

Supporting Information

Nickel-Catalyzed Methylation of Aryl Halides/Tosylates with Methyl Tosylate

Jiawang Wang[†], Jianhong Zhao^{†,*} and Hegui Gong^{†,*}

[†]Center for Supramolecular Chemistry and Catalysis and Department of Chemistry, Shanghai
University, 99 Shang-Da Road, Shanghai 200444, China

^{*}Laboratory of Green Pharmaceutical Process & Technology, School of Pharmacy, East China University of
Science and Technology, Shanghai 200237

E-mail: Hegui_Gong@shu.edu.cn

zjhpharm@163.com

Table of Contents

I.	Experimental Section	S2-S29
	Part 1. General Information.....	S2
	Part 2. Preparation of Aryl Tosylates	S3-S8
	Part 3. Control Experiments and Optimization.....	S9-S10
	Part 4. Mechanistic Consideration.....	S11-S12
	Part 5. Methylation of Aryl Halides/Tosylates.....	S13-S29
II.	Spectral Data for New Compounds.....	S30-S68
III.	Reference.....	S69

I. Experimental Section

Part 1. General Information

1. Chemicals and Reagents

All manipulations were carried out under an atmosphere of nitrogen using standard Schlenk or glove box techniques. The following anhydrous solvents were purchased from Acros, THF (99.5%, stabilized), MeCN (acetonitrile, 99.9%), DMF (*N,N*-dimethylformamide, 99.8%), DME (1,2-dimethoxyethane, 99%), DMSO (dimethyl sulfoxide, 99.7%), DMA (*N,N*-dimethylacetamide, 99.5%, extra pure), NMP (*N*-methylpyrrolidinone, 99.5%), 1,4-Dioxane (99.5%), DMI (*N,N*-1,3-dimethylimidazolidin-2-one, Aldrich) were purchased and used directly. Deuterated solvents were purchased and used as received (CDCl_3 from Maclin Co., China). NiCl_2 (Alfa Aesar), NiBr_2 (Alfa Aesar), NiI_2 (Alfa Aesar), $\text{Ni}(\text{COD})_2$ (Strem), $\text{Ni}(\text{ClO}_4)_2$ (Alfa Aesar), $\text{Ni}(\text{acac})_2$ (Maclin Co., China), NiCl_2 -glyme (Strem), were used as received. Zinc powder (Aladdin, China) was activated with hydrochloric acid before use. Anhydrous MgCl_2 (Alfa Aesar) and Anhydrous LiCl_2 (TCI) was purchased, and used directly. Unless otherwise noted, all other reagents and starting materials were purchased from commercial sources and used without further purification.

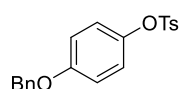
2. Physical Method

Column chromatography was performed using silica gel 300-400 mesh (purchased from Qingdao-Haiyang Co., China) as the solid support. All NMR spectra were recorded on Bruker Avance 500 MHz spectrometer at STP unless otherwise indicated. ^1H NMR and ^{13}C NMR chemical shifts were reported in δ units, parts per million (ppm) relative to the chemical shift of residual solvent. Reference peaks for chloroform in ^1H NMR and ^{13}C NMR spectra were set at 7.26 ppm and 77.00 ppm, respectively. High-resolution mass spectra (HRMS) were obtained using a Bruker APEXIII 7.0 and IonSpec 4.7 TESLA FTMS. Melting point was recorded on a micro melting point apparatus (X-4, YUHUA Co., Ltd, Gongyi, China).

Part 2. Preparation of Aryl Tosylates

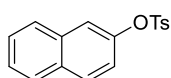
A general procedure for the preparation of aryl tosylates: To a solution of an alcohol (20.0 mmol) in CH₂Cl₂ (70 mL) was added 150 mol % NEt₃ (4 mL, 30 mmol) and 20 mol % DMAP (0.488 g, 4 mmol). After the resulting solution was cooled to 0 °C with an ice water bath, a solution of TsCl (4.56 g, 24.0 mmol) in CH₂Cl₂ (30 mL) was slowly added within 15 min at 0 °C. After addition of TsCl, the ice-water bath was removed and the reaction mixture was stirred for 2 h. To the mixture was then added CH₂Cl₂ (100 mL). The organic layer was washed with brine, dried over MgSO₄ and concentrated under reduced pressure. The residue was purified by flash chromatography over silica.

4-(Benzyloxy)phenyl 4-methylbenzenesulfonate¹



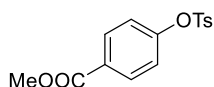
This compound was prepared from 4-(benzyloxy) phenol (4.00 g, 20.0 mmol) according to the *General Procedure*. The crude residue was purified by silica gel chromatography (7% ethyl acetate/hexanes) to yield the aryl tosylate as a white solid in 98% yield.

Naphthalen-2-yl 4-methylbenzenesulfonate²



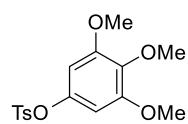
This compound was prepared from naphthalen-2-ol (2.88 g, 20.0 mmol) according to the *General Procedure*. The crude residue was purified by silica gel chromatography (7% ethyl acetate/hexanes) to yield the aryl tosylate as a white solid in 99% yield.

Methyl 4-(tosyloxy)benzoate³



This compound was prepared from methyl 4-hydroxybenzoate (3.04 g, 20.0 mmol) according to the *General Procedure*. The crude residue was purified by silica gel chromatography (8% ethyl acetate/hexanes) to yield the aryl tosylate as a white solid in 99% yield.

3,4,5-Trimethoxyphenyl 4-methylbenzenesulfonate



This compound was prepared from 3,4,5-trimethoxyphenol (3.68 g, 20.0 mmol) according to the *General Procedure*. The crude residue was purified by silica gel chromatography (15% ethyl acetate/hexanes) to yield the aryl tosylate as a white solid in 98% yield.

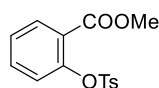
¹H NMR (500 MHz, CDCl₃) δ = 7.74 (d, J = 8.3 Hz, 2H), 7.33 (d, J = 8 Hz, 2H), 6.19 (s, 2H), 3.79 (s, 3H), 3.70 (s, 6H), 2.45 (s, 3H).

¹³C NMR (125 MHz, CDCl₃) δ = 153.3, 145.4, 145.3, 136.7, 132.3, 129.6, 128.6, 99.9, 60.9, 56.0, 21.6.

HRMS (ESI) exact mass calculated for [M+Na⁺] (C₁₆H₁₆NaO₆S⁺): m/z 361.0716; found: 361.0716.

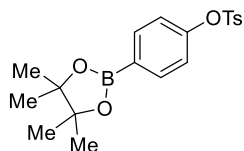
M.p. 112-113 °C

Methyl 2-(tosyloxy)benzoate³



This compound was prepared from methyl 2-hydroxybenzoate (3.04 g, 20.0 mmol) according to the *General Procedure*. The crude residue was purified by silica gel chromatography (10% ethyl acetate/hexanes) to yield the aryl tosylate as a white solid in 96% yield.

4-(4,4,5,5-Tetramethyl-1,3,2-dioxaborolan-2-yl)phenyl 4-methylbenzenesulfonate



This compound was prepared from 4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)phenol (4.40 g, 20.0 mmol) according to the *General Procedure*. The crude residue was purified by silica gel chromatography (7% ethyl acetate/hexanes) to yield the aryl tosylate as a white solid in 99% yield.

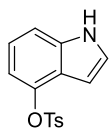
¹H NMR (500 MHz, CDCl₃) δ = 7.71 (d, J = 8.5 Hz, 2H), 7.68 (d, J = 8.3 Hz, 2H), 7.29 (d, J = 8 Hz, 2H), 6.96 (d, J = 8.6 Hz, 2H), 2.43 (s, 3H), 1.32 (s, 12H).

¹³C NMR (125 MHz, CDCl₃) δ = 151.9, 145.3, 136.2, 132.3, 129.7, 128.4, 121.6, 84.0, 24.8, 21.6.

HRMS (ESI) exact mass calculated for [M+Na⁺] (C₁₉H₂₃BNaO₅S⁺): m/z 397.1251; found: 397.1248.

M.p. 98-99 °C

1H-Indol-4-yl 4-methylbenzenesulfonate



This compound was prepared from 1H-indol-4-ol (2.66 g, 20.0 mmol) according to the *General Procedure*. The crude residue was purified by silica gel chromatography (20% ethyl acetate/hexanes) to yield the aryl tosylate as a lilac solid in 60% yield.

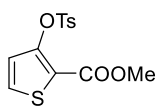
¹H NMR (500 MHz, CDCl₃) δ = 8.21 (broad s, 1H), 7.75 (d, J = 8.3 Hz, 2H), 7.27-7.26 (m, 3H), 7.12 (t, J = 2.7 Hz, 1H), 7.04 (t, J = 8 Hz, 1H), 6.71 (d, J = 7.7 Hz, 1H), 6.38 (s, 1H), 2.42 (s, 3H).

¹³C NMR (125 MHz, CDCl₃) δ = 145.0, 142.4, 137.7, 132.9, 129.6, 128.4, 124.8, 122.0, 121.8, 112.8, 110.2, 99.7, 21.6.

HRMS (ESI) exact mass calculated for [M+Na⁺] (C₁₅H₁₃NNaO₃S⁺): m/z 310.0508; found: 310.0511.

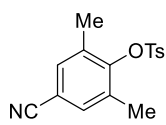
M.p. 104- 105 °C

Methyl 3-(tosyloxy)thiophene-2-carboxylate⁴



This compound was prepared from methyl 3-hydroxythiophene-2-carboxylate (3.16 g, 20.0 mmol) according to the *General Procedure*. The crude residue was purified by silica gel chromatography (10% ethyl acetate/hexanes) to yield the aryl tosylate as a white solid in 96% yield.

4-Cyano-2,6-dimethylphenyl 4-methylbenzenesulfonate



This compound was prepared from 4-hydroxy-3,5-dimethylbenzonitrile (2.94 g, 20.0 mmol) according to the *General Procedure*. The crude residue was purified by silica gel chromatography (8% ethyl acetate/hexanes) to yield the aryl tosylate as a white solid in 95% yield.

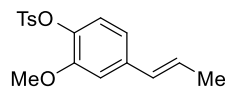
¹H NMR (500 MHz, CDCl₃) δ = 7.84 (d, J = 8.3 Hz, 2H), 7.39 (d, J = 8.1 Hz, 2H), 7.34 (s, 2H), 2.48 (s, 3H), 2.16 (s, 3H).

¹³C NMR (125 MHz, CDCl₃) δ = 150.5, 145.8, 134.2, 133.7, 132.8, 130.0, 128.0, 118.0, 110.6, 21.7, 17.2.

HRMS (ESI) exact mass calculated for [M+Na⁺] (C₁₆H₁₅NNaO₃S⁺): m/z 324.0665; found: 324.0655.

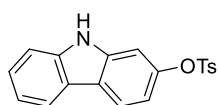
M.p. 142 °C

(E)-2-Methoxy-4-(prop-1-en-1-yl)phenyl 4-methylbenzenesulfonate⁵



This compound was prepared from isoeugenol (3.28 g, 20.0 mmol) according to the *General Procedure*. The crude residue was purified by silica gel chromatography (8% ethyl acetate/hexanes) to yield the aryl tosylate as a white solid in 97% yield.

9H-Carbazol-2-yl 4-methylbenzenesulfonate



This compound was prepared from 9H-carbazol-2-ol (3.66 g, 20.0 mmol) according to the *General Procedure*. The crude residue was purified by silica gel chromatography (15% ethyl acetate/hexanes) to yield the aryl tosylate as a brown solid in 70% yield.

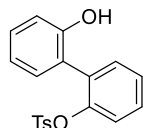
¹H NMR (500 MHz, d-DMSO) δ = 11.6 (s, 1H), 8.09 (d, J = 7.8 Hz, 1H), 7.85 (d, J = 8.2 Hz, 2H), 7.52 (d, J = 8.1 Hz, 1H), 7.45 – 7.42 (m, 4H), 7.32 (t, J = 8 Hz, 1H), 7.19 (td, J = 7.5, 0.9 Hz, 1H), 6.69 (dd, J = 7.9, 0.5 Hz, 1H), 2.36 (s, 3H).

¹³C NMR (125 MHz, d-DMSO) δ = 146.2, 144.5, 142.0, 140.1, 132.8, 130.6, 128.6, 126.6, 126.2, 122.4, 120.1, 119.5, 115.6, 111.6, 110.9, 110.4, 21.5.

HRMS (ESI) exact mass calculated for $[M+Na^+]$ ($C_{19}H_{15}NNaO_3S^+$): m/z 360.0665; found: 360.0668.

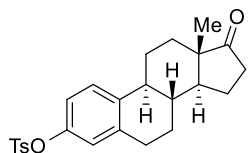
M.p. 192- 193 °C

2'-Hydroxy-[1,1'-biphenyl]-2-yl 4-methylbenzenesulfonate⁶



This compound was prepared from [1,1'-biphenyl]-2,2'-diol (3.72 g, 20.0 mmol) according to the *General Procedure*. The crude residue was purified by silica gel chromatography (15% ethyl acetate/hexanes) to yield the aryl tosylate as a white solid in 80% yield.

Estra-1,3,5(10)-trien-17-one, 3-[[4-(4-methylphenyl)sulfonyl]oxy]- (9CI)



This compound was prepared from 1,3,5(10)-Estratrien-3-ol-17-one (5.40 g, 20.0 mmol) according to the *General Procedure*. The crude residue was purified by silica gel chromatography (15% ethyl acetate/hexanes) to yield the aryl tosylate as a white solid in 96% yield.

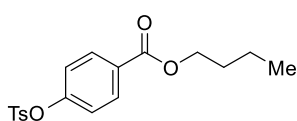
¹H NMR (500 MHz, CDCl₃) δ = 7.76 (d, J = 8.3 Hz, 2H), 7.34 (d, J = 8 Hz, 2H), 7.18 (d, J = 8.5 Hz, 1H), 6.81 (d, J = 2.5 Hz, 1H), 6.68 (dd, J = 8.5, 2.5 Hz, 1H), 2.87 – 2.85 (m, 2H), 2.52 (dd, J = 19.1, 8.7 Hz, 1H), 2.48 (s, 3H), 2.39 – 2.35 (m, 1H), 2.29 – 2.24 (m, 1H), 2.20 – 2.12 (m, 1H), 2.10 – 1.95 (m, 3H), 1.63 – 1.40 (m, 6H), 0.92 (s, 3H).

¹³C NMR (125 MHz, CDCl₃) δ = 220.5, 147.5, 145.1, 138.7, 138.3, 132.8, 129.7, 128.4, 126.4, 122.4, 119.2, 53.4, 50.4, 47.8, 44.1, 37.8, 35.8, 31.5, 29.3, 26.2, 25.6, 21.7, 21.5, 13.8.

HRMS (ESI) exact mass calculated for [M+Na⁺] (C₂₅H₂₈NaO₄S⁺): m/z 447.1601; found: 447.1604.

M.p. 143 – 144 °C

Butyl 4-(tosyloxy)benzoate



This compound was prepared from butyl 4-hydroxybenzoate (3.88 g, 20.0 mmol) according to the *General Procedure*. The crude residue was purified by silica gel chromatography (7% ethyl acetate/hexanes) to yield the aryl tosylate as a white solid in 96% yield.

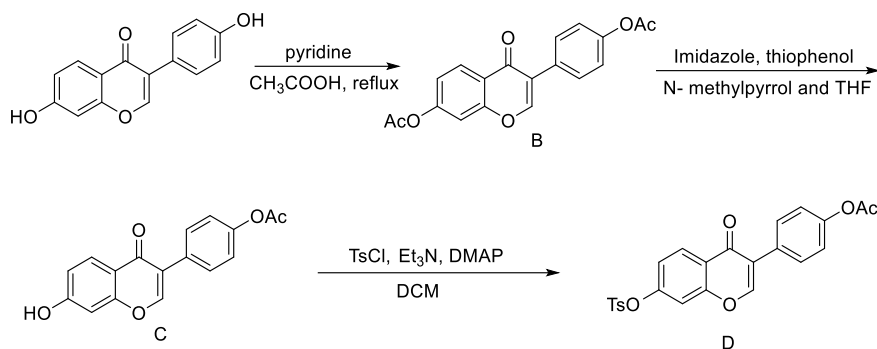
¹H NMR (500 MHz, CDCl₃) δ = 7.96 (d, J = 8.7 Hz, 2H), 7.69 (d, J = 8.3 Hz, 2H), 7.31 (d, J = 8 Hz, 2H), 7.04 (d, J = 8.7 Hz, 2H), 4.29 (t, J = 6.6 Hz, 2H), 2.44 (s, 3H), 1.75 – 1.69 (m, 2H), 1.48 – 1.41 (m, 2H), 0.96 (t, J = 7.4 Hz, 3H).

¹³C NMR (125 MHz, CDCl₃) δ = 165.5, 152.8, 145.6, 132.0, 131.2, 129.8, 129.2, 128.4, 122.2, 65.1, 30.6, 21.7, 19.1, 13.6.

HRMS (ESI) exact mass calculated for [M+Na⁺] (C₁₈H₂₀NaO₅S⁺): m/z 371.0924; found: 371.0924.

M.p. 51 – 52 °C

Synthesis of 4-(4-oxo-7-(tosyloxy)-4H-chromen-3-yl)phenyl acetate



To solution of daidzein (3.0 mmol) in acetic anhydride (6.0 mL) was added pyridine (0.6 mL). The mixture was heated to reflux until consumption of daidzein, at which point it was poured into ice cold water (70 mL) to afford B as a white solid. The crude product was recrystallized to give pure compound B.

