Supporting Information

Direct synthesis of *N*-aryl/alkyl *β*-carbonylpyrrole from Morita–Baylis–Hillman acetate of 2,2-dimethoxyacetaldehyde and primary amine

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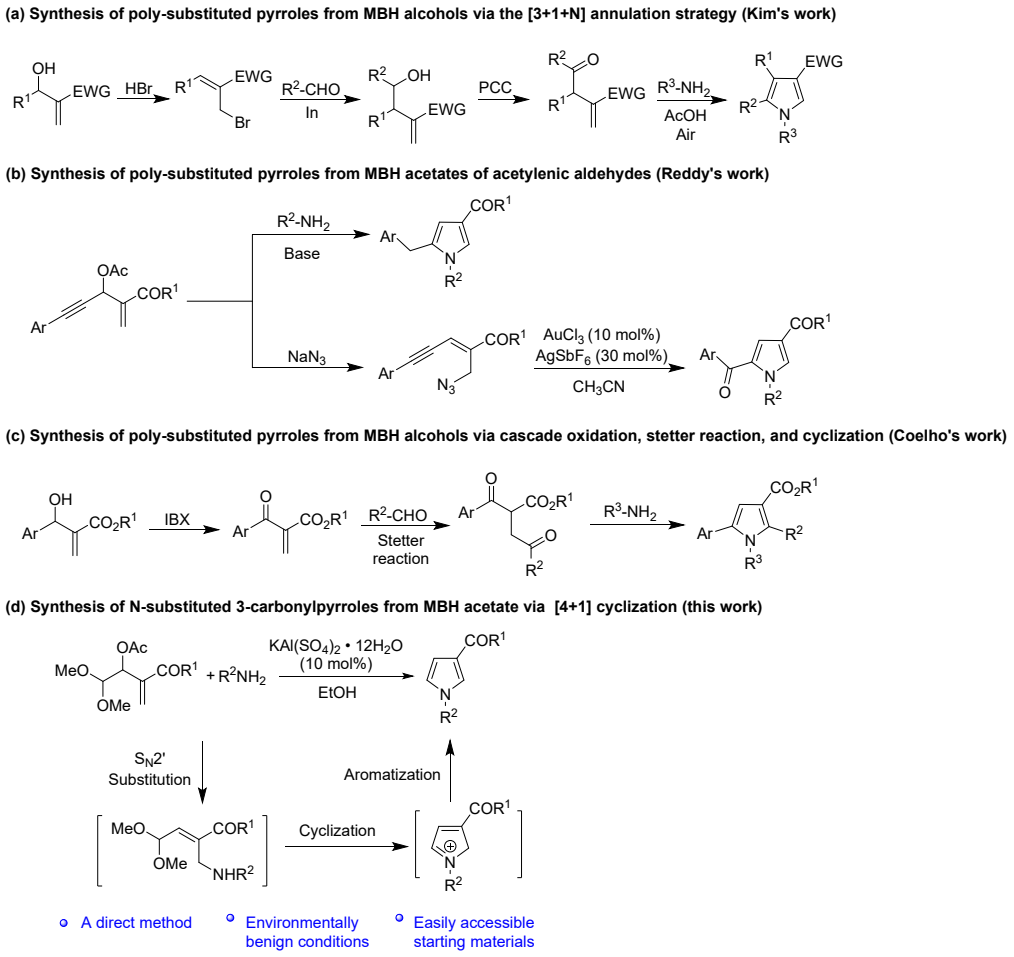
1. General information

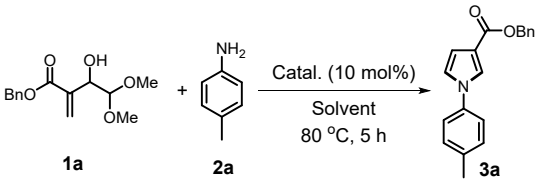
Unless otherwise noted, all reagents were purchased from commercial suppliers and used without further purification. The reactions were monitored by TLC with Haiyang GF-254 silica gel plates (Qingdao Haiyang chemical industry Co. Ltd, Qingdao, China) using UV light or $KMnO_4$ as visualizing agents as needed. Flash column chromatography was performed using 200-300 mesh silica gel at increased pressure. ^1H NMR spectra and ^{13}C NMR spectra were respectively recorded on Brüker AV-400 spectrometers. Chemical shifts (δ) were expressed in ppm relative to Me_4Si in $CDCl_3$ or DMSO-d_6, and coupling constants (J) were reported in Hz. High-resolution mass spectra (HRMS) were obtained on Brüker Compass Data Analysis 4.0. Melting points were determined on a microscopic melting point apparatus and are uncorrected. IR spectra were recorded on a Bruker FT-IR (EQUINOX 55) using KBr pellets or neat liquid technology.

2. Scheme S1 Synthesis of substituted pyrroles from MBH adducts



Scheme S1. Synthesis of substituted pyrroles from MBH adducts

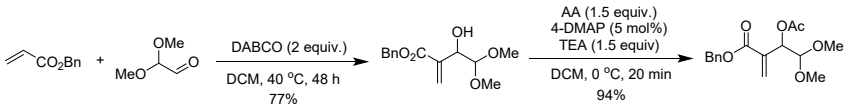
3. Table S1 Condition optimization for the reaction of MBH alcohol and *p*-toluidine



Entry[a]	Catal. (mol%)	Solvent	Yield (%)[b]
1	TFA	1,4-Dioxane	37
2	$BF_3 \cdot Et_2O$	1,4-Dioxane	Trace
3	$NiCl_2$	1,4-Dioxane	N.R.
4	$AlCl_3$	1,4-Dioxane	15
5	$BiCl_3$	1,4-Dioxane	Trace
6	$Sc(OTf)_3$	1,4-Dioxane	20
7	$Bi(OTf)_3$	1,4-Dioxane	73%
8	$Ni(ClO_4)_2 \cdot 6H_2O$	1,4-Dioxane	N.R.
9	$Bi(OTf)_3$	CH_3CN	30
10	$Bi(OTf)_3$	CH_3NO_2	48
11	$Bi(OTf)_3$	Toluene	21
12	$Bi(OTf)_3$	DCE	47
13	$Bi(OTf)_3$	PEG-400	N.R.
14	$Bi(OTf)_3$	DMI	Trace
15[c]	$Bi(OTf)_3$	1,4-Dioxane	36
16[d]	$Bi(OTf)_3$	1,4-Dioxane	78

[a]Reaction conditions: unless otherwise noted, all reactions were performed with **1a** (0.30 mmol), **2a** (0.30 mmol), in solvent (1 mL). [b]Isolated yield. [c]40 °C, 10 h. [d]**1a** (0.36 mmol).

4. General procedure for the synthesis of MBH acetates.



Step I: Preparation of MBH alcohol 1a: benzyl acrylate (2.43 g, 15 mmol) and DABCO (1.68 g, 15 mmol) was mixed with DCM (15 mL) in a 100 mL of round bottomed flask equipped with a magnetic stirring bar. The mixture was stirred at room temperature until dissolution completely. Then the 2,2-dimethoxyacetaldehyde (60 wt. % in H_2O, 1.73 g, 10 mmol) was added. The mixture was stirred at 40 ℃ for 48 h. After completion of reaction, the mixture washed with 0.5 M HCl solution (3 × 15 mL). The organic phase was washed with brine (30 mL) and dried over Na_2SO_4. After removing volatile components, the organic residue was subjected to silica column chromatography for isolation (eluting solution: petroleum ether / ethyl acetate = 10/1 (v/v)) to yield a colourless transparent liquid (MBH alcohol, 2.07 g, 77% yield).

Step II: Preparation of MBH acetates 1b: To a solution of MBH alcohol (2.66 g, 10 mmol) prepared by Step I, Ac_2O (1.5 g, 1.5 equiv.), 4-dimethylaminopyridine (DMAP, 0.06g, 5 mol%), and Et_3N (1.5 g, 1.5 equiv.) in anhydrous dichloromethane (15 mL) were added. The mixture was stirred at 0°C for 20 min. Upon completion of the reaction, the mixture was washed with a saturated solution of $NaHCO_3$ in 20 mL of water. The organic phase was collected and dried over anhydrous sodium sulphate. After filtration and concentration, the organic residue was subjected to silica column chromatography (eluting solution: petroleum ether / ethyl acetate = 20/1 (v/v)) and the MBH acetate was obtained as a yellow liquid.

Tests for different MBH acetates were all performed with an analogous procedure.

5. General procedure for the reaction of MBH acetates and primary amine

In a 10 mL of V-type flask equipped with a triangle magnetic stirring bar, MBH acetate **1a** (0.3 mmol, 79.8 mg) and *p*-toluidine (0.3 mmol, 32.1 mg) were dissolved in EtOH (1 mL), then $KAl(SO_4)_2{\cdot}6H_2O$ (10 mol%, 0.03 mmol, 21.9 mg) was added. The mixture was stirred at 80 ℃ for 5 h. After the reaction was completed, the mixture was cooled to room temperature, and directly subjected to preparative TLC plate for isolation (eluting solution: petroleum ether / ethyl acetate = 20/1 (v/v)). The 3-carbonylpyrrole 3a was obtained as a yellow liquid (78.6 mg, yield = 90%). Tests for substrate scope were all performed with an analogous procedure.

6. The procedure for preparation of 4a

Benzyl 1-(3-hydroxyphenyl)-1*H*-pyrrole-3-carboxylate (58.8 mg, 0.2 mmol) and KOH (3 equiv. 58 mg) were added in EtOH (5 mL) in a 25 mL of round bottomed flask equipped with a magnetic stirring bar. The mixture was then stirred at 80 °C for 6 h. After completion of reaction (TLC), the mixture was naturalized with HCl solution to pH = 4. The organic phase was washed with brine (5 mL) and dried over Na_2SO_4. After removing organic phase, the crude product was dissolved in anhydrous THF (2 ml). Then the oxalyl chloride (3 equiv.) and one drop of DMF were added. The mixture was stirring at 0 °C for 20 min following by evaporation on a rotary evaporator. Subsequently the residue was dissolved in anhydrous THF (2 ml) and NH_3 (*aq,* 1 ml) was added at

room temperature. After completion of reaction, the mixture was extracted by ethyl acetate, dried over anhydrous Na_2SO_4, and concentrated on a rotary evaporator. Finally, the residual was subjected to preparative TLC plate for isolation (eluting solution: $CHCl_3$ / MeOH = 95/5 (v/v)). The product 4a was obtained as a yellow solid (33.1 mg, 82% yield).

7. The procedure for preparation of JMC-2004

The compound 3ak (93.9 mg, 0.3 mmol) was dissolved in anhydrous DCM (2 ml) in a 5 mL of round bottomed flask equipped with a magnetic stirring bar at 0 ℃. Then BBr_3 (5.0 equiv.) was added slowly at 0 ℃. Subsequently, the mixture was stirred at room temperature for 12 h. After completion of addition, the mixture was directly subjected to preparative TLC plate for isolation (eluting solution: PE / EA = 5/1 (v/v)). The product JMH-2004 was obtained as a colorless liquid (78.0 mg, 87% yield).

8. The procedure for preparation of 5a

In a 10 mL of V-type flask equipped with a magnetic stirring bar, 3ai (0.3 mmol, 68.7 mg) and 2,5-dimethoxy-2,5-dihydrofuran (0.3 mmol, 39.6 mg) were dissolved in EtOH (1 mL). Then the TfOH (0.06 mmol, 9.0 mg) was added to the mixture. The mixture was stirring for 5 h under fluxing condition. After the reaction was completed, the mixture was cooled to room temperature and the mixture was directly subjected to preparative TLC plate for isolation (eluting solution: petroleum ether / ethyl acetate = 10/1 (v/v)). The product 5a was obtained as a colorless liquid (67.8 mg, 81% yield).

9. The procedure for scaled-up preparation of 3ah

In a 100 mL of round-bottom flask equipped with a magnetic stirring, MBH acetate of 2,2-dimethoxylacetaldehyde and ethyl acrylate (10 mmol, 2.46 g), aniline (10 mmol, 0.93 g) were dissolved in EtOH (20 mL). Then the $KAl(SO_4)_2{\cdot}12H_2O$ (1 mmol, 0.47 g) was added. The mixture was stirred at 80 ℃ for 5 h. After the reaction was completed, the catalyst was recovered by filtration and the filtrate was concentrated by rotary evaporation. The residual was subjected to silica gel column chromatography for isolation (eluting solution: petroleum ether / ethyl acetate = 50/1 (v/v)). 1.76 gram of 3ah was obtained (yield = 82%).

It is noted that although 88% (w/w) catalyst can be recovered, the catalytic activity of recovered catalyst significantly decreased, which might be resulted from the changes of surface chemical composition and crystalline structure (**Figure S1**).

a. XPS surface element analysis

Quantify By: Components

Component	BE [eV]	FWHM [eV]	RSF	Atomic conc. [%]	Error [%]	Mass conc. [%]	Error [%]
S 2p	169.11	0.00	0.67	11.3	0.28	19.6	0.44
C 1s	285.06	0.00	0.28	31.4	0.51	20.4	0.36
K 2p	293.11	0.00	1.47	6.7	0.14	14.2	0.27
O 1s	532.16	0.00	0.78	46.8	0.60	40.4	0.57
Al 2p	75.61	0.00	0.19	3.7	0.20	5.4	0.28

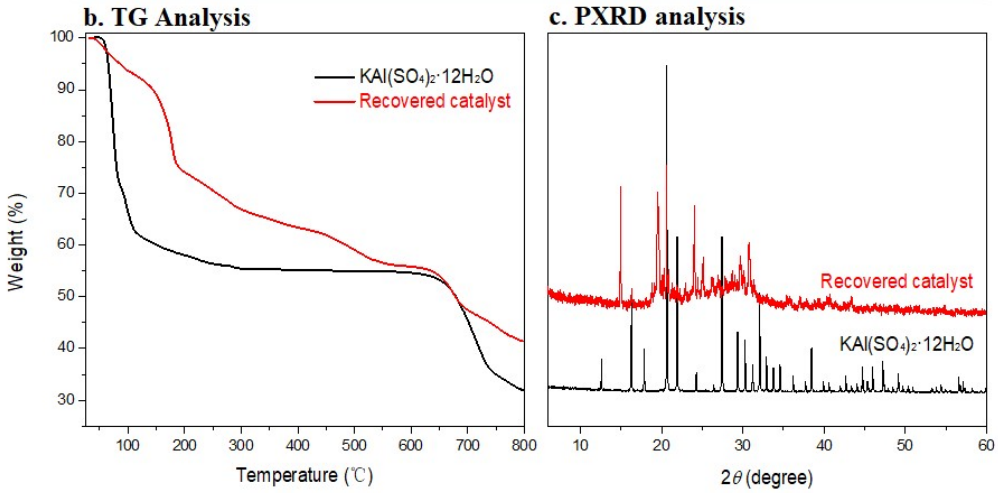
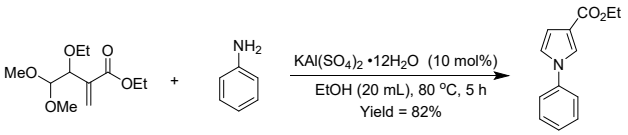


Figure S1 Characterizations of recovered catalyst

10. Scheme S2 E-factor and Eco-Scale value calculation

(a) *E*-factor and Eco-Scale value calculation based on the scaled-up process for our method



1c (10 mmol, 2.32g) 10 mmol, 0.93 g 3ah (1.76 g)

Reactant 1	1c	2.46 g	10 mmol	FW = 232.28
Reactant 2	aniline	0.93 g	10 mmol	FW = 93.13
Catalyst	$KAl(SO_4)_2{\cdot}12H_2O$	0.47 g	1 mmol	FW = 474.39
Solvent	EtOH (20 mL)	15.7 g		
Product	3ah	1.76 g		
Recovered solvent (18 mL)		14.3 g		

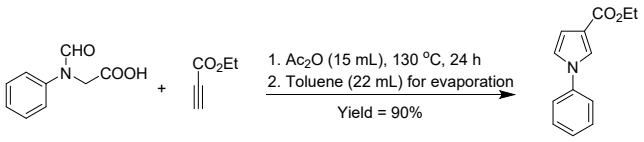
***E*-factor** = $\frac{2.46 + 0.93 + 0.47 + 15.7 - 14.3}{1.76}$ = **2.99 Kg waste/1 Kg product**

The penalty points to calculate the EcoScale

Parameter		Penalty points
1. Yield	(100 - %yield)/2	9
2. Price of reaction components (to obtain 10 mmol of end product)		
a.1c =3.00 g = $5.38 (synthetic cost) b. aniline = 1.13 g = $0.12 c. $KAl(SO_4)_2{\cdot}12H_2O$ = 0.57 g = $0.12 d. EtOH = 25 mL = $3.15		
	Total price = 8.77 Thus, inexpensive (< $10)	0
3. Safety solvent: EtOH		
Toxic (T)		5
Highly flammable (F)		5
4. Technical setup		
Common setup		0
5. Temperature/time		
Heating, > 1 h		3
6. Workup and purification		
Removal of solvent with bp < 150 °C		0
Classical chromatography		10
	Total penalty points	32

EcoScale = 100 - 32 = 68 (an acceptable synthesis)
EcoScale: > 75, excellent; > 50, acceptable; < 50, inadequate

(b) *E*-factor and Eco-Scale value calculation for the patented method (Eur. Pat. Appl., EP 771790 A1, 1997)



15 mmol, 2.69 g 55.8 mmol, 5.47 g 2.89 g

Reactant 1	*N*-formyl-*N*-phenylglycine	2.69g	15 mmol	FW = 179.18
Reactant 2	Ethyl propiolate	5.47 g	55.8 mmol	FW =98.10
Solvent 1	Acetic anhydride (15 mL)	16.1 g		
Solvent 2	Toluene (22 mL)	19.2 g		
Product		2.89 g		

***E*-factor** = $\frac{\mathbf{2.69 + 5.47 + 16.1 + 19.2}}{\mathbf{2.89}}$ **= 15.04 Kg waste/1 Kg product**

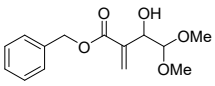
The penalty points to calculate the EcoScale

Parameter		Penalty points
1. Yield	(100 - %yield)/2	5
2. Price of reaction components (to obtain 10 mmol of end product)		
a. *N*-formyl-*N*-phenylglycine = 2.00 g = $5.07 (synthetic cost) b. Ethyl propiolate = 4.05 g = $14.3 c. Ac_2O = 11 mL = $1.2 d. Toluene = 16 mL = $0.55		
	Total price = $21.12 Tus, expensive (> $10 and < $50)	3
3. Safety		
solvent: Ac_2O and Toluene		
Toxic (T)		5
Highly flammable (F)		5
4. Technical setup		
Common setup		0
5. Temperature/time		
Heating, > 1 h		3
6. Workup and purification		
Removal of solvent with bp < 150 °C		0
Classical chromatography		10
	Total penalty points	31

EcoScale = 100 - 31 = 69 (an acceptable synthesis)
EcoScale: > 75, excellent; > 50, acceptable; < 50, inadequate

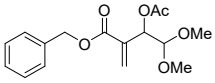
11. Characterization data of products

Benzyl 3-hydroxy-4,4-dimethoxy-2-methylenebutanoate (1a)



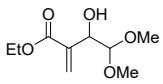
The crude mixture was purified by silica column chromatography (petroleum ether to petroleum ether/ehyl acetate = 10/1 v/v gradient elution) to yield the title compound as a colorless liquid with 77% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41 – 7.28 (m, 5H), 6.41 – 6.36 (m, 1H), 5.98 (s, 1H), 5.23 (d, J = 1.3 Hz, 2H), 4.58 (d, J = 4.6 Hz, 1H), 4.42 (d, J = 5.0 Hz, 1H), 3.41 (s, 3H), 3.36 (s, 3H), 2.92 (d, J = 5.3 Hz, 1H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) δ 166.1, 138.7, 135.8, 128.6, 128.3, 128.2, 127.3, 105.6, 71.0, 66.6, 55.5, 55.0 ppm. IR: v = 3475, 3033, 2942, 2835, 1718, 1631, 1499, 1455, 1381, 1271, 1157, 1125, 1078, 972, 818, 752, 699, 701, 492 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{14}H_{18}O_5$, [M + Na]$^+$: 289.1046, found: 289.1046.

Benzyl 3-acetoxy-4,4-dimethoxy-2-methylenebutanoate (1b)



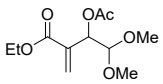
The crude mixture was purified by silica column chromatography (petroleum ether to petroleum ether/ehyl acetate = 20/1 v/v gradient elution) to yield the title compound as a colorless liquid with 94% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43 – 7.29 (m, 5H), 6.41 (d, J = 1.0 Hz,1H), 5.92 (t, J = 1.0 Hz, 1H), 5.81 (dd, J = 5.8, 1.0 Hz, 1H), 5.26 – 5.17 (m, 2H), 4.58 (d, J = 5.8 Hz, 1H), 3.35 (d, J = 16.4 Hz, 6H), 2.10 (s, 3H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) δ 169.5, 165.1, 136.7, 135.8, 128.5, 128.3, 128.2, 128.1, 104.0, 70.5, 66.7, 55.5, 54.2, 21.0 ppm. IR: v = 3034, 2943, 2836, 1745, 1634, 1455, 1373, 1264, 1235, 1156, 1037, 979, 815, 752, 699, 604 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{16}H_{20}O_6$, [M + Na]$^+$: 331.1152, found: 331.1152.

Ethyl 3-hydroxy-4,4-dimethoxy-2-methylenebutanoate



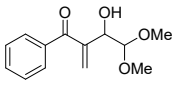
The crude mixture was purified by silica column chromatography (petroleum ether to petroleum ether/ehyl acetate = 10/1 v/v gradient elution) to yield the title compound as a colorless liquid with 72% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.34 (d, J = 1.2 Hz, 1H), 5.95 (t, J = 1.3 Hz, 1H), 4.55 (d, J = 4.5 Hz, 1H), 4.45 (d, J = 5.0 Hz, 1H), 4.25 (q, J = 7.2 Hz, 2H), 3.43 (d, J = 11.6 Hz, 6H), 2.91 (d, J = 5.4 Hz, 1H), 1.32 (t, J = 7.1 Hz, 3H) ppm. ^{13}C {^{1}H} NMR (100 MHz, $CDCl_3$) δ 166.3, 138.7, 126.8, 105.5, 71.2, 60.9, 55.4, 55.1, 14.2 ppm. IR: v = 3472, 2940, 2836, 1717, 1631, 1449, 1372, 1327, 1178, 1155, 1626, 977, 886, 816, 697 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_9H_{16}O_5$, [M + Na]$^+$: 227.0890, found: 227.0890.

3-Benzoyl-1,1-dimethoxybut-3-en-2-yl acetate (1c)



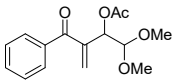
The crude mixture was purified by silica column chromatography (petroleum ether to petroleum ether/ehyl acetate = 20/1 v/v gradient elution) to yield the title compound as a colorless liquid with 91% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.40 − 6.33 (m, 1H), 5.93 − 5.87 (m, 1H), 5.84 − 5.76 (m, 1H), 4.71 − 4.41 (m, 1H), 4.26 (dt, J = 7.5, 3.6 Hz, 2H), 3.55 – 3.05 (m, 6H), 2.24 – 1.92 (m, 3H), 1.44 − 1.21 (m, 3H) ppm. ^{13}C {^{1}H} NMR (100 MHz, $CDCl_3$) δ 164.7, 160.4, 132.1, 122.8, 99.2, 65.7, 56.1, 50.6, 49.5, 16.1, 9.3 ppm. IR: v = 2947, 2840, 1719, 1632, 1450, 1372, 1329, 1183, 1155, 1146, 1044, 979, 887, 820, 688 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{11}H_{18}O_6$, [M + Na]$^+$: 269.0996, found: 269.0996.

3-Hydroxy-4,4-dimethoxy-2-methylene-1-phenylbutan-1-one



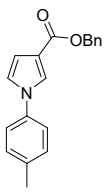
The crude mixture was purified by silica column chromatography (petroleum ether to petroleum ether/ehyl acetate = 10/1 v/v gradient elution) to yield the title compound as a colorless liquid with 63% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.91 – 7.74 (m, 2H), 7.62 – 7.51 (m, 1H), 7.45 (t, *J* = 7.6 Hz, 2H), 6.13 (s, 1H), 5.71 (s, 1H), 4.78 (d, *J* = 5.3 Hz, 1H), 4.44 (d, *J* = 5.3 Hz, 1H), 3.43 (s, 3H), 3.36 (s, 3H), 3.26 – 3.20 (m, 1H) ppm.^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 197.8, 145.8, 137.3, 132.7, 129.8, 128.3, 125.8, 105.8, 71.9, 55.4, 54.7 ppm. IR: *v* =3480, 2943, 1708, 1653, 1624, 1500, 1372, 1340, 1184, 1105, 1142, 1042, 1006, 979, 961, 887, 820, 688 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{13}H_{16}O_4$, $[M + Na]^+$: 259.0941, found: 259.0940.

3-Benzoyl-1,1-dimethoxybut-3-en-2-yl acetate



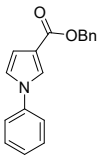
The crude mixture was purified by silica column chromatography (petroleum ether to petroleum ether/ehyl acetate = 20/1 v/v gradient elution) to yield the title compound as a colorless liquid with 90% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.83 – 7.75 (m, 2H), 7.55 (d, *J* = 2.3 Hz,1H), 7.49 – 7.40 (m, 2H), 6.07 – 6.01 (m, 1H), 5.99 (d, *J* = 5.6 Hz, 1H), 5.72 (d, *J* = 2.5 Hz, 1H), 4.59 (dd, *J* = 5.6, 2.4 Hz, 1H), 3.37 (dd, *J* = 6.2, 2.4 Hz, 6H), 2.16 (d, *J* = 2.6 Hz, 3H).^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) δ 195.7, 169.6, 143.8, 137.3, 132.6, 129.7, 128.3, 125.8, 104.1, 71.3, 55.60, 54.1, 21.0 ppm. IR: *v* =2933, 1710, 1651, 1643, 1504, 1370, 1345, 1191, 1107, 1176, 1003, 979, 964, 890, 827, 690 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{15}H_{18}O_5$, $[M + Na]^+$: 301.1046, found: 301.1046.

Benzyl 1-(p-tolyl)-1*H*-pyrrole-3-carboxylate (3a)



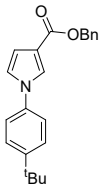
The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 20/1 v/v as the eluent) to yield the title compound as a yellow liquid with 90% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.68 (t, *J* = 2.0 Hz, 1H), 7.46 – 7.42 (m, 2H), 7.38 (t, *J* = 7.2 Hz, 2H), 7.33 (d, *J* = 7.0 Hz, 1H), 7.28 (d, *J* = 8.5 Hz, 2H), 7.24 (d, *J* = 8.3 Hz, 2H), 6.99 (s, 1H), 6.78 (dd, *J* = 3.0, 1.6 Hz, 1H), 5.31 (s, 2H), 2.39 (s, 3H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) δ 164.5, 137.5, 136.8, 136.7, 130.3, 128.5, 128.1, 128.0, 124.7, 121.0, 120.7, 117.5, 111.50, 65.6, 20.9 ppm. IR: *v* = 3133, 3030, 2952, 1780, 1602, 1543, 1511, 1455, 1430, 1403, 1360, 1258, 1222, 1131, 1080, 981, 906, 756, 692, 598, 550, 508 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{19}H_{17}NO_2$, $[M + Na]^+$: 314.1151, found: 314.1152.

Benzyl 1-phenyl-1*H*-pyrrole-3-carboxylate (3b)



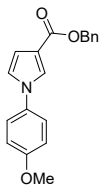
The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 20/1 v/v as the eluent) to yield the title compound as a yellow liquid with 90% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.72 (d, *J* = 2.0 Hz, 1H), 7.50 – 7.28 (m, 10H), 7.02 (s, 1H), 6.83 – 6.75 (m, 1H), 5.31 (s, 2H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) δ 164.5, 139.9, 136.7, 129.8, 128.5, 128.1, 128.0, 126.9, 124.6, 121.0, 120.7, 117.8, 111.7, 65.7 ppm. IR: *v* = 3138, 3033, 2952, 1780, 1600, 1543, 1509, 1456, 1403, 1361, 1258, 1220, 1132, 1079, 980, 908, 756, 693, 593, 548, 512 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{18}H_{15}NO_2$, $[M + H]^+$: 278.1176, found: 278.1175.

Benzyl 1-(4-(tert-butyl)phenyl)-1H-pyrrole-3-carboxylate (3c)



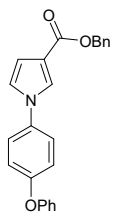
The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 20/1 v/v as the eluent) to yield the title compound as a yellow liquid with 92% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.69 (s, 1H), 7.45 (dd, *J* = 8.0, 5.8 Hz, 4H), 7.37 (s, 2H), 7.31 (d, *J* = 8.7 Hz, 3H), 6.99 (s, 1H), 6.78 (d, *J* = 1.3 Hz, 1H), 5.31 (s, 2H), 1.34 (s, 9H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) δ 164.6, 150.1, 137.4, 136.7, 128.5, 128.1, 128.0, 126.6, 124.7, 120.7, 117.5, 111.5, 65.6, 34.6, 31.3 ppm. IR: *v* = 3609, 3545, 3395, 2961, 2868, 1705, 1541, 1522, 1457, 1362, 1258, 1211, 1138, 1005, 937, 368, 756, 697, 564, 457 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{22}H_{23}NO_2$, $[M + H]^+$: 334.1802, found: 334.1801.

Benzyl 1-(4-methoxyphenyl)-1*H*-pyrrole-3-carboxylate (3d)



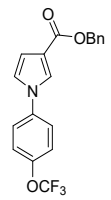
The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 20/1 v/v as the eluent) to yield the title compound as a yellow liquid with 87% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.62 (t, *J* = 1.9 Hz, 1H), 7.49 – 7.42 (m, 2H), 7.38 (t, *J* = 7.2 Hz, 2H), 7.35 – 7.28 (m, 3H), 7.02 – 6.90 (m, 3H), 6.77 (dd, *J* = 3.0, 1.7 Hz, 1H), 5.31 (s, 2H), 3.84 (s, 3H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) δ 164.6, 158.5, 136.7, 133.4, 128.5, 128.1, 128.0, 124.9, 122.6, 121.0, 117.3, 114.8, 111.4, 65.6, 55.6 ppm. IR: *v* = 3136, 2918, 1707, 1540, 1519, 1457, 1400, 1252, 1218, 1132, 1045, 980, 829, 757, 697, 619 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{19}H_{13}NO_3$, $[M + H]^+$: 330.1101, found: 330.1101.

Benzyl 1-(4-phenoxyphenyl)-1*H*-pyrrole-3-carboxylate(3e)



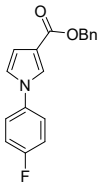
The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 20/1 v/v as the eluent) to yield the title compound as a yellow liquid with 85% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.65 (t, *J* = 2.0 Hz, 1H), 7.47 – 7.33 (m, 2H), 7.37 – 7.28 (m, 7H), 7.14 (t, *J* = 7.4 Hz, 1H), 7.11 – 7.00 (m, 4H), 6.96 (t, *J* = 2.6 Hz, 1H), 6.78 (dd, *J* = 3.0, 1.7 Hz, 1H), 5.31 (s, 2H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) δ 164.5, 156.8, 156.3, 136.7, 135.3, 130.0, 128.5, 128.1, 128.0, 124.8, 123.8, 122.7, 120.9, 119.7, 119.1, 117.7, 111.6, 65.6 ppm. IR: *v* = 3136, 3034, 2919, 1709, 1542, 1514, 1489, 1401, 1362, 1239, 1133, 1077, 981, 869, 840, 755, 695, 593, 497 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{24}H_{19}NO_3$, $[M + H]^+$: 370.1438, found: 370.1438.

Benzyl 1-(4-(trifluoromethoxy)phenyl)-1*H*-pyrrole-3-carboxylate (3f)



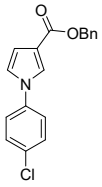
The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 20/1 v/v as the eluent) to yield the title compound as a yellow liquid with 72% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.68 (t, *J* = 2.0 Hz, 1H), 7.46 – 7.35 (m, 6H), 7.35 – 7.28 (m, 3H), 6.99 (t, *J* = 2.7 Hz, 1H), 6.81 (dd, *J* = 3.1, 1.6 Hz, 1H), 5.31 (s, 2H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) δ 164.3, 147.6, 138.4, 136.5, 128.6, 128.1, 128.1, 124.6, 124.2 (q, $^1J_{C\text{-}F}$ = 185.0 Hz), 122.4, 122.3, 120.7, 118.4, 112.2, 65.8 ppm. ^{19}F NMR (376 MHz, $CDCl_3$) δ -58.05 (s, 3F) ppm. IR: *v* = 3132, 3033, 2917, 2849, 1703, 1544, 1519, 1455, 1401, 1362, 1255, 1209, 1167, 1137, 1079, 982, 937, 846, 763, 698, 622, 524 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{19}H_{14}F_3NO_3$, $[M + H]^+$: 362.0999, found: 362.0998.

Benzyl 1-(4-fluorophenyl)-1*H*-pyrrole-3-carboxylate (3g)



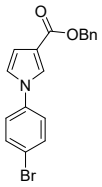
The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 20/1 v/v as the eluent) to yield the title compound as a yellow liquid with 83% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.64 (t, *J* = 2.0 Hz, 1H), 7.44 (d, *J* = 6.9 Hz, 2H), 7.42 – 7.30 (m, 5H), 7.15 (t, *J* = 8.5 Hz, 2H), 6.95 (t, *J* = 2.6 Hz, 1H), 6.79 (dd, *J* = 3.0, 1.6 Hz, 1H), 5.31 (s, 2H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) δ 164.3, 161.3 (d, $^{1}J_{C\text{-}F}$ = 245.0 Hz), 136.6, 136.1 (d, $^{4}J_{C\text{-}F}$ = 3.0 Hz), 128.5, 128.1, 128.0, 124.8, 122.9 (d, $^{3}J_{C\text{-}F}$ = 8.0 Hz), 120.9, 117.9, 116.5 (d, $^{2}J_{C\text{-}F}$ = 22.0 Hz), 111.8, 65.7 ppm. ^{19}F NMR (376 MHz, $CDCl_3$) δ -114.89 − -114.94 (m, 1F) ppm. IR: *v* = 2918, 2850, 1707, 1544, 1517, 1454, 1399, 1362, 1259, 1218, 1133, 1078, 980, 835, 757, 697, 619, 458 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{18}H_{14}FNO_2$, $[M + H]^+$: 296.1081, found: 296.1081.

Benzyl 1-(4-chlorophenyl)-1*H*-pyrrole-3-carboxylate (3h)



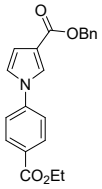
The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 20/1 v/v as the eluent) to yield the title compound as a yellow liquid with 81% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.67 (t, *J* = 2.0 Hz, 1H), 7.46 – 7.40 (m,4H), 7.38 (s, 2H), 7.33 (d, *J* = 8.8 Hz, 3H), 6.98 (t, *J* = 2.7 Hz, 1H), 6.80 (dd, *J* = 3.1, 1.6 Hz, 1H), 5.31 (s, 2H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) δ 164.3, 138.4, 136.6, 132.6, 129.9, 128.5, 128.2, 128.1, 124.5, 122.2, 120.6, 118.2, 112.1, 65.8 ppm. IR: *v* = 3138, 3033, 2923, 2852, 1708, 1543, 1506, 1454, 1361, 1258, 1221, 1134, 1095, 980, 933, 823, 755, 698, 595, 518, 474 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{18}H_{14}ClNO_2$, $[M + H]^+$: 312.0786, found: 312.0786.

Benzyl 1-(4-bromophenyl)-1*H*-pyrrole-3-carboxylate (3i)



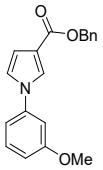
The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 20/1 v/v as the eluent) to yield the title compound as a white solid (m.p. 135 − 136 °C) with 75% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.66 (s, 1H), 7.56 (d, *J* = 8.8 Hz, 2H), 7.43 (d, *J* = 6.7 Hz, 2H), 7.40 – 7.30 (m, 3H), 7.33 – 7.23 (m, 2H), 6.98 (s, 1H), 6.80 (d, *J* = 1.4 Hz, 1H), 5.30 (s, 2H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) δ 164.3, 138.8, 136.6, 132.9, 128.6, 128.2, 128.1, 124.4, 122.5, 120.5, 120.3, 118.3, 112.1, 65.8 ppm. IR: *v* = 3138, 3032, 2919, 1709, 1544, 1506, 1401, 1361, 1258, 1223, 1135, 1076, 981, 934, 821, 757, 698, 594, 511 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{18}H_{14}BrNO_2$, $[M + H]^+$: 356.0281, found: 356.0281.

Benzyl 1-(4-(ethoxycarbonyl)phenyl)-1*H*-pyrrole-3-carboxylate (3j)



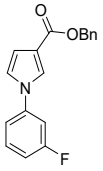
The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 10/1 v/v as the eluent) to yield the title compound as a white solid (m.p. 162 − 163 °C) with 71% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.13 (d, *J* = 8.6 Hz, 2H), 7.78 (t, *J* = 2.0 Hz, 1H), 7.50 – 7.38 (m, 4H), 7.43 – 7.29 (m, 3H), 7.09 (t, *J* = 2.7 Hz, 1H), 6.82 (dd, *J* = 3.0, 1.6 Hz, 1H), 5.32 (s, 2H), 4.40 (q, *J* = 7.1 Hz, 2H), 1.41 (t, *J* = 7.1 Hz, 3H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) δ 165.7, 164.2, 143.0, 136.5, 131.4, 128.7, 128.6, 128.2, 128.1, 124.3, 120.3, 120.1, 118.7, 112.5, 65.8, 61.3, 14.3 ppm. IR: *v* = 3132, 3030, 2953, 2904, 1984, 1750, 1602, 1551, 1510, 1458, 1410, 1364, 1258, 1221, 1230, 1133, 1081, 981, 908, 756, 698, 582, 548, 517 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{18}H_{14}BrNO_2$, $[M + H]^+$: 356.0281, found: 356.0281.

Benzyl 1-(3-methoxyphenyl)-1*H*-pyrrole-3-carboxylate (3k)



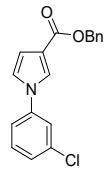
The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 20/1 v/v as the eluent) to yield the title compound as a yellow liquid with 85% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.71 (t, *J* = 2.0 Hz, 1H), 7.44 (d, *J* = 7.0 Hz, 2H), 7.36 (dt, *J* = 16.1, 7.3 Hz, 4H), 7.04 – 6.95 (m, 2H), 6.92 (t, *J* = 2.3 Hz, 1H), 6.86 (dd, *J* = 8.3, 2.4 Hz, 1H), 6.78 (dd, *J* = 3.1, 1.6 Hz, 1H), 5.31 (s, 2H), 3.85 (s, 3H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) δ 164.5, 160.6, 141.0, 136.7, 130.6, 128.5, 128.1, 128.0, 124.6, 120.7, 117.8, 113.3, 112.3, 111.7, 107.2, 65.7, 55.5 ppm. IR: *v* = 3137, 3032, 2928, 2849, 1710, 1608, 1543, 1508, 1455, 1362, 1314, 1268, 1210, 1177, 1132, 1051, 980, 960, 824, 757, 696, 590, 537, 456, cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{19}H_{17}NO_3$, $[M + H]^+$: 308.1281, found: 308.1280.

Benzyl 1-(3-fluorophenyl)-1*H*-pyrrole-3-carboxylate (3l)



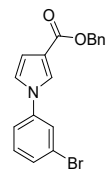
The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 20/1 v/v as the eluent) to yield the title compound as a yellow liquid with 74% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.70 (t, *J* = 2.0 Hz, 1H), 7.46 – 7.30 (m,6H), 7.19 (dd, *J* = 8.1, 2.1 Hz, 1H), 7.12 (d, *J* = 9.7 Hz, 1H), 7.01 (dd, *J* = 5.2, 2.4 Hz, 2H), 6.80 (dd, *J* = 3.1, 1.6 Hz, 1H), 5.31 (s, 2H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) δ 164.2, 163.2 (d, $^1J_{CF}$ = 246.0 Hz), 141.1 (d, $^3J_{CF}$ = 10.0 Hz), 136.5, 131.1 (d, $^3J_{CF}$ = 9.0 Hz), 128.5, 128.1, 128.0, 124.3, 120.4, 118.3, 116.3 (d, $^4J_{CF}$ = 3.0 Hz), 113.7 (d, $^2J_{CF}$ = 20.0 Hz), 112.1, 108.4 (d, $^2J_{CF}$ = 25.0 Hz), 65.7 ppm. ^{19}F NMR (376 MHz, $CDCl_3$) δ -110.21 − -110.27 (m, 1F) ppm. IR: *v* = 2917, 2853, 1700, 1544, 1516, 1450, 1400, 1360, 1256, 1223, 1130, 1076, 976, 840, 750, 690, 618, 452 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{18}H_{14}FNO_2$, $[M + H]^+$: 296.1081, found: 296.1081.

