Zn(II)-catalyzed asymmetric [3+2] cycloaddition of acyclic enones with azomethine ylides

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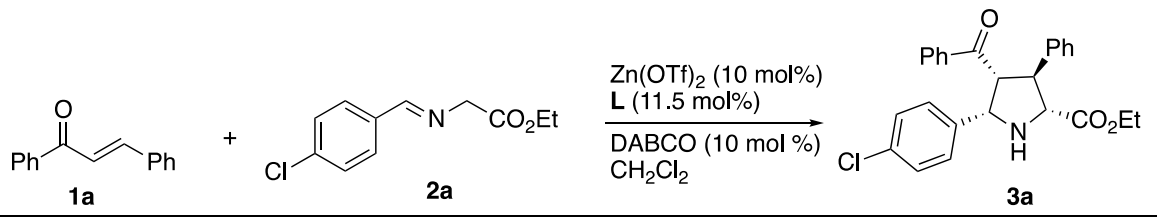
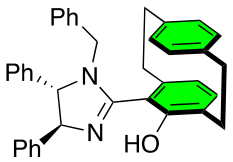
1. General Information

Unless otherwise noted, all commercial reagents were used as received without further purification. $Zn(OTf)_2$ was purchased from sigma Aldrich and used as received. Dichloromethane (CH_2Cl_2) and tetrahydrofuran (THF) and were obtained from a PureSolv- 300-3-MD dry solvents dispenser. Standard Schlenk techniques were employed for moisture sensitive reactions. Column chromatography was performed on Davisil LC60A 40–63 micron silica gel. Thin-layer chromatography (TLC) was performed on aluminium-backed sheets purchased from Merck pre-coated with silica gel 60 F254. ^{1}H NMR spectra were recorded on Varian-Inova spectrometers (400/500 MHz) using tetramethylsilane as an internal standard. ^{13}C NMR spectra were recorded on 400/500 MHz Varian-Inova spectrometers (101 MHz and 126 MHz) using tetramethylsilane as an internal standard. ^{19}F NMR spectra were recorded on a 400/500 MHz Varian-Inova spectrometer (376 MHz). HRMS were measured on a Micromass/Waters LCT mass spectrometer. Infrared spectra were recorded on a FT-IR spectrometer and are reported in terms wavenumbers (νmax) with units of reciprocal centimetres (cm^{-1}). High performance liquid chromatography (HPLC) or Supercritical fluid chromatography (SFC) was performed on a Waters Acquity UPC2 ® or Shimadzu instrument with Chiralpak® IB3, IC3 and ID3 columns. Optical rotation measurements were recorded using a Schmidt-Haensch Unipol L2000 polarimeter at 589 nm and are quoted in units of deg $dm^{-1}cm^3$ g^{-1} (concentration c is given in g/100 mL).

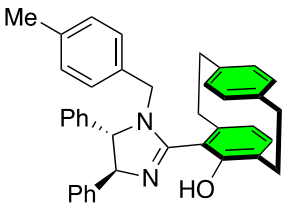
2. Reaction Optimization

2.1 The Ligand Screen[a,b,c,d]





4a
55%
endo/exo 93:7
95:5 er



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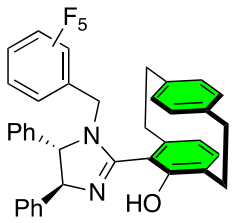
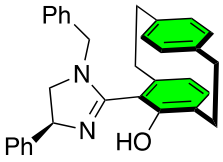
43%
endo/exo 90:10
90:10 er



4c
46%
endo/exo 92:8
87:13 er



4d
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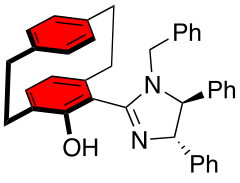
endo/exo 94:6
95:5 er



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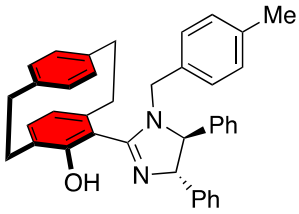
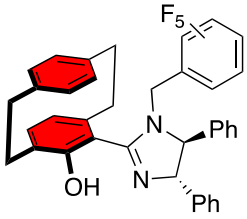
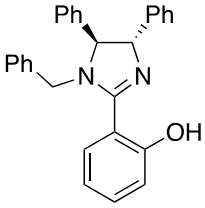
endo/exo 85:15
46:54 er



5b
35%
endo/exo 81:19
49:51 er



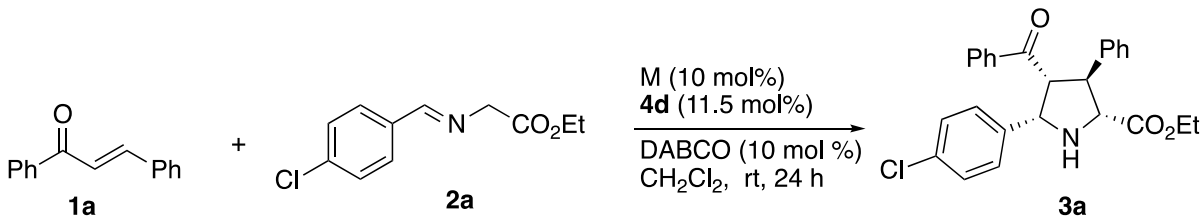
5c
48%
endo/exo 83:12
47:53 er



6
38%
endo/exo 78:12
54:46 er

[a] All reactions were carried out with $Zn(OTf)_2$ (10 mol %), **L** (11.5 mol %), **1a** (0.15 mmol), **2a** (0.225 mmol), DABCO (10 mol %) in CH_2Cl_2 (1.5 mL) for 24 h. [b] Isolated yield after purification. [c]The *endo*/*exo* was determined by ^1H NMR spectra of the crude product. [d]Determined by chiral HPLC analysis.

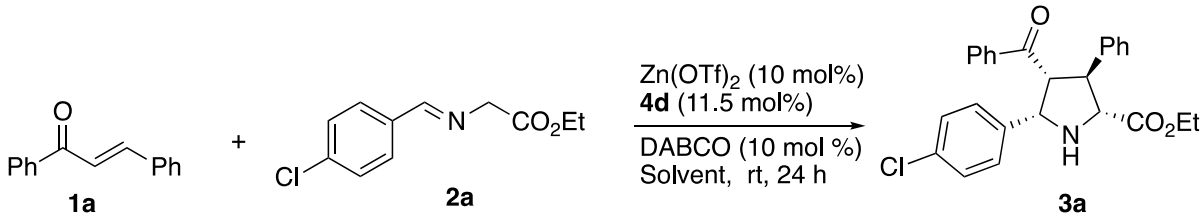
2.2 Metal Screen for 3a[a]



Entry	Catalyst (10 mol%)	Yield (%)[b]	*endo/exo*[c]	er[d]
1	AgOAc	58	99:1	55:45
2	$Cu(OTf)_2$	trace	ND	ND
3	$Zn(OTf)_2$	79	94:6	94.5:5.5

[a] All reactions were carried out with metal salt (10 mol %), **4d** (11.5 mol %), **1a** (0.15 mmol), **2a** (0.225 mmol), DABCO (10 mol %) in CH_2Cl_2 (1.5 mL) for 24 h. [b] Isolated yield after purification. [c]The *endo*/*exo* was determined by ^{1}H NMR spectra of the crude product. [d]Determined by chiral HPLC analysis.

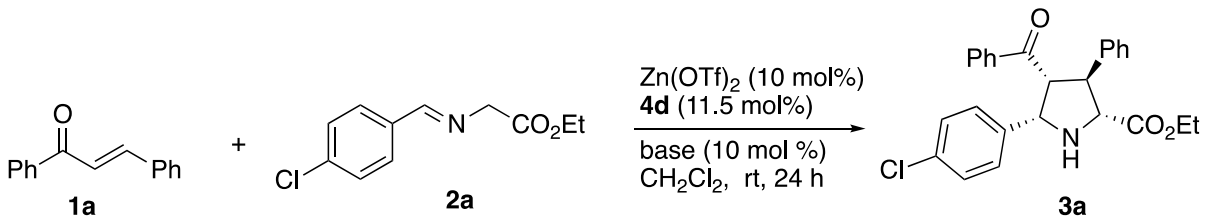
2.3 Solvent Screen for 3a[a]



Entry	Solvent	Yield (%)[b]	*endo/exo*[c]	er[d]
1	Et_2O	19	83:17	95.5:4.5
2	THF	36	91:9	87:13
3	PhMe	63	89:11	93.5:6.5
4	$CHCl_3$	73	97:3	94.5:5.5
5	CH_2Cl_2	79	94:6	94.5:5.5

[a] All reactions were carried out with $Zn(OTf)_2$ (10 mol %), **3d** (11.5 mol %), **1a** (0.15 mmol), **2a** (0.225 mmol) DABCO (10 mol %) in solvent (1.5 mL) for 24 h. [b] Isolated yield after purification. [c]The *endo*/*exo* was determined by ^{1}H NMR spectra of the crude product. [d]Determined by chiral HPLC analysis.

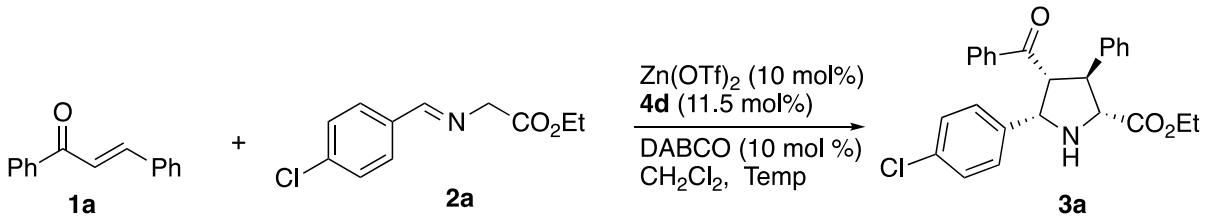
2.4 Base Screen for 3a[a]



Entry	Base	Yield (%)[b]	*endo/exo*[c]	er[d]
1	DABCO	79	94:6	94.5:5.5
2	DBU	48	91:9	84:16
3	DIPEA	63	72:18	85:15
4	Et_3N	45	97:3	94.5:5.5
5	K_2CO_3	trace	ND	ND

[a] All reactions were carried out with $Zn(OTf)_2$ (10 mol %), **4d** (11.5 mol %), **1a** (0.15 mmol), **2a** (0.225 mmol), base (10 mol%) in CH_2Cl_2 (1.5 mL) for 24 h. [b] Isolated yield after purification. [c]The *endo*/*exo* was determined by ^1H NMR spectra of the crude product. [d]Determined by chiral HPLC analysis.

2.5 Temperature Screen for 3a[a]



Entry	Temp. (^oC)	Yield (%)[b]	*endo/exo*[c]	er[d]
1	rt	79	94:6	94.5:5.5
2[e]	rt	90	97:3	94.5:5.5
3[e,f]	0	95	99:1	96.5:3.5
4[g]	0	86	99:1	96:4

[a] All reactions were carried out with $Zn(OTf)_2$ (10 mol %), **4d** (11.5 mol %), **1a** (0.15 mmol), **2a** (0.225 mmol), base (10 mol%) in CH_2Cl_2 (1.5 mL) for 24 h. [b] Isolated yield after purification. [c]The *endo*/*exo* was determined by ^1H NMR spectra of the crude product. [d]Determined by chiral HPLC analysis. [e] 0.3 mmol of **2a** was used.[f] 48 h. [g] $Zn(OTf)_2$ (5 mol %) and **4d** (5.75 mol%) for 72h.

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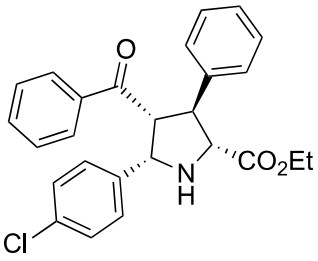
3. General Procedure for the Zn-Catalyzed [3+2] Azomethine Ylide Cycloaddition

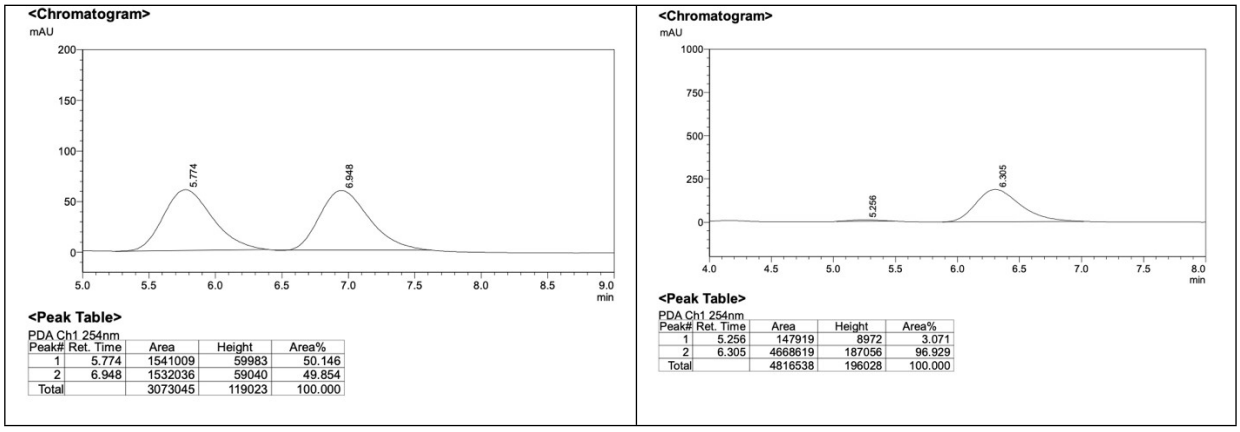
Under a nitrogen atmosphere, ligand (S,S,S_P)-**4d** (11.5 mol %) and $Zn(OTf)_2$ (10 mol %) was added to a flame-dried 10 mL Schlenk tube. Then dry CH_2Cl_2 (0.5 mL) was added and stirred for 60 minutes. After cooled at 0 °C, acyclic enone **1** (0.15 mmol, 1.0 equiv) in CH_2Cl_2 (0.4 mL), α-iminoester **2** (0.3 mmol, 2 equiv) in CH_2Cl_2, (0.4 mL) and DABCO (10 mol %) in CH_2Cl_2 (0.2 mL) were added sequentially. The reaction mixture was stirred at the same temperature for 48 h. After completion, the reaction mixture was directly purified by silica gel column chromatography (30% ethyl acetate in cyclohexane) to afford the desired product **3**. The *endo*/*exo* ratio was determined by ^{1}H-NMR before purification and the enantioselectivity was determined by HPLC analysis of the isolated product. The configuration of the products was assigned by comparison with the optical rotation values of prepared compounds and the reported optical rotation of the cycloadducts.[1,2]

(2*R*,3*S*,4*R*,5*S*)-Ethyl-4-benzoyl-5-(4-chlorophenyl)-3-phenylpyrrolidine-2-carboxylate (3a)



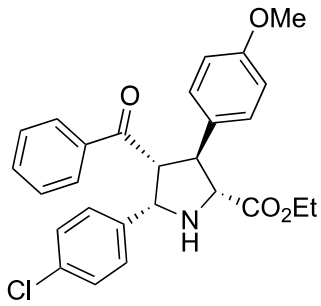
White solid, yield = 95% (62 mg); m.p.= 141 –143 ºC, Rf = 0.49 (cyclohexane/ethyl acetate, 3:1), $[\alpha]_D^{20}$ = +103.67 (c = 1, $CHCl_3$), (*endo*/*exo* = 99:1), 97:3 er; **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.57 – 7.55 (m, 2H), 7.46 – 7.42 (m, 1H), 7.38 – 7.22 (m, 7H), 7.06 (s, 4H), 4.97 (d, *J* = 8.6 Hz, 1H), 4.53 (dd, *J* = 8.8, 8.1 Hz, 1H), 4.26 (dq, *J* = 10.8, 7.1 Hz, 1H), 4.19 – 4.06 (m, 3H), 3.01 (s, 1H), 1.17 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (101 MHz, $CDCl_3$)** δ 198.3, 173.0, 140.4, 138.2, 137.5, 133.5, 133.2, 128.95, 128.9, 128.6, 128.4, 128.2, 128.0, 127.3, 67.7, 65.9, 61.4, 60.5, 52.6, 14.3. **FT-IR (neat, cm^{-1}):** 2920.3, 2851.1, 1726.1, 1674.0, 1207.8, 1184.6, 688.4. **HRMS: (ESI-TOF)** calculated for $C_{26}H_{25}ClNO_3$ $[M+H]^+$ 434.1517, found 434.1515.

HPLC analysis: CHIRALPAK IC, heptane/2-propanol (50/50, 0.5 mL/min), λ = 254 nm, t_R = 5.256 (minor), 6.305 (major).

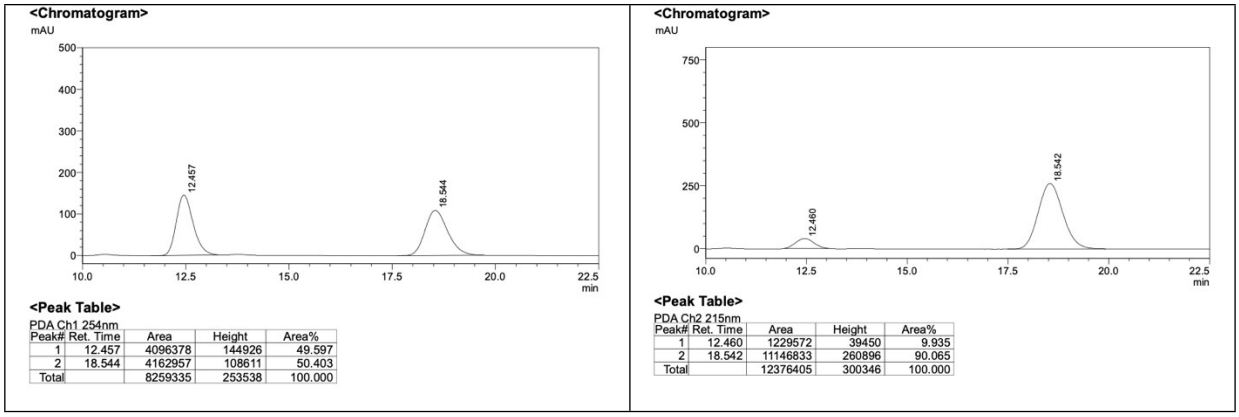


(2*R*,3*S*,4*R*,5*S*)-Ethyl-4-benzoyl-5-(4-chlorophenyl)-3-(4-methoxyphenyl)pyrrolidine-2-carboxylate (3b)

White solid, yield = 49% (34 mg); m.p.= 130 – 131 ºC, Rf = 0.39 (cyclohexane/ethyl acetate, 3:1), $[\alpha]_D^{20}$ = +86.80 (c = 1, $CHCl_3$), (*endo*/*exo* = >99:1), 90:10 er; **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.58 – 7.56 (m, 2H), 7.44 (ddt, *J* = 7.8, 6.9, 1.3 Hz, 1H), 7.32 – 7.27 (m, 4H), 7.06 (s, 4H), 6.88 – 6.84 (m, 2H), 4.95 (d, *J* = 8.8 Hz, 1H), 4.49 (t, *J* = 8.5 Hz, 1H), 4.26 (dq, *J* = 10.7, 7.1 Hz, 1H), 4.19 – 4.13 (m, 1H), 4.11 – 4.01 (m, 2H), 3.78 (s, 3H), 2.96 (s, 1H), 1.19 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (101 MHz, $CDCl_3$)** δ 198.3, 173.1, 158.8, 138.4, 137.5, 133.5, 133.2, 132.3, 128.9, 128.6, 128.4, 128.2, 114.3, 67.8, 65.8, 61.4, 60.6, 55.4, 51.9, 14.3. **FT-IR (neat, cm^{-1}):** 2922.7, 2852.7, 1729.7, 1675.4, 1513.8, 1248.9, 1178.4, 820.9. **HRMS: (ESI-TOF)** calculated for $C_{27}H_{27}ClNO_4$ $[M+H]^+$ 464.1623, found 464.1623.

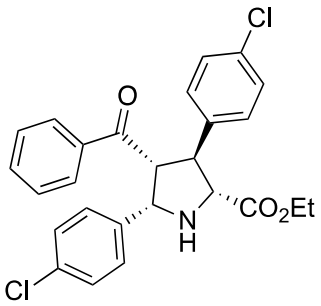


HPLC analysis: CHIRALPAK IC, heptane/2-propanol (90/10, 0.5 mL/min), λ = 254 nm, t_R = 12.460 min (minor), 18.542 min (major).



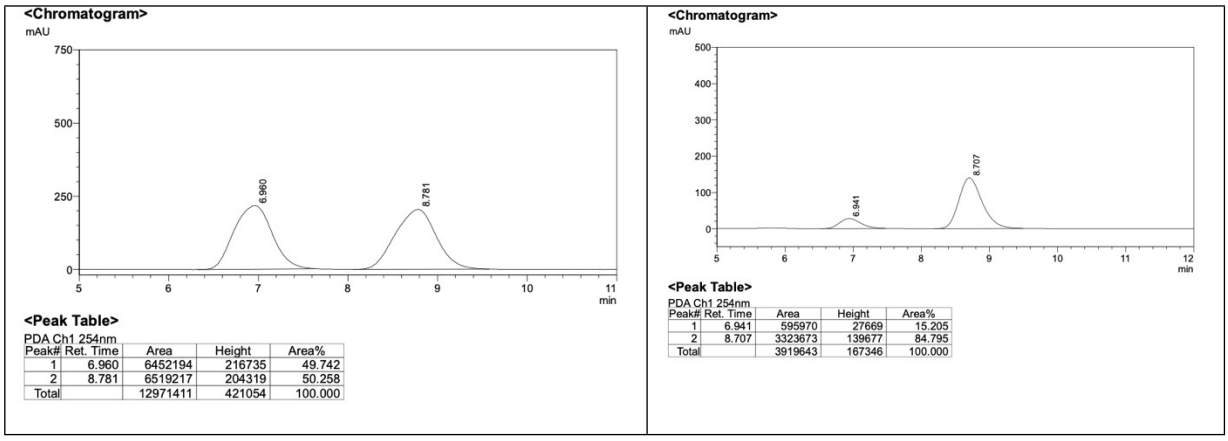
(2*R*,3*S*,4*R*,5*S*)-Ethyl-4-benzoyl-3,5-bis(4-chlorophenyl)pyrrolidine-2-carboxylate (3c)

White solid, Yield = 74% (52 mg); m.p.= 164 – 165 ºC, Rf = 0.46 (cyclohexane/ethyl acetate, 3:1), $[\alpha]_D^{20}$ = +74.92 (c = 0.47, $CHCl_3$), (*endo*/*exo* = >99:1), 85:15 er; **^{1}H NMR (500 MHz, $CDCl_3$) δ** 7.57 – 7.56 (m, 2H), 7.47 – 7.44 (m, 1H), 7.32 – 7.28 (m, 6H), 7.04 – 7.02 (m, 4H), 4.97 (d, *J* = 8.9 Hz, 1H), 4.48 (t, *J* = 8.6 Hz, 1H), 4.25 (dq, *J* = 10.7, 7.1 Hz, 1H), 4.18 – 4.12 (m, 1H), 4.11 – 4.05 (m, 2H), 2.95 (s, 1H), 1.18 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (126 MHz, $CDCl_3$)** δ 197.6, 172.6, 138.5, 138.1, 137.2, 133.5, 133.2, 132.9, 129.2, 128.9, 128.8, 128.5, 128.3, 128.0, 67.2, 65.5, 60.5, 51.4, 14.1. **FT-IR (neat, cm^{-1}):** 2930.3, 1738.9, 1672.0, 1488.3,



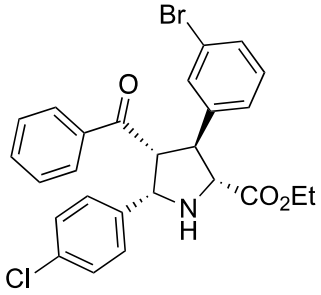
1255.6, 1178.3, 756.4. **HRMS: (ESI-TOF)** calculated for $C_{26}H_{24}Cl_2NO_3$ $[M+H]^+$ 468.1128, found 468.1124.

HPLC analysis: CHIRALPAK IC, heptane/2-propanol (90/10, 0.5 mL/min), λ = 254 nm, t_R = 6.941 min (minor), 8.707 min (minor).

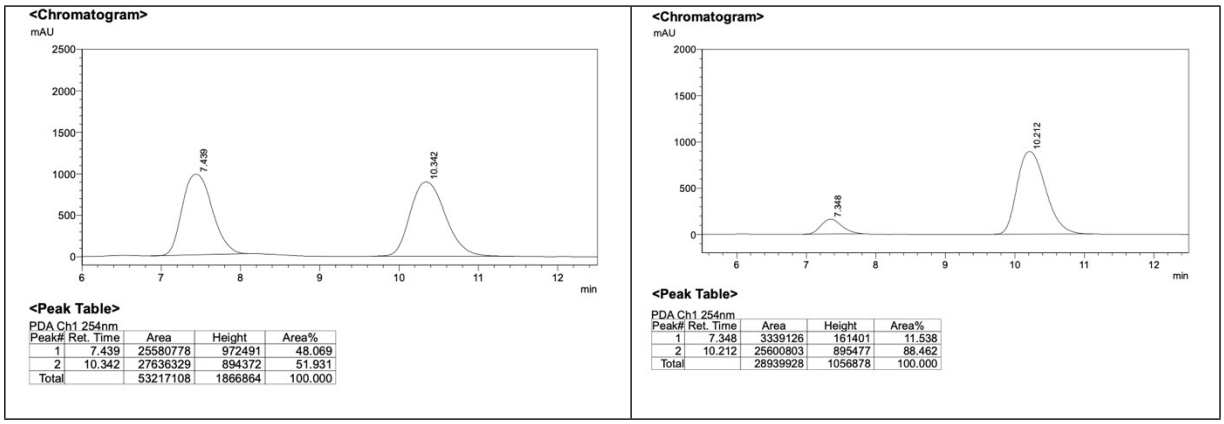


(2*R*,3*S*,4*R*,5*S*)-Ethyl-4-benzoyl-3-(3-bromophenyl)-5-(4-chlorophenyl)pyrrolidine-2-carboxylate (3e)

White solid, yield = 74% (57 mg); m.p.= 116 – 117 ºC, Rf = 0.30 (cyclohexane/ethyl acetate, 3:1), $[\alpha]_D^{20}$ = +89.65 (c = 0.47, $CHCl_3$), (*endo*/*exo* = >99:1), 88:12 er; **^{1}H NMR (400 MHz, $CDCl_3$)** δ 8.19 (d, *J* = 8.8 Hz, 2H), 7.59 – 7.55 (m, 4H), 7.50 – 7.46 (m, 1H), 7.35 – 7.31 (m, 2H), 7.08 – 7.01 (m, 4H), 5.03 (d, *J* = 9.4 Hz, 1H), 4.54 (t, *J* = 9.0 Hz, 1H), 4.28 – 4.11 (m, 4H), 1.16 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (101 MHz, $CDCl_3$)** δ 197.7, 172.7, 142.7, 138.1, 137.3, 133.6, 133.3, 131.1, 130.5, 130.4, 129.0, 128.6, 128.4, 128.2, 126.8, 122.9, 67.4, 65.7, 61.5, 60.4, 51.7, 14.3. **FT-IR (neat, cm^{-1}):** 2951.9, 2920.8, 1733.8, 1675.0, 1210.9, 1188.5, 785.0. **HRMS: (ESI-TOF)** calculated for $C_{26}H_{24}BrClNO_3$ $[M+H]^+$ 514.0603, found 514.0600.

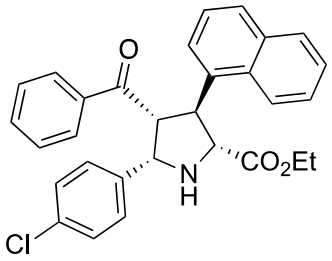


HPLC analysis: CHIRALPAK IC, heptane/2-propanol (90/10, 0.5 mL/min), λ = 254 nm, t_R = 7.348 min (minor), 10.212 min (major).



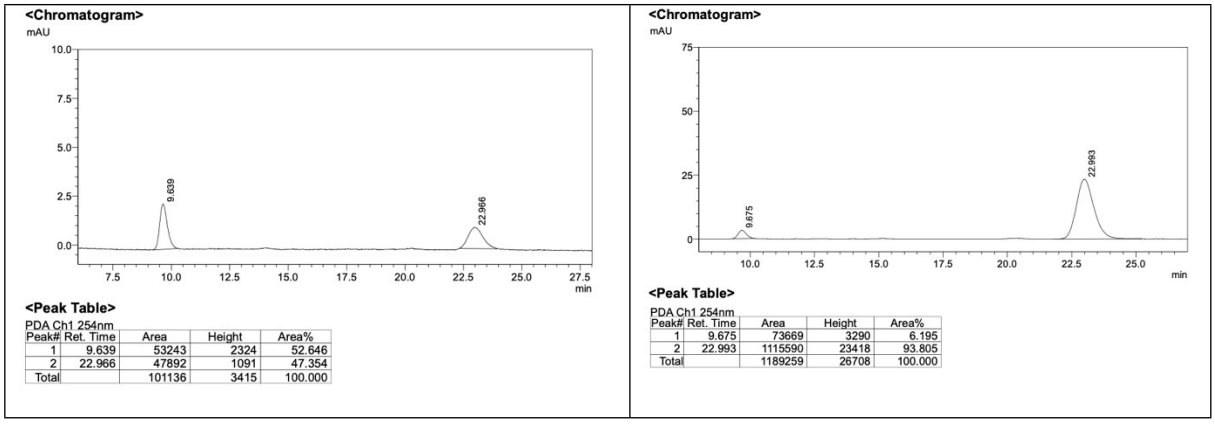
(2*R*,3*S*,4*R*,5*S*)-Ethyl-4-benzoyl-5-(4-chlorophenyl)-3-(naphthalen-1-yl)pyrrolidine-2-carboxylate (3f)

White solid, yield = 94% (68.1 mg); mp.= 120 – 121 ºC, Rf = 0.46 (cyclohexane/ethyl acetate, 3:1),



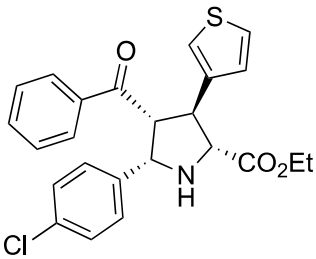
$[\alpha]_D^{20}$ = +3.27 (c = 1, $CHCl_3$), (*endo*/*exo* = >99:1), 94:6 er; **^{1}H NMR (400 MHz, $CDCl_3$)** δ 8.19 – 8.16 (m, 1H), 7.87 – 7.85 (m, 1H), 7.79 (d, *J* = 8.2 Hz, 1H), 7.68 (dd, *J* = 7.2, 1.3 Hz, 1H), 7.53 – 7.45 (m, 4H), 7.41 – 7.36 (m, 1H), 7.23 – 7.20 (m, 2H), 7.10 – 7.13 (m, 2H), 7.07 – 7.03 (m, 2H), 5.04 – 5.00 (m, 2H), 4.59 (dd, *J* = 8.5, 6.7 Hz, 1H), 4.31 (d, *J* = 7.8 Hz, 1H), 4.16 – 4.04 (m, 2H), 0.93 (t, *J* = 7.2 Hz, 3H). **^{13}C NMR (101 MHz, $CDCl_3$)** δ 199.4, 173.5, 137.6, 137.4, 134.1, 133.5, 133.1, 132.2, 129.0, 128.9, 128.44, 128.42, 128.2, 127.9, 126.5, 125.9, 125.6, 123.4, 67.9, 66.3, 61.5, 60.5, 13.9. **FT-IR (neat, cm^{-1}):** 2974.1, 2957.7, 1727.9, 1672.7, 1212.9, 1190.6, 776.8. **HRMS: (ESI-TOF)** calculated for $C_{30}H_{26}ClNO_3$ $[M+H]^+$ 484.1674, found 484.1673.

HPLC analysis: CHIRALPAK IC, heptane/2-propanol (90/10, 0.5 mL/min), λ = 254 nm, t_R = 9.675 min (minor), 22.993 min (major).



(2*R*,3*S*,4*R*,5*S*)- Ethyl-4-benzoyl-5-(4-chlorophenyl)-3-(thiophen-3-yl)pyrrolidine-2-carboxylate (3g)

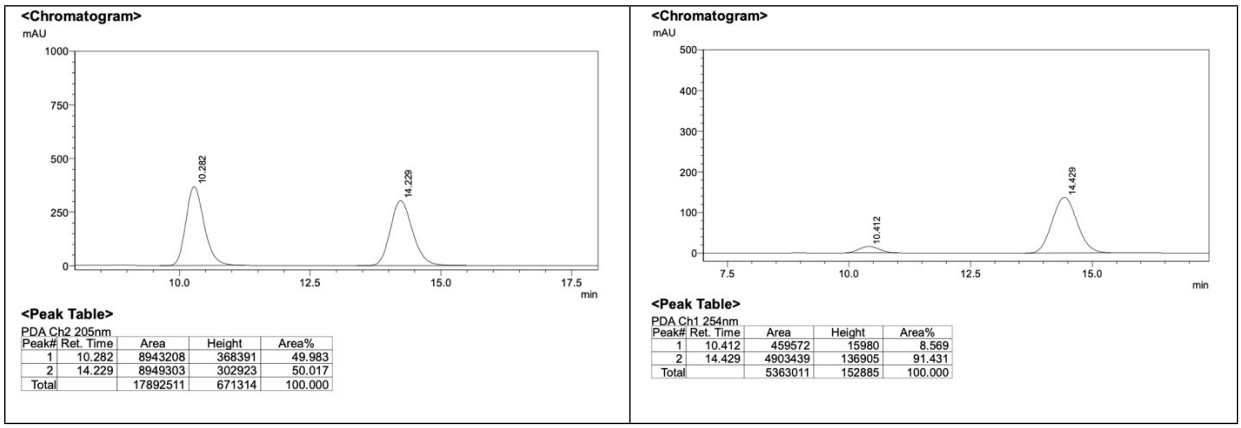
White solid, yield = 50% (33 mg); m.p.= 105 – 106 ºC, Rf = 0.46 (cyclohexane/ethyl acetate, 3:1),



$[\alpha]_D^{20}$ = +3.27 (c = 1, $CHCl_3$), (*endo*/*exo* = >99:1), 91:9 er; **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.59 (dd, *J* = 8.4, 1.4 Hz, 2H), 7.48 – 7.43 (m, 1H), 7.33 – 7.28 (m, 3H), 7.18 (ddd, *J* = 3.0, 1.4, 0.6 Hz, 1H), 7.09 (dd, *J* = 5.0, 1.4 Hz, 1H), 7.05 (s, 4H), 4.92 (d, *J* = 8.7 Hz, 1H), 4.46 (t, *J* = 8.5 Hz, 1H), 4.32 – 4.18 (m, 3H), 4.14 (d, *J* = 9.1 Hz, 1H), 1.23 (t, *J* = 7.1, 3H). **^{13}C NMR (101 MHz, $CDCl_3$)** δ 198.3, 172.9, 140.9, 138.1, 137.4, 133.5, 133.2, 128.9, 128.6, 128.4,

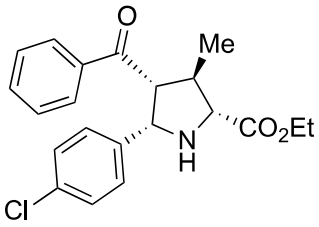
128.2, 126.7, 126.3, 121.7, 67.0, 65.5, 61.5, 60.0, 47.6, 14.3. **FT-IR (neat, cm^{-1}):** 2362.9, 1733.4, 1674.8, 1210.3, 1188.6, 722.2. **HRMS: (ESI-TOF)** calculated for $C_{24}H_{23}ClNO_3S$ $[M+H]^+$ 440.1082, found 440.1080

HPLC analysis: CHIRALPAK IC, heptane/2-propanol (90/10, 0.5 mL/min), λ = 254 nm, t_R = 10.412 min (minor), 14.429 min (major).

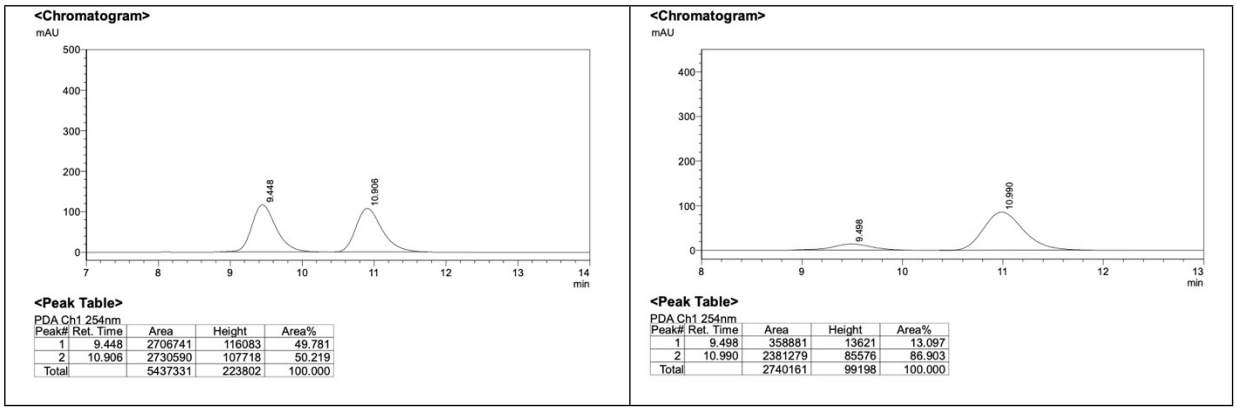


(2*R*,3*R*,4*R*,5*S*)-Ethyl-4-benzoyl-5-(4-chlorophenyl)-3-methylpyrrolidine-2-carboxylate (3h)

White solid, yield = 35% (19.5 mg); m.p.= 85 – 86 ºC, Rf = 0.40 (cyclohexane/ethyl acetate, 3:1), $[\alpha]_D^{20}$ = +108.70 (c = 0.65, $CHCl_3$), (*endo*/*exo* = >99:1), 87:13 er; **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.69 – 7.66 (m, 2H), 7.50 (ddt, *J* = 7.8, 6.8, 1.3 Hz, 1H), 7.39 – 7.35 (m, 2H), 7.04 – 7.01 (m, 2H), 6.97 – 6.94 (m, 2H), 4.77 (d, *J* = 8.9 Hz, 1H), 4.38 – 4.25 (m, 2H), 3.99 (t, *J* = 8.9 Hz, 1H), 3.62 (d, *J* = 9.4 Hz, 1H), 2.98 – 2.88 (m, 1H), 2.81 (s, 1H), 1.36 (t, *J* = 7.1 Hz, 3H), 1.25 (d, *J* = 6.6 Hz, 3H). **^{13}C NMR (101 MHz, $CDCl_3$) δ** 198.4, 173.7, 139.0, 137.7, 133.3, 133.2, 128.8, 128.7, 128.3, 128.2, 67.1, 65.0, 61.4, 60.3, 41.1, 17.5, 14.4. **FT-IR (neat, cm^{-1}):** 2986.1, 2956.9, 1736.8, 1671.7, 1252.7, 1196.5, 686.5. **HRMS: (ESI-TOF)** calculated for $C_{21}H_{23}ClNO_3$ $[M+H]^+$ 372.1361, found 372.1366.