Compound B was dissolved in *N*-methylpyrrolidone (12.5 mL) and THF (37.5 mL) at 0 °C, followed by the addition of imidazole (0.06 g) and thiophenol (0.3 mL). The mixture was allowed to slowly warm to r.t., and the reaction was monitored by TLC. The reaction solvent was evaporated under reduced pressure. Then the residue was diluted with ethyl acetate (100 mL) and washed with 1M of HCl (aq, 30 mL \times 5). The organic phase was collected, dried over anhydrous Na₂SO₄ overnight. After filtration and concentration, the crude mixture was washed with ethanol to afford compound C.

Compound D was prepared from compound C (0.39 g, 2.0 mmol) according to the *General Procedure*. The crude residue was purified by silica gel chromatography (20% ethyl acetate/hexanes) to yield the aryl tosylate as a white solid in 90% yield.

¹H NMR (500 MHz, CDCl₃) δ = 8.21 (d, J = 8.8 Hz, 1H), 7.99 (s, 1H), 7.75 (d, J = 8.3 Hz, 2H), 7.55 (d, J = 8.7 Hz, 2H), 7.35 (d, J = 8 Hz, 2H), 7.28 (d, J = 2.2 Hz, 1H), 7.16 (d, J = 8.6 Hz, 2H), 6.97 (dd, J = 8.8, 2.2 Hz, 1H), 2.46 (s, 3H), 2.32 (s, 3H).

¹³C NMR (125 MHz, CDCl₃) δ = 175.2, 169.4, 156.4, 153.2, 153.0, 150.8, 146.1, 131.9, 130.08, 130.00, 128.9, 128.5, 128.2, 124.9, 123.1, 121.8, 119.8, 112.0, 21.7, 21.1.

HRMS (ESI) exact mass calculated for [M+Na⁺] (C₂₄H₁₈NaO₇S⁺): m/z 473.0665; found: 473.0672.

M.p. 176 - 177 °C

Part 3. Control Experiments and Optimization

Table S1. Control experiment for the synthesis of **2** with aryl bromide.^{a,b}

<p style="text-align: center;"> </p>		
entry	variations	yield ^b
1	none	93% ^c
2	Ni(acac) ₂ instead of NiI ₂	83%
3	KI instead of TBAI	25%
4	DMSO instead of DMA	67%
5	DMA:NMP = 3:7	87%
6	DMA:NMP = 7:3	63%
7	TBAI(50%)	77%
8	MgCl ₂ (100%)	40%
9	MgCl ₂ (200%)	90%

^a Reaction Conditions: ArBr as the limiting reagent (0.3 mmol), NiI₂ (5 mol %), **L1a** (7 mol %), MgCl₂ (150 mol %), TBAI (100 mol %), Zn (200 mol %), DMA (1 mL). ^b Yield was determined by ¹H NMR using 2,5-dimethylfuran as the internal reference, from a mixture containing other impurities after a quick flash column chromatography. ^c Isolated yield: 93%.

Table S2. Control experiment for the synthesis of **2** with aryl tosylate.

<p style="text-align: center;"> </p>		
entry	variations	yield ^b
1	none	75% ^c
2	PPh ₃ instead of dppf	45%
3	dppf (15%)	47%
4	dppf (10%)	49%
5	dppe instead of dppf	16%
6	NiCl ₂ (dppf) instead of NiCl ₂ glyme	49%
7	NiCl ₂ (dppf) instead of NiCl ₂ · glyme, without dppf	53%
8	without NiCl ₂ glyme	N.D. ^d
9	without dppf	N.D. ^d
10	NaI instead of TBAI	18%
11	without TBAI	55%
12	25 °C	63%
13	0 °C to 20 °C	61%
14	without Zn	N.D. ^d
15	Zn (300%)	33%
16	without LiCl	20%
18	THF instead of DMA	N.D. ^d
19	standard method A	40%

^a Reaction Conditions: ArOTs as the limiting reagent (0.15 mmol), NiCl₂-glyme (10 mol %), dppf (20 mol %), LiCl (600 mol %), TBAI (150 mol %), Zn (600 mol %), DMA (1.2 mL). ^b Yield was determined by ¹H NMR using trimethyl(phenyl)silane as the internal reference, from a mixture containing other impurities after a quick flash column chromatography. ^c Isolated yield: 75%. ^d Not detected by ¹H NMR.

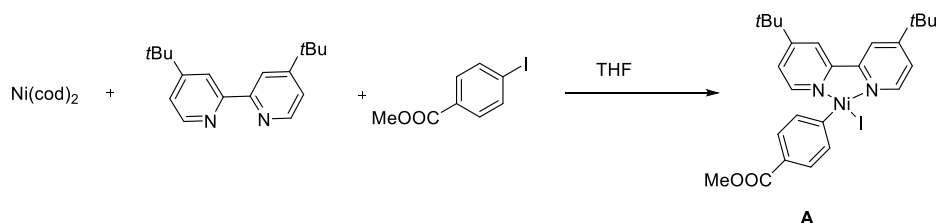
Table S3. Control experiment for the synthesis of **3** with aryl tosylate.

entry	variations	yield% ^b
1	none	73% ^c
2	dppf instead of PPh ₃	27%
3	dppe instead of PPh ₃	37%
4	without PPh ₃	N.D. ^d
5	NiI ₂ instead of NiCl ₂ -glyme	16%
6	NiCl ₂ (PPh ₃) instead of NiCl ₂ -glyme	57%
7	NiCl ₂ (dppe) instead of NiCl ₂ -glyme, without PPh ₃	51%
8	without NiCl ₂ -glyme	N.D. ^d
9	0 °C	34%
10	40 °C	49%
12	without MgCl ₂	33%
14	without Zn	N.D. ^d
15	without TBAI	40%
16	dppf (20%) instead of PPh ₃ , LiCl (600%) instead of MgCl ₂	48%
17	naphthalen-2-yl pivalate instead of methyl 4-(tosyloxy)benzoate	30% ^e

^a Reaction Conditions: ArOTs as the limiting reagent (0.15 mmol), NiCl₂-glyme (10 mol %), PPh₃ (20 mol %), MgCl₂ (300 mol %), TBAI (150 mol %), Zn (600 mol %), DMA (1.2 mL). ^b Yield was determined by ¹H NMR using trimethyl(phenyl)silane as the internal reference, from a mixture containing other impurities after a quick flash column chromatography. ^c Isolated yield: 73%. ^d Not detected by ¹H NMR. ^e GC yield

Part 4. Mechanistic consideration

(1) Preparation of complex (A)⁸



In a glove box, a suspension of Ni(cod)_2 (330.4 mg, 1.20 mmol, 100 mol %) in 8 mL of dry THF was stirred for 1 minute in a 50 mL flame-dried Schlenk tube, at which point a solution of ligand **L1b** (322.1 mg, 1.20 mmol, 100 mol %) in 8 mL of dry THF was added dropwise. The resulting mixture was allowed to stir overnight at ambient temperature. A solution of methyl 4-iodobenzoate (314.4 mg, 1.20 mmol, 100 mol %) in 4 mL of dry THF was added via syringe. The resultant mixture was allowed to stir for 1 h. The solvent was removed under vacuum, and the residue was filtrated with a fritted funnel, and washed with diethyl ether (6×3mL). The brownish red solid was collected, and further stirred in ether (50 mL) to dissolve aryl dimer. After filtration, and dried in vacuum, the title compound was obtained in ~70% yield (494.7 mg, 0.84 mmol, with trace THF and diethyl ether), which was stored in the glove box at -30 °C.

¹H NMR (500 MHz, Acetone-*d*₆) δ = 9.54 (s, 1H), 8.46 (d, *J* = 10.9, 2H), 7.79 (d, *J* = 6.6, 2H), 7.68 (s, 1H), 7.50 (d, *J* = 7.2, 2H), 7.47 (d, *J* = 4.5, 1H), 6.92 (s, 1H), 3.83 (s, 3H), 1.45 (s, 9H), 1.39 (s, 9H).

¹³C NMR (125 MHz, Acetone- *d*₆) δ = 167.58, 165.98, 163.94, 163.75, 163.45, 155.91, 153.82, 153.49, 149.70, 144.00, 138.01, 130.04, 128.23, 127.33, 125.14, 123.95, 123.59, 119.16, 118.50, 67.23, 53.53, 51.60, 50.76, 35.38, 33.90, 27.74, 25.41, 22.03, 15.53, 13.38.

(2) Preparation of the organozinc reagents⁹

To a Schlenk tube (10 mL) was charged with zinc powder (195 mg, 2.00 mmol, 100 mol %). The zinc powder was heated to 70 °C under high vacuum for 30 min. After back-filling with argon, iodine (25.4 mg, 0.10 mmol, 5 mol%) and DMA (to give a total volume of 2 mL) were added, the resulting mixture was stirred until the red color of iodine faded. Then, methyl iodide (284 mg, 2

mmol, 100 mol%) or deuterated methyl iodide (290 mg, 2 mmol, 100 mol%) was added. The colorless reaction mixture was allowed to stir for 4 h at 25 °C. The gray solution was stored under nitrogen in a dry container. The alkylzinc solution was titrated with iodine following the Knochel method,¹⁰ which established that the alkylzinc reagent had been formed in good yield (~0.95 M).

Part 5. Methylation of Aryl Halides/Tosylates

(1) Method A for Aromatic Halides:

To a flame dried Schlenk tube was charged with aryl bromide (0.30 mmol, 100 mol %, if solid), Zn (39.2 mg, 0.60 mmol, 200 mol %), 4,4'-di-*methyl*-2,2'-bipyridine (3.8 mg, 0.021 mmol, 7 mol %), MgCl₂ (42.8 mg, 0.45 mmol, 150 mol %) and TBAI (110.8 mg, 0.30 mmol, 100 mol%). The tube was moved into a glove box, to which NiI₂ (4.68 mg, 0.015 mmol, 5 mol %) was added. It was capped with a rubber septum and moved out of the glove box. After aryl bromide (0.30 mmol, 100 mol %, if liquid) and TsOMe (0.60 mmol, 200 mol %) were added via syringes, DMA (1.0 mL) was added via a syringe. The reaction mixture was allowed to stir at room temperature for 12 h. The reaction mixture was directly load onto a silica column without work-up. The residue was rinsed with small amount of DCM or the eluent. Column chromatography provided the product.

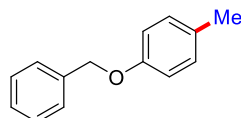
Note: for heterocyclic bromides, NiI₂ (9.4 mg, 0.030 mmol, 10 mol %), 4,4'-di-*methyl*-2,2'-bipyridine (8.3 mg, 0.045 mmol, 15 mol %) were used; **for bis(halo)arenes**, NiI₂ (18.8 mg, 0.060 mmol, 20 mol %), 4,4'-di-*methyl*-2,2'-bipyridine (16.6 mg, 0.09 mmol, 30 mol %), TBAI (221.6 mg, 0.60 mmol, 200 mol%) and TsOMe (1.50 mmol, 500 mol %) in DMA (1.5 mL) were employed and the reaction was run for 24 h.

(2) Method B for Aryl Tosylates:

To a flame dried Schlenk tube was charged with aryl tosylate (0.15 mmol, 100 mol %), Zn (58.8 mg, 0.90 mmol, 600 mol %), dppf (16.6 mg, 0.03 mmol, 20 mol %), LiCl (38.2 mg, 0.90 mmol, 600 mol %) and TBAI (83.1 mg, 0.225 mmol, 150 mol%) for electron-rich aryl tosylates. The tube was moved into a glove box, to which NiCl₂·glyme (3.3 mg, 0.015 mmol, 10 mol%) was added. It was capped with a rubber septum and moved out of the glove box. After TsOMe (0.45 mmol, 300 mol%,) were added via syringes, DMA (1.2 mL) was added via a syringe. The reaction mixture was allowed to stir at 40 °C for 12 h. The reaction mixture was directly load onto a silica column without work-up. The residue was rinsed with small amount of DCM or the eluent. Column chromatography provided the product.

Note: for electron-deficient aryl tosylates, the reaction mixture was allowed to stir at 25 °C for 12 h, PPh₃ (7.8 mg, 0.03 mmol, 20 mol %), MgCl₂ (42.8 mg, 0.45 mmol, 300 mol %) was used, dppf and LiCl were eliminated out.

1-(Benzyloxy)-4-methylbenzene (2)¹¹



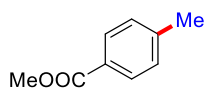
This compound was prepared according to the *method A* using 1-(benzyloxy)-4-bromobenzene (78.9 mg, 0.300 mmol, 100 mol%), TsOMe (111.6 mg, 0.600 mmol, 200 mol%). After purification by column chromatography (SiO₂: 0.5% ethyl acetate in petroleum ether), the title compound was isolated in 93% yield (55.2 mg, 0.279 mmol) as a canary solid.

This compound can also be prepared according to the *method B*, using 4-(benzyloxy) phenyl 4-methylbenzenesulfonate (53.1 mg, 0.150 mmol, 100 mol%), TsOMe (83.7 mg, 0.450 mmol, 300 mol%). After purification by column chromatography (SiO₂: 0.5% ethyl acetate in petroleum ether), the title compound was isolated in 75% yield (22.2 mg, 0.112 mmol) as a canary solid.

¹H NMR (500 MHz, CDCl₃) δ = 7.45 (d, *J* = 7.2 Hz, 2H), 7.41 – 7.38 (m, 2H), 7.35 – 7.32 (m, 1H), 7.11 (d, *J* = 8.3 Hz, 2H), 6.91 – 6.89 (m, 2H), 5.06 (s, 2H), 2.31 (s, 3H).

¹³C NMR (125 MHz, CDCl₃) δ = 156.7, 137.3, 130.1, 129.9, 128.5, 127.9, 127.4, 114.7, 70.1, 20.5.

Methyl 4-methylbenzoate (3)¹²



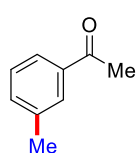
This compound was prepared according to the *method A* using methyl 4-bromobenzoate (64.5 mg, 0.300 mmol, 100 mol%), TsOMe (111.6 mg, 0.600 mmol, 200 mol%). After purification by column chromatography (SiO₂: 0.5% ethyl acetate in petroleum ether), the title compound was isolated in 90% yield (40.5 mg, 0.270 mmol) as a colorless oil.

This compound can also be prepared according to the *method B*, using methyl 4- (tosyloxy) benzoate (46.0 mg, 0.150 mmol, 100 mol%), TsOMe (83.7 mg, 0.450 mmol, 300 mol%), PPh₃ (7.8 mg, 0.03 mmol, 20 mol %), MgCl₂ (42.8 mg, 0.45 mmol, 300 mol %). After purification by column chromatography (SiO₂: 0.5% ethyl acetate in petroleum ether), the title compound was isolated in 73% yield (16.4 mg, 0.110 mmol) as a colorless oil.

¹H NMR (500 MHz, CDCl₃) δ = 7.92 (d, *J* = 8.1 Hz, 2H), 7.22 (d, *J* = 8 Hz, 2H), 3.89 (s, 3H), 2.39 (s, 3H).

¹³C NMR (125 MHz, CDCl₃) δ = 167.2, 143.5, 129.6, 129.0, 127.4, 51.9, 21.6.

3-Methylacetophenone (4)¹³

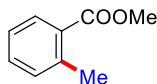


This compound was prepared according to the *method A* using 1-(3-bromophenyl)ethan-1-one (59.7 mg, 0.300 mmol, 100 mol%), TsOMe (111.6 mg, 0.600 mmol, 200 mol%). After purification by column chromatography (SiO₂: 0.5% ethyl acetate in petroleum ether), the title compound was isolated in 95% yield (39.4 mg, 0.285 mmol) as a colorless oil.

¹H NMR (500 MHz, CDCl₃) δ = 7.77 – 7.74 (m, 2H), 7.38 – 7.33 (m, 2H), 2.59 (s, 3H), 2.41 (s, 3H).

¹³C NMR (125 MHz, CDCl₃) δ = 198.4, 138.3, 137.1, 133.8, 128.7, 128.4, 125.5, 26.6, 21.3.

Methyl 2-methylbenzoate (5)¹⁴



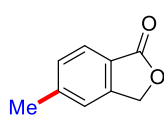
This compound was prepared according to the *method A* using methyl 2-bromobenzoate (64.5 mg, 0.300 mmol, 100 mol%), TsOMe (111.6 mg, 0.600 mmol, 200 mol%). After purification by column chromatography (SiO₂: 0.5% ethyl acetate in petroleum ether), the title compound was isolated in 72% yield (32.4 mg, 0.216 mmol) as a canary oil.

This compound can also be prepared according to the *method B*, using methyl 2-(tosyloxy) benzoate (46.0 mg, 0.150 mmol, 100 mol%), TsOMe (83.7 mg, 0.450 mmol, 300 mol%), PPh₃ (7.8 mg, 0.03 mmol, 20 mol %), MgCl₂ (42.8 mg, 0.45 mmol, 300 mol %). After purification by column chromatography (SiO₂: 0.5% ethyl acetate in petroleum ether), the title compound was isolated in 68% yield (15.3 mg, 0.102 mmol) as a canary oil.

¹H NMR (500 MHz, CDCl₃) δ = 7.91 (d, *J* = 7.6 Hz, 1H), 7.39 – 7.36 (m, 1H), 7.24 – 7.21 (m, 2H), 3.88 (s, 3H), 2.60 (s, 3H).

¹³C NMR (125 MHz, CDCl₃) δ = 167.8, 140.0, 131.8, 131.5, 130.4, 129.4, 125.5, 51.6, 21.5.

5-Methylisobenzofuran-1(3H)-one (6)¹⁵

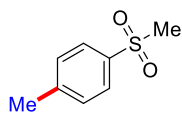


This compound was prepared according to the *method A* using 5-bromoisobenzofuran-1(3H)-one (63.9 mg, 0.300 mmol, 100 mol%), TsOMe (111.6 mg, 0.600 mmol, 200 mol%). After purification by column chromatography (SiO₂: 0.5% ethyl acetate in petroleum ether), the title compound was isolated in 87% yield (38.6 mg, 0.261 mmol) as a yellow solid.