Benzyl 1-(3-chlorophenyl)-1*H*-pyrrole-3-carboxylate (3m)



The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 20/1 v/v as the eluent) to yield the title compound as a yellow liquid with 71% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.61 (t, *J* = 2.0 Hz, 1H), 7.36 (d, *J* = 6.9 Hz, 2H), 7.34 – 7.24 (m, 5H), 7.20 (dt, *J* = 8.2, 2.2 Hz, 2H), 6.92 (t, *J* = 2.7 Hz, 1H), 6.72 (dd, *J* = 3.1, 1.6 Hz, 1H), 5.23 (s, 2H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) δ 164.3, 140.8, 136.5, 135.5, 130.8, 128.6, 128.2, 128.1, 127.0, 124.4, 121.2, 120.5, 118.4, 119.0, 112.2, 65.8 ppm. IR: *v* = 3138, 3033, 2917, 2850, 1710, 1596, 1545, 1503, 1454, 1400, 1361, 1310, 1266, 1223, 1138, 1079, 985, 781, 757, 698, 594, 440 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{18}H_{14}ClNO_2$, $[M + H]^+$: 312.0786, found: 312.0786.

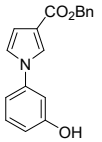
Benzyl 1-(3-bromophenyl)-1*H*-pyrrole-3-carboxylate (3n)



The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 20/1 v/v as the eluent) to yield the title compound as a white solid (m.p. 132 − 133 °C) with 76% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.68 (t, *J* = 1.9 Hz, 1H), 7.56 (d, *J* = 2.1 Hz, 1H), 7.47 – 7.42 (m, 3H), 7.41 – 7.35 (m, 2H), 7.35 – 7.29 (m, 3H), 7.00 (t, *J* = 2.7 Hz, 1H), 6.80 (dd, *J* = 3.1, 1.6 Hz, 1H), 5.31 (s, 2H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) δ 164.2, 140.9, 136.5, 131.1, 129.9, 128.6, 128.2, 128.1, 124.4, 124.1, 123.3, 120.5, 119.5, 118.4, 112.2, 65.8 ppm. IR: *v* = 3138, 3032, 2918, 2850, 1709, 1593, 1545, 1480, 1401, 1310, 1264, 1223, 1137,

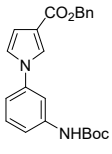
1078, 991, 864, 756, 735, 698, 621, 533, 435 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{18}H_{14}BrNO_2$, $[M + H]^+$: 356.0281, found: 356.0281.

Benzyl 1-(3-hydroxyphenyl)-1*H*-pyrrole-3-carboxylate (3o)



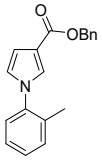
The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 5/1 v/v as the eluent) to yield the title compound as a white solid (m.p. 149 − 150 °C) with 70% yield. ^1H NMR (400 MHz, DMSO-*d6*) δ 9.93 (s, 1H), 7.99 (t, J = 2.0 Hz, 1H), 7.53 – 7.27 (m, 7H), 7.12 (dd, J = 8.0, 2.2 Hz, 1H), 7.05 (t, J = 2.3 Hz, 1H), 6.81 (dd, J = 8.2, 2.3 Hz, 1H), 6.71 (t, J = 2.5 Hz, 1H), 5.32 (s, 2H) ppm. $^{13}C\{^1H\}$ NMR (100 MHz, DMSO-*d6*) δ 164.0, 159.0, 140.6, 137.3, 131.1, 128.9, 128.3, 128.2, 124.6, 121.6, 117.3, 114.2, 111.5, 111.4, 107.9, 65.2 ppm. IR: *v* = 3350, 3110, 3030, 2953, 1789, 1606, 1546, 1510, 1459, 1412, 1360, 1260, 1207, 1130, 1053, 980, 908, 756, 693, 593, 548, 511 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{18}H_{15}NO_3$, $[M + H]^+$: 294.1125, found: 294.1125.

Benzyl 1-(3-((tert-butoxycarbonyl)amino)phenyl)-1*H*-pyrrole-3-carboxylate (3p)



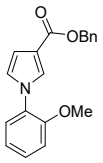
The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 2/1 v/v as the eluent) to yield the title compound as a white solid (m.p. 151 − 153 °C) with 68% yield. ^1H NMR (400 MHz, $CDCl_3$) δ 7.73 – 7.64 (m, 2H), 7.47 – 7.26 (m, 6H), 7.14 (dd, J = 8.1, 2.1 Hz, 1H), 7.01 (d, J = 2.5 Hz, 2H), 6.84 (s, 1H), 6.79 – 6.73 (m, 1H), 5.30 (s, 2H), 1.51 (s, 9H) ppm. $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$) δ 164.6, 152.6, 140.5, 140.0, 136.7, 130.1, 128.5, 128.1, 128.0, 124.7, 120.8, 117.7, 116.6, 115.2, 111.7, 111.1, 81.0, 65.7, 28.3 ppm. IR: *v* = 3400, 3140, 3015, 2950, 1780, 1603, 1537, 1519, 1501, 1450, 1400, 1365, 1258, 1223, 1130, 1071, 982, 908, 750, 694, 508 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{23}H_{24}N_2O_4$, $[M + H]^+$: 393.1809, found: 393.1807.

Benzyl 1-(o-tolyl)-1*H*-pyrrole-3-carboxylate (3q)



The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 20/1 v/v as the eluent) to yield the title compound as a yellow liquid with 75% yield. ^1H NMR (400 MHz, $CDCl_3$) δ 7.47 – 7.41 (m, 3H), 7.36 (d, *J* = 7.6 Hz,2H), 7.34 – 7.29 (m, 3H), 7.26 (d, *J* = 2.8 Hz, 1H), 7.23 (d, *J* = 1.5 Hz, 1H), 6.77 (dd, *J* = 2.9, 1.6 Hz, 1H), 6.75 – 6.67 (m, 1H), 5.30 (s, 2H), 2.19 (s, 3H) ppm. $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$) δ 164.7, 139.5, 136.8, 133.8, 131.2, 128.5, 128.4, 128.1, 128.0, 127.3, 126.8, 126.5, 123.3, 116.6, 110.4, 65.6, 17.7 ppm. IR: *v* = 3132, 3032, 2919, 2851, 1710, 1539, 1507, 1456, 1361, 1253, 1217, 1196, 1137, 1115, 982, 759, 698, 640, 455 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{19}H_{17}NO_2$, $[M + H]^+$: 292.1332, found: 292.1331.

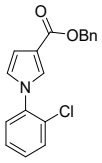
Benzyl 1-(2-methoxyphenyl)-1*H*-pyrrole-3-carboxylate (3r)



The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 20/1 v/v as the eluent) to yield the title compound as a yellow liquid with 72% yield. ^1H NMR (400 MHz, $CDCl_3$) δ 7.62 (t, *J* = 2.0 Hz, 1H), 7.43 (d, *J* = 6.8 Hz, 2H), 7.39 – 7.24 (m, 5H), 7.05 – 6.96 (m, 2H), 6.90 (t, *J* = 2.6 Hz, 1H), 6.75 (dd, *J* = 3.2, 1.7 Hz, 1H), 5.30 (s, 2H), 3.82 (s, 3H) ppm. $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$) δ 164.7, 152.8, 136.9, 129.2, 128.7, 128.5, 128.1, 127.9, 127.7, 125.9, 123.4, 121.0, 116.5, 112.4, 110.2, 65.5, 55.9 ppm. IR: *v* = 3396, 3032,

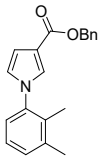
2939, 2840, 1708, 1541, 1514, 1463, 1361, 1324, 1265, 1216, 1135, 1024, 982, 755, 968, 634 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{19}H_{17}NO_3$, $[M + H]^+$: 308.1281, found: 308.1280.

Benzyl 1-(2-chlorophenyl)-1*H*-pyrrole-3-carboxylate (3s)



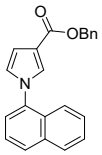
The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 20/1 v/v as the eluent) to yield the title compound as a yellow liquid with 63% yield. ^1H NMR (400 MHz, $CDCl_3$) δ 7.54 (t, *J* = 1.9 Hz, 2H), 7.44 (d, *J* = 6.7 Hz, 2H), 7.40 – 7.31 (m, 6H), 6.84 (t, *J* = 2.6 Hz, 1H), 6.79 (dd, *J* = 3.1, 1.6 Hz, 1H), 5.31 (s, 2H) ppm. $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$) δ 164.4, 137.8, 136.7, 130.8, 129.8, 129.3, 128.5, 128.1, 128.0, 127.8, 127.8, 127.4, 123.4, 117.2, 110.7, 65.6 ppm. IR: *v* = 2931, 2853, 1707, 1640, 1452, 1361, 1197, 1109, 1077, 990, 759, 743, 698, 459, 420 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{18}H_{14}ClNO_2$, $[M + H]^+$:312.0786, found: 312.0785.

Benzyl 1-(2,3-dimethylphenyl)-1*H*-pyrrole-3-carboxylate (3t)



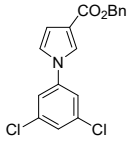
The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 20/1 v/v as the eluent) to yield the title compound as a colorless liquid with 78% yield. ^1H NMR (400 MHz, $CDCl_3$) δ 7.47 – 7.35 (m, 3H), 7.39 – 7.27 (m, 3H), 7.25 – 7.05 (m, 3H), 6.76 (dd, *J* = 3.0, 1.6 Hz, 1H), 6.69 (t, *J* = 2.6 Hz, 1H), 5.30 (s, 2H), 2.34 (s, 3H), 2.03 (s,3H) ppm. $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$) δ 164.7, 139.6, 138.5, 136.8, 132.8, 130.0, 128.5, 128.1, 128.0, 127.6, 126.0, 124.3, 123.6, 116.4, 110.3, 65.5, 20.4, 14.2 ppm. IR: *v* = 2918, 2850, 1711, 1539, 1502, 1455, 1361, 1261, 1218, 1194, 1171, 1144, 1101, 989, 912, 760, 698, 647, 458, 421 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{20}H_{19}NO_2$, $[M + H]^+$: 306.1489, found: 306.1488.

Benzyl 1-(naphthalen-1-yl)-1*H*-pyrrole-3-carboxylate (3u)



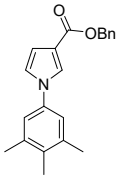
The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 15/1 v/v as the eluent) to yield the title compound as a colorless liquid with 80% yield. ^1H NMR (400 MHz, $CDCl_3$) δ 7.91 (dd, *J* = 8.0, 4.8 Hz, 2H), 7.68 – 7.60 (m, 2H), 7.59 – 7.27 (m, 9H), 6.89 (dt, *J* = 21.4, 2.5 Hz, 2H), 5.33 (s, 2H) ppm. 13C{^1H} NMR (100 MHz, $CDCl_3$) δ 164.7, 137.0, 136.7, 134.2, 129.4, 128.9, 128.5, 128.3, 128.3, 128.1, 128.0, 127.5, 126.9, 125.2, 124.4, 123.5, 122.7, 116.9, 110.7, 65.6 ppm. *v* = 3132, 3060, 2950, 1709, 1540, 1499, 1411, 1378, 1267, 1181, 1141, 1101, 980, 803, 760, 698, 593, 522, 430 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{22}H_{17}NO_2$, $[M + H]^+$: 328.1332, found: 328.1333.

Benzyl 1-(3,5-dichlorophenyl)-1*H*-pyrrole-3-carboxylate (3v)



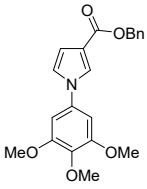
The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 10/1 v/v as the eluent) to yield the title compound as a white solid (m.p. 144 − 145 °C) with 63% yield. ^1H NMR (400 MHz, $CDCl_3$) δ 7.67 (t, *J* = 2.0 Hz, 1H), 7.41 (d, *J* = 16.1 Hz, 5H), 7.31 (s, 3H), 6.99 (t, *J* = 2.7 Hz, 1H), 6.81 (dd, *J* = 3.1, 1.5 Hz, 1H), 5.31 (s, 2H) ppm. $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$) δ 164.0, 155.2, 141.3, 136.2, 128.6, 128.2, 128.1, 126.9, 124.2, 120.4, 119.4, 119.4, 112.6, 65.9 ppm. IR: *v* = 3137, 3030, 2917, 2851, 1711, 1599, 1550, 1509, 1454, 1400, 1360, 1310, 1267, 1223, 1140, 1078, 985, 781, 758, 699, 594, 445 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{18}H_{13}C_{l2}NO_2$, $[M + H]^+$: 346.0396, found: 346.0396.

Benzyl 1-(3,4,5-trimethylphenyl)-1*H*-pyrrole-3-carboxylate (3w)



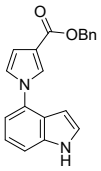
The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 20/1 v/v as the eluent) to yield the title compound as a colorless liquid with 90% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.66 (t, *J* = 1.9 Hz, 1H), 7.43 (s, 2H), 7.40 – 7.28 (m, 3H), 7.04 (s, 2H), 6.97 (t, *J* = 2.7 Hz, 1H), 6.76 (dd, *J* = 3.0, 1.7 Hz, 1H), 5.30 (s, 2H), 2.33 (s, 6H), 2.19 (s, 3H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) δ 164.6, 138.0, 137.1, 136.8, 134.0, 128.5, 128.1, 128.0, 124.7, 120.7, 120.1, 117.2, 111.3, 65.6, 20.7, 15.1 ppm. IR: *v* = 2918, 2851, 1710, 1541, 1501, 1453, 1364, 1282, 1213, 1127, 1078, 979, 817, 758, 698, 633 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{21}H_{21}NO_2$, $[M + H]^+$: 320.1645, found: 320.1644.

Benzyl 1-(3,4,5-trimethoxyphenyl)-1*H*-pyrrole-3-carboxylate (3x)



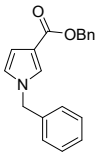
The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 15/1 v/v as the eluent) to yield the title compound as a colorless liquid with 92% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.65 (t, *J* = 2.0 Hz, 1H), 7.48 – 7.29 (m, 5H), 6.96 (t, *J* = 2.6 Hz, 1H), 6.78 (dd, *J* = 3.1, 1.7 Hz, 1H), 6.59 (s, 2H), 5.32 (s, 2H), 3.90 (s, 6H), 3.87 (s, 3H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) δ 164.5, 153.9, 136.6, 136.1, 128.5, 128.2, 128.1, 125.0, 121.1, 117.6, 111.6, 102.2, 99.2, 65.7, 61.0, 56.4 ppm. IR: *v* = 2918, 2849, 1709, 1600, 1542, 1512, 1466, 1426, 1313, 1242, 1211, 1129, 1079, 1004, 835, 817, 759, 699 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{21}H_{21}NO_5$, $[M + H]^+$: 368.1492, found: 368.1492.

Benzyl 1-(1H-indol-4-yl)-1*H*-pyrrole-3-carboxylate (3y)



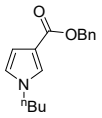
The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 20/1 v/v as the eluent) to yield the title compound as a colorless liquid with 75% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.64 (s, 1H), 7.81 (d, *J* = 1.9 Hz, 1H), 7.45 (d, *J* = 7.3 Hz, 2H), 7.41 – 7.28 (m, 4H), 7.28 – 7.16 (m, 2H), 7.12 (t, *J* = 2.6 Hz, 1H), 7.07 (d, *J* = 7.4 Hz, 1H), 6.87 – 6.81 (m, 1H), 6.63 (t, *J* = 2.6 Hz, 1H), 5.34 (s, 2H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) δ 164.9, 137.3, 136.8, 132.7, 128.5, 128.0, 127.9, 126.5, 125.4, 122.5, 122.3, 122.1, 116.8, 113.9, 110.8, 110.6, 100.3, 65.6 ppm. IR: *v* = 3395, 2918 2850, 1691, 182, 1540, 1513, 1411, 1344, 1253, 1215, 1174, 1146, 1215, 1174, 1146, 1119, 1081, 981, 749, 697, 638, 471 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{20}H_{16}N_2O_2$, $[M + H]^+$: 317.1285, found: 317.1284.

Benzyl 1-benzyl-1*H*-pyrrole-3-carboxylate (3z)



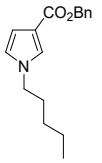
The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 15/1 v/v as the eluent) to yield the title compound as a colorless liquid with 63% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41 (d, *J* = 7.0 Hz, 2H), 7.40 – 7.28 (m, 7H), 7.16 – 7.10 (m, 2H), 6.63 (dt, *J* = 12.6, 2.8 Hz, 2H), 5.26 (s, 2H), 5.05 (s, 2H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) δ 164.6, 136.8, 136.6, 128.9, 128.7, 128.5, 128.3, 128.3, 128.2, 128.1, 127.9, 127.3, 127.0, 126.6, 122.2, 110.6, 65.5, 53.9 ppm. IR: *v* = 3031, 2955, 1777, 1600, 1549, 1501, 1450, 1410, 1362, 1255, 1200, 1132, 1081, 999, 900, 756, 675, 601cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{19}H_{17}NO_2$, $[M + Na]^+$: 292.1332, found: 292.1335.

Benzyl 1-butyl-1*H*-pyrrole-3-carboxylate (3aa)



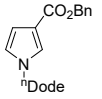
The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 15/1 v/v as the eluent) to yield the title compound as a colorless liquid with 75% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.45 – 7.29 (m, 6H), 6.59 (dt, *J* = 9.3, 2.6 Hz, 2H), 5.27 (s, 2H), 3.86 (t, *J* = 7.1 Hz, 2H), 1.75 (p, *J* = 7.2 Hz, 2H), 1.30 (q, *J* = 7.5 Hz, 2H), 0.93 (t, *J* = 7.4 Hz, 3H) ppm. ^{13}C{^{1}H} NMR (100 MHz, CDCl3) δ 164.7, 136.9, 128.5, 128.0, 127.9, 126.1, 121.6, 110.1, 65.4, 49.9, 33.2, 19.8, 13.6 ppm. IR: *v* = 2958, 2930, 2873, 1707, 1539, 1456, 1353, 1210, 1190, 1109, 1075, 986, 760, 698 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{16}H_{19}NO_2$, $[M + H]^+$: 258.1489, found: 258.1489.

Benzyl 1-pentyl-1*H*-pyrrole-3-carboxylate (3ab)



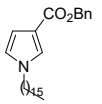
The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 15/1 v/v as the eluent) to yield the title compound as a colorless liquid with 69% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.31 (d, 1H), 6.59 (dt, *J* = 9.3, 2.6 Hz, 5H), 5.27 (s, 2H), 3.86 (t, *J* = 7.1 Hz, 2H), 1.80-1.69 (m, 2H), 1.26 (m, 4H), 0.93 (t, *J* = 7.4 Hz, 3H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) δ 164.7, 136.8, 128.4, 128.0, 127.89, 126.1, 121.6, 110.01, 65.4, 49.8, 33.2, 29.7, 19.8, 13.6 ppm. IR: *v* = 2959, 2936, 2877, 2865, 1710, 1539, 1456, 1353, 1218, 1192, 1110, 1079, 988, 760, 698 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{17}H_{21}NO_2$, $[M + H]^+$: 272.1645, found: 272.1644.

Benzyl 1-dodecyl-1H-pyrrole-3-carboxylate (3ac)



The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 15/1 v/v as the eluent) to yield the title compound as a colorless liquid with 66% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.45 – 7.27 (m, 6H), 6.59 (dt, *J* = 8.8, 2.6 Hz, 2H), 5.27 (s, 2H), 3.85 (t, *J* = 7.2 Hz, 2H), 3.13 (qd, *J* = 7.3, 4.4 Hz, 6H), 1.41 (t, *J* = 7.3 Hz, 10H), 0.88 (t, *J* = 6.7 Hz, 7H) ppm.^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) δ 164.7, 136.9, 128.5, 128.0, 127.9, 126.1, 121.6, 110.1, 65.3, 50.2, 45.9, 31.9, 31.2, 29.6, 29.4, 29.3, 29.1, 26.6, 22.7, 14.1, 8.61 ppm. IR: *v* = 3033, 2925, 2853,1710, 1539, 1457, 1354, 1208, 1190, 1108, 983, 813, 759, 697, 597 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{24}H_{35}NO_2$, $[M + H]^+$: 370.2741, found: 370.2741.

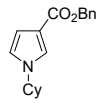
Benzyl 1-hexadecyl-1H-pyrrole-3-carboxylate (3ad)



The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 15/1 v/v as the eluent) to yield the title compound as a colorless liquid with 60% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.45 − 7.27 (m, 12H), 6.59 (dt, *J* = 8.8, 2.6 Hz, 2H), 5.27 (s, 2H), 3.85 (t, *J* = 7.2 Hz, 2H), 3.13 (qd, *J* = 7.3, 4.4 Hz, 6H), 1.41 (t, *J* = 7.3 Hz, 10H), 0.88 (t, *J* = 6.7 Hz, 7H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) δ 164.7, 136.9, 128.5, 128.0, 127.9, 126.1, 121.6, 115.4, 110.1, 65.3, 50.2, 46.0, 31.9, 31.2, 29.7, 29.7, 29.6, 29.6, 29.4, 29.4, 29.1, 26.6, 22.7, 14.1, 8.6 ppm. IR: *v* = 3030, 2930, 2850, 1719, 1539, 1460, 1355, 1208, 1191, 1112, 980, 815, 762, 700, 599, 427 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{28}H_{43}NO_2$, $[M + H]^+$: 426.3367, found: 426.3367.

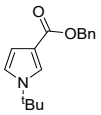
Benzyl 1-cyclohexyl-1*H*-pyrrole-3-carboxylate (3ae)

The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 15/1 v/v as the eluent) to yield the title compound as a colorless liquid with 76% yield. ^{1}H NMR (400 MHz, $CDCl_3$)



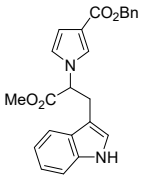
δ 7.44 – 7.30 (m, 6H), 6.63 (dt, *J* = 23.8, 2.6 Hz, 2H), 5.26 (s, 2H), 3.79 (ddt, *J* = 11.8, 7.7, 3.8 Hz, 1H), 3.13 (q, *J* = 7.4 Hz, 4H), 2.12 – 2.03 (m, 2H), 1.89 (dt, *J* = 13.5, 3.3 Hz, 2H), 1.60 (qd, *J* = 12.5, 3.4 Hz, 2H), 1.41 (t, *J* = 7.3 Hz, 2H) ppm. $^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) δ 164.79, 128.44, 128.03, 127.86, 124.11, 119.84, 109.67, 107.53, 103.39, 65.30, 59.29, 45.92, 34.41, 25.52, 25.29, 8.61 ppm. IR: *v* = 2931, 2853, 1701, 1640, 1540, 1452, 1361, 1179, 1077, 990, 759, 698, 459, 420 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{18}H_{21}NO_2$, $[M + H]^+$: 284.1645, found: 284.1645.

Benzyl 1-(tert-butyl)-1*H*-pyrrole-3-carboxylate (3af)



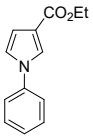
The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 15/1 v/v as the eluent) to yield the title compound as a colorless liquid with 74% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.49 (s, 1H), 7.42 (s, 2H), 7.37 (s, 3H), 6.79 (t, *J* = 2.7 Hz, 1H), 6.63 (dd, *J* = 3.1, 1.7 Hz, 1H), 5.27 (s, 2H), 1.53 (s, 9H) ppm. $^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) δ 164.9, 128.5, 128.1, 127.9, 123.5, 118.8, 114.9, 109.8, 65.3, 55.8, 30.6 ppm. IR: *v* = 2977, 2918, 2850, 1707, 1537, 1460, 1374, 1330, 1226, 1210, 1161, 1101, 993, 759, 698, 642 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{16}H_{19}NO_2$, $[M + H]^+$: 258.1489, found: 258.1489.

Benzyl 1-(3-(1H-indol-3-yl)-1-methoxy-1-oxopropan-2-yl)-1*H*-pyrrole-3-carboxylate (3ag)



The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 5/1 v/v as the eluent) to yield the title compound as a colorless liquid with 59% yield. ^{1}H NMR (400 MHz, CDCl3) δ 8.07 (s, 1H), 7.56 (d, J = 7.9 Hz, 1H), 7.32 (m, J = 4.4 Hz, 5H), 7.17 (t, J = 7.5 Hz, 2H), 7.09 (t, J = 7.4 Hz, 2H), 7.03 (s, 1H), 6.71 (d, J = 6.0 Hz, 1H), 5.10 – 4.99 (m, 1H), 4.91 (s, 1H), 3.66 (s, 3H), 3.27 (d, J = 7.6 Hz, 2H) ppm. $^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) δ 174.8, 166.3, 139.7, 136.3, 135.7, 133.6, 128.6, 128.5, 128.3, 128.2, 128.08, 127.3, 123.1, 122.1, 119.5, 118.7, 111.2, 99.1, 66.6, 60.6, 43.6, 29.1 ppm. IR: *v* = 3345, 3284, 3067, 2954, 2923, 2850, 2755, 2613, 1691, 1590, 1540, 1513, 1400, 1340, 1253, 1218, 1174, 1215, 1121, 1081, 945, 860, 749, 722, 669 cm-1. HRMS (ESI): *m/z* calcd for $C_{24}H_{22}N_2O_4$, $[M + H]^+$: 403.1652, found: 403.1653.

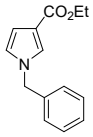
Ethyl 1-phenyl-1*H*-pyrrole-3-carboxylate (3ah)



The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 20/1 v/v as the eluent) to yield the title compound as a colorless liquid with 87% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.62 (t, *J* = 2.0 Hz, 1H), 7.40 – 7.30 (m, 4H), 7.24 (s, 1H), 6.95 (t, *J* = 2.7 Hz, 1H), 6.69 (dd, *J* = 2.9, 1.6 Hz, 1H), 4.24 (q, *J* = 7.2 Hz, 2H), 1.29 (t, *J* = 7.2 Hz, 3H) ppm.$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) δ 164.8, 139.9, 129.8, 126.8, 124.3, 121.0, 120.5, 118.3, 111.6, 59.9, 14.5 ppm.IR: *v* = 3008, 2989, 1712, 1535, 1452, 1381, 1221, 1188, 1110, 1032, 998, 820, 763, 710, 656, 477 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{13}H_{13}NO_2$, $[M + H]^+$: 216.1019, found: 216.1019.

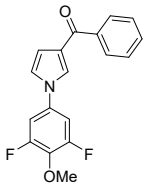
Ethyl 1-benzyl-1*H*-pyrrole-3-carboxylate (3ai)

The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 20/1 v/v as the eluent) to yield the title compound as a colorless liquid with 79% yield. ^{1}H NMR (400 MHz, $CDCl_3$)



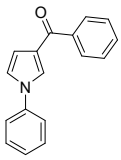
δ 7.38 – 7.25 (m, 4H), 7.16 – 7.10 (m, 2H), 6.61 (d, J = 2.0 Hz, 2H), 5.03 (s, 2H), 4.25 (q, J = 7.1 Hz, 2H), 1.31 (t, J = 7.1 Hz, 3H) ppm. $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$) δ 164.9, 136.8, 128.9, 128.1, 127.3, 126.3, 122.1, 116.6, 110.5, 59.7, 53.8, 14.5 ppm. IR: v = 3128, 2980, 1704, 1541, 1450, 1373, 1220, 1188, 1113, 1025, 965, 819, 763, 712, 629, 461 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{14}H_{15}NO_2$, $[M + H]^+$: 230.1181, found: 230.1175.

(1-(3,5-Difluoro-4-methoxyphenyl)-1*H*-pyrrol-3-yl)(phenyl)methanone (3aj)



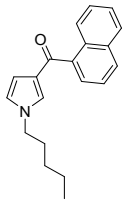
The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 15/1 v/v as the eluent) to yield the title compound as a yellow solid (m.p. 166 − 167 °C) with 81% yield. ^1H NMR (400 MHz, $CDCl_3$) δ 7.89 – 7.83 (m, 2H), 7.57 (t, J = 7.4 Hz, 1H), 7.53 – 7.45 (m, 3H), 7.07 – 6.95 (m, 3H), 6.87 (dd, J = 3.1, 1.7 Hz, 1H), 4.03 (s, 3H) ppm. $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$) δ 190.5, 156.0 (dd, $^1J_{CF}$ = 248.0 Hz, $^3J_{CF}$ = 8.0 Hz), 139.4, 135.4 (t, $^3J_{CF}$ = 14.0 Hz), 134.4 (t, $^2J_{CF}$ = 12.0 Hz), 131.8, 128.9, 128.3, 126.7, 125.7, 121.0, 112.9, 105.6 (dd, $^2J_{CF}$ = 18.0 Hz, $^4J_{CF}$ = 9.0 Hz), 62.1 ppm. ^{19}F NMR (376 MHz, $CDCl_3$) δ -125.34 (d, J_{F-H} = 7.5 Hz, 2F) ppm. IR: v = 2995, 2851, 1700, 1544, 1516, 1450, 1400, 1360, 1260, 1240, 1220, 1133, 1077, 1037, 978, 840, 750, 690, 618 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{18}H_{13}F_2NO_2$, $[M + H]^+$: 314.0987, found: 314.0987.

Phenyl(1-phenyl-1*H*-pyrrol-3-yl)methanone[1] (3ak)



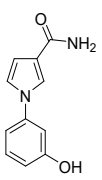
The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 15/1 v/v as the eluent) to yield the title compound as a colorless liquid with 77% yield. ^1H NMR (400 MHz, $CDCl_3$) δ7.88 (d, J = 7.7 Hz, 2H), 7.61 (s, 1H), 7.55 (t, J = 7.4 Hz, 1H), 7.49 (d, J = 7.4 Hz, 2H), 7.46 (d, J = 7.2 Hz, 2H), 7.42 (d, J = 7.5 Hz, 2H), 7.34 (t, J = 7.2 Hz, 1H), 7.11 (d, J = 2.1 Hz, 1H), 6.88 (s, 1H), ppm. $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$) δ 190.8, 139.8, 139.8, 131.6, 129.8, 129.0, 128.3, 127.1, 126.2, 126.2, 121.2, 121.2, 112.4 ppm.

Naphthalen-1-yl(1-pentyl-1*H*-pyrrol-3-yl)methanone[2] (JWH-030)



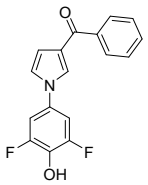
The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 15/1 v/v as the eluent) to yield the title compound as a colorless liquid with 77% yield. ^1H NMR (400 MHz, $CDCl_3$) δ 8.21 – 8.13 (m, 1H), 7.97 – 7.85 (m, 2H), 7.65 (d, J = 7.0 Hz, 1H), 7.57 – 7.44 (m, 3H), 7.07 (d, J = 1.9 Hz, 1H), 6.68 (dt, J = 10.4, 2.7 Hz, 2H), 3.84 (t, J = 7.2 Hz, 2H), 1.75 (p, J = 7.3 Hz, 2H), 1.41 – 1.29 (m, 4H), 0.87 (q, J = 13.8, 10.3 Hz, 3H) ppm. $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$) δ 192.1, 143.4, 138.5, 130.7, 130.1, 128.7, 128.1, 126.7, 126.3, 126.2, 126.0, 126.0, 124.4, 122.5, 110.6, 50.2, 30.8, 29.7, 28.7, 22.2, 13.9 ppm.

(1-(3,5-Difluoro-4-hydroxyphenyl)-1*H*-pyrrol-3-yl)(phenyl)methanon[3] (4a)



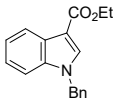
The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 5/1 v/v as the eluent) to yield the title compound as a yellow solid (m.p. 184 − 185 °C) with 82% yield. ^1H NMR (400 MHz, DMSO) δ 9.91 (s, 1H), 7.80 (s, 1H), 7.44 (s, 1H), 7.27 (s, 1H), 6.99 (d, J = 8.0 Hz, 1H), 6.90 (d, J = 14.3 Hz, 2H), 6.72 (d, J = 7.9 Hz, 1H), 6.63 (s, 1H) ppm. $^{13}C\{^1H\}$ 13C NMR (101 MHz, DMSO) δ 165.6, 159.01, 141.0, 131.1, 122.3, 121.7, 120.3, 113.7, 110.9, 110.7, 107.3 ppm.

1-(3-Hydroxyphenyl)-1*H*-pyrrole-3-carboxamide[4] (JMC-2004)



The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 5/1 v/v as the eluent) to yield the title compound as a colorless liquid with 87% yield. ^{1}H NMR (400 MHz, DMSO-*d6*) δ 10.44 (br s, 1H), 7.92 – 7.94 (m, 1H), 7.84 (d, J = 4.0 Hz, 2H), 7.59 – 7.64 (m, 2H), 7.51 – 7.55 (m, 3H), 6.72 – 6.74 (m, 1H), 6.56 (s, 1H) ppm. ^{13}C{^{1}H} NMR (100 MHz, DMSO-*d6*) δ 189.1, 152.4 (dd, $^{1}J_{C\text{-}F}$ = 241.0 Hz, $^{3}J_{CF}$ = 9.0 Hz), 139.1, 132.4 (t, $^{3}J_{C\text{-}F}$ = 16.0 Hz), 131.8, 130.0 (t, $^{3}J_{C\text{-}F}$ = 12.0 Hz), 128.7, 128.5, 125.9, 125.2, 121.6, 111.7, 104.8 (dd, $^{2}J_{CF}$ = 18.0 Hz, $^{4}J_{CF}$ = 10.0 Hz) ppm. ^{19}F NMR (376 MHz, DMSO-*d6*) δ -130.39 (d, $J_{F\text{-}H}$ = 7.5 Hz, 2F) ppm.

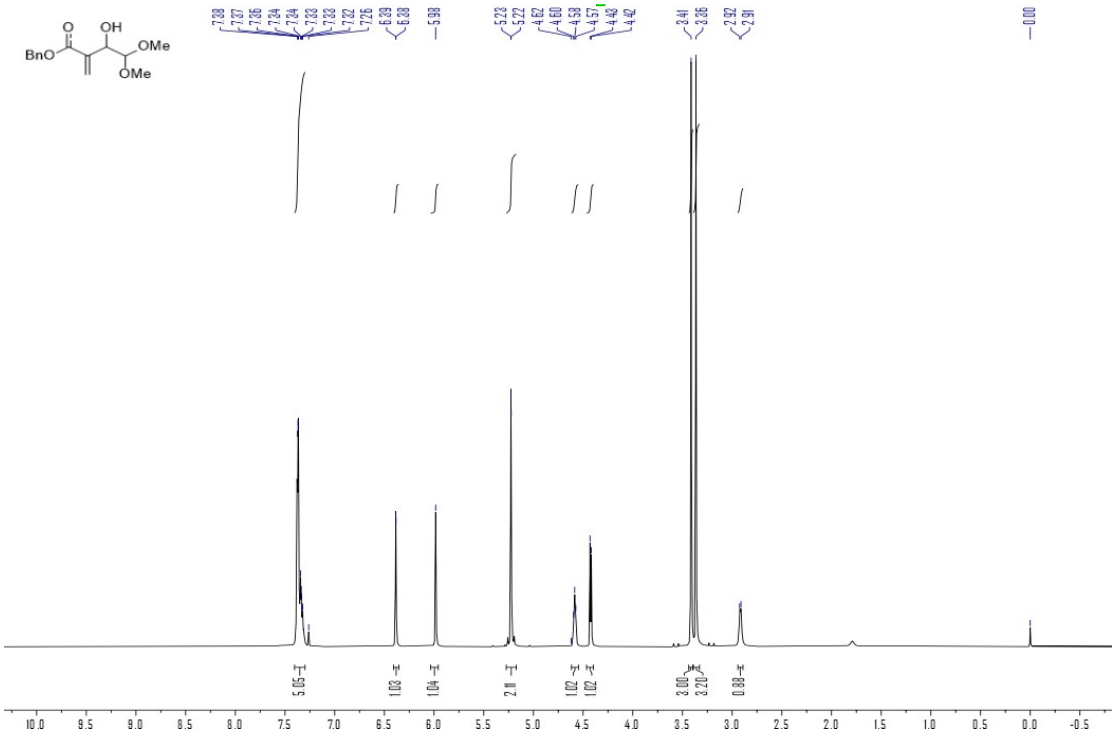
Ethyl 1-benzyl-1*H*-indole-3-carboxylate (5a)

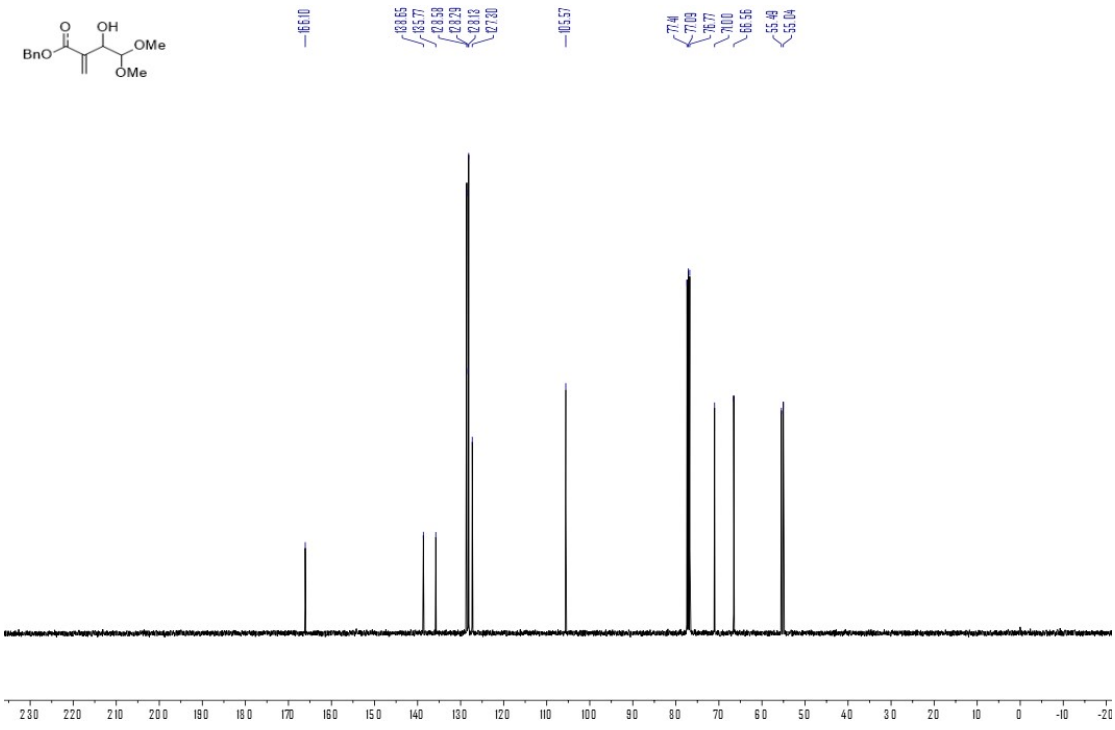


The crude mixture was purified by preparative TLC plate (petroleum ether/ehyl acetate = 15/1 v/v as the eluent) to yield the title compound as a colorless liquid with 81% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.24 – 8.17 (m, 1H), 7.86 (s, 1H), 7.35 – 7.20 (m, 6H), 7.18 – 7.12 (m, 2H), 5.34 (s, 2H), 4.41 (s, 2H), 1.42 (t, *J* = 7.1 Hz, 3H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) δ 165.2, 136.8, 136.0, 134.6, 129.0, 128.1, 127.0, 126.8, 122.9, 122.0, 121.8, 110.3, 107.9, 59.8, 50.7, 14.6 ppm.