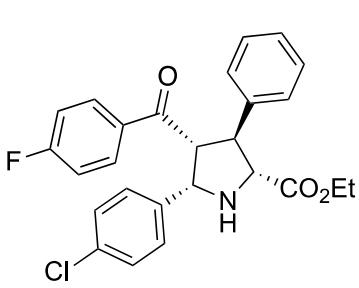


HPLC analysis: CHIRALPAK IC, heptane/2-propanol (90/10, 0.5 mL/min), λ = 254 nm, t_R = 9.498 min (minor), 10.990 min (major).

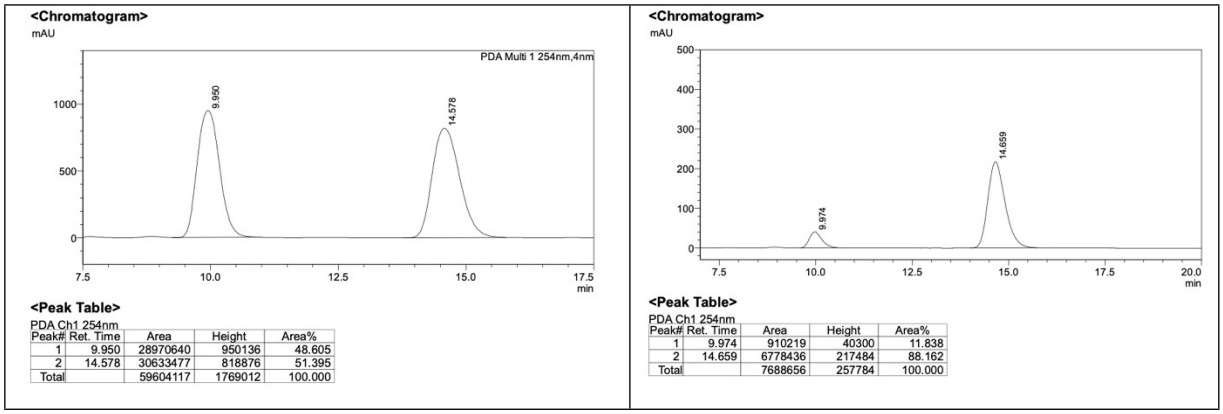


(2*R*,3*S*,4*R*,5*S*)-Ethyl-5-(4-chlorophenyl)-4-(4-fluorobenzoyl)-3-phenylpyrrolidine-2-carboxylate (3i)

White solid, yield = 60% (37.8 mg); m.p.= 125 – 126 ºC, Rf = 0.50 (cyclohexane/ethyl acetate, 3:1), $[\alpha]_D{}^{20}$ = +0.58 (c = 1, $CHCl_3$), (*endo*/*exo* = >99:1), 88:12 er; **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.61 – 7.56 (m, 2H), 7.38 – 7.31 (m, 4H), 7.27 – 7.22 (m, 1H), 7.05 – 7.10 (m, 4H), 6.99 – 6.93 (m, 2H), 4.96 (d, *J* = 8.8 Hz, 1H), 4.46 (dd, *J* = 8.8, 7.9 Hz, 1H), 4.26 (dq, *J* = 10.8, 7.1 Hz, 1H), 4.19 – 4.05 (m, 3H), 3.00 (s, 1H), 1.17 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (101 MHz, $CDCl_3$)** δ 196.8, 172.9, 165.7 (d, *J* = 255.6 Hz), 140.4, 138.0, 133.9 (d, *J* = 3.1 Hz), 133.6, 130.8 (d, *J* = 9.5 Hz), 128.93, 128.92, 128.5, 127.9, 127.4, 115.7 (d, *J* = 21.7 Hz), 67.7, 65.9, 61.4, 60.5, 52.7, 14.3. **^{19}F NMR (376 MHz, $CDCl_3$)** δ -104.8. **FT-IR (neat, cm^{-1}):** 2925.0, 2907.3, 1718.7, 1675.8, 1224.8, 1172.6, 755.0. **HRMS: (ESI-TOF)** calculated for $C_{26}H_{24}ClFNO_3$ $[M+H]^+$ 452.1423, found 452.1424.

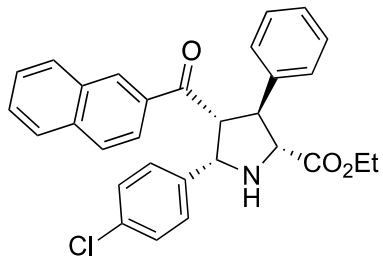


HPLC analysis: CHIRALPAK IC, heptane/2-propanol (90/10, 0.5 mL/min), λ = 254 nm, t_R = 9.974 min (minor), 14.659 min (major).

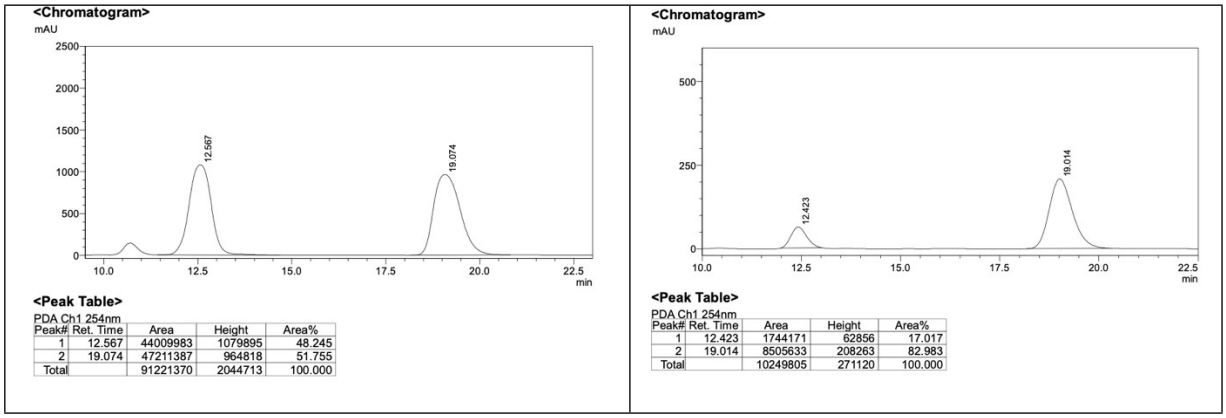


(2*R*,3*S*,4*R*,5*S*)-Ethyl-4-(2-naphthoyl)-5-(4-chlorophenyl)-3-phenylpyrrolidine-2-carboxylate (3j)

White solid, yield = 92% (68.1 mg); m.p.= 166 – 167 ºC, Rf = 0.47 (cyclohexane/ethyl acetate, 3:1), $[\alpha]_D^{20}$ = +122.35 (c = 1, $CHCl_3$), (*endo*/*exo* = >99:1), 83:17 er; **^{1}H NMR (400 MHz, $CDCl_3$)** δ 8.14 (d, *J* = 2.0 Hz, 1H), 7.86 (dd, *J* = 8.3, 1.1 Hz, 1H), 7.80 (d, *J* = 8.2 Hz, 1H), 7.72 (d, *J* = 9.1 Hz, 1H), 7.61 – 7.50 (m, 3H), 7.42 – 7.39 (m, 2H), 7.34 (ddd, *J* = 7.8, 6.9, 1.2 Hz, 2H), 7.25 – 7.22 (m, 1H), 7.09 – 7.06 (m, 2H), 7.03 – 6.99 (m, 2H), 5.06 (d, *J* = 8.6 Hz, 1H), 4.71 (t, *J* = 8.5 Hz, 1H), 4.27 (dq, *J* = 10.7, 7.2 Hz, 1H), 4.20 – 4.11 (m, 3H), 3.04 (brs, 1H), 1.18 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (101 MHz, $CDCl_3$)** δ 198.1, 173.1, 140.4, 138.4, 135.6, 134.9, 133.5, 132.4, 129.9, 129.6, 128.91, 128.90, 128.7, 128.5, 128.4, 128.0, 127.9, 127.4, 126.9, 123.9, 67.7, 66.0, 61.4, 60.6, 52.6, 14.3. **FT-IR (neat, cm^{-1}):** 2968.2, 2952.5, 1729.6, 1669.1, 1177.8, 1158.8, 745.3. **HRMS: (ESI-TOF)** calculated for $C_{30}H_{27}ClNO_3$ $[M+H]^+$ 484.1674, found 484.1673.

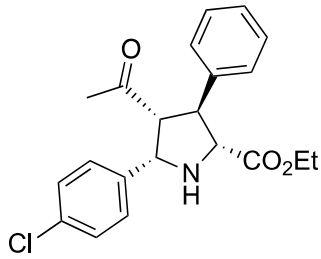


HPLC analysis: CHIRALPAK IC, heptane/2-propanol (90/10, 0.5 mL/min), λ = 254 nm, t_R = 12.423 min (minor), 19.014 min (major).



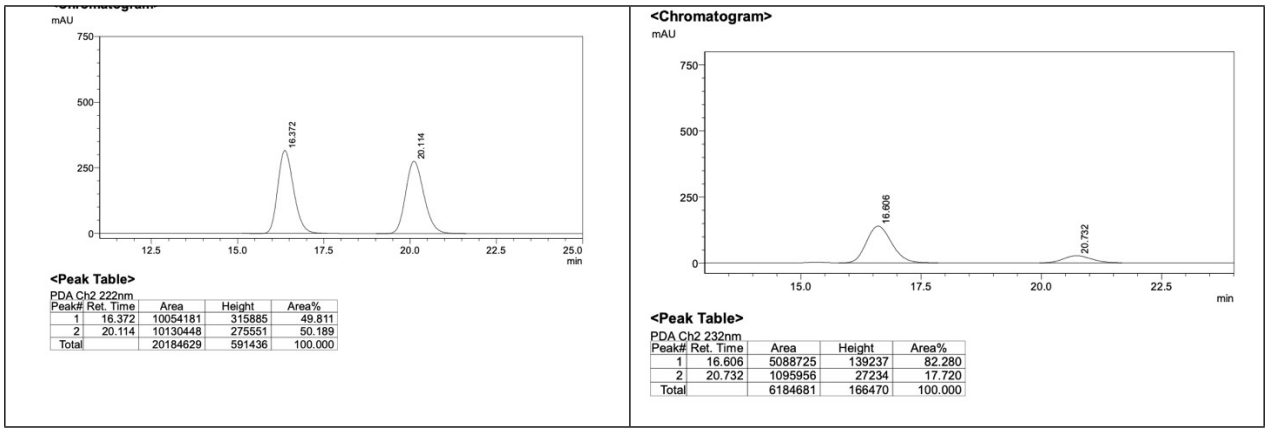
(2*R*,3*S*,4*R*,5*S*)-Ethyl-4-acetyl-5-(4-chlorophenyl)-3-phenylpyrrolidine-2-carboxylate (3k)

White solid, yield = 21 % (12 mg); m.p.= 104 – 105 ºC, Rf = 0.48 (cyclohexane/ethyl acetate, 3:1), $[\alpha]_D^{20}$ = +21.63 (c = 0.65, $CHCl_3$), (*endo*/*exo* = >99:1), 82:18 er; **^{1}H NMR (500 MHz, $CDCl_3$)** δ 7.35 – 7.26 (m, 8H), 7.26 – 7.24 (m, 1H), 4.85 (d, *J* = 8.7 Hz, 1H), 4.24 (dq, *J* = 10.8, 7.1 Hz, 1H), 4.14 (dq, *J* = 10.8, 7.2 Hz, 1H), 3.99 (d, *J* = 8.7 Hz, 1H), 3.89 (dd, *J* = 8.7, 7.5 Hz, 1H), 3.64 (dd, *J* = 8.9, 7.4 Hz, 1H), 2.85 (s, 1H), 1.60 (s, 3H), 1.18 (t, *J* = 7.2 Hz, 3H). **^{13}C NMR (126 MHz, $CDCl_3$)** δ 207.2, 172.7, 140.8, 138.0, 134.0, 129.0, 128.9, 128.88, 127.9, 127.3, 67.9, 65.8, 65.0, 61.4, 52.1, 31.6, 14.3. **FT-IR (neat, cm^{-1}):**



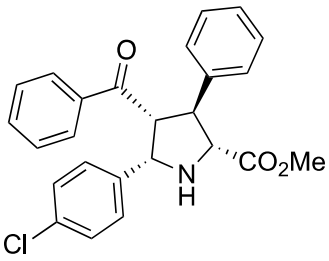
2975.0, 2915.3, 1729.8, 1162.5, 1120.3, 765.6. **HRMS: (ESI-TOF)** calculated for $C_{21}H_{23}ClNO_3$ $[M+H]^+$ 372.1361, found 372.1365.

HPLC analysis: CHIRALPAK IC, heptane/2-propanol (90/10, 0.5 mL/min), λ = 254 nm, t_R = 16.606 min (major), 20.732 min (minor).

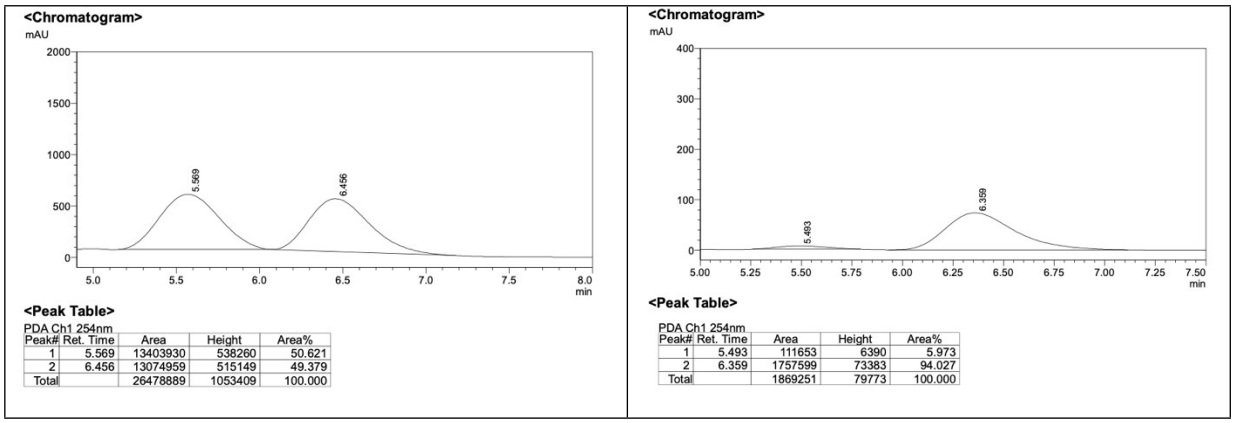


(2*R*,3*S*,4*R*,5*S*)-Methyl-4-benzoyl-5-(4-chlorophenyl)-3-phenylpyrrolidine-2-carboxylate (3l)[1]

White solid, yield = 91% (57.5 mg); m.p.= 164 –166 ºC, Rf = 0.46 (cyclohexane/ethyl acetate, 3:1), $[\alpha]_D^{20}$ = +84.14 (c = 1, $CHCl_3$), (*endo*/*exo* = >99:1), 94:6 er; **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.60 – 7.54 (m, 2H), 7.43 (t, *J* = 7.4 Hz, 1H), 7.38 – 7.33 (m, 4H), 7.32 – 7.28 (m, 2H), 7.24 – 7.23 (m, 1H), 7.06 (s, 4H), 4.97 (d, *J* = 8.7 Hz, 1H), 4.51 (t, *J* = 8.3 Hz, 1H), 4.18 (d, *J* = 9.0 Hz, 1H), 4.10 (t, *J* = 8.7 Hz, 1H), 3.74 (s, 3H). **^{13}C NMR (101 MHz, $CDCl_3$)** δ 198.5, 173.5, 140.5, 138.0, 137.5, 133.5, 133.2, 129.6, 130.0, 128.9, 128.5, 128.4, 128.2, 127.9, 127.4, 67.7, 65.9, 60.5, 52.5. **FT-IR (neat, cm^{-1}):** 2921.2, 2851.8, 1732.0, 1673.9, 1211.9, 1179.8, 757.1. **HRMS: (ESI-TOF)** calculated for $C_{25}H_{23}ClNO_3$ $[M+H]^+$ 420.1361, found 420.1361.

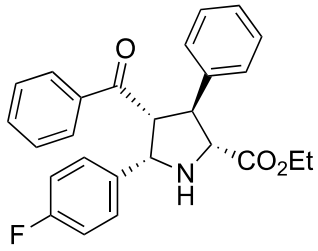


HPLC analysis: CHIRALPAK IC, heptane/2-propanol (50/50, 0.5 mL/min), λ = 254 nm, t_R = 5.493 (minor), 6.359 (major).

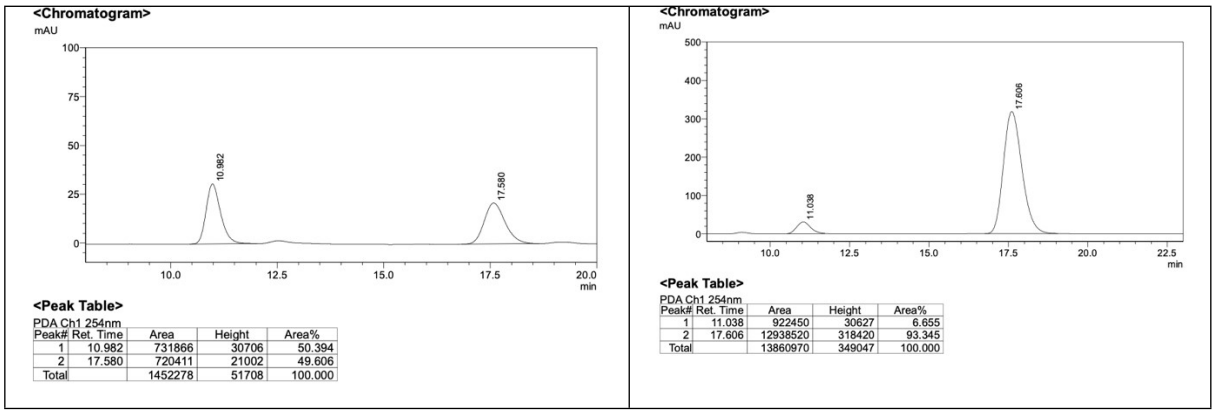


(2*R*,3*S*,4*R*,5*S*)-Ethyl-4-benzoyl-5-(4-fluorophenyl)-3-phenylpyrrolidine-2-carboxylate (3m)[2]

White solid, yield = 77% (48.1 mg); m.p.= 149 –150 ºC, Rf = 0.33 (cyclohexane/ethyl acetate, 3:1), $[\alpha]_D^{20}$ = +59.86 (c = 1, $CHCl_3$), (*endo*/*exo* = >99:1), 93:7 er; **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.57–7.54 (m, 2H), 7.44 – 7.21 (m, 8H), 7.12 – 7.07 (m, 2H), 6.80 – 6.74 (m, 2H), 4.99 (d, *J* = 8.7 Hz, 1H), 4.52 (dd, *J* = 9.1, 7.8 Hz, 1H), 4.26 (dq, *J* = 10.8, 7.1 Hz, 1H), 4.17 – 4.08 (m, 3H), 2.98 (s, 1H), 1.17 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (101 MHz, $CDCl_3$)** δ 198.4, 173.1, 162.2 (d, $^1J_{C\text{-}F}$ = 246.4 Hz), 140.5, 137.5, 135.4 (d, $^4J_{C\text{-}F}$ = 3.4 Hz), 133.1, 129.3 (d, $^3J_{C\text{-}F}$ = 8.4 Hz), 128.9, 128.5, 128.2, 128.0, 127.3, 115.1 (d, $^2J_{C\text{-}F}$ = 21.4 Hz), 67.7, 65.9, 61.4, 60.7, 52.6, 14.3. **^{19}F NMR (376 MHz, $CDCl_3$)** δ -114.7. **FT-IR (neat, cm^{-1}):** 2934.1, 2909.5, 1733.3, 1673.0, 1177.4, 1157.6, 766.9. **HRMS: (ESI-TOF)** calculated for $C_{26}H_{25}FNO_3$ $[M+H]^+$ 418.1813, found 418.1812.

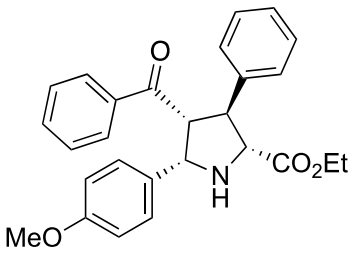


HPLC analysis: CHIRALPAK IC, heptane/2-propanol (90/10, 0.5 mL/min), λ = 254 nm, t_R = 11.038 (minor), 3.683 (major).



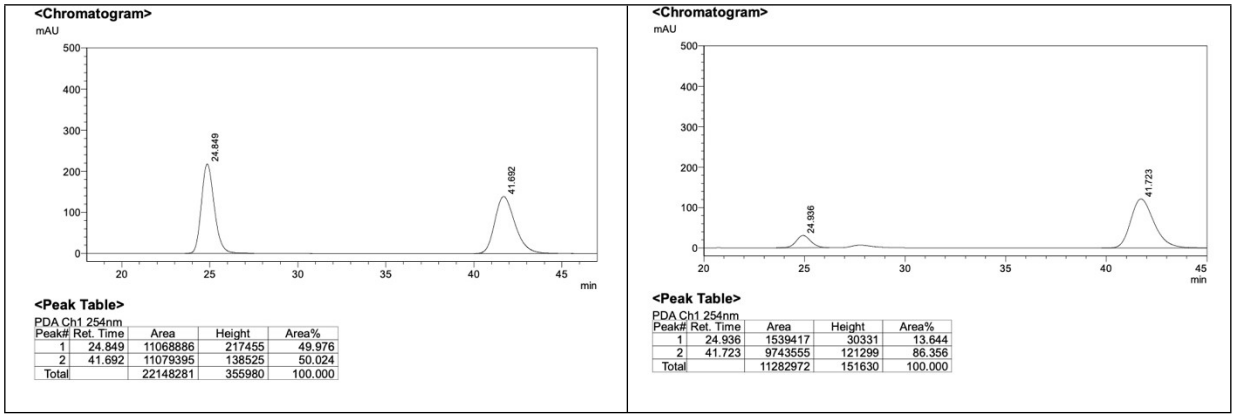
(2*R*,3*S*,4*R*,5*S*)- Ethyl-4-benzoyl-5-(4-methoxyphenyl)-3-phenylpyrrolidine-2-carboxylate (3n)[2]

White solid, yield = 79% (50.8 mg); m.p.= 142 –143 ºC, Rf = 0.28 (cyclohexane/ethyl acetate, 3:1), $[\alpha]_D^{20}$ = +59.02 (c = 1.05, $CHCl_3$), (*endo*/*exo* = >99:1), 86:14 er; **^{1}H NMR (400 MHz, $CDCl_3$)** δ



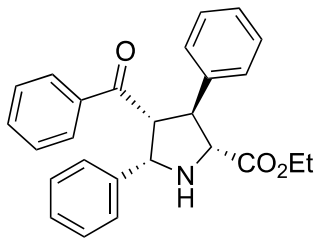
7.58 – 7.55 (m, 2H), 7.40 (ddt, *J* = 13.8, 6.8, 1.3 Hz, 3H), 7.34 – 7.21 (m, 5H), 7.50 – 7.00 (m, 2H), 6.64 – 6.60 (m, 2H), 4.97 (d, *J* = 9.2 Hz, 1H), 4.51 (ddd, *J* = 8.8, 6.6, 1.8 Hz, 1H), 4.26 (dq, *J* = 10.8, 7.1 Hz, 1H), 4.18 – 4.07 (m, 3H), 3.68 (s, 3H), 2.98 (s, 1H) 1.16 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (101 MHz, $CDCl_3$)** δ 198.6, 173.1, 159.0, 140.7, 137.6, 132.9, 131.6, 128.82, 128.80, 128.76, 128.4, 128.2, 128.0, 127.2, 113.7, 67.8, 66.2, 61.3, 61.0, 55.3, 52.8, 14.3. **FT-IR (neat, cm^{-1}):** 2924.1, 2906.4, 1729.1, 1670.1, 1261.9, 1205.9, 1177.1, 767.2. **HRMS: (ESI-TOF)** calculated for $C_{27}H_{28}NO_4$ $[M+H]^+$ 430.2013, found 430.2015.

HPLC analysis: CHIRALPAK IC, heptane/2-propanol (90/10, 0.5 mL/min), λ = 254 nm, t_R = 24.936 (minor), 41.723 (major).



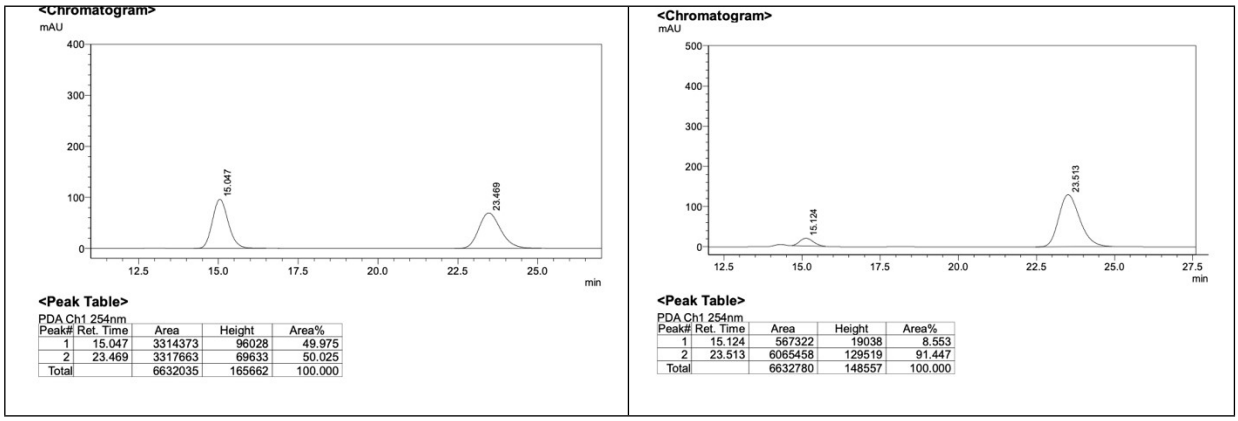
(2*R*,3*S*,4*R*,5*S*)-Ethyl-4-benzoyl-3,5-diphenylpyrrolidine-2-carboxylate (3o)[2]

White solid, yield = 71% (42.4 mg); m.p.= 144 –145 ºC, Rf = 0.40 (cyclohexane/ethyl acetate, 3:1), $[\alpha]_D^{20}$ = +69.67 (c = 1.00, $CHCl_3$), (*endo*/*exo* = >99:1), 91:9 er; **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.56



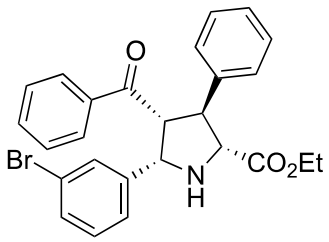
– 7.52 (m, 2H), 7.42 – 7.37 (m, 3H), 7.33 (ddd, *J* = 8.0, 6.9, 1.3 Hz, 2H), 7.27 – 7.22 (m, 3H), 7.13 – 7.06 (m, 5H), 5.00 (d, *J* = 8.8 Hz, 1H), 4.54 (dd, *J* = 8.9, 7.6 Hz, 1H), 4.27 (dq, *J* = 10.8, 7.1 Hz, 1H), 4.19 – 4.08 (m, 3H), 1.18 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (101 MHz, $CDCl_3$) δ** 198.6, 173.0, 140.8, 139.3, 137.6, 132.9, 128.8, 128.4, 128.3, 128.2, 128.00, 127.8, 127.6, 127.2, 67.9, 66.8, 61.4, 60.8, 53.0, 14.3. **FT-IR (neat, cm^{-1}):** 2973.6, 2913.9, 1723.6, 1669.4, 1210.6, 1179.9, 1160.7, 766.6. **HRMS: (ESI-TOF)** calculated for $C_{26}H_{26}NO_3$ $[M+H]^+$ 400.1907, found 400.1907.

HPLC analysis: CHIRALPAK IC, heptane/2-propanol (90/10, 0.5 mL/min), λ = 254 nm, t_R = 15.124 (minor), 23.513 (major).

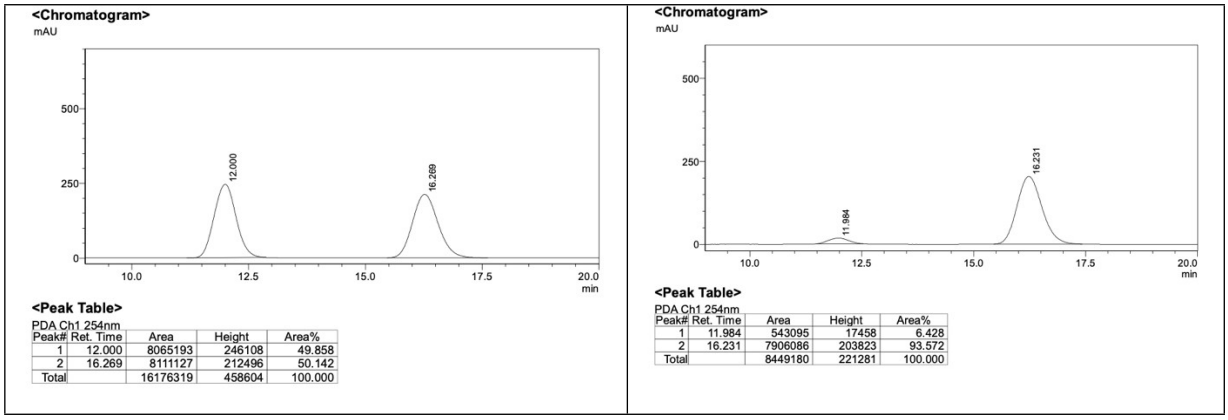


(2*R*,3*S*,4*R*,5*S*)-Ethyl-4-benzoyl-5-(3-bromophenyl)-3-phenylpyrrolidine-2-carboxylate (3p)

White solid, yield = 84% (60.2 mg); m.p.= 130 –131 ºC, Rf = 0.44 (cyclohexane/ethyl acetate, 3:1), $[\alpha]_D^{20}$ = +44.48 (c = 1.00, $CHCl_3$), (*endo*/*exo* = >99:1), 94:6 er; **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.57 – 7.54 (m, 2H), 7.44 (ddt, *J* = 8.7, 6.9, 1.3 Hz, 1H), 7.39 – 7.30 (m, 5H), 7.29 – 7.22 (m, 2H), 7.20 – 7.18 (m, 2H), 7.11 (dt, *J* = 7.5, 1.7 Hz, 1H), 7.00 – 6.96 (m, 1H), 4.94 (d, *J* = 9.1 Hz, 1H), 4.52 (dd, *J* = 8.8, 7.7 Hz, 1H), 4.27 (dq, *J* = 10.8, 7.1 Hz, 1H), 4.21 – 4.06 (m, 3H), 1.20 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (101 MHz, $CDCl_3$)** δ 198.4, 172.9, 141.8, 140.6, 137.6, 133.2, 130.9, 130.8, 129.8, 128.92, 128.90, 128.6, 128.1, 128.0, 127.3, 125.9, 122.3, 67.8, 66.0, 61.4, 60.4, 52.4, 14.3. **FT-IR (neat, cm^{-1}):** 1731.4, 1672.5, 1210.2, 1178.8, 1157.6, 770.9. **HRMS: (ESI-TOF)** calculated for $C_{26}H_{24}BrNO_3Na$ $[M+Na]^+$ 500.0832, found 500.0832.

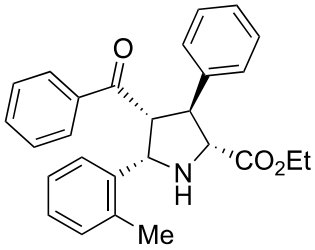


HPLC analysis: CHIRALPAK IC, heptane/2-propanol (90/10, 0.5 mL/min), λ = 254 nm, t_R = 11.984 (minor), 16.231 (major).



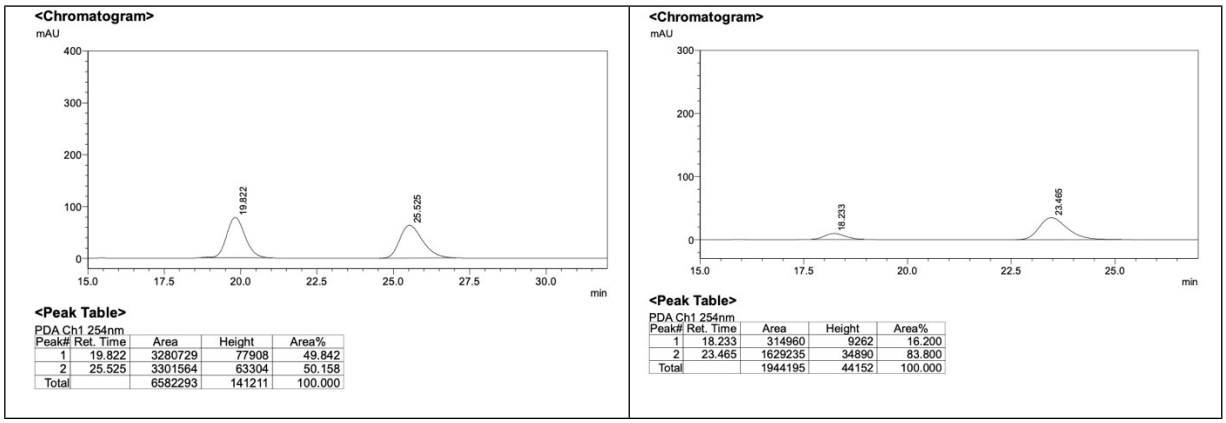
(2*R*,3*S*,4*R*,5*S*)-Ethyl-4-benzoyl-3-phenyl-5-(*o*-tolyl)pyrrolidine-2-carboxylate (3q)

White solid, yield = 54% (33.7 mg); m.p.= 156 –157 ºC, Rf = 0.44 (cyclohexane/ethyl acetate, 3:1), $[\alpha]_D^{20}$ = +26.89 (c = 1.00, $CHCl_3$), (*endo*/*exo* = >99:1), 84:16 er; **^{1}H NMR (400 MHz, $CDCl_3$)** δ



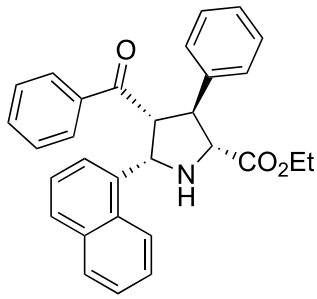
7.39 – 7.30 (m, 6H), 7.28 – 7.24 (m, 3H), 7.16 – 7.11 (m, 2H), 7.07 (tdd, *J* = 7.9, 1.5, 0.7 Hz, 1H), 6.92 (td, *J* = 7.4, 1.3 Hz, 1H), 6.74 (ddt, *J* = 7.5, 1.4, 0.6 Hz, 1H), 5.11 (d, *J* = 8.2 Hz, 1H), 4.48 (dd, *J* = 8.5, 5.9 Hz, 1H), 4.28 (dq, *J* = 10.8, 7.1 Hz, 1H), 4.21 – 4.05 (m, 3H), 3.15 (s, 1H), 2.12 (s, 3H), 1.20 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (101 MHz, $CDCl_3$)** δ 200.5, 172.5, 141.8, 137.9, 136.2, 135.0, 132.6, 130.0, 129.0, 128.1, 127.8, 127.6, 127.4, 127.2, 126.5, 126.3, 68.4, 62.9, 61.3, 59.7, 54.4, 19.7, 14.3. **FT-IR (neat, cm^{-1}):** 2972.4, 2934.7, 1742.9, 1674.6, 1206.7, 1176.7, 763.9. **HRMS: (ESI-TOF)** calculated for $C_{27}H_{28}NO_3$ $[M+H]^+$ 414.2064, found 414.2063.

HPLC analysis: CHIRALPAK IC, heptane/2-propanol (90/10, 0.5 mL/min), λ = 254 nm, t_R = 18.223 (minor), 23.465 (major).



(2*R*,3*S*,4*R*,5*S*)-Ethyl-4-benzoyl-5-(naphthalen-1-yl)-3-phenylpyrrolidine-2-carboxylate (3r)[2]

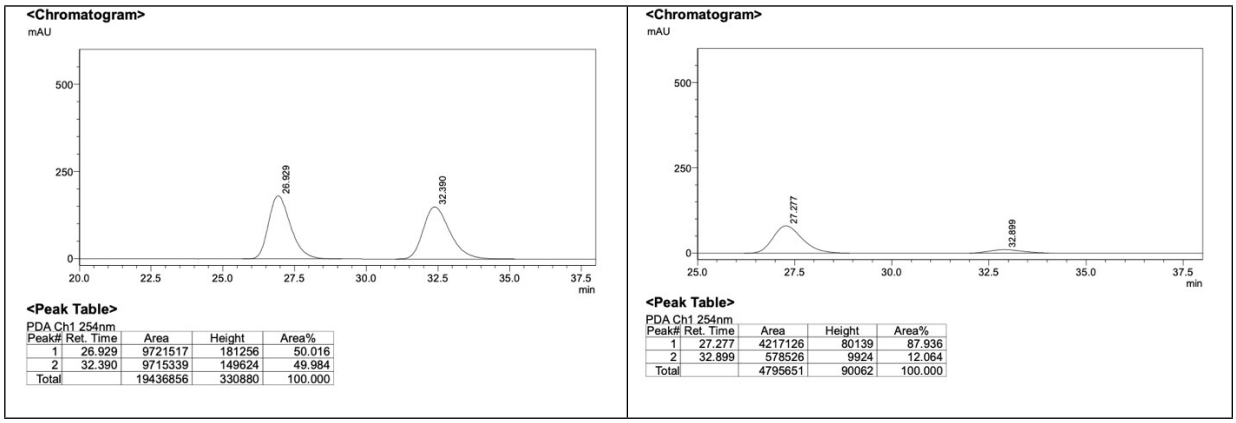
White solid, Yield = 72% (48.4 mg); m.p.= 147 –148 ºC, Rf = 0.48 (cyclohexane/ethyl acetate, 3:1), $[\alpha]_D^{20}$ = -51.48 (c = 1.00, $CHCl_3$), (*endo*/*exo* = >99:1), 12:88 er; **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.96



(d, *J* = 8.2 Hz, 1H), 7.61 – 7.58 (m, 1H), 7.52 – 7.38 (m, 7H), 7.34 – 7.28 (m, 3H), 7.12 – 7.09 (m, 2H), 7.05 – 6.99 (m, 1H), 6.80 – 6.77 (m, 2H), 5.73 (d, *J* = 7.7 Hz, 1H), 4.67 (dd, *J* = 7.8, 4.5 Hz, 1H), 4.35 (dq, *J* = 10.9, 7.2 Hz, 1H), 4.30 – 4.21 (m, 2H), 4.15 (dd, *J* = 7.7, 4.5 Hz, 1H), 3.48 (s, 1H), 1.28 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (101 MHz, $CDCl_3$)** δ 200.8, 172.5, 142.8, 136.9, 133.4, 133.2, 132.2, 131.0, 129.2, 129.0, 128.0, 127.9, 127.5, 127.4, 127.3, 126.1, 125.32, 125.30, 124.0, 122.7, 68.6, 63.1, 61.4, 59.8, 54.3, 14.4.