¹H NMR (500 MHz, CDCl₃) δ = 7.78 (d, *J* = 7.8 Hz, 1H), 7.32 (d, *J* = 7.8 Hz, 1H), 7.27 (s, 1H), 5.25 (s, 2H), 2.48 (s, 3H).

¹³C NMR (125 MHz, CDCl₃) δ = 171.1, 147.0, 145.2, 130.0, 125.4, 123.1, 122.3, 69.3, 22.0.

1-Methyl-(4-methylsulfonyl) benzene (7)¹⁶

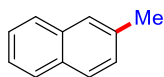


This compound was prepared according to the *method A* using 1-bromo-4-(methylsulfonyl) benzene (70.5 mg, 0.300 mmol, 100 mol%), TsOMe (111.6 mg, 0.600 mmol, 200 mol%). After purification by column chromatography (SiO₂: 0.5% ethyl acetate in petroleum ether), the title compound was isolated in 83% yield (42.3 mg, 0.250 mmol) as a white solid.

¹H NMR (500 MHz, CDCl₃) δ = 7.79 (d, J = 8 Hz, 2H), 7.34 (d, J = 8 Hz, 2H), 3.01 (s, 3H), 2.42 (s, 3H).

¹³C NMR (125 MHz, CDCl₃) δ = 144.5, 137.5, 129.8, 127.2, 44.4, 21.4.

2-Methylnaphthalene (8)¹⁷



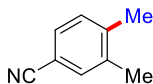
This compound was prepared according to the *method A* using 2-bromonaphthalene (62.1 mg, 0.300 mmol, 100 mol%), TsOMe (111.6 mg, 0.600 mmol, 200 mol%). After purification by column chromatography (SiO₂: 0.5% ethyl acetate in petroleum ether), the title compound was isolated in 90% yield (42.5 mg, 0.270 mmol) as a canary crystal.

This compound can also be prepared according to the *method B*, using naphthalen-2-yl 4-methylbenzenesulfonate (44.7 mg, 0.150 mmol, 100 mol%), TsOMe (83.7 mg, 0.450 mmol, 300 mol%), PPh₃ (7.8 mg, 0.03 mmol, 20 mol %), MgCl₂ (42.8 mg, 0.45 mmol, 300 mol %). After purification by column chromatography (SiO₂: 0.5% ethyl acetate in petroleum ether), the title compound was isolated in 65% yield (13.8 mg, 0.096 mmol) as a canary crystal.

¹H NMR (500 MHz, CDCl₃) δ = 7.87 (d, J = 7.9 Hz, 1H), 7.83 – 7.81 (m, 2H), 7.68 (s, 1H), 7.53 – 7.46 (m, 2H), 7.39 (dd, J = 1.5, 8.3 Hz, 1H), 2.59 (s, 3H).

¹³C NMR (125 MHz, CDCl₃) δ = 135.3, 133.6, 131.6, 128.1, 127.6, 127.5, 127.2, 126.8, 125.8, 124.9, 21.6.

3,4-Dimethylbenzonitrile (9)¹⁸



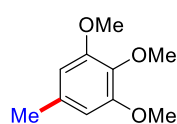
This compound was prepared according to the *method A* using 4-bromo-3-methylbenzonitrile (58.8 mg, 0.300 mmol, 100 mol%), TsOMe (111.6 mg, 0.600 mmol, 200 mol%). After purification by column chromatography (SiO₂: 0.5% ethyl acetate in

petroleum ether), the title compound was isolated in 72% yield (28.3 mg, 0.216 mmol) as a brown solid.

¹H NMR (500 MHz, CDCl₃) δ = 7.40 (s, 1H), 7.38 (d, J = 7.8 Hz, 1H), 7.20 (d, J = 7.8 Hz, 1H), 2.31 (s, 3H), 2.28 (s, 3H).

¹³C NMR (125 MHz, CDCl₃) δ = 142.4, 137.8, 132.7, 130.2, 129.5, 119.2, 109.4, 20.0, 19.5.

1,2,3-Trimethoxy-5-methylbenzene (10)¹⁹



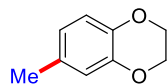
This compound was prepared according to the *method A* using 5-bromo-1,2,3-trimethoxybenzene (74.1 mg, 0.300 mmol, 100 mol%), TsOMe (111.6 mg, 0.600 mmol, 200 mol%). After purification by column chromatography (SiO₂: 3% ethyl acetate in petroleum ether), the title compound was isolated in 92% yield (50.2 mg, 0.276 mmol) as a colorless oil.

This compound can also be prepared according to the *method B*, using 3,4,5-trimethoxyphenyl 4-methylbenzenesulfonate (50.7 mg, 0.150 mmol, 100 mol%), TsOMe (83.7 mg, 0.450 mmol, 300 mol%). After purification by column chromatography (SiO₂: 3% ethyl acetate in petroleum ether), the title compound was isolated in 40% yield (11.0 mg, 0.006 mmol) as a colorless oil.

¹H NMR (500 MHz, CDCl₃) δ = 6.38 (s, 2H), 3.83 (s, 6H), 3.81 (s, 3H), 2.30 (s, 3H).

¹³C NMR (125 MHz, CDCl₃) δ = 152.8, 135.6, 133.4, 105.7, 60.7, 55.8, 21.6.

6-Methyl-2,3-dihydrobenzo[b][1,4]dioxine (11)

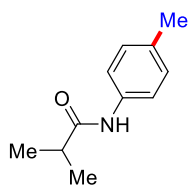


This compound was prepared according to the *method A* using 6-bromo-2,3-dihydrobenzo[b][1,4]dioxine (64.5 mg, 0.300 mmol, 100 mol%), TsOMe (111.6 mg, 0.600 mmol, 200 mol%). After purification by column chromatography (SiO₂: 1% ethyl acetate in petroleum ether), the title compound was isolated in 80% yield (36.0 mg, 0.240 mmol) as a colorless oil.

¹H NMR (500 MHz, CDCl₃) δ = 6.76 (d, J = 8.1 Hz, 1H), 6.69 (d, J = 1.5 Hz, 1H), 6.63 – 6.65 (m, 1H), 4.25 – 4.21 (m, 4H), 2.25 (s, 3H).

¹³C NMR (125 MHz, CDCl₃) δ = 143.1, 141.2, 131.0, 121.9, 117.5, 116.8, 64.3, 64.2, 20.6.

N-(p-tolyl)isobutyramide (**12**)²⁰



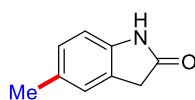
This compound was prepared according to the *method A* using N-(4-bromophenyl)isobutyramide (72.6 mg, 0.300 mmol, 100 mol%), TsOMe (111.6 mg, 0.600 mmol, 200 mol%). After purification by column chromatography (SiO₂: 7% ethyl acetate in petroleum ether), the title compound was isolated in

86% yield (45.7 mg, 0.258 mmol) as a white solid.

¹H NMR (500 MHz, CDCl₃) δ = 7.51 (broad s, 1H), 7.41 (d, J = 8.2 Hz, 2H), 7.09 (d, J = 8 Hz, 2H), 2.54 – 2.45 (m, 1H), 2.29 (s, 3H), 1.22 (d, J = 6.8 Hz, 6H).

¹³C NMR (125 MHz, CDCl₃) δ = 175.4, 135.4, 133.6, 129.2, 120.0, 36.4, 20.7, 19.5.

5-Methylindolin-2-one (**13**)²¹



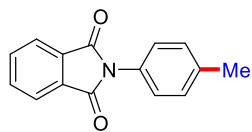
This compound was prepared according to the *method A* using 5-bromoindolin-2-one (63.6 mg, 0.300 mmol, 100 mol%), TsOMe (111.6 mg, 0.600 mmol, 200 mol%). After purification by column chromatography (SiO₂: 20% ethyl acetate

in petroleum ether), the title compound was isolated in 74% yield (32.6 mg, 0.222 mmol) as a white solid.

¹H NMR (500 MHz, CDCl₃) δ = 8.65 (broad s, 1H), 7.09 (d, J = 7.5 Hz, 1H), 6.82 (d, J = 7.5 Hz, 1H), 6.72 (s, 1H), 3.50 (s, 2H), 2.33 (s, 3H).

¹³C NMR (125 MHz, CDCl₃) δ = 178.1, 142.5, 138.0, 124.2, 122.8, 122.1, 110.5, 35.9, 21.5.

p-Tolylisoindoline-1,3-dione (**14**)²²

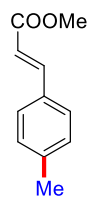


This compound was prepared according to the *method A* using 2-(4-bromophenyl)isoindoline-1,3-dione (90.6 mg, 0.300 mmol, 100 mol%), TsOMe (111.6 mg, 0.600 mmol, 200 mol%). After purification by column chromatography (SiO₂: 7% ethyl acetate in petroleum ether), the title compound was isolated in 89% yield (63.3 mg, 0.267 mmol) as a white solid.

¹H NMR (500 MHz, CDCl₃) δ = 7.93 (dd, J = 5.3, 3 Hz, 2H), 7.76 (dd, J = 5.3, 3 Hz, 2H), 7.31 (s, 4H), 2.40 (s, 3H).

¹³C NMR (125 MHz, CDCl₃) δ = 167.3, 138.0, 134.2, 131.6, 129.6, 128.8, 126.3, 123.5, 21.1.

Methyl (E)-3-(p-tolyl)acrylate (**15**)²³

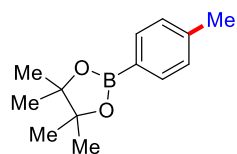


This compound was prepared according to the *method A* using methyl (E)-3-(4-bromophenyl)acrylate (72.3mg, 0.300 mmol, 100 mol%), TsOMe (111.6 mg, 0.600 mmol, 200 mol%). After purification by column chromatography (SiO₂: 1% ethyl acetate in petroleum ether), the title compound was isolated in 78% yield (41.2 mg, 0.234 mmol) as a white solid.

¹H NMR (500 MHz, CDCl₃) δ = 7.66 (d, J = 16 Hz, 1H), 7.42 (d, J = 8 Hz, 2H), 7.19 (d, J = 8 Hz, 2H), 6.39 (d, J = 16 Hz, 1H), 3.79 (s, 3H), 2.37 (s, 3H).

¹³C NMR (125 MHz, CDCl₃) δ = 167.6, 144.8, 140.7, 131.6, 129.5, 128.0, 116.6, 51.6, 21.4.

4,4,5,5-Tetramethyl-2-p-tolyl-1,3,2-dioxaborolane (**16**)²⁴



This compound was prepared according to the *method A* using 2-(4-bromophenyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (84.9 mg, 0.300 mmol, 100 mol%), TsOMe (111.6 mg, 0.600 mmol, 200 mol%). After

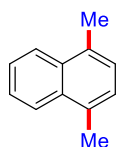
purification by column chromatography (SiO₂: 1% ethyl acetate in petroleum ether), the title compound was isolated in 93% yield (60.8 mg, 0.279 mmol) as a white solid.

This compound can also be prepared according to the *method B*, using 4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)phenyl 4-methylbenzenesulfonate (56.1 mg, 0.150 mmol, 100 mol%), TsOMe (83.7 mg, 0.450 mmol, 300 mol%). After purification by column chromatography (SiO₂: 1% ethyl acetate in petroleum ether), the title compound was isolated in 70% yield (22.9 mg, 0.105 mmol) as a white solid.

¹H NMR (500 MHz, CDCl₃) δ = 7.71 (d, J = 7.6 Hz, 2H), 7.19 (d, J = 7.6 Hz, 2H), 2.37 (s, 3H), 1.34 (s, 12H).

¹³C NMR (125 MHz, CDCl₃) δ = 141.3, 134.7, 128.4, 83.5, 24.8, 21.6.

1,4-Dimethylnaphthalene (17)²⁵

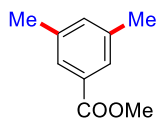


This compound was prepared according to the *method A* using 1,4-dibromonaphthalene (85.5 mg, 0.300 mmol, 100 mol%), TsOMe (279 mg, 1.50 mmol, 500 mol%), Zn (58.9 mg, 0.90 mmol, 300 mol %), 4,4'-di-*methyl*-2,2'-bipyridine (16.6 mg, 0.090 mmol, 30 mol %), MgCl₂ (85.6 mg, 0.90 mmol, 300 mol %), TBAI (221.6 mg, 0.60 mmol, 200 mol%) and NiI₂ (18.8 mg, 0.060 mmol, 20 mol %). After purification by column chromatography (SiO₂: 0.5% ethyl acetate in petroleum ether), the title compound was isolated in 60% yield (28.0 mg, 0.180 mmol) as a colorless oil.

¹H NMR (500 MHz, CDCl₃) δ = 8.13 – 8.10 (m, 2H), 7.65 – 7.62 (m, 2H), 7.32 (s, 2H), 2.77 (s, 6H).

¹³C NMR (125 MHz, CDCl₃) δ = 132.6, 132.2, 126.2, 125.3, 124.6, 19.3.

Methyl 3,5-Dimethylbenzoate (18)²⁶

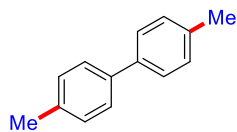


This compound was prepared according to the *method A* using methyl 3,5-dibromobenzoate (88.2 mg, 0.300 mmol, 100 mol%), TsOMe (279 mg, 1.50 mmol, 500 mol%), Zn (58.9 mg, 0.90 mmol, 300 mol %), 4,4'-di-*methyl*-2,2'-bipyridine (16.6 mg, 0.090 mmol, 30 mol %), MgCl₂ (85.6 mg, 0.90 mmol, 300 mol %), TBAI (221.6 mg, 0.60 mmol, 200 mol%) and NiI₂ (18.8 mg, 0.060 mmol, 20 mol %). After purification by column chromatography (SiO₂: 0.5% ethyl acetate in petroleum ether), the title compound was isolated in 80% yield (39.4 mg, 0.240 mmol) as a colorless oil.

¹H NMR (500 MHz, CDCl₃) δ = 7.65 (d, J = 0.6 Hz, 2H), 7.18 (s, 1H), 3.89 (s, 3H), 2.35 (d, J = 0.5 Hz, 6H).

¹³C NMR (125 MHz, CDCl₃) δ = 167.4, 137.9, 134.5, 129.9, 127.2, 51.9, 21.1.

4,4'-Dimethylbiphenyl (19)²⁷

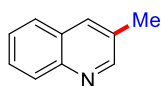


This compound was prepared according to the *method A* using 4,4'-dibromo-1,1'-biphenyl (93.6 mg, 0.300 mmol, 100 mol%), TsOMe (279 mg, 1.50 mmol, 500 mol%), Zn (58.9 mg, 0.90 mmol, 300 mol %), 4,4'-di-*methyl*-2,2'-bipyridine (16.6 mg, 0.090 mmol, 30 mol %), MgCl₂ (85.6 mg, 0.90 mmol, 300 mol %), TBAI (221.6 mg, 0.60 mmol, 200 mol%) and NiI₂ (18.8 mg, 0.060 mmol, 20 mol %). After purification by column chromatography (SiO₂: 0.5% ethyl acetate in petroleum ether), the title compound was isolated in 95% yield (51.9 mg, 0.285 mmol) as a white solid.

¹H NMR (500 MHz, CDCl₃) δ = 7.48 (d, J = 8.1 Hz, 4H), 7.24 (d, J = 7.9 Hz, 4H), 2.39 (s, 6H).

¹³C NMR (125 MHz, CDCl₃) δ = 138.2, 136.6, 129.4, 126.7, 21.0.

3-Methylquinoline (20)²⁸

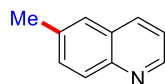


This compound was prepared according to the *method A* using 3-bromoquinoline (62.4 mg, 0.300 mmol, 100 mol%), TsOMe (111.6 mg, 0.600 mmol, 200 mol%), 4,4'-di-*methyl*-2,2'-bipyridine (8.3 mg, 0.045 mmol, 15 mol %), NiI₂ (9.4 mg, 0.030 mmol, 10 mol %). After purification by column chromatography (SiO₂: 20% ethyl acetate in petroleum ether), the title compound was isolated in 84% yield (36.0 mg, 0.252 mmol) as a brown oil.

¹H NMR (500 MHz, CDCl₃) δ = 8.76 (d, *J* = 1.3 Hz, 1H), 8.07 (d, *J* = 8.5 Hz, 1H), 7.90 (s, 1H), 7.72 (d, *J* = 8.2 Hz, 1H), 7.65 – 7.62 (m, 1H), 7.51 – 7.48 (m, 1H), 2.50 (s, 3H).

¹³C NMR (125 MHz, CDCl₃) δ = 152.2, 146.3, 134.7, 130.4, 129.0, 128.4, 128.0, 127.0, 126.5, 18.7.

6-Methylquinoline (21)⁴

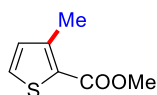


This compound was prepared according to the *method A* using 6-bromoquinoline (62.4 mg, 0.300 mmol, 100 mol%), TsOMe (111.6 mg, 0.600 mmol, 200 mol%), 4,4'-di-*methyl*-2,2'-bipyridine (8.3 mg, 0.045 mmol, 15 mol %), NiI₂ (9.4 mg, 0.030 mmol, 10 mol %). After purification by column chromatography (SiO₂: 20% ethyl acetate in petroleum ether), the title compound was isolated in 84% yield (36.0 mg, 0.252 mmol) as a brown oil.

¹H NMR (500 MHz, CDCl₃) δ = 8.84 (s, 1H), 8.01 (d, *J* = 8.2 Hz, 1H), 7.98 (d, *J* = 8.5 Hz, 1H), 7.53 – 7.50 (m, 2H), 7.31 (dd, *J* = 8.2, 4.2 Hz, 1H), 2.50 (s, 3H).