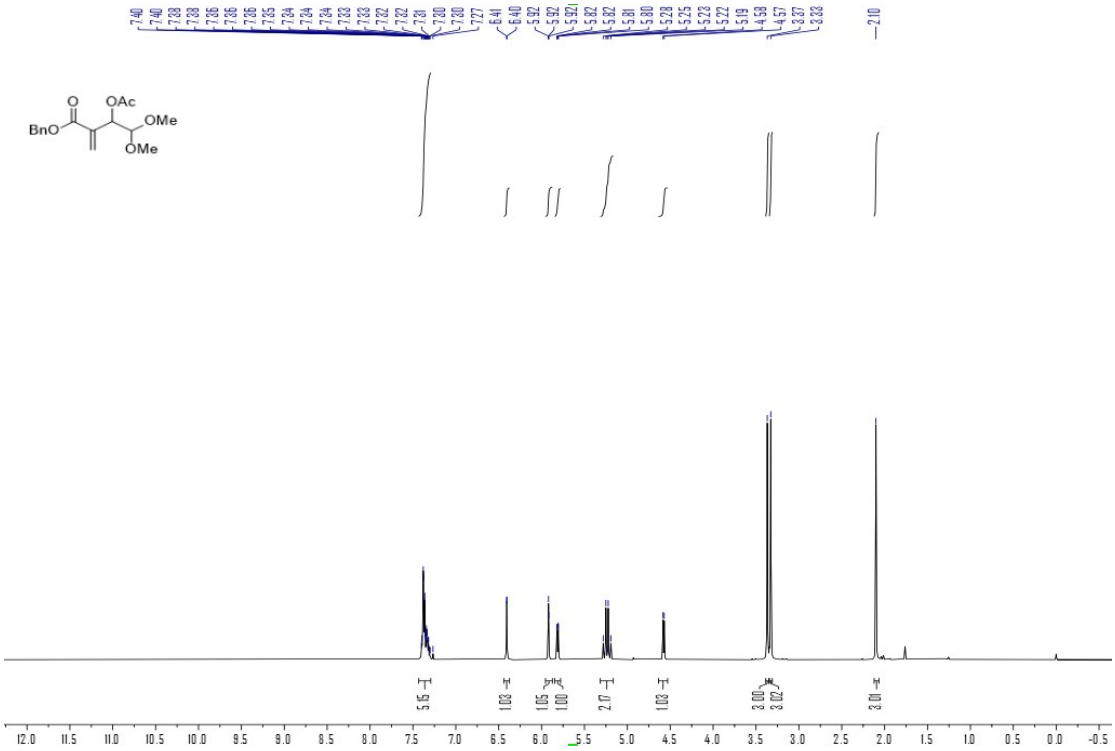
12. ^{1}H NMR and ^{13}C NMR spectra of products

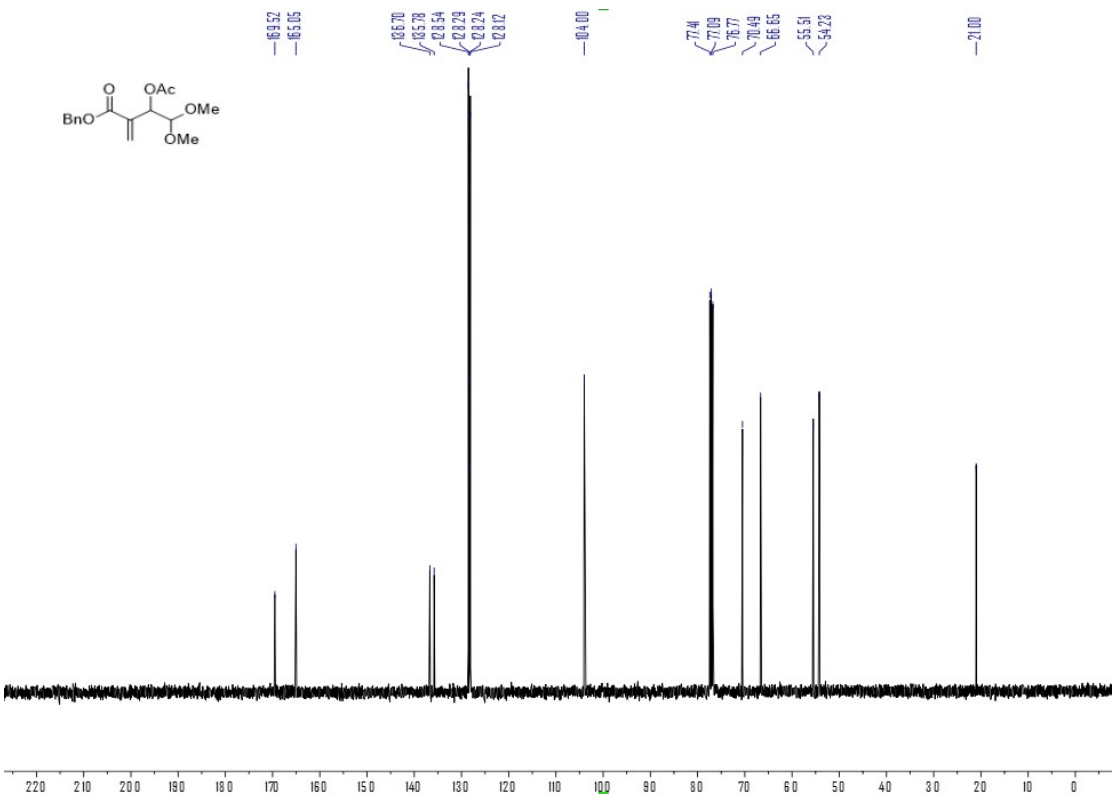
Benzyl 3-hydroxy-4,4-dimethoxy-2-methylenebutanoate (1a)



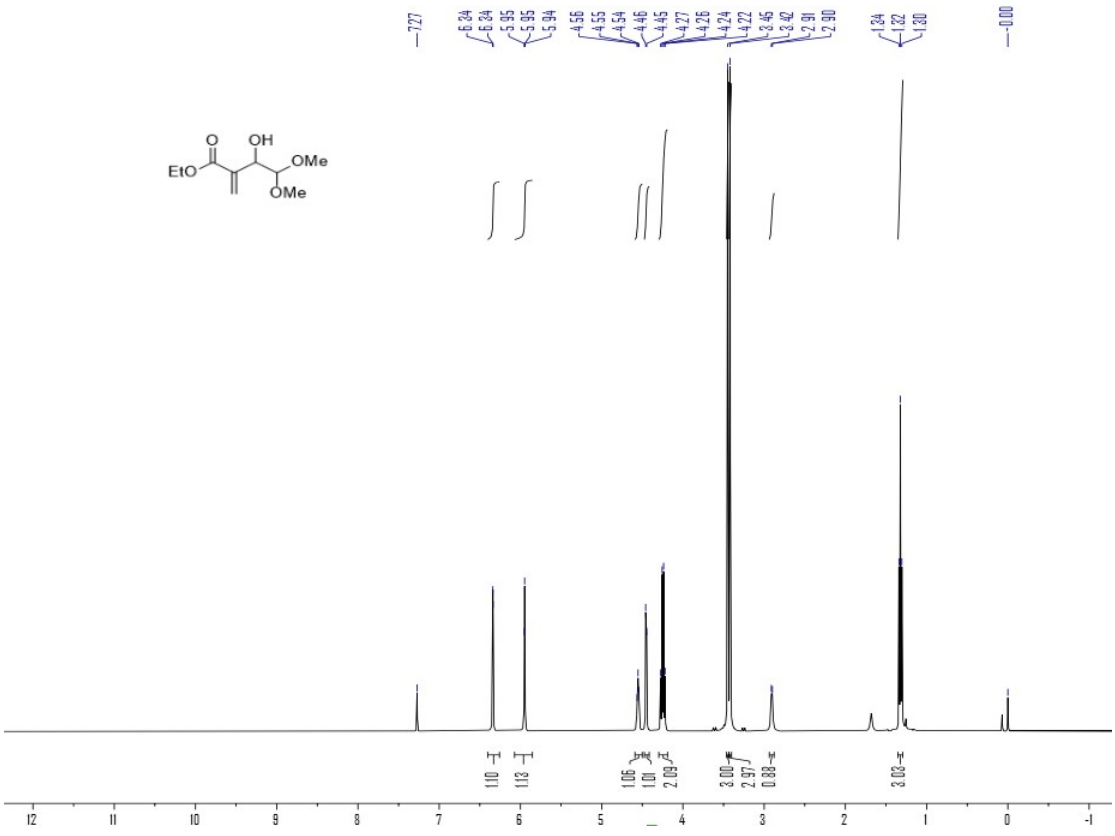


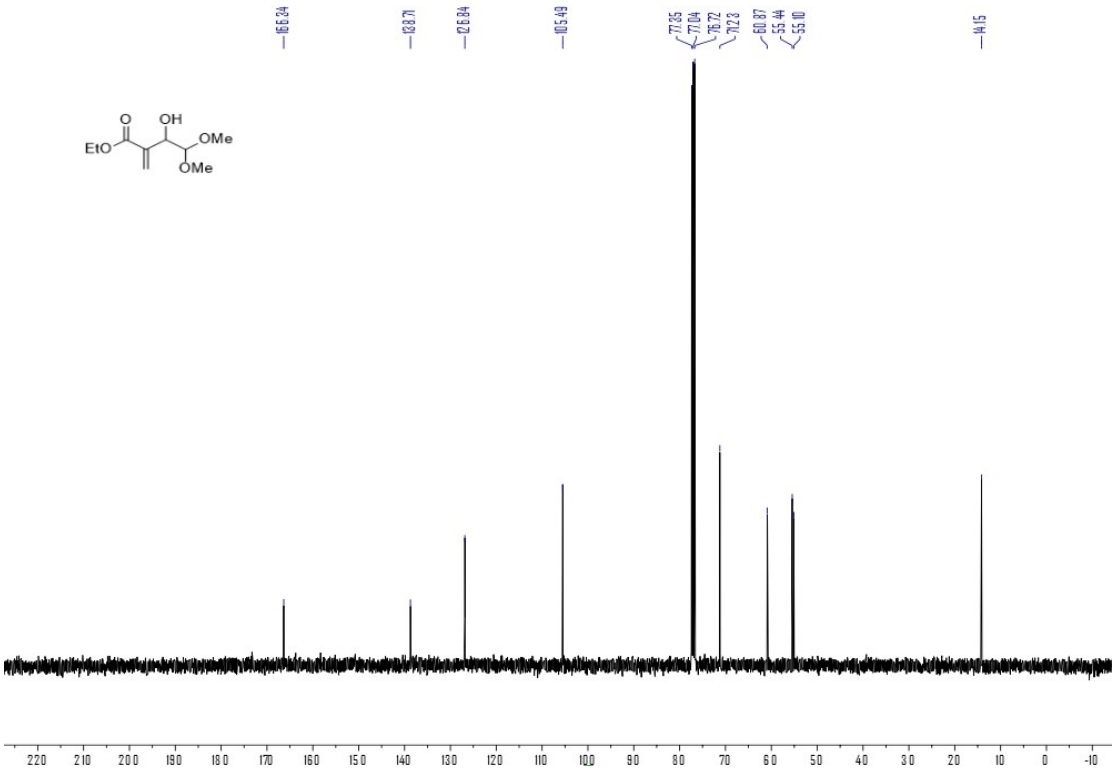
Benzyl 3-acetoxy-4,4-dimethoxy-2-methylenebutanoate (1b)



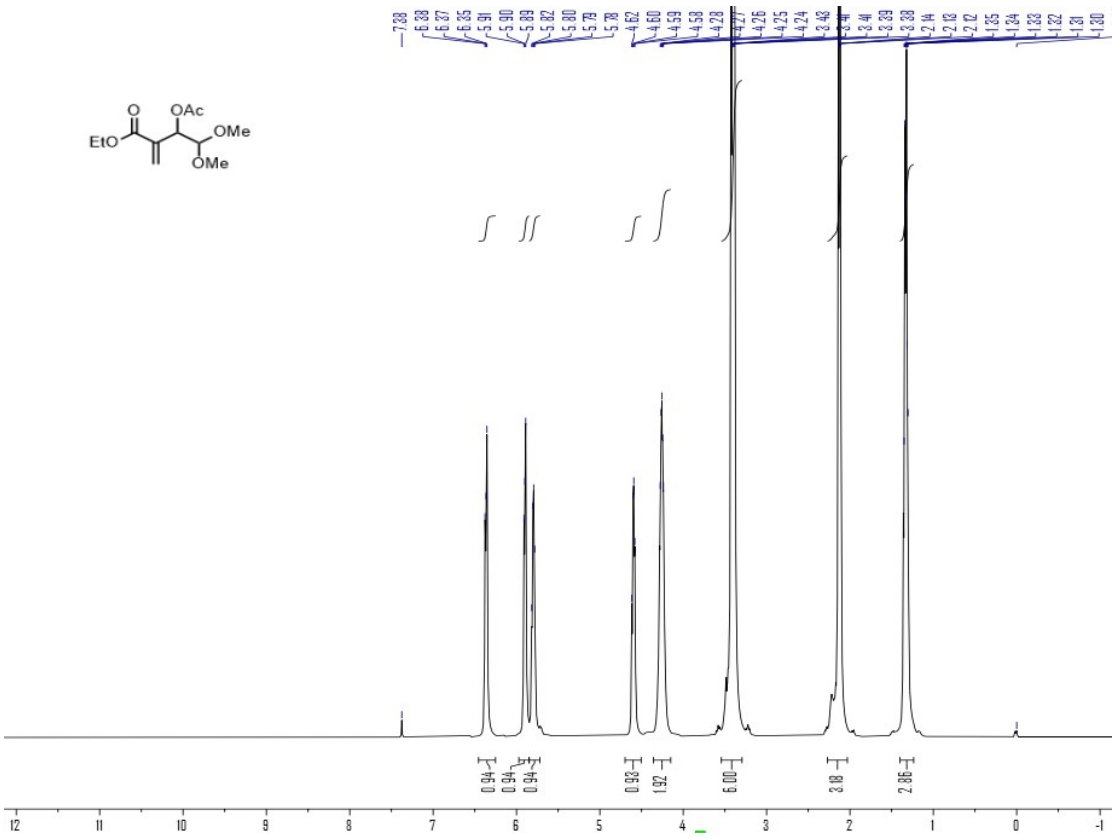


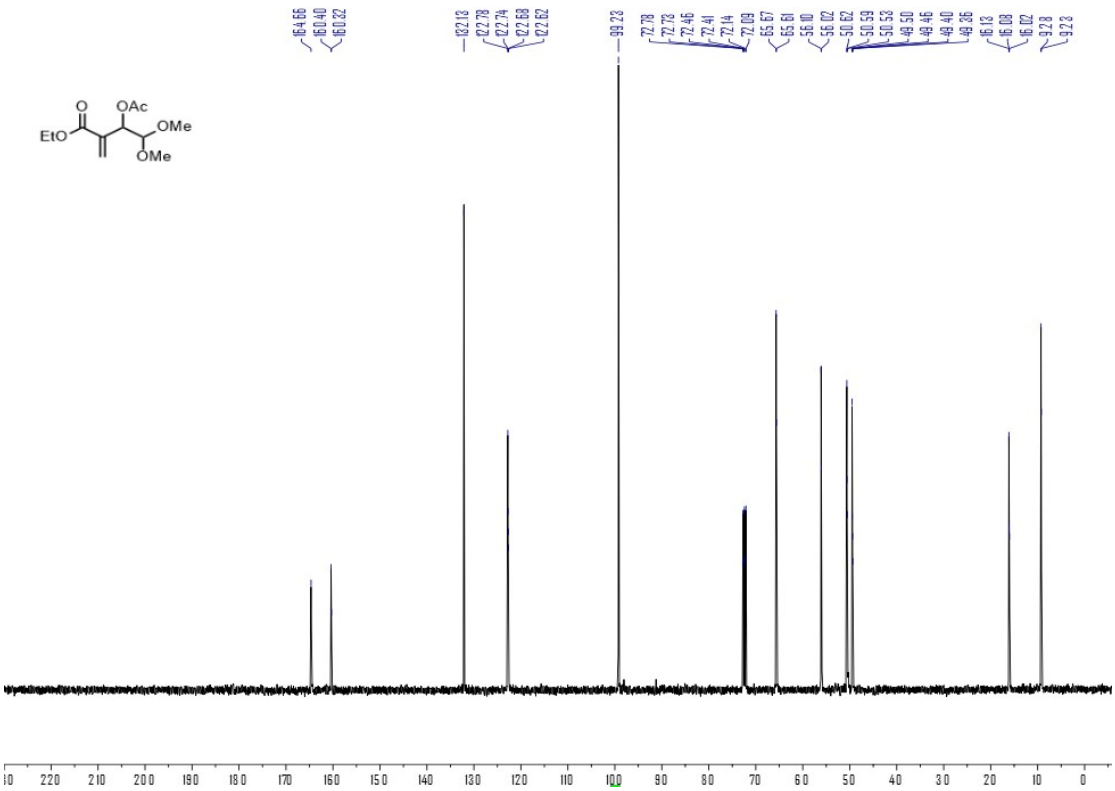
Ethyl 3-hydroxy-4,4-dimethoxy-2-methylenebutanoate



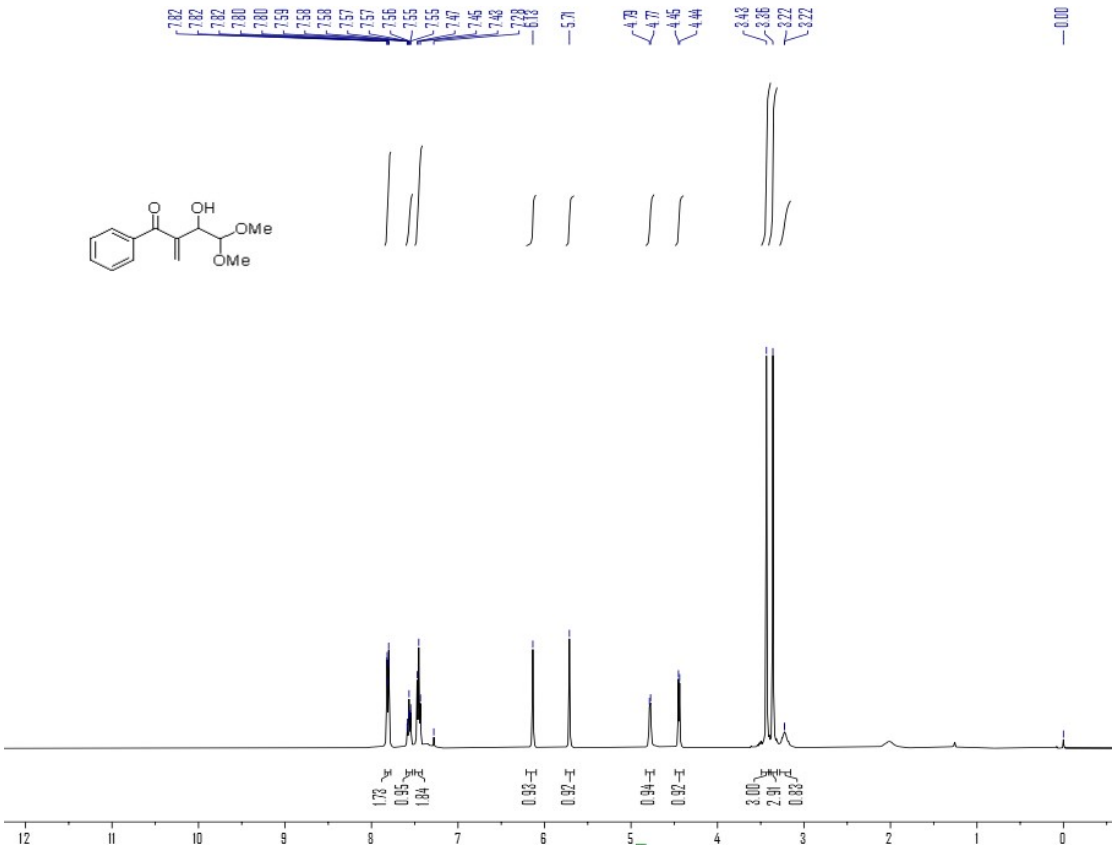


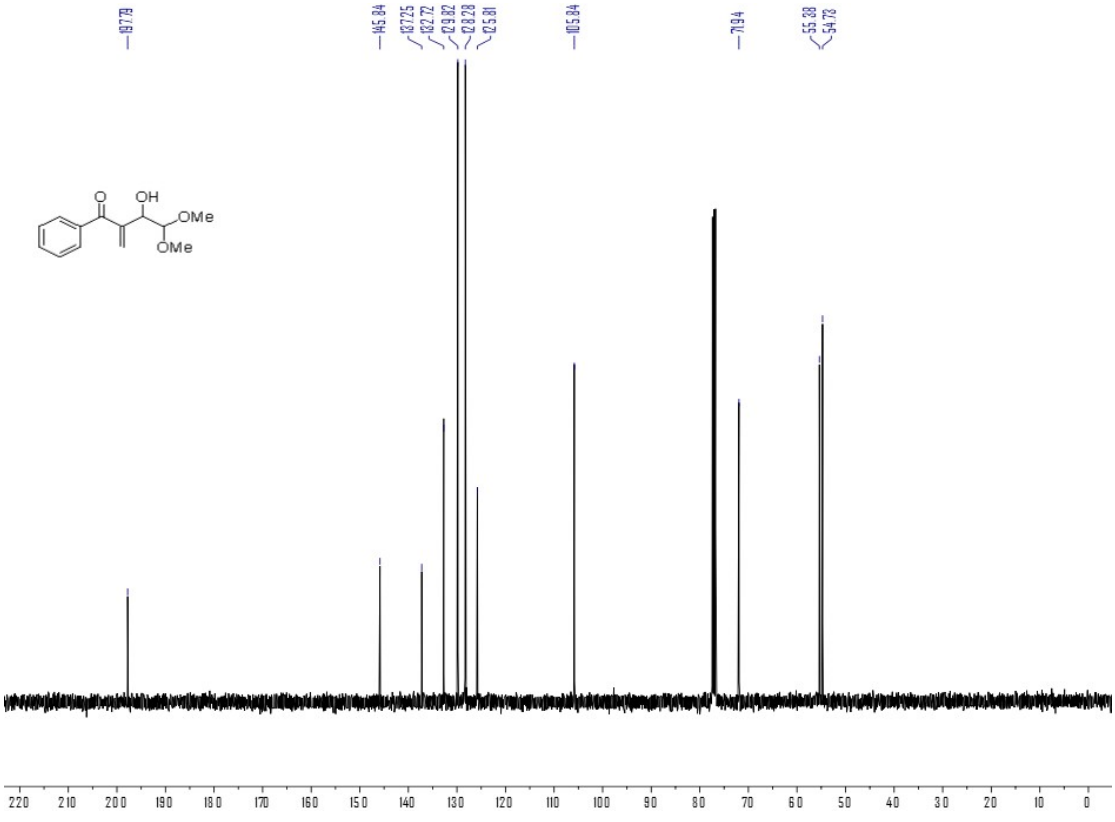
3-Benzoyl-1,1-dimethoxybut-3-en-2-yl acetate (1c)



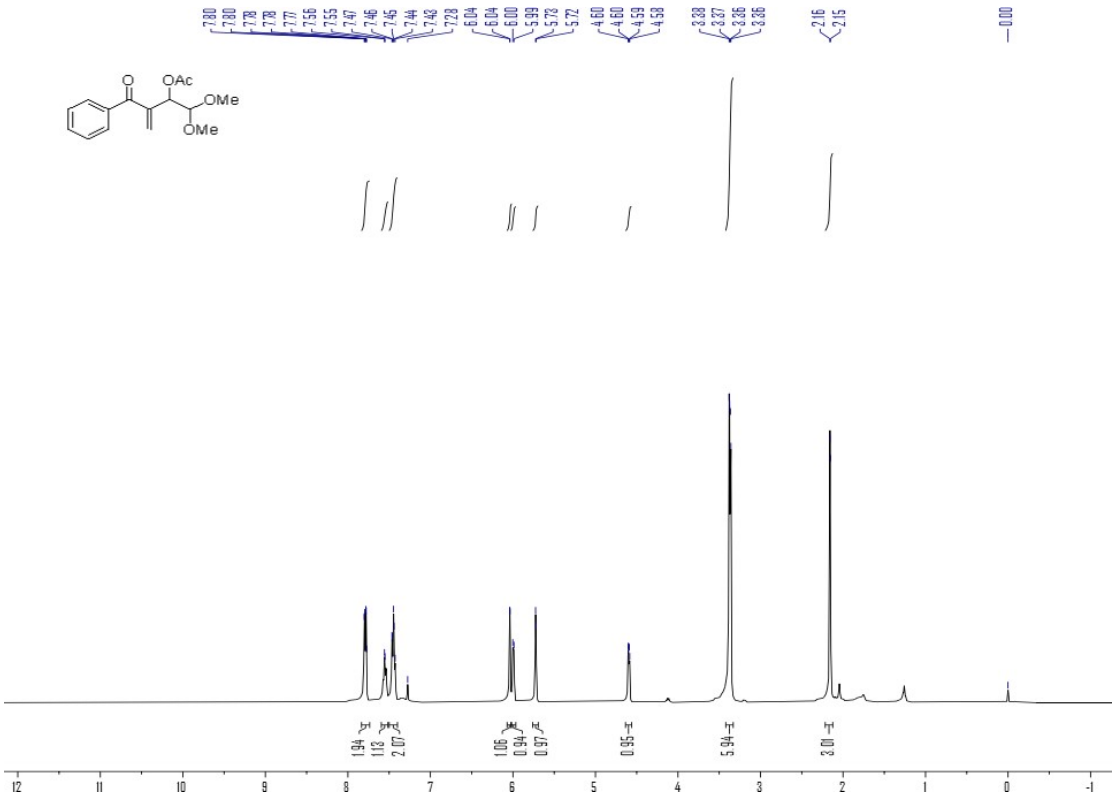


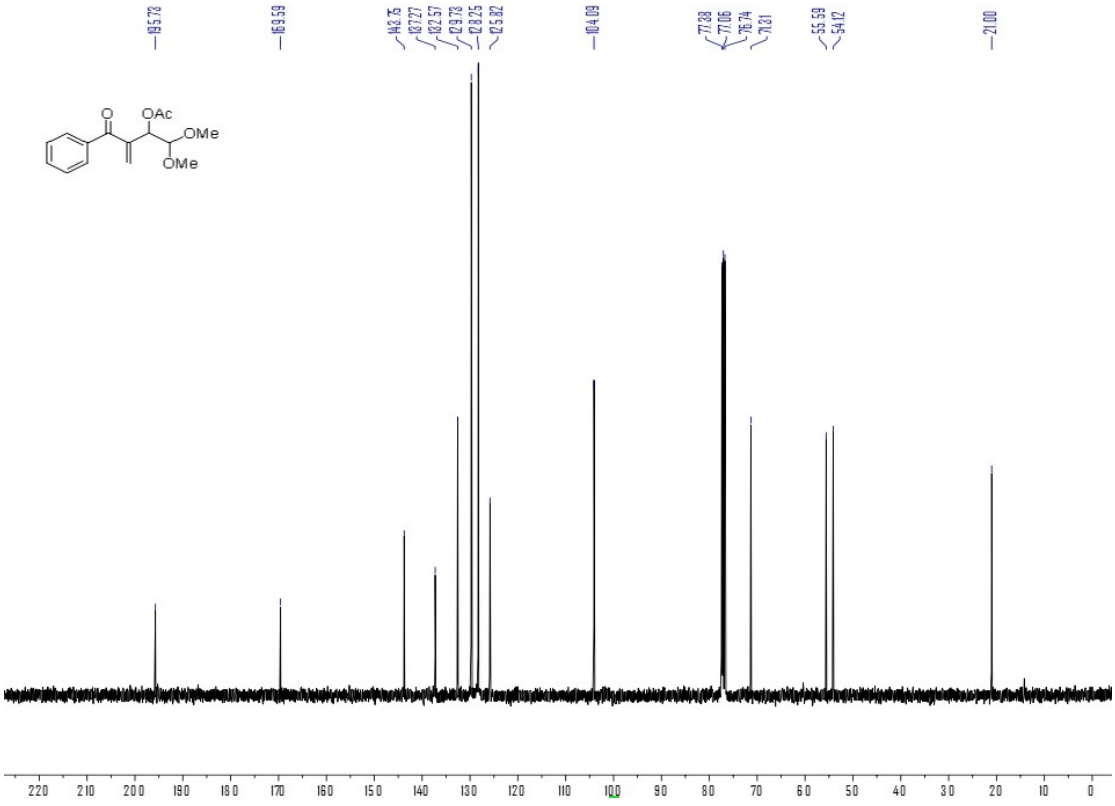
3-Hydroxy-4,4-dimethoxy-2-methylene-1-phenylbutan-1-one



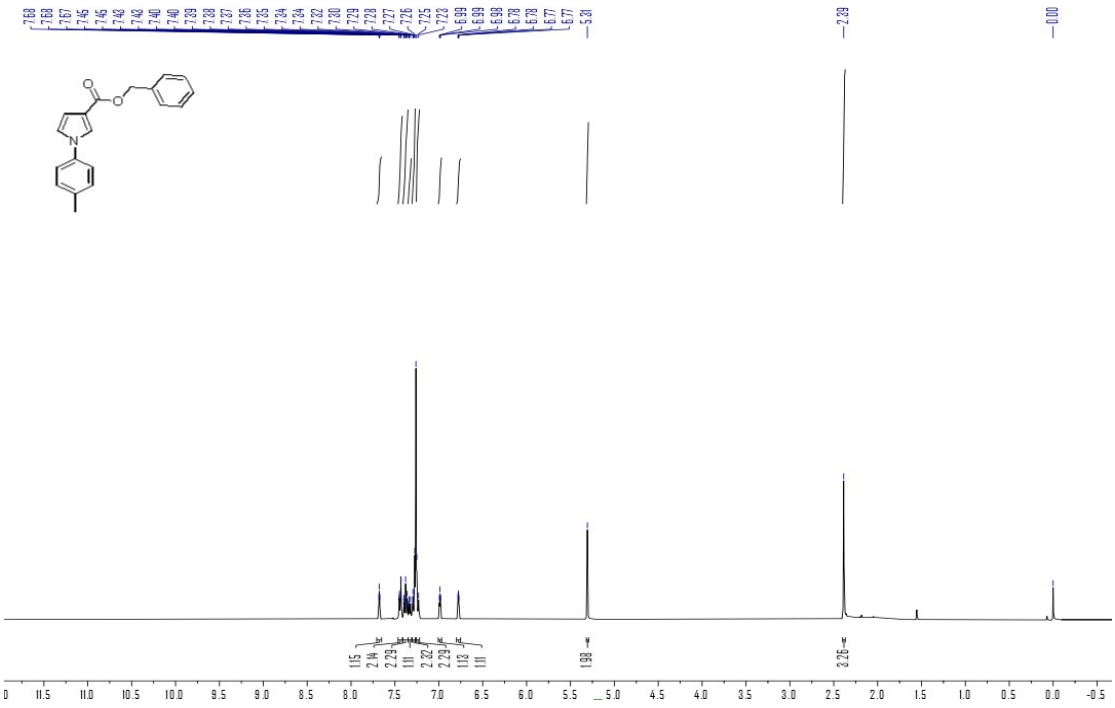


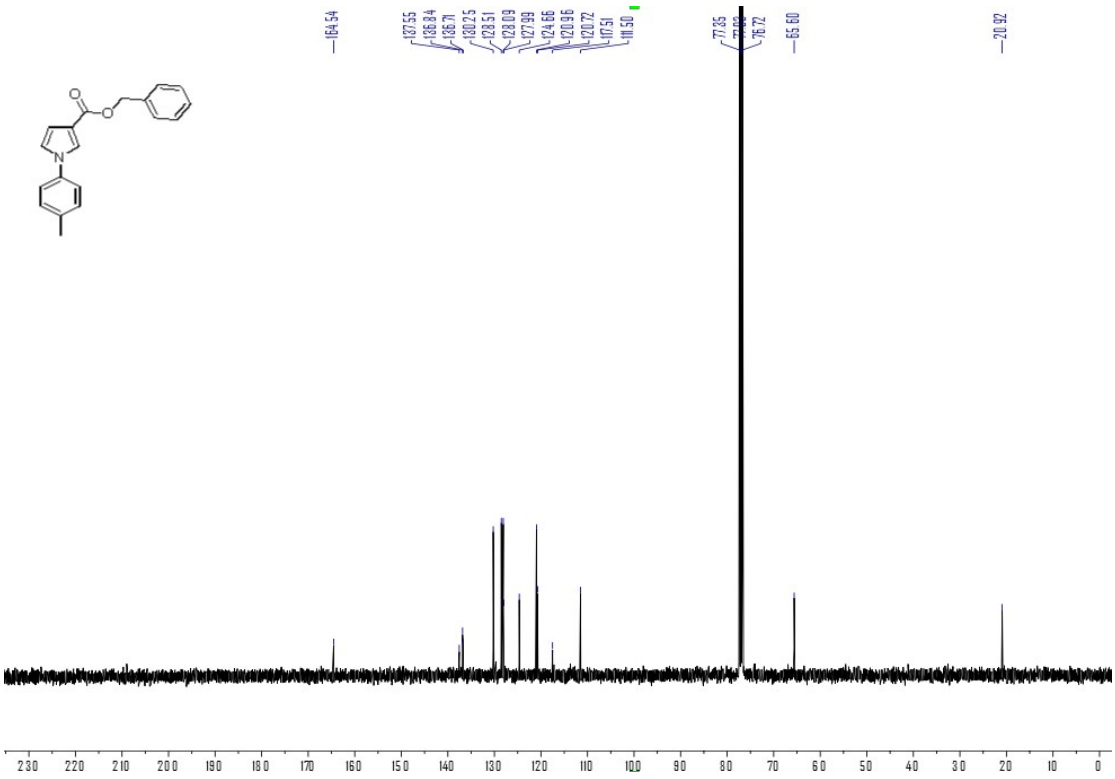
3-Benzoyl-1,1-dimethoxybut-3-en-2-yl acetate



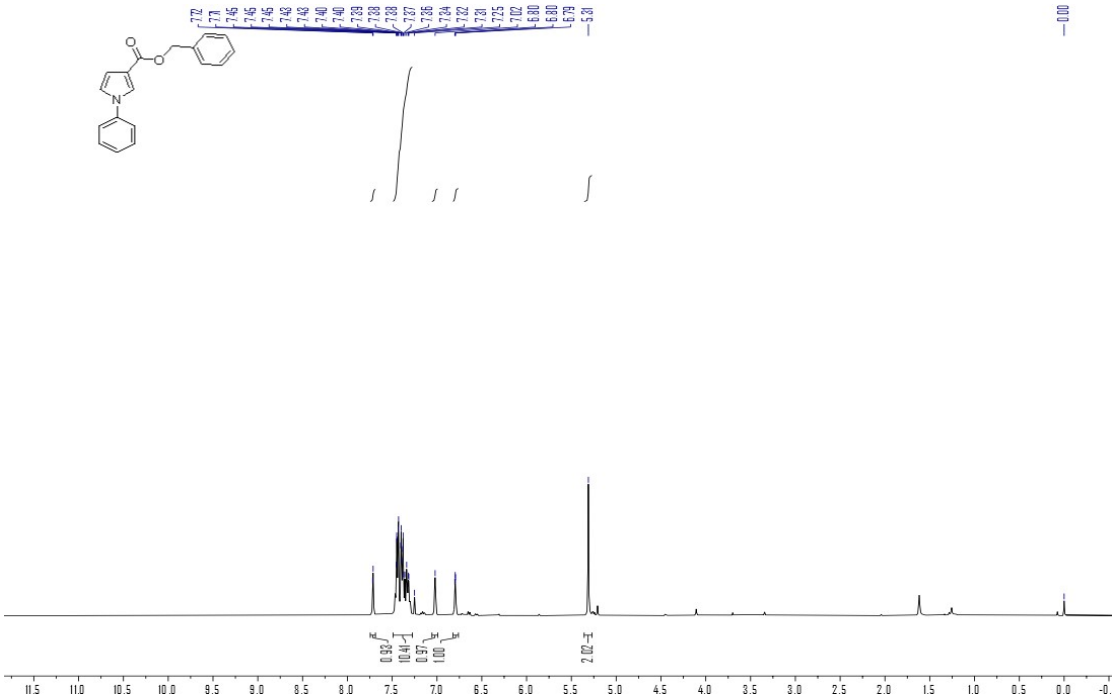


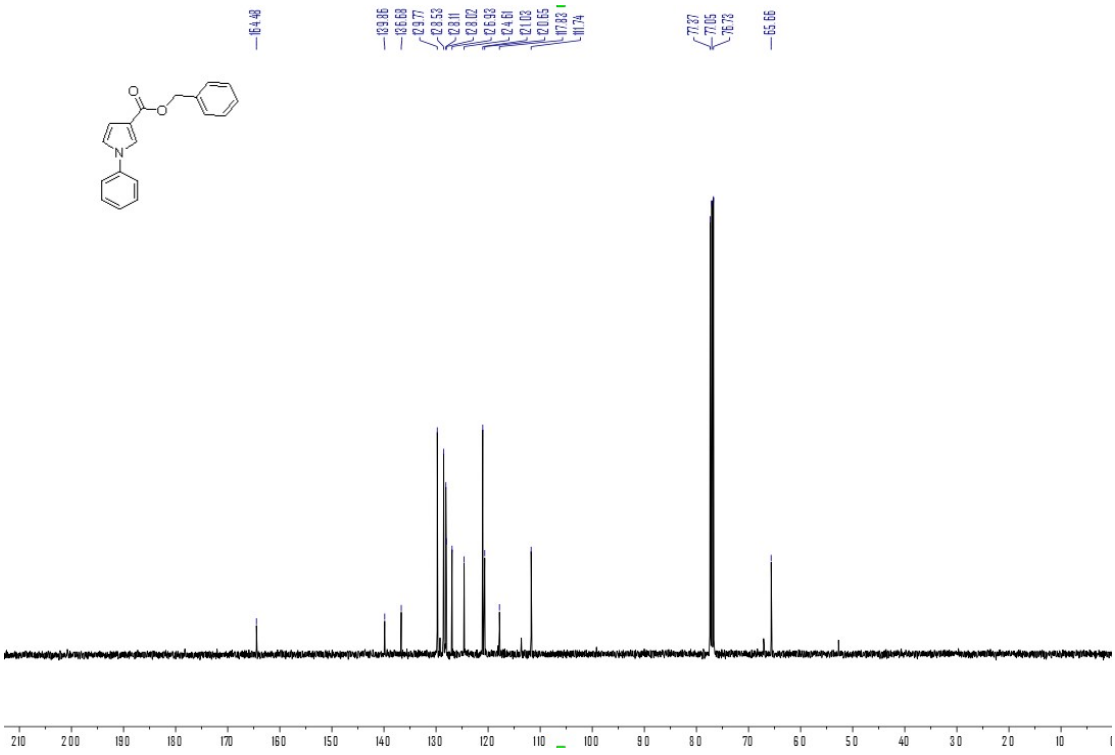
Benzyl 1-(p-tolyl)-1*H*-pyrrole-3-carboxylate (3a)



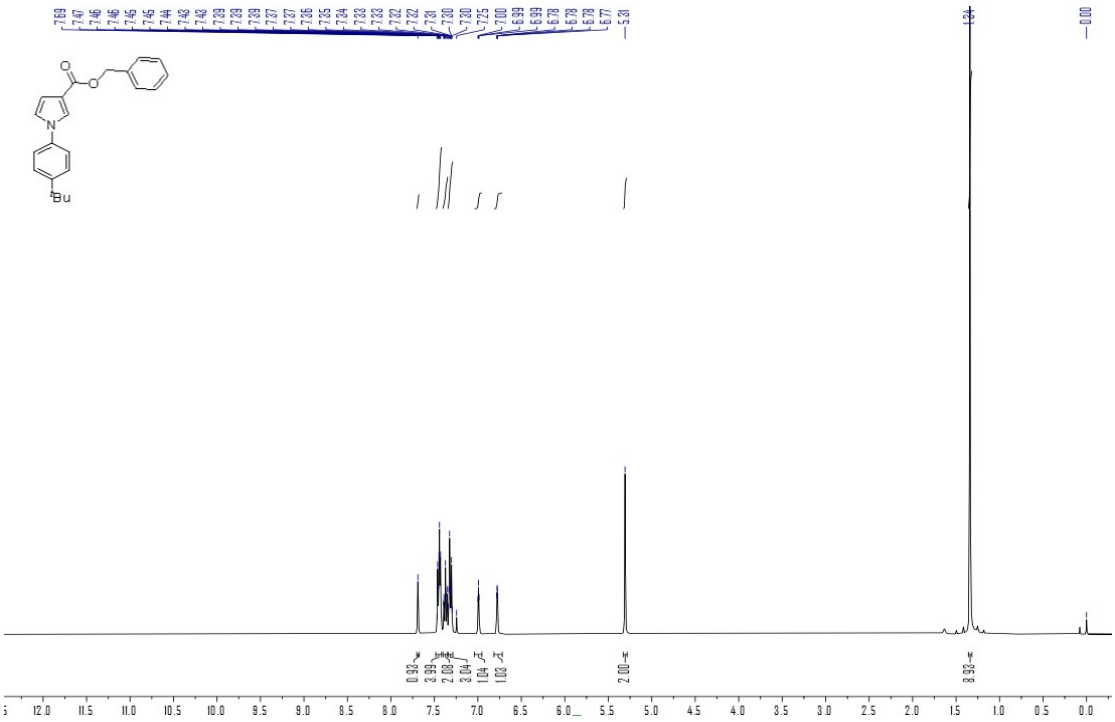


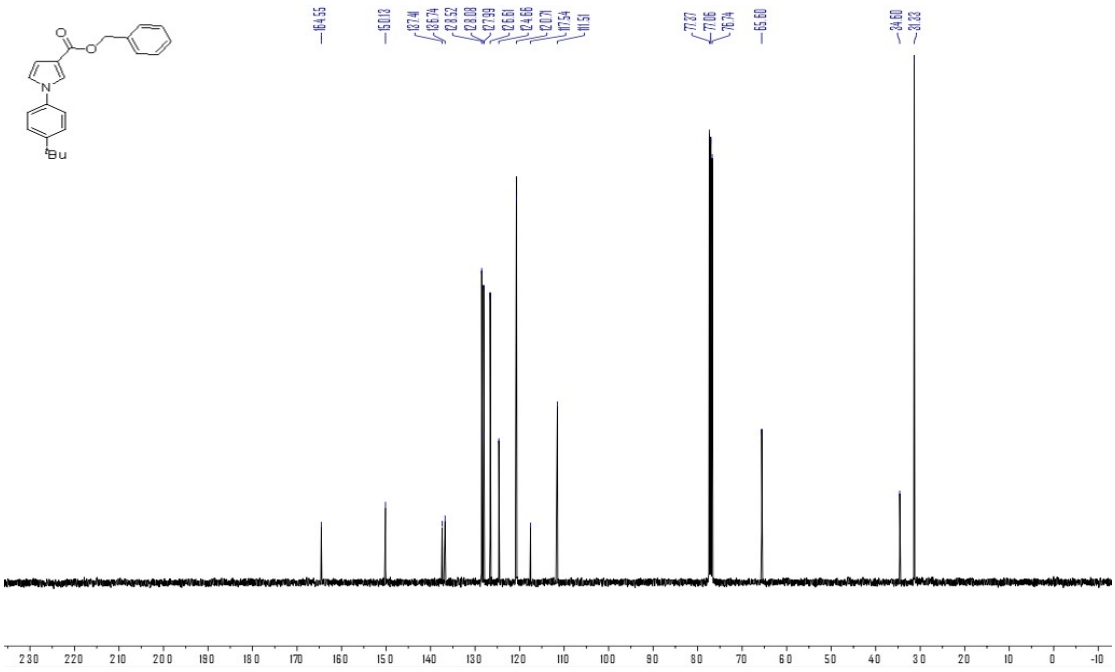
Benzyl 1-phenyl-1*H*-pyrrole-3-carboxylate (3b)