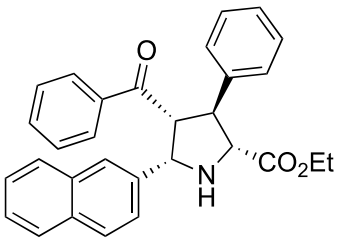
FT-IR (neat, cm^{-1}): 2921.7, 2851.9, 1741.8, 1670.7, 1210.4, 1193.6, 1173.1, 757.1. **HRMS: (ESI-TOF)** calculated for $C_{30}H_{28}NO_3$ $[M+H]^+$ 450.2064, found 450.2064.

HPLC analysis: CHIRALPAK IC, heptane/2-propanol (90/10, 0.5 mL/min), λ = 254 nm, t_R = 27.277 min (major), 32.899 min (minor).

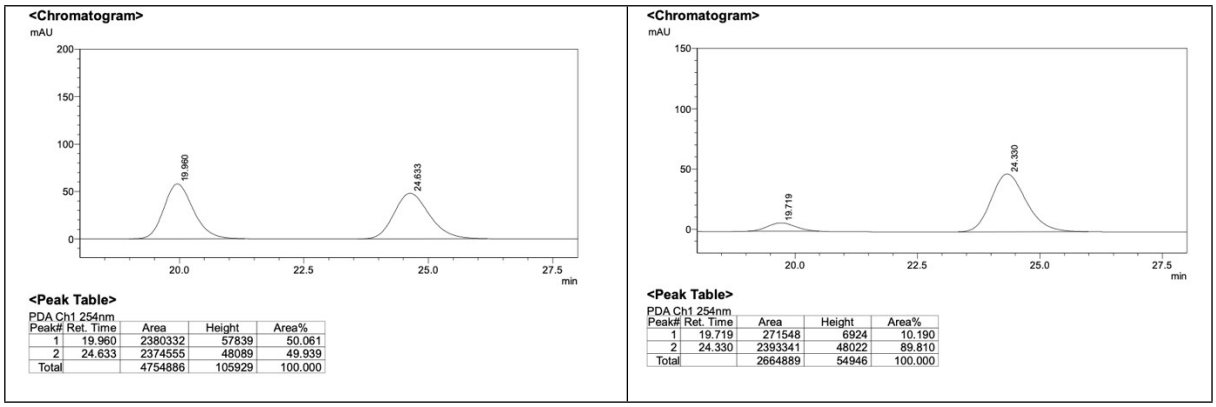


(2*S*,3*R*,4*S*,5*R*)- Ethyl-4-benzoyl-5-(naphthalen-2-yl)-3-phenylpyrrolidine-2-carboxylate (3s)

White solid, yield = 59% (40.0 mg); m.p.= 174 –175 ºC, Rf = 0.47 (cyclohexane/ethyl acetate, 3:1), $[\alpha]_D^{20}$ = +114.52 (c = 1.00, $CHCl_3$), (*endo*/*exo* = >99:1), 90:10 er; **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.68 – 7.61 (m, 2H), 7.58 – 7.54 (m, 2H), 7.50 – 7.48 (m, 2H), 7.43 – 7.29 (m, 7H), 7.26 – 7.25 (m, 1H), 7.24 – 7.22 (m, 1H), 7.18 – 7.13 (m, 2H), 5.17 (d, *J* = 8.6 Hz, 1H), 4.62 (dd, *J* = 9.0, 7.3 Hz, 1H), 4.29 (dq, *J* = 10.8, 7.1 Hz, 1H), 4.22 – 4.14 (m, 3H), 3.22 (s, 1H), 1.19 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (101 MHz, $CDCl_3$)** δ 198.7, 173.0, 140.8, 137.6, 136.8, 133.0, 132.84, 132.82, 128.9, 128.3, 128.1, 128.0, 127.99, 127.98, 127.6, 127.2, 126.6, 126.1, 125.9, 125.4, 68.0, 66.9, 61.3, 60.8, 53.0, 14.3. **FT-IR (neat, cm^{-1}):** 2925.3, 1724.7, 1671.0, 1208.0, 1178.9, 1123.9, 767.3. **HRMS: (ESI-TOF)** calculated for $C_{30}H_{28}NO_3$ $[M+H]^+$ 450.2064, found 450.2066.

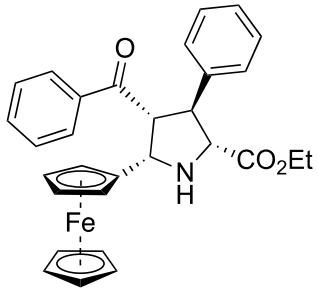


HPLC analysis: CHIRALPAK IC, heptane/2-propanol (90/10, 0.5 mL/min), λ = 254 nm, t_R = 19.719 min (minor), 24.330 min (major).

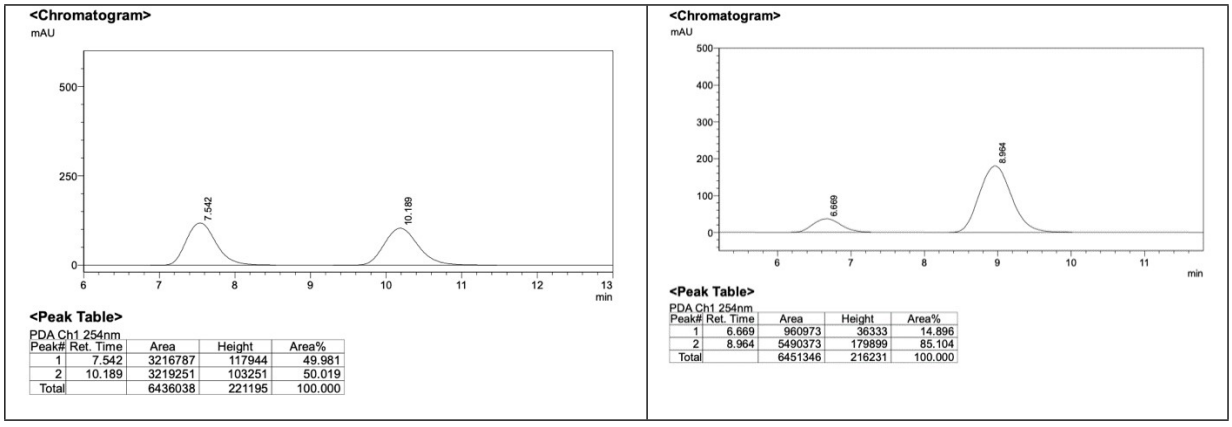


(2*S*,3*R*,4*S*,5*R*)- Ethyl-4-benzoyl-5-(ferrocenyl)-3-phenylpyrrolidine-2-carboxylate (3t)

Yellow solid, yield = 20% (15.2 mg); m.p.= 140 – 141 ºC, Rf = 0.48 (cyclohexane/ethyl acetate, 3:1), $[\alpha]_D^{20}$ = +31.69 (c = 0.26, $CHCl_3$), (*endo*/*exo* = >99:1), 85:15 er; **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.72 – 7.70 (m, 2H), 7.52 – 7.64 (m, 1H), 7.39 – 7.33 (m, 4H), 7.29 – 7.26 (m, 2H), 7.20 – 7.16 (m, 1H), 4.73 (d, *J* = 8.4 Hz, 1H), 4.51 (dd, *J* = 10.7, 8.4 Hz, 1H), 4.39 (dd, *J* = 2.6, 1.4 Hz, 1H), 4.27 (dq, *J* = 10.8, 7.1 Hz, 1H), 4.19 (s, 5H), 4.13 – 4.04 (m, 3H), 3.91 (t, *J* = 10.4 Hz, 1H), 3.84 (td, *J* = 2.4, 1.3 Hz, 1H), 3.30 (dt, *J* = 2.6, 1.4 Hz, 1H), 3.13 (s, 1H), 1.13 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (101 MHz, $CDCl_3$)** δ 196.2, 174.2, 139.7, 137.6, 133.0, 128.6, 128.6, 128.3, 128.2, 127.1, 88.6, 68.9, 68.7, 68.7, 67.8, 66.9, 65.8, 61.6, 61.4, 60.5, 50.7, 27.1, 14.3. **FT-IR (neat, cm^{-1}):** 2980.1, 2927.1, 1728.1, 1673.3, 1219.6, 1197.8, 1184.5, 753.7. **HRMS: (ESI-TOF)** calculated for $C_{30}H_{30}FeNO_3$ $[M+H]^+$ 508.1570, found 508.1568.



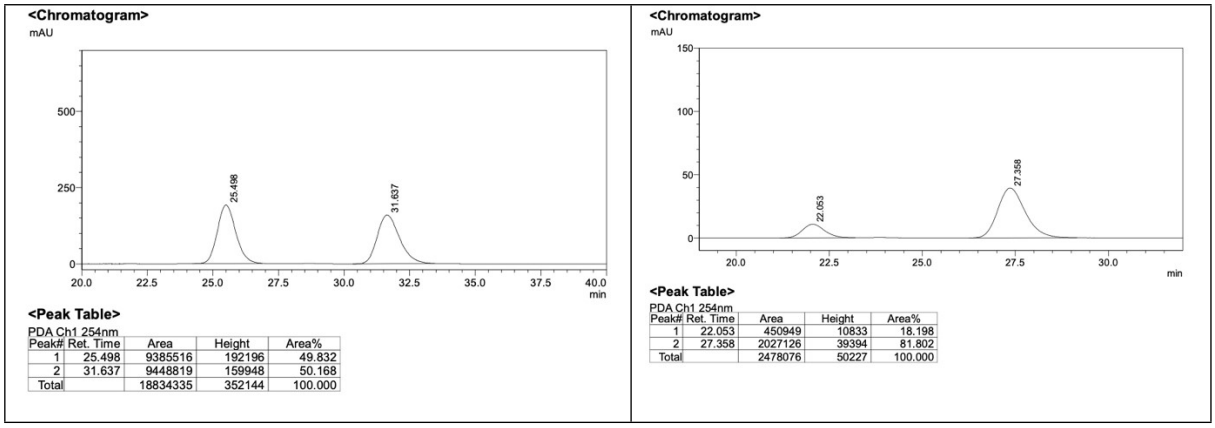
HPLC analysis: CHIRALPAK IC, heptane/2-propanol (90/10, 0.5 mL/min), λ = 254 nm, t_R = 6.669 min (minor), 8.964 min (minor).



(2*R*,3*S*,4*R*,5*S*)-Ethyl-4-benzoyl-3-phenyl-5-(thiophen-2-yl)pyrrolidine-2-carboxylate (3u)[2]

White solid, Yield = 37% (22.8 mg); m.p.= 152 – 153 ºC, Rf = 0.40 (cyclohexane/ethyl acetate, 3:1), $[\alpha]_D^{20}$ = +37.75 (c = 0.5, $CHCl_3$), (*endo*/*exo* = >99:1), 82:18 er; **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.71 – 7.68 (m, 2H), 7.47 (ddt, *J* = 7.9, 6.9, 1.3 Hz, 1H), 7.40 – 7.30 (m, 6H), 7.24 – 7.20 (m, 1H), 7.04 (dd, *J* = 5.0, 1.3 Hz, 1H), 6.74 (dd, *J* = 5.0, 3.5 Hz, 1H), 6.71 (ddd, *J* = 3.6, 1.3, 0.7 Hz, 1H), 5.28 (d, *J* = 8.2 Hz, 1H), 4.54 (t, *J* = 8.6 Hz, 1H), 4.26 (dq, *J* = 10.8, 7.1 Hz, 1H), 4.17 – 4.09 (m, 3H), 3.08 (s, 1H), 1.17 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (101 MHz, $CDCl_3$)** δ 197.5, 172.9, 143.4, 140.4, 137.4, 133.1, 128.8, 128.6, 128.3, 128.1, 127.2, 126.7, 125.6, 124.8, 67.4, 61.8, 61.4, 60.4, 51.7, 14.3. **FT-IR (neat, cm^{-1}):** 2907.5, 1722.7, 1670.6, 1210.1, 1182.8, 1159.3, 706.6. **HRMS: (ESI-TOF)** calculated for $C_{24}H_{24}NO_3S$ $[M+H]^+$ 406.1471, found 406.1471.

HPLC analysis: CHIRALPAK IC, heptane/2-propanol (90/10, 0.5 mL/min), λ = 254 nm, t_R = 22.053 min (minor), 27.358 min (minor).

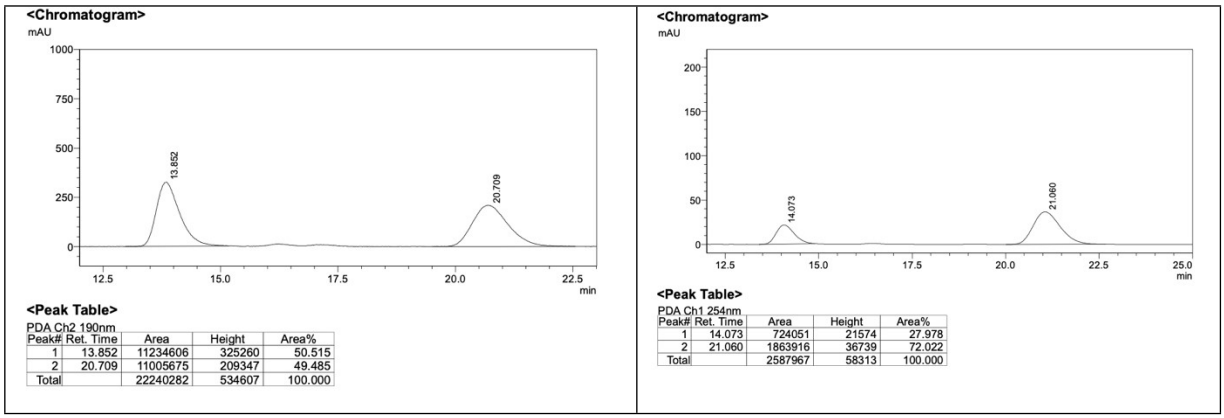


(2*R*,3*S*,4*R*,5*R*)-Ethyl-4-benzoyl-5-cyclohexyl-3-phenylpyrrolidine-2-carboxylate (3v)

White solid, yield = 28% (17.2 mg); m.p.= 82 – 83 ºC, Rf = 0.52 (cyclohexane/ethyl acetate, 3:1), $[\alpha]_D^{20}$ = +9.73 (c = 0.31, $CHCl_3$), (*endo*/*exo* = >99:1), 72:28 er; **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.77 (dd, *J* = 8.5, 1.3 Hz, 2H), 7.52 (ddt, *J* = 7.7, 6.7, 1.3 Hz, 1H), 7.41 – 7.33 (m, 4H), 7.29 – 7.26 (m, 3H), 4.25 – 4.13 (m, 2H), 4.09 (dd, *J* = 6.4, 4.1 Hz, 1H), 3.93 (d, *J* = 7.3 Hz, 1H), 3.52 (dd, *J* = 7.3, 4.1 Hz, 1H), 3.38 (dd, *J* = 9.4, 6.4 Hz, 1H), 2.92 (s, 1H), 2.13 (d, *J* = 12.9 Hz, 1H), 1.71 (d, *J* = 12.4 Hz, 1H), 1.57 (d, *J* = 10.8 Hz, 2H), 1.44 (d, *J* = 4.2 Hz, 1H), 1.31 (d, *J* = 6.5 Hz, 1H), 1.19 (t, *J* = 7.1 Hz, 3H), 1.12 – 1.07 (m, 3H), 0.96 – 0.90 (m, 2H). **^{13}C NMR (101 MHz, $CDCl_3$)** δ 202.7, 172.4, 142.9, 138.0, 133.3, 129.0, 128.9, 128.1, 127.6, 127.2, 71.7, 69.6, 61.2, 56.7, 56.7, 38.6, 31.9, 31.6, 26.4, 25.9, 25.8, 14.3. **FT-IR (neat, cm^{-1}):** 2927.8, 2851.0, 1731.8,

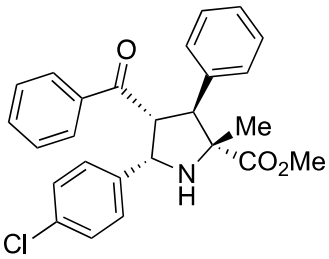
1665.4, 1197.9, 1181.4, 1161.6, 696.3. **HRMS: (ESI-TOF)** calculated for $C_{26}H_{32}NO_3$ $[M+H]^+$ 406.2377, found 406.2379.

HPLC analysis: CHIRALPAK ID, heptane/2-propanol (90/10, 0.5 mL/min), λ = 254 nm, t_R = 14.073 min (minor), 21.060 min (minor).



(2*R*,3*S*,4*R*,5*S*)-Ethyl-(2*R*,3*S*,4*R*,5*S*)-4-benzoyl-5-(4-chlorophenyl)-2-methyl-3-phenylpyrrolidine-2-carboxylate (3w)

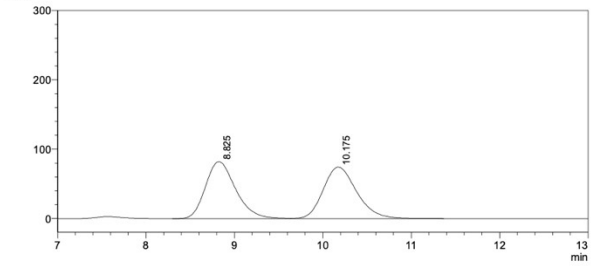
White solid, yield = 48% (33.1 mg); m.p.= 198 – 199 ºC, Rf = 0.41 (cyclohexane/ethyl acetate, 3:1),



$[\alpha]_D^{20}$ = +34.74 (c = 1.00, $CHCl_3$), (*endo*/*exo* = >99:1), 75:25 er; ^1H NMR (400 MHz, $CDCl_3$) δ 7.63 – 7.60 (m, 2H), 7.48 – 7.44 (m, 1H), 7.34 – 7.30 (m, 2H), 7.28 – 7.26 (m, 5H), 7.09 – 7.03 (m, 4H), 5.02 (d, *J* = 9.5 Hz, 1H), 4.89 (dd, *J* = 10.5, 9.4 Hz, 1H), 4.44 (d, *J* = 10.5 Hz, 1H), 3.83 (s, 3H), 3.13 (s, 1H), 1.29 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 197.7, 175.9, 138.7, 137.7, 137.6, 133.5, 133.2, 129.3, 128.7, 128.6, 128.5, 128.3, 128.1, 127.4, 68.7, 63.5, 56.5, 54.7, 52.7, 21.8. FT-IR (neat, cm^{-1}): 2919.0, 2853.4, 1730.7, 1671.5, 1202.7, 1166.2, 1145.2, 699.2. HRMS: (ESI-TOF) calculated for $C_{26}H_{25}ClNO_3$ $[M+H]^+$ 434.1517, found 434.1523.

HPLC analysis: CHIRALPAK IC, heptane/2-propanol (90/10, 0.5 mL/min), λ = 254 nm, t_R = 8.874 min (minor), 10.248 min (minor).

<Chromatogram>



<Peak Table>

PDA Ch1 254nm

Peak#	Ret. Time	Area	Height	Area%
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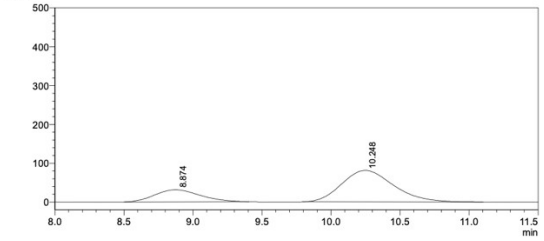
2	10.175	1960771	74379	50.097
Total		3913955	156621	100.000

<Chromatogram>



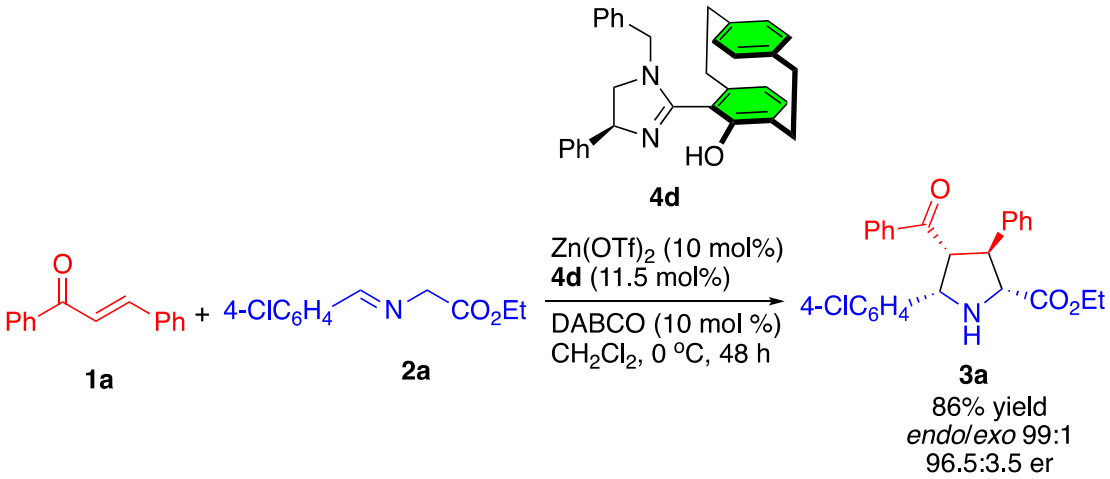
<Peak Table>

PDA Ch1 254nm

Peak#	Ret. Time	Area	Height	Area%
1	8.874	708169	31048	25.046
2	10.248	2119268	80904	74.954
Total		2827437	111952	100.000

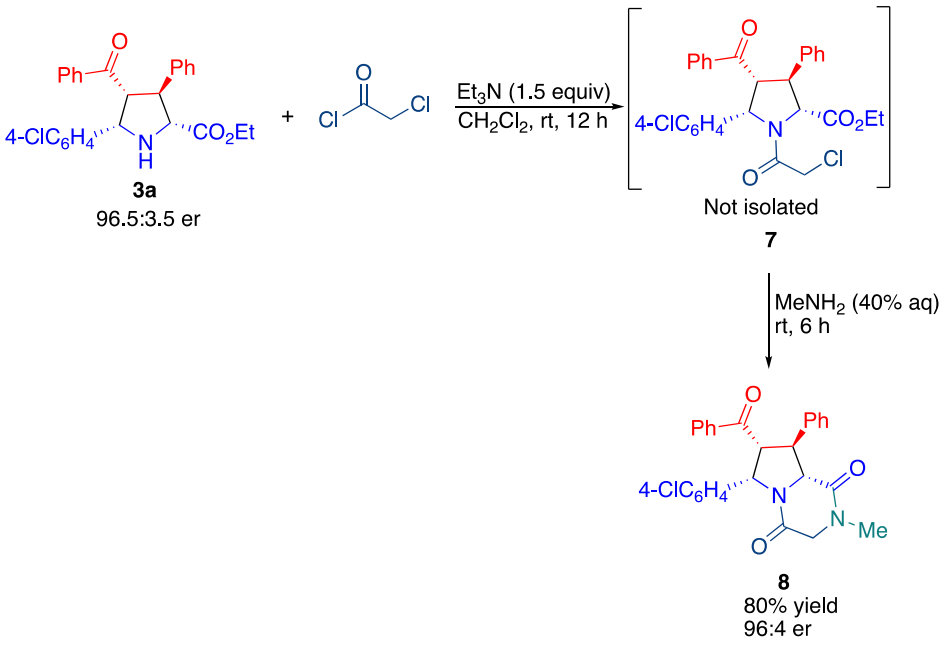
4. Scaled-up Synthesis of 3a and its Derivatization

4.1 General Procedure for the Zn-Catalyzed [3+2] Azomethine Ylide Cycloaddition



Under nitrogen atmosphere, ligand (*S*,*S*,*S*$_P$)-**4d** (52.7 mg, 11.5 mol %) and $Zn(OTf)_2$ (36.3 mg, 10 mol %) was added to a flame-dried 20 mL schlenk tube. Then dry CH_2Cl_2 (3 mL) was added and stirred for 60 minutes. After cooled at 0 °C, acyclic enone **1** (208.3 mg, 1 mmol, 1.0 equiv) in CH_2Cl_2 (3 mL), α-iminoester **2** (451.2 mg, 2 mmol, 2 equiv) in CH_2Cl_2, (3 mL) and DABCO (11.2 mg, 10 mol %) in CH_2Cl_2 (1 mL) were added sequentially. The reaction mixture was stirred at the same temperature for 48 h. After completion, the reaction mixture was directly purified by silica gel column chromatography (30% ethyl acetate in cyclohexane) to afford the desired product **3**a in 86% yield (376.5 mg) with 99:1 *endo*/*exo* and 96.5:3.5 er.

4.2 General procedure for the synthesis of diketopiperazine 8[3]

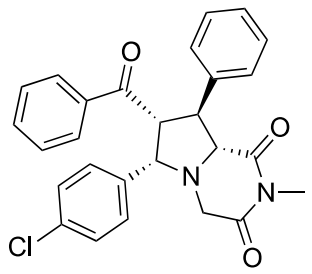


To a mixture of **3a** (1 equiv, 0.2 mmol, 86.8 mg) and triethylamine (1.5 equiv, 0.3 mmol, 41.8 µL) in CH_2Cl_2 (5 mL) at 0 ºC was added chloroacetyl chloride (1.5 equiv, 0.3 mmol, 23.9 µL). The

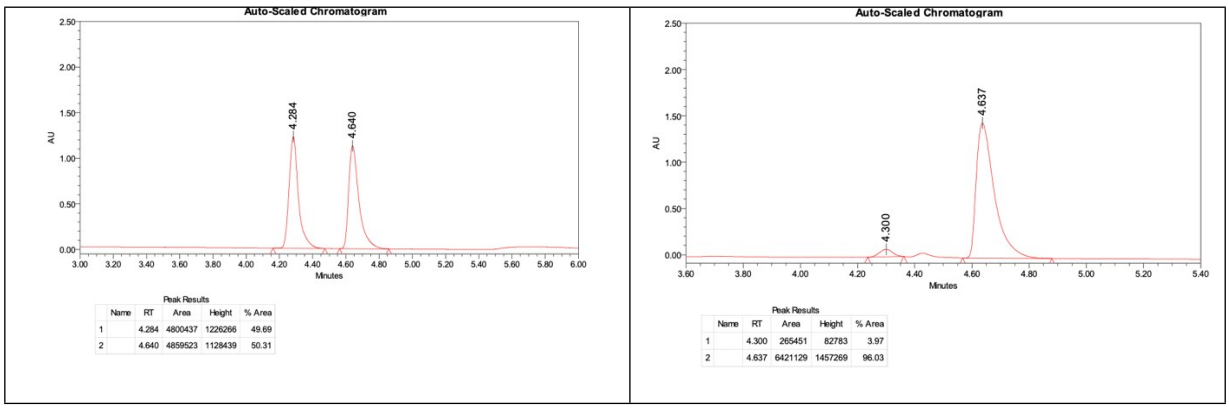
reaction was stirred for 30 min. at 0 ºC and warmed to room temperature. After being stirred for another 3 h, the reaction mixture was quenched with water (5 mL) and extracted three times with CH_2Cl_2. The combined organic layers were dried over Na_2SO_4 and concentrated under vacuum, gave crude product 7. The crude product 7 was dissolved in CH_2Cl_2 (5 mL) follow by the addition of methylamine (40% aq. 1.6 mL). The mixture was stirred overnight. The resulting reaction mixture was quenched with water (5 mL) and extracted three times with CH_2Cl_2. The combined organic layers were dried over Na_2SO_4 and concentrated under reduce pressure afforded the crude product which silica gel column chromatography (100% ethyl acetate) to deliver the desired product **8** in 80% (73.5 mg) yield.

(6*S*,7*R*,8*S*,8a*R*)-7-benzoyl-6-(4-chlorophenyl)-2-methyl-8-phenyltetrahydropyrrolo[1,2-*a*]pyrazine-1,3(2*H*,4*H*)-dione (8)

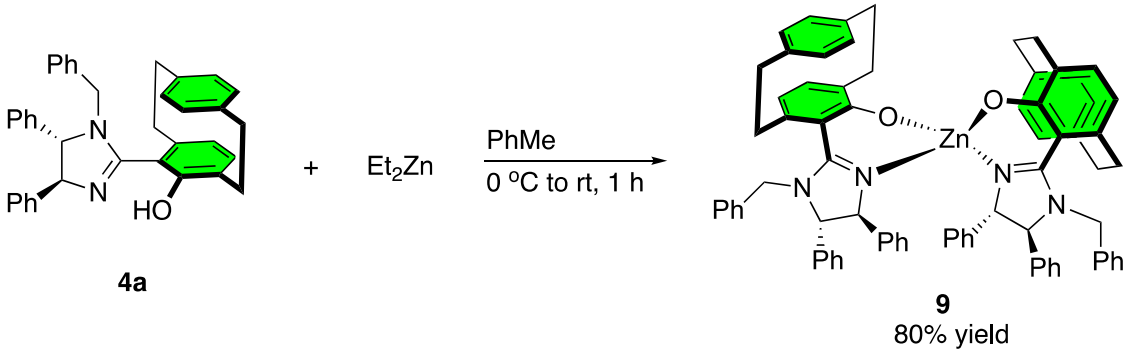
White solid, yield = 80 % (73.5 mg); m.p.= 283 – 284 ºC, Rf = 0.28 (ethyl acetate), $[\alpha]_D^{20}$ = +72.23 (c = 1, $CHCl_3$), 96:4 er; **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.70 (dd, *J* = 8.4, 1.3 Hz, 2H), 7.55 (ddt, *J* = 7.8, 6.9, 1.3 Hz, 1H), 7.51 – 7.48 (m, 2H), 7.43 – 7.39 (m, 2H), 7.33 – 7.29 (m, 2H), 7.22 – 7.18 (m, 1H), 7.09 – 7.05 (m, 2H), 6.74 – 6.71 (m, 2H), 5.68 (d, *J* = 8.6 Hz, 1H), 4.69 – 4.56 (m, 3H), 4.22 (dd, *J* = 16.8, 1.3 Hz, 1H), 3.77 (d, *J* = 16.8 Hz, 1H), 3.02 (s, 3H). **^{13}C NMR (101 MHz, $CDCl_3$)** δ 193.5, 167.3, 164.3, 138.0, 137.0, 135.1, 134.2, 133.9, 129.0, 128.9, 128.7, 128.5, 128.21, 128.19, 127.7, 64.0, 61.9, 57.1, 54.0, 45.5, 33.8. **FT-IR (neat, cm^{-1}):** 1688.7, 1669.9, 1415.6, 1402.0, 1212.6, 692.6. **HRMS: (ESI-TOF)** calculated for $C_{27}H_{24}ClN_2O_3$ $[M+H]^+$ 459.1470, found 459.1472.



HPLC analysis: CHIRALPAK IB, CO_2/MEOH (60 to 40, 3 mL/min), λ = 254 nm, t_R = 4.300 min (major), 4.637 min (minor).



5. General procedure for the synthesis of Zn-complex 9



Under a nitrogen atmosphere, ligand (S,S,S_P)-**4a** (0.25 mmol, 2 equiv.) and Et_2Zn (0.125 mmol, 1 equiv.) were added to a flame-dried 15 mL schlenk tube. Then dry toluene (2 mL) was added and stirred at 0 °C. Then Et_2Zn was added, and the reaction mixture was stirred at room temperature for 2 h. After completion, the solvent was evaporated under vacuum, and the crude product was recrystalized using a $CHCl_3/Et_2O$ mixture, which gave the pure complex **9** in 80% yield (113.5 mg). Yellow solid, m.p. 170–171; $[\alpha]_D^{20}$ = -304.66 (c = 1.0, $CHCl_3$)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.54 (d, *J* = Hz, 2H), 7.50 – 7.46 (m, 6H), 7.40 – 7.36 (m, 3H), 7.24 – 7.20 (m, 5H), 7.12 – 7.07 (m, 4H), 7.04 – 7.02 (m, 2H), 6.96 – 6.92 (m, 4H), 6.81 – 6.77 (m, 4H), 6.72 (dd, *J* = 8.0, 2.3, 1H), 6.69 – 6.66 (m, 4H), 6.63 (dd, *J* = 7.7, 2.0 , 1H), 6.59 – 6.55 (m, 3H), 6.50 (d, *J* = 7.7 Hz, 1H), 6.40 (d, *J* = 7.6 Hz, 1H), 6.23 (d, *J* = 7.8 Hz, 1H), 5.83 (d, *J* = 7.3 Hz, 1H), 5.30 (d, *J* = 4.4 Hz, 1H), 4.98 (d, *J* = 16.4 Hz, 1H), 4.67 (d, *J* = 16.1 Hz, 1H), 4.60 (d, *J* = Hz, 1H), 4.58 (d, *J* = Hz, 1H), 3.85 (td, *J* = 11.4, 4.4 Hz, 1H), 3.74 (d, *J* = 16.8 Hz, 1H), 3.62 (d, *J* = 16.4 Hz, 1H), 3.49 (ddd, *J* = 12.7, 10.0, 2.3 Hz, 1H), 3.32 – 3.27 (m, 1H), 3.23 – 3.13 (m, 2H), 3.01 – 2.99 (m, 2H), 2.98 – 2.92 (m, 2H), 2.89 – 2.71 (m, 4H), 2.64 – 2.59 (m, 1H), 2.58 – 2.53 (m, 2H). **^{13}C NMR (101 MHz, $CDCl_3$)** δ 170.6, 169.6, 144.24, 142.20, 141.7, 140.6, 140.44, 140.42, 140.2, 138.2, 137.9, 137.8, 137.6, 137.0, 136.9, 136.4, 133.0, 132.9, 132.5, 132.2, 132.1, 132.0, 131.0, 129.2, 129.1, 129.0, 128.6, 128.45, 128.40, 128.0, 127.70, 127.66, 127.5, 127.14, 127.10, 127.0, 126.4, 126.3, 126.2, 125.5, 122.4, 110.7, 76.1, 71.7, 71.1, 70.1, 49.5, 48.4, 35.9, 35.5, 35.2, 35.0, 34.9, 34.2, 31.3, 29.4. **FT-IR (neat, cm^{-1}):** 2921.2, 2850.3, 1515.6, 1495.9, 1410.6, 1385.0, 802.4, 752.2, 696.8.

6. References

1. G. S. Caleffi, O. Larrañaga, M. Martín-Rodríguez, P. R. R. Costa, C. Nájera, A. Cózar, F. P. Cossío and J. M. Sansano, *J. Org. Chem.* **2019**, *84*, 10593.

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3. García-Mingüens, E.; Selva, V.; Larrañaga, O.; Nájera, C.; Sansano, J. M.; Cózar, A. Nitroprolinates as nucleophiles in Michael-type additions and acylations. Synthesis of enantiomerically enriched fused aminopyrrolidino-[1,2-a]pyrazinones and -diketopiperazines. *ChemCatChem* **2020**, *12*, 2014–2021.

7. X-Ray crystallographic structure and information for Zn-complex 9

SCXRD- REPORT

Research group	Guiry
Sample Code	V-464
Internal sample code	Exp-1339
Data collection time (hours)	9

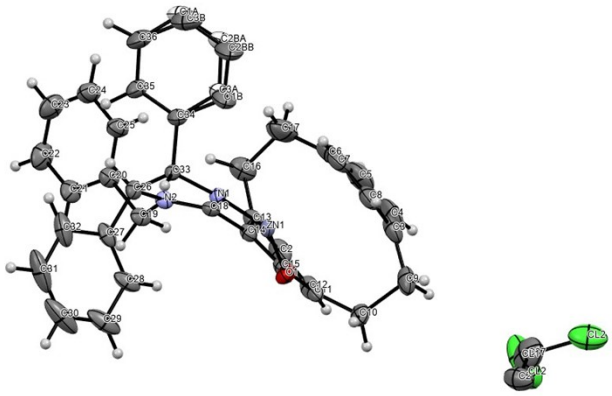


Figure 1. Asymmetric unit, showing the atom-labelling scheme. Displacement ellipsoids are drawn at the 50% probability level. Graphics were obtained using Mercury 3.0.