¹³C NMR (125 MHz, CDCl₃) δ = 149.3, 146.7, 136.2, 135.2, 131.6, 128.9, 128.2, 126.4, 121.0, 21.4.

Methyl 3-methylthiophene-2-carboxylate (22)²⁹



This compound was prepared according to the *method A* using methyl 3-bromothiophene-2-carboxylate (66.3 mg, 0.300 mmol, 100 mol%), TsOMe (111.6 mg, 0.600 mmol, 200 mol%), 4,4'-di-*methyl*-2,2'-bipyridine (8.3 mg, 0.045 mmol, 15 mol %), NiI₂ (9.4 mg, 0.030 mmol, 10 mol %). After purification by column chromatography (SiO₂: 1% ethyl

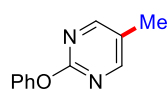
acetate in petroleum ether), the title compound was isolated in 86% yield (40.2 mg, 0.258 mmol) as a brown oil.

This compound can also be prepared according to the *method B*, using methyl 3-(tosyloxy)thiophene-2-carboxylate (46.8 mg, 0.150 mmol, 100 mol%), TsOMe (83.7 mg, 0.450 mmol, 300 mol%), PPh₃ (7.8 mg, 0.03 mmol, 20 mol %), MgCl₂ (42.8 mg, 0.45 mmol, 300 mol %). After purification by column chromatography (SiO₂: 1% ethyl acetate in petroleum ether), the title compound was isolated in 85% yield (19.9 mg, 0.128 mmol) as a brown oil.

¹H NMR (500 MHz, CDCl₃) δ = 7.37 (d, J = 4.9 Hz, 1H), 6.90 (d, J = 4.9 Hz, 1H), 3.85 (s, 3H), 2.55 (s, 3H).

¹³C NMR (125 MHz, CDCl₃) δ = 163.2, 146.2, 131.6, 129.9, 126.4, 51.6, 15.8.

5-Methyl-2-phenoxy pyrimidine (23)



This compound was prepared according to the *method A* using 5-bromo-2-phenoxy pyrimidine (75.3 mg, 0.300 mmol, 100 mol%), TsOMe (111.6 mg, 0.600 mmol, 200 mol%), 4,4'-di-*methyl*-2,2'-bipyridine (8.3 mg, 0.045 mmol, 15 mol %), NiI₂ (9.4 mg, 0.030 mmol, 10 mol %). After purification by column chromatography (SiO₂: 8% ethyl acetate in petroleum ether), the title compound was isolated in 56% yield (31.2 mg, 0.168 mmol) as a white solid.

¹H NMR (500 MHz, CDCl₃) δ = 8.36 (s, 2H), 7.43 – 7.39 (m, 2H), 7.24 – 7.21 (m, 1H), 7.18 – 7.17 (m, 2H), 2.24 (s, 3H).

¹³C NMR (125 MHz, CDCl₃) δ = 163.8, 159.4, 153.0, 129.5, 125.2, 125.0, 121.4, 14.5.

HRMS (ESI) exact mass calculated for [M+Na⁺] (C₁₁H₁₀N₂NaO⁺): m/z 209.0685; found: 209.0681.

M.p. 91 - 92 °C

4-Methyl-1H-indole (24)³⁰



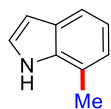
This compound was prepared according to the *method A* using 4-bromo-1H-indole (58.8 mg, 0.300 mmol, 100 mol%), TsOMe (111.6 mg, 0.600 mmol, 200 mol%), 4,4'-dimethyl-2,2'-bipyridine (8.3 mg, 0.045 mmol, 15 mol %), NiI₂ (9.4 mg, 0.030 mmol, 10 mol %). After purification by column chromatography (SiO₂: 5% ethyl acetate in petroleum ether), the title compound was isolated in 76% yield (29.8 mg, 0.228 mmol) as a brown solid.

This compound can also be prepared according to the *method B*, using 1H-indol-4-yl 4-methylbenzenesulfonate (43.0 mg, 0.150 mmol, 100 mol%), TsOMe (83.7 mg, 0.450 mmol, 300 mol%). After purification by column chromatography (SiO₂: 5% ethyl acetate in petroleum ether), the title compound was isolated in 60% yield (11.8 mg, 0.090 mmol) as a brown solid.

¹H NMR (500 MHz, CDCl₃) δ = 8.17 (broad s, 1H), 7.27 (s, 1H), 7.22 (t, J = 2.8 Hz, 1H), 7.14 – 7.11 (m, 1H), 6.94 (d, J = 7.1 Hz, 1H), 6.60 – 6.59 (m, 1H), 2.59 (s, 3H).

¹³C NMR (125 MHz, CDCl₃) δ = 135.4, 130.2, 127.7, 123.4, 122.0, 119.8, 108.5, 101.1, 18.8.

7-Methyl-1H-indole (25)³¹

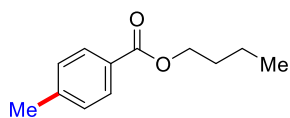


This compound was prepared according to the *method A* using 7-bromo-1H-indole (58.8mg, 0.300 mmol, 100 mol%), TsOMe (111.6 mg, 0.600 mmol, 200 mol%), 4,4'-dimethyl-2,2'-bipyridine (8.3 mg, 0.045 mmol, 15 mol %), NiI₂ (9.4 mg, 0.030 mmol, 10 mol %). After purification by column chromatography (SiO₂: 5% ethyl acetate in petroleum ether), the title compound was isolated in 60% yield (23.6 mg, 0.180 mmol) as a brown solid.

¹H NMR (500 MHz, CDCl₃) δ = 8.06 (broad s, 1H), 7.53 (d, J = 7.8 Hz, 1H), 7.21 (t, J = 2.8 Hz, 1H), 7.07 (t, J = 7.65 Hz, 1H), 7.03 (d, J = 7 Hz, 1H), 6.59 (dd, J = 3.1, 2.0 Hz, 1H), 2.52 (s, 3H).

¹³C NMR (125 MHz, CDCl₃) δ = 135.3, 127.3, 123.7, 122.4, 120.1, 119.9, 118.4, 103.0, 16.6.

Butyl 4-methylbenzoate (26)³²

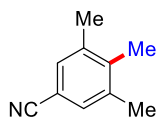


This compound can also be prepared according to the *method B*, using butyl 4-(tosyloxy)benzoate (52.2 mg, 0.150 mmol, 100 mol%), TsOMe (83.7 mg, 0.450 mmol, 300 mol%), PPh₃ (7.8 mg, 0.03 mmol, 20 mol %), MgCl₂ (42.8 mg, 0.45 mmol, 300 mol %). After purification by column chromatography (SiO₂: 1% ethyl acetate in petroleum ether), the title compound was isolated in 80% yield (23.0 mg, 0.120 mmol) as a colorless oil.

¹H NMR (500 MHz, CDCl₃) δ = 7.93 (d, *J* = 8.0 Hz, 2H), 7.23 (d, *J* = 8.0 Hz, 2H), 4.30 (t, *J* = 6.6 Hz, 2H), 2.40 (s, 3H), 1.77 – 1.71 (m, 2H), 1.51 – 1.44 (m, 2H), 0.97 (t, *J* = 7.4 Hz, 3H).

¹³C NMR (125 MHz, CDCl₃) δ = 166.7, 143.3, 129.5, 128.9, 127.7, 64.6, 30.7, 21.5, 19.2, 13.7.

3,4,5-Trimethylbenzonitrile (27)



This compound can also be prepared according to the *method B*, using 4-cyano-2,6-dimethylphenyl 4-methylbenzenesulfonate (45.2 mg, 0.150 mmol, 100 mol%), TsOMe (83.7 mg, 0.450 mmol, 300 mol%). After purification by column chromatography (SiO₂: 1% ethyl acetate in petroleum ether), the title compound was isolated in 73% yield (15.9 mg, 0.110 mmol) as a white solid.

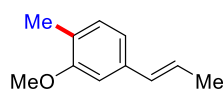
¹H NMR (500 MHz, CDCl₃) δ = 7.26 (s, 2H), 2.29 (s, 6H), 2.21 (s, 3H).

¹³C NMR (125 MHz, CDCl₃) δ = 141.1, 137.5, 130.7, 119.4, 108.7, 20.3, 15.7.

HRMS (ESI) exact mass calculated for [M+Na⁺] (C₁₀H₁₁NNa⁺): *m/z* 168.0784; found: 168.0788.

M.p. 90 - 91 °C

(*E*)-2-Methoxy-1-methyl-4-(prop-1-en-1-yl) benzene (28)

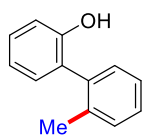


This compound can also be prepared according to the *method B*, using (E)-2-methoxy-4-(prop-1-en-1-yl)phenyl 4-methylbenzenesulfonate (47.7 mg, 0.150 mmol, 100 mol%), TsOMe (83.7 mg, 0.450 mmol, 300 mol%). After purification by column chromatography (SiO₂: 2% ethyl acetate in petroleum ether), the title compound was isolated in 65% yield (15.8 mg, 0.098 mmol) as a colorless oil.

¹H NMR (500 MHz, CDCl₃) δ = 7.06 (d, J = 7.5 Hz, 1H), 6.86 – 6.84 (m, 1H), 6.83 (s, 1H), 6.40 (dd, J = 15.7, 1.5 Hz, 1H), 6.25 – 6.18 (m, 1H), 3.85 (s, 3H), 2.22 (s, 3H), 1.90 (dd, J = 6.6, 1.6 Hz, 3H)

¹³C NMR (125 MHz, CDCl₃) δ = 157.7, 136.8, 131.1, 130.5, 125.2, 124.6, 118.0, 107.1, 55.1, 18.3, 15.9.

2'-Methyl-[1,1'-biphenyl]-2-ol (29)⁶

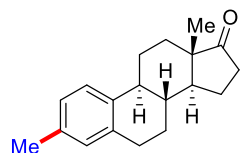


This compound can also be prepared according to the *method B*, using 2'-hydroxy-[1,1'-biphenyl]-2-yl 4-methylbenzenesulfonate (50.7 mg, 0.150 mmol, 100 mol%), TsOMe (83.7 mg, 0.450 mmol, 300 mol%). After purification by column chromatography (SiO₂: 5% ethyl acetate in petroleum ether), the title compound was isolated in 70% yield (19.3 mg, 0.105 mmol) as a yellow oil.

¹H NMR (500 MHz, CDCl₃) δ = 7.34 – 7.24 (m, 5H), 7.12 (dd, J = 7.4, 1.5 Hz, 1H), 7.00 – 6.96 (m, 2H), 4.80 (s, 1H), 2.18 (s, 3H).

¹³C NMR (125 MHz, CDCl₃) δ = 152.5, 137.4, 135.6, 130.6, 130.4, 130.1, 129.1, 128.5, 127.7, 126.4, 120.4, 115.2, 19.7.

Estra-1,3,5(10)-trien-17-one, 3-methyl-(9CI) (30)



This compound can also be prepared according to the *method B*, using Estradiol (63.6 mg, 0.150 mmol, 100 mol%), TsOMe (83.7 mg, 0.450 mmol, 300 mol%). After purification by column chromatography (SiO₂: 8% ethyl acetate in petroleum ether), the title compound was isolated in 73% yield (29.5 mg, 0.110 mmol) as a white solid.

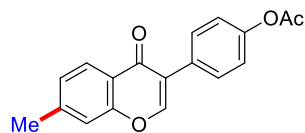
¹H NMR (500 MHz, CDCl₃) δ = 7.19 (d, J = 7.9 Hz, 1H), 6.98 (d, J = 7.9 Hz, 1H), 6.93 (s, 1H), 2.91 – 2.88 (m, 2H), 2.50 (dd, J = 19.0, 8.7 Hz, 1H), 2.44 – 2.42 (m, 1H), 2.30 (s, 3H), 2.18 – 2.11 (m, 1H), 2.09 – 1.99 (m, 2H), 1.97 – 1.94 (m, 1H), 1.67 – 1.57 (m, 3H), 1.55 – 1.48 (m, 3H), 1.46 – 1.40 (m, 1H), 0.91 (s, 3H).

¹³C NMR (125 MHz, CDCl₃) δ = 220.9, 136.6, 136.2, 135.2, 129.6, 126.5, 125.2, 50.4, 47.9, 44.2, 38.2, 35.8, 31.5, 29.3, 26.5, 25.7, 21.5, 20.8, 13.8.

HRMS (ESI) exact mass calculated for [M+Na⁺] (C₁₉H₂₄NaO⁺): m/z 291.1719; found: 291.1696.

M.p. 158 - 159 °C

4-(7-Methyl-4-oxo-4H-chromen-3-yl)phenyl acetate (31)



This compound can also be prepared according to the *method B*, using 4-(4-oxo-7-(tosyloxy)-4H-chromen-3-yl)phenyl acetate (67.5 mg, 0.150 mmol, 100 mol%), TsOMe (83.7 mg, 0.450 mmol, 300 mol%), PPh₃ (7.8 mg, 0.03 mmol, 20 mol %), MgCl₂ (42.8 mg, 0.45 mmol, 300 mol %). After purification by column chromatography (SiO₂: 20% ethyl acetate in petroleum ether), the title compound was isolated in 75% yield (33.0 mg, 0.112 mmol) as a white solid.

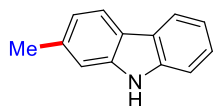
¹H NMR (500 MHz, CDCl₃) δ = 8.18 (d, J = 8.1 Hz, 1H), 7.98 (s, 1H), 7.58 (d, J = 8.6 Hz, 2H), 7.27 (s, 1H), 7.24 (d, J = 8.1 Hz, 1H), 7.16 (d, J = 8.6 Hz, 2H), 2.50 (s, 3H), 2.31 (s, 3H).

¹³C NMR (125 MHz, CDCl₃) δ = 176.0, 169.4, 156.3, 152.8, 150.5, 145.0, 130.0, 129.6, 126.8, 126.1, 124.4, 122.2, 121.6, 117.7, 21.7, 21.1.

HRMS (ESI) exact mass calculated for $[M+H^+]$ ($C_{18}H_{14}NaO_4^+$): m/z 317.0784; found: 317.0767.