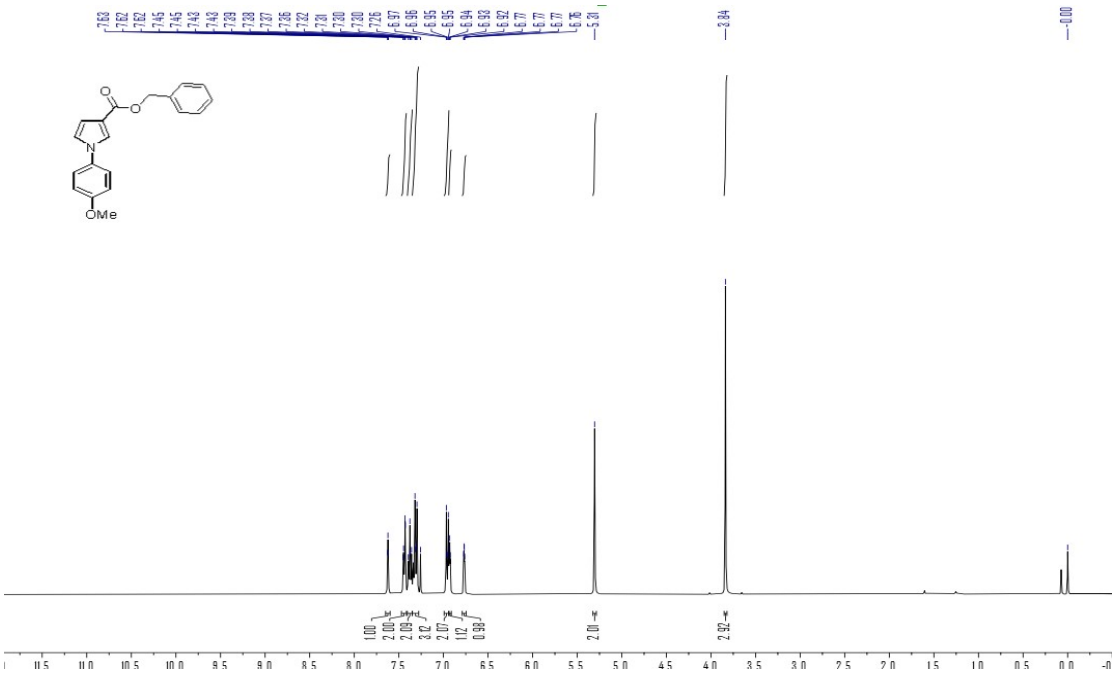


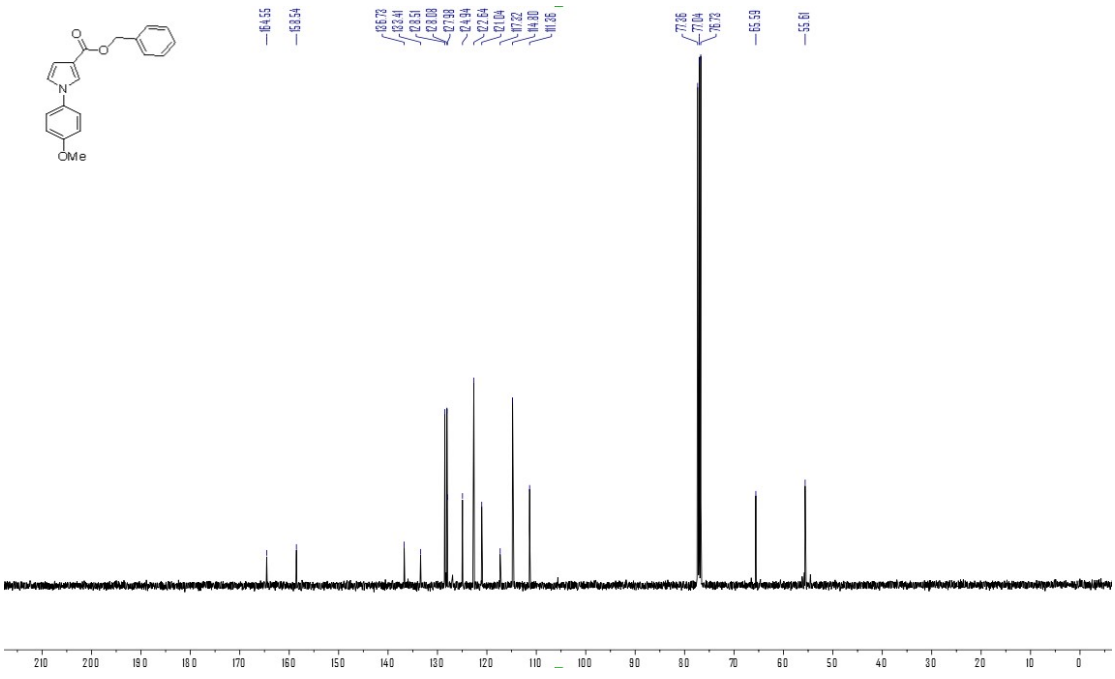
Benzyl 1-(4-(tert-butyl)phenyl)-1H-pyrrole-3-carboxylate (3c)



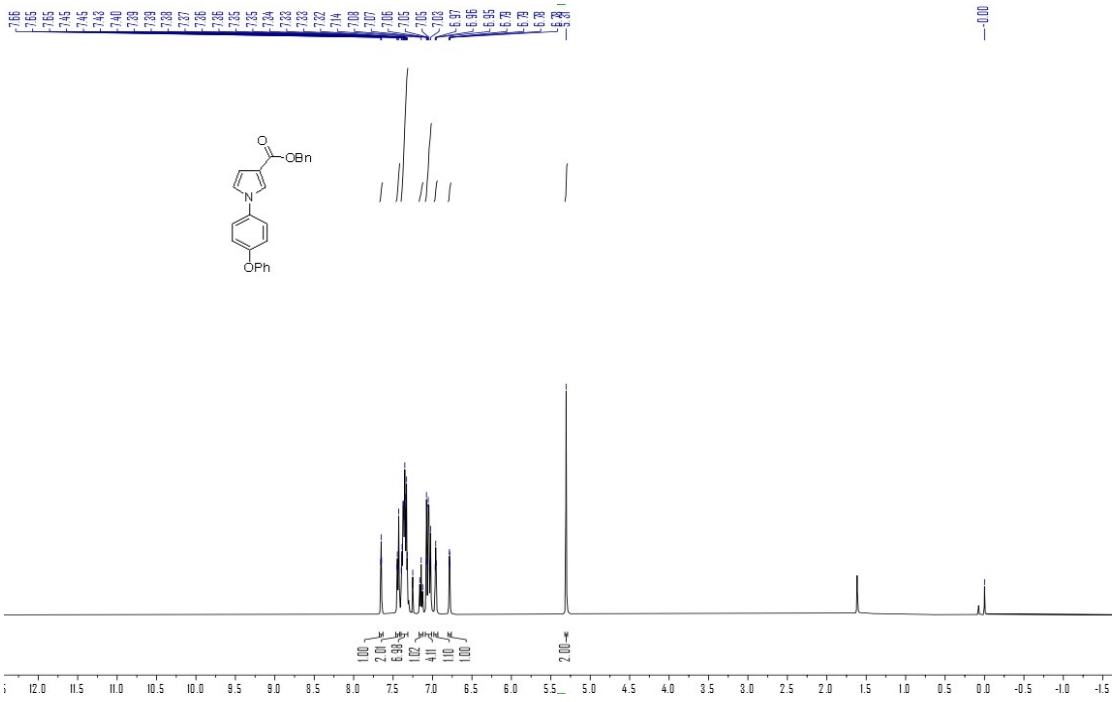


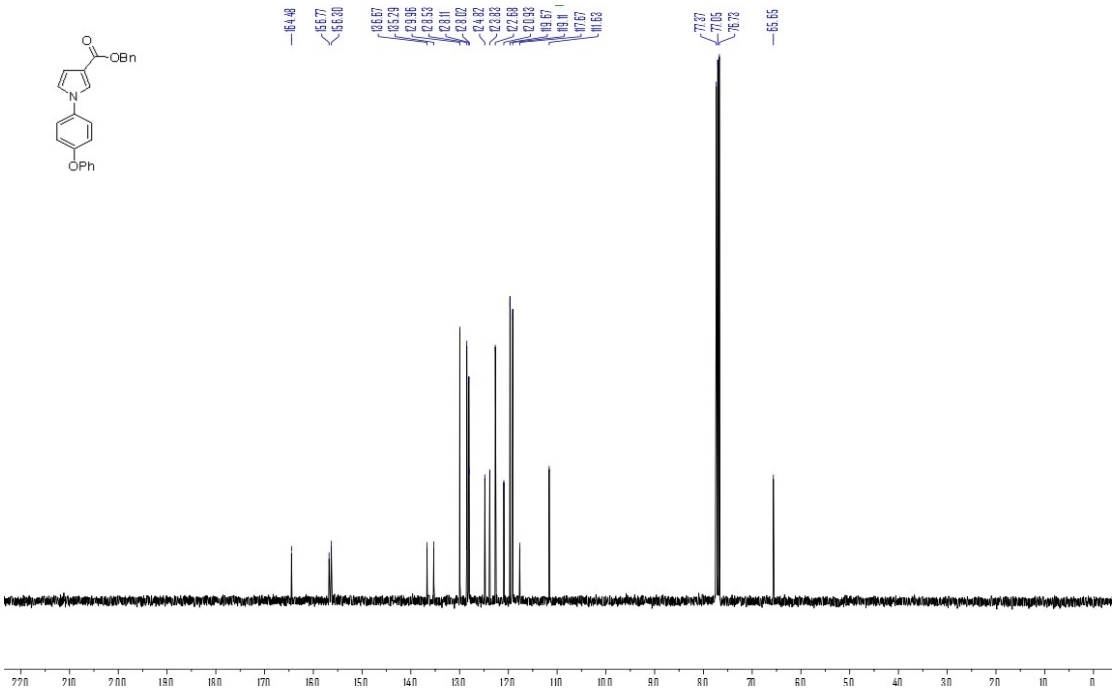
Benzyl 1-(4-methoxyphenyl)-1*H*-pyrrole-3-carboxylate (3d)



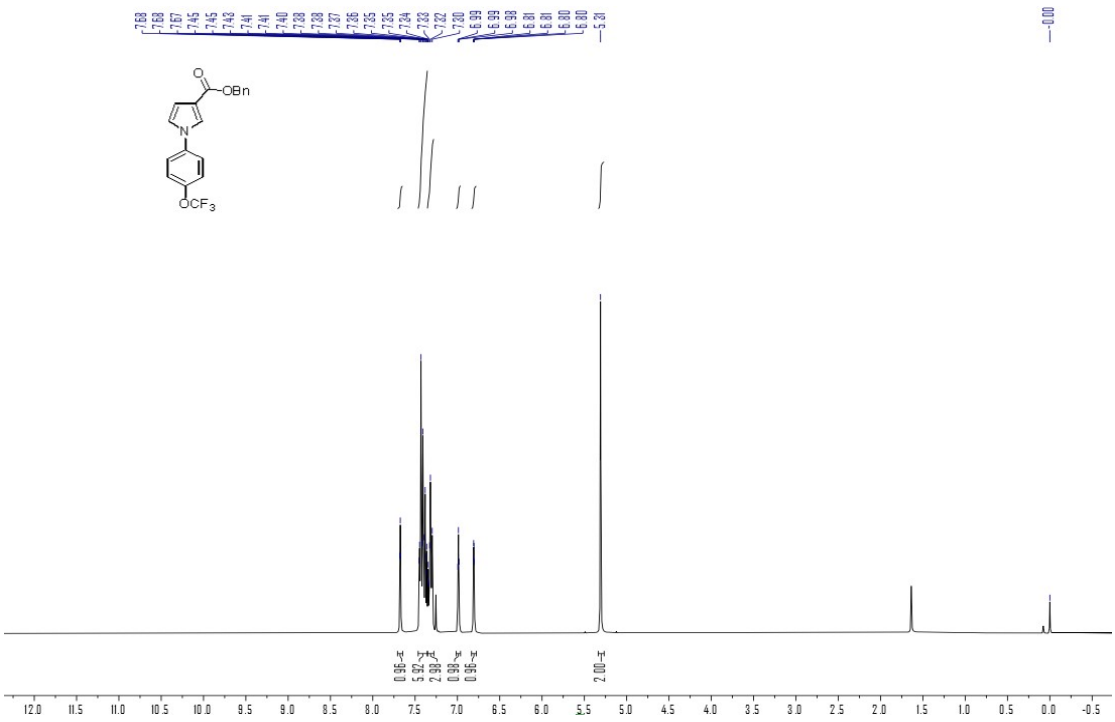


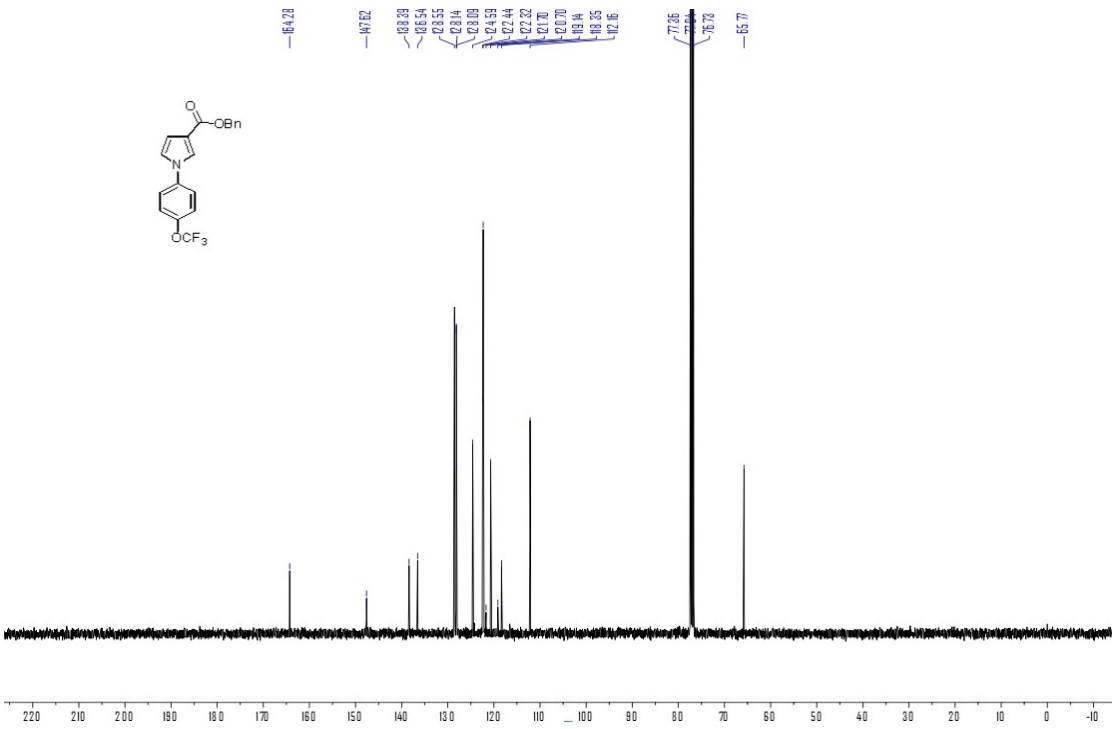
Benzyl 1-(4-phenoxyphenyl)-1*H*-pyrrole-3-carboxylate (3e)

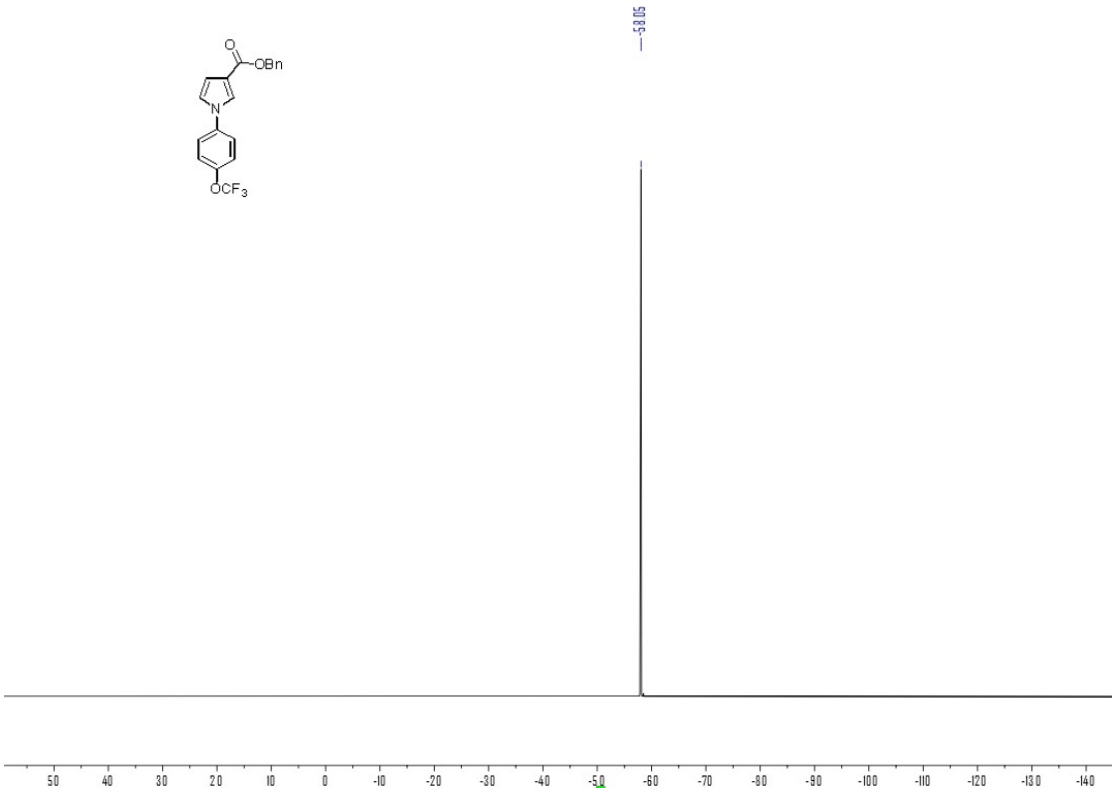




Benzyl 1-(4-(trifluoromethoxy)phenyl)-1*H*-pyrrole-3-carboxylate (3f)



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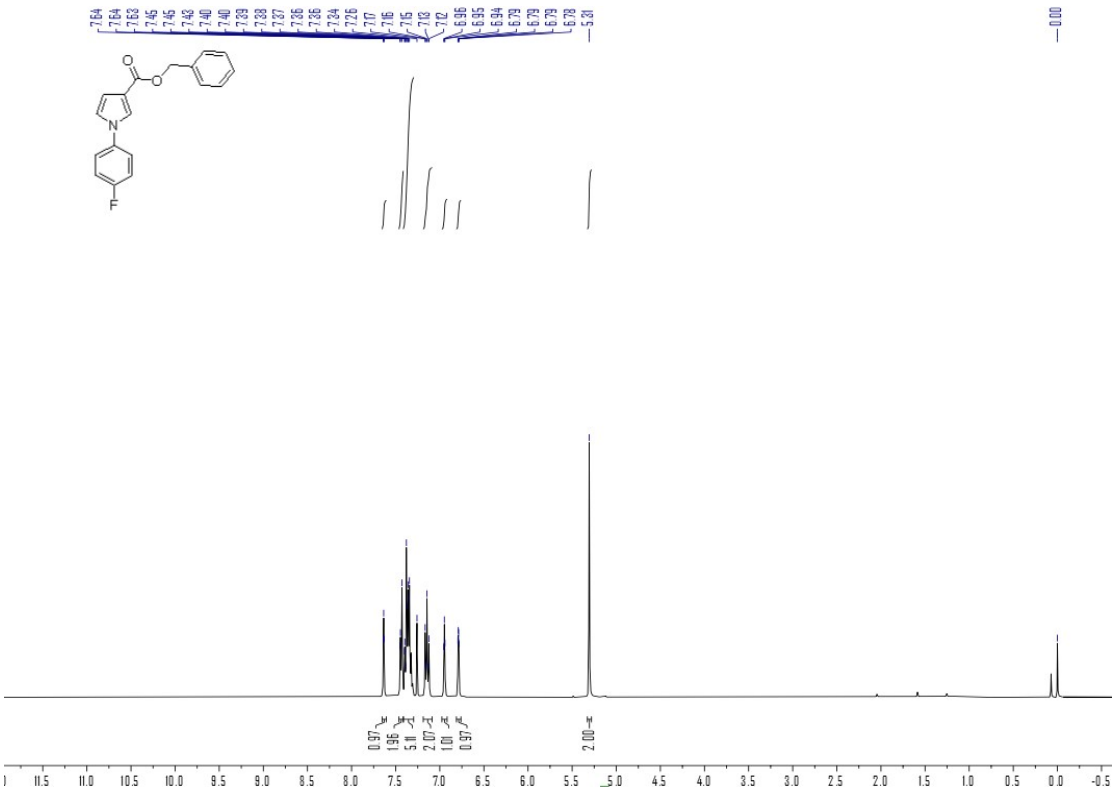
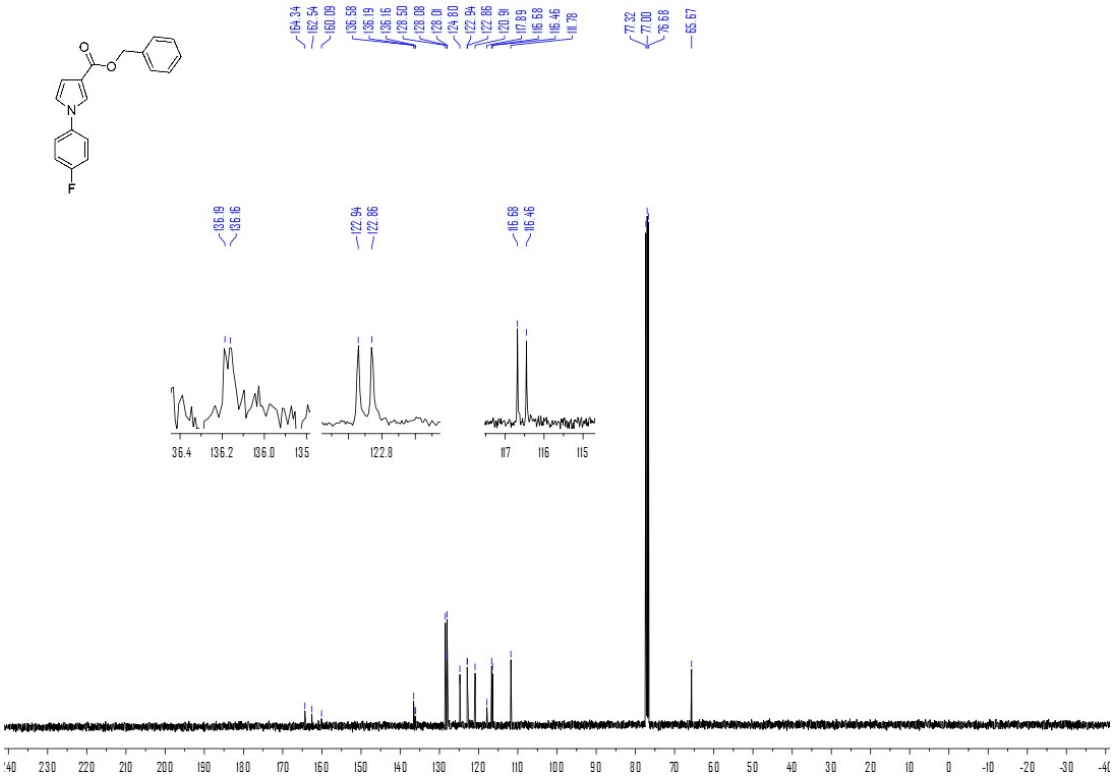
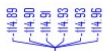
Benzyl 1-(4-fluorophenyl)-1*H*-pyrrole-3-carboxylate (3g)



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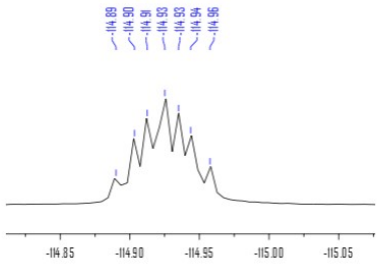
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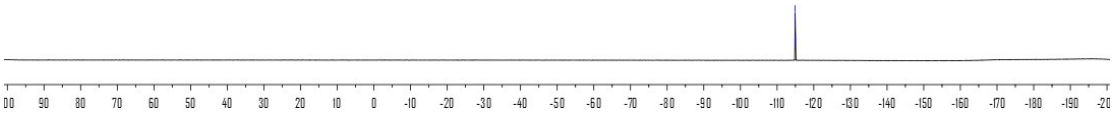
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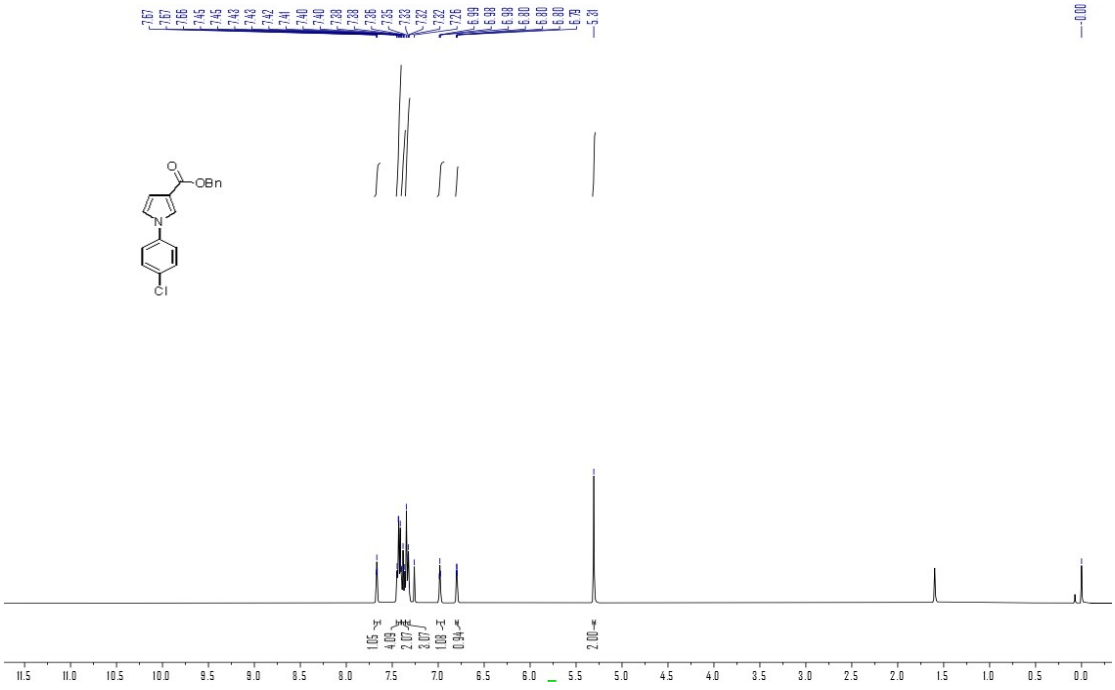
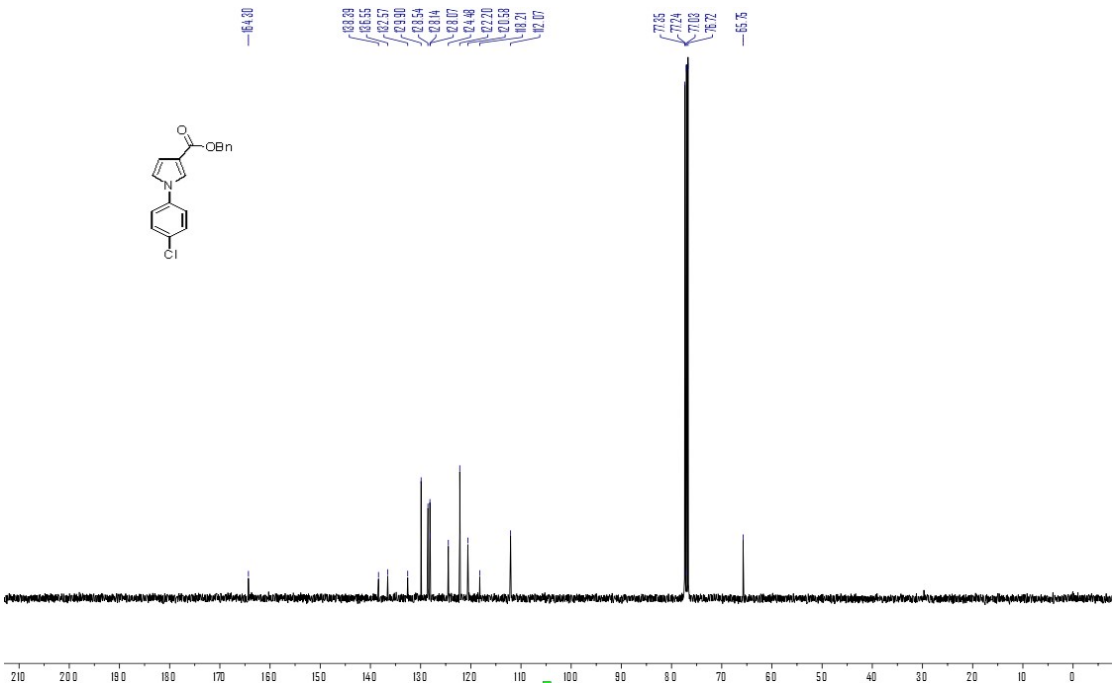
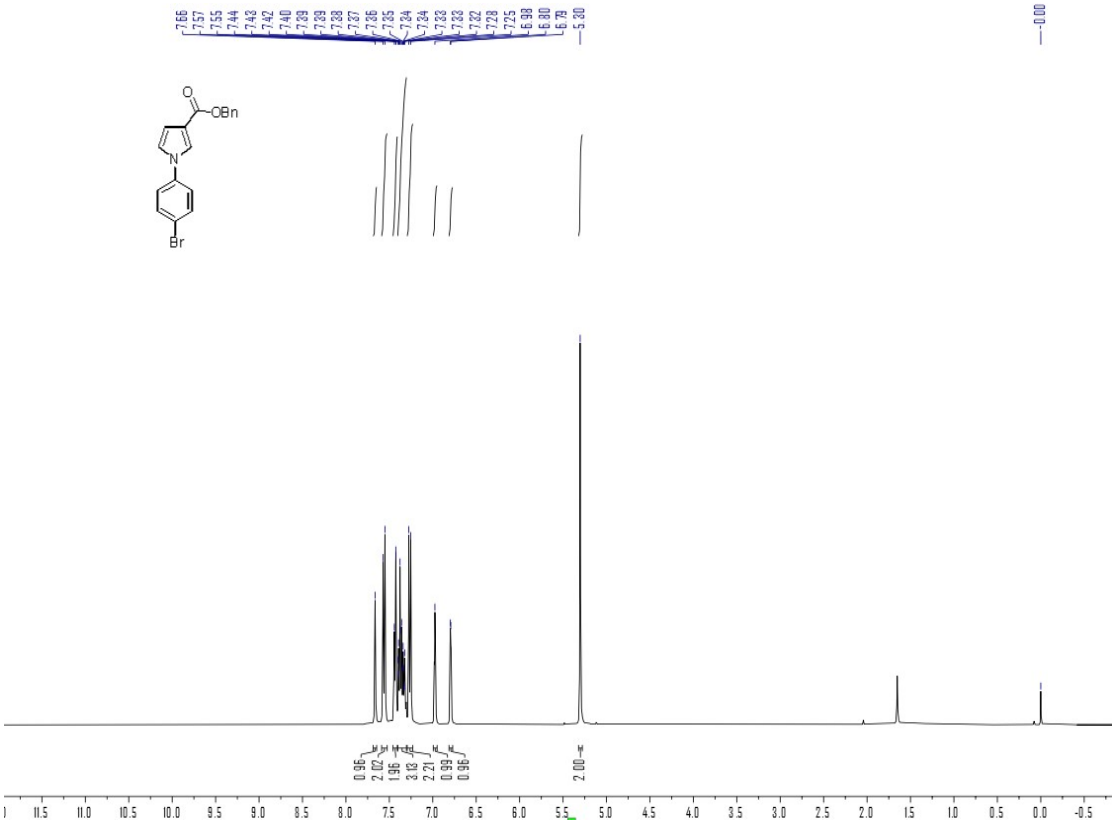
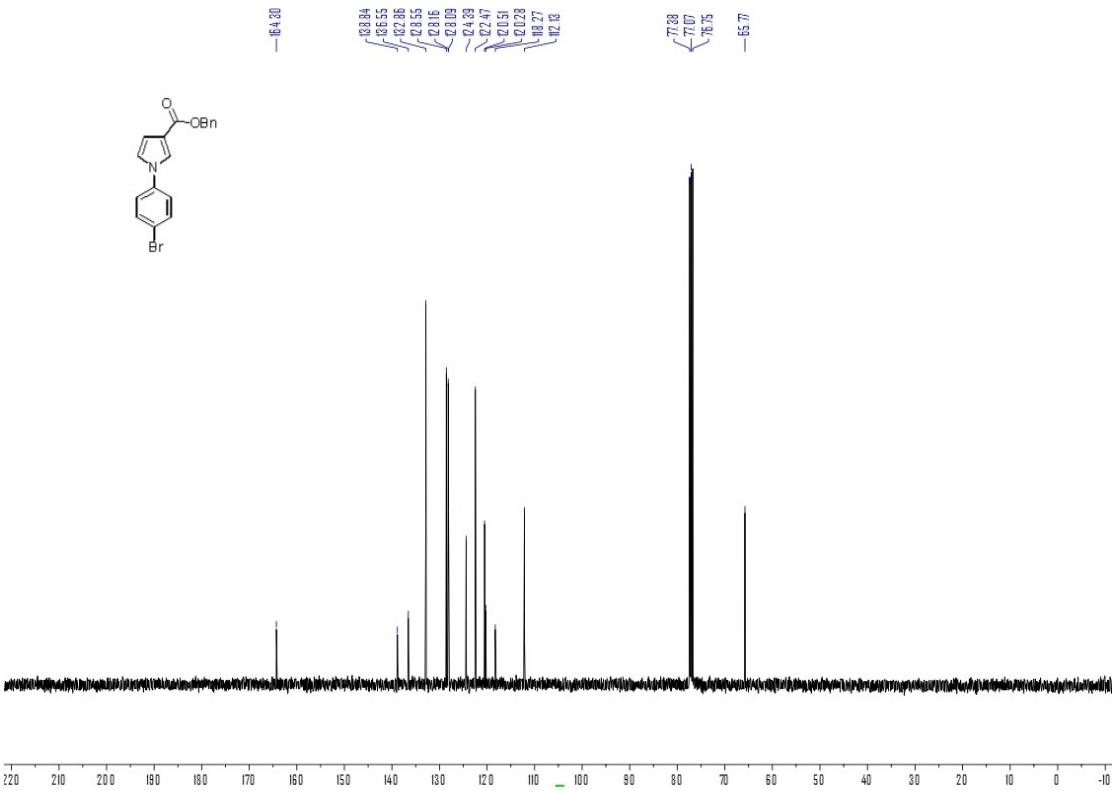
Benzyl 1-(4-chlorophenyl)-1*H*-pyrrole-3-carboxylate (3h)



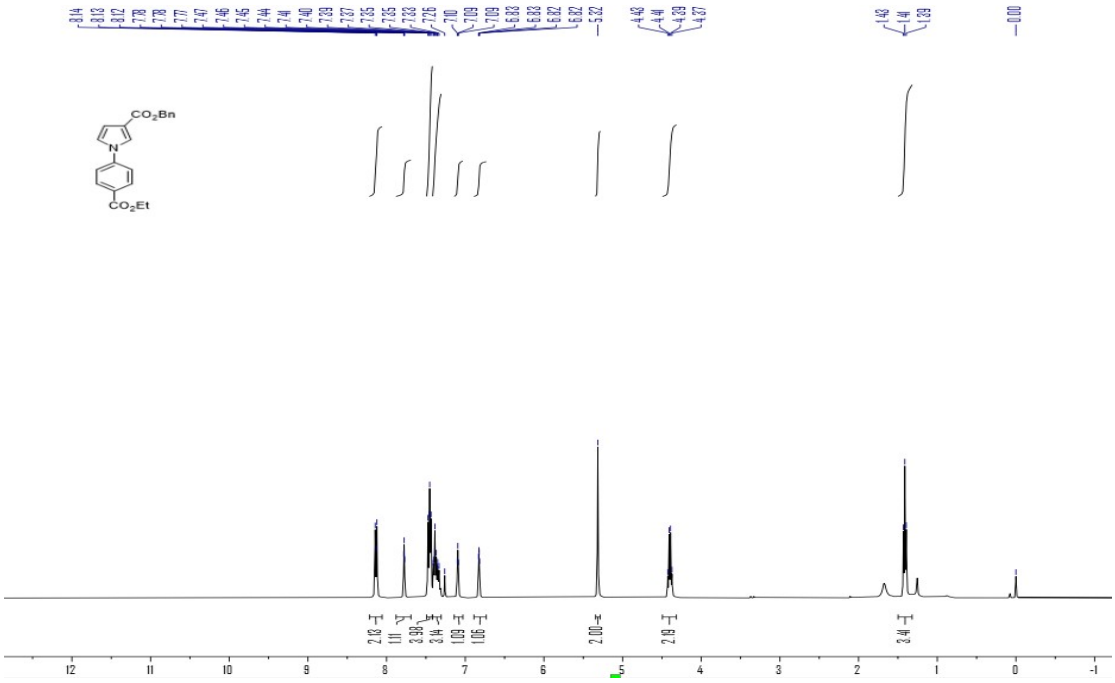


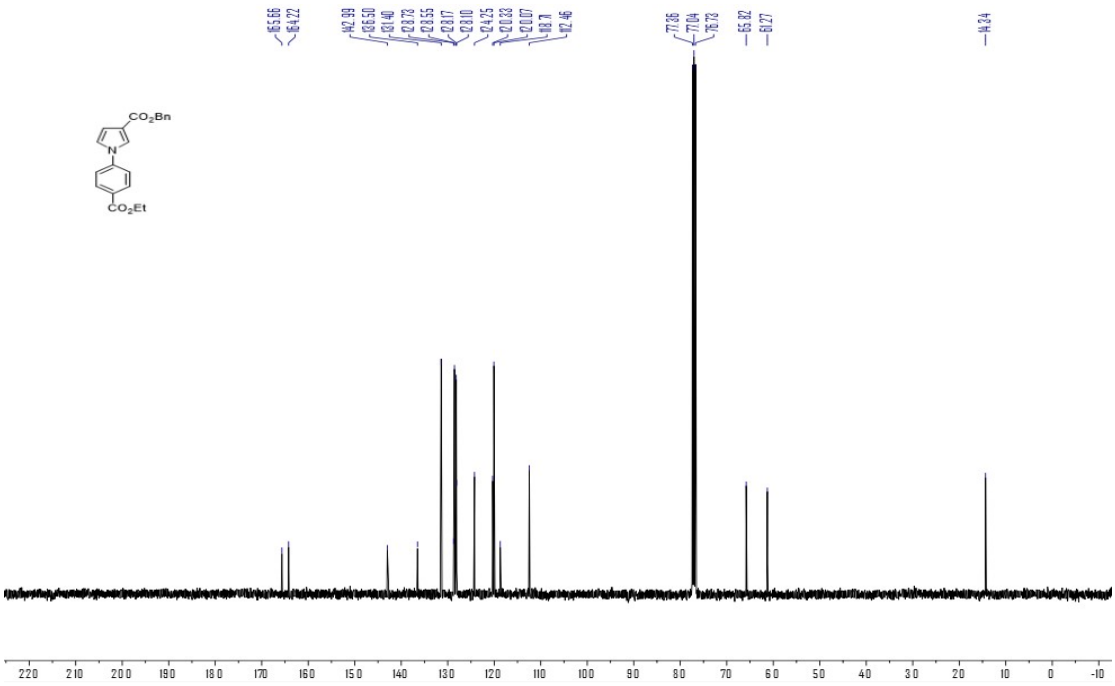
Benzyl 1-(4-bromophenyl)-1*H*-pyrrole-3-carboxylate (3i)