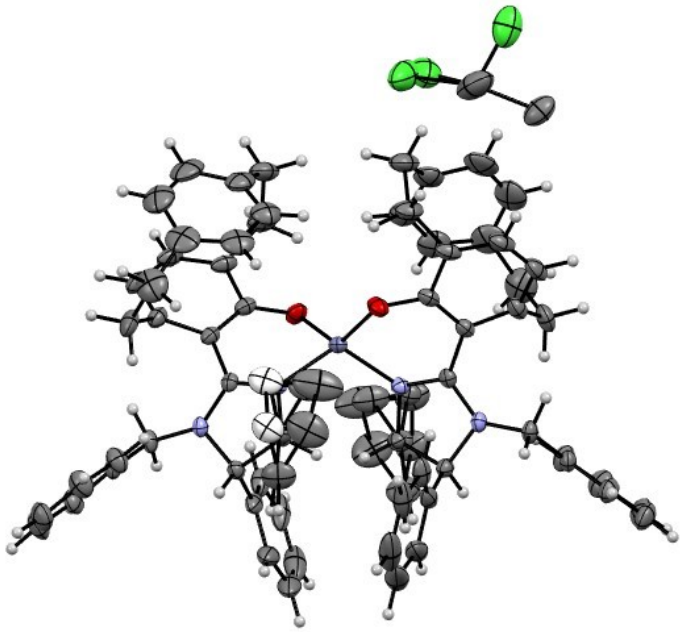


Figure 2. Crystal structure of V-464

Table 1. Crystal data and structure refinement for V-464

Empirical formula	C80.41H60Cl4N4O2Zn
Formula weight	1321.37
Temperature [K]	108(5)
Crystal system	trigonal
Space group (number)	$P3_121$ (152)
a [Å]	14.39140(10)
b [Å]	14.39140(10)
c [Å]	27.12110(10)
α [°]	90
β [°]	90
γ [°]	120
Volume [Å3]	4864.56(7)
Z	3
ρcalc [gcm−3]	1.353
μ [mm−1]	2.456
F(000)	2053
Crystal size [mm3]	0.362×0.27×0.247
Crystal colour	translucent light colourless
Crystal shape	block
Radiation	Cu Kα (λ=1.54184 Å)
2θ range [°]	7.09 to 152.83 (0.79 Å)
Index ranges	−18 ≤ h ≤ 17 −16 ≤ k ≤ 18 −34 ≤ l ≤ 34
Reflections collected	66795
Independent reflections	6788 Rint = 0.0405 Rsigma = 0.0150
Completeness to θ = 67.684°	100.0 %
Data / Restraints / Parameters	6788/0/457
Goodness-of-fit on F2	1.058
Final R indexes [I≥2σ(I)]	R1 = 0.0351 wR2 = 0.0977
Final R indexes [all data]	R1 = 0.0354 wR2 = 0.0981
Largest peak/hole [eÅ−3]	0.32/-0.50
Flack X parameter	-0.002(5)

Refinement details for V-464

Table 2. Atomic coordinates and Ueq [Å2] for V-464

Atom	x	y	z	Ueq
C2BA	1.0619(5)	0.6919(5)	0.5923(3)	0.055(3)
Cl1	0.1804(3)	0.4558(3)	0.45651(13)	0.0918(12)
Cl2	0.1488(4)	0.4770(5)	0.4580(2)	0.0709(11)
H36	1.295(4)	0.918(3)	0.6104(15)	0.051(10)
Zn1_1	0.79963(3)	0.79963(3)	0.500000	0.02126(12)
O1_1	0.73430(15)	0.74336(15)	0.43703(7)	0.0309(4)
N1_1	0.93698(16)	0.80749(16)	0.48177(7)	0.0208(4)
N2_1	1.05510(17)	0.82458(17)	0.42385(7)	0.0230(4)
C27_1	1.1261(2)	1.0212(2)	0.43128(10)	0.0325(6)
C32_1	1.2129(3)	1.1202(3)	0.44366(14)	0.0520(10)
H32_1	1.268342	1.124552	0.464301	0.062
C31_1	1.2180(4)	1.2147(3)	0.4251(2)	0.0741(16)
H31_1	1.276917	1.282805	0.433627	0.089
C30_1	1.1392(5)	1.2087(4)	0.39521(18)	0.0756(17)
H30_1	1.143322	1.272561	0.383093	0.091
C29_1	1.0544(4)	1.1115(3)	0.38259(12)	0.0569(11)
H29_1	1.000021	1.107906	0.361494	0.068
C28_1	1.0473(3)	1.0177(3)	0.40047(10)	0.0382(7)
H28_1	0.987747	0.950296	0.391518	0.046
C26_1	1.1154(2)	0.9205(2)	0.45471(9)	0.0246(5)
H26_1	1.187834	0.930987	0.462839	0.030
C33_1	1.04387(18)	0.88659(19)	0.50109(8)	0.0210(4)
H33_1	1.040890	0.950076	0.514090	0.025
C18_1	0.95027(19)	0.77324(19)	0.43868(8)	0.0207(4)
C34_1	1.0811(2)	0.8408(2)	0.54194(10)	0.0318(6)
C35_1	1.1851(2)	0.8986(3)	0.55955(11)	0.0349(6)
H35_1	1.234243	0.963244	0.543274	0.042
C36_1	1.2202(3)	0.8663(3)	0.59956(15)	0.0529(9)
C15_1	0.7602(2)	0.68767(19)	0.40788(9)	0.0256(5)
C11_1	0.6792(2)	0.6135(2)	0.37490(9)	0.0320(6)
C12_1	0.7058(3)	0.5587(2)	0.34148(10)	0.0378(7)
H12_1	0.658149	0.522038	0.314995	0.045
C2_1	0.8007(3)	0.5557(2)	0.34549(10)	0.0380(7)
H2_1	0.815296	0.514339	0.322792	0.046
C13_1	0.8741(2)	0.6127(2)	0.38242(9)	0.0308(6)
C14_1	0.8617(2)	0.69175(19)	0.40869(8)	0.0239(5)
C19_1	1.0991(2)	0.8236(2)	0.37548(8)	0.0264(5)
H19A_1	1.113769	0.889057	0.357173	0.032
H19B_1	1.045172	0.760729	0.356597	0.032
C20_1	1.2018(2)	0.8186(2)	0.37928(9)	0.0274(5)
C21_1	1.2745(2)	0.8571(3)	0.34025(10)	0.0363(6)
H21_1	1.260081	0.887332	0.312195	0.044
C22_1	1.3680(3)	0.8513(3)	0.34215(12)	0.0477(8)
H22_1	1.417438	0.878279	0.315499	0.057
C23_1	1.3897(3)	0.8065(3)	0.38273(13)	0.0473(7)

H23_1	1.452938	0.801354	0.383537	0.057
C24_1	1.3192(3)	0.7695(3)	0.42185(13)	0.0435(7)
H24_1	1.334177	0.739439	0.449802	0.052
C25_1	1.2258(3)	0.7762(3)	0.42046(11)	0.0365(6)
H25_1	1.178108	0.751596	0.447777	0.044
C10_1	0.5635(2)	0.5824(3)	0.38474(11)	0.0398(7)
H10A_1	0.526706	0.574910	0.352906	0.048
H10B_1	0.561870	0.640397	0.403643	0.048
C9_1	0.5004(3)	0.4732(3)	0.41460(13)	0.0501(9)
H9A_1	0.457782	0.481710	0.441030	0.060
H9B_1	0.450085	0.415768	0.392159	0.060
C3_1	0.5757(3)	0.4410(3)	0.43708(13)	0.0500(8)
C8_1	0.6410(3)	0.4968(3)	0.47793(12)	0.0490(8)
H8_1	0.617215	0.530682	0.500649	0.059
C7_1	0.7386(3)	0.5027(3)	0.48533(14)	0.0538(9)
H7_1	0.781614	0.541868	0.512683	0.065
C6_1	0.7750(4)	0.4525(3)	0.45352(17)	0.0606(11)
C5_1	0.7013(4)	0.3788(3)	0.42050(18)	0.0670(12)
H5_1	0.718221	0.331677	0.403266	0.080
C4_1	0.6020(4)	0.3727(3)	0.41216(17)	0.0653(12)
H4_1	0.552634	0.321816	0.389398	0.078
C16_1	0.9437(3)	0.5698(3)	0.40195(11)	0.0409(7)
H16A_1	1.015101	0.630935	0.410606	0.049
H16B_1	0.954085	0.528210	0.375623	0.049
C17_1	0.8944(4)	0.4959(4)	0.44874(18)	0.0663(11)
H17A_1	0.908155	0.435153	0.446600	0.080
H17B_1	0.930793	0.537711	0.478680	0.080
C1A_1	1.1637(6)	0.7587(6)	0.6128(3)	0.051(3)
C3A_1	1.0222(5)	0.7320(5)	0.5558(3)	0.035(2)
C1B_1	0.9994(8)	0.7699(10)	0.5764(4)	0.057(5)
C2BB_1	1.0277(10)	0.7429(12)	0.6214(5)	0.090(7)
C3B_1	1.1369(10)	0.7949(12)	0.6355(5)	0.079(6)
Cl2_2	0.04454(12)	0.43376(11)	0.54429(4)	0.0769(3)
C37_2	0.1532(4)	0.5239(4)	0.5069(2)	0.0827(15)
C2_3	0.1370(4)	0.6316(3)	0.53160(16)	0.0586(10)

Ueq is defined as 1/3 of the trace of the orthogonalized Uij tensor.

Table 3. Anisotropic displacement parameters [Å2] for V-464.
The anisotropic displacement factor exponent takes the form:
−2π2[h2(a*)2U11 + k2(b*)2U22 + … + 2hka*b*U12]

Atom	U11	U22	U33	U23	U13	U12
C2BA	0.054(4)	0.052(4)	0.059(4)	0.025(3)	−0.002(3)	0.028(3)
Cl1	0.115(3)	0.0615(16)	0.0546(12)	−0.0107(11)	0.0286(17)	0.0110(16)
Cl2	0.071(2)	0.066(2)	0.069(2)	0.0131(17)	0.0152(16)	0.0290(16)
Zn1_1	0.01876(16)	0.01876(16)	0.0232(2)	−0.00052(8)	0.00052(8)	0.00708(17)
O1_1	0.0276(9)	0.0295(9)	0.0355(9)	−0.0102(7)	−0.0099(7)	0.0142(7)
N1_1	0.0203(9)	0.0219(9)	0.0186(8)	−0.0014(7)	−0.0023(7)	0.0093(8)
N2_1	0.0262(10)	0.0266(10)	0.0179(9)	−0.0021(8)	0.0016(8)	0.0144(9)
C27_1	0.0417(15)	0.0255(12)	0.0251(12)	0.0024(10)	0.0150(11)	0.0128(12)
C32_1	0.0500(19)	0.0310(15)	0.0525(19)	−0.0028(14)	0.0264(16)	0.0034(14)
C31_1	0.082(3)	0.0244(16)	0.093(3)	0.0048(18)	0.057(3)	0.0097(18)
C30_1	0.127(5)	0.050(2)	0.068(3)	0.032(2)	0.063(3)	0.058(3)
C29_1	0.105(3)	0.059(2)	0.0337(16)	0.0207(15)	0.0325(19)	0.061(2)
C28_1	0.063(2)	0.0403(15)	0.0232(12)	0.0098(11)	0.0144(13)	0.0350(15)
C26_1	0.0229(11)	0.0281(12)	0.0207(10)	−0.0018(9)	0.0020(9)	0.0111(10)
C33_1	0.0186(10)	0.0229(10)	0.0196(10)	−0.0006(8)	0.0002(8)	0.0090(9)
C18_1	0.0262(11)	0.0205(10)	0.0187(10)	0.0017(8)	0.0003(9)	0.0142(9)
C34_1	0.0302(13)	0.0341(13)	0.0282(12)	0.0045(10)	−0.0056(10)	0.0141(11)
C35_1	0.0310(14)	0.0428(16)	0.0326(13)	−0.0025(12)	−0.0088(11)	0.0196(12)
C36_1	0.0434(19)	0.061(2)	0.054(2)	0.0038(17)	−0.0209(16)	0.0257(17)
C15_1	0.0299(13)	0.0187(10)	0.0220(10)	−0.0001(8)	−0.0040(9)	0.0075(9)
C11_1	0.0341(14)	0.0238(12)	0.0228(11)	0.0014(9)	−0.0068(10)	0.0030(10)
C12_1	0.0440(15)	0.0268(13)	0.0221(11)	−0.0041(10)	−0.0047(11)	0.0024(11)
C2_1	0.0540(18)	0.0267(13)	0.0240(12)	−0.0073(10)	0.0013(12)	0.0132(13)
C13_1	0.0432(15)	0.0227(11)	0.0229(11)	−0.0010(9)	0.0037(10)	0.0139(11)
C14_1	0.0304(12)	0.0188(10)	0.0193(10)	−0.0004(8)	−0.0008(9)	0.0100(9)
C19_1	0.0332(13)	0.0328(13)	0.0183(10)	0.0015(9)	0.0050(9)	0.0205(11)
C20_1	0.0327(13)	0.0291(13)	0.0250(11)	−0.0017(10)	0.0046(10)	0.0190(11)
C21_1	0.0378(14)	0.0458(16)	0.0245(12)	0.0012(11)	0.0084(11)	0.0204(13)
C22_1	0.0381(16)	0.066(2)	0.0388(15)	−0.0028(15)	0.0118(13)	0.0254(16)
C23_1	0.0374(16)	0.063(2)	0.0516(17)	−0.0063(17)	0.0028(15)	0.0324(15)
C24_1	0.0411(16)	0.0526(19)	0.0458(17)	0.0060(14)	0.0001(13)	0.0302(15)
C25_1	0.0381(15)	0.0451(16)	0.0339(14)	0.0078(12)	0.0059(12)	0.0266(13)
C10_1	0.0316(14)	0.0359(15)	0.0341(14)	−0.0042(11)	−0.0112(11)	0.0036(12)
C9_1	0.0385(16)	0.0387(17)	0.0431(17)	−0.0021(14)	0.0000(13)	−0.0032(14)
C3_1	0.0520(19)	0.0274(14)	0.0478(18)	0.0098(13)	0.0097(15)	0.0027(13)
C8_1	0.0531(19)	0.0414(16)	0.0398(15)	0.0157(13)	0.0065(14)	0.0142(15)
C7_1	0.063(2)	0.0428(18)	0.0457(17)	0.0238(15)	0.0057(16)	0.0192(17)
C6_1	0.073(3)	0.0383(18)	0.070(2)	0.0297(18)	0.008(2)	0.0275(19)
C5_1	0.088(3)	0.0324(17)	0.079(3)	0.0144(18)	0.015(2)	0.029(2)
C4_1	0.078(3)	0.0209(14)	0.072(3)	0.0083(15)	0.009(2)	0.0062(16)
C16_1	0.061(2)	0.0335(14)	0.0372(14)	−0.0073(12)	0.0018(14)	0.0307(15)
C17_1	0.082(3)	0.063(2)	0.071(3)	0.019(2)	0.003(2)	0.050(2)
C1A_1	0.052(4)	0.061(4)	0.048(4)	0.017(3)	−0.005(3)	0.035(3)
C3A_1	0.039(3)	0.032(3)	0.033(3)	0.006(2)	−0.002(2)	0.016(2)
C1B_1	0.053(5)	0.061(7)	0.039(5)	0.023(5)	−0.008(4)	0.015(4)

C2BB_1	0.070(8)	0.101(10)	0.068(8)	0.046(7)	−0.023(6)	0.019(7)
C3B_1	0.069(6)	0.107(10)	0.063(8)	0.026(7)	−0.017(5)	0.046(6)
Cl2_2	0.1163(10)	0.0916(8)	0.0493(5)	−0.0053(5)	−0.0107(5)	0.0719(8)
C37_2	0.070(3)	0.052(2)	0.113(4)	−0.024(3)	−0.027(3)	0.021(2)
C2_3	0.080(3)	0.0419(19)	0.057(2)	−0.0033(16)	−0.017(2)	0.033(2)

Table 4. Bond lengths and angles for V-464

Atom–Atom	Length [Å]
C2BA–C1A_1	1.404(10)
C2BA–C3A_1	1.402(7)
Cl1–C37_2	1.833(7)
Cl2–C37_2	1.474(8)
Zn1_1–O1_1	1.9223(18)
Zn1_1–O1_1#1	1.9224(18)
Zn1_1–N1_1	1.985(2)
Zn1_1–N1_1#1	1.985(2)
O1_1–C15_1	1.306(3)
N1_1–C33_1	1.478(3)
N1_1–C18_1	1.319(3)
N2_1–C26_1	1.471(3)
N2_1–C18_1	1.367(3)
N2_1–C19_1	1.460(3)
C27_1–C32_1	1.387(5)
C27_1–C28_1	1.389(5)
C27_1–C26_1	1.518(4)
C32_1–H32_1	0.9500
C32_1–C31_1	1.417(6)
C31_1–H31_1	0.9500
C31_1–C30_1	1.362(8)
C30_1–H30_1	0.9500
C30_1–C29_1	1.361(8)
C29_1–H29_1	0.9500
C29_1–C28_1	1.389(4)
C28_1–H28_1	0.9500
C26_1–H26_1	1.0000
C26_1–C33_1	1.542(3)
C33_1–H33_1	1.0000
C33_1–C34_1	1.517(3)
C18_1–C14_1	1.472(3)
C34_1–C35_1	1.384(4)
C34_1–C3A_1	1.408(6)
C34_1–C1B_1	1.449(9)
C35_1–H35_1	0.9500
C35_1–C36_1	1.372(4)
C36_1–H36	0.99(5)
C36_1–C1A_1	1.388(8)
C36_1–C3B_1	1.487(13)
C15_1–C11_1	1.433(3)
C15_1–C14_1	1.431(4)
C11_1–C12_1	1.375(4)
C11_1–C10_1	1.517(4)
C12_1–H12_1	0.9500
C12_1–C2_1	1.393(5)
C2_1–H2_1	0.9500
C2_1–C13_1	1.388(4)
C13_1–C14_1	1.427(3)
C13_1–C16_1	1.511(4)
C19_1–H19A_1	0.9900
C19_1–H19B_1	0.9900
C19_1–C20_1	1.519(4)
C20_1–C21_1	1.394(4)
C20_1–C25_1	1.397(4)
C21_1–H21_1	0.9500
C21_1–C22_1	1.390(4)
C22_1–H22_1	0.9500
C22_1–C23_1	1.388(5)
C23_1–H23_1	0.9500
C23_1–C24_1	1.378(5)
C24_1–H24_1	0.9500
C24_1–C25_1	1.394(4)
C25_1–H25_1	0.9500
C10_1–H10A_1	0.9900
C10_1–H10B_1	0.9900
C10_1–C9_1	1.588(4)
C9_1–H9A_1	0.9900
C9_1–H9B_1	0.9900
C9_1–C3_1	1.504(6)
C3_1–C8_1	1.414(5)
C3_1–C4_1	1.392(6)
C8_1–H8_1	0.9500
C8_1–C7_1	1.379(6)
C7_1–H7_1	0.9500
C7_1–C6_1	1.385(6)
C6_1–C5_1	1.388(7)
C6_1–C17_1	1.512(7)

C5_1–H5_1	0.9500
C5_1–C4_1	1.406(8)
C4_1–H4_1	0.9500
C16_1–H16A_1	0.9900
C16_1–H16B_1	0.9900
C16_1–C17_1	1.578(5)
C17_1–H17A_1	0.9900
C17_1–H17B_1	0.9900
C1B_1–C2BB_1	1.400(11)
C2BB_1–C3B_1	1.414(15)
Cl2_2–C37_2	1.769(7)
C37_2–C2_3	1.808(7)
Atom–Atom–Atom	Angle [°]
C3A_1–C2BA–C1A_1	119.8(5)
O1_1–Zn1_1–O1_1	125.85(13)
O1_1–Zn1_1–N1_1	114.40(8)
O1_1–Zn1_1–N1_1	93.79(8)
O1_1–Zn1_1–N1_1	93.79(8)
O1_1–Zn1_1–N1_1	114.40(8)
N1_1–Zn1_1–N1_1	116.48(12)
C15_1–O1_1–Zn1_1	124.52(16)
C33_1–N1_1–Zn1_1	125.36(15)
C18_1–N1_1–Zn1_1	121.72(16)
C18_1–N1_1–C33_1	108.20(19)
C18_1–N2_1–C26_1	108.30(18)
C18_1–N2_1–C19_1	128.7(2)
C19_1–N2_1–C26_1	117.7(2)
C32_1–C27_1–C28_1	118.9(3)
C32_1–C27_1–C26_1	119.2(3)
C28_1–C27_1–C26_1	121.7(3)
C27_1–C32_1–H32_1	120.4
C27_1–C32_1–C31_1	119.1(5)
C31_1–C32_1–H32_1	120.4
C32_1–C31_1–H31_1	119.7
C30_1–C31_1–C32_1	120.6(4)
C30_1–C31_1–H31_1	119.7
C31_1–C30_1–H30_1	119.8
C29_1–C30_1–C31_1	120.3(4)
C29_1–C30_1–H30_1	119.8
C30_1–C29_1–H29_1	119.9
C30_1–C29_1–C28_1	120.2(4)
C28_1–C29_1–H29_1	119.9
C27_1–C28_1–C29_1	120.8(4)
C27_1–C28_1–H28_1	119.6
C29_1–C28_1–H28_1	119.6
N2_1–C26_1–C27_1	112.9(2)
N2_1–C26_1–H26_1	110.4
N2_1–C26_1–C33_1	100.34(19)
C27_1–C26_1–H26_1	110.4
C27_1–C26_1–C33_1	112.1(2)
C33_1–C26_1–H26_1	110.4
N1_1–C33_1–C26_1	103.17(18)
N1_1–C33_1–H33_1	109.0
N1_1–C33_1–C34_1	112.4(2)
C26_1–C33_1–H33_1	109.0

C34_1–C33_1–C26_1	114.1(2)
C34_1–C33_1–H33_1	109.0
N1_1–C18_1–N2_1	112.7(2)
N1_1–C18_1–C14_1	123.9(2)
N2_1–C18_1–C14_1	123.4(2)
C35_1–C34_1–C33_1	120.1(2)
C35_1–C34_1–C3A_1	116.4(3)
C35_1–C34_1–C1B_1	117.0(4)
C3A_1–C34_1–C33_1	122.1(3)
C1B_1–C34_1–C33_1	116.0(4)
C34_1–C35_1–H35_1	118.7
C36_1–C35_1–C34_1	122.7(3)
C36_1–C35_1–H35_1	118.7
C35_1–C36_1–H36	115(2)
C35_1–C36_1–C1A_1	118.2(4)
C35_1–C36_1–C3B_1	116.5(5)
C1A_1–C36_1–H36	124(2)
C3B_1–C36_1–H36	121(2)
O1_1–C15_1–C11_1	117.3(2)
O1_1–C15_1–C14_1	124.3(2)
C14_1–C15_1–C11_1	118.3(2)
C15_1–C11_1–C10_1	118.3(2)
C12_1–C11_1–C15_1	118.9(3)
C12_1–C11_1–C10_1	121.7(2)
C11_1–C12_1–H12_1	119.2
C11_1–C12_1–C2_1	121.6(3)
C2_1–C12_1–H12_1	119.2
C12_1–C2_1–H2_1	119.8
C13_1–C2_1–C12_1	120.4(3)
C13_1–C2_1–H2_1	119.8
C2_1–C13_1–C14_1	118.0(3)
C2_1–C13_1–C16_1	118.4(3)
C14_1–C13_1–C16_1	121.6(2)
C15_1–C14_1–C18_1	120.0(2)
C13_1–C14_1–C18_1	120.4(2)
C13_1–C14_1–C15_1	119.4(2)
N2_1–C19_1–H19A_1	109.2
N2_1–C19_1–H19B_1	109.2
N2_1–C19_1–C20_1	112.1(2)
H19A_1–C19_1–H19B_1	107.9
C20_1–C19_1–H19A_1	109.2
C20_1–C19_1–H19B_1	109.2
C21_1–C20_1–C19_1	119.0(2)
C21_1–C20_1–C25_1	118.7(3)
C25_1–C20_1–C19_1	122.3(2)
C20_1–C21_1–H21_1	119.8
C22_1–C21_1–C20_1	120.4(3)
C22_1–C21_1–H21_1	119.8
C21_1–C22_1–H22_1	119.8

C23_1–C22_1–C21_1	120.4(3)
C23_1–C22_1–H22_1	119.8
C22_1–C23_1–H23_1	120.1
C24_1–C23_1–C22_1	119.8(3)
C24_1–C23_1–H23_1	120.1
C23_1–C24_1–H24_1	120.0
C23_1–C24_1–C25_1	120.1(3)
C25_1–C24_1–H24_1	120.0
C20_1–C25_1–H25_1	119.7
C24_1–C25_1–C20_1	120.6(3)
C24_1–C25_1–H25_1	119.7
C11_1–C10_1–H10A_1	109.1
C11_1–C10_1–H10B_1	109.1
C11_1–C10_1–C9_1	112.5(3)
H10A_1–C10_1–H10B_1	107.8
C9_1–C10_1–H10A_1	109.1
C9_1–C10_1–H10B_1	109.1
C10_1–C9_1–H9A_1	109.3
C10_1–C9_1–H9B_1	109.3
H9A_1–C9_1–H9B_1	108.0
C3_1–C9_1–C10_1	111.6(3)
C3_1–C9_1–H9A_1	109.3
C3_1–C9_1–H9B_1	109.3
C8_1–C3_1–C9_1	121.3(3)
C4_1–C3_1–C9_1	120.9(4)
C4_1–C3_1–C8_1	116.2(4)
C3_1–C8_1–H8_1	119.4
C7_1–C8_1–C3_1	121.1(4)
C7_1–C8_1–H8_1	119.4
C8_1–C7_1–H7_1	119.5
C8_1–C7_1–C6_1	121.1(4)
C6_1–C7_1–H7_1	119.5
C7_1–C6_1–C5_1	117.1(4)
C7_1–C6_1–C17_1	119.1(4)
C5_1–C6_1–C17_1	122.5(5)
C6_1–C5_1–H5_1	119.5
C6_1–C5_1–C4_1	121.1(4)
C4_1–C5_1–H5_1	119.5
C3_1–C4_1–C5_1	120.3(4)
C3_1–C4_1–H4_1	119.8
C5_1–C4_1–H4_1	119.8
C13_1–C16_1–H16A_1	109.0
C13_1–C16_1–H16B_1	109.0
C13_1–C16_1–C17_1	113.0(3)
H16A_1–C16_1–H16B_1	107.8
C17_1–C16_1–H16A_1	109.0
C17_1–C16_1–H16B_1	109.0
C6_1–C17_1–C16_1	112.5(3)
C6_1–C17_1–H17A_1	109.1
C6_1–C17_1–H17B_1	109.1
C16_1–C17_1–H17A_1	109.1
C16_1–C17_1–H17B_1	109.1
H17A_1–C17_1–H17B_1	107.8
C36_1–C1A_1–C2BA	119.4(5)
C2BA–C3A_1–C34_1	120.3(5)
C2BB_1–C1B_1–C34_1	120.7(9)
C1B_1–C2BB_1–C3B_1	119.4(10)

C2BB_1–C3B_1–C36_1	119.1(8)
Cl2–C37_2–Cl2_2	111.1(3)
Cl2–C37_2–C2_3	137.0(5)
Cl2_2–C37_2–Cl1	112.5(3)
Cl2_2–C37_2–C2_3	88.3(3)
C2_3–C37_2–Cl1	152.6(4)

Symmetry transformations used to generate equivalent atoms:
#1: +Y, +X, 1-Z;

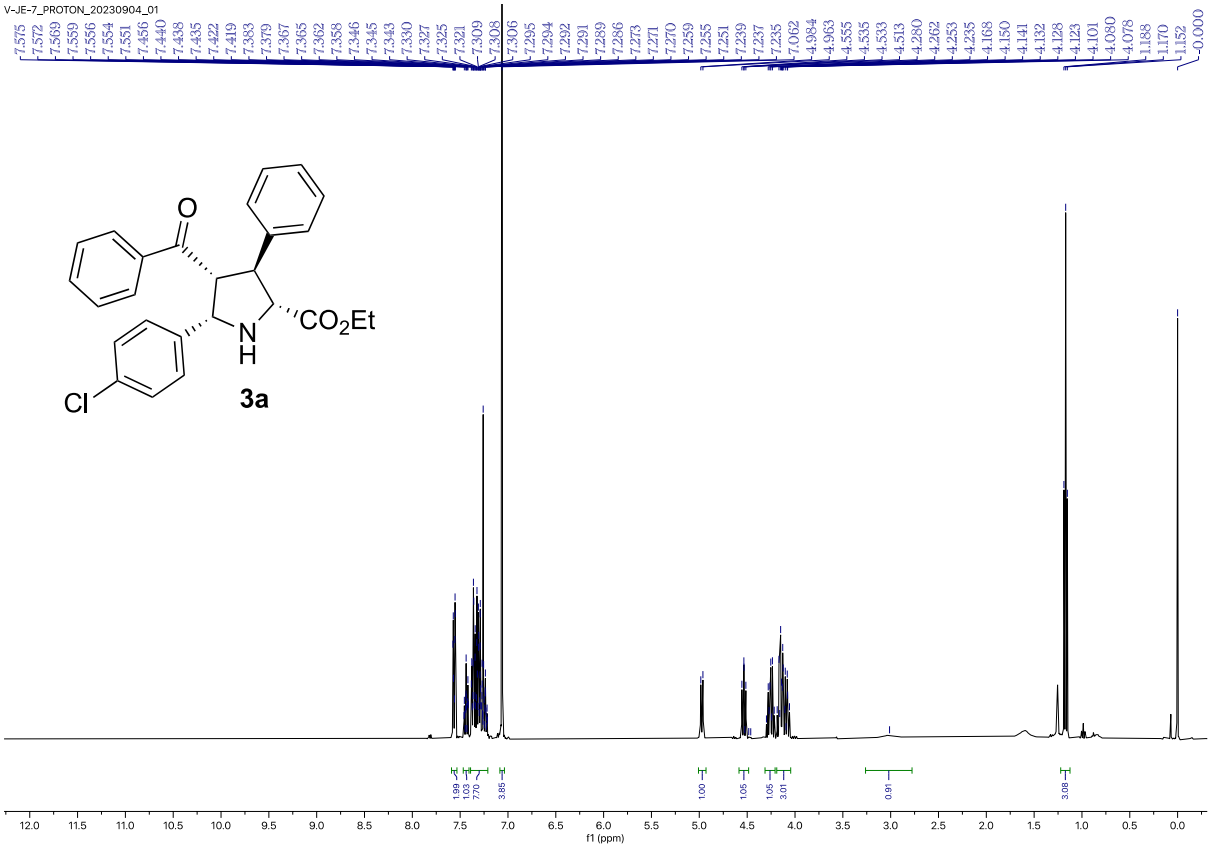
Table 5. Torsion angles for V-464

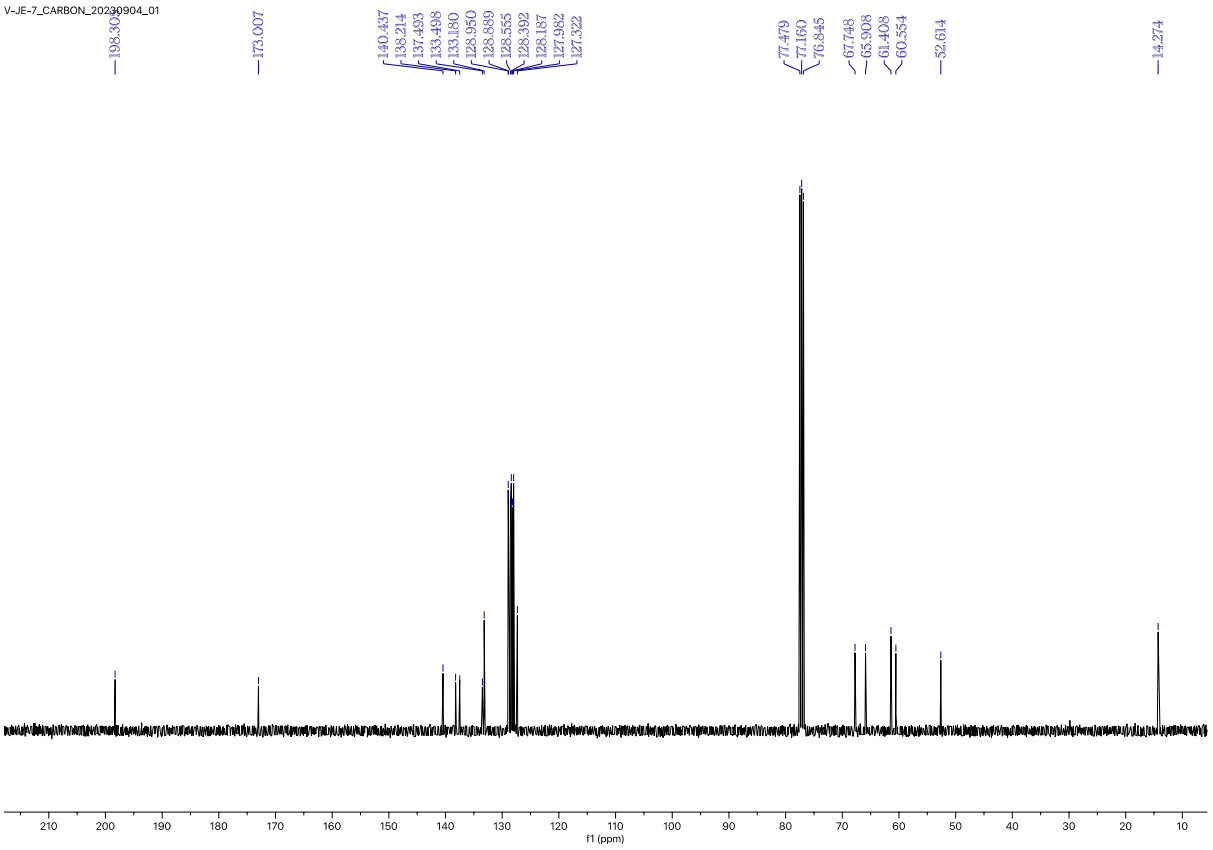
Atom–Atom–Atom–Atom	Torsion Angle [°]
Zn1_1–O1_1–C15_1–C11_1	153.04(18)
Zn1_1–O1_1–C15_1–C14_1	−23.4(3)
Zn1_1–N1_1–C33_1–C26_1	−136.66(17)
Zn1_1–N1_1–C33_1–C34_1	100.0(2)
Zn1_1–N1_1–C18_1–N2_1	153.04(16)
Zn1_1–N1_1–C18_1–C14_1	−24.6(3)
O1_1–C15_1–C11_1–C12_1	175.8(2)
O1_1–C15_1–C11_1–C10_1	−16.0(4)
O1_1–C15_1–C14_1–C18_1	−9.0(4)
O1_1–C15_1–C14_1–C13_1	167.6(2)
N1_1–C33_1–C34_1–C35_1	171.0(3)
N1_1–C33_1–C34_1–C3A_1	5.1(5)
N1_1–C33_1–C34_1–C1B_1	−38.9(8)
N1_1–C18_1–C14_1–C15_1	35.4(3)
N1_1–C18_1–C14_1–C13_1	−141.1(2)
N2_1–C26_1–C33_1–N1_1	−25.5(2)
N2_1–C26_1–C33_1–C34_1	96.7(2)
N2_1–C18_1–C14_1–C15_1	−142.0(2)
N2_1–C18_1–C14_1–C13_1	41.5(3)
N2_1–C19_1–C20_1–C21_1	−155.8(2)
N2_1–C19_1–C20_1–C25_1	24.6(4)
C27_1–C32_1–C31_1–C30_1	−0.5(5)
C27_1–C26_1–C33_1–N1_1	94.5(2)
C27_1–C26_1–C33_1–C34_1	−143.2(2)
C32_1–C27_1–C28_1–C29_1	−0.6(4)
C32_1–C27_1–C26_1–N2_1	−153.3(2)
C32_1–C27_1–C26_1–C33_1	94.3(3)
C32_1–C31_1–C30_1–C29_1	−0.2(6)
C31_1–C30_1–C29_1–C28_1	0.5(5)
C30_1–C29_1–C28_1–C27_1	−0.1(5)
C28_1–C27_1–C32_1–C31_1	0.9(4)
C28_1–C27_1–C26_1–N2_1	31.4(3)
C28_1–C27_1–C26_1–C33_1	−81.0(3)
C26_1–N2_1–C18_1–N1_1	−14.4(3)
C26_1–N2_1–C18_1–C14_1	163.3(2)
C26_1–N2_1–C19_1–C20_1	68.4(3)
C26_1–C27_1–C32_1–C31_1	−174.6(3)
C26_1–C27_1–C28_1–C29_1	174.8(2)
C26_1–C33_1–C34_1–C35_1	54.0(3)
C26_1–C33_1–C34_1–C3A_1	−111.9(5)

C26_1–C33_1–C34_1–C1B_1	−155.9(8)
C33_1–N1_1–C18_1–N2_1	−3.8(3)
C33_1–N1_1–C18_1–C14_1	178.6(2)
C33_1–C34_1–C35_1–C36_1	173.4(3)
C33_1–C34_1–C3A_1–C2BA	177.1(6)
C33_1–C34_1–C1B_1–C2BB_1	−165.2(13)
C18_1–N1_1–C33_1–C26_1	19.1(2)
C18_1–N1_1–C33_1–C34_1	−104.3(2)
C18_1–N2_1–C26_1–C27_1	−94.9(2)
C18_1–N2_1–C26_1–C33_1	24.6(2)
C18_1–N2_1–C19_1–C20_1	−140.3(2)
C34_1–C35_1–C36_1–C1A_1	21.5(8)
C34_1–C35_1–C36_1–C3B_1	−24.4(10)
C34_1–C1B_1–C2BB_1–C3B_1	7(3)
C35_1–C34_1–C3A_1–C2BA	10.7(9)
C35_1–C34_1–C1B_1–C2BB_1	−14.2(19)
C35_1–C36_1–C1A_1–C2BA	−13.4(12)
C35_1–C36_1–C3B_1–C2BB_1	16(2)
C15_1–C11_1–C12_1–C2_1	13.8(4)
C15_1–C11_1–C10_1–C9_1	−96.1(3)
C11_1–C15_1–C14_1–C18_1	174.6(2)
C11_1–C15_1–C14_1–C13_1	−8.9(3)
C11_1–C12_1–C2_1–C13_1	−3.1(5)
C11_1–C10_1–C9_1–C3_1	14.4(4)
C12_1–C11_1–C10_1–C9_1	71.7(3)
C12_1–C2_1–C13_1–C14_1	−13.6(4)
C12_1–C2_1–C13_1–C16_1	150.5(3)
C2_1–C13_1–C14_1–C18_1	−164.1(2)
C2_1–C13_1–C14_1–C15_1	19.3(4)
C2_1–C13_1–C16_1–C17_1	−93.1(4)
C13_1–C16_1–C17_1–C6_1	20.0(5)
C14_1–C15_1–C11_1–C12_1	−7.6(4)
C14_1–C15_1–C11_1–C10_1	160.7(2)
C14_1–C13_1–C16_1–C17_1	70.5(4)
C19_1–N2_1–C26_1–C27_1	61.8(3)
C19_1–N2_1–C26_1–C33_1	−178.7(2)
C19_1–N2_1–C18_1–N1_1	−167.7(2)
C19_1–N2_1–C18_1–C14_1	9.9(4)
C19_1–C20_1–C21_1–C22_1	−178.5(3)
C19_1–C20_1–C25_1–C24_1	177.7(3)
C20_1–C21_1–C22_1–C23_1	0.5(6)
C21_1–C20_1–C25_1–C24_1	−1.8(5)
C21_1–C22_1–C23_1–C24_1	−1.4(6)
C22_1–C23_1–C24_1–C25_1	0.6(6)
C23_1–C24_1–C25_1–C20_1	1.0(6)
C25_1–C20_1–C21_1–C22_1	1.1(5)
C10_1–C11_1–C12_1–C2_1	−154.0(3)
C10_1–C9_1–C3_1–C8_1	72.3(4)
C10_1–C9_1–C3_1–C4_1	−92.8(4)
C9_1–C3_1–C8_1–C7_1	−151.0(3)
C9_1–C3_1–C4_1–C5_1	151.9(4)

