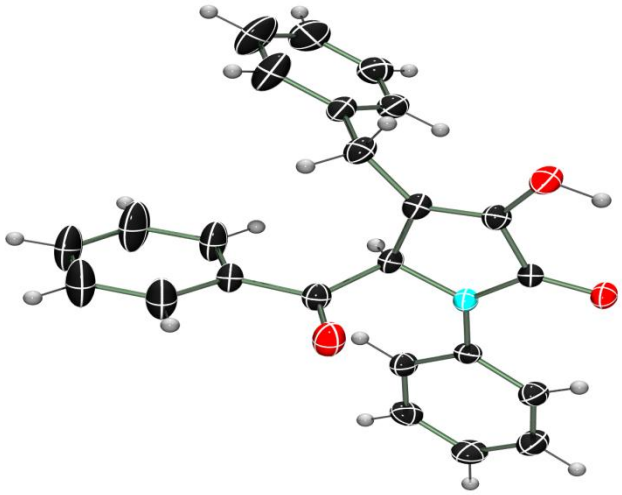
5c

-115.2
-75
-80
-85
-90
-95
-100
-105
-110
-115
-120
-125
-130
f1 (ppm)



Crystallographic experimental section:

Crystal structure of compound **3a (CCDC number: 1867654):**



Empirical formula	C24 H19 N O3
Formula weight	369.40
Temperature	296(2) K
Crystal system, space group	Triclinic, P1
Unit cell dimensions	a = 5.8336 (6) Å alpha = 77.575 (5) deg.
	b = 11.4947 (15) Å beta = 81.412 (5) deg.
	c = 14.982 (2) Å gamma = 77.375 (4) deg
Volume	951.8 (2) A^3
Z, Calculated density	2, Absorption coefficient 0.09 mm^-1
Crystal size	0.25 × 0.10 × 0.08 mm
Radiation type	Mo Kα
Data collection	
Diffractometer	Bruker APEX-II CCD
Absorption correction –	8650, 2268, 1499
No. of measured, independent and	
observed [I > 2σ(I)] reflections	
Rint	0.055
θmax (°)	21.8
(sin θ/λ)max (Å−1)	0.523
Refinement	
R[F2 > 2σ(F2)], wR(F2)	S 0.051, 0.151, 1.03
No. of reflections	2268
No. of parameters	258
H-atom treatment H atoms treated by a mixture of independent and constrained refinement	
Δρmax, Δρmin (e Å−3)	0.16, −0.16