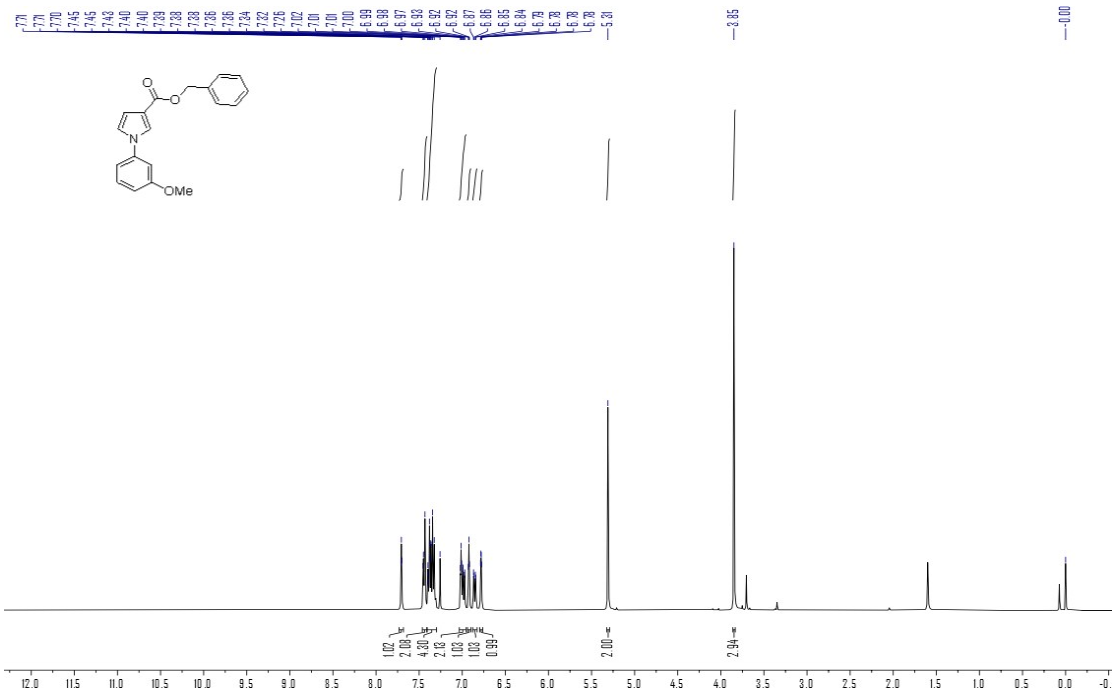


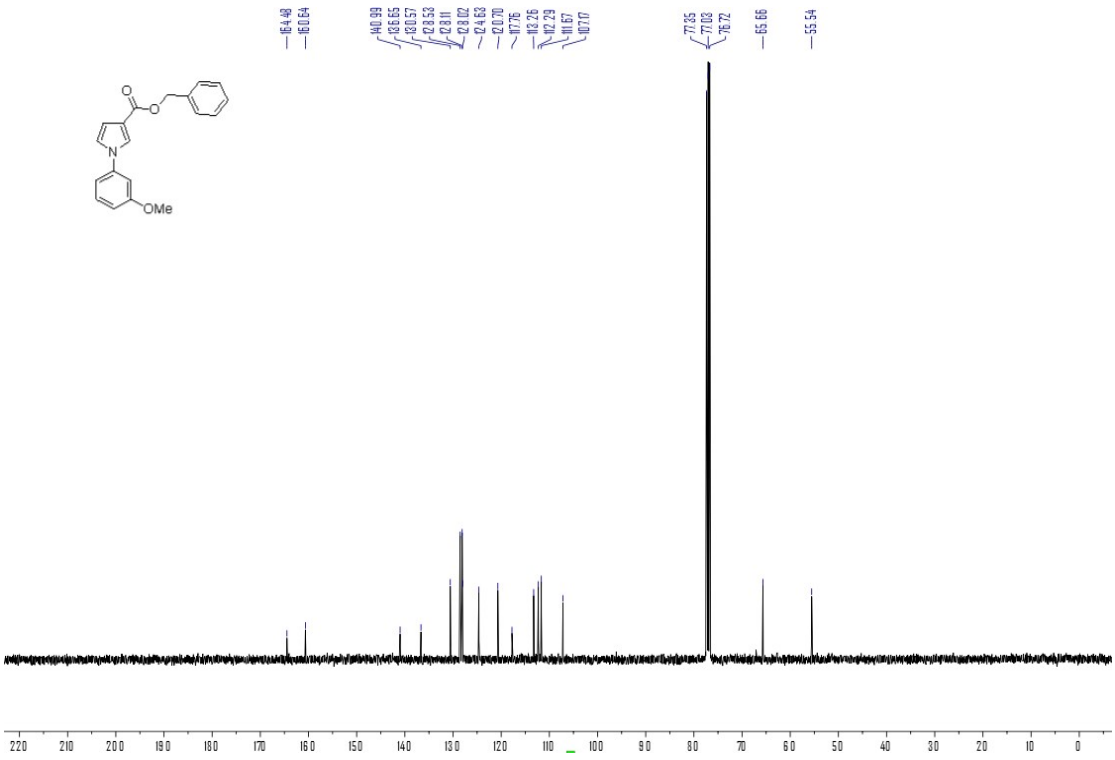
Benzyl 1-(4-(ethoxycarbonyl)phenyl)-1*H*-pyrrole-3-carboxylate (3j)



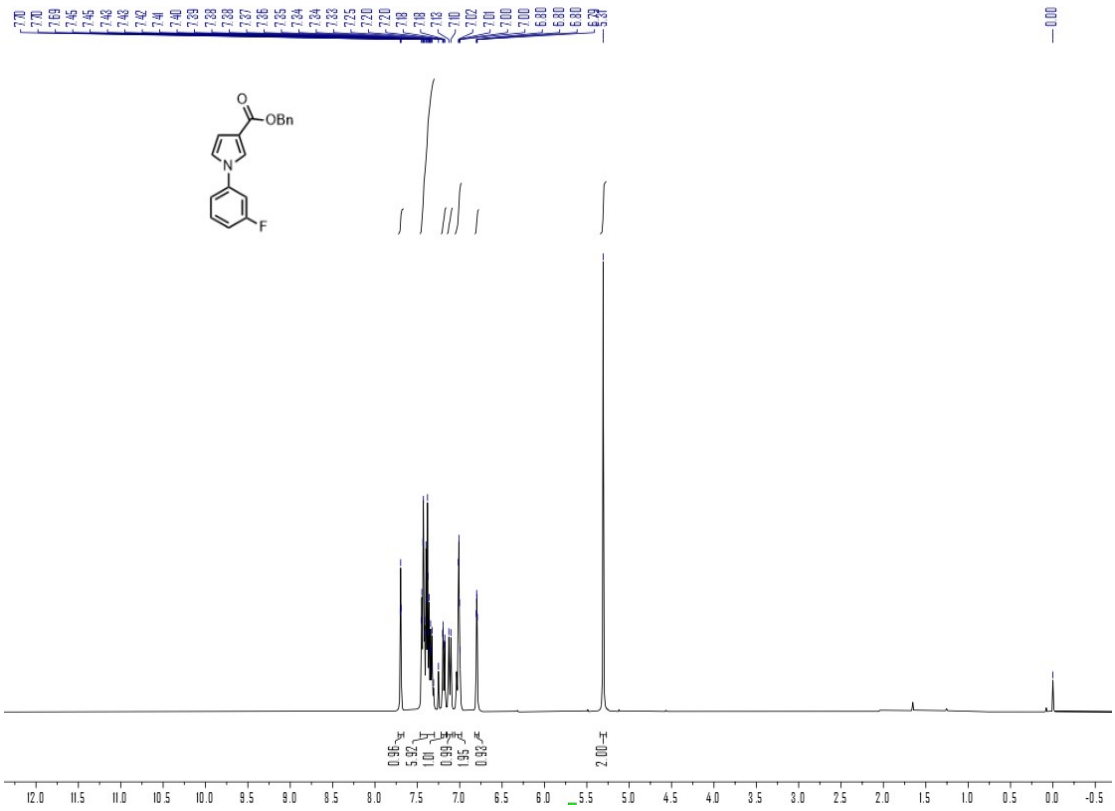


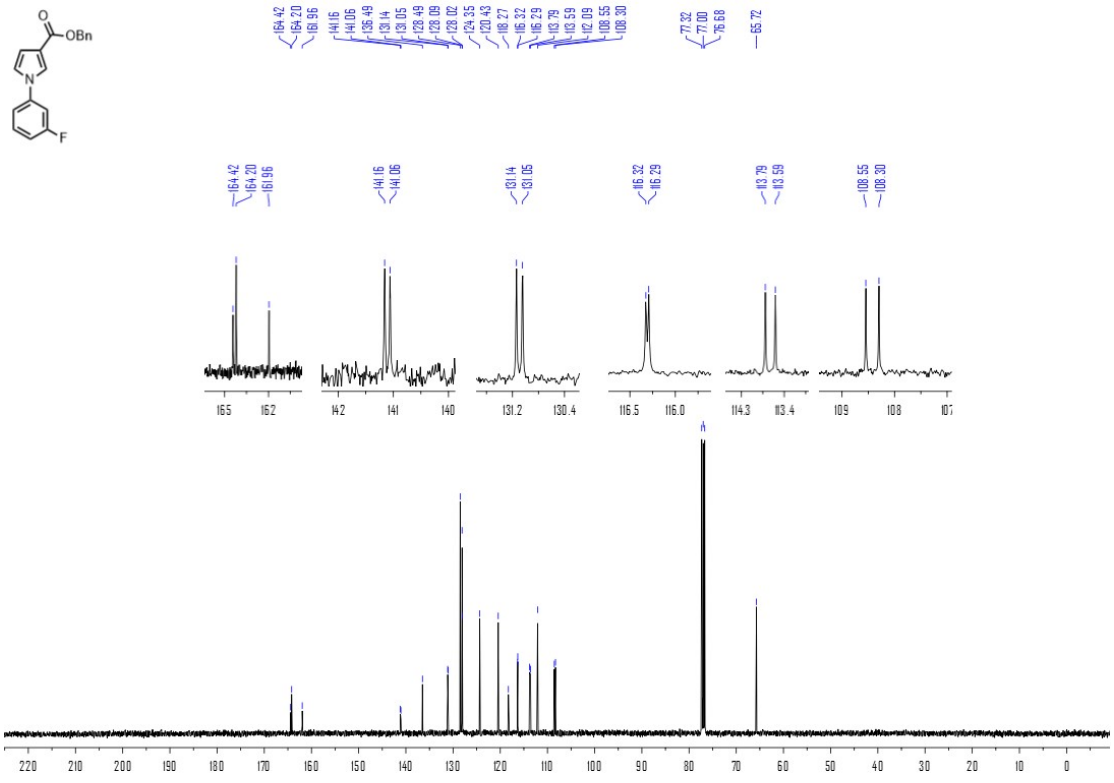
Benzyl 1-(3-methoxyphenyl)-1*H*-pyrrole-3-carboxylate (3k)

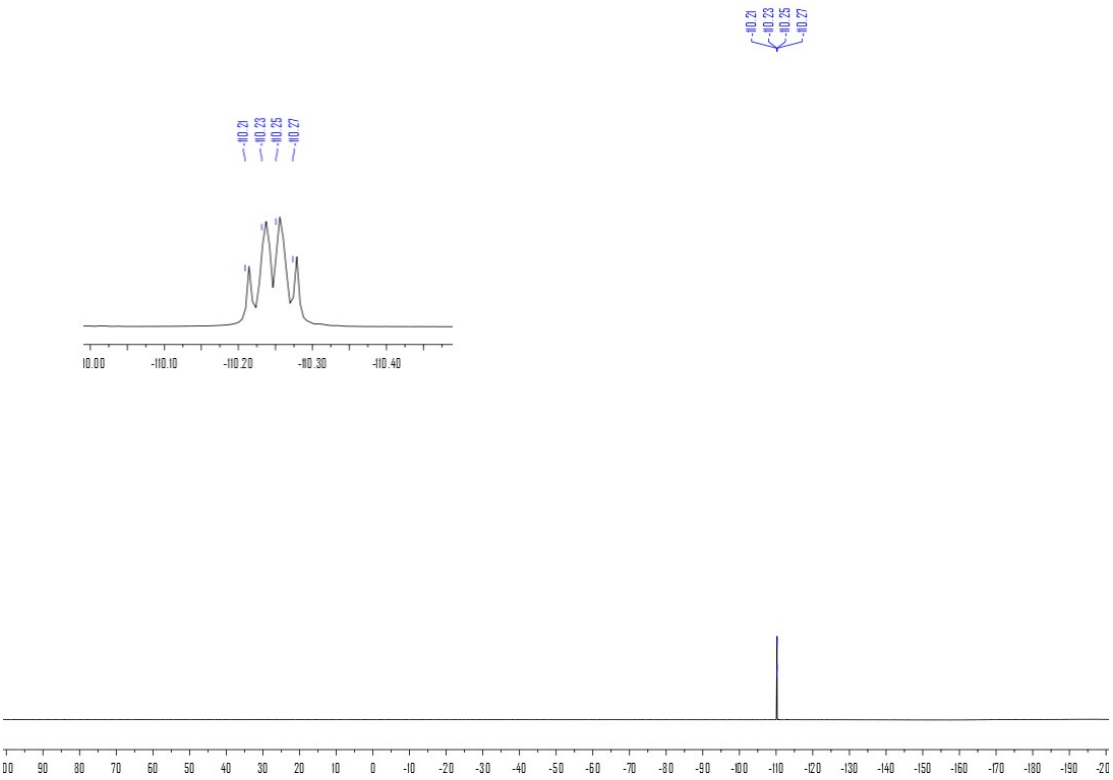




Benzyl 1-(3-fluorophenyl)-1*H*-pyrrole-3-carboxylate (3l)



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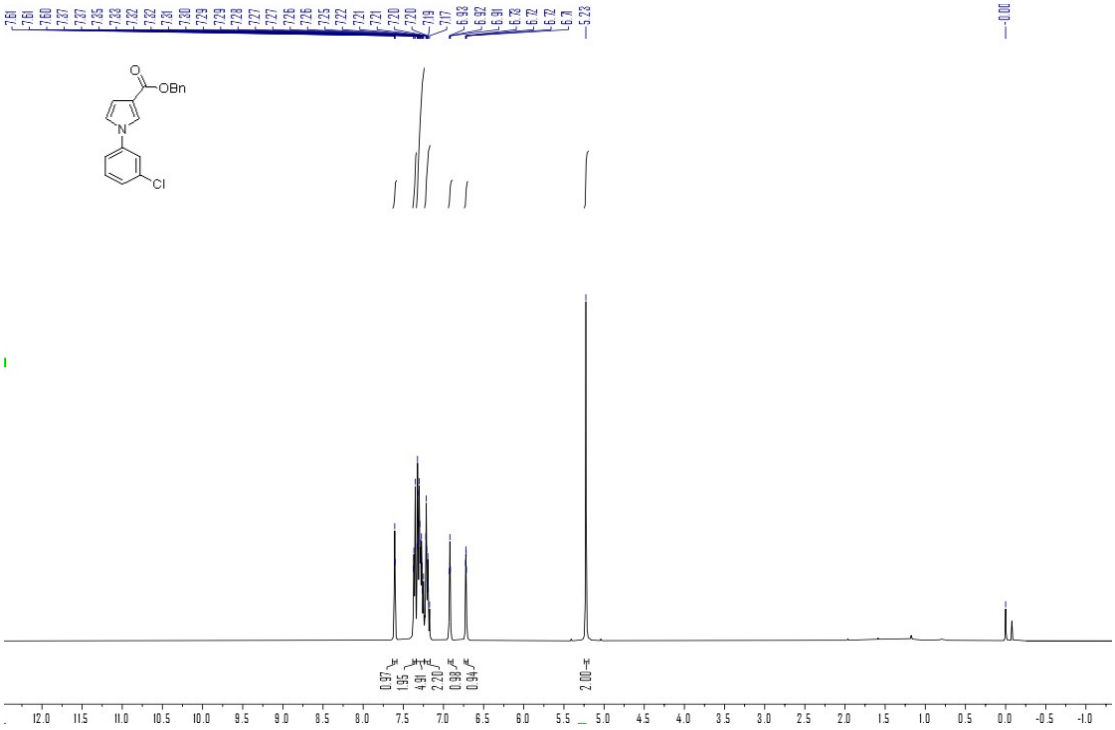
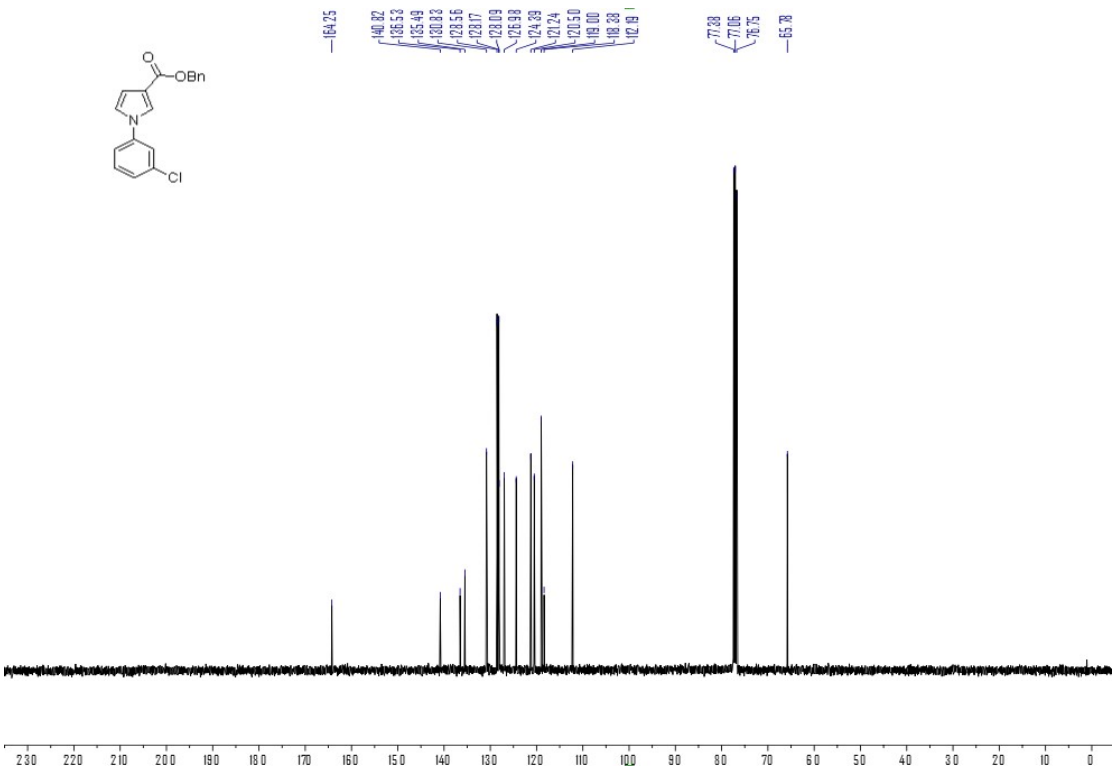
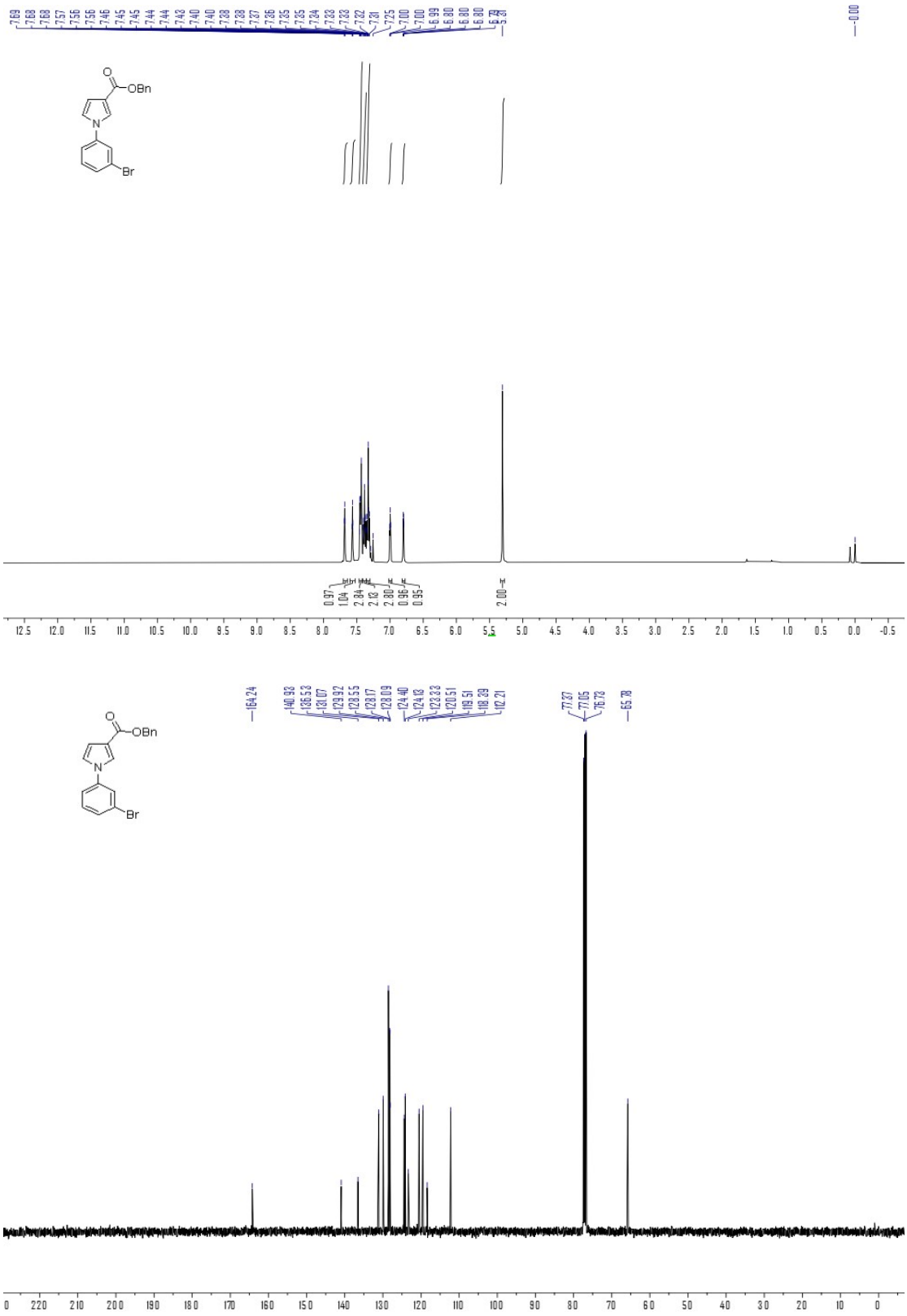
Benzyl 1-(3-chlorophenyl)-1*H*-pyrrole-3-carboxylate (3m)

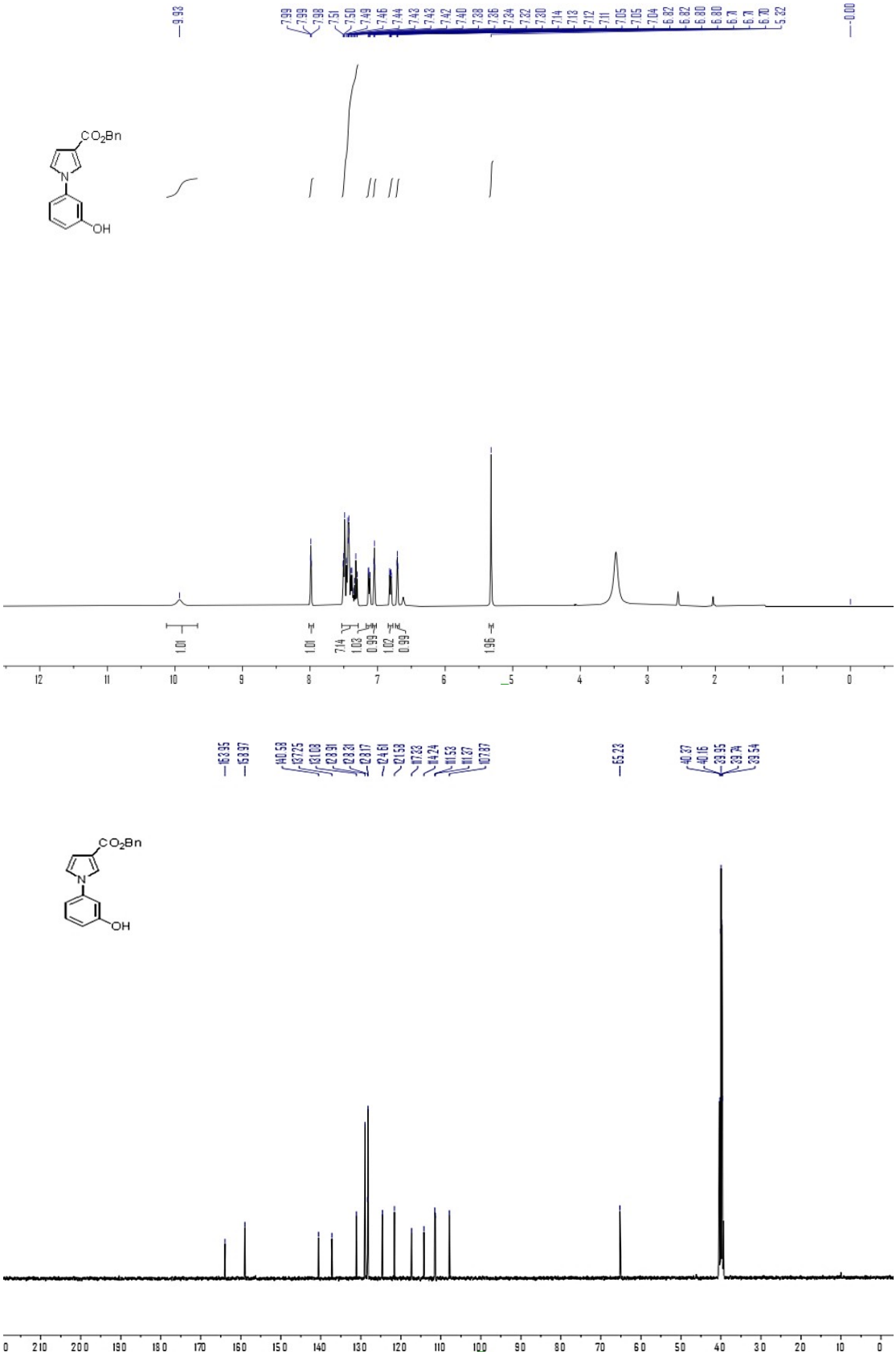




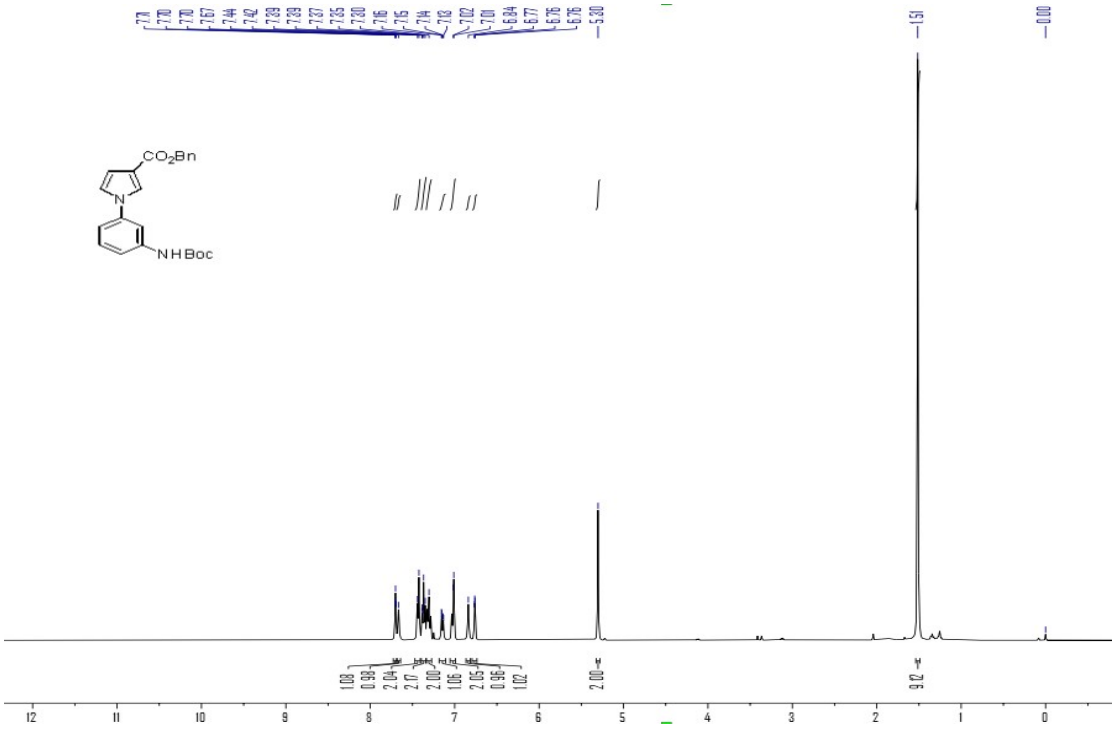
Benzyl 1-(3-bromophenyl)-1*H*-pyrrole-3-carboxylate (3n)

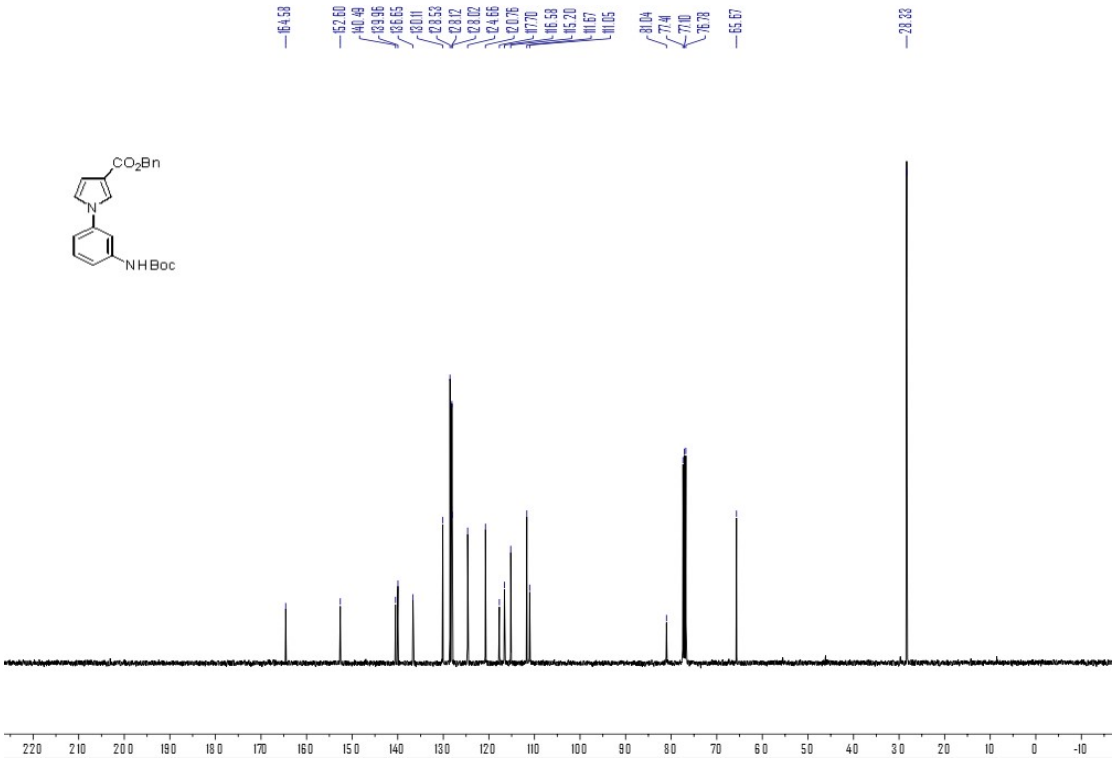


Benzyl 1-(3-hydroxyphenyl)-1*H*-pyrrole-3-carboxylate (3o)

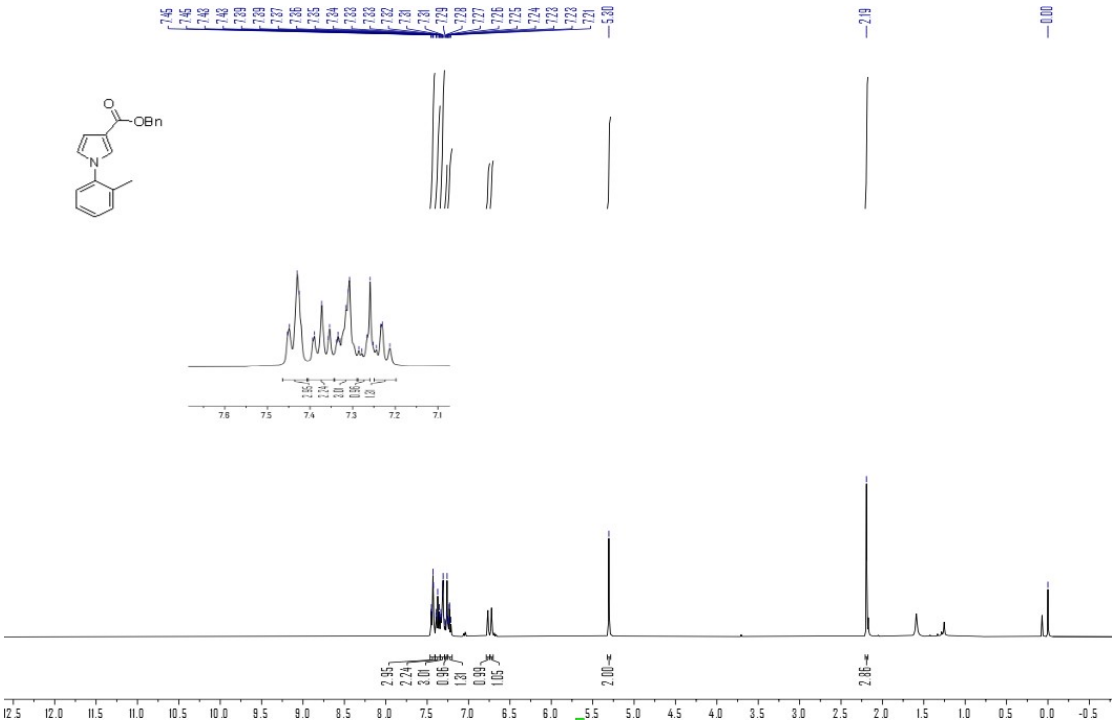


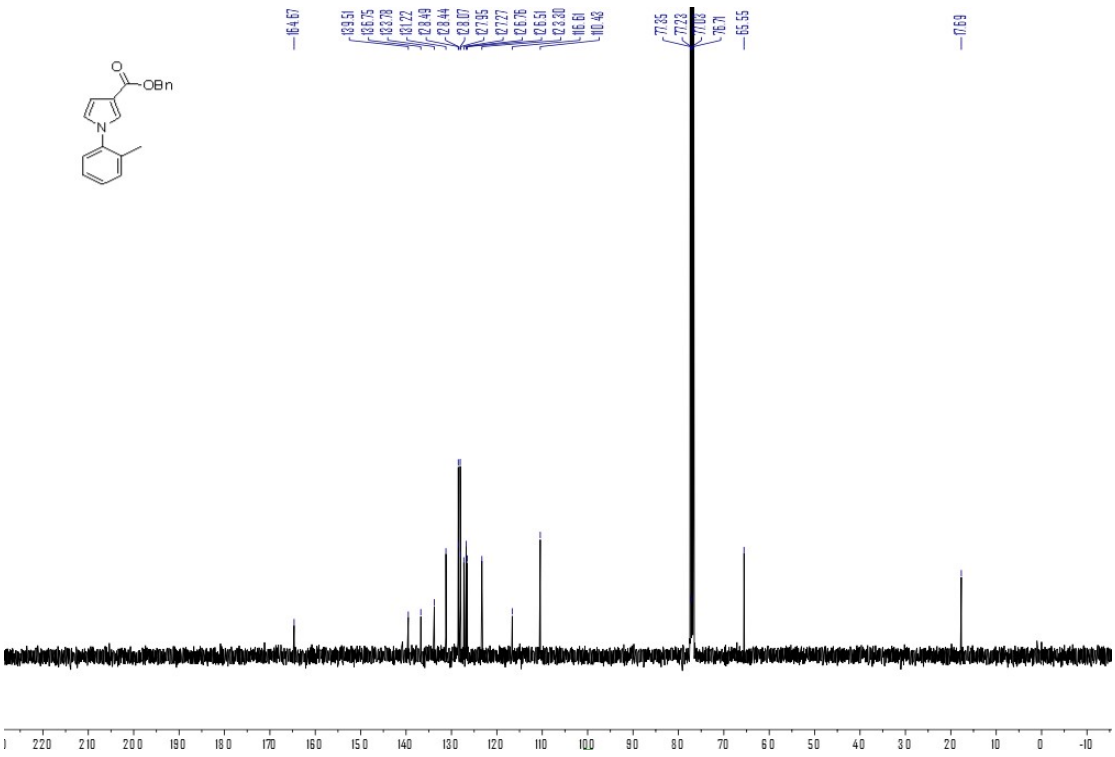
Benzyl 1-(3-((tert-butoxycarbonyl)amino)phenyl)-1*H*-pyrrole-3-carboxylate (3p)



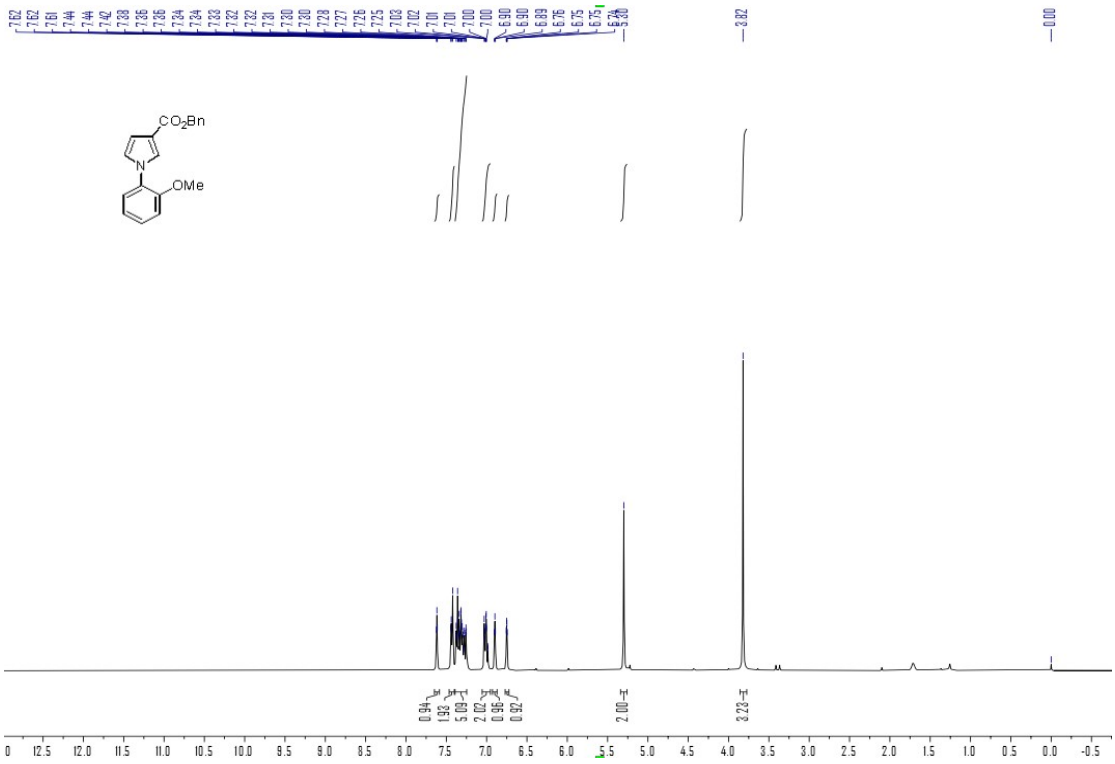


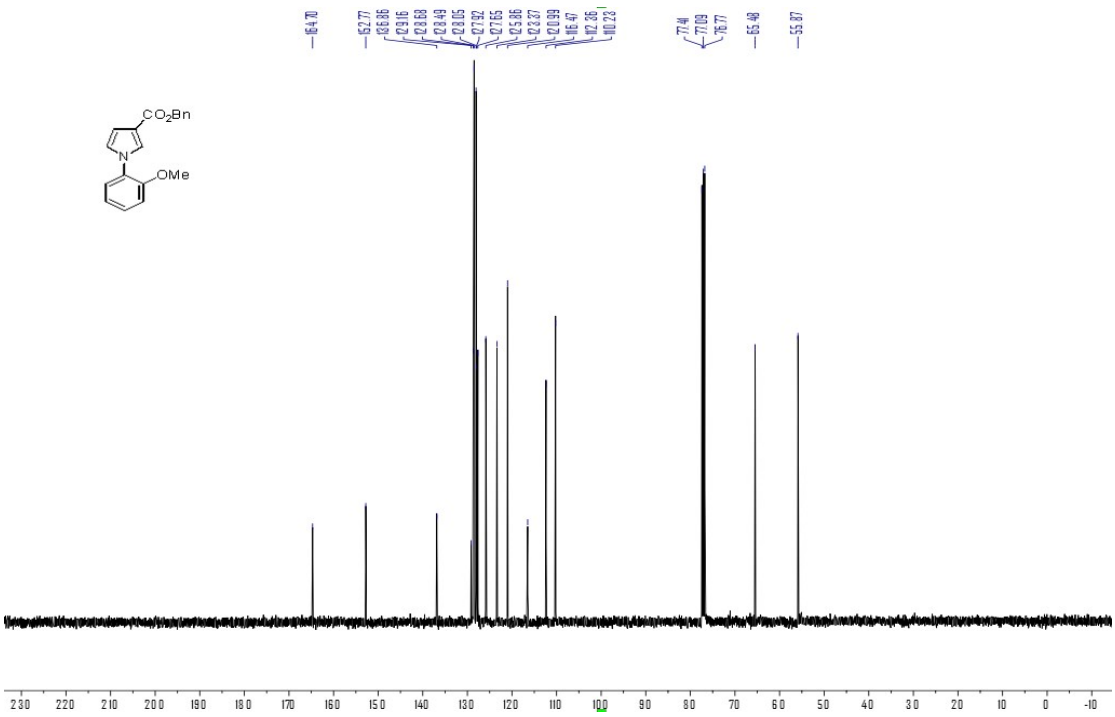
Benzyl 1-(o-tolyl)-1*H*-pyrrole-3-carboxylate (3q)