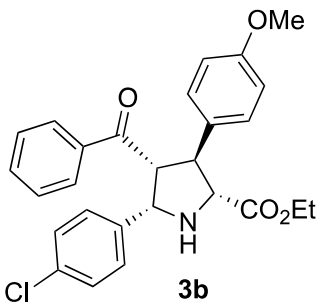
C3_1–C8_1–C7_1–C6_1	−1.3(5)
C8_1–C3_1–C4_1–C5_1	−13.9(5)
C8_1–C7_1–C6_1–C5_1	−12.9(5)
C8_1–C7_1–C6_1–C17_1	154.3(3)
C7_1–C6_1–C5_1–C4_1	13.6(5)
C7_1–C6_1–C17_1–C16_1	−98.8(4)
C6_1–C5_1–C4_1–C3_1	0.0(6)
C5_1–C6_1–C17_1–C16_1	67.7(5)
C4_1–C3_1–C8_1–C7_1	14.7(4)
C16_1–C13_1–C14_1–C18_1	32.4(4)
C16_1–C13_1–C14_1–C15_1	−144.2(3)
C17_1–C6_1–C5_1–C4_1	−153.1(4)
C1A_1–C2BA–C3A_1–C34_1	−4.0(13)
C3A_1–C2BA–C1A_1–C36_1	5.2(14)
C3A_1–C34_1–C35_1–C36_1	−19.9(6)
C1B_1–C34_1–C35_1–C36_1	23.6(9)
C1B_1–C2BB_1–C3B_1–C36_1	−8(3)

7. Copy of NMR spectra



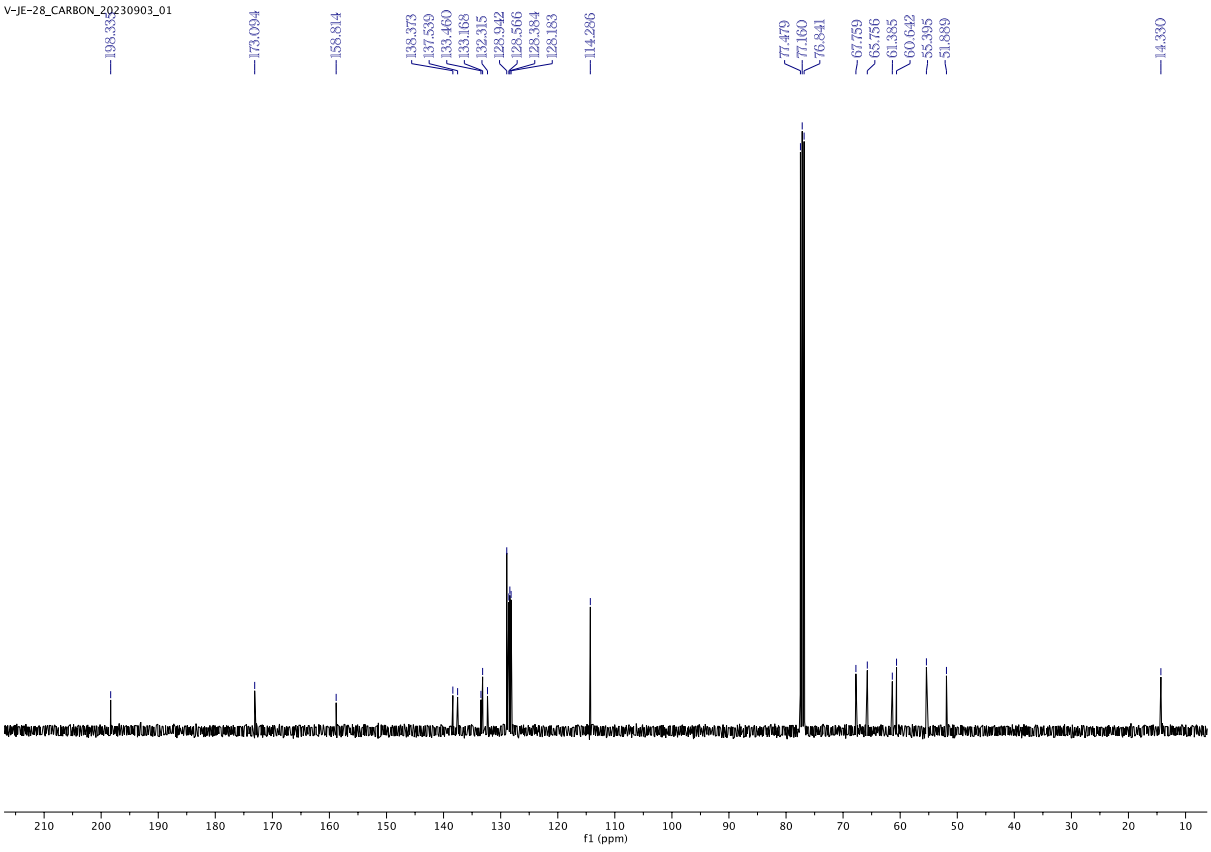


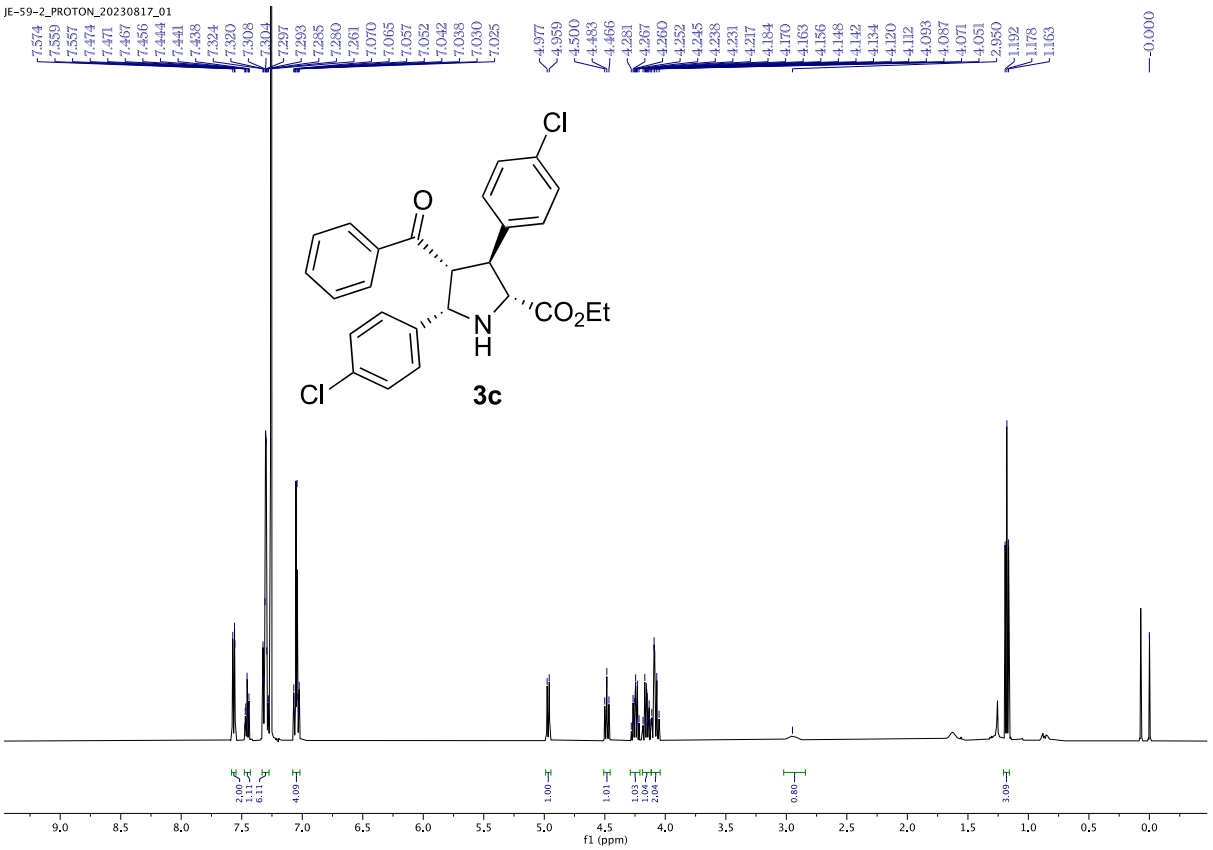
V-JE-28_PROTON_20230903_01

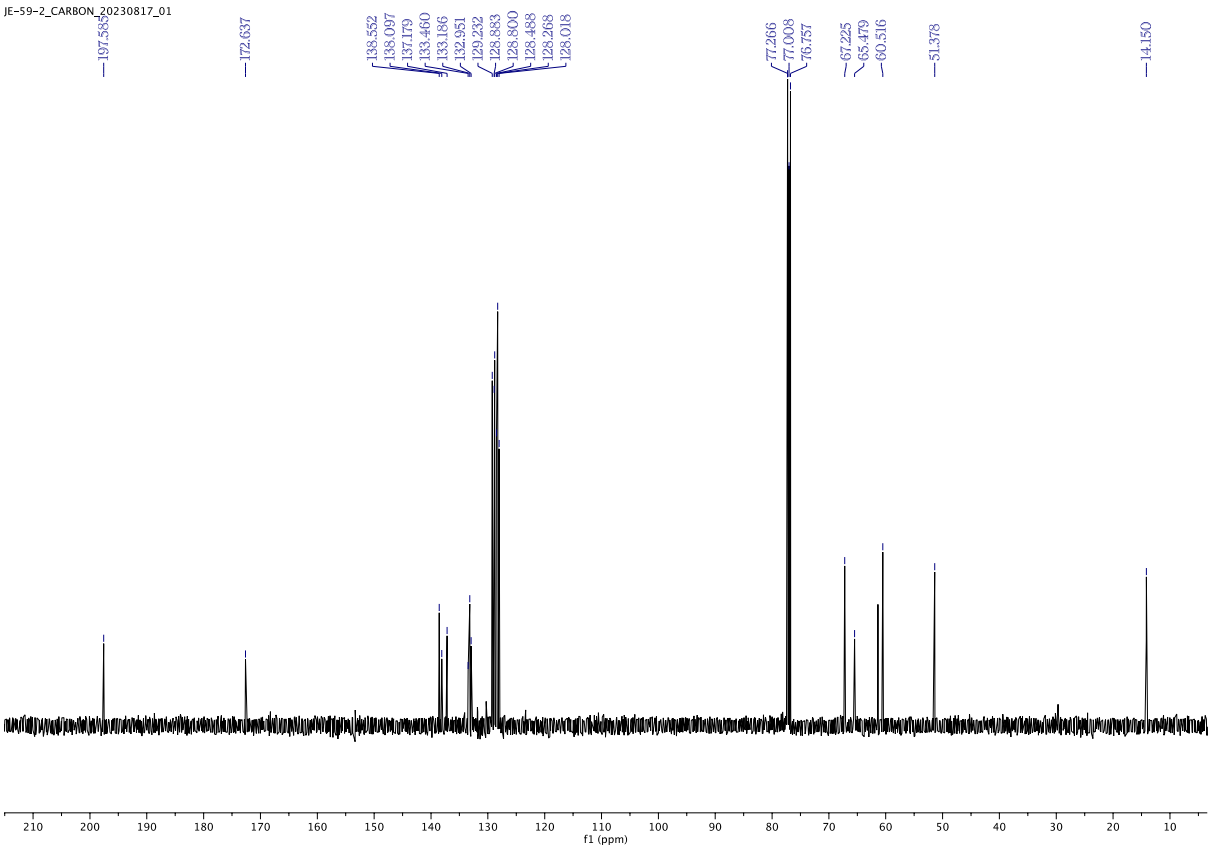


3b

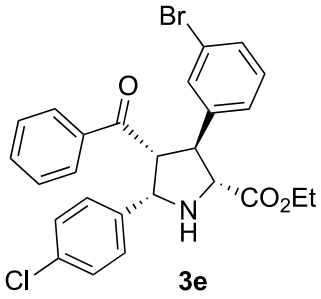
V-JE-28_CARBON_20230903_01



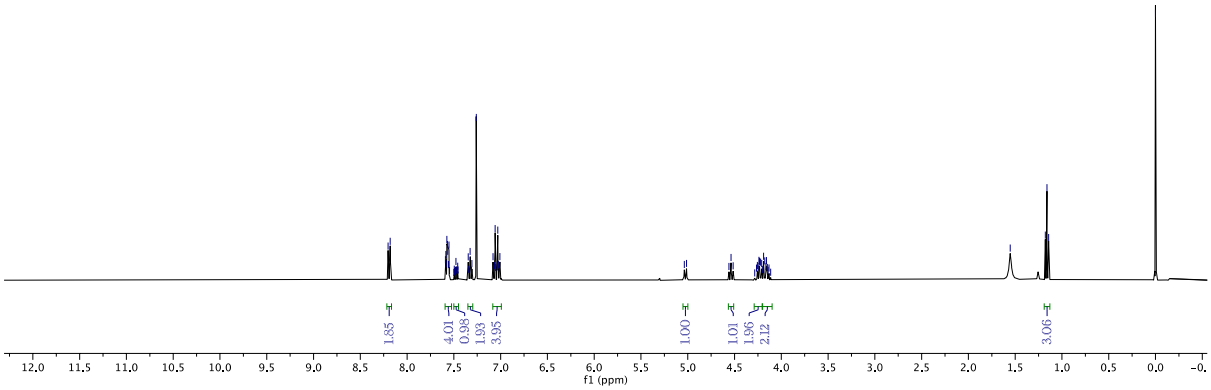

JE-59-2_PROTON_20230817_01
7.574
7.559
7.557
7.474
7.471
7.467
7.456
7.444
7.441
7.438
7.324
7.320
7.308
7.301
7.297
7.293
7.285
7.280
7.261
7.070
7.065
7.057
7.052
7.042
7.038
7.030
7.025
4.977
4.959
4.500
4.483
4.466
4.281
4.267
4.260
4.252
4.245
4.238
4.231
4.217
4.184
4.170
4.163
4.156
4.148
4.142
4.134
4.120
4.112
4.093
4.087
4.071
4.051
2.950
1.192
1.178
1.163
0.000
Cl
O
CO2Et
N
H
Cl
3c
2.00
1.11
6.11
4.09
1.00
1.01
1.03
1.04
2.04
0.80
3.09
f1 (ppm)


JE-59-2_CARBON_20230817_01
197.585
172.637
138.552
138.097
137.179
133.460
133.186
132.951
129.232
128.883
128.800
128.488
128.268
128.018
77.266
77.008
76.757
67.225
65.479
60.516
51.378
14.150
f1 (ppm)

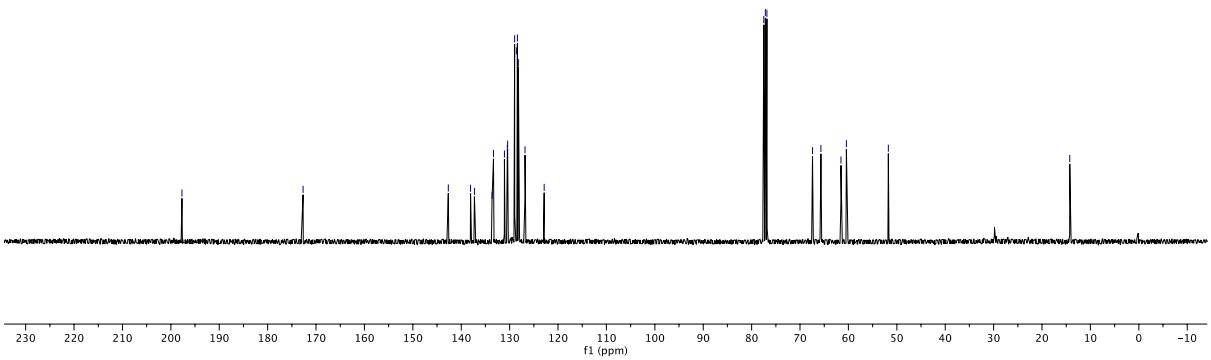
JE-31_PROTON_20230711_01



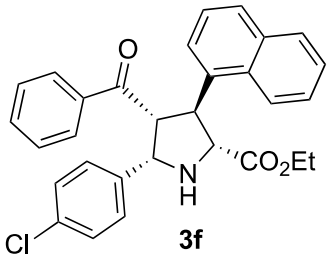
3e



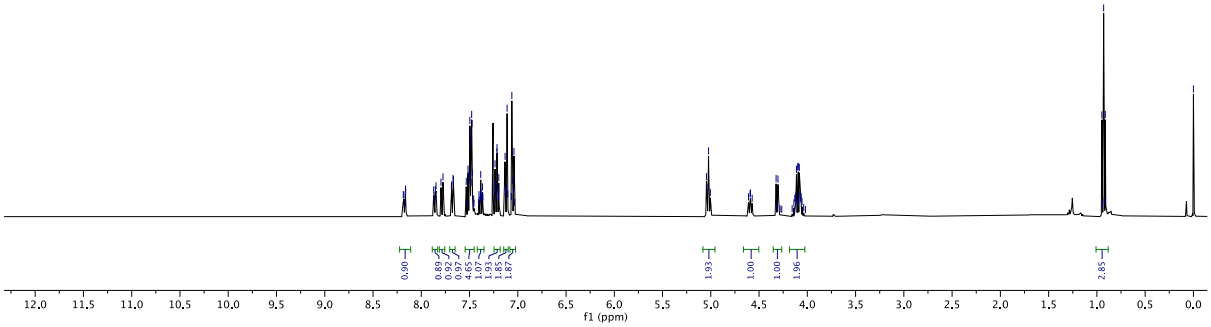
V-JE-31_CARBON_20230904_01



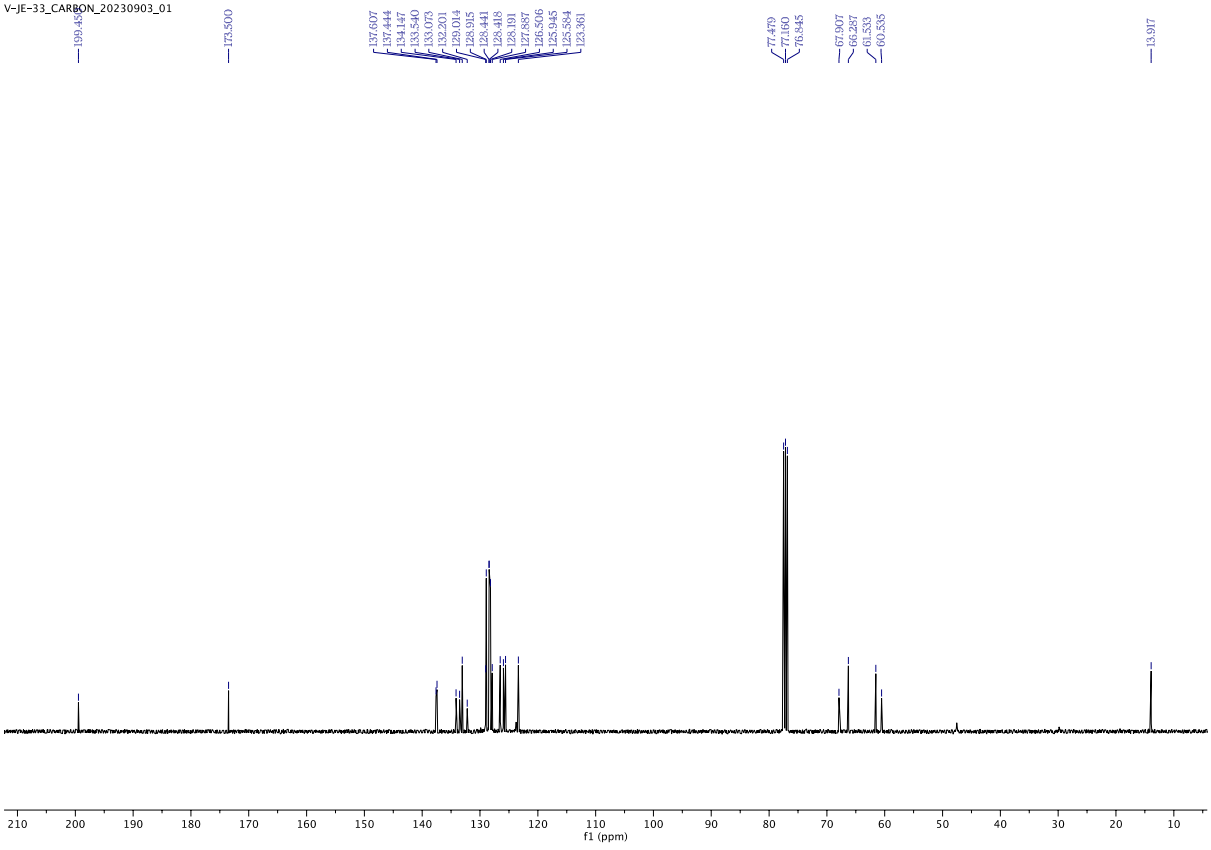
V-JE-33_PROTON_20230903_01



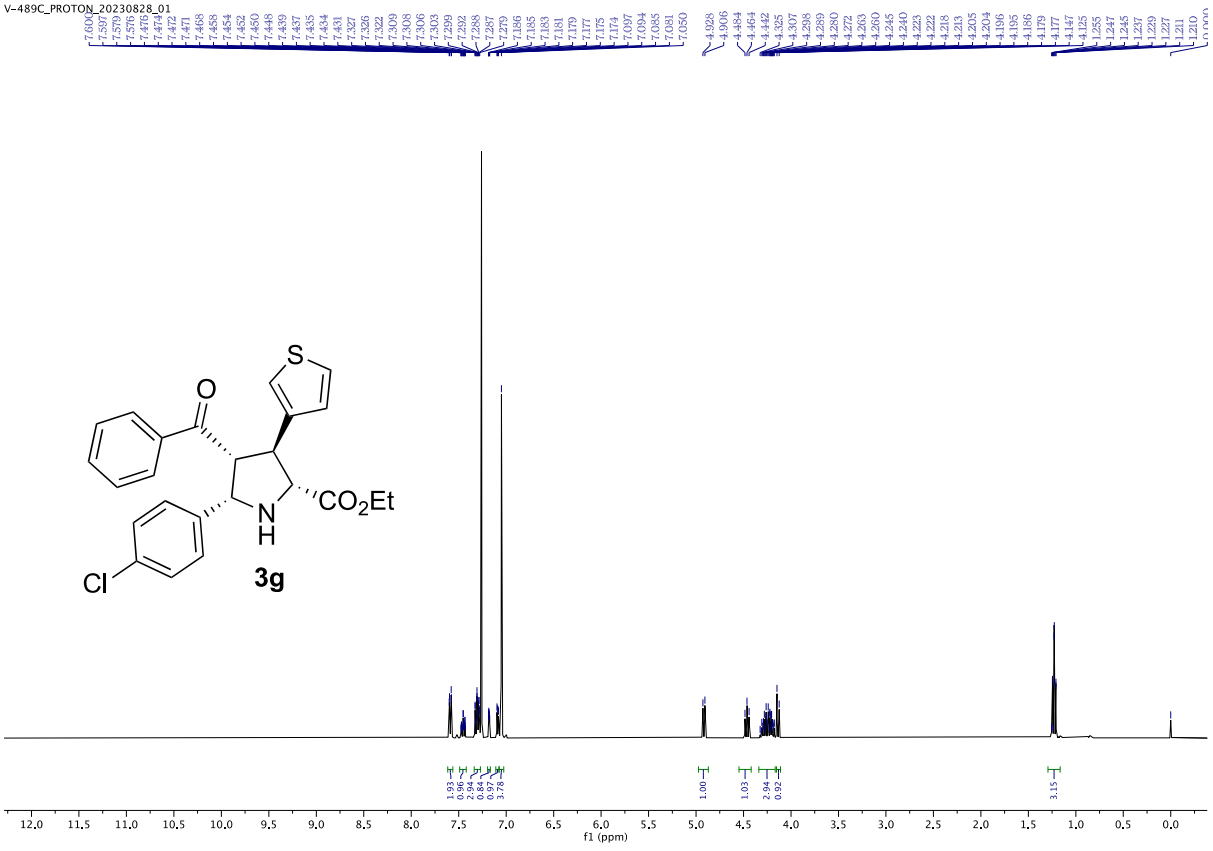
3f



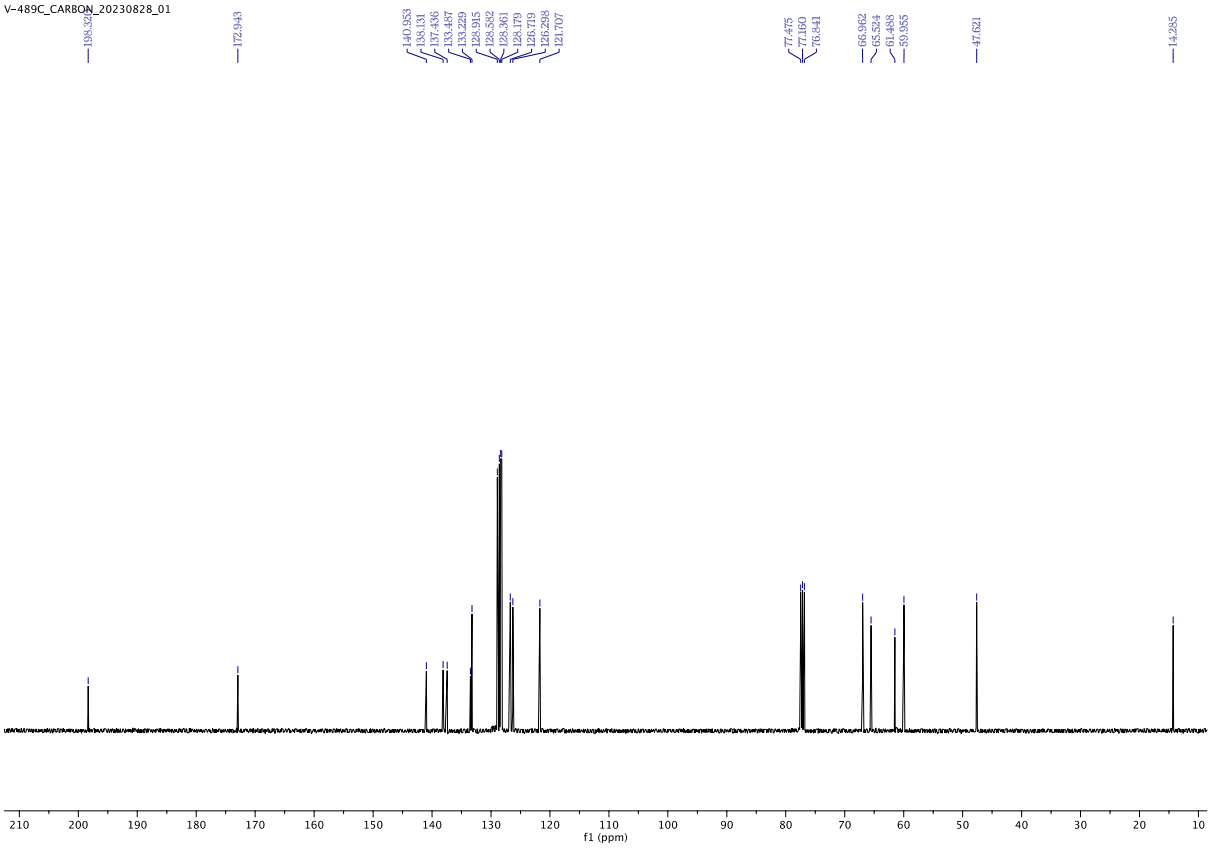
V-JE-33_CARBON_20230903_01

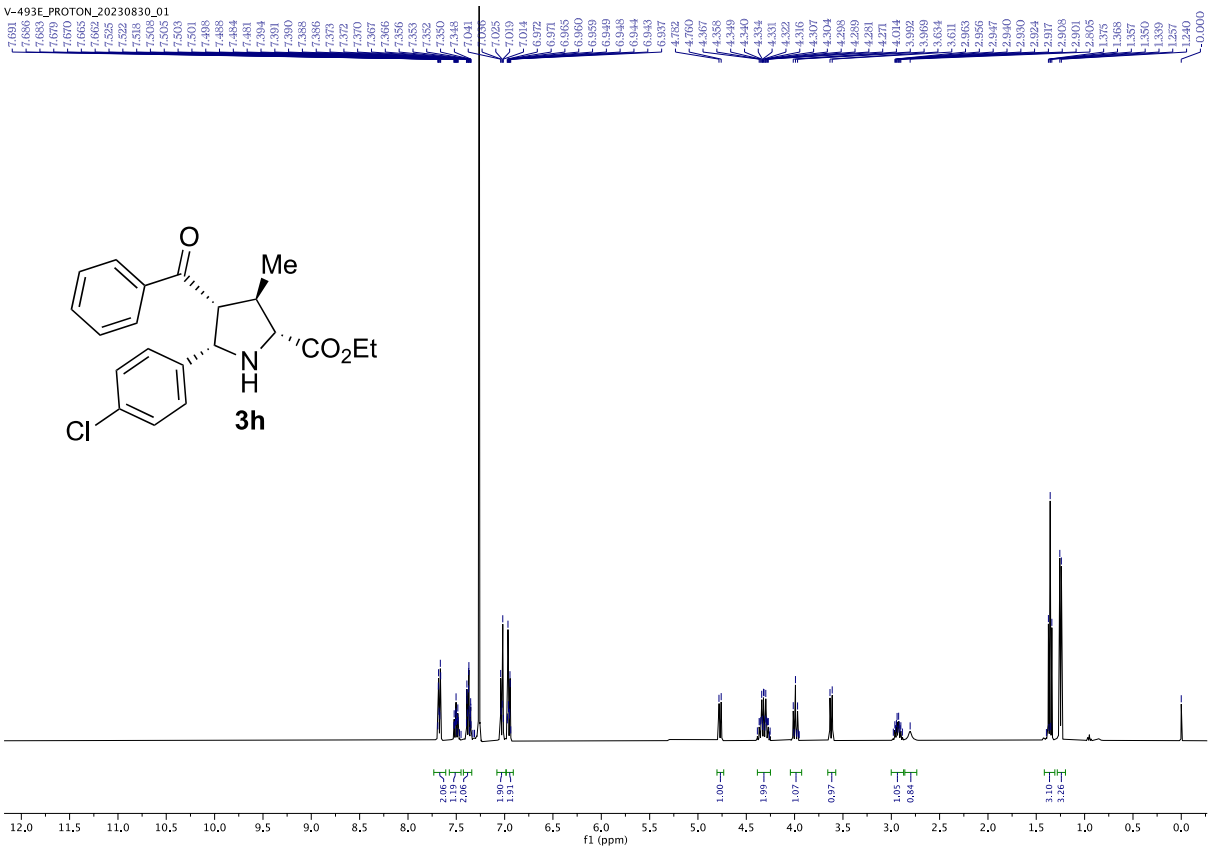


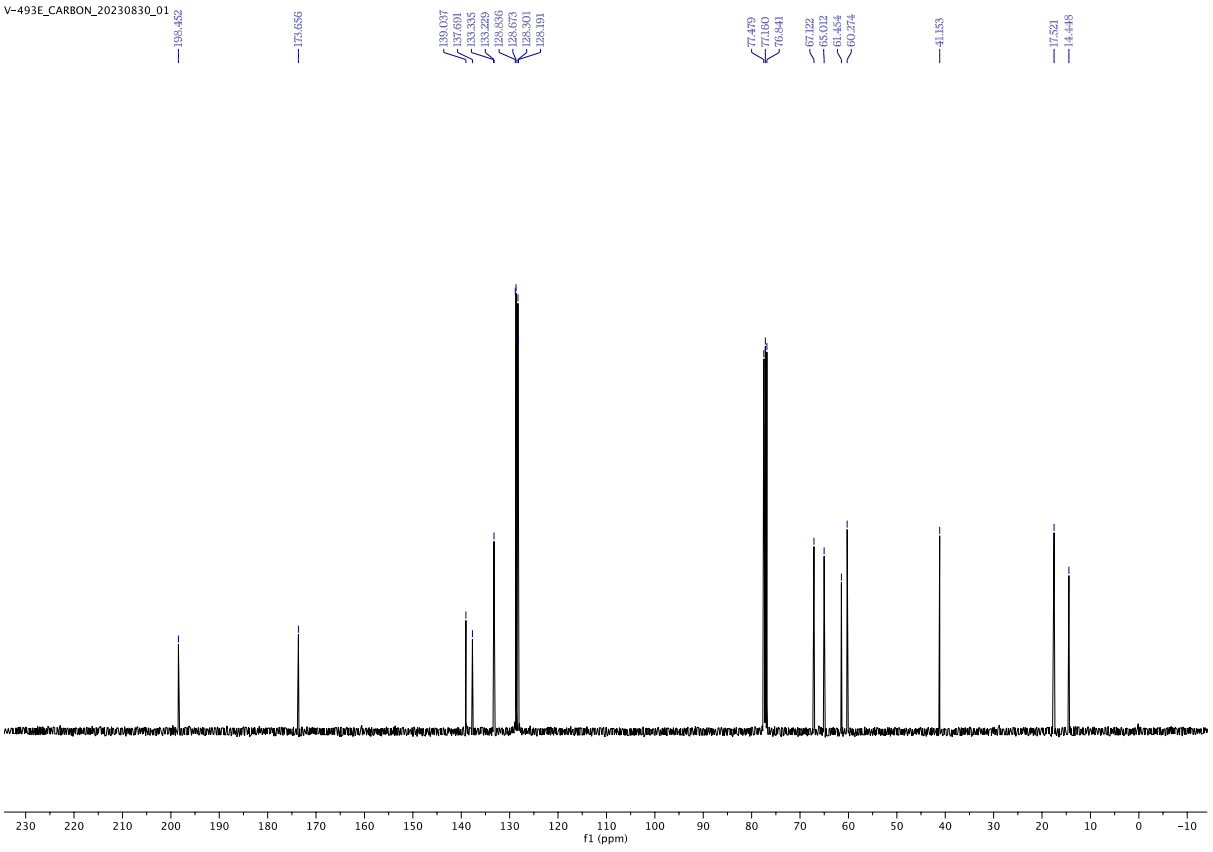
V-489C_PROTON_20230828_01



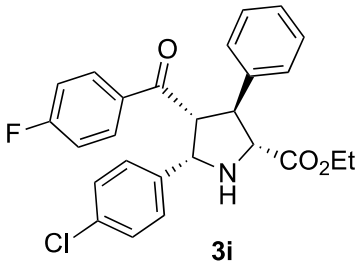
V-489C_CARBON_20230828_01



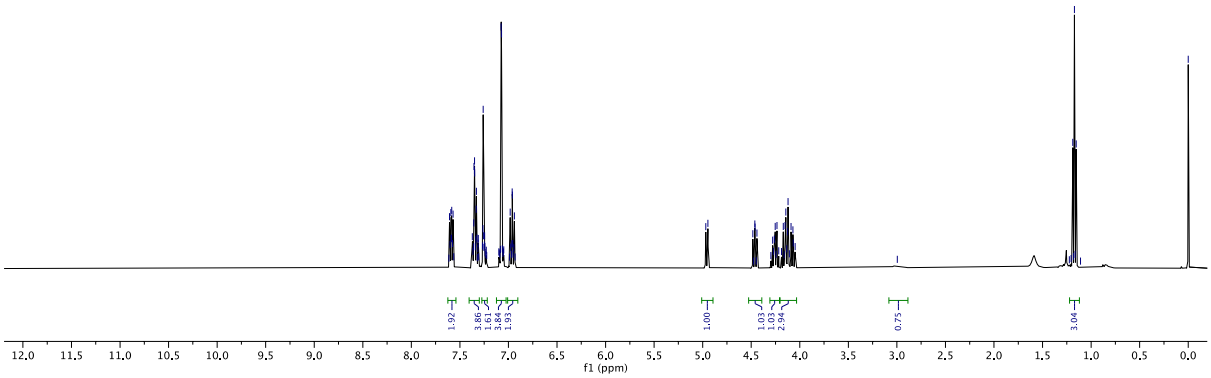

V-493E_PROTON_20230830_01
O
Me
CO2Et
N
H
Cl
3h
f1 (ppm)


V-493E_CARBON_20230830_01
f1 (ppm)