M.p. 181 - 182 °C

2-Methyl-9H-carbazole (32)³³

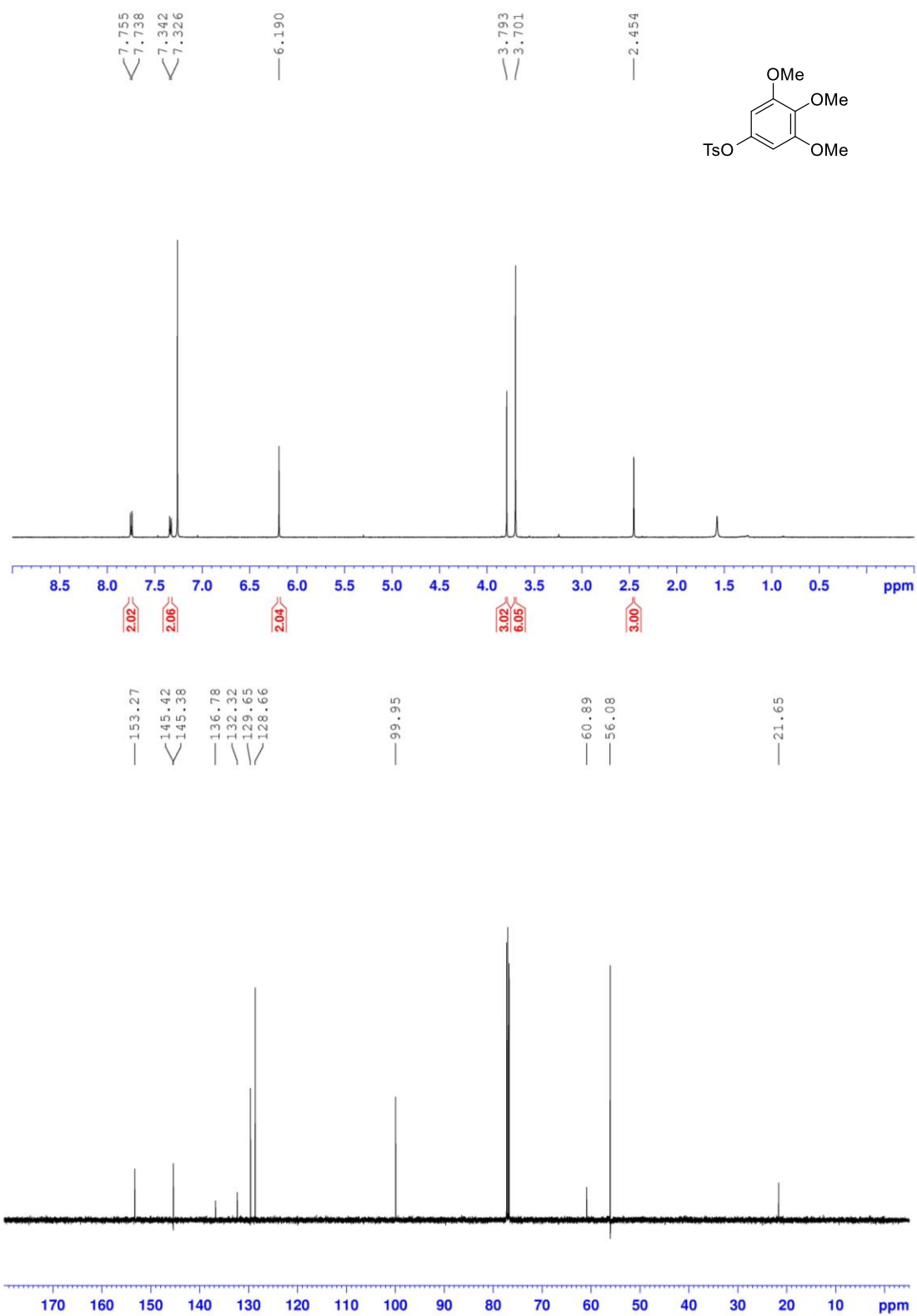


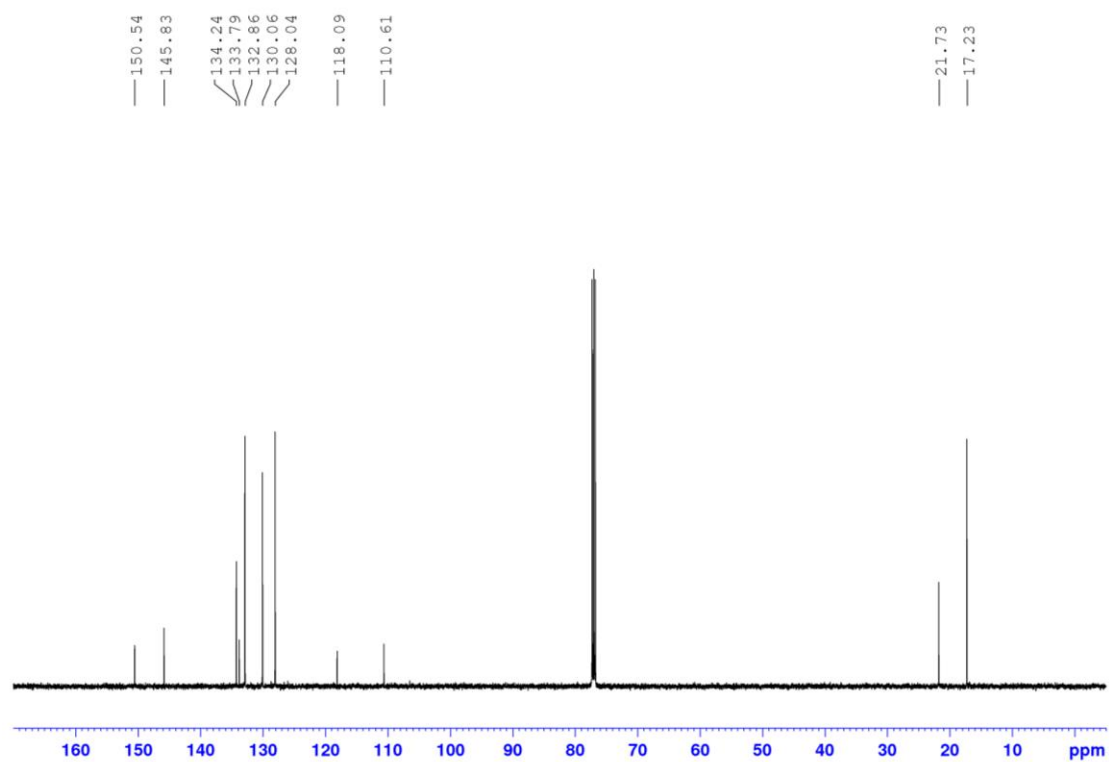
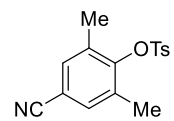
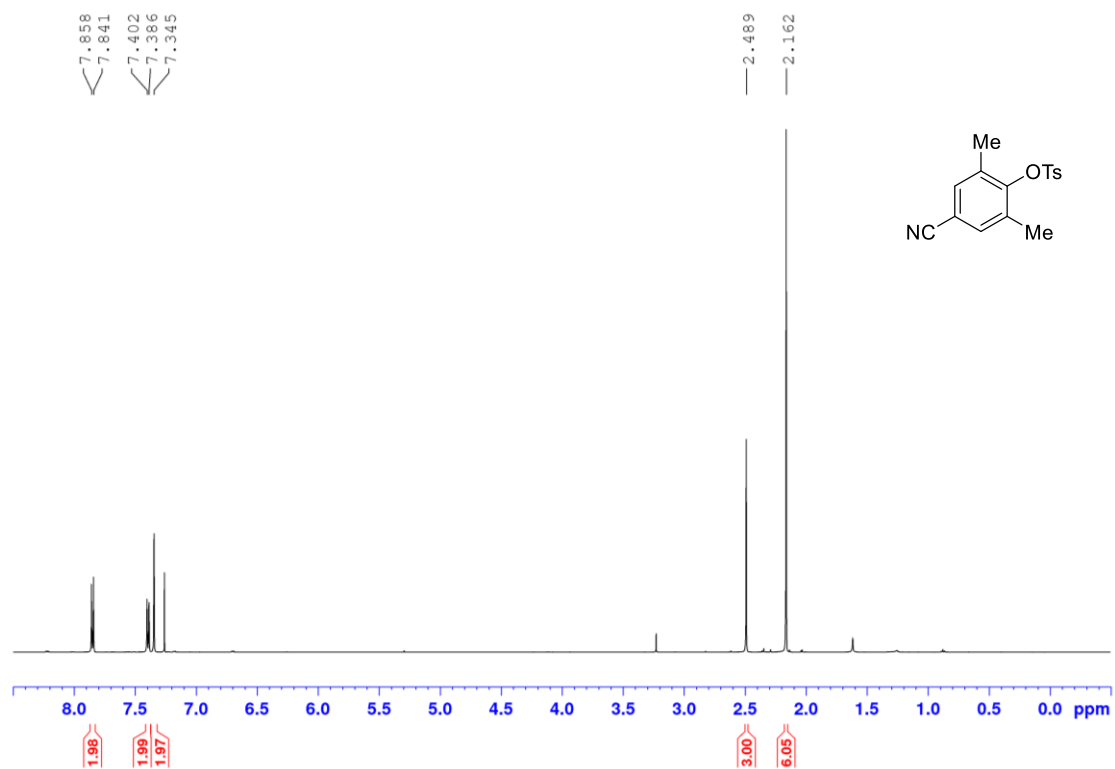
This compound can also be prepared according to the *method B*, using 9H-carbazol-2-yl 4-methylbenzenesulfonate (50.5 mg, 0.150 mmol, 100 mol%), TsOMe (83.7 mg, 0.450 mmol, 300 mol%). After purification by column chromatography (SiO₂: 5% ethyl acetate in petroleum ether), the title compound was isolated in 75% yield (20.4 mg, 0.112 mmol) as a reddish brown crystal.

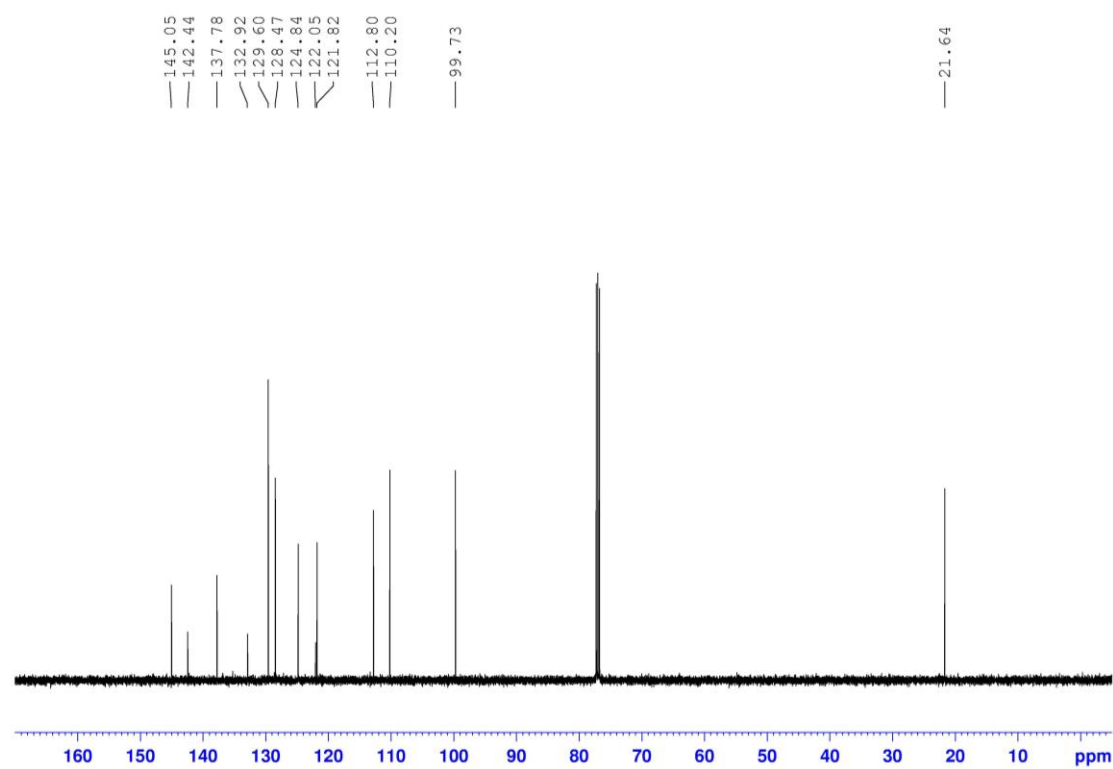
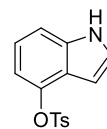
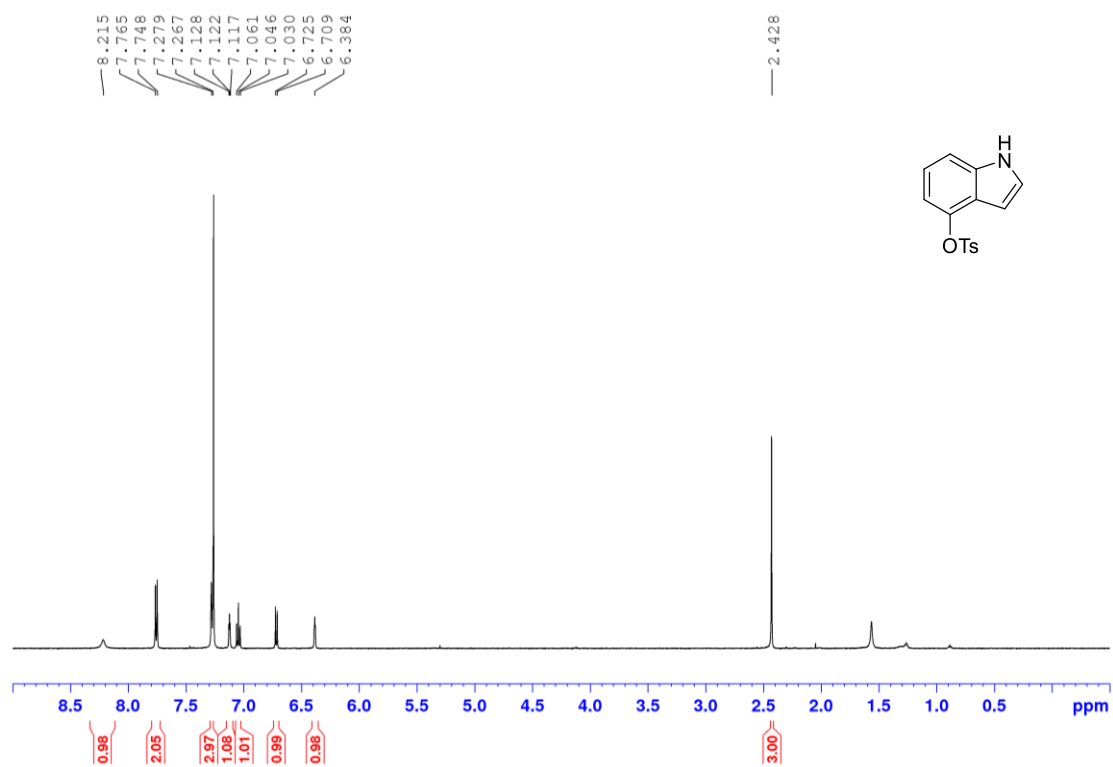
¹H NMR (500 MHz, CDCl₃) δ = 8.20 (dd, J = 8.1, 0.5 Hz, 1H), 8.05 (broad s, 1H), 7.44 – 7.43 (m, 2H), 7.35 – 7.32 (m, 1H), 7.29 – 7.26 (m, 2H), 7.04 (d, J = 7.1 Hz, 1H), 2.90 (s, 3H).

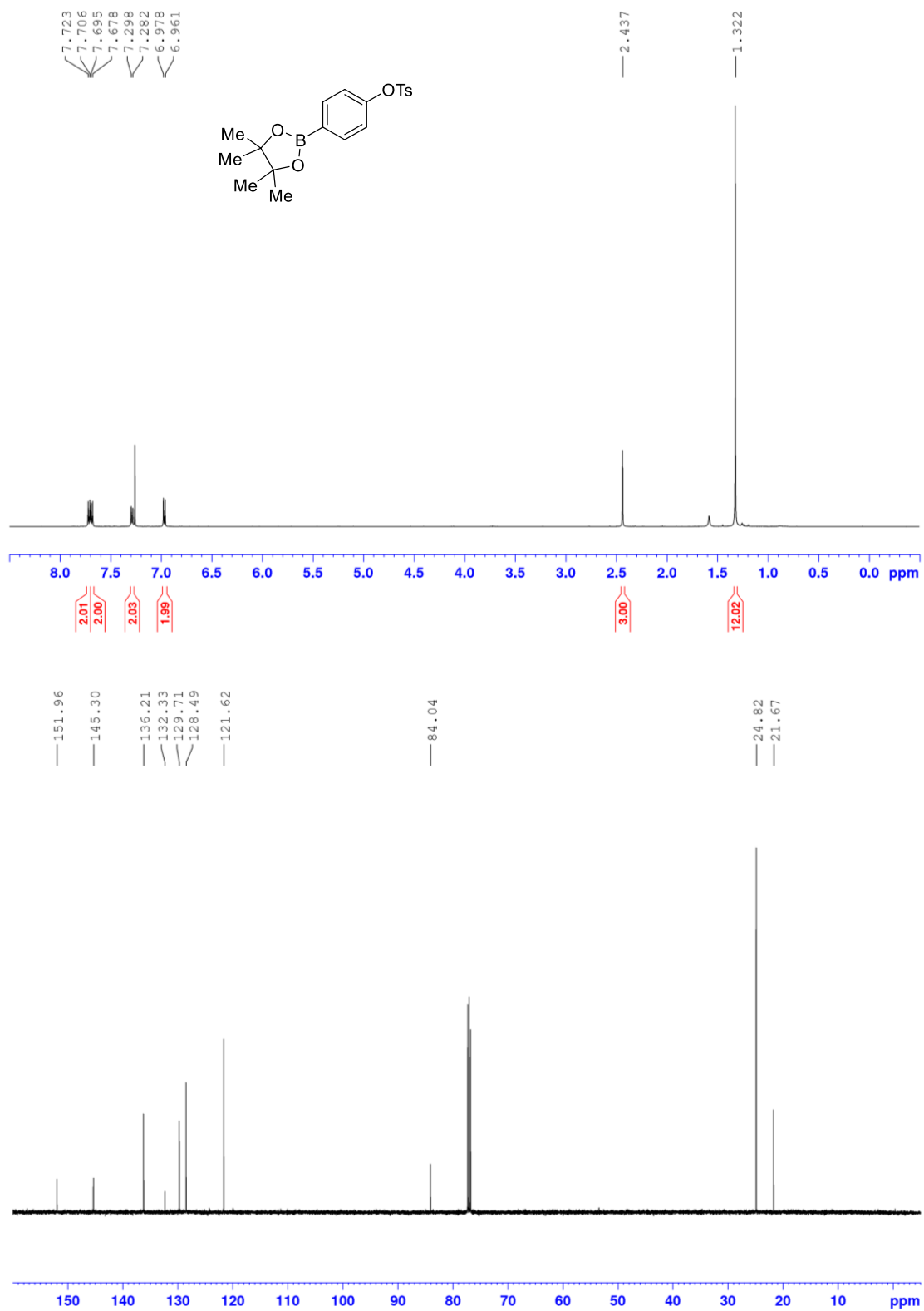
¹³C NMR (125 MHz, CDCl₃) δ = 139.45, 139.43, 133.3, 125.6, 125.1, 123.9, 122.5, 121.8, 120.9, 119.3, 110.3, 108.0, 20.7