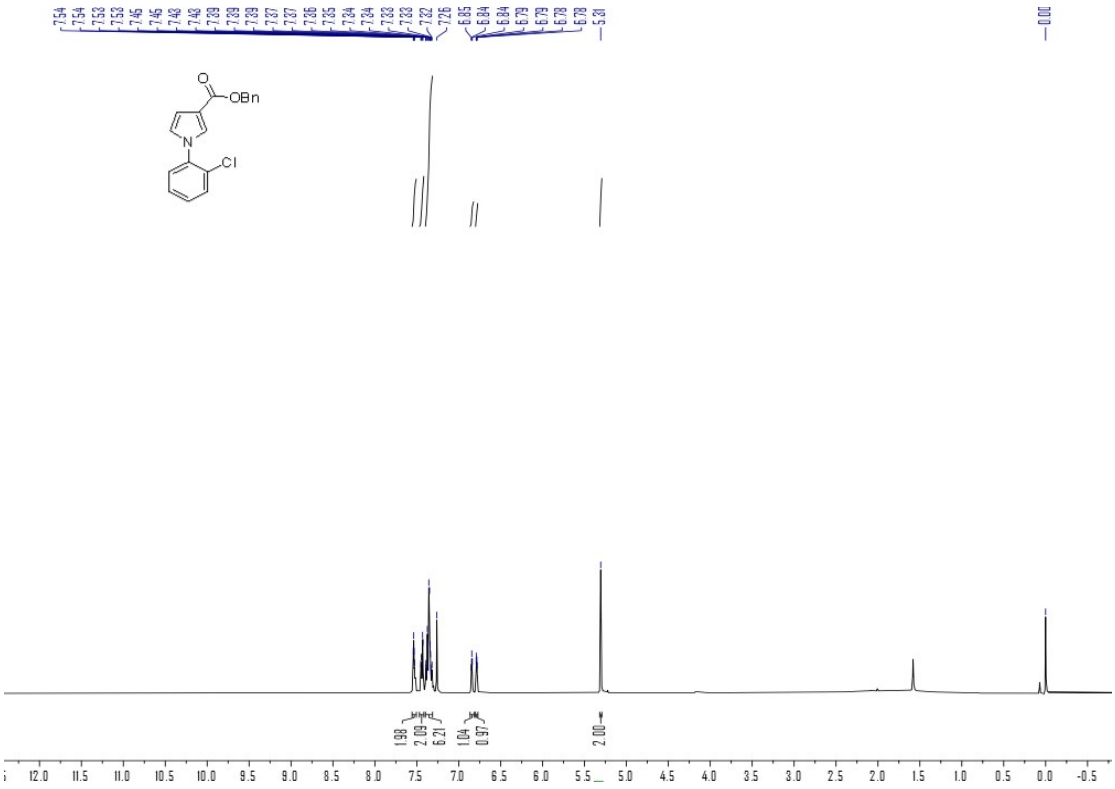


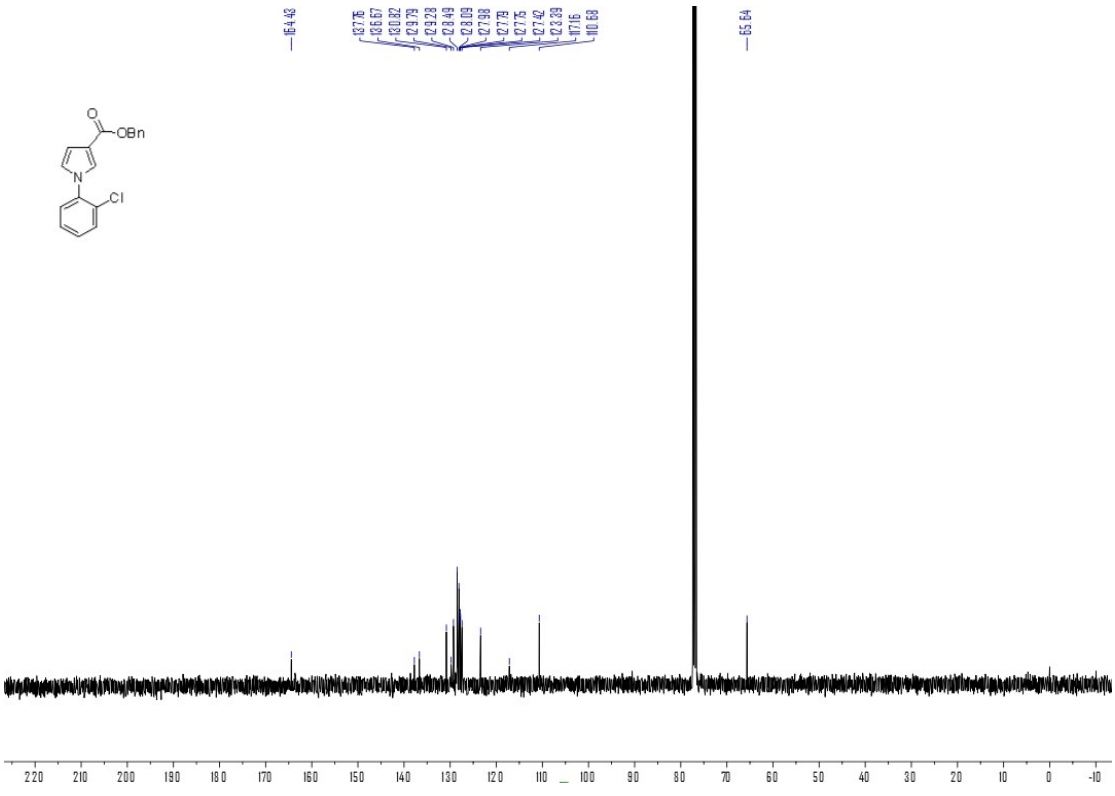
Benzyl 1-(2-methoxyphenyl)-1*H*-pyrrole-3-carboxylate (3r)



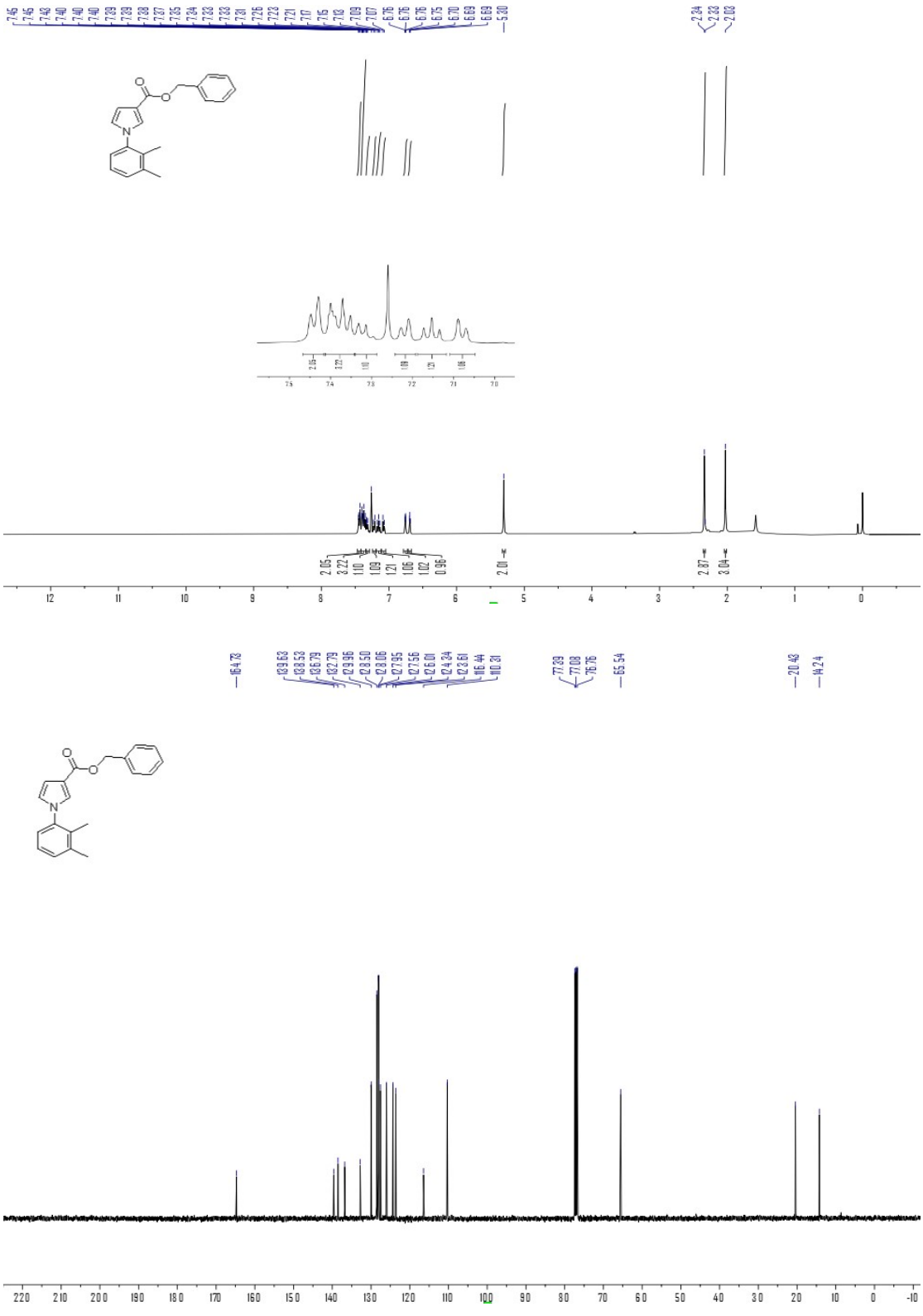


Benzyl 1-(2-chlorophenyl)-1*H*-pyrrole-3-carboxylate (3s)

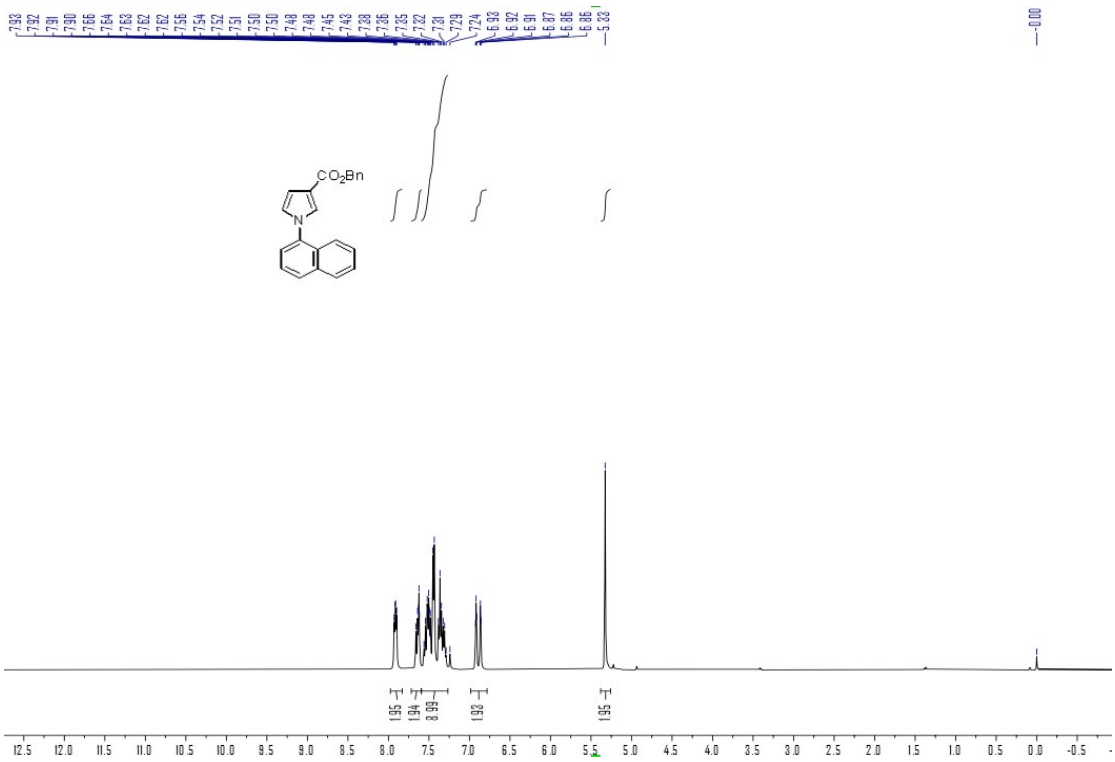


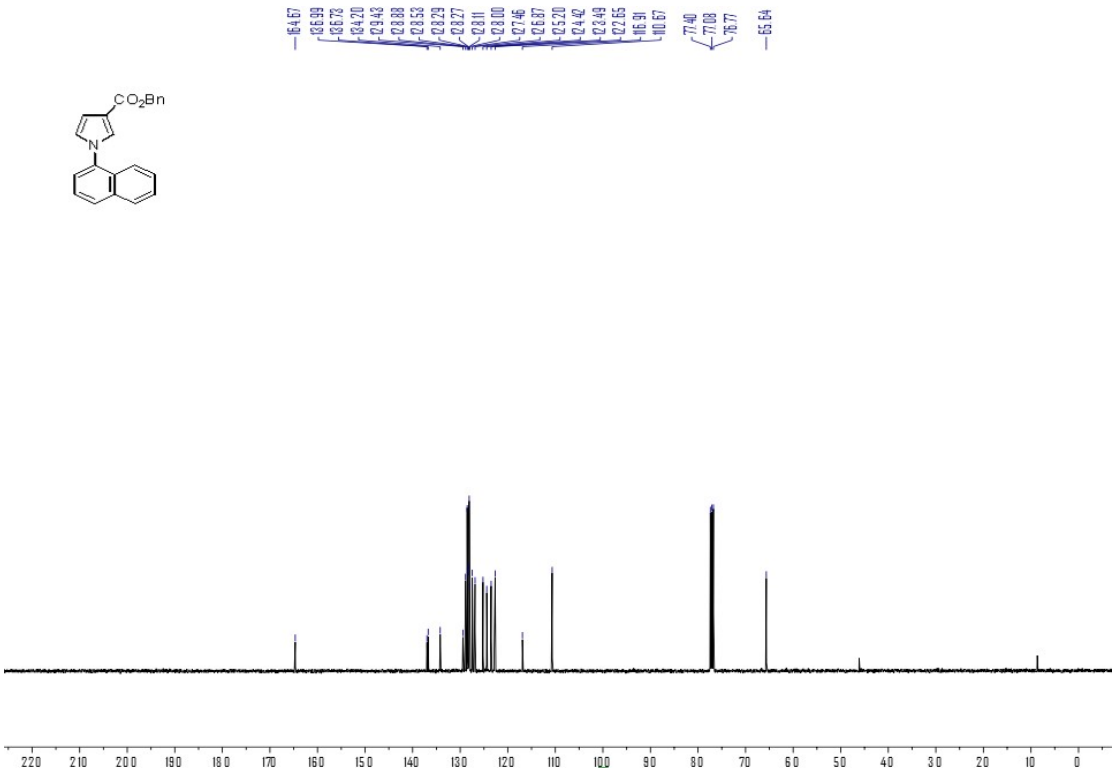


Benzyl 1-(2,3-dimethylphenyl)-1*H*-pyrrole-3-carboxylate (3t)

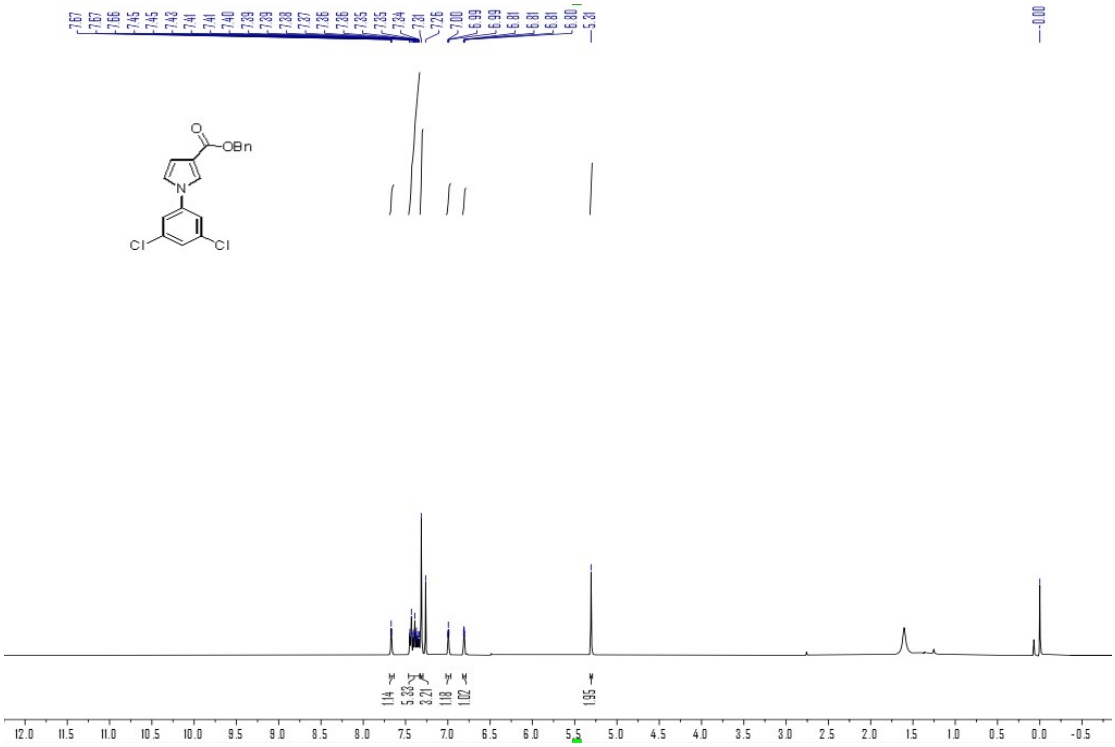


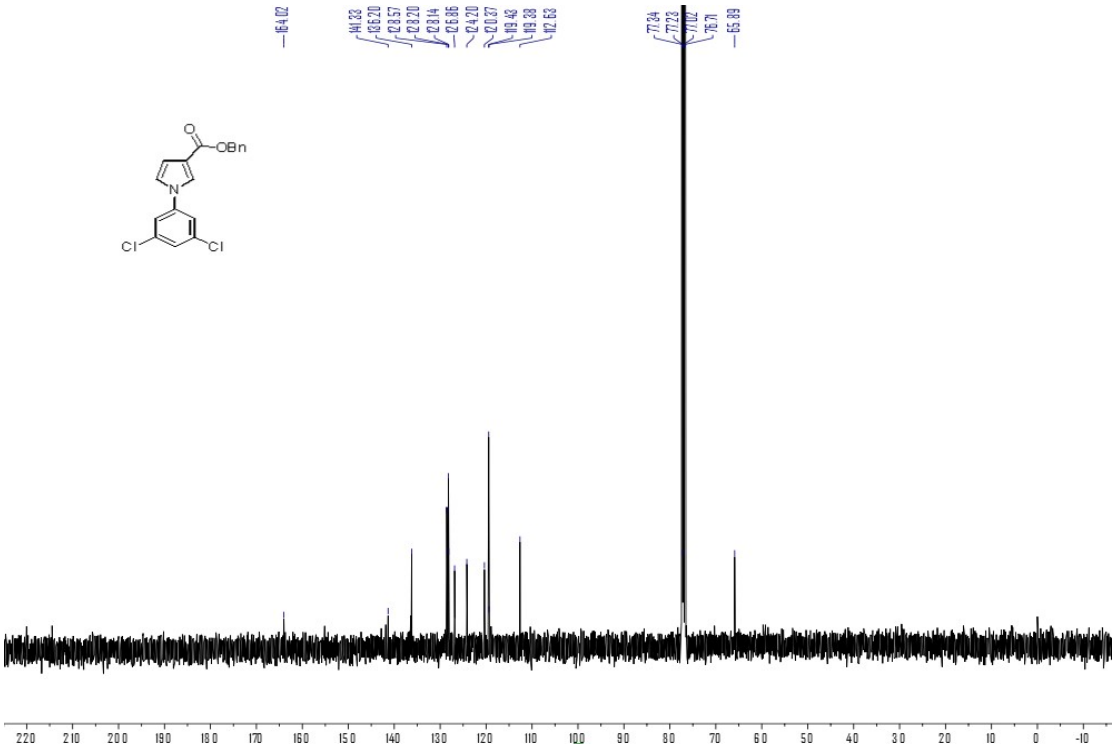
Benzyl 1-(naphthalen-1-yl)-1*H*-pyrrole-3-carboxylate (3u)



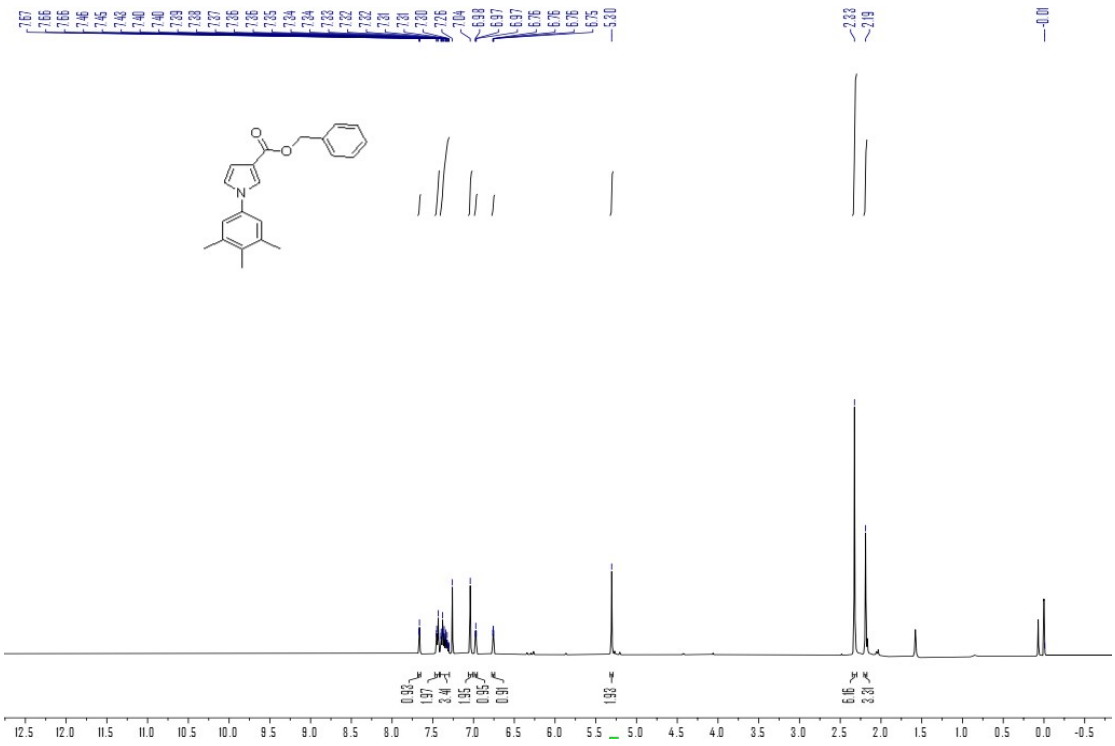


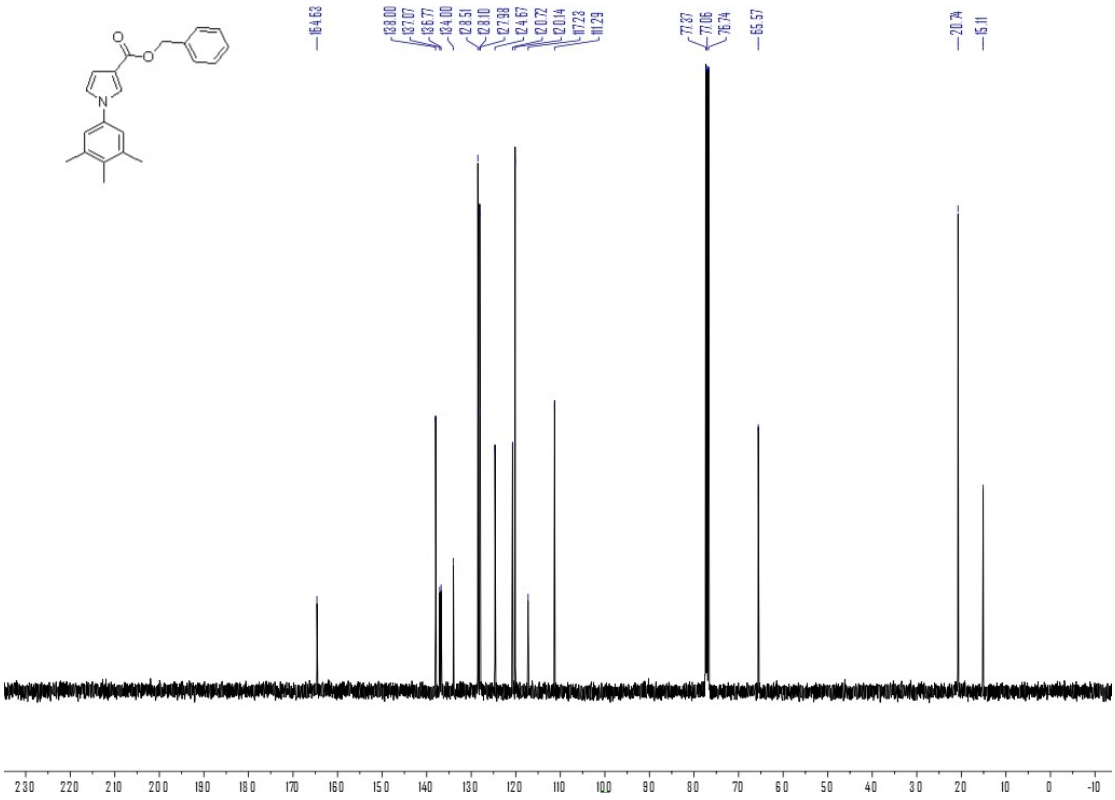
Benzyl 1-(3,5-dichlorophenyl)-1*H*-pyrrole-3-carboxylate (3v)



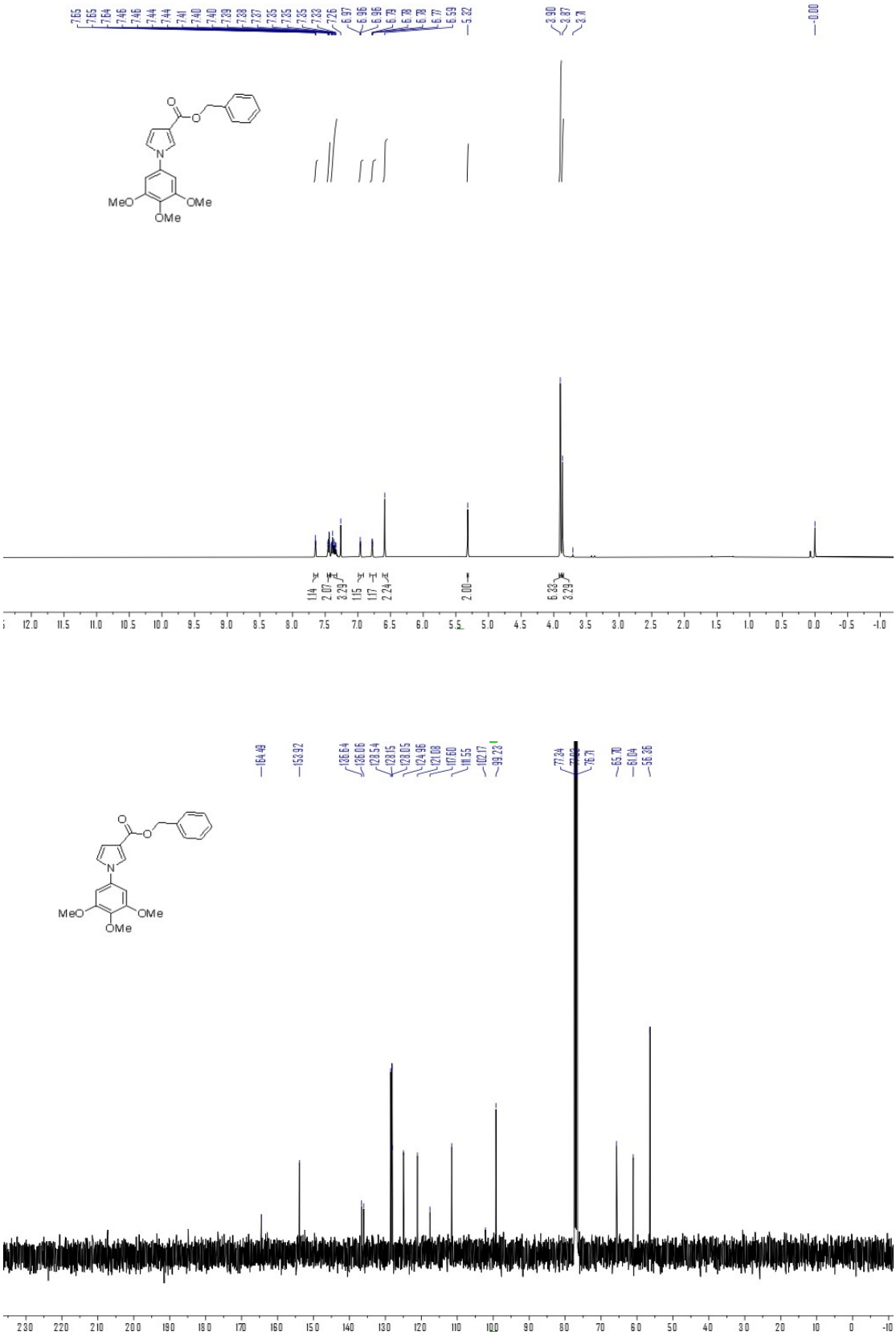


Benzyl 1-(3,4,5-trimethylphenyl)-1*H*-pyrrole-3-carboxylate (3w)

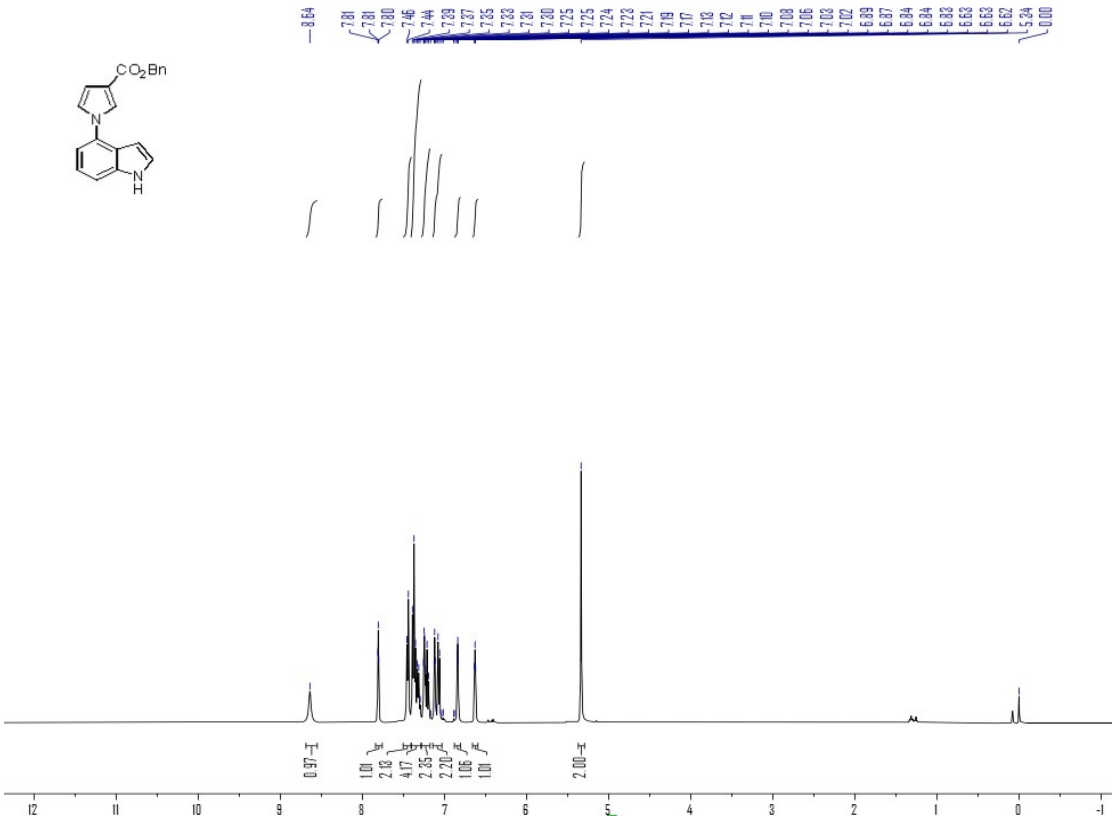


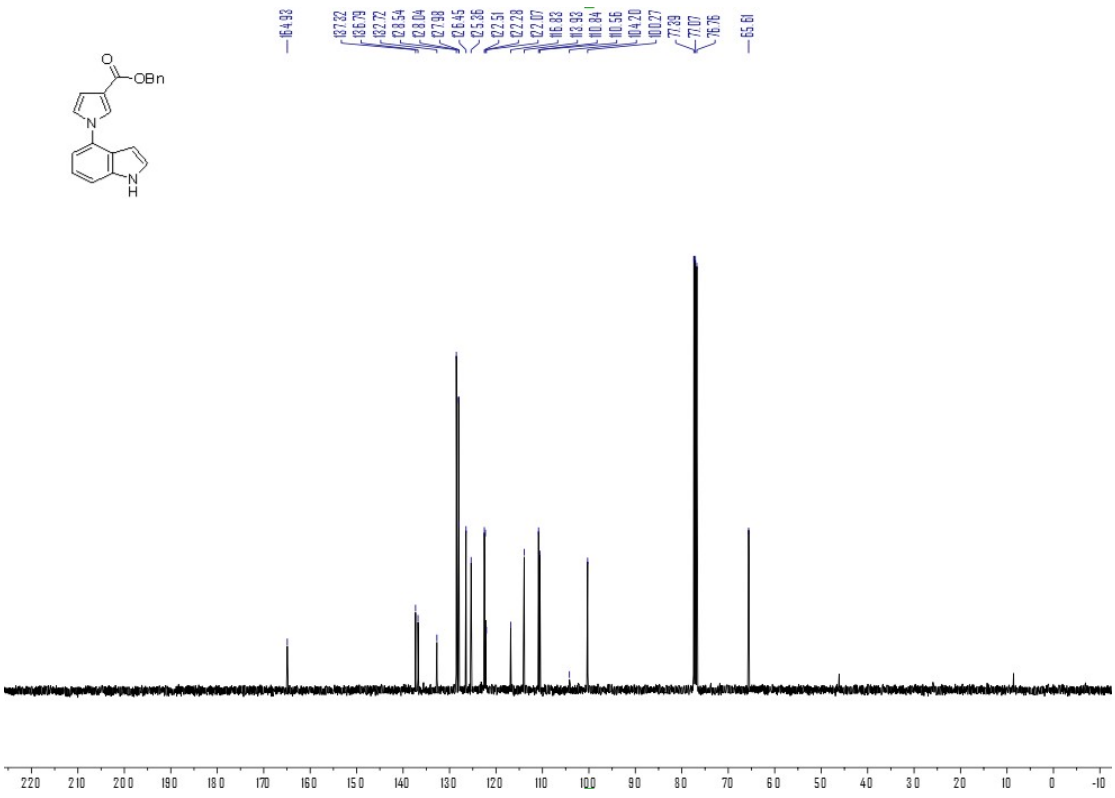


Benzyl 1-(3,4,5-trimethoxyphenyl)-1*H*-pyrrole-3-carboxylate (3x)

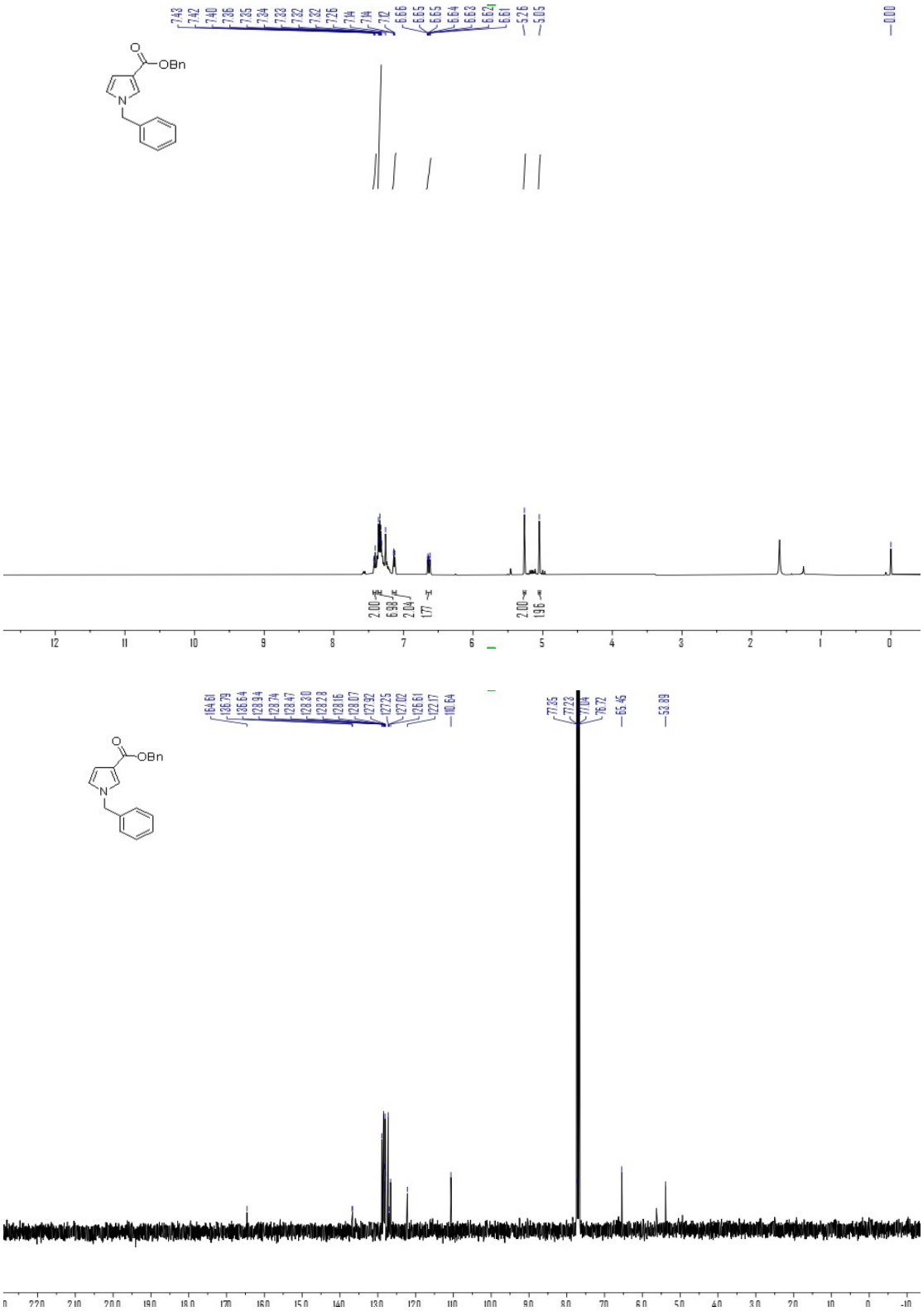


Benzyl 1-(1H-indol-4-yl)-1*H*-pyrrole-3-carboxylate (3y)