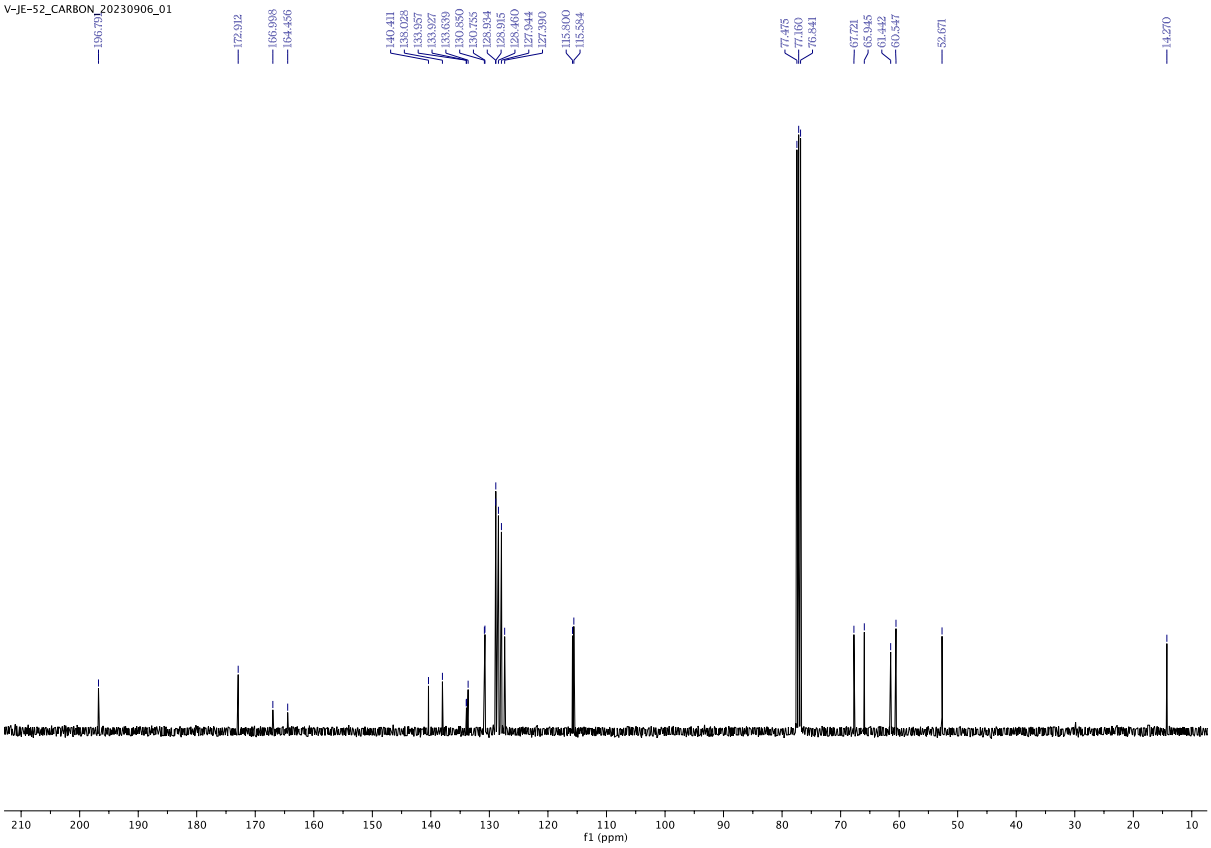
V-JE-52_PROTON_20230906_01

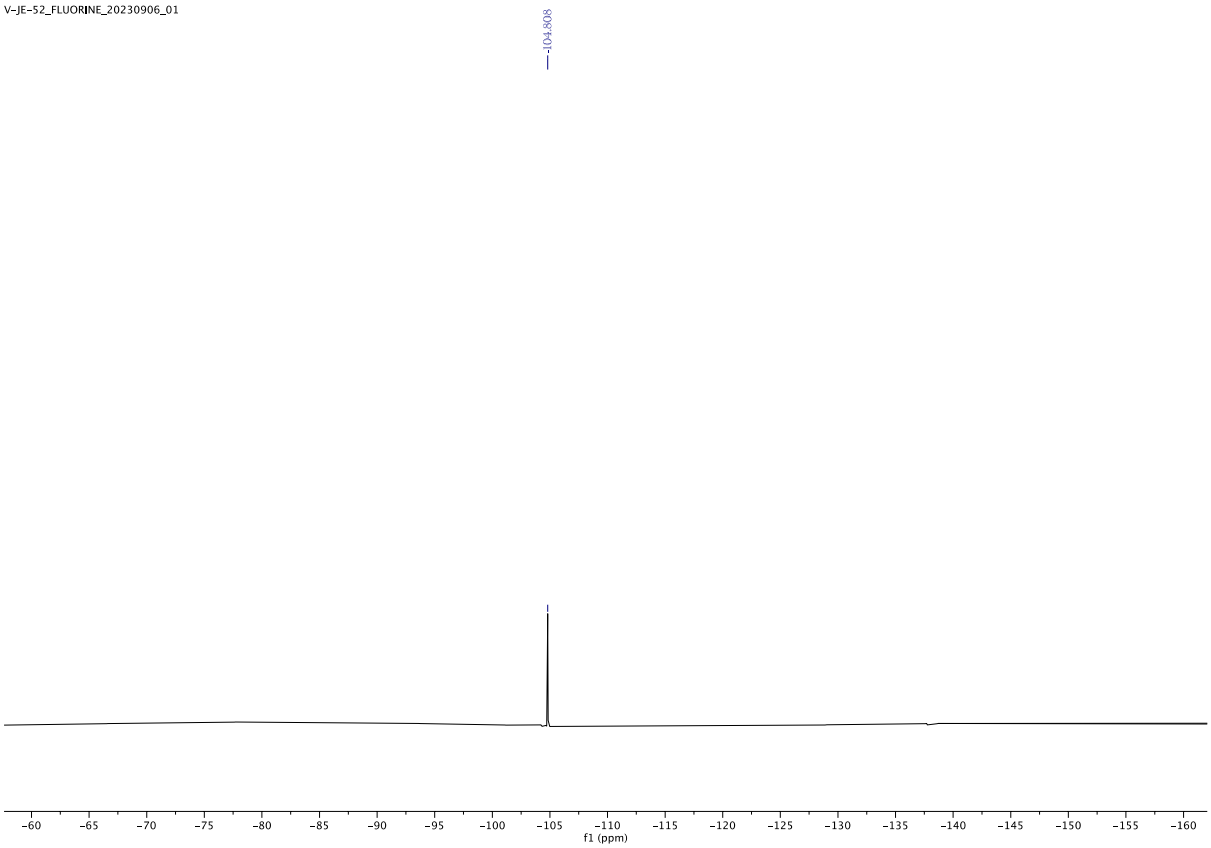


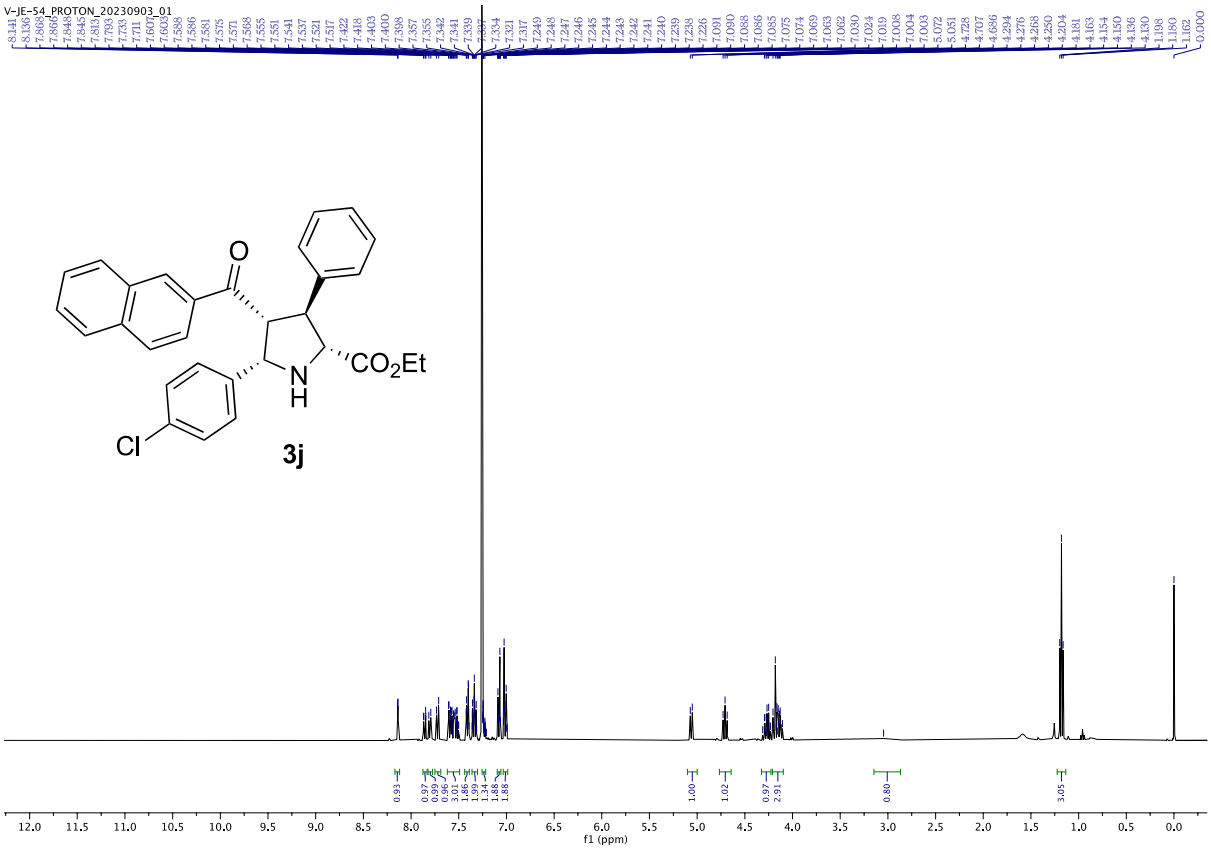
3i



V-JE-52_CARBON_20230906_01

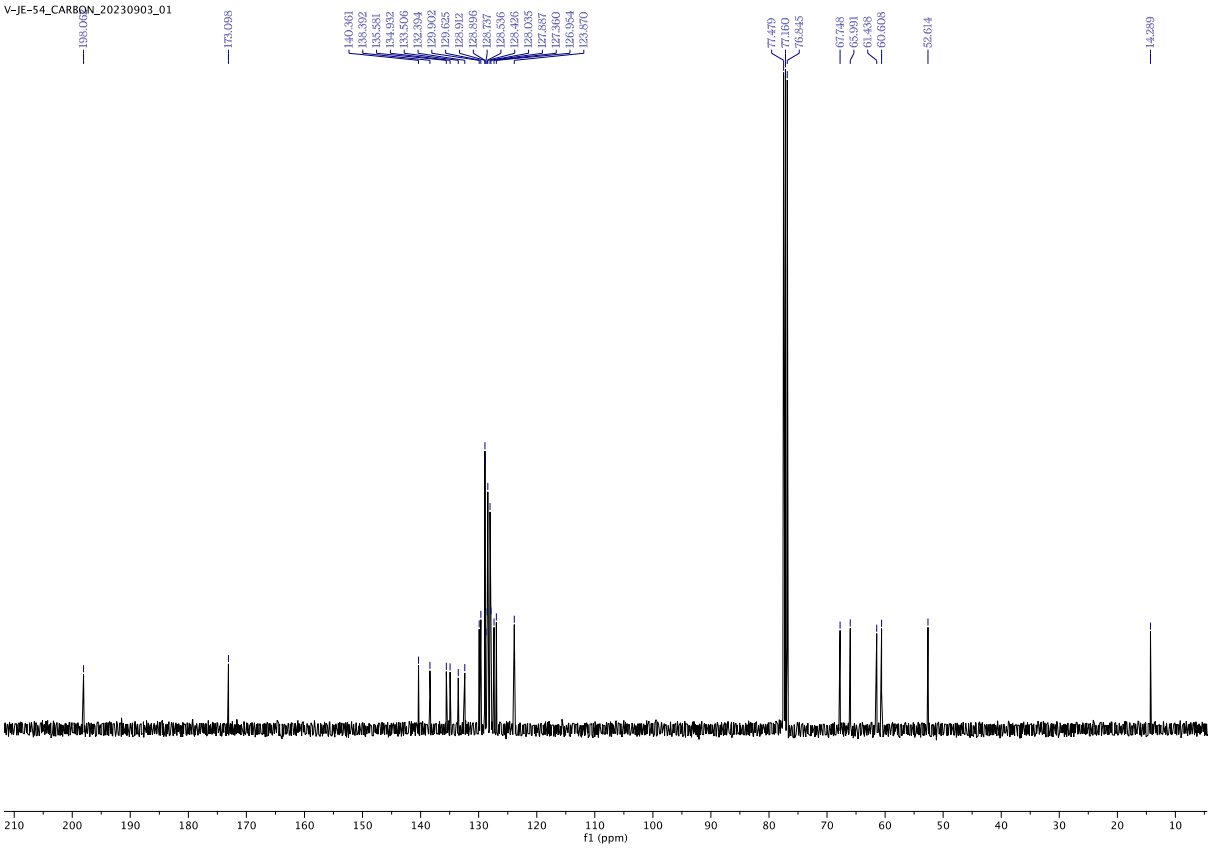


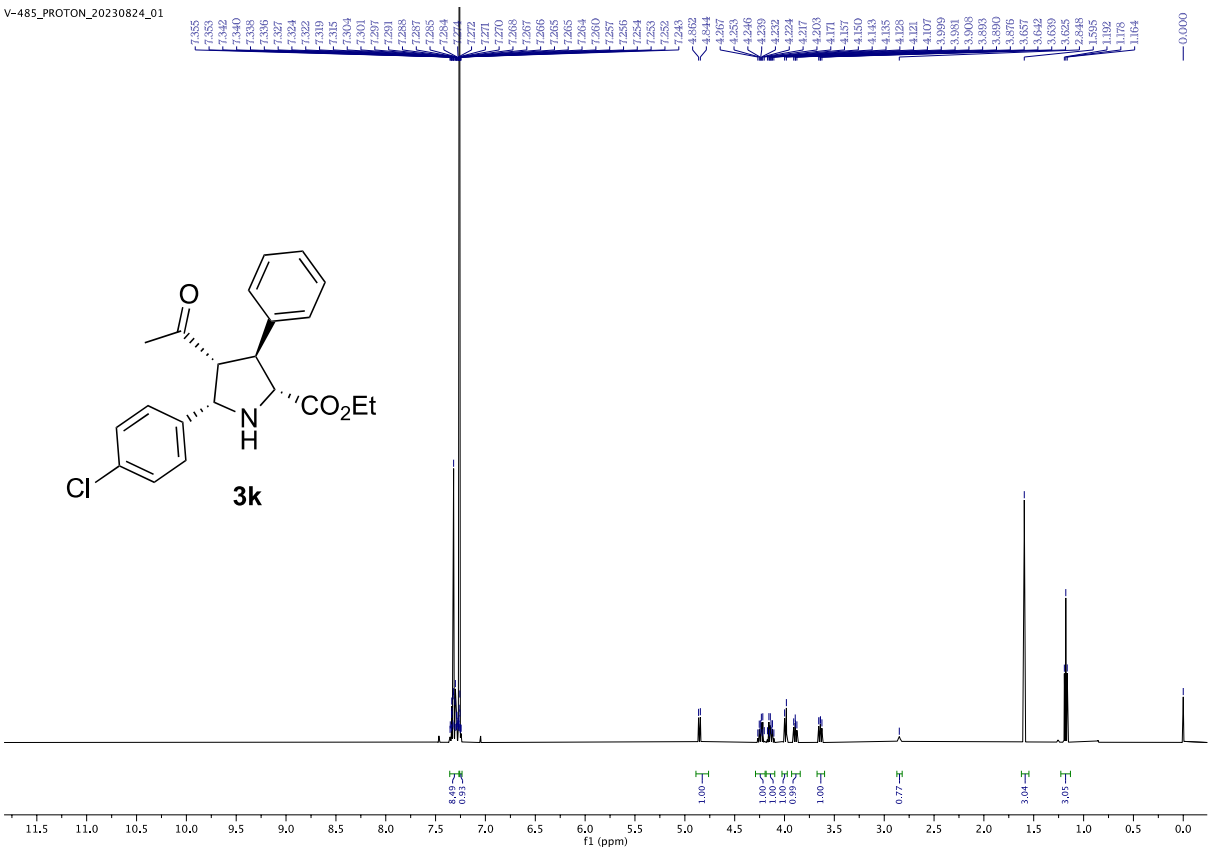

V-JE-52_FLUORINE_20230906_01
-104.808
f1 (ppm)


V-JE-54_PROTON_20230903_01
f1 (ppm)

O
N
H
CO2Et
Cl

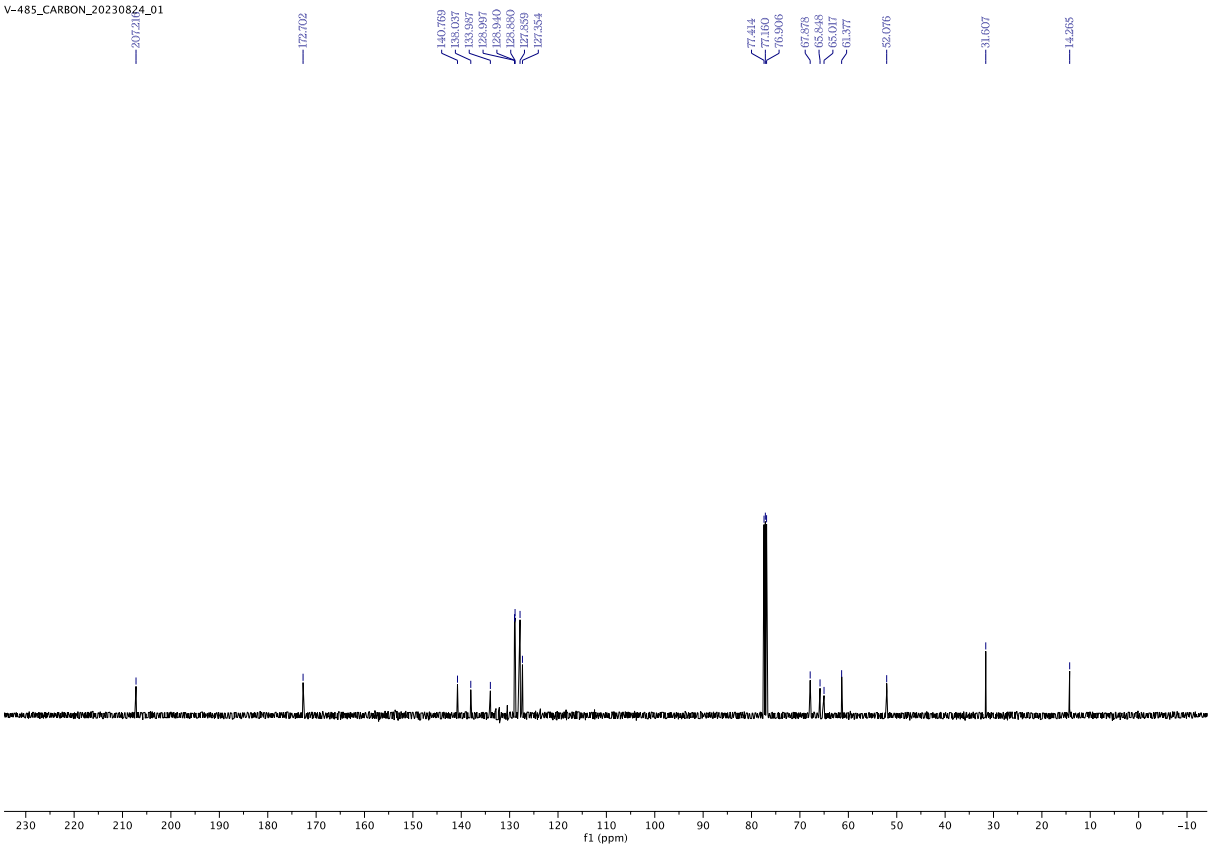
3j

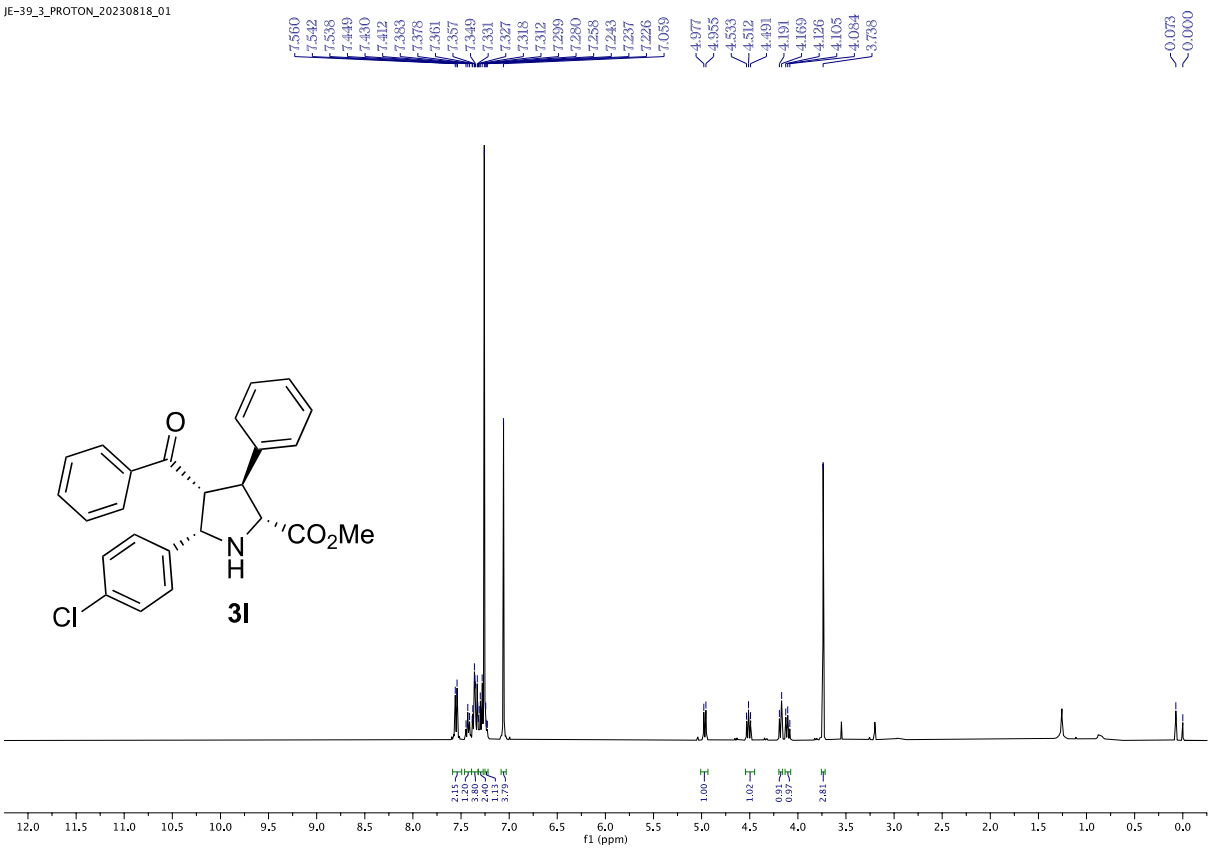

V-JE-54_CARBON_20230903_01
198.066
173.098
140.361
138.392
135.581
134.932
133.506
132.394
129.902
129.625
128.912
128.896
128.737
128.536
128.426
128.035
127.887
127.360
126.954
123.670
77.479
77.160
76.845
67.748
65.991
61.438
60.608
52.614
14.289
f1 (ppm)

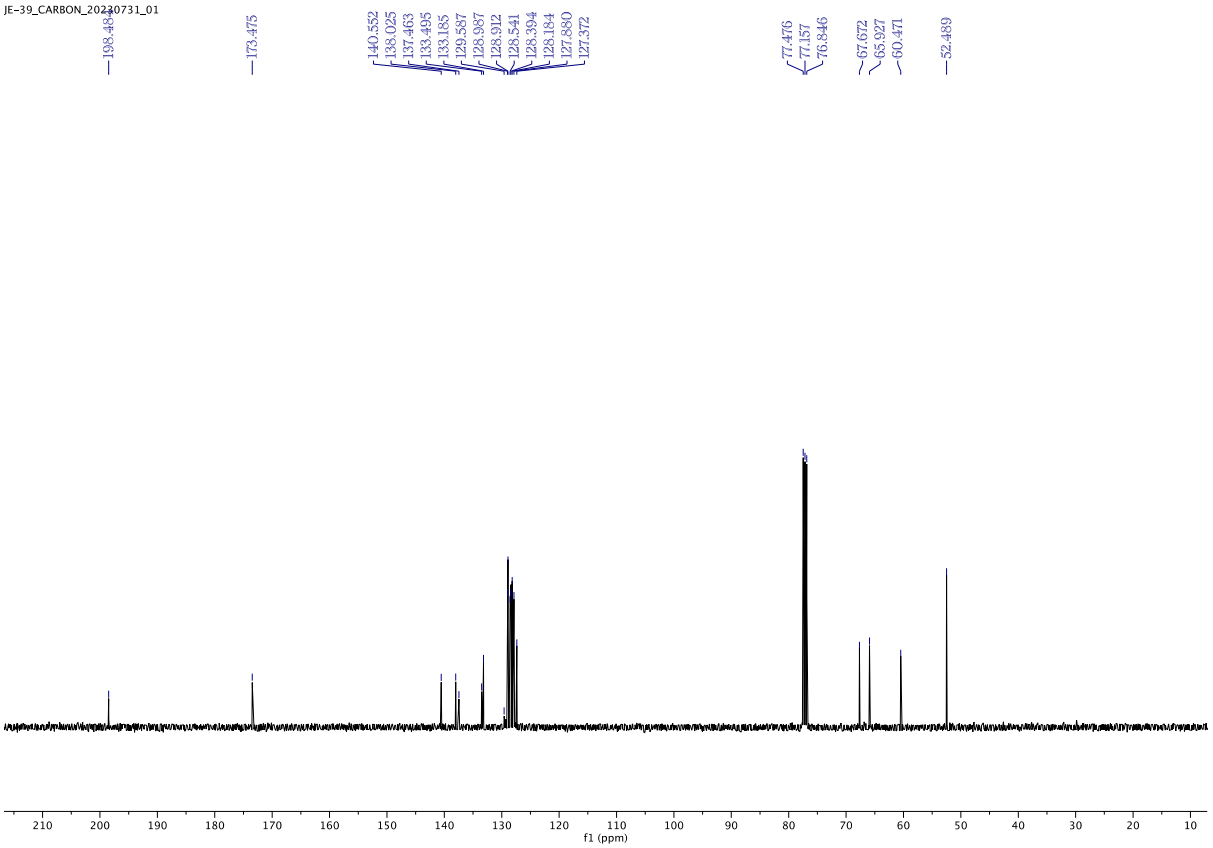

V-485_PROTON_20230824_01
7.355
7.353
7.342
7.340
7.338
7.336
7.327
7.324
7.322
7.319
7.315
7.304
7.301
7.297
7.291
7.288
7.287
7.285
7.284
7.274
7.272
7.271
7.270
7.268
7.267
7.266
7.265
7.265
7.264
7.260
7.257
7.256
7.254
7.253
7.252
7.243
4.862
4.844
4.267
4.253
4.246
4.239
4.232
4.224
4.217
4.203
4.171
4.157
4.150
4.143
4.135
4.125
4.121
4.107
3.999
3.981
3.908
3.893
3.890
3.876
3.657
3.642
3.639
3.625
2.848
1.595
1.192
1.178
1.164
0.000
8.49
0.93
1.00
1.00
1.00
1.00
0.99
1.00
0.77
3.04
3.05
f1 (ppm)

O
CO2Et
N
H
Cl

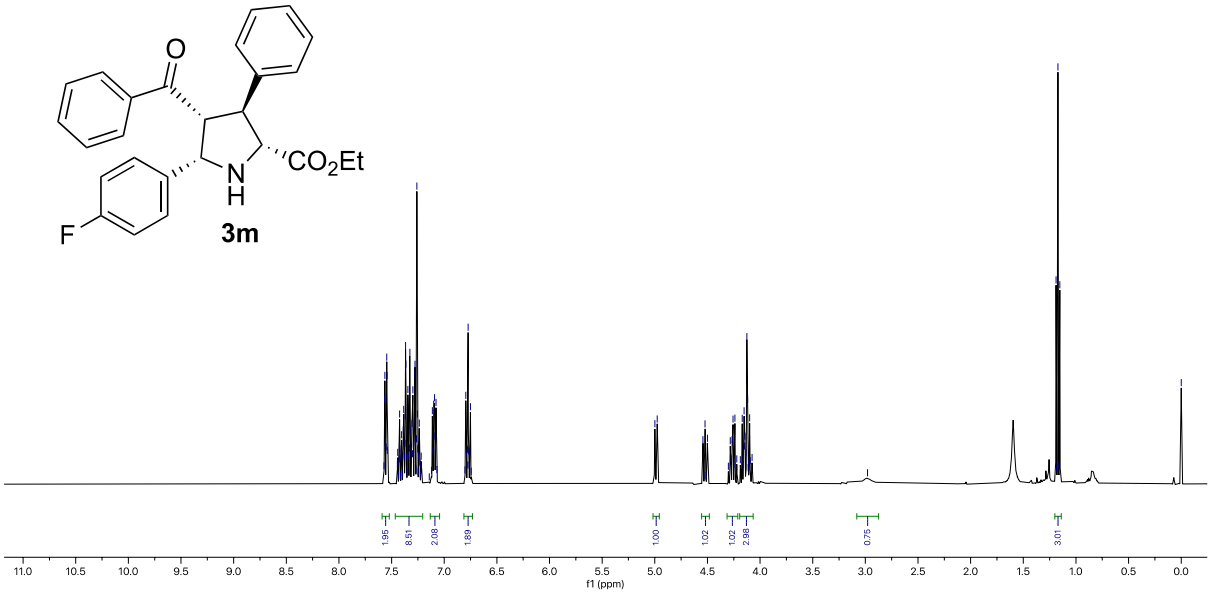
3k

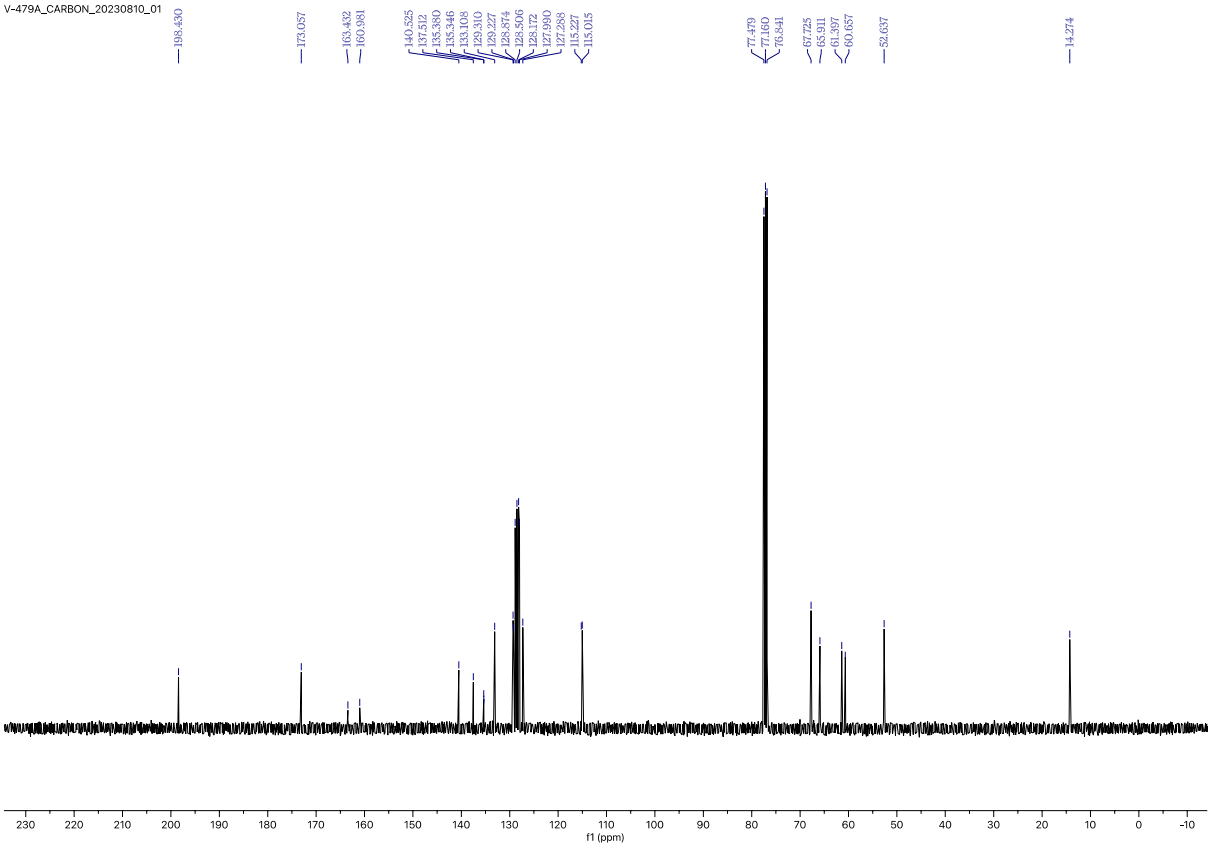

V-485_CARBON_20230824_01
207.201
172.702
140.769
134.037
133.987
129.997
129.940
128.860
127.859
127.354
77.414
77.160
76.906
67.878
65.848
65.017
61.377
52.076
31.607
14.265
f1 (ppm)

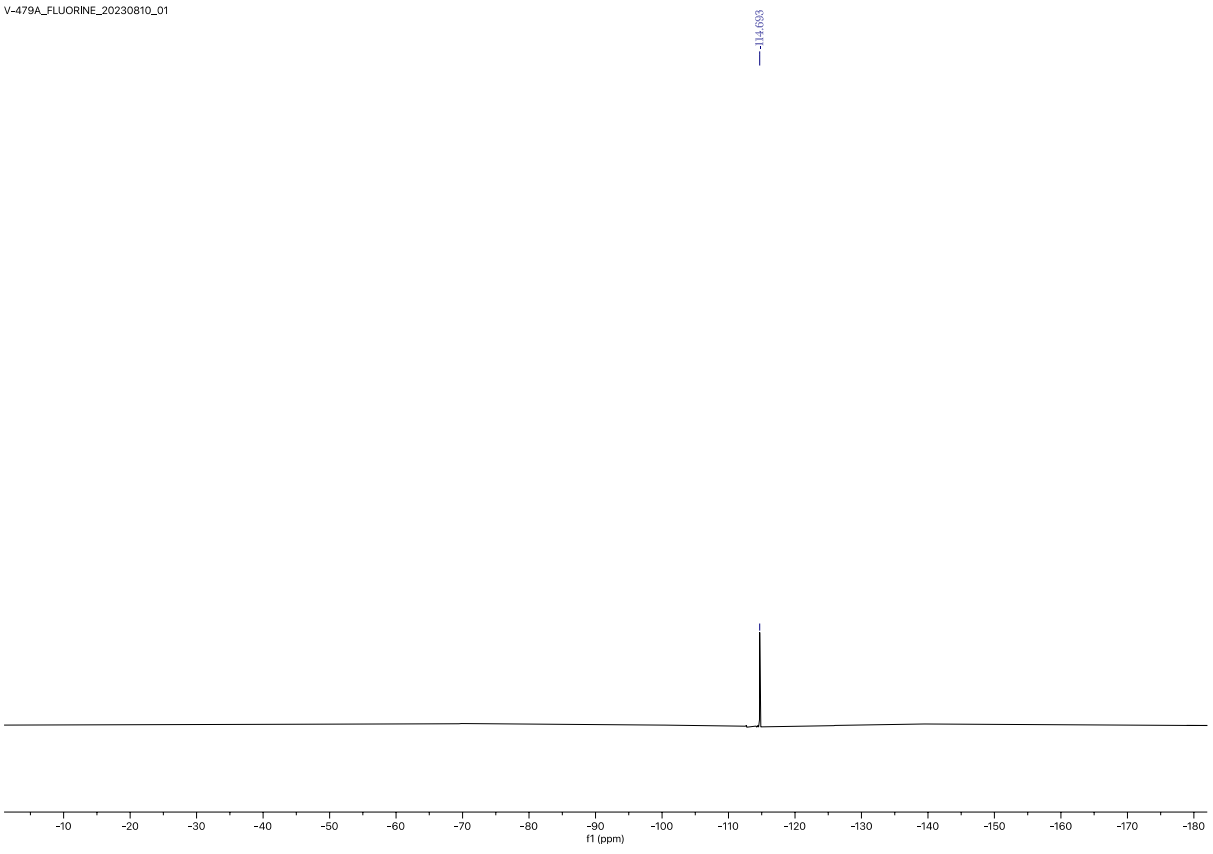

JE-39_3_PROTON_20230818_01
7.560
7.542
7.538
7.449
7.430
7.412
7.383
7.378
7.361
7.357
7.349
7.331
7.327
7.318
7.312
7.299
7.280
7.258
7.243
7.237
7.226
7.059
4.977
4.955
4.533
4.512
4.491
4.191
4.169
4.126
4.105
4.084
3.738
0.073
0.000
O
CO2Me
N
H
Cl
3l
2.15
1.20
3.80
3.49
2.19
3.79
1.00
1.02
0.91
0.97
2.81
f1 (ppm)


JE-39_CARBON_20230731_01
198.468
173.475
140.552
138.025
137.463
133.495
133.185
129.587
128.987
128.912
128.541
128.394
128.184
127.880
127.372
77.476
77.157
76.846
67.672
65.927
60.471
52.489
f1 (ppm)

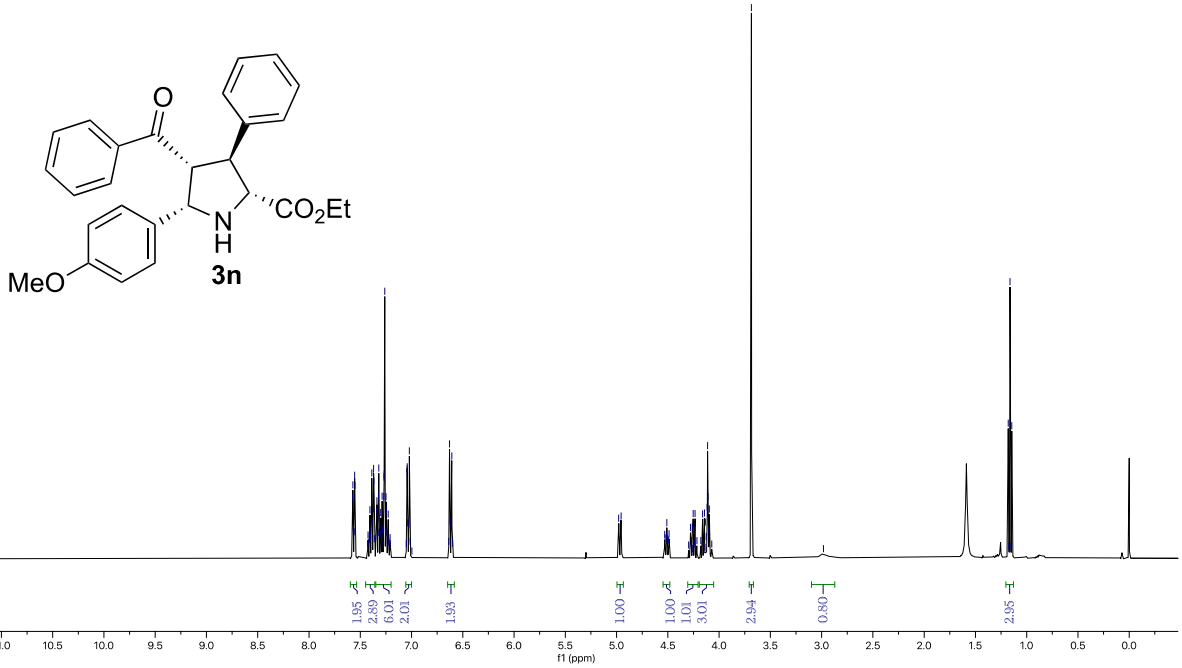

V-479A_PROTON_20230810_01


O
CO2Et
N
H
F
3m
1.95
8.51
2.08
1.89
1.00
1.02
1.02
2.98
0.75
3.01
f1 (ppm)