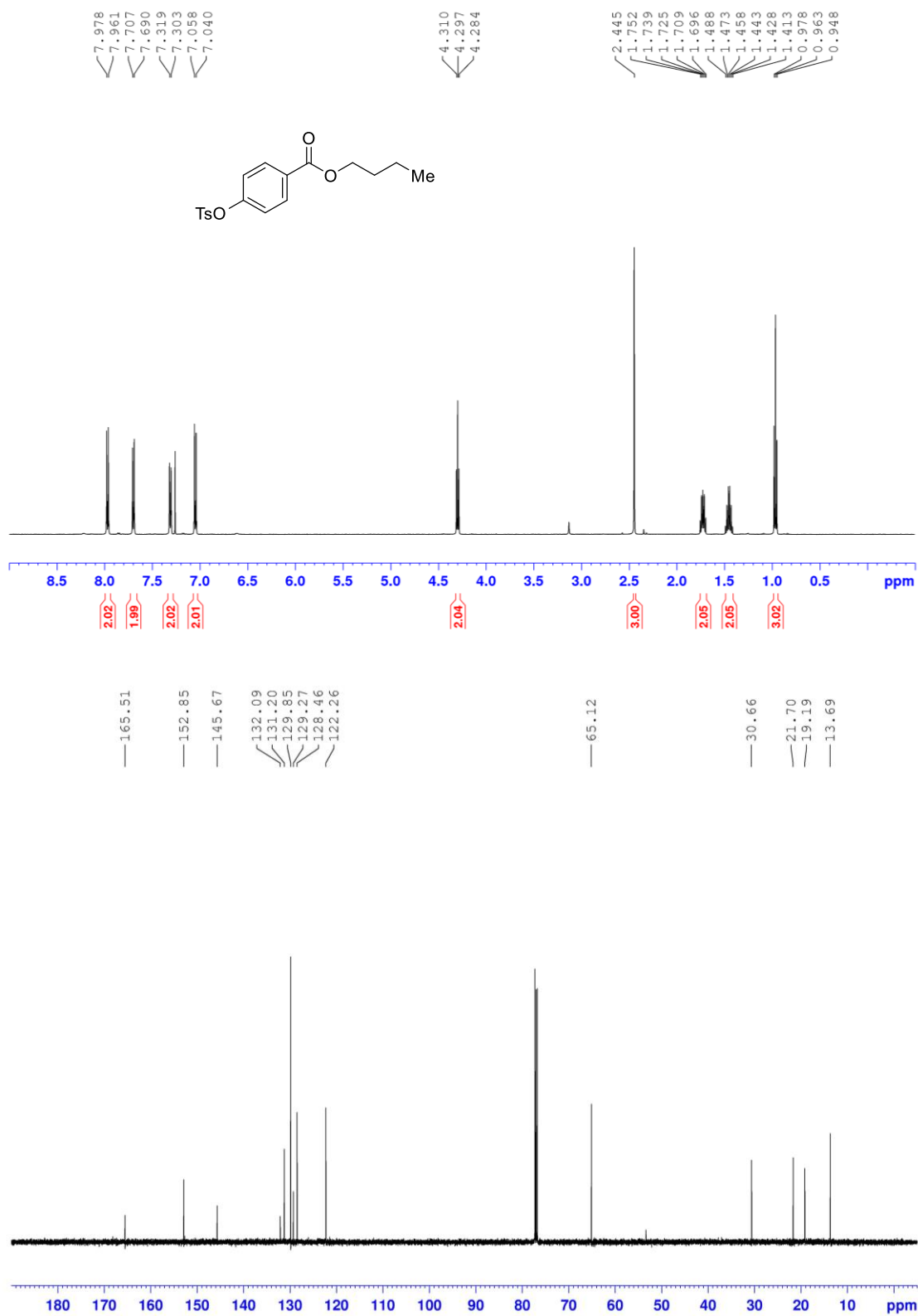
II. NMR Data for New Compounds

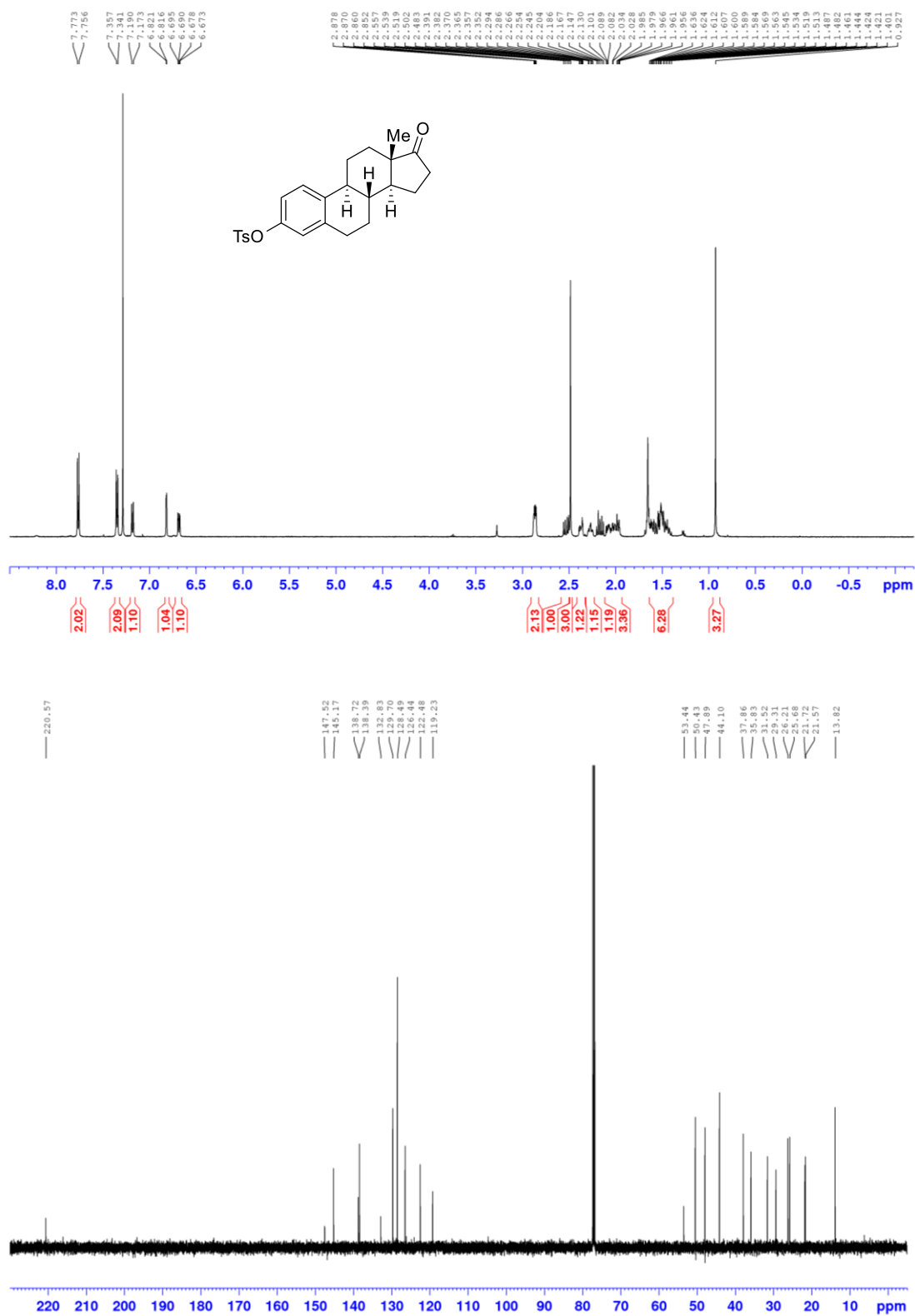


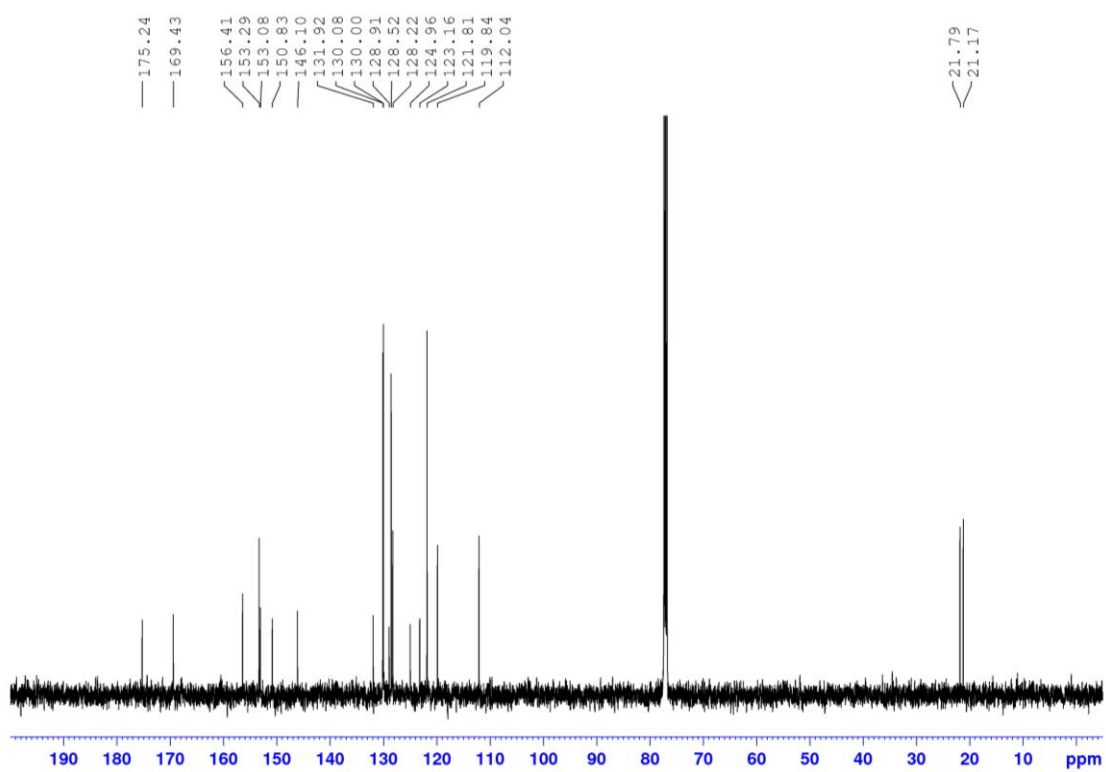
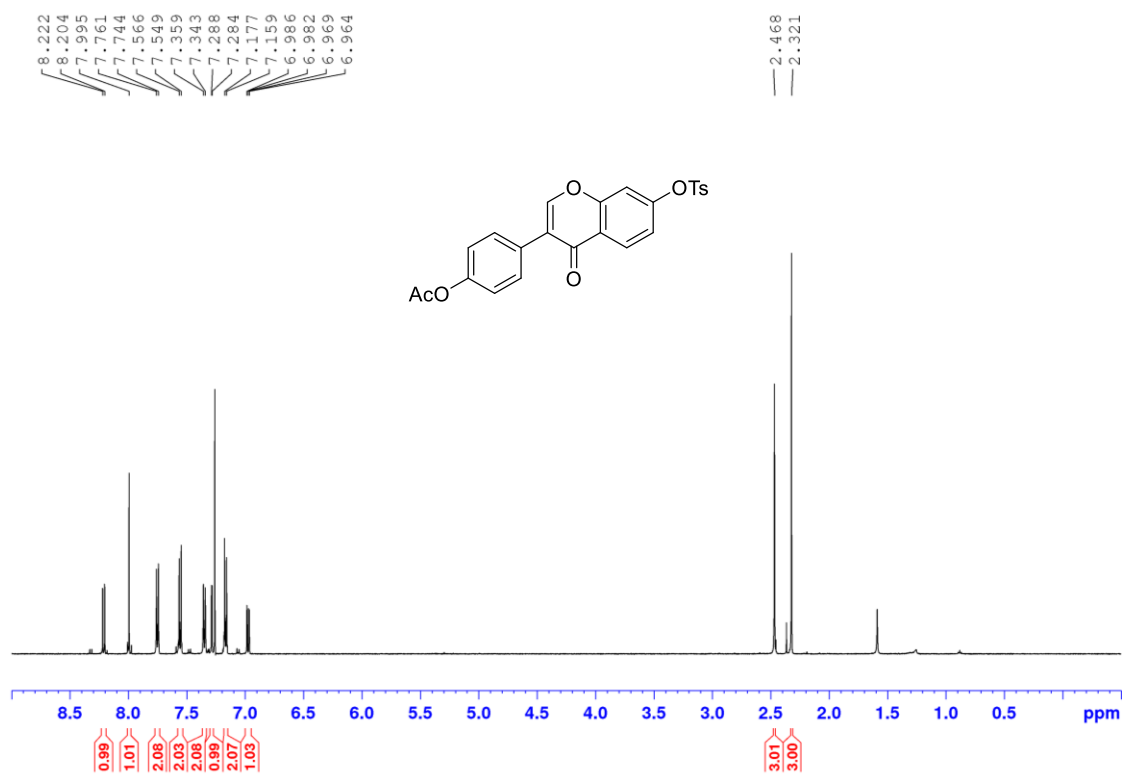


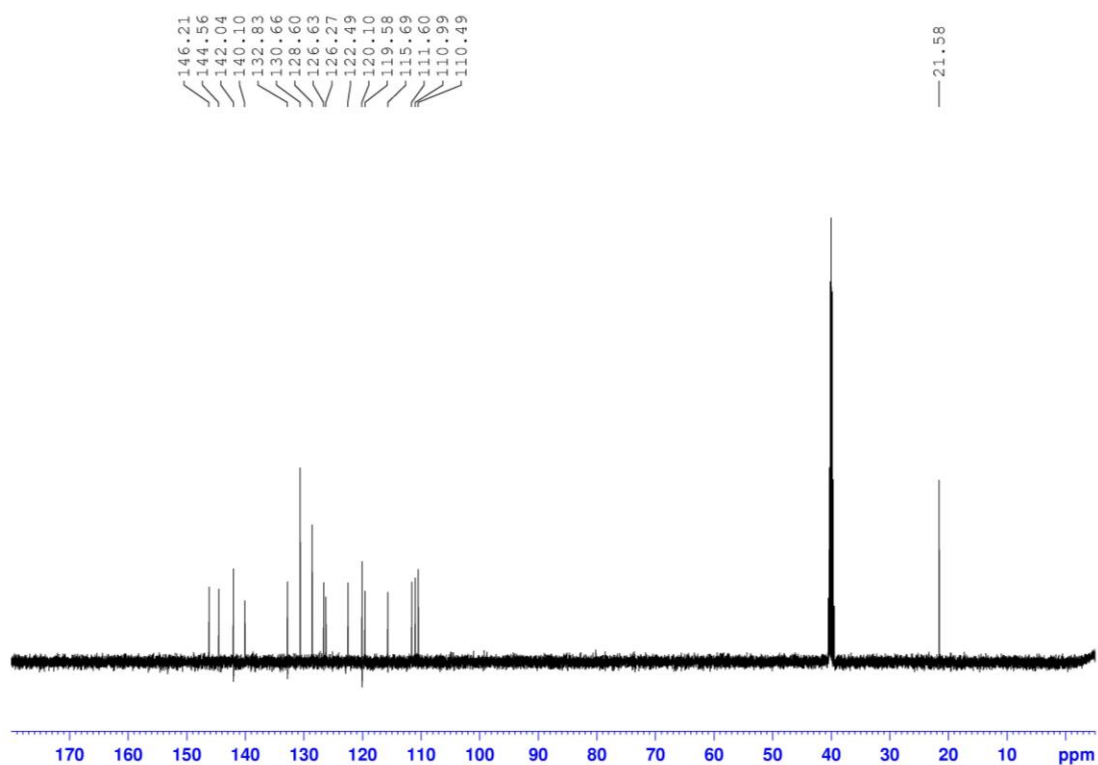
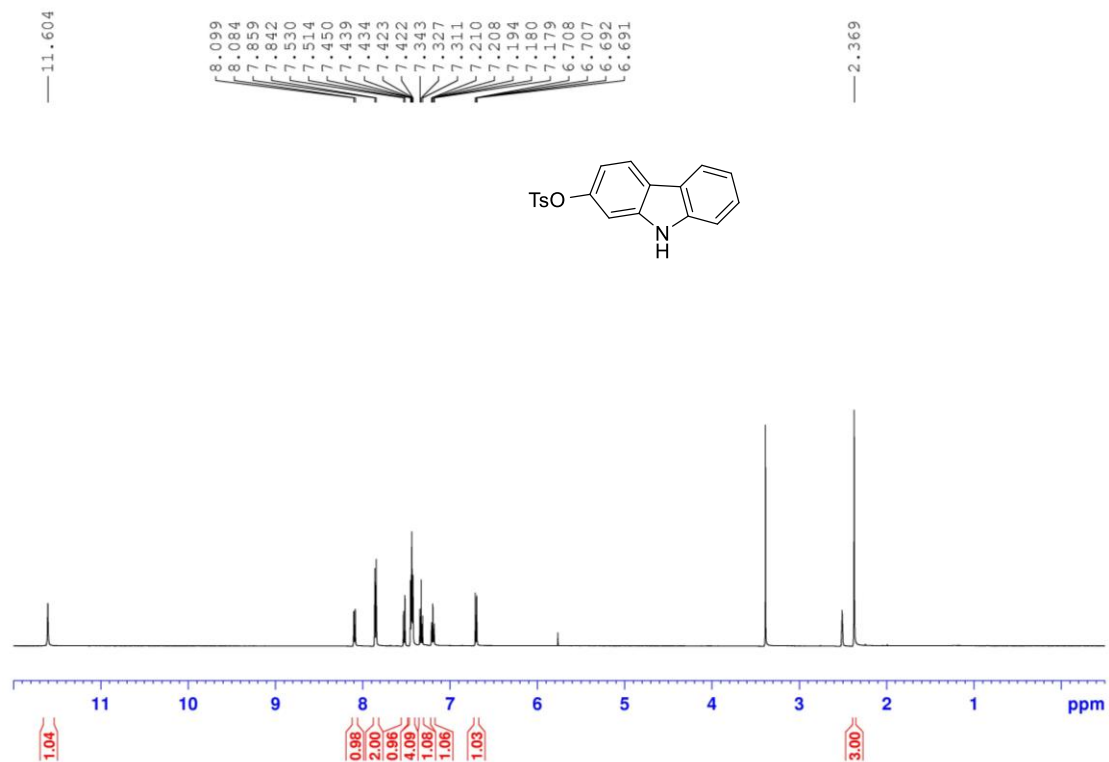