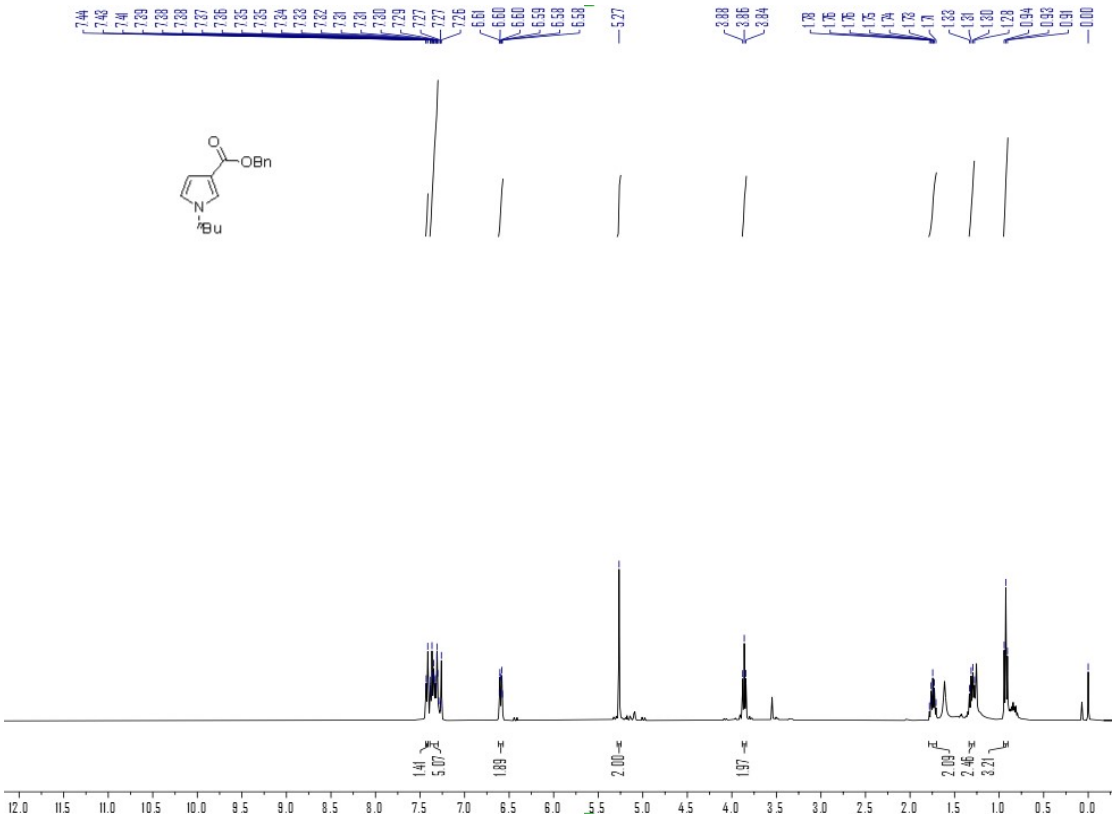


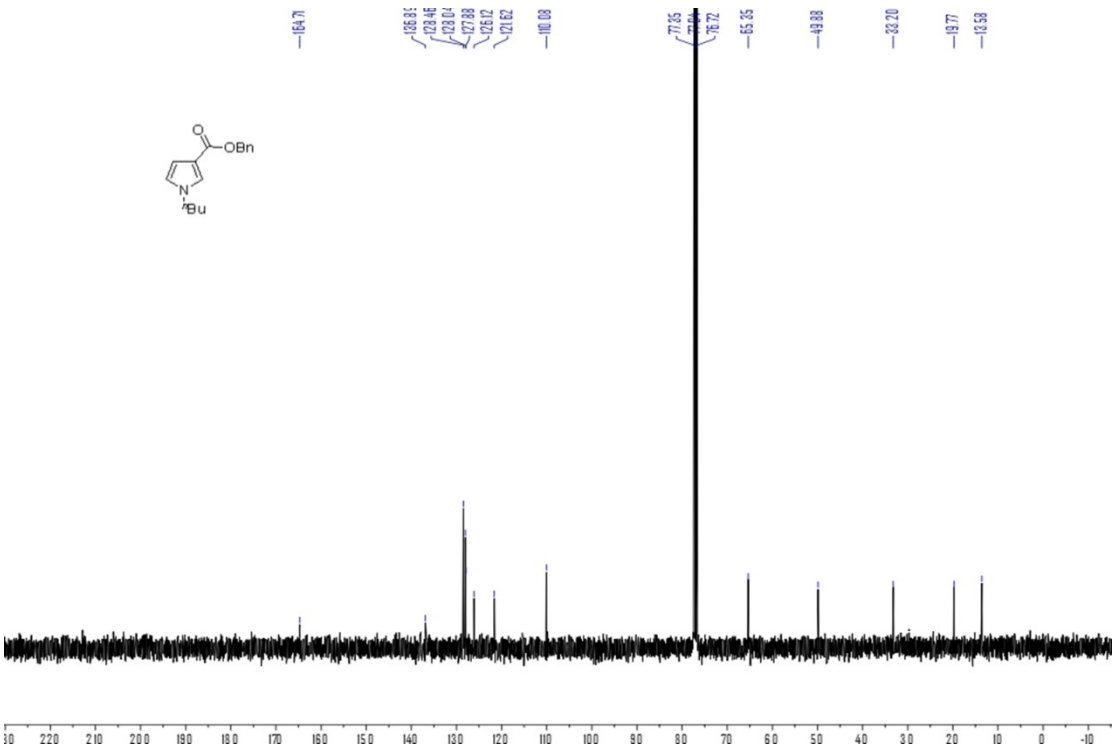


Benzyl 1-benzyl-1*H*-pyrrole-3-carboxylate (3z)

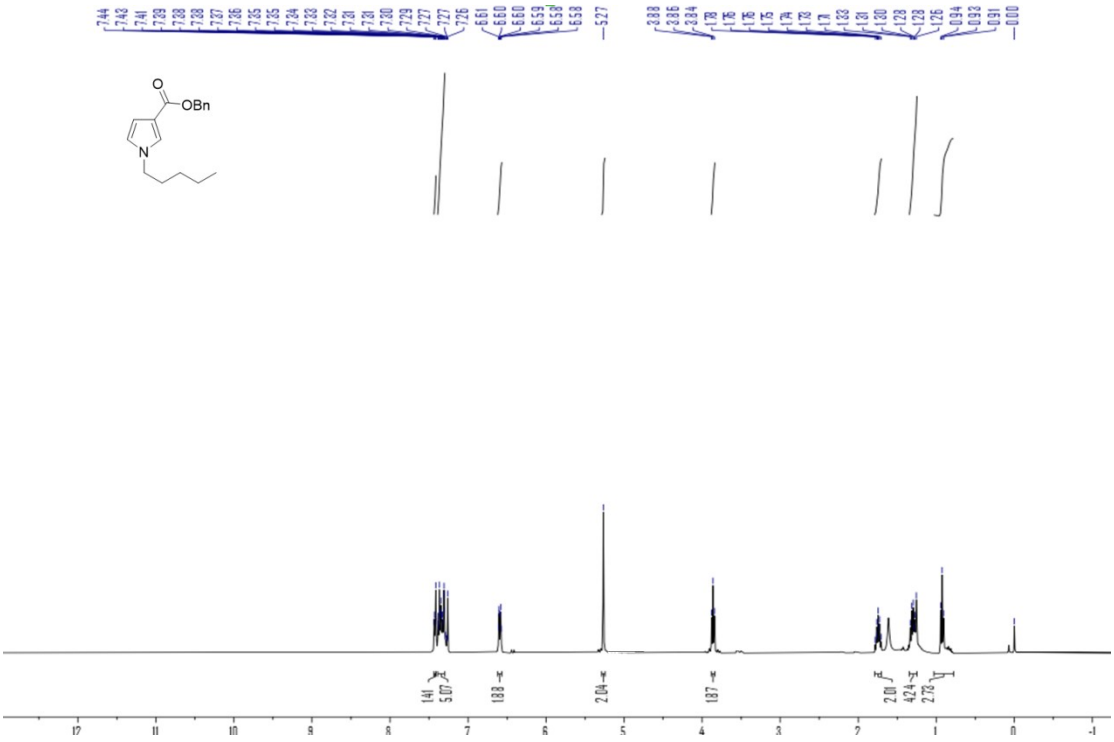


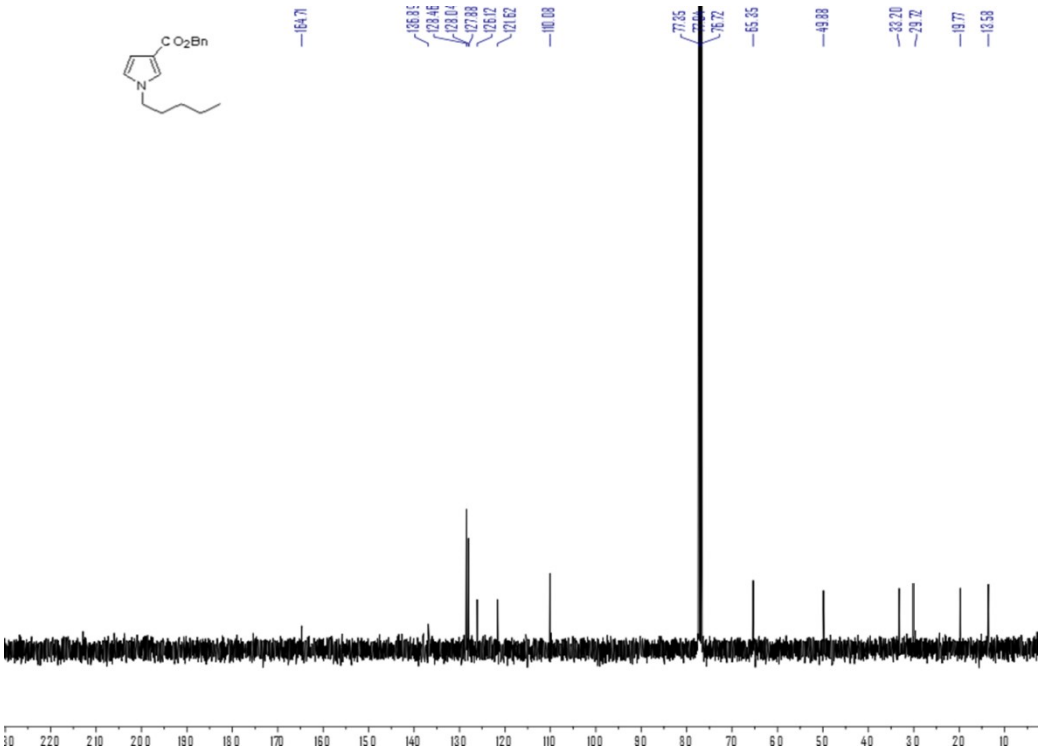
Benzyl 1-butyl-1*H*-pyrrole-3-carboxylate (3aa)



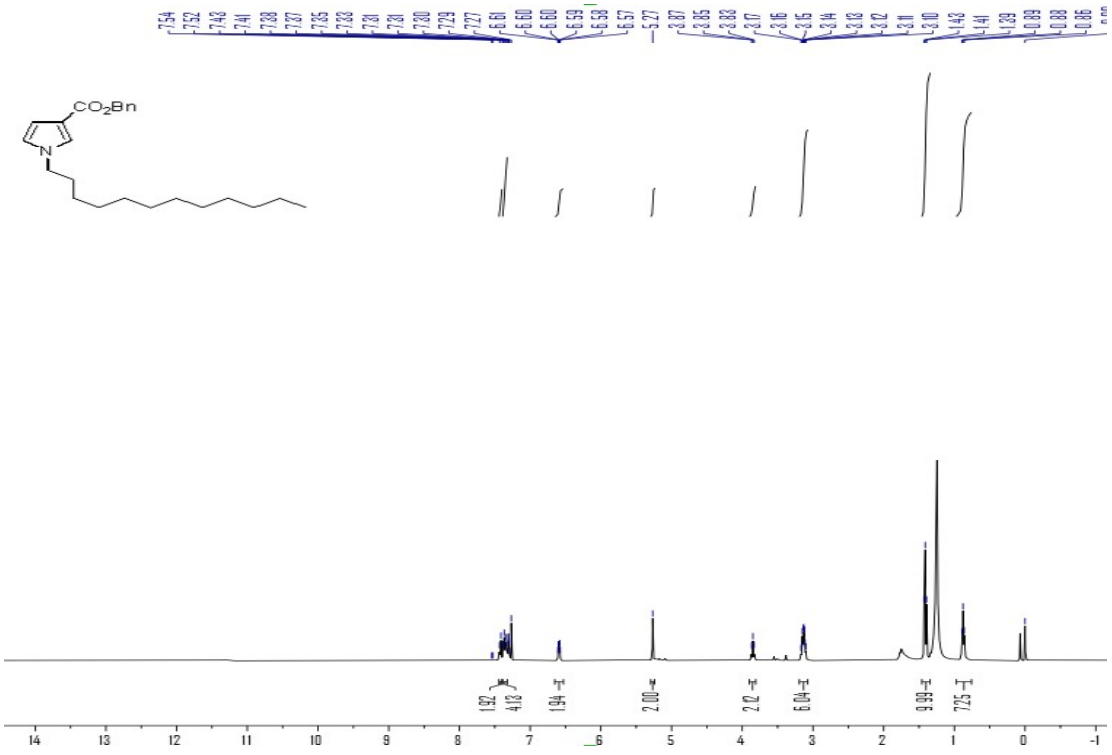


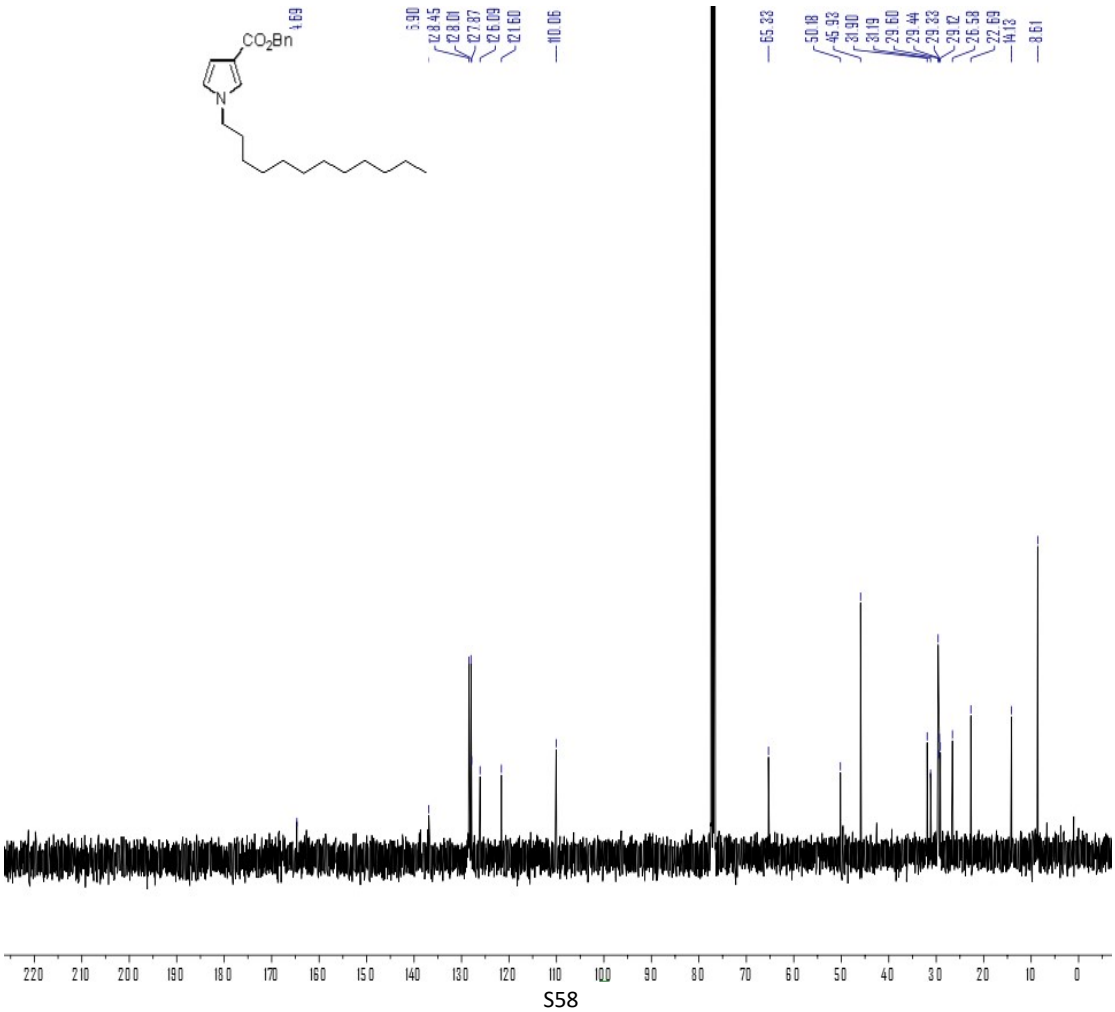
Benzyl 1-pentyl-1*H*-pyrrole-3-carboxylate (3ab)



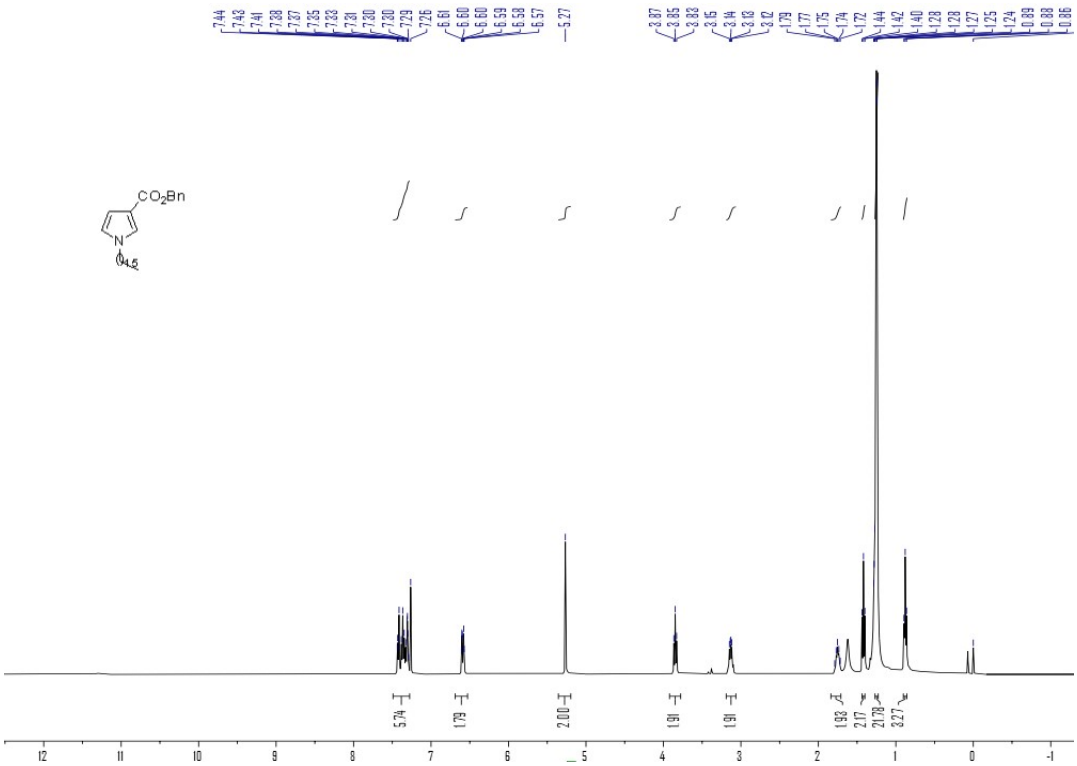


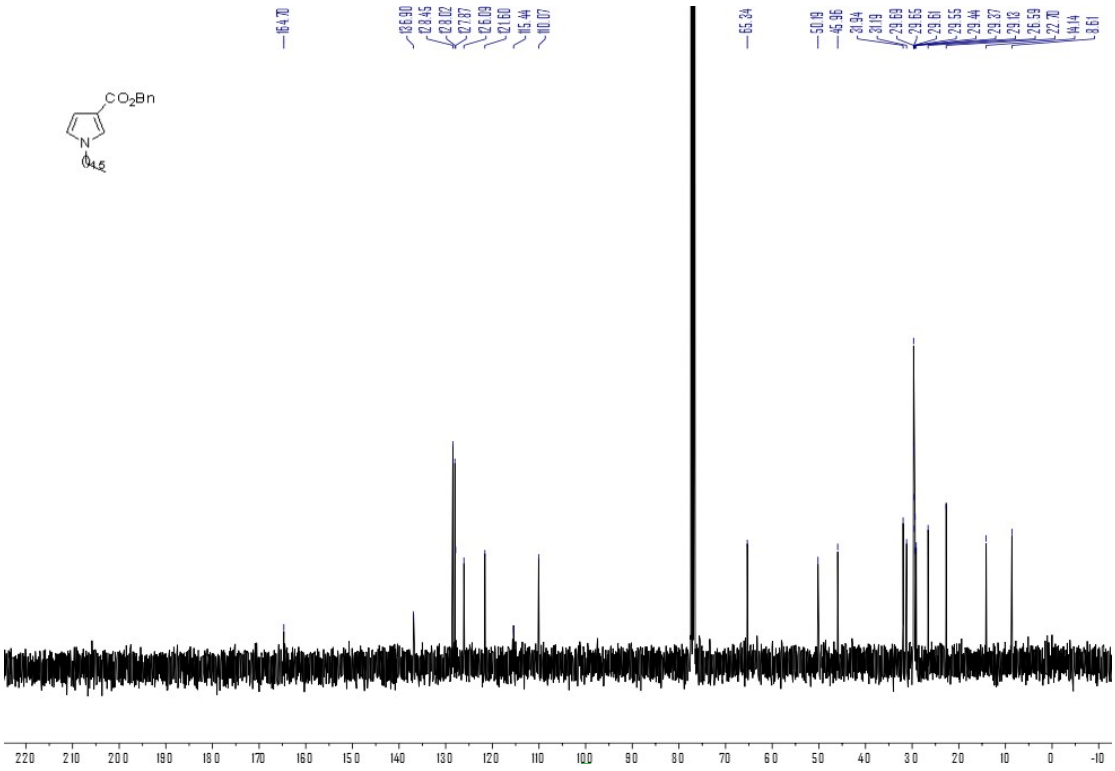
Benzyl 1-dodecyl-1H-pyrrole-3-carboxylate (3ac)



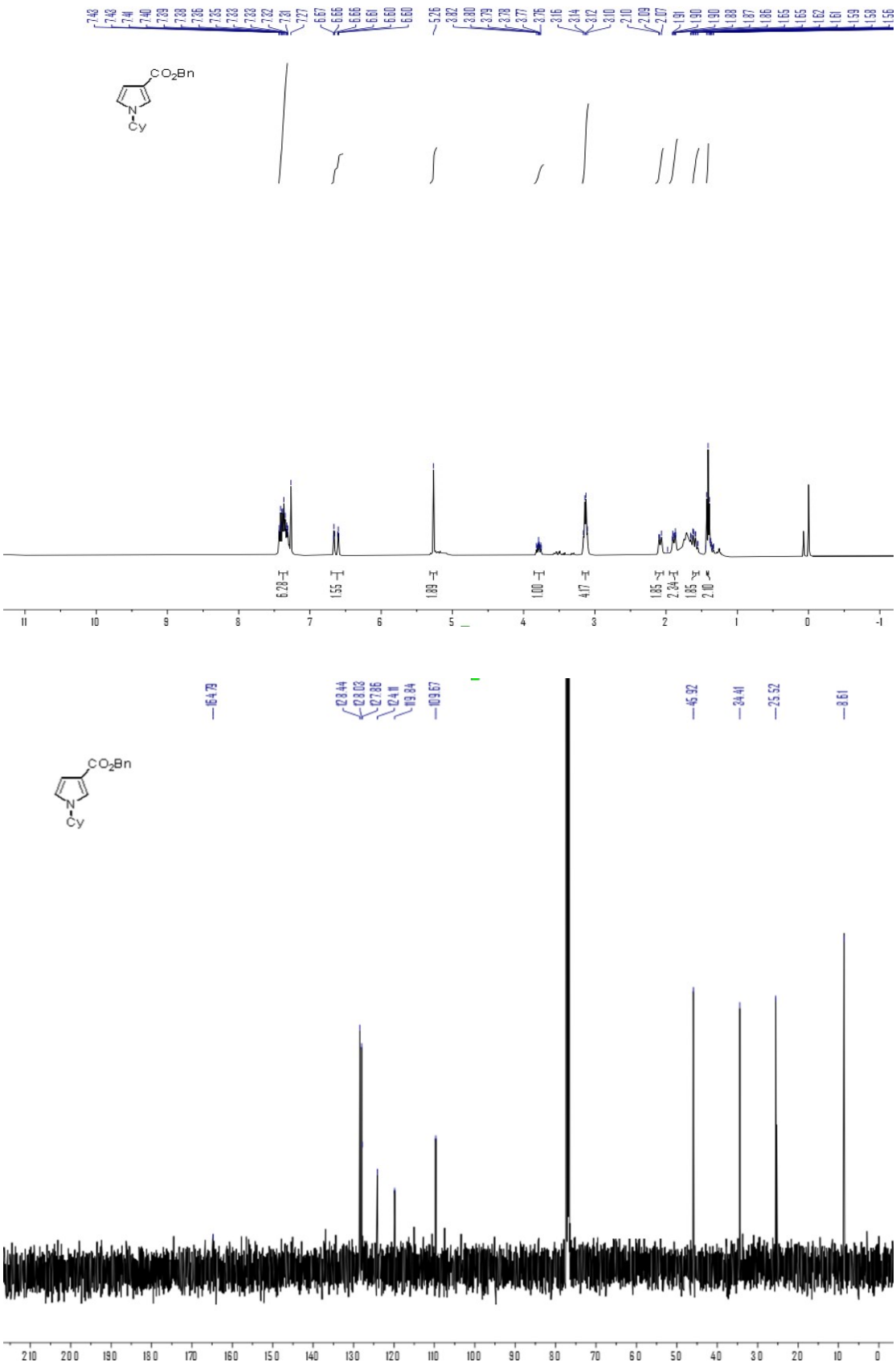


Benzyl 1-hexadecyl-1H-pyrrole-3-carboxylate (3ad)

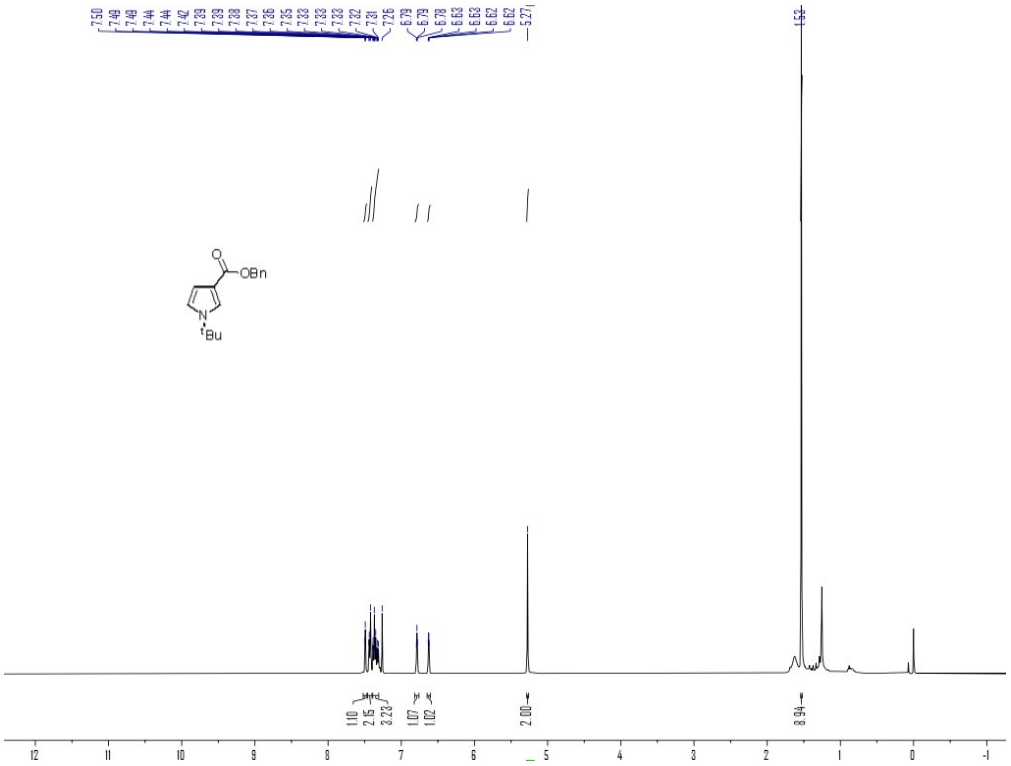


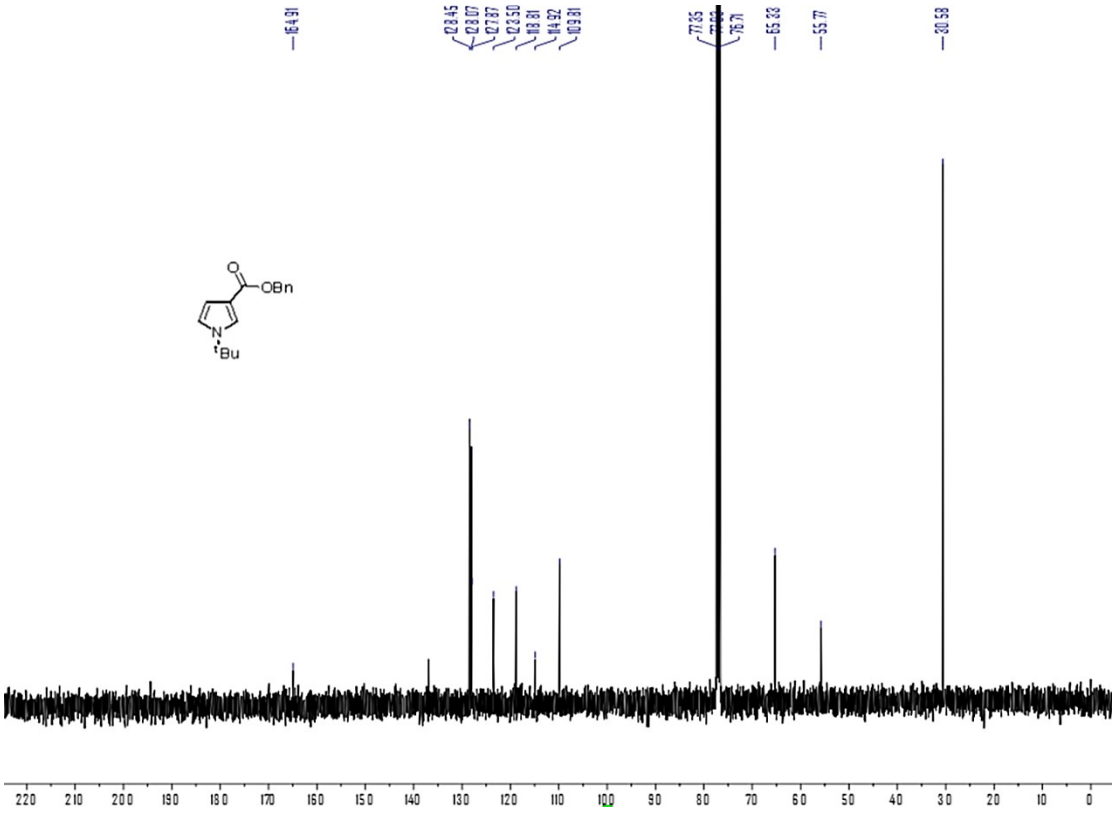


Benzyl 1-cyclohexyl-1*H*-pyrrole-3-carboxylate (3ae)

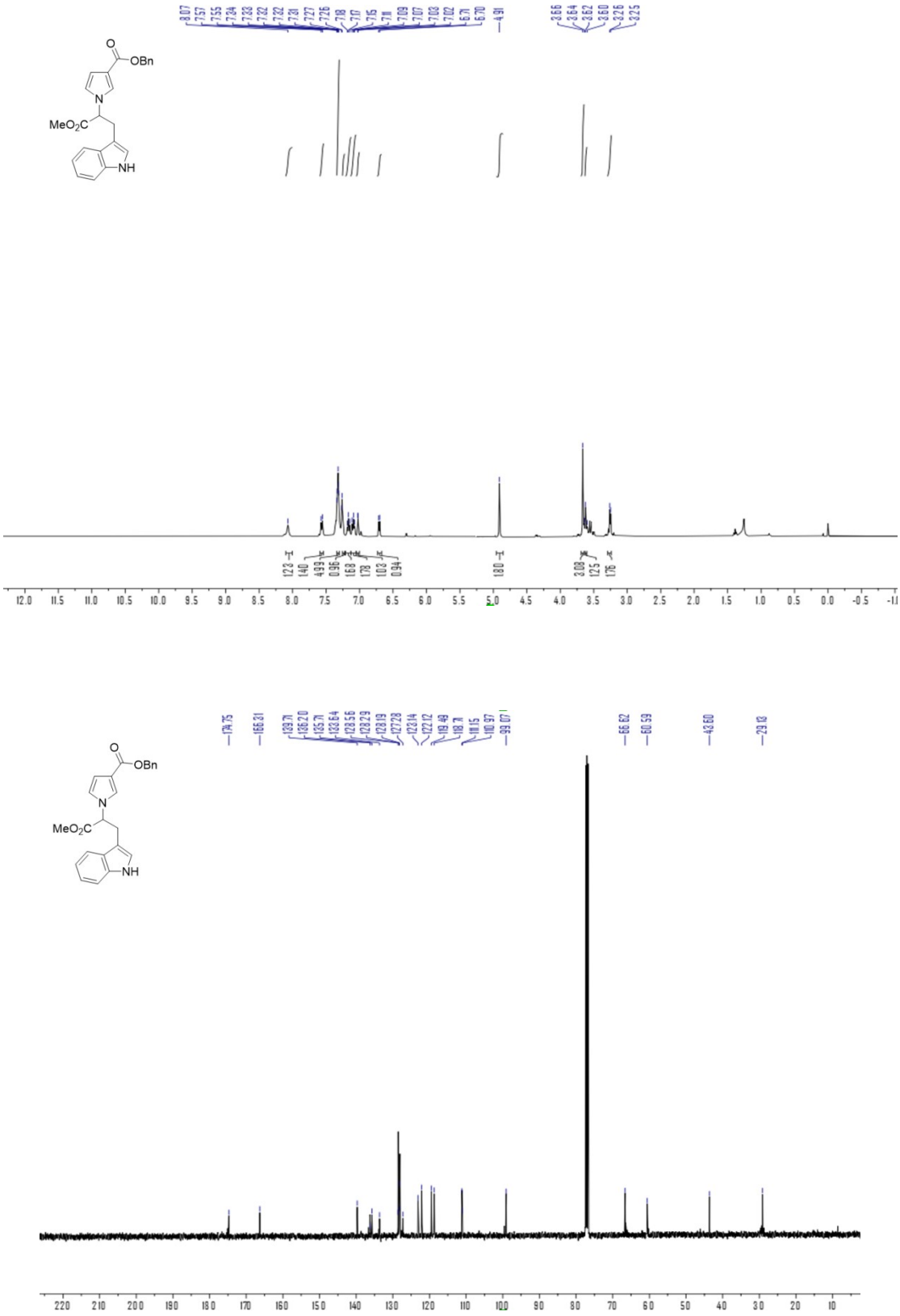


Benzyl 1-(tert-butyl)-1*H*-pyrrole-3-carboxylate (3af)

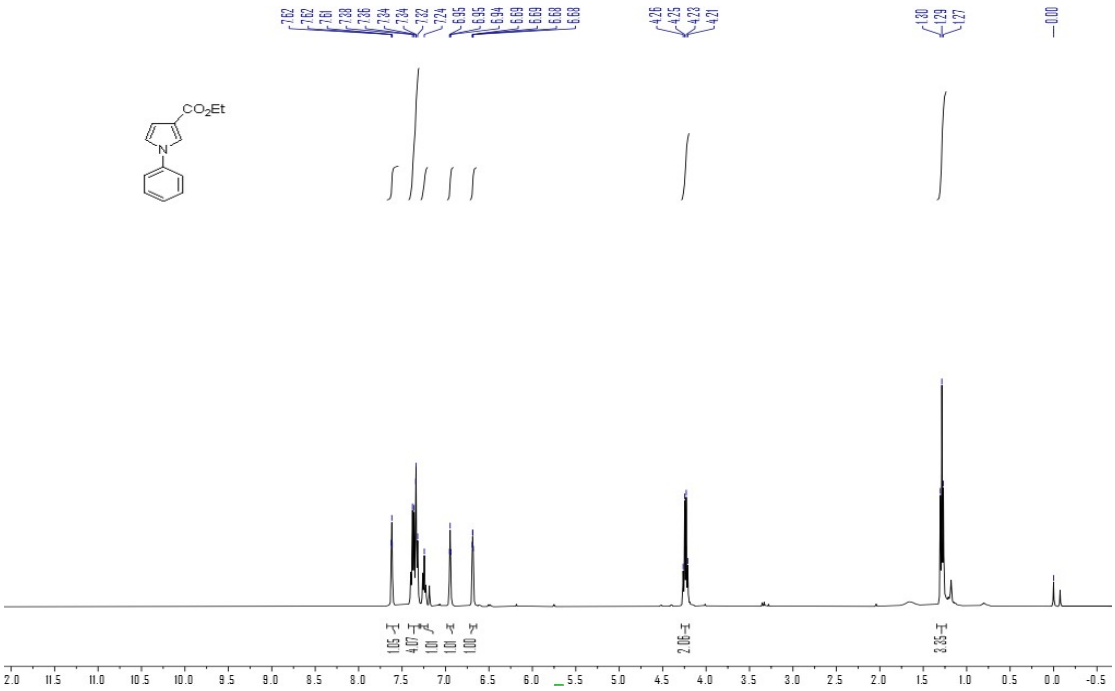


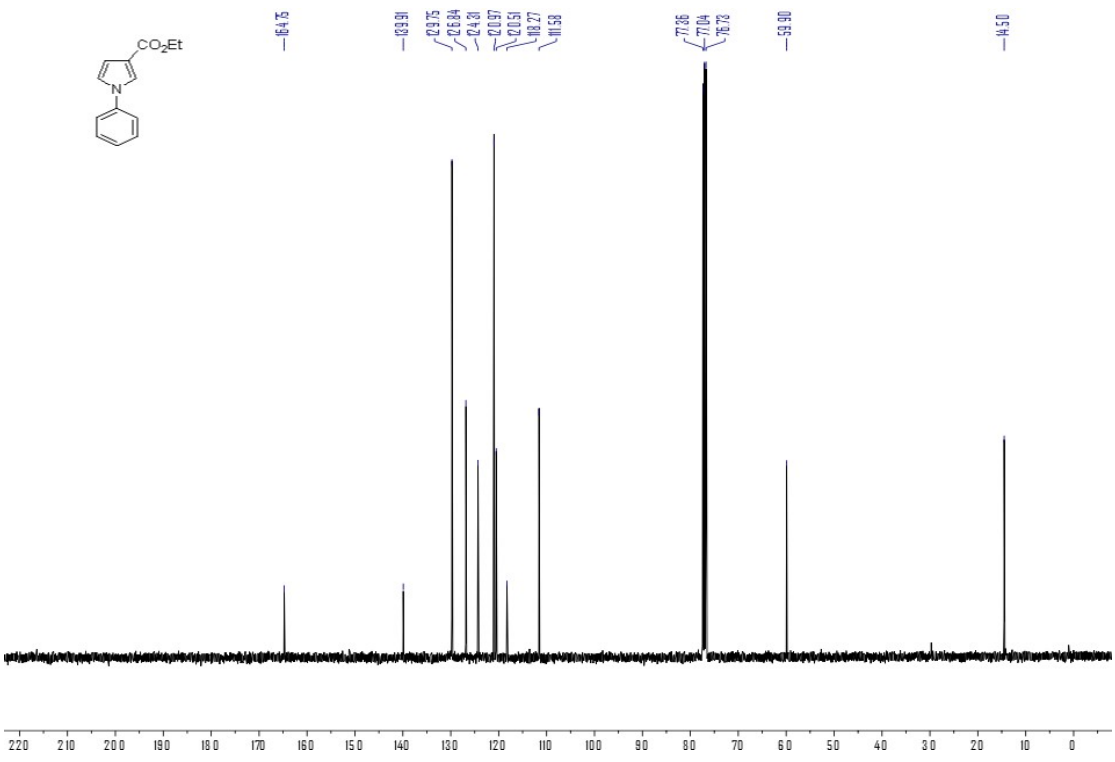


Benzyl 1-(3-(1H-indol-3-yl)-1-methoxy-1-oxopropan-2-yl)-1*H*-pyrrole-3-carboxylate (3ag)