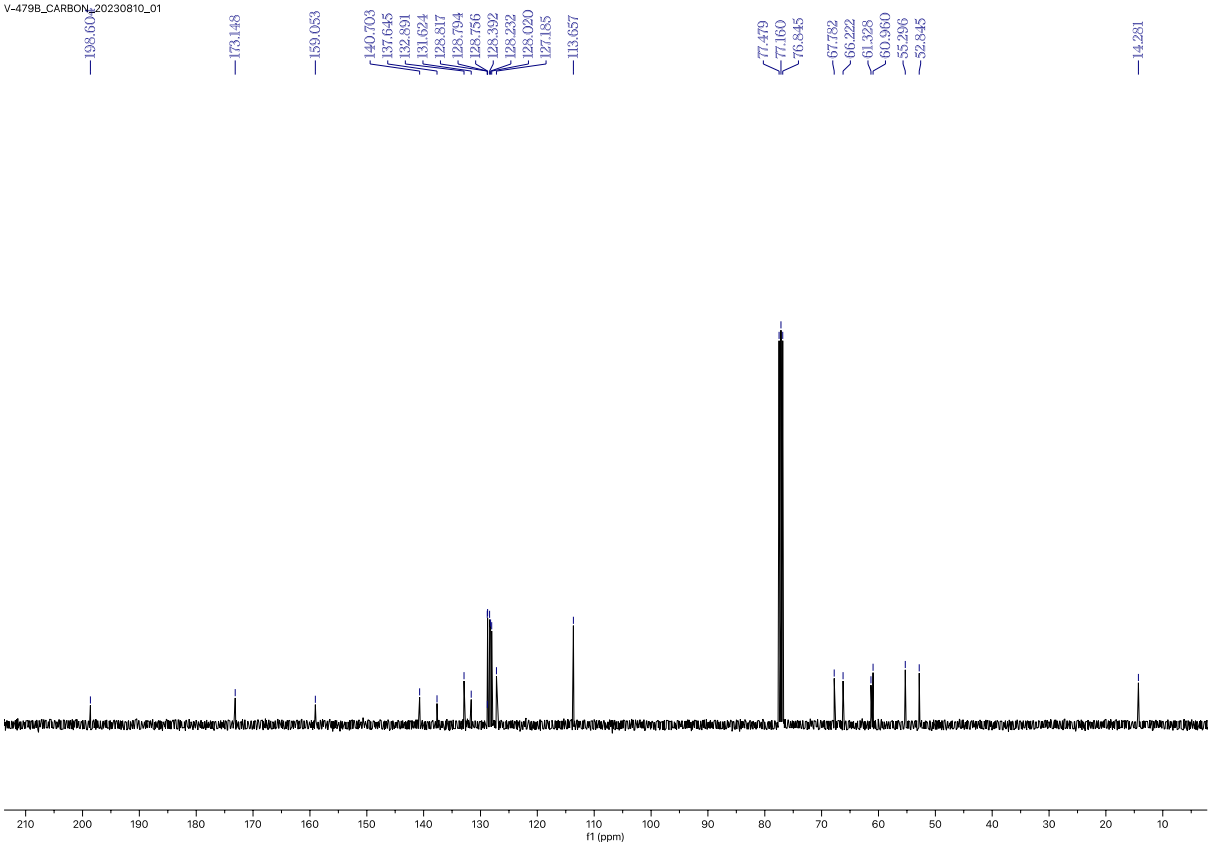

V-479A_CARBON_20230810_01
198.430
173.057
163.432
160.981
140.525
137.512
135.380
135.346
133.108
129.310
129.227
128.874
128.506
128.172
127.990
127.298
115.227
115.015
77.479
77.160
76.841
67.725
65.911
61.397
60.657
52.637
14.274
f1 (ppm)


V-479A_FLUORINE_20230810_01
-114.693
f1 (ppm)

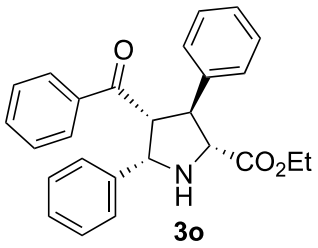
V-479B_PROTON_20230810_01



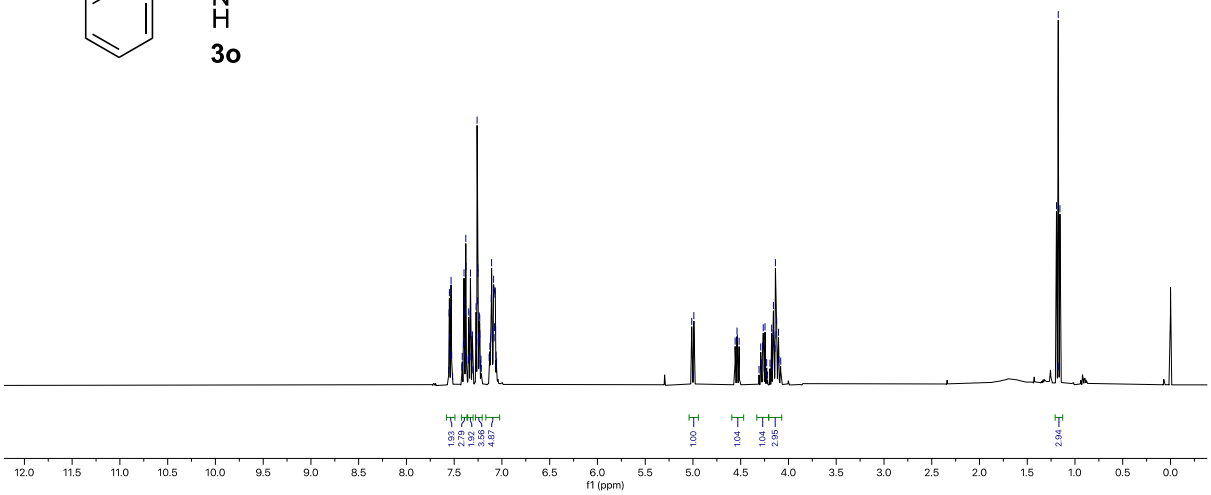
V-479B_CARBON_20230810_01

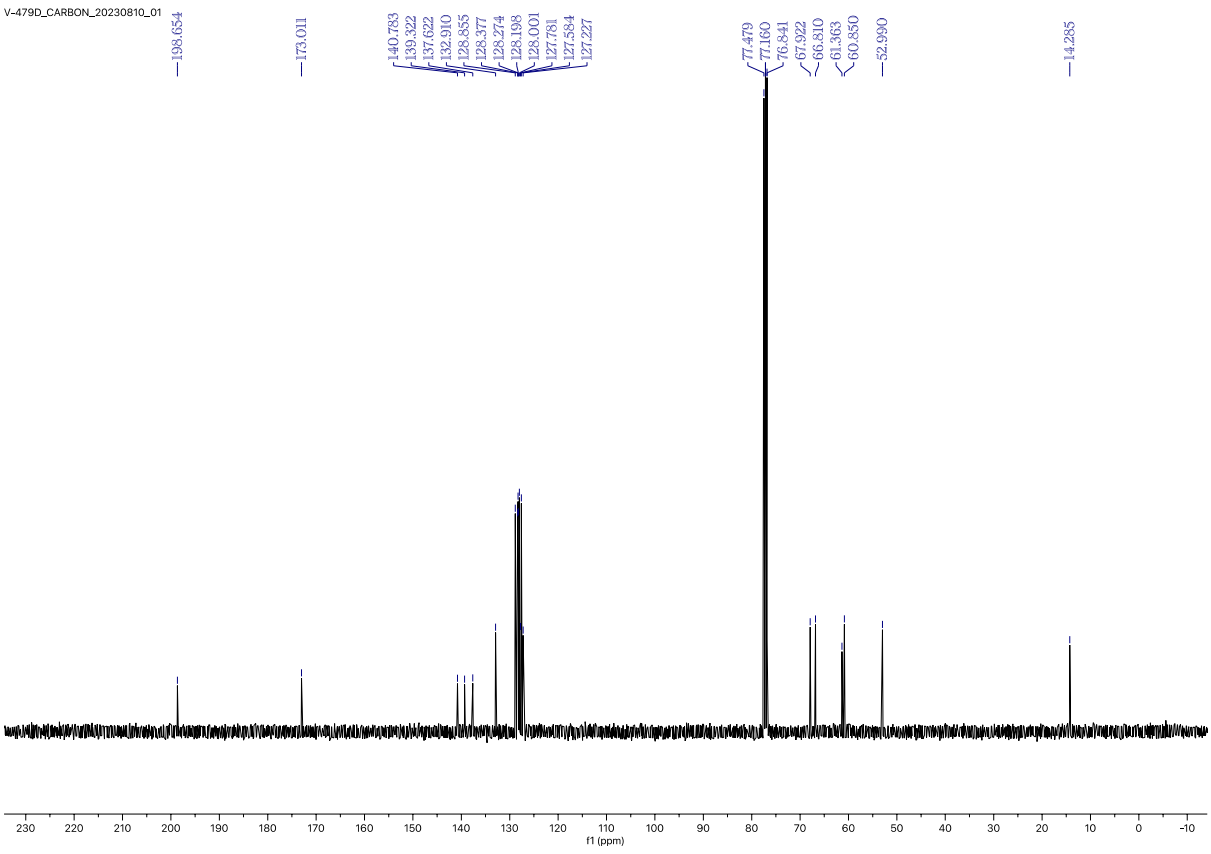



V-479D_PROTON_20230810_01

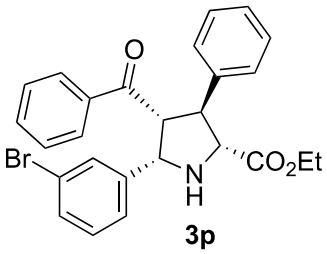

O
CO2Et
N
H

3o

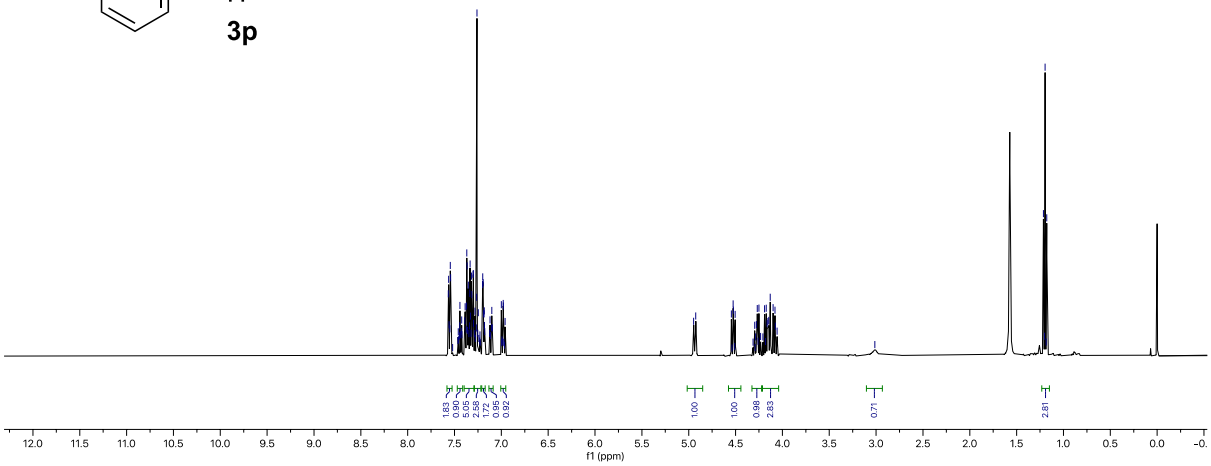

1.93
2.79
1.66
3.58
4.87
1.00
1.04
1.04
2.95
2.94
f1 (ppm)

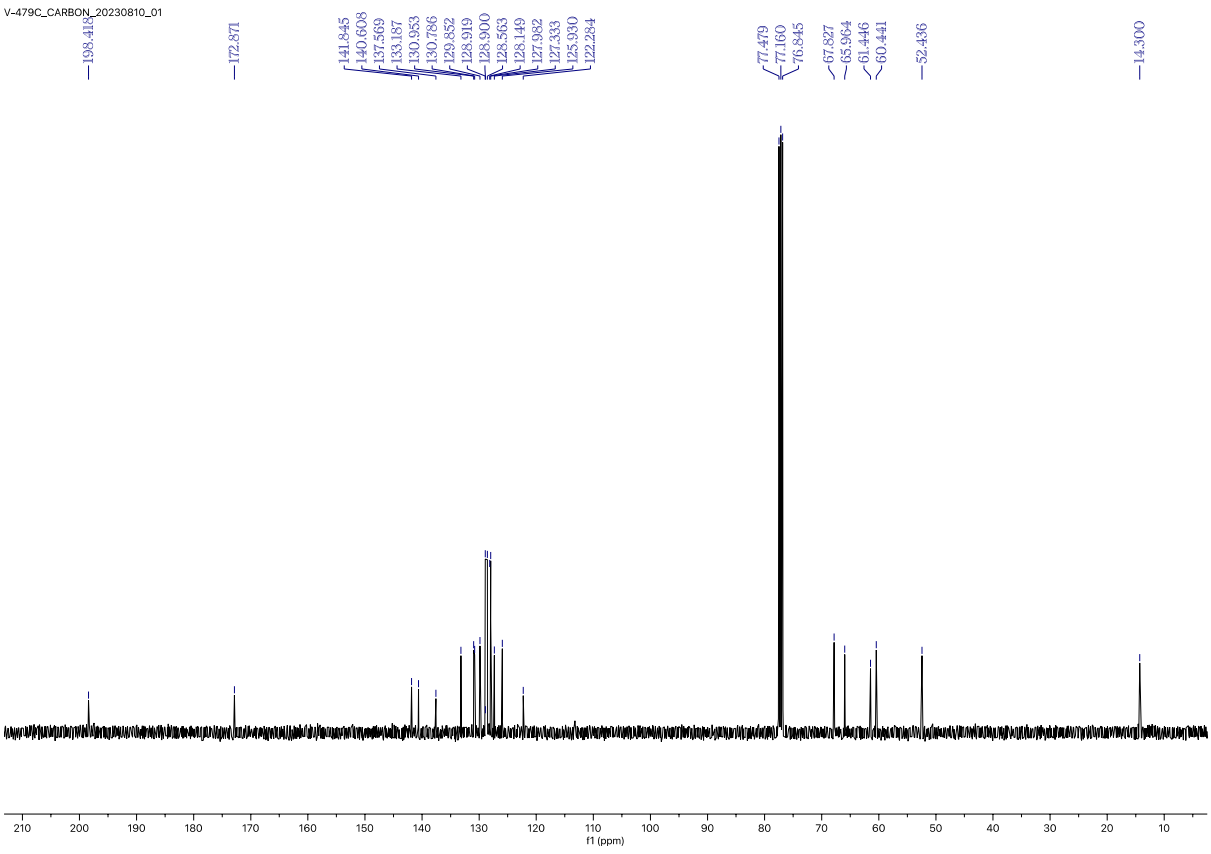

V-479D_CARBON_20230810_01
198.654
173.011
140.783
139.322
137.622
132.910
128.855
128.377
128.274
128.198
128.001
127.781
127.584
127.227
77.479
77.160
76.841
67.922
66.810
61.363
60.850
52.990
14.285
f1 (ppm)

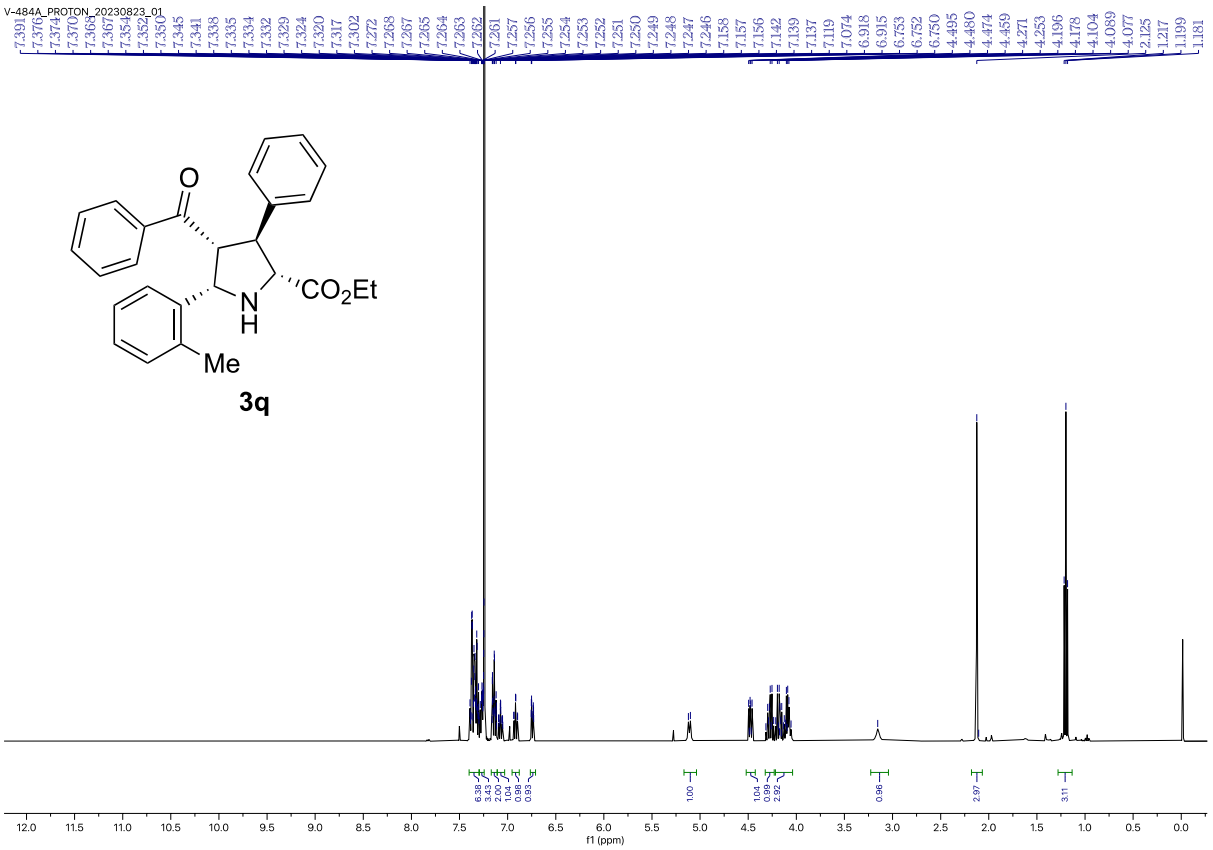

V-479C_PROTON_20230810_01


O
Br
N
H
CO2Et

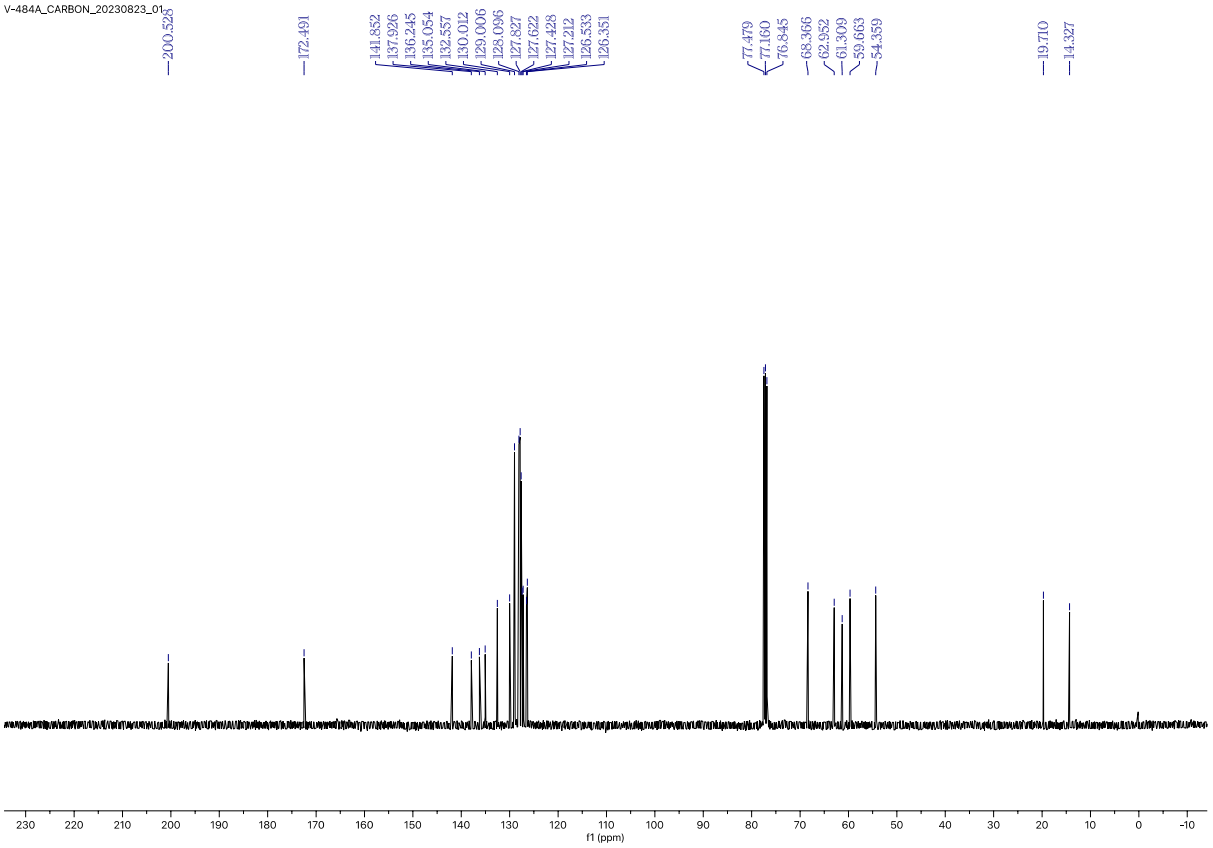
3p

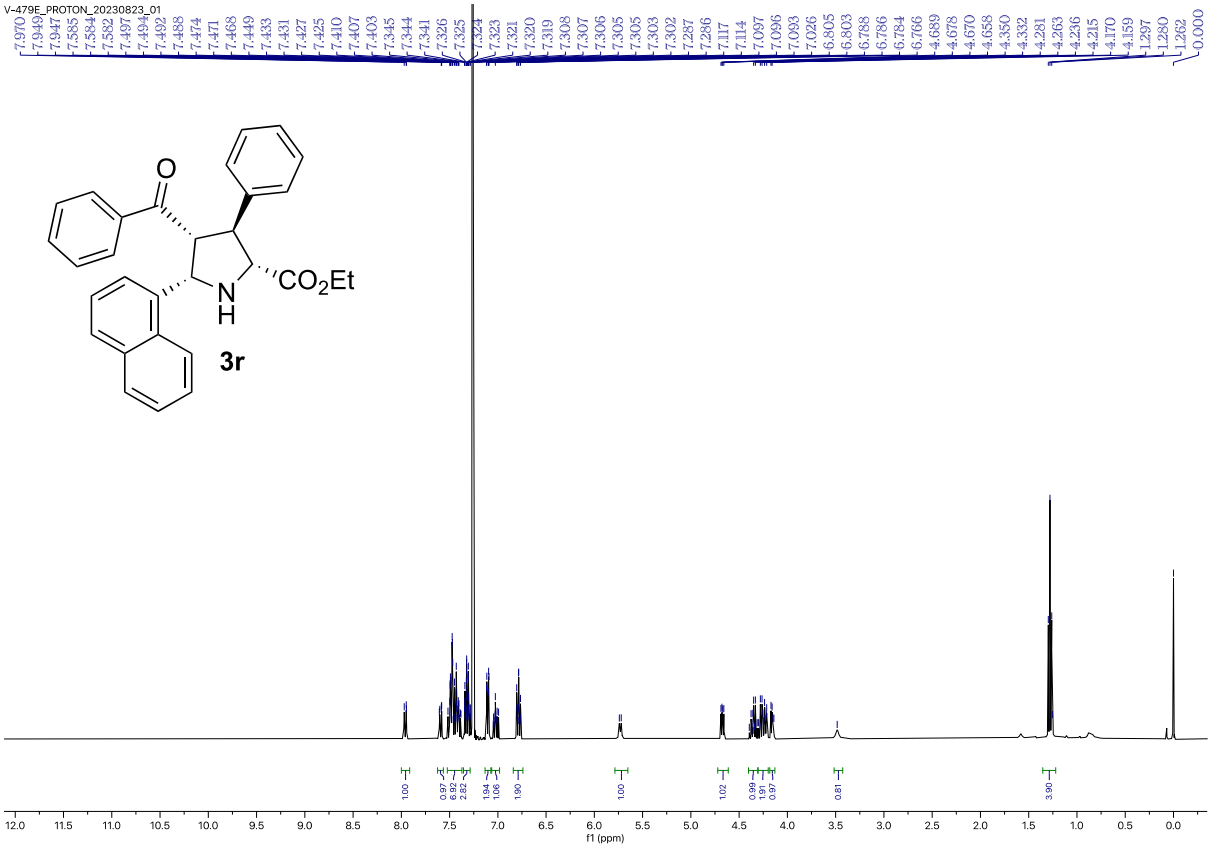

1.83
0.99
5.05
2.58
1.72
0.95
0.92
1.00
1.00
0.98
2.83
0.71
2.81
f1 (ppm)

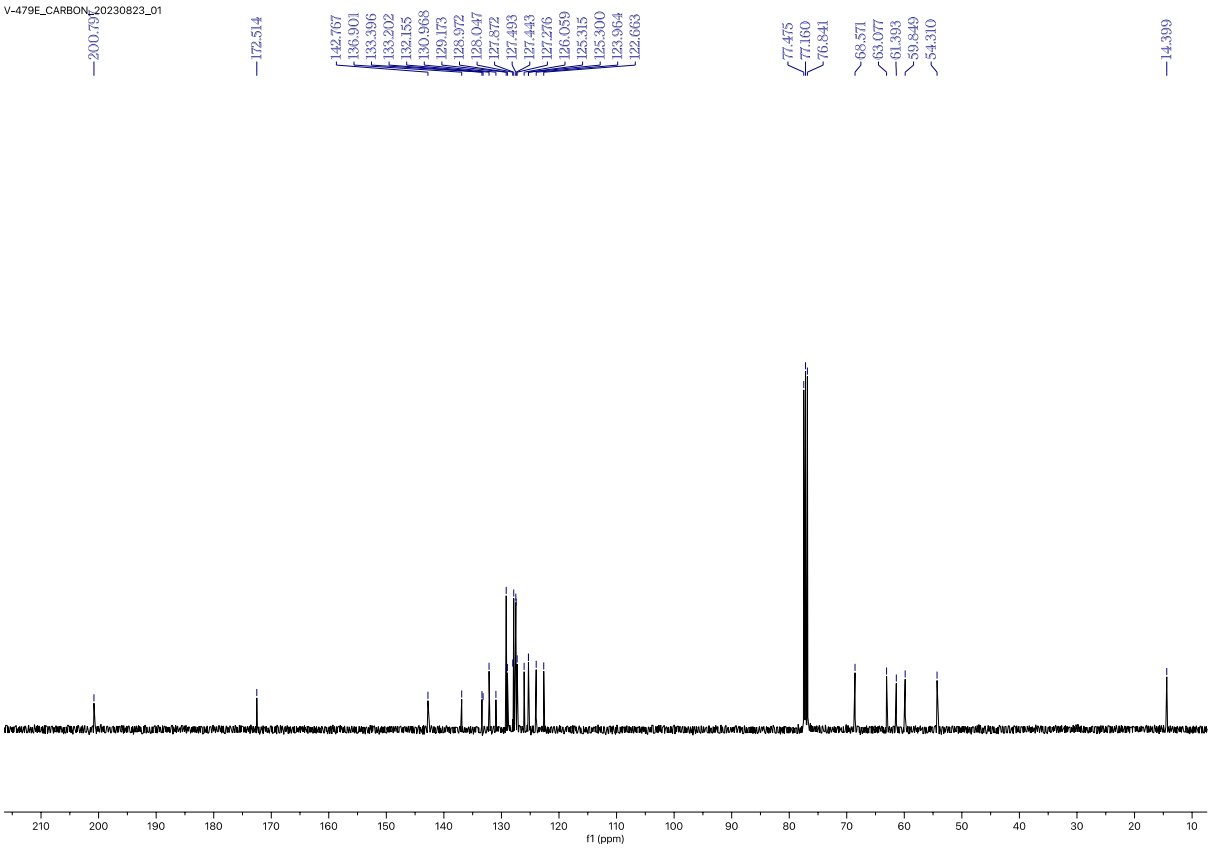

V-479C_CARBON_20230810_01
198.418
172.871
141.845
140.608
137.569
133.187
130.953
130.786
129.852
128.919
128.900
128.563
128.149
127.982
127.333
125.930
122.284
77.479
77.160
76.845
67.827
65.964
61.446
60.441
52.436
14.300
f1 (ppm)

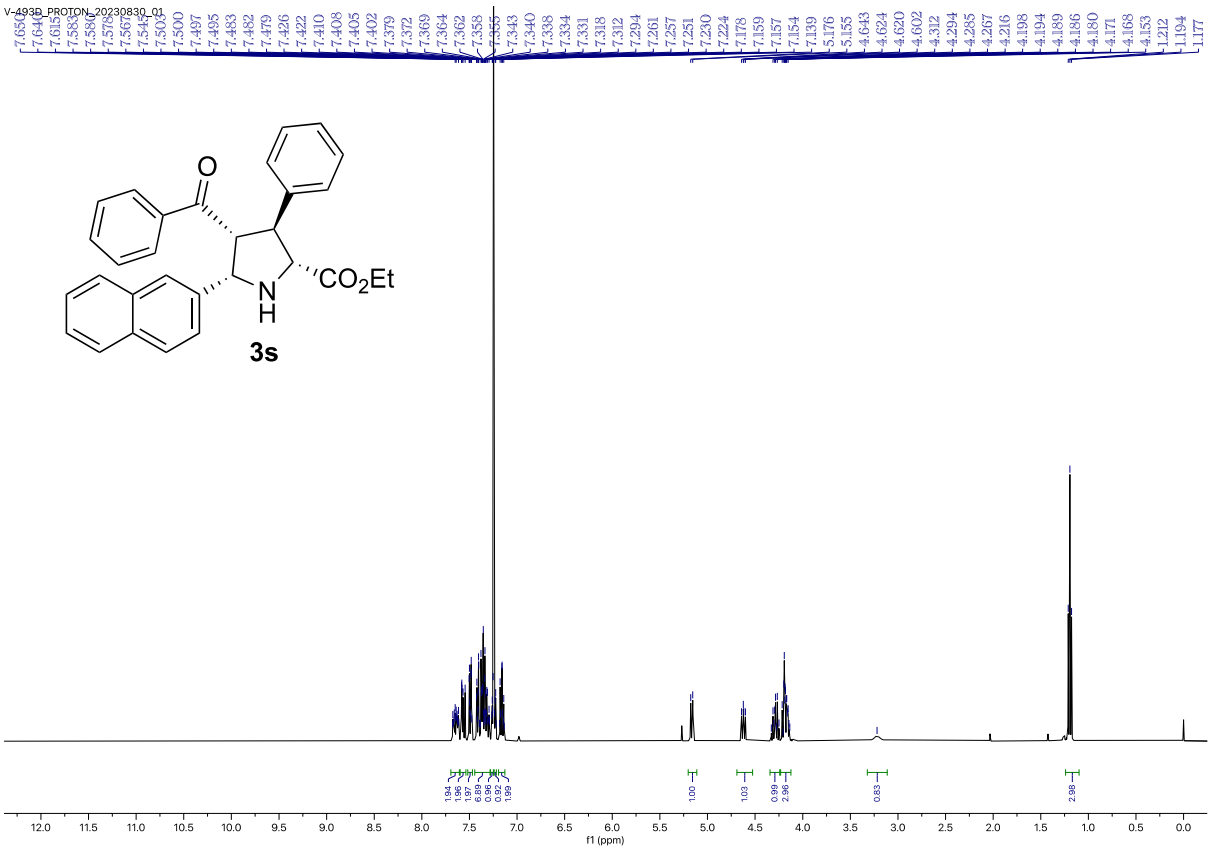

V-484A_PROTON_20230823_01
O
CO2Et
N
H
Me
f1 (ppm)

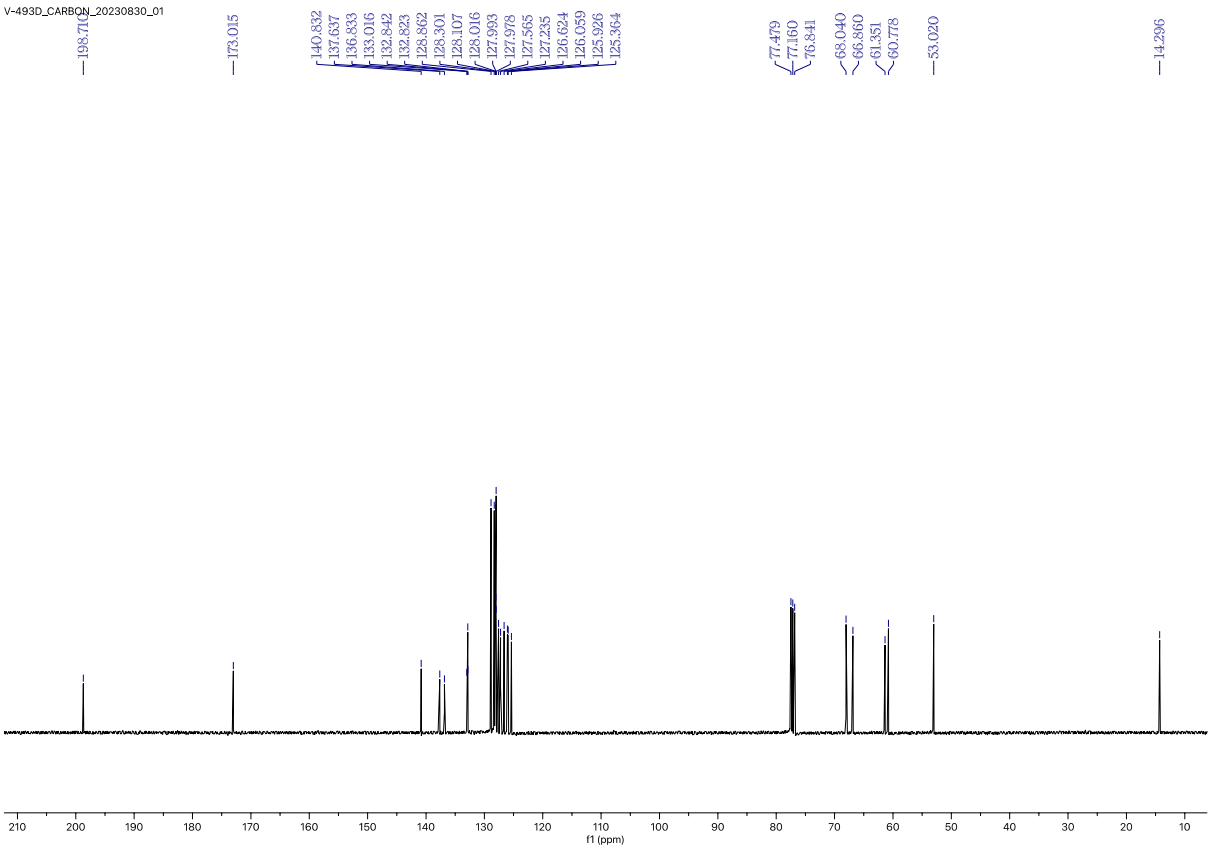
3q

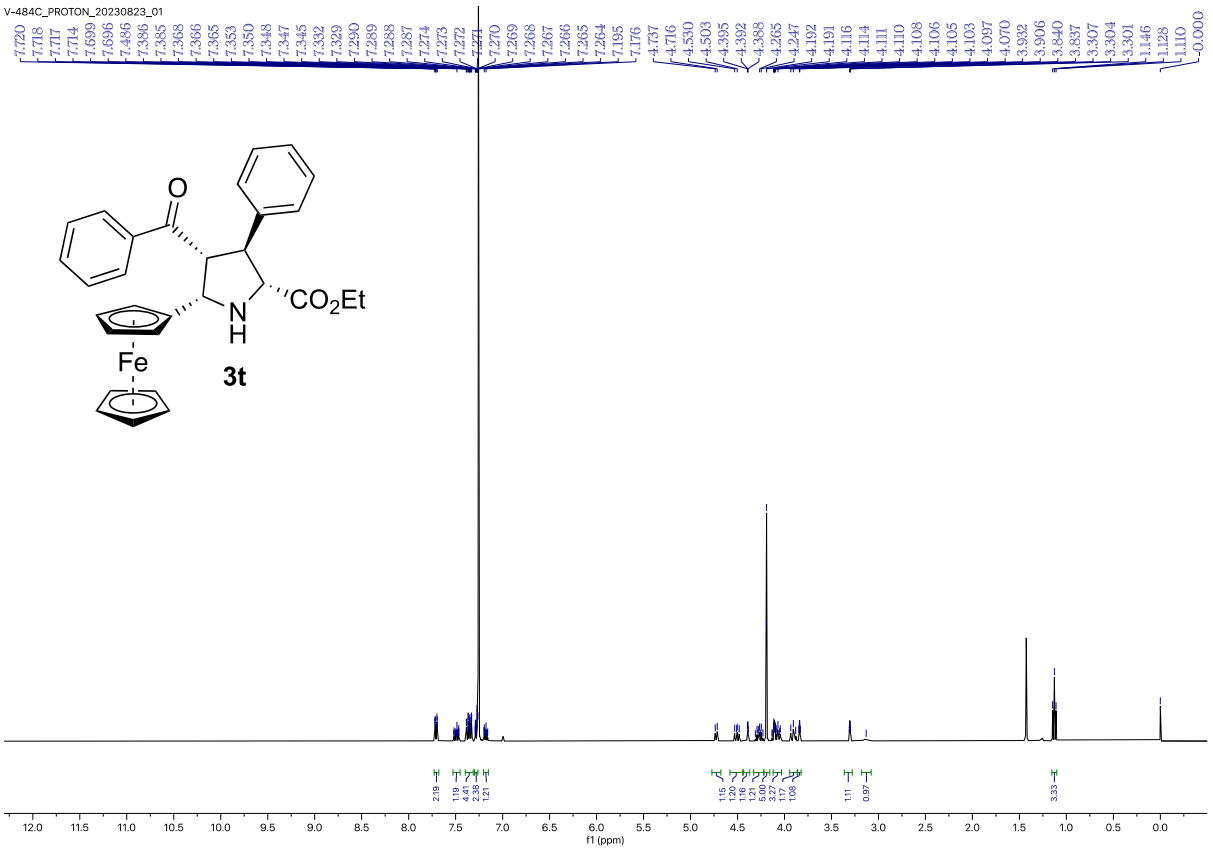

V-484A_CARBON_20230823_01
200.528
172.491
141.852
137.926
136.245
135.054
132.557
130.012
129.006
128.096
127.827
127.622
127.428
127.212
126.533
126.351
77.479
77.160
76.843
68.366
62.952
61.309
59.663
54.359
19.710
14.327
f1 (ppm)

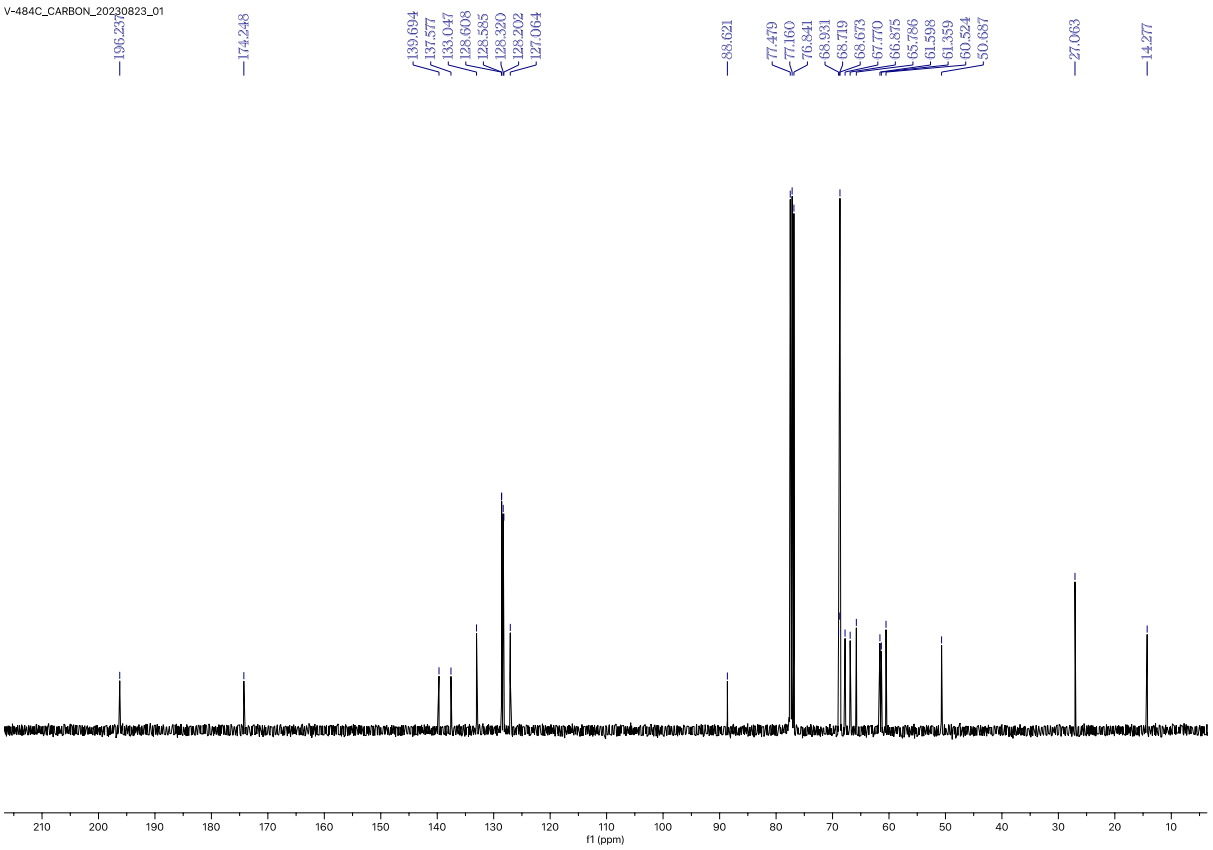

V-479E_PROTON_20230823_01
O
CO2Et
N
H
3r
f1 (ppm)

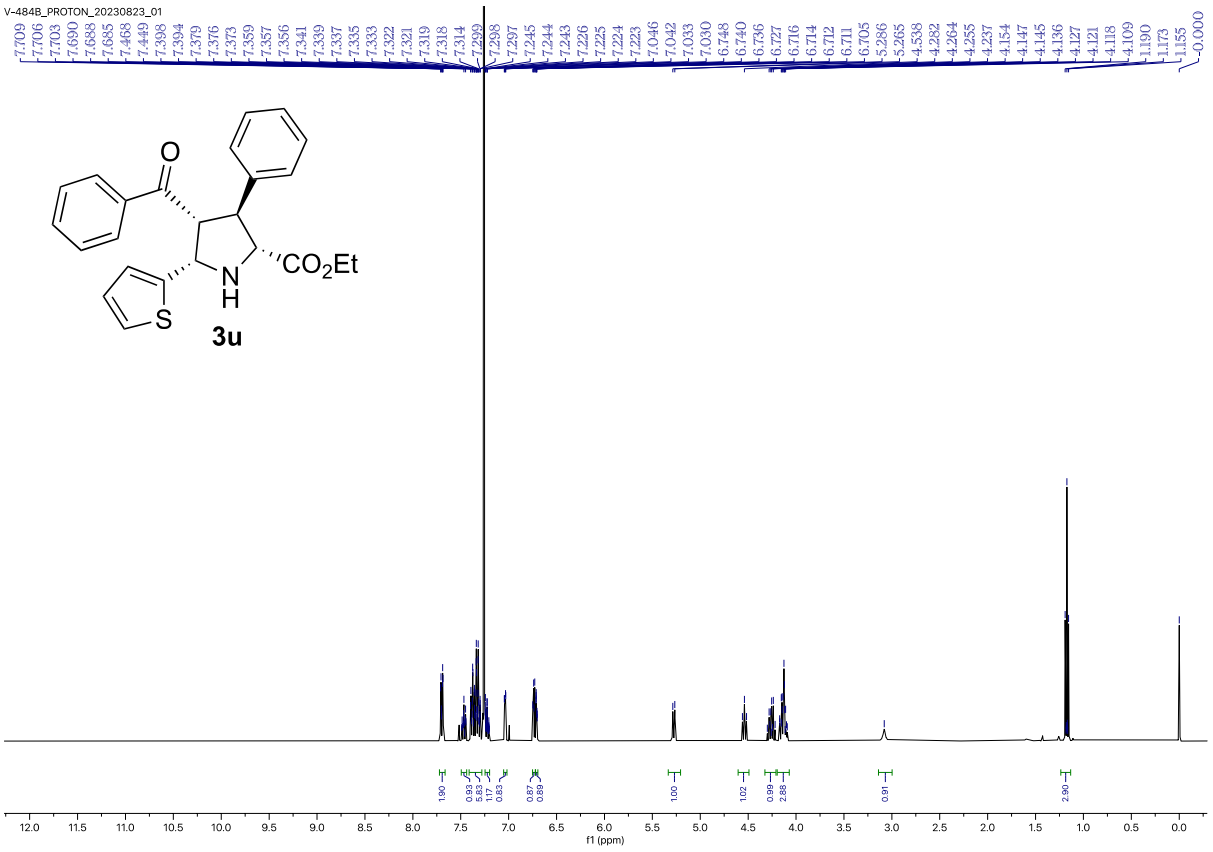

V-479E_CARBON_20230823_01
f1 (ppm)

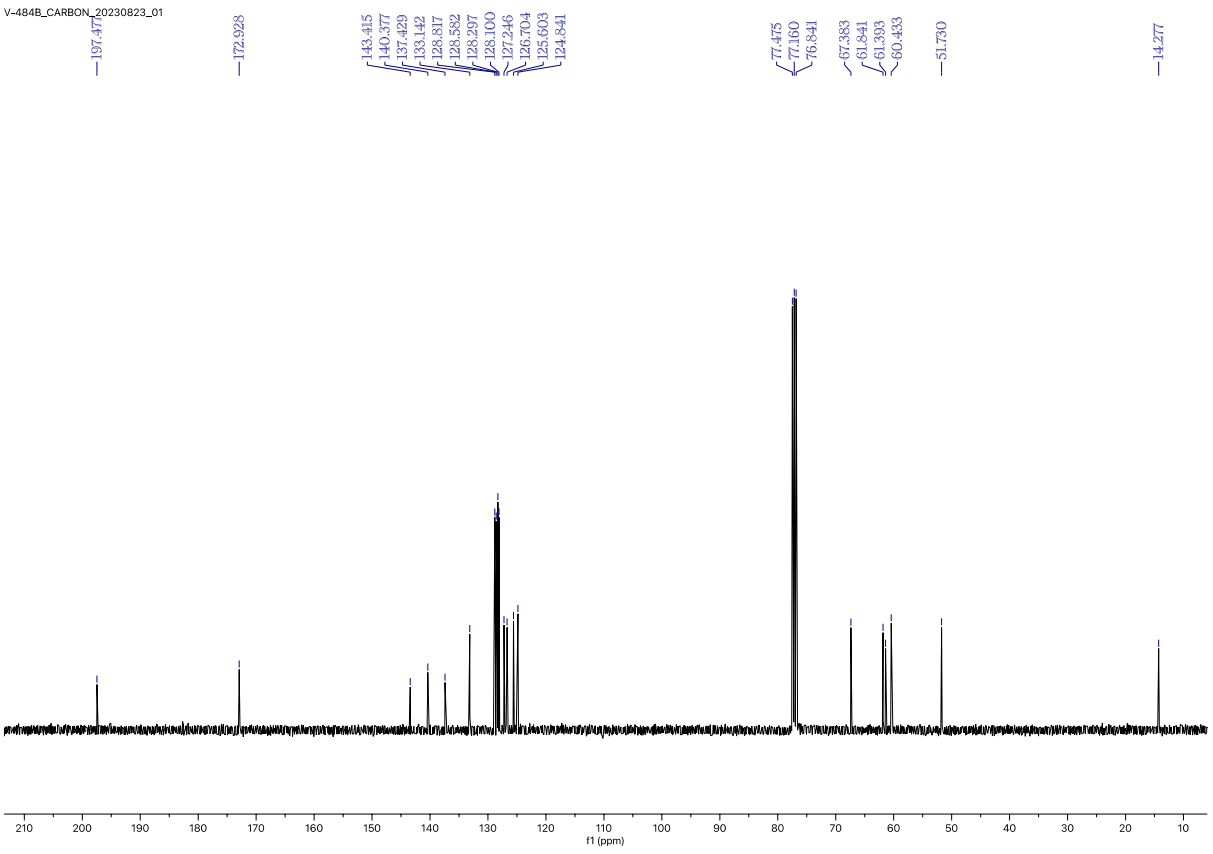

V-493D_PROTON_20230830_01
O
CO2Et
N
H
3s
f1 (ppm)

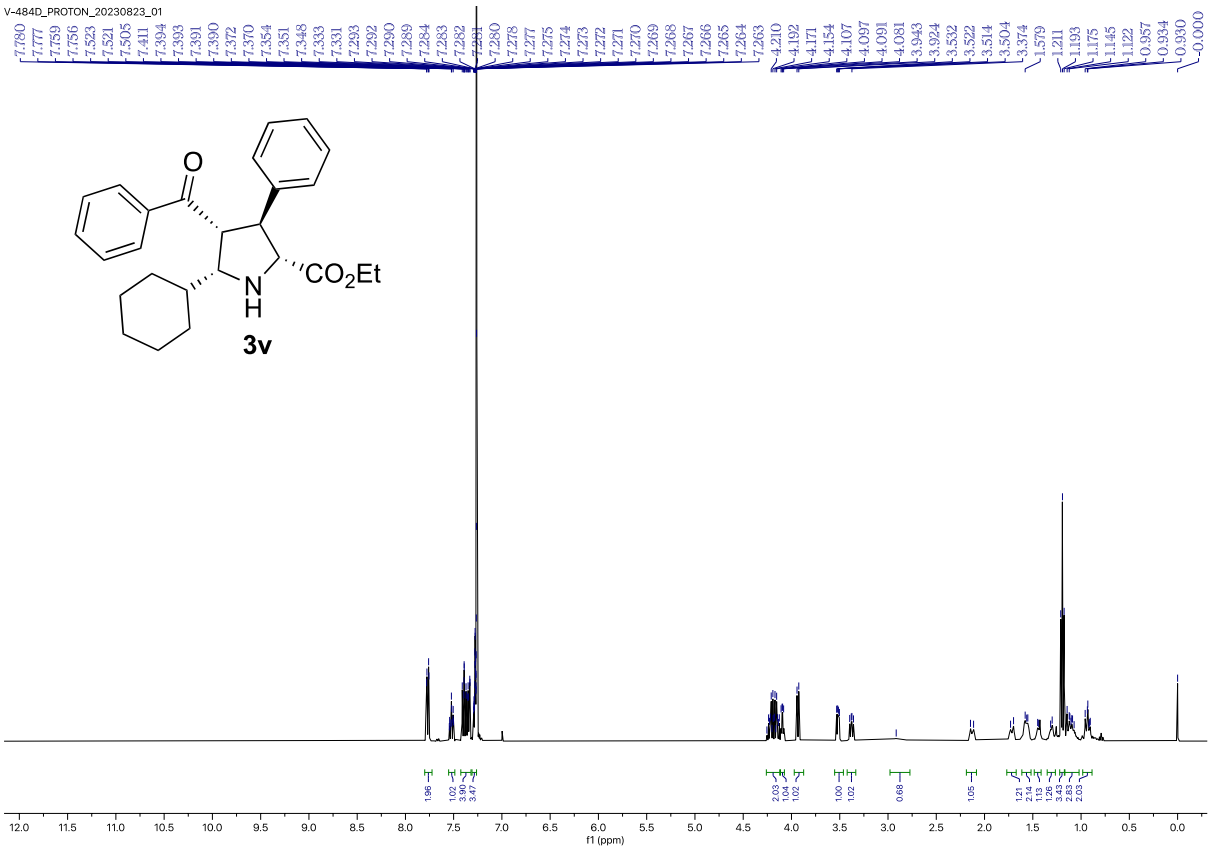

V-493D_CARBON_20230830_01
198.710
173.015
140.832
137.637
136.833
133.016
132.842
132.823
128.862
128.301
128.107
128.016
127.993
127.978
127.565
127.235
126.624
126.059
125.926
125.364
77.479
77.160
76.841
68.040
66.860
61.351
60.778
53.020
14.296
f1 (ppm)

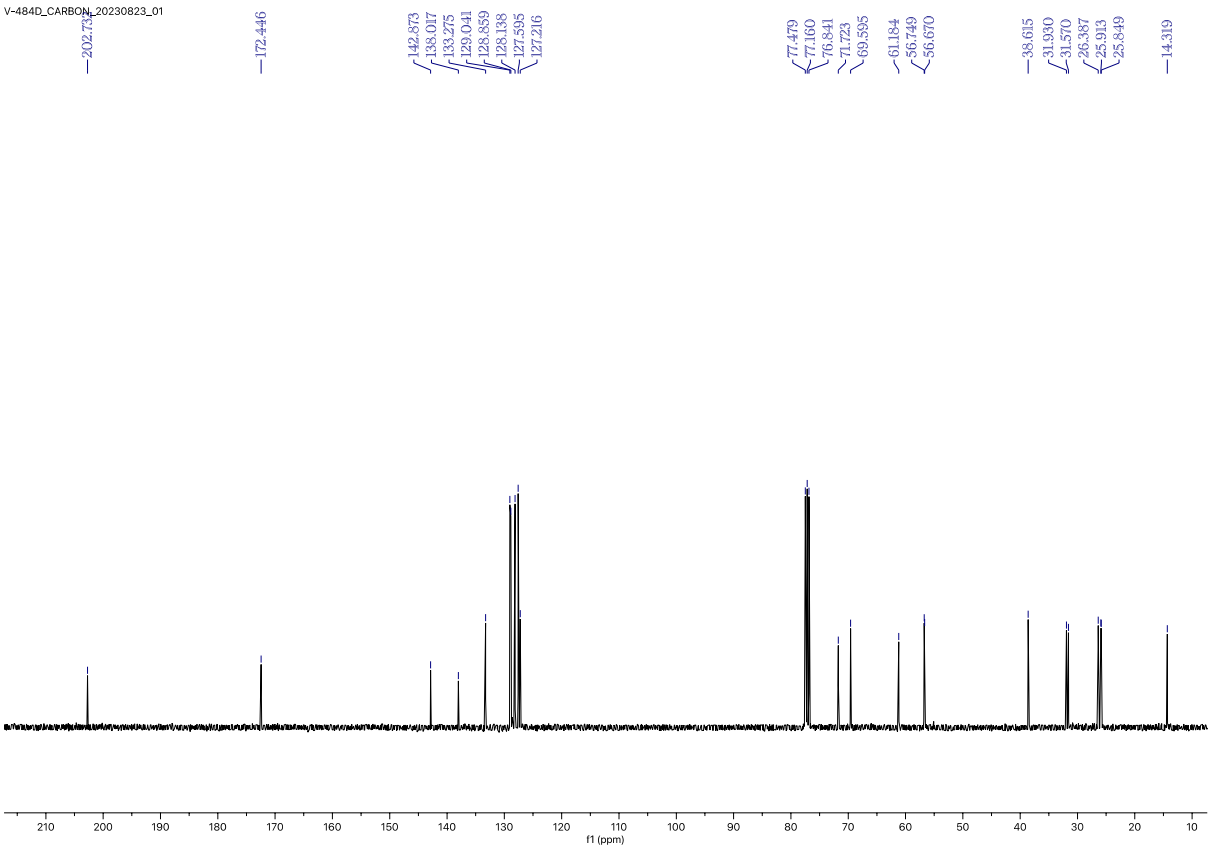

V-484C_PROTON_20230823_01
O
CO2Et
N
H
Fe
3t
f1 (ppm)

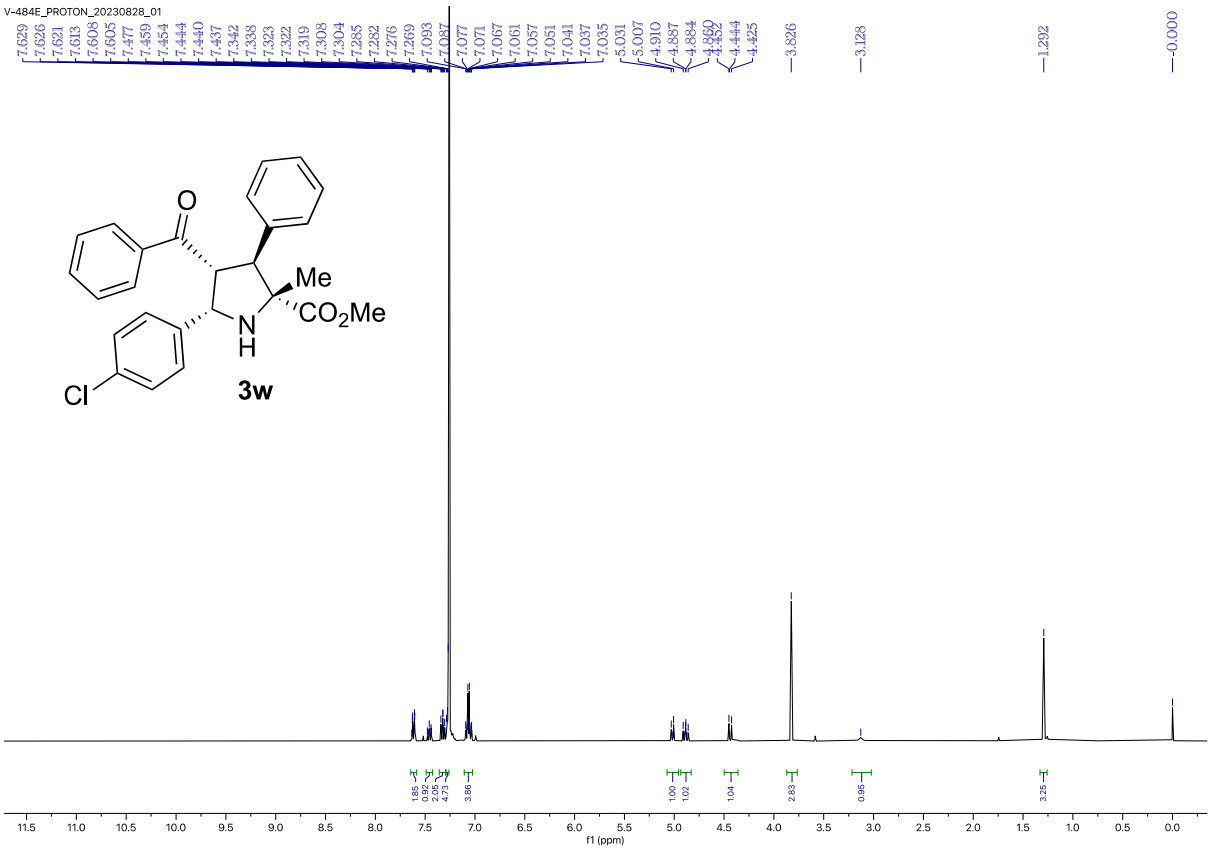

V-484C_CARBON_20230823_01
196.237
174.248
139.694
137.577
133.047
128.608
128.585
128.320
128.202
127.064
88.621
77.479
77.160
76.841
68.931
68.719
68.673
67.770
66.875
65.786
61.598
61.359
60.524
50.687
27.063
14.277
f1 (ppm)

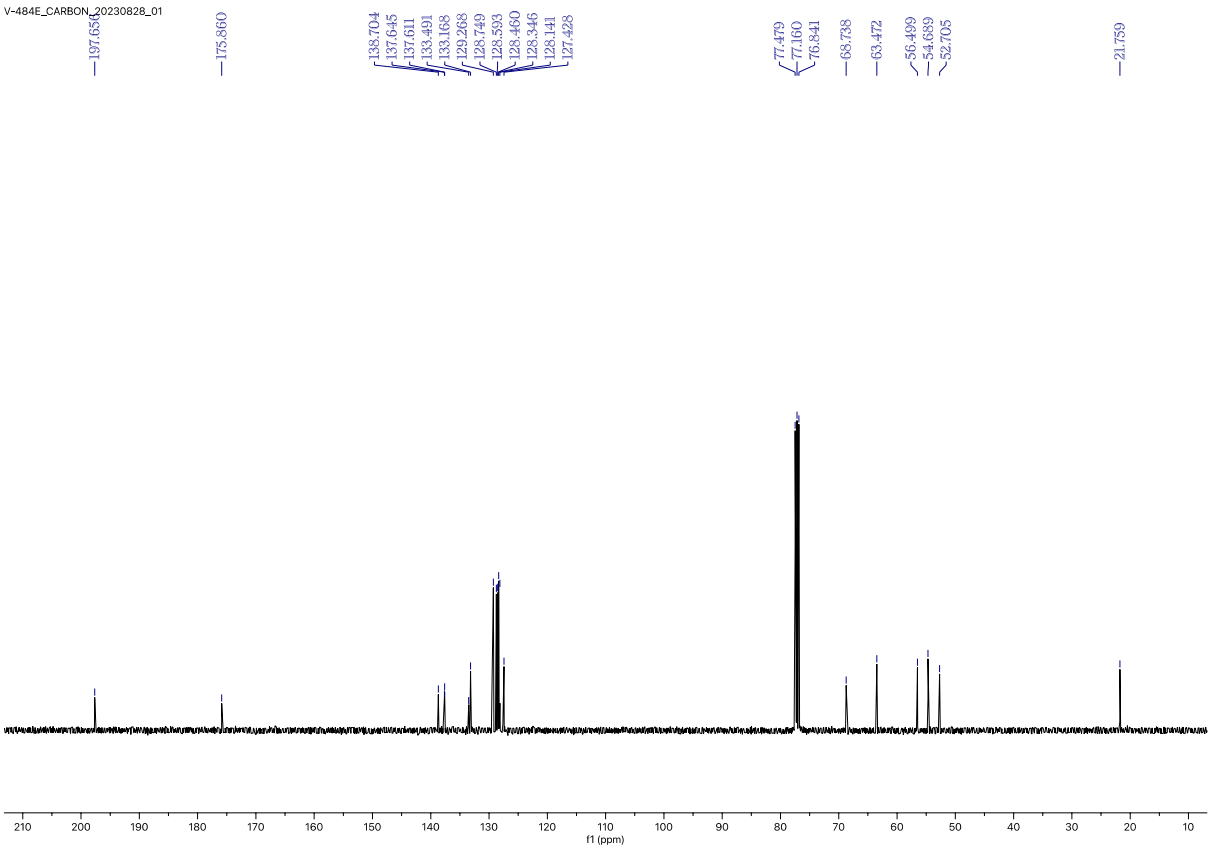

V-484B_PROTON_20230823_01
O
CO2Et
N
H
S
3u
f1 (ppm)

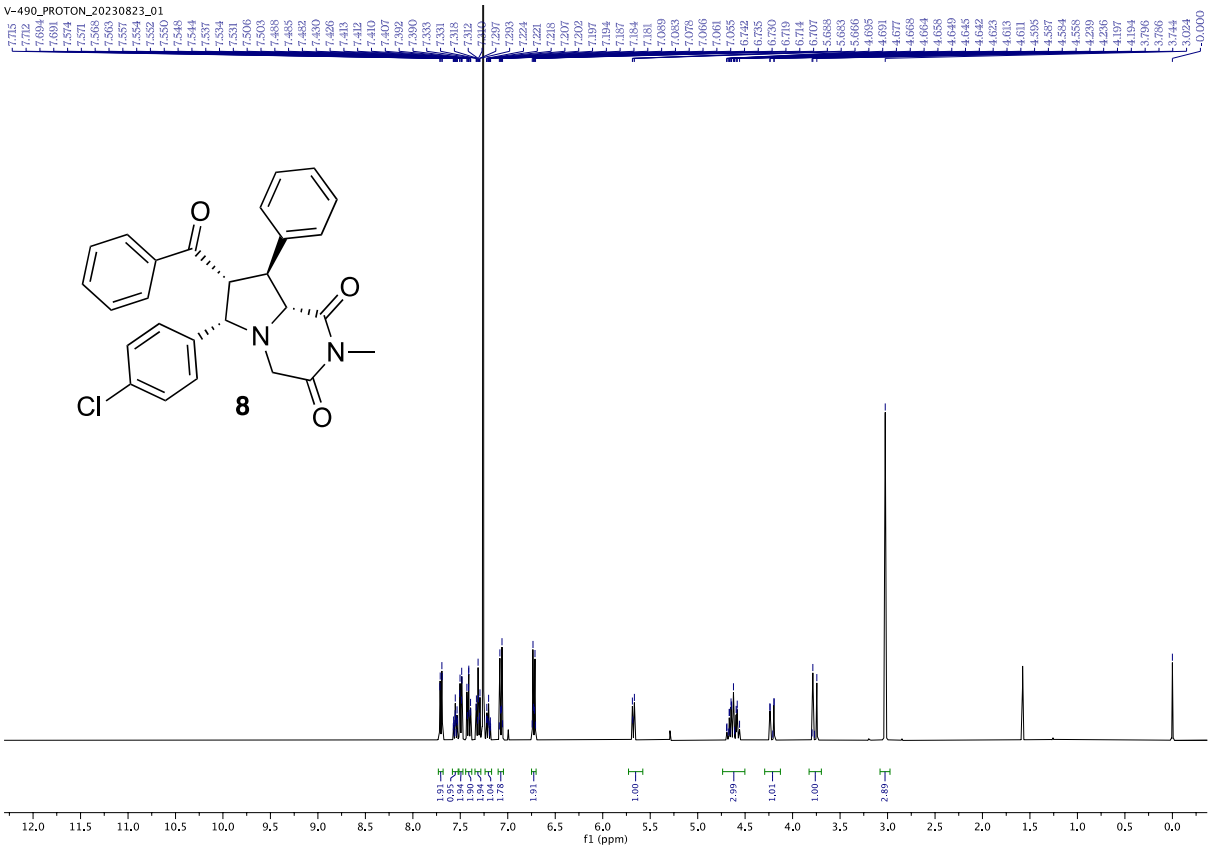

V-484B_CARBON_20230823_01
197.477
172.928
143.415
140.377
137.429
133.142
128.817
128.582
128.297
128.100
127.246
126.704
125.603
124.841
77.475
77.160
76.841
67.383
61.841
61.393
60.433
51.730
14.277
f1 (ppm)

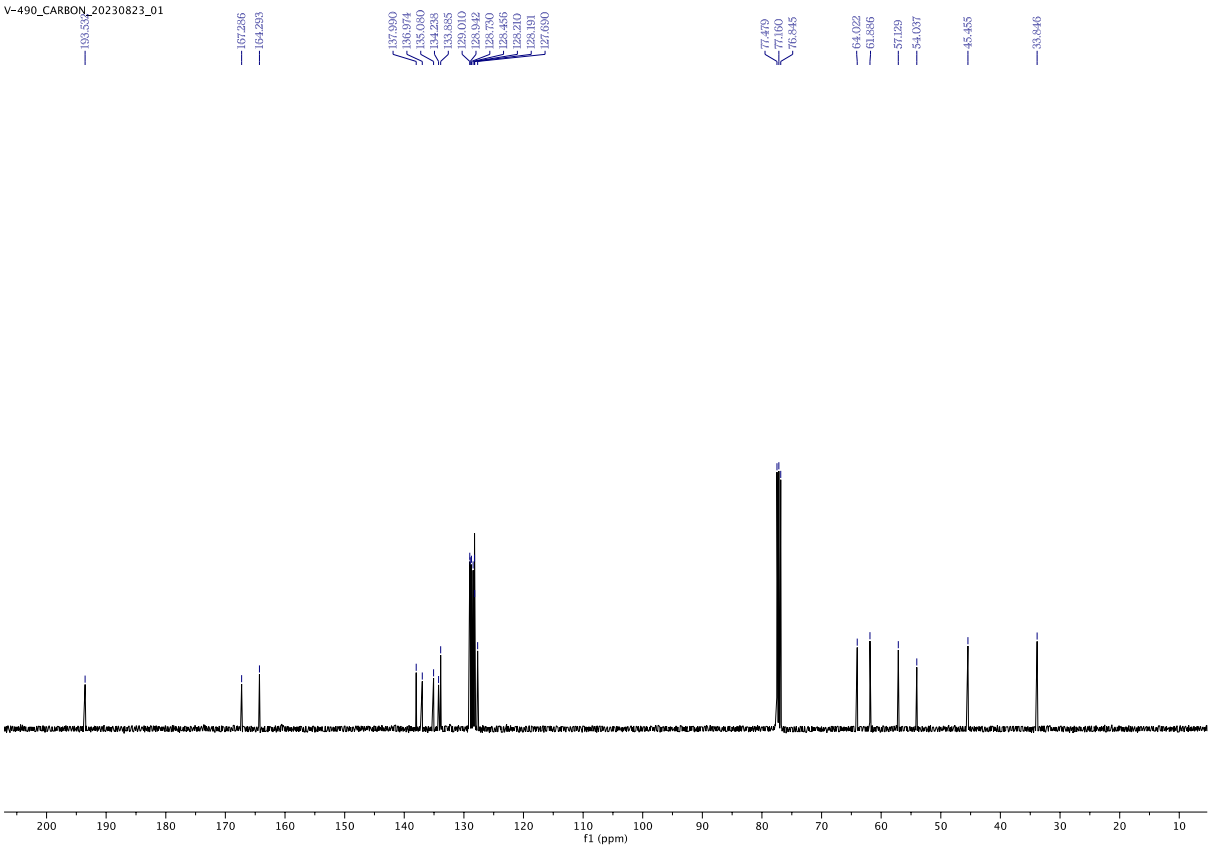

V-484D_PROTON_20230823_01
O
CO2Et
N
H
3v
f1 (ppm)

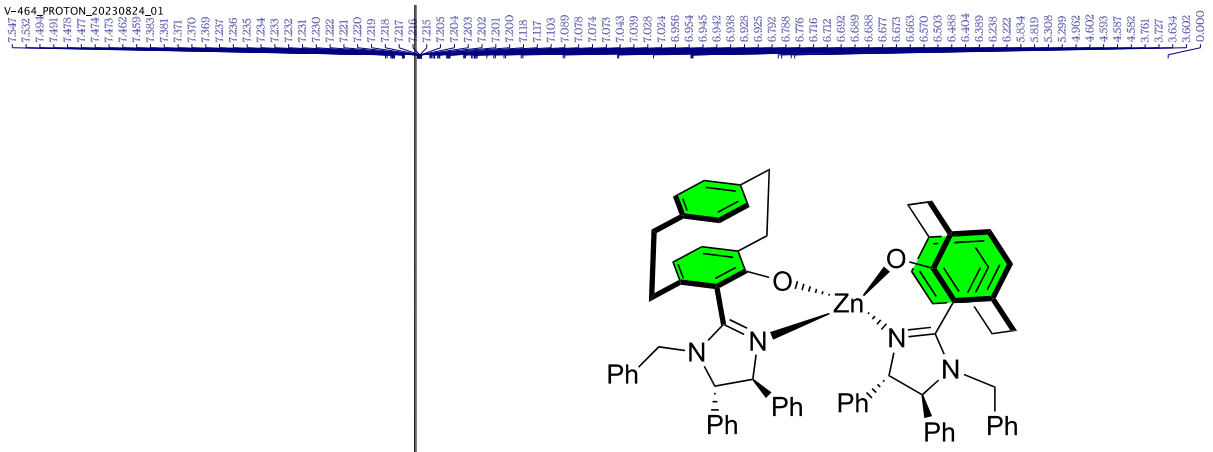

V-484D_CARBON_20230823_01
f1 (ppm)


V-484E_PROTON_20230828_01
7.629
7.626
7.621
7.613
7.608
7.605
7.477
7.459
7.454
7.444
7.440
7.437
7.342
7.338
7.323
7.322
7.319
7.308
7.304
7.285
7.282
7.276
7.269
7.093
7.087
7.077
7.071
7.067
7.061
7.057
7.051
7.041
7.037
7.035
5.031
5.007
4.910
4.887
4.884
4.860
4.444
4.425
3.826
3.128
1.292
0.000
O
Me
CO2Me
N
H
Cl
3w
1.95
0.92
2.05
4.73
3.86
1.00
1.02
1.04
2.83
0.95
3.25
f1 (ppm)


V-484E_CARBON_20230828_01
197.656
175.860
138.704
137.645
137.611
133.491
133.168
129.268
128.749
128.593
128.460
128.346
128.141
127.428
77.479
77.160
76.841
68.738
63.472
56.499
54.689
52.705
21.759
f1 (ppm)

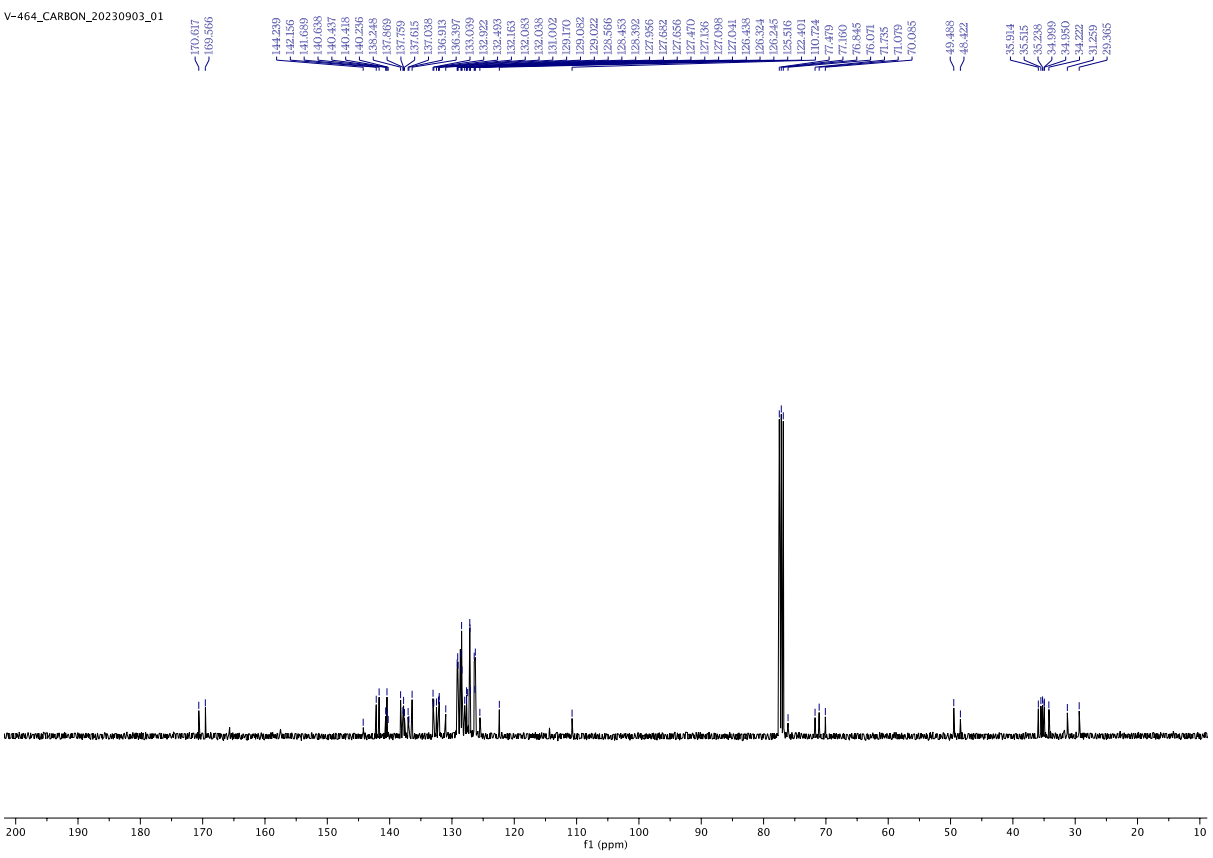

V-490_PROTON_20230823_01
8
f1 (ppm)


V-490_CARBON_20230823_01
f1 (ppm)


O
Zn
O
N
N
N
N
Ph
Ph
Ph
Ph
Ph
Ph

9

V-464_PROTON_20230824_01
f1 (ppm)


V-464_CARBON_20230903_01
f1 (ppm)