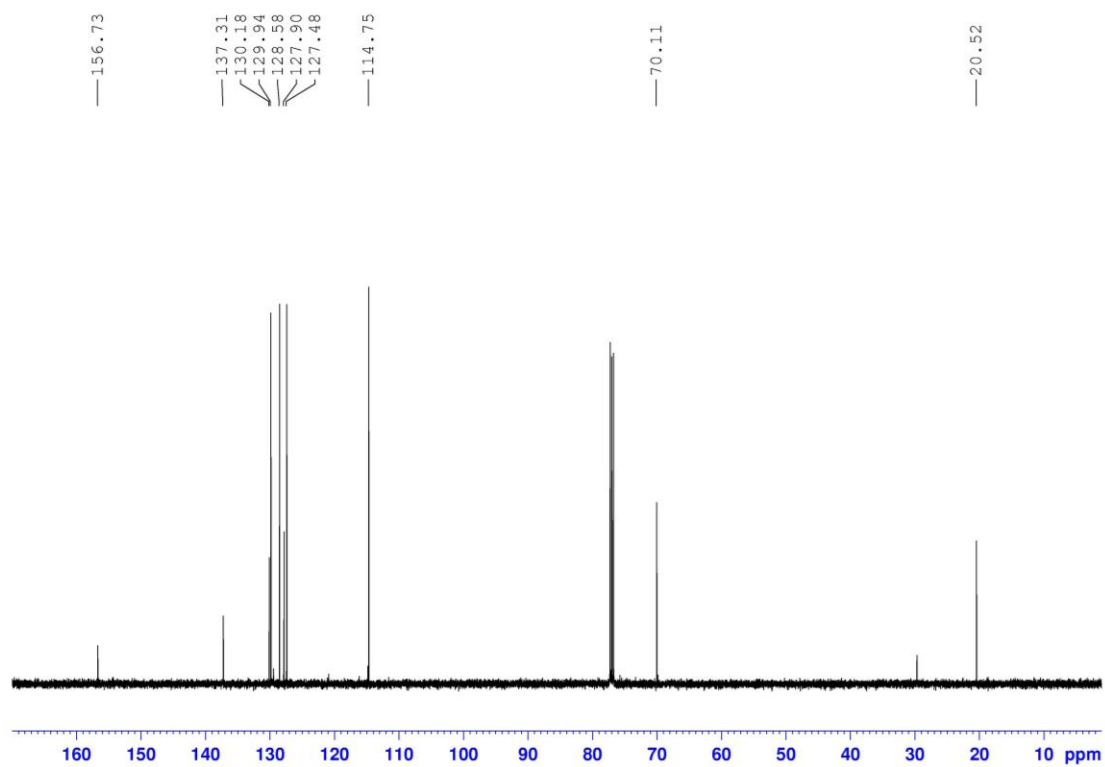
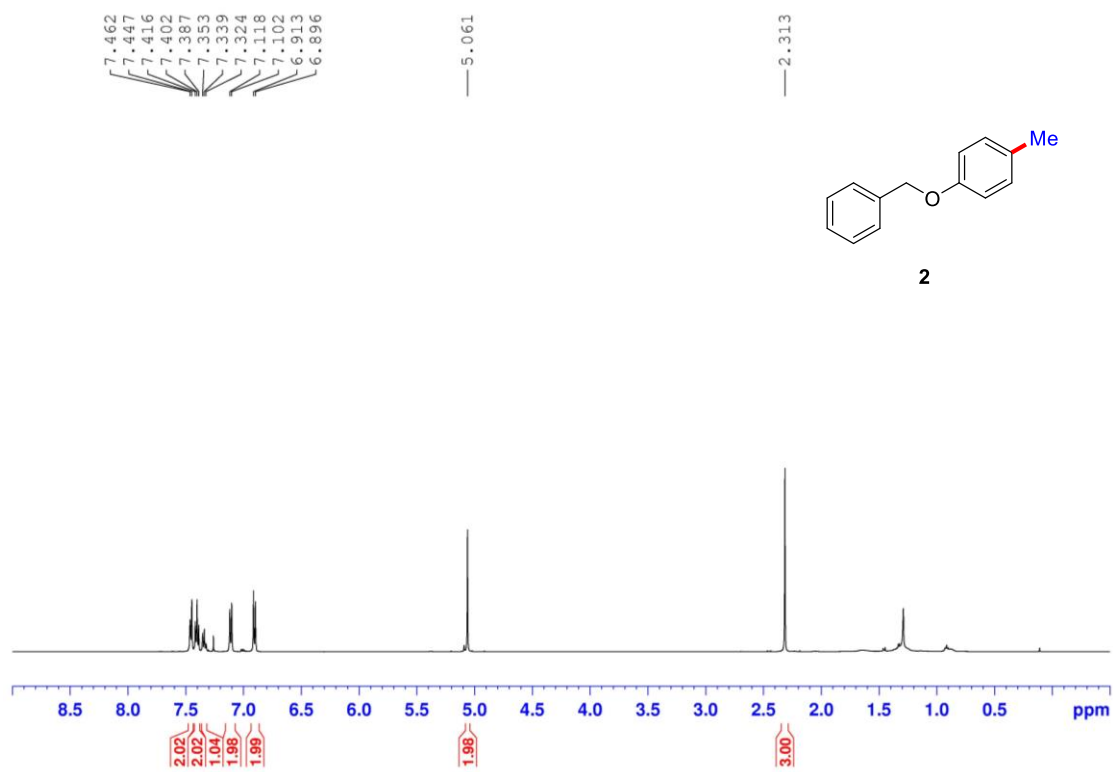


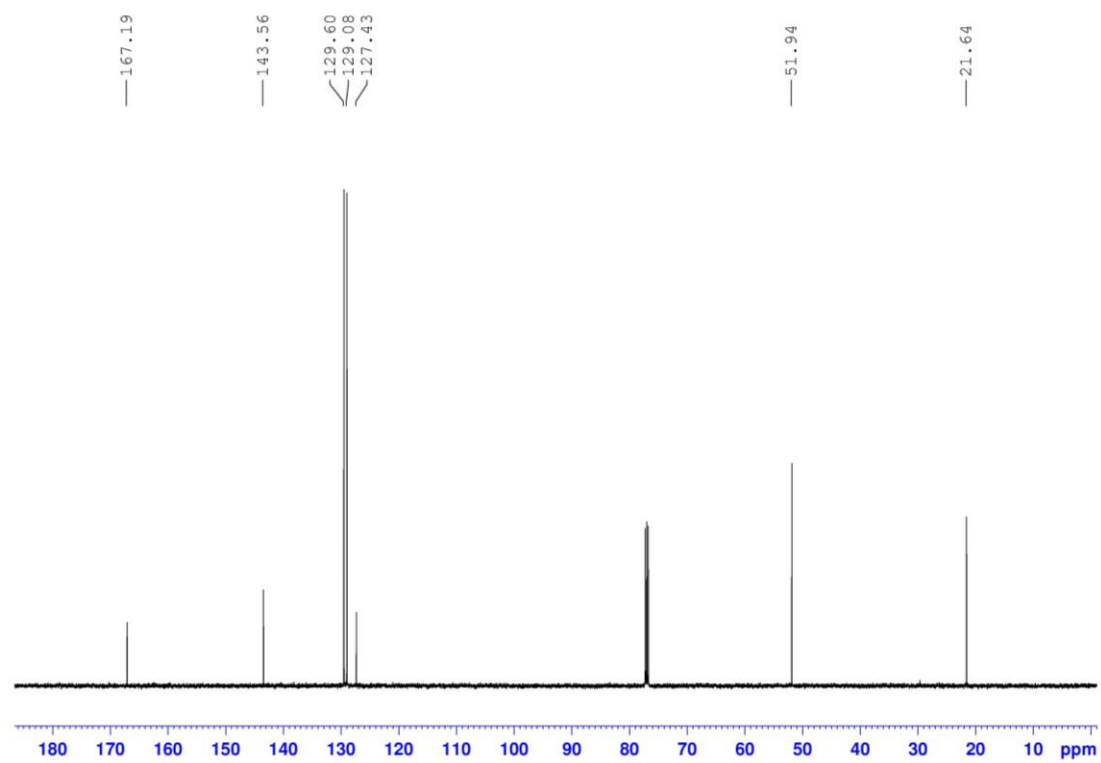
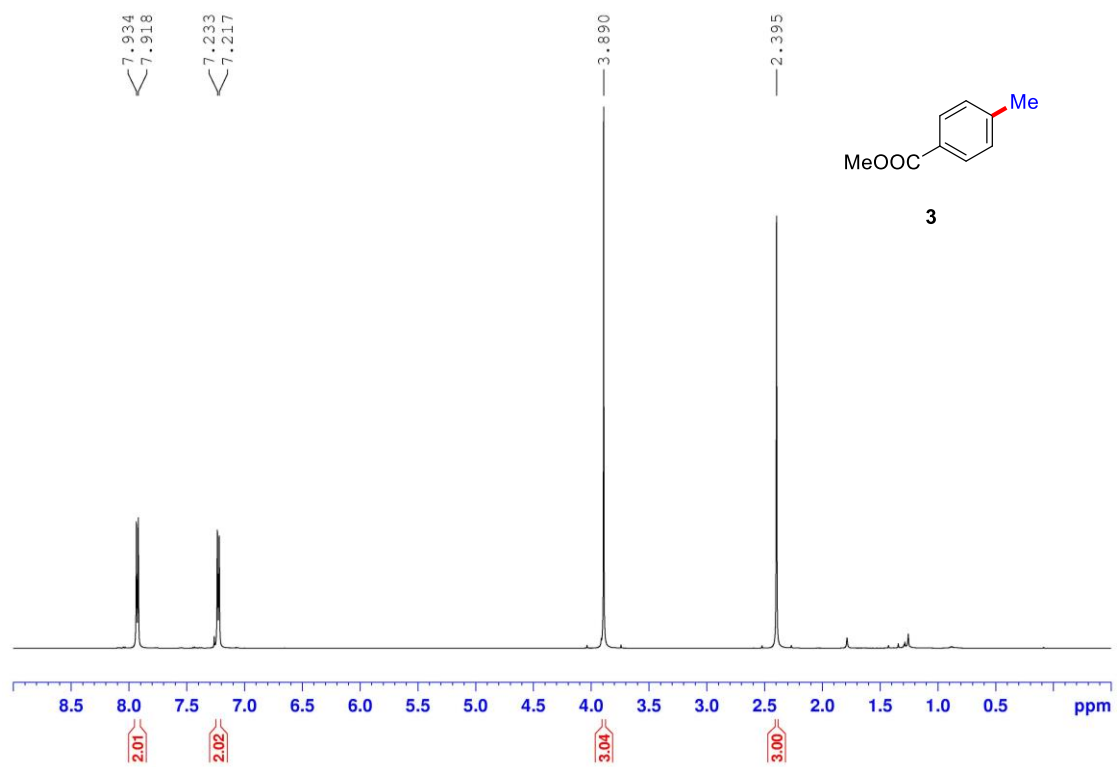


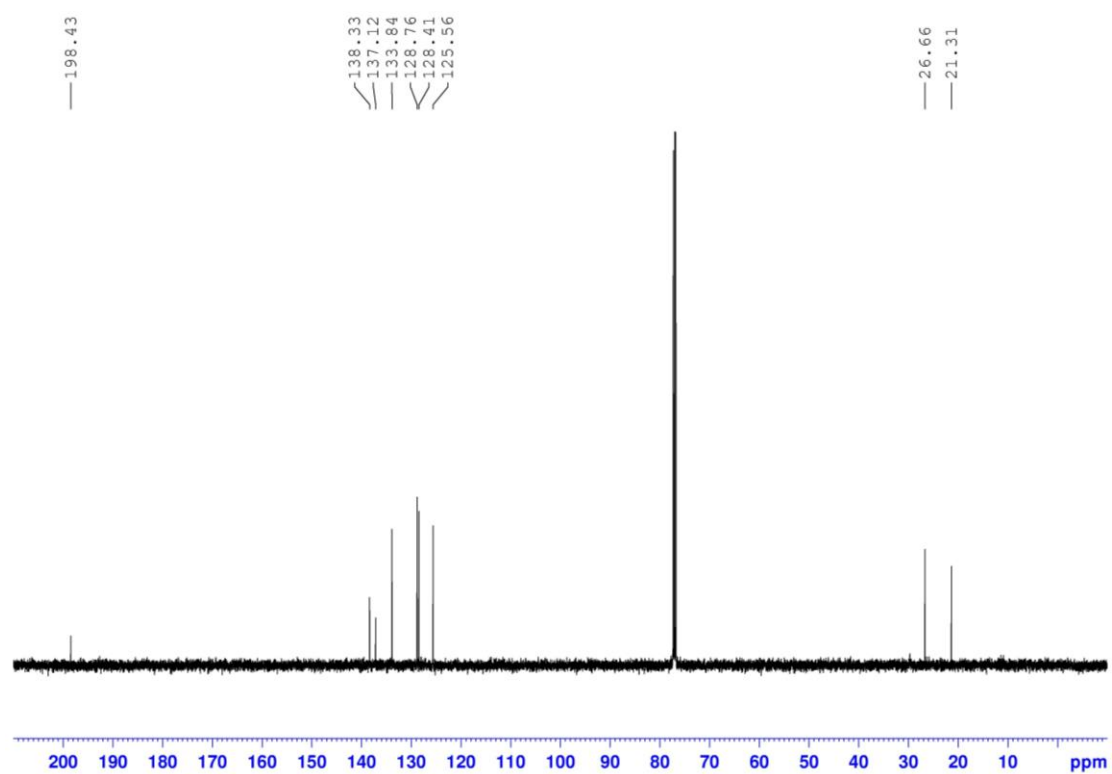
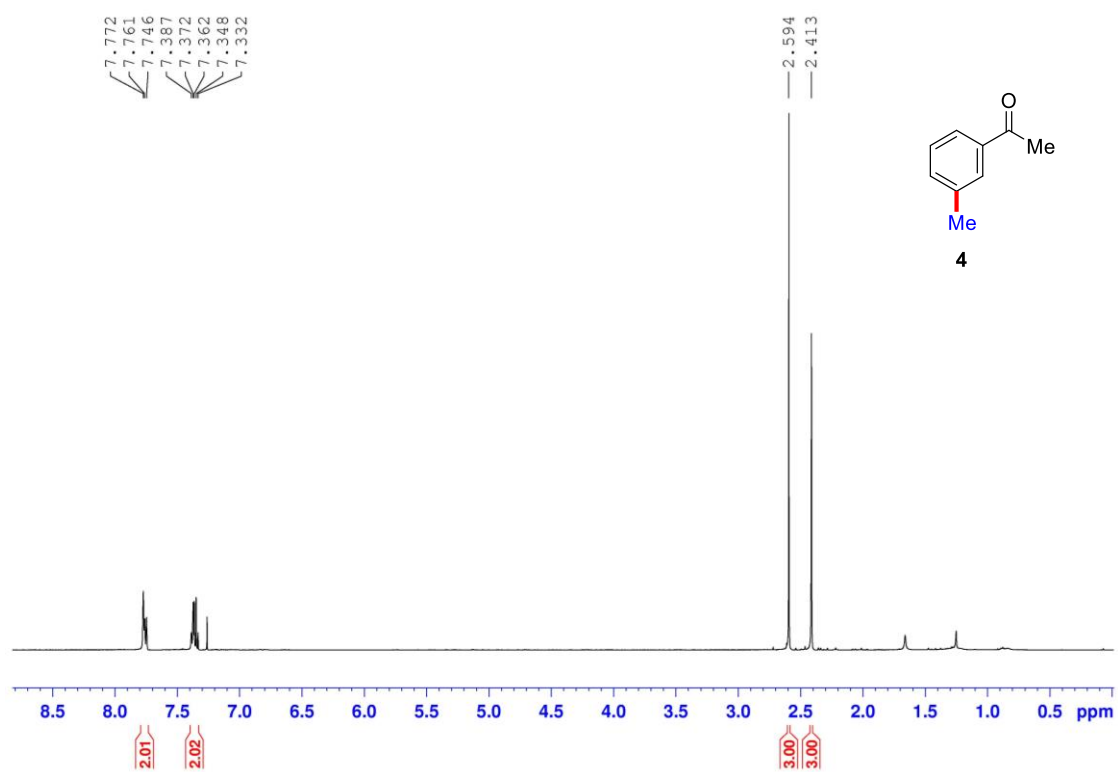


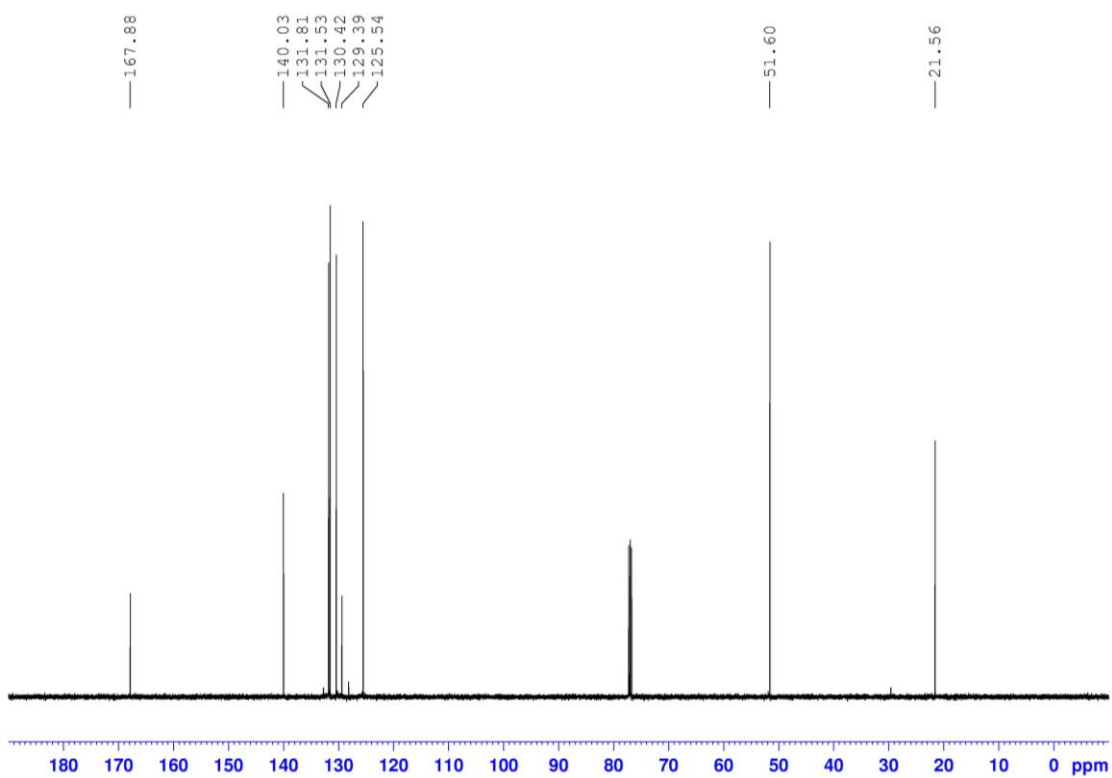
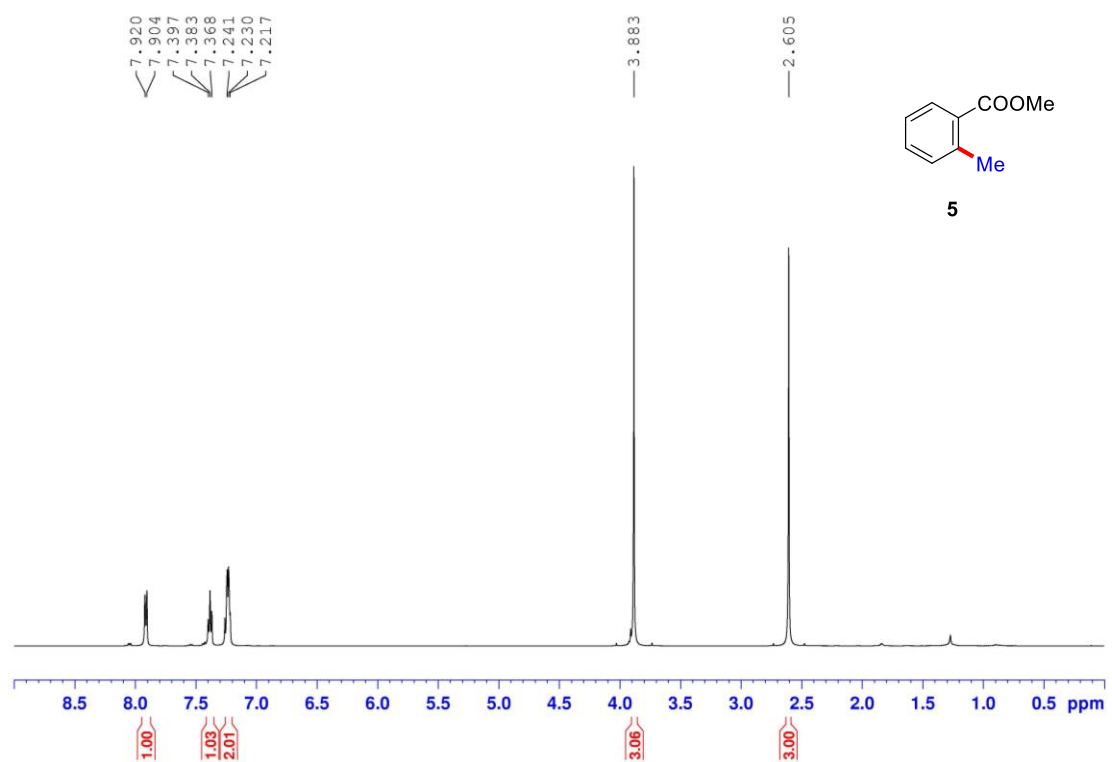


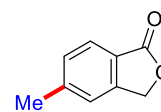
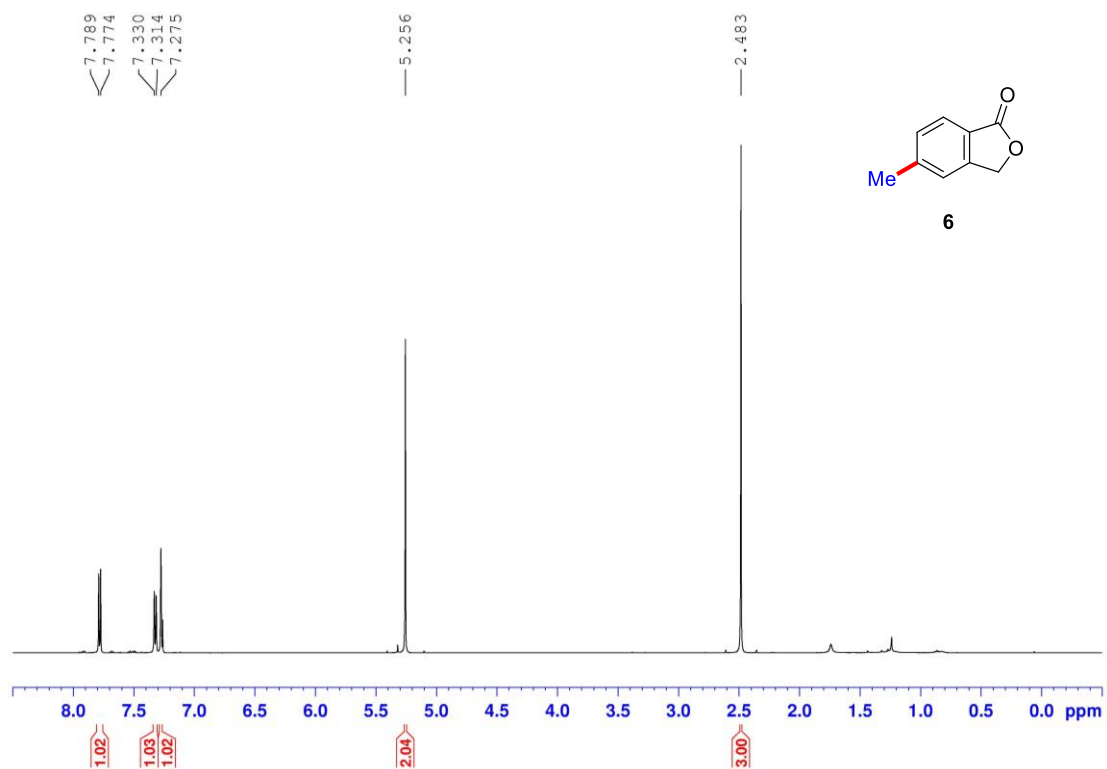




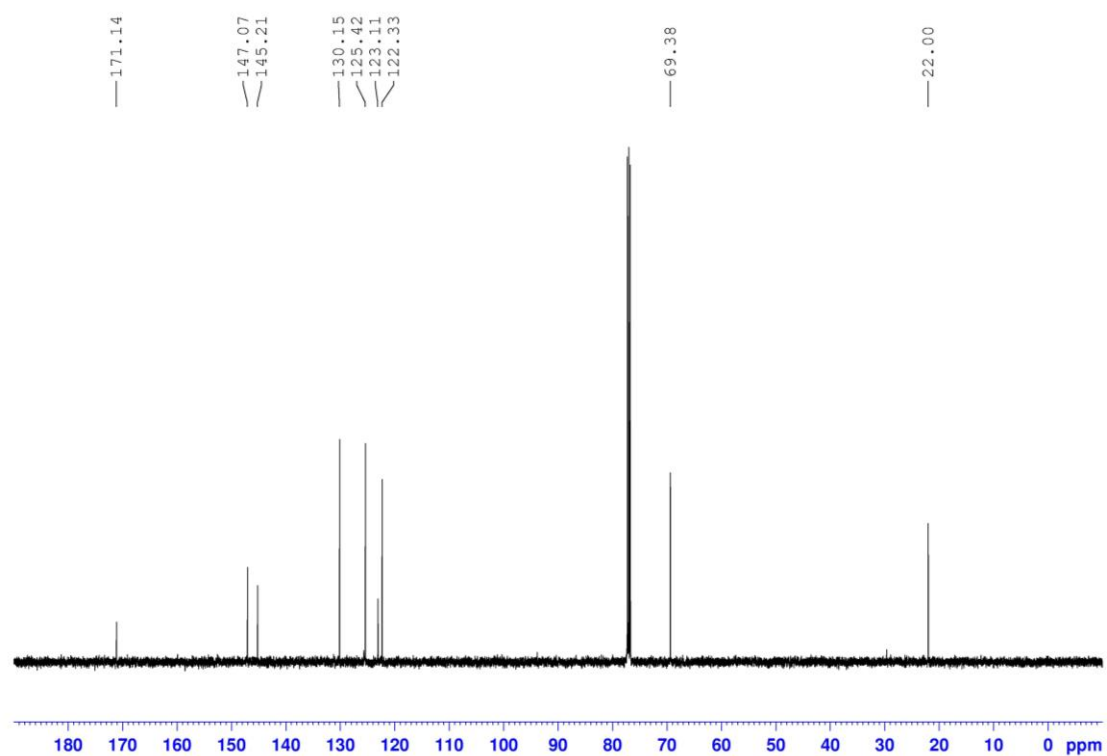


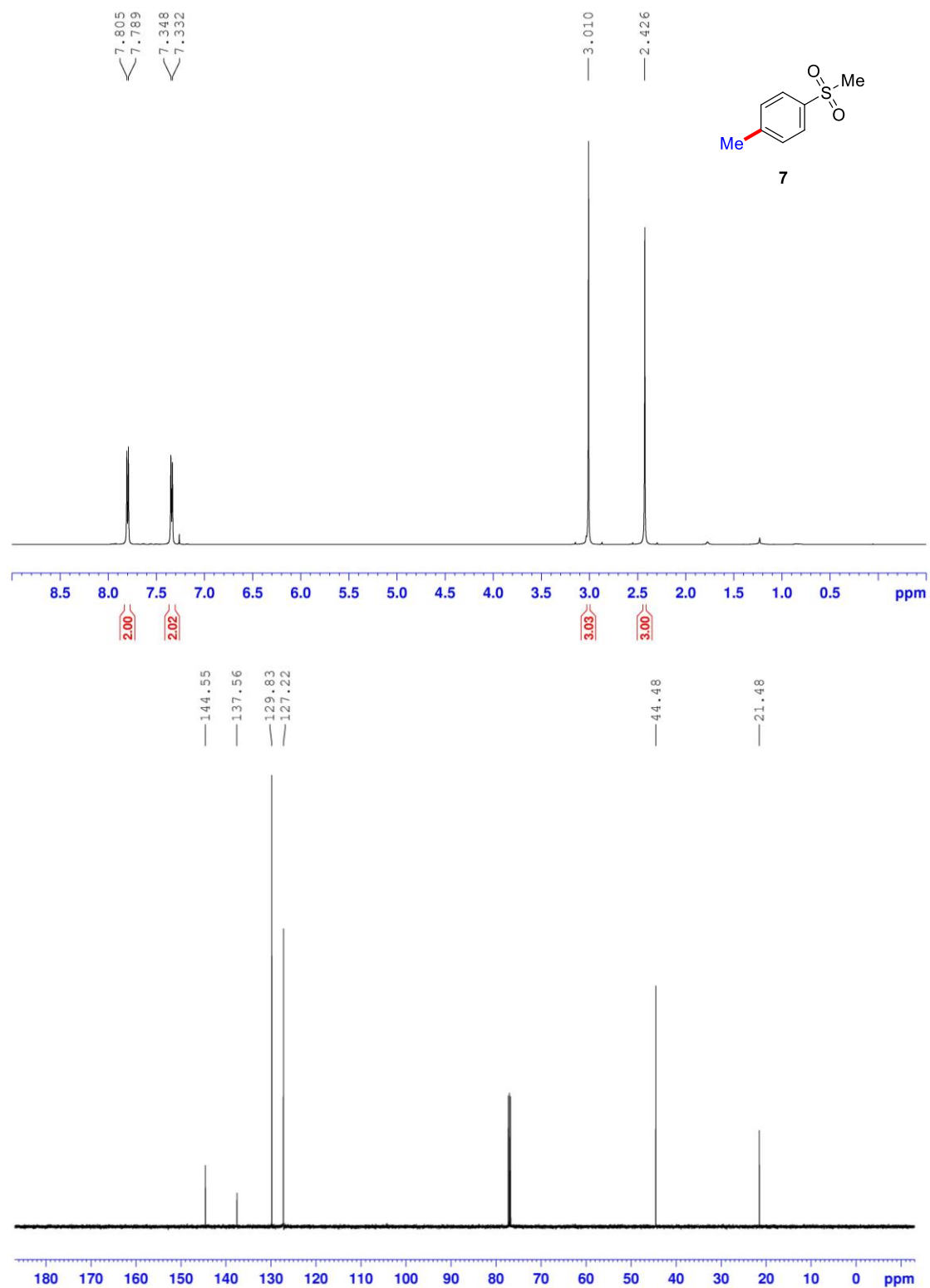


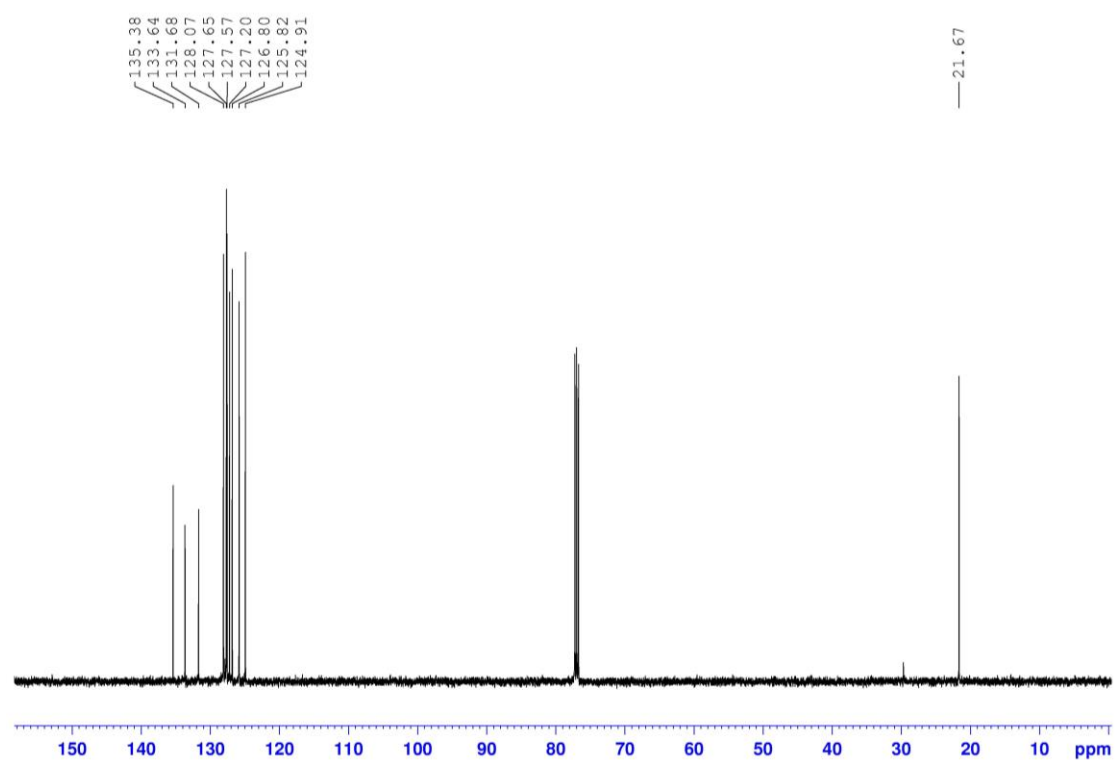
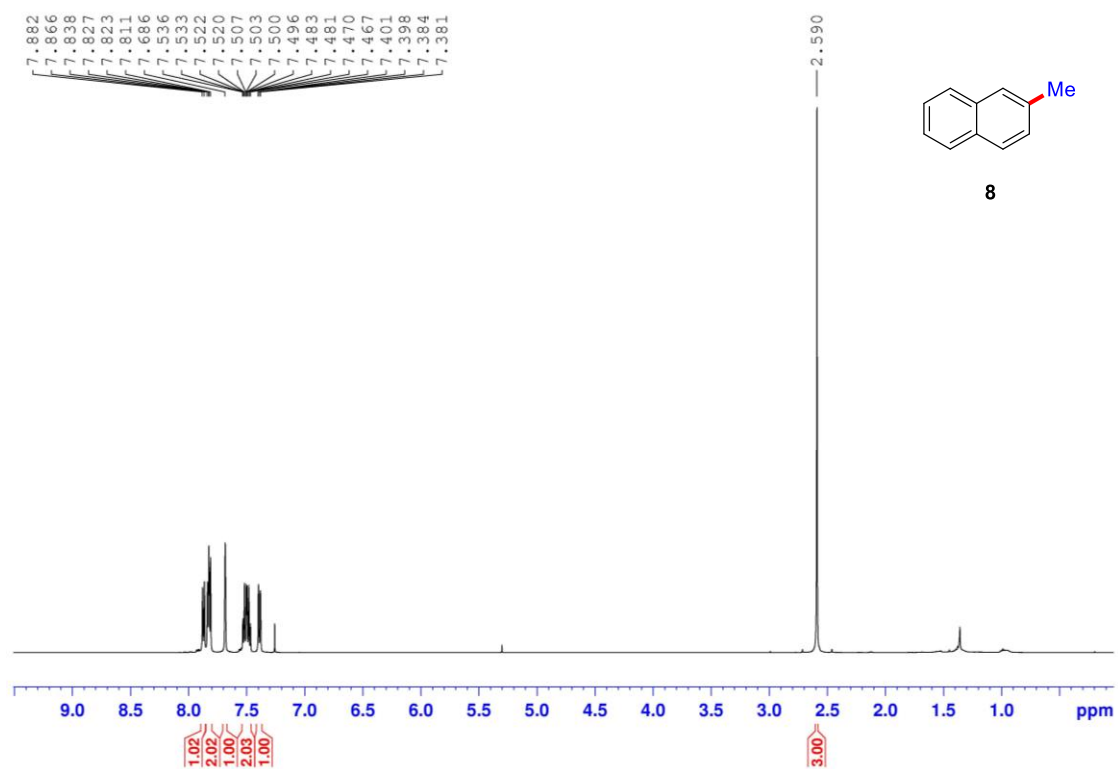