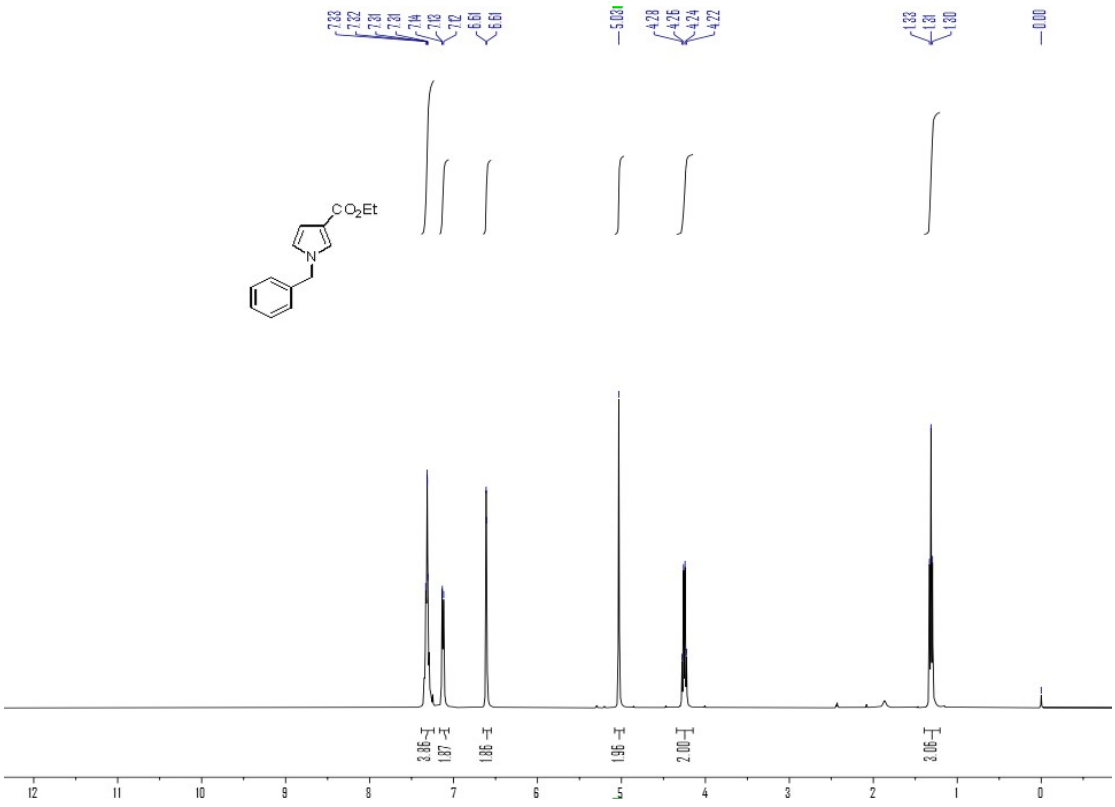


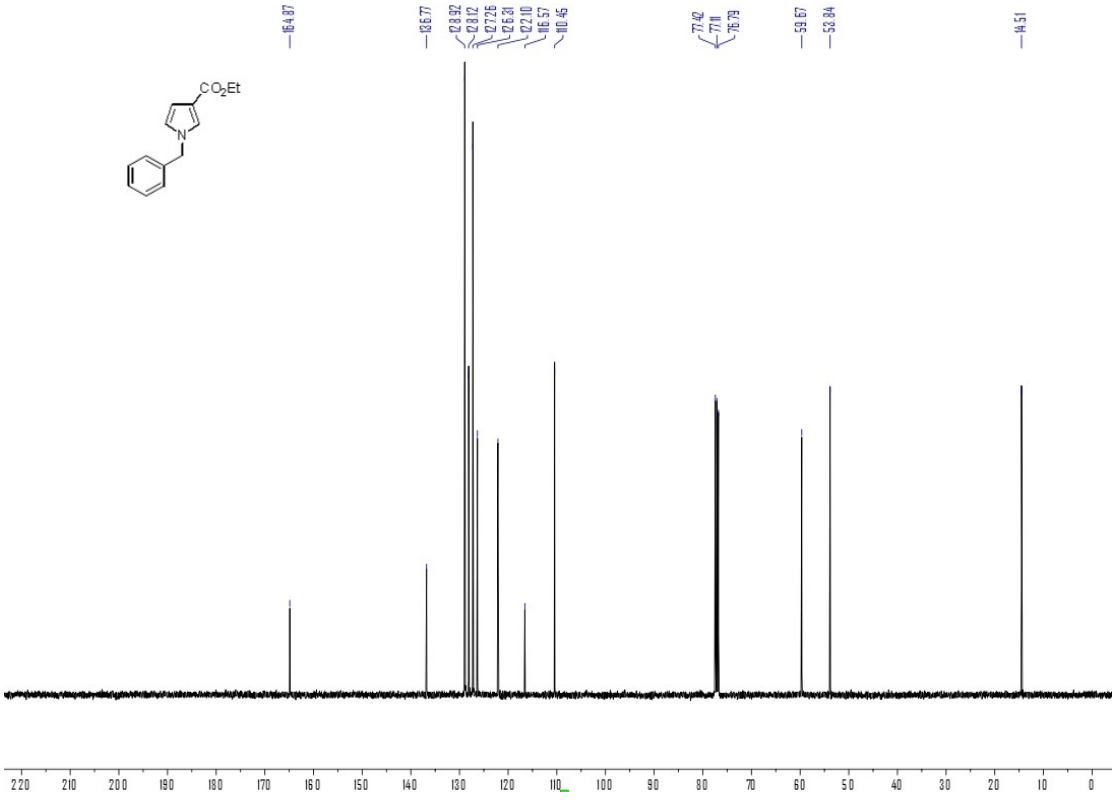
Ethyl 1-phenyl-1*H*-pyrrole-3-carboxylate (3ah)



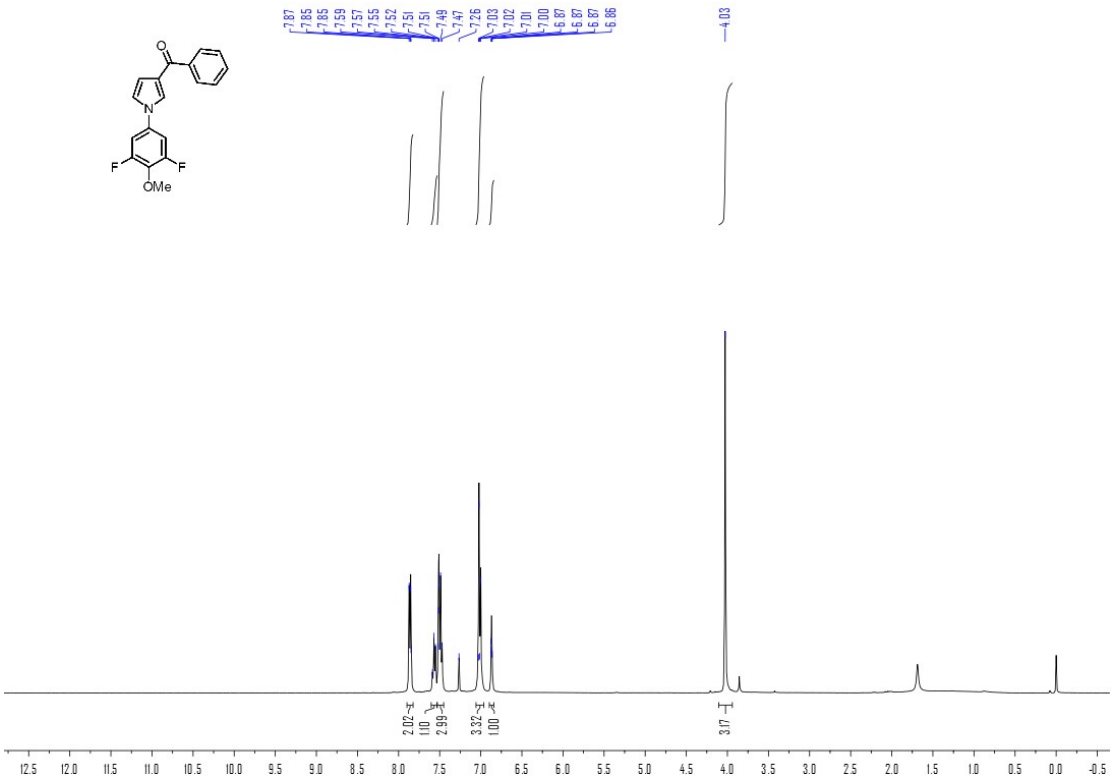


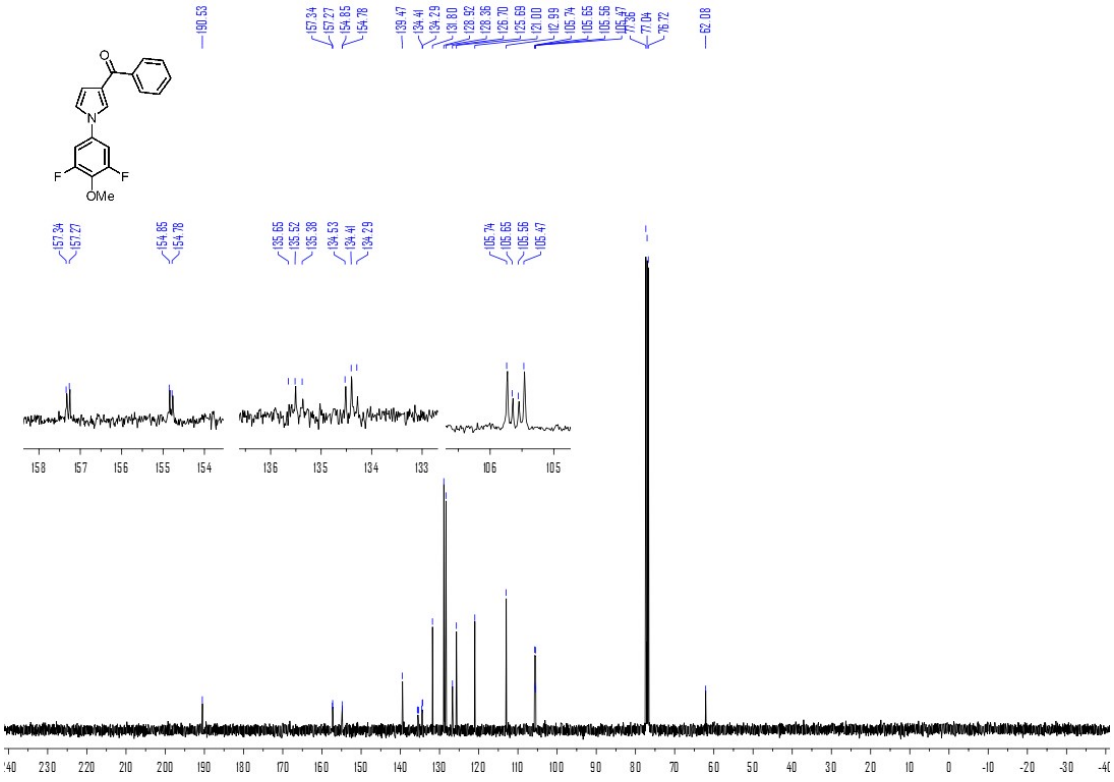
Ethyl 1-benzyl-1*H*-pyrrole-3-carboxylate (3ai)

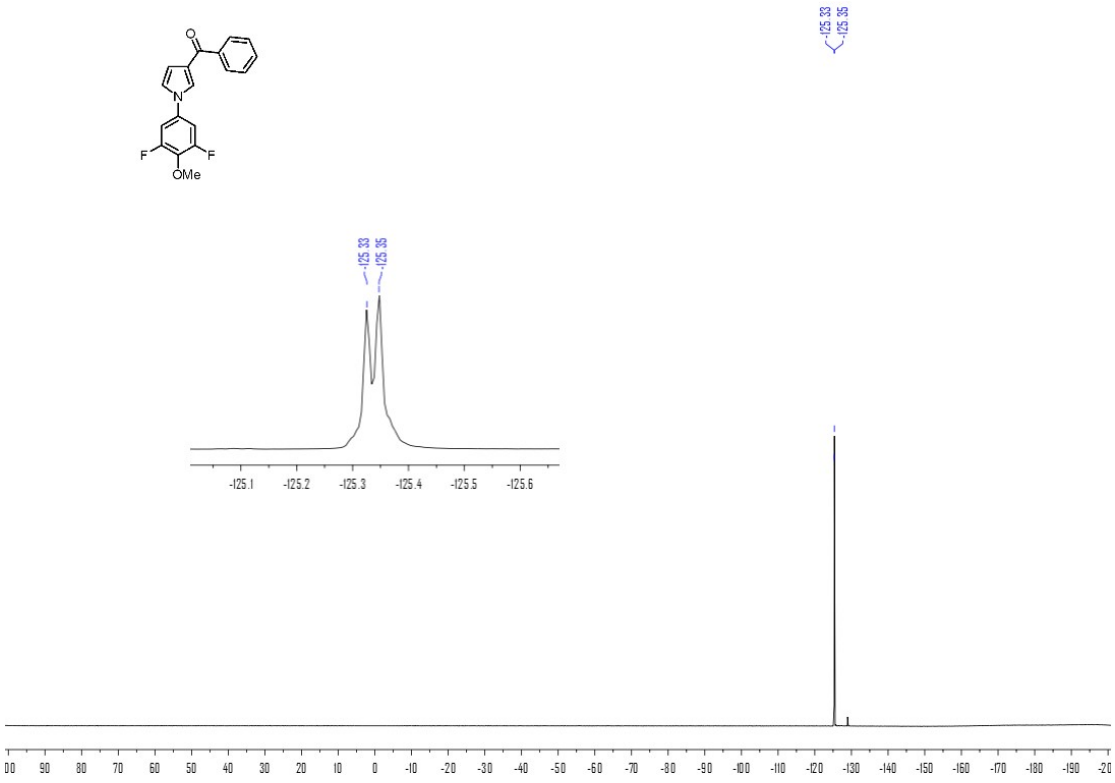




(1-(3,5-Difluoro-4-methoxyphenyl)-1*H*-pyrrol-3-yl)(phenyl)methanone (3aj)



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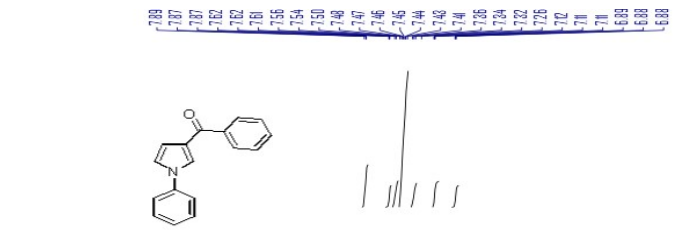
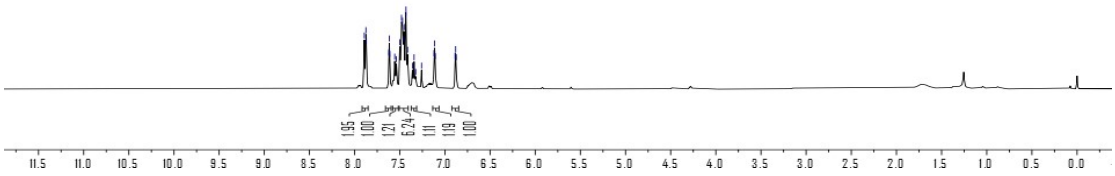
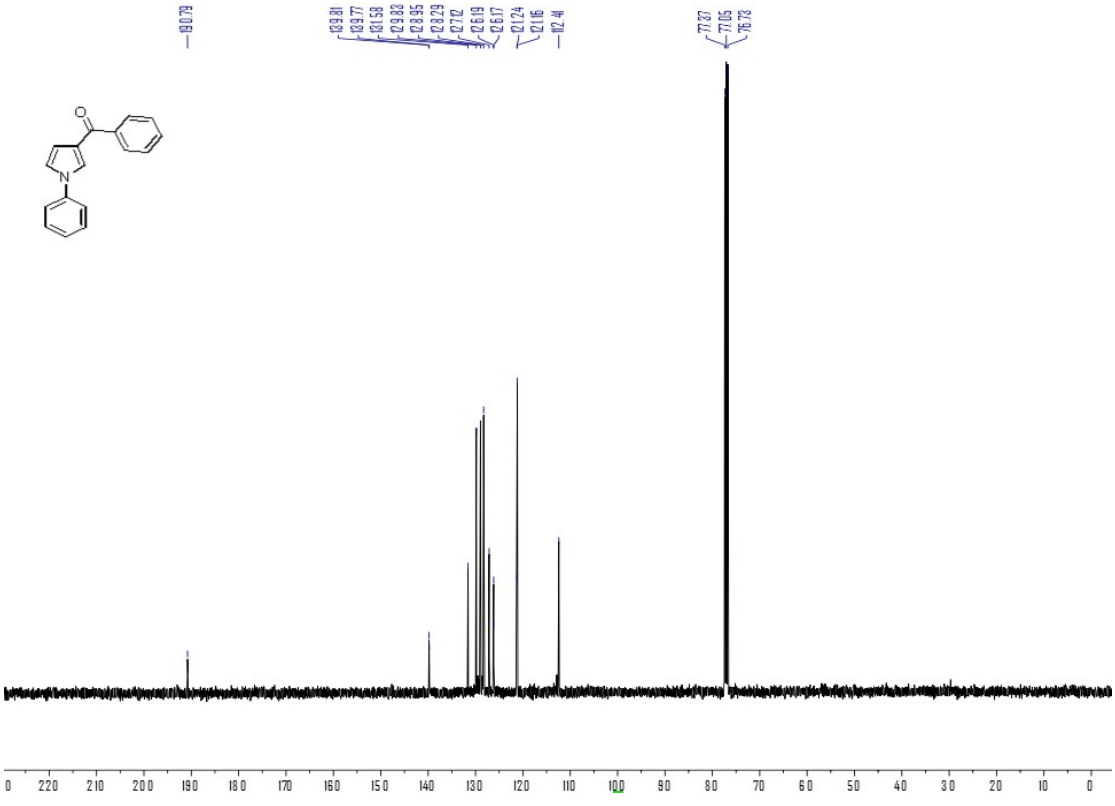
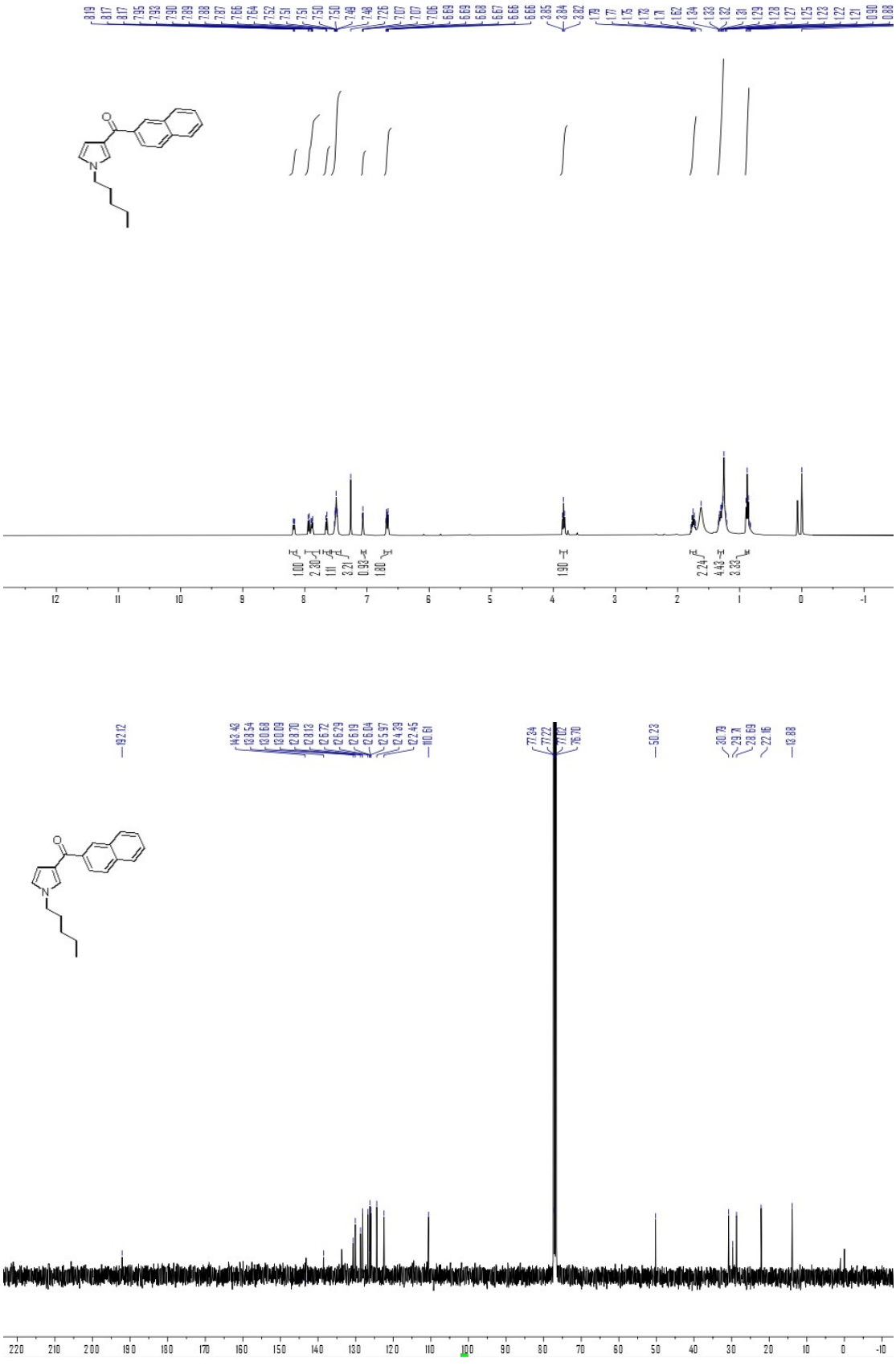
Phenyl(1-phenyl-1*H*-pyrrol-3-yl)methanone (3ak)



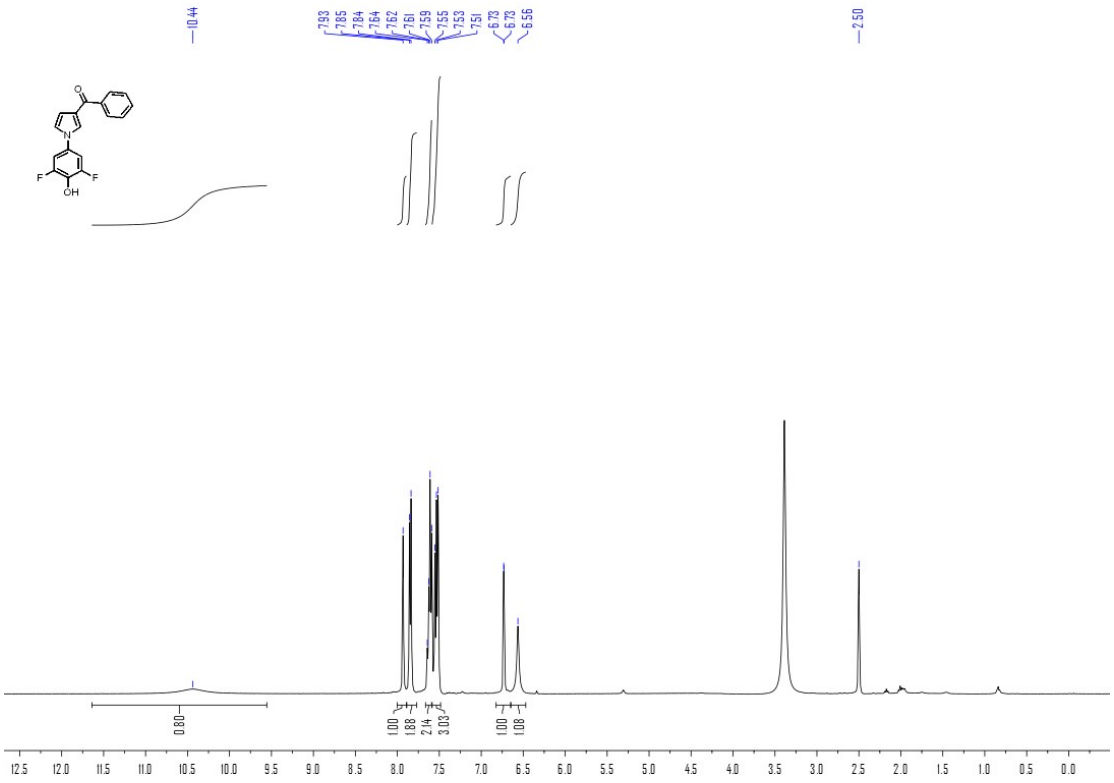


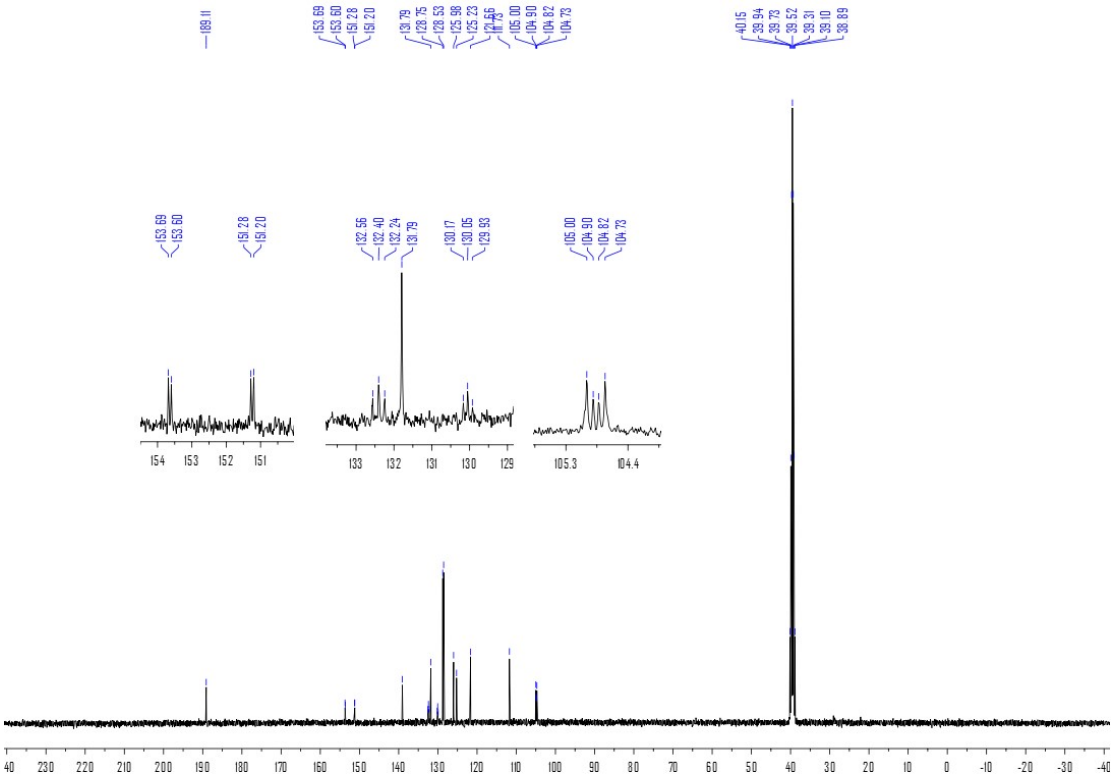


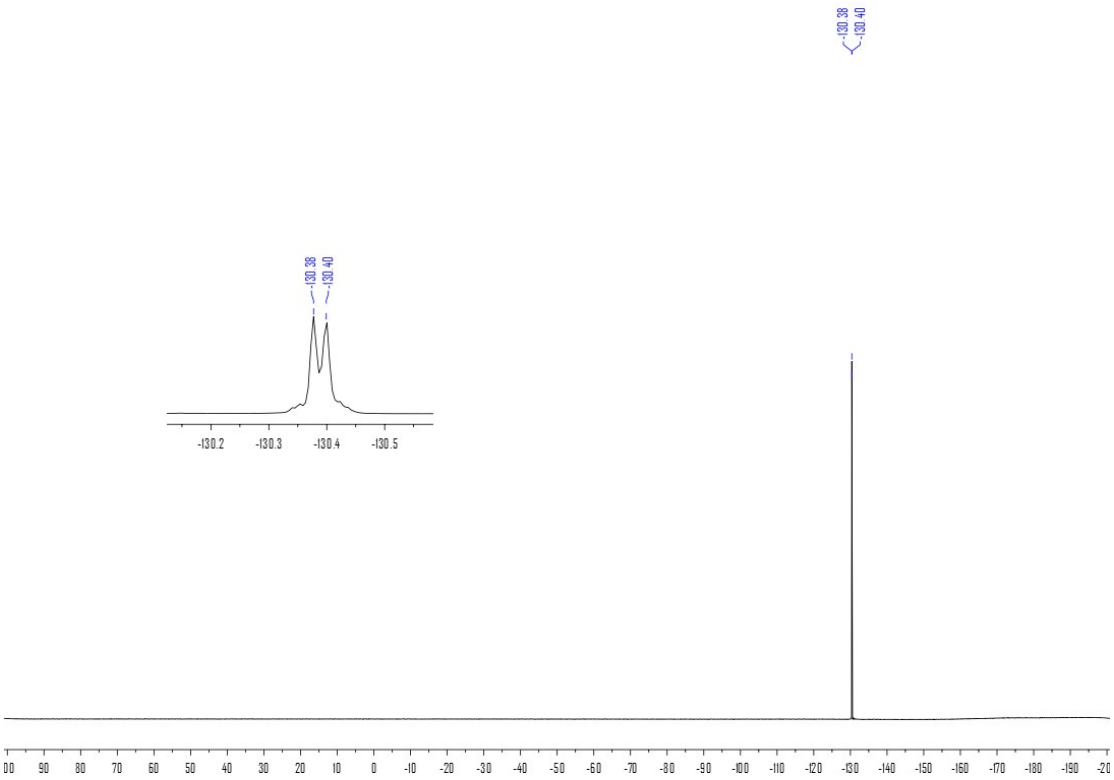
Naphthalen-1-yl(1-pentyl-1*H*-pyrrol-3-yl)methanone (3al, JWH-030)



1-(3-Hydroxyphenyl)-1*H*-pyrrole-3-carboxamide (JMC-2004)



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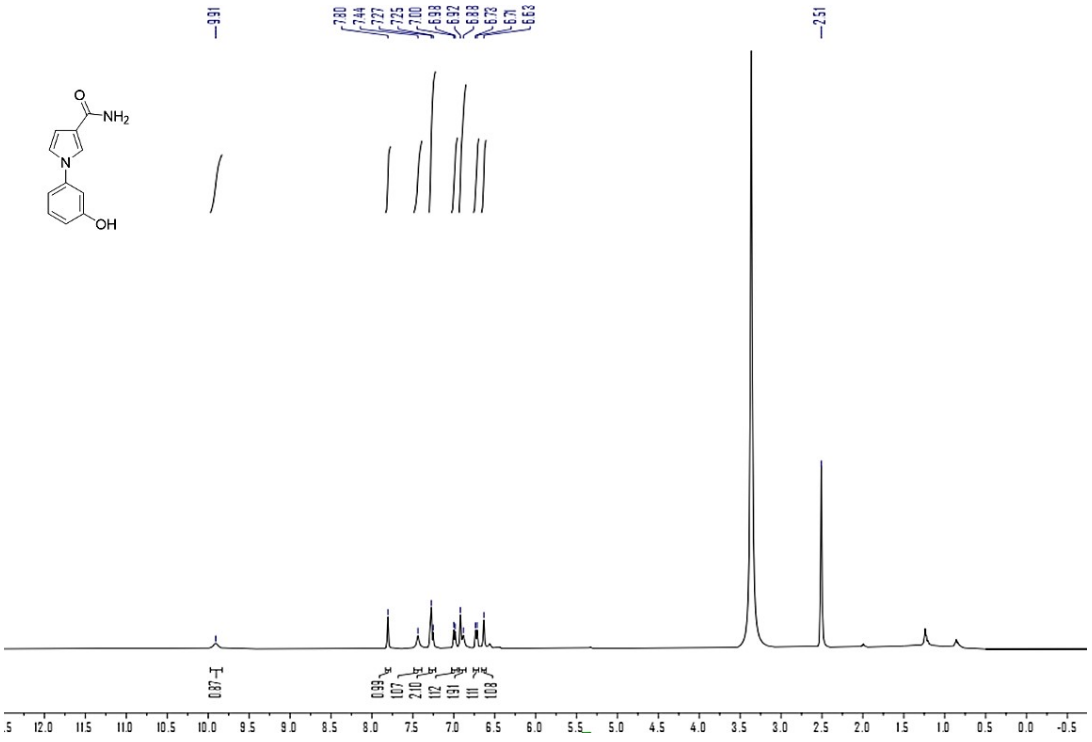
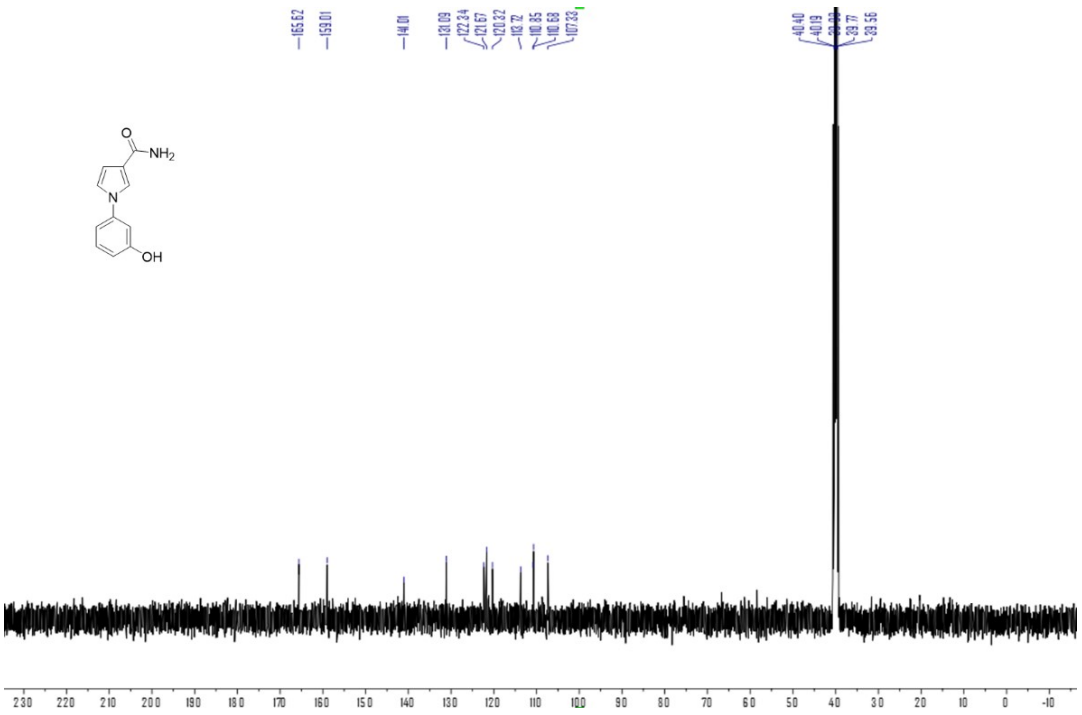
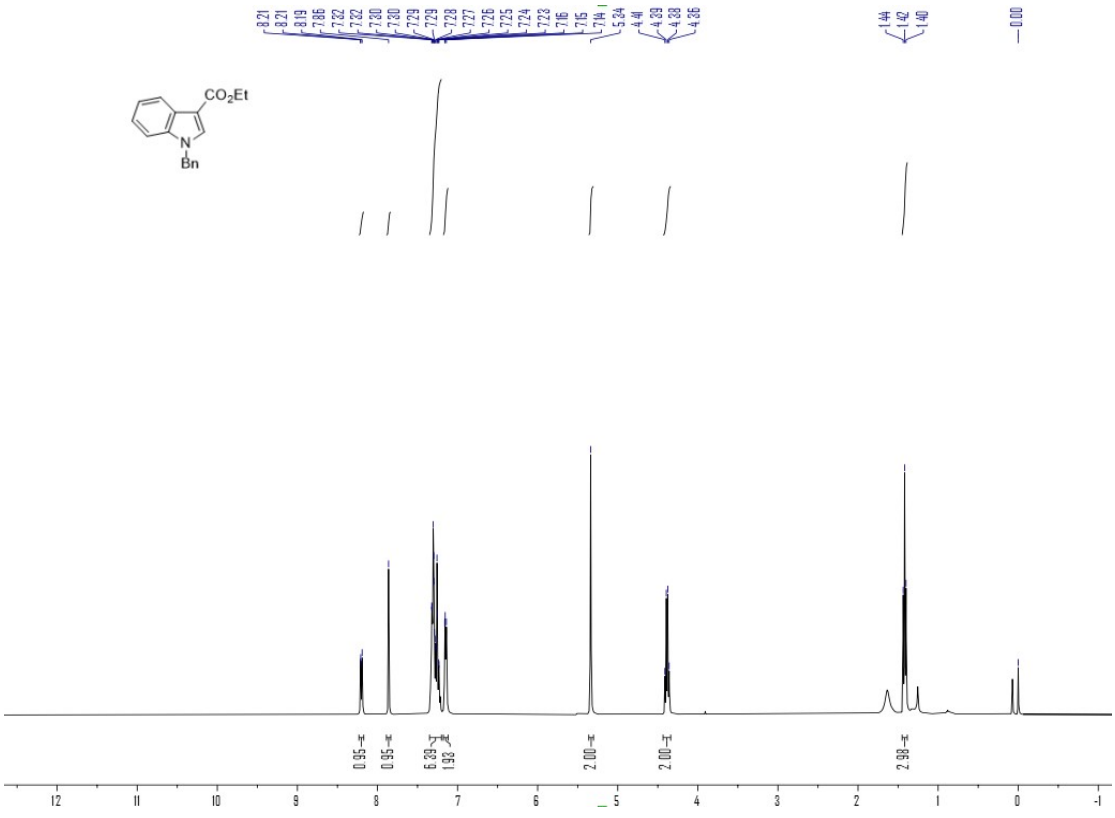
-190

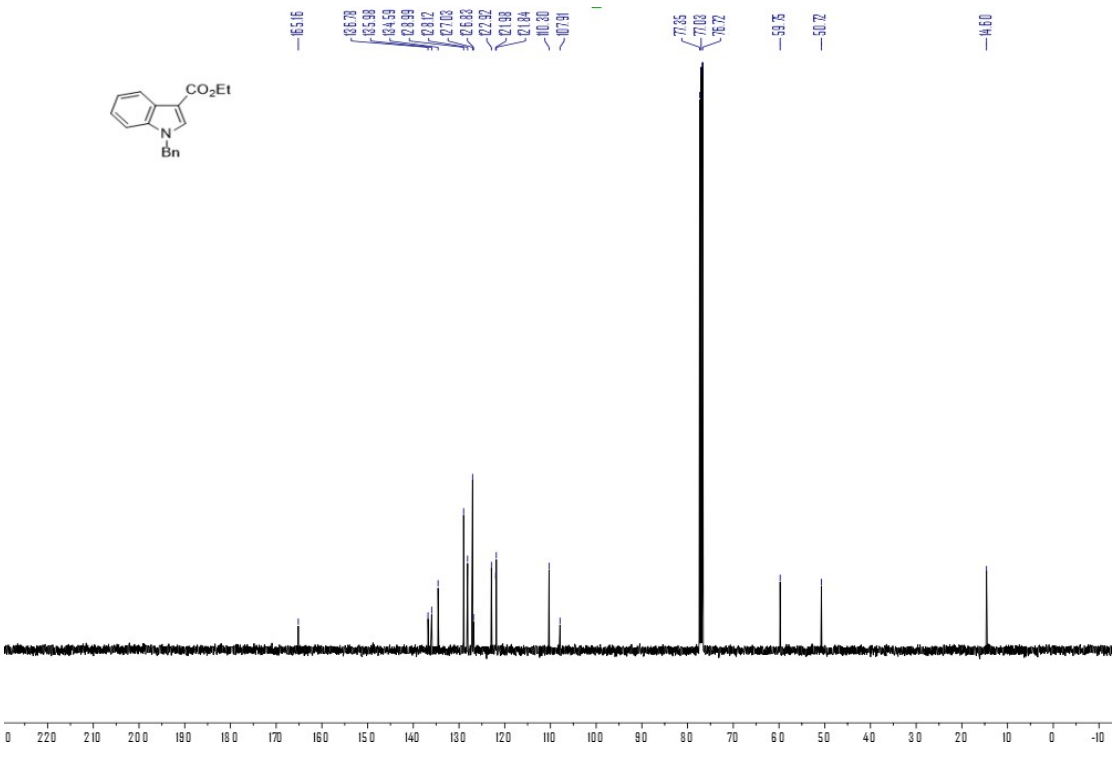
(1-(3,5-Difluoro-4-hydroxyphenyl)-1*H*-pyrrol-3-yl)(phenyl)methanon (4a)





Ethyl 1-benzyl-1*H*-indole-3-carboxylate (5a)





13. Reference

[1] N. Kontonikas, P. Kotsampasakou, N. Sakalis, and V. J. Demopoulos, *Org. Prep. Proced. Int.*, **2019**, *51*, 147-152.
[2] I. Nicolaou, C. Zika, and V. J. Demopoulos, *J. Med. Chem.*, **2004**, *47*, 2706-2709.
[3] S. Butini, M. Brindisi, S. Gemma, P. Minetti, W. Cabri, G. Gallo, et al., *J. Med. Chem.,* **2012**, *55*, 6898-6915.
[4] G. La Regina, R. Bai, A. Coluccia, V. Famiglini, S. Pelliccia, S. Passacantilli, et al., *J. Med. Chem.*, **2014**, *57*, 6531-6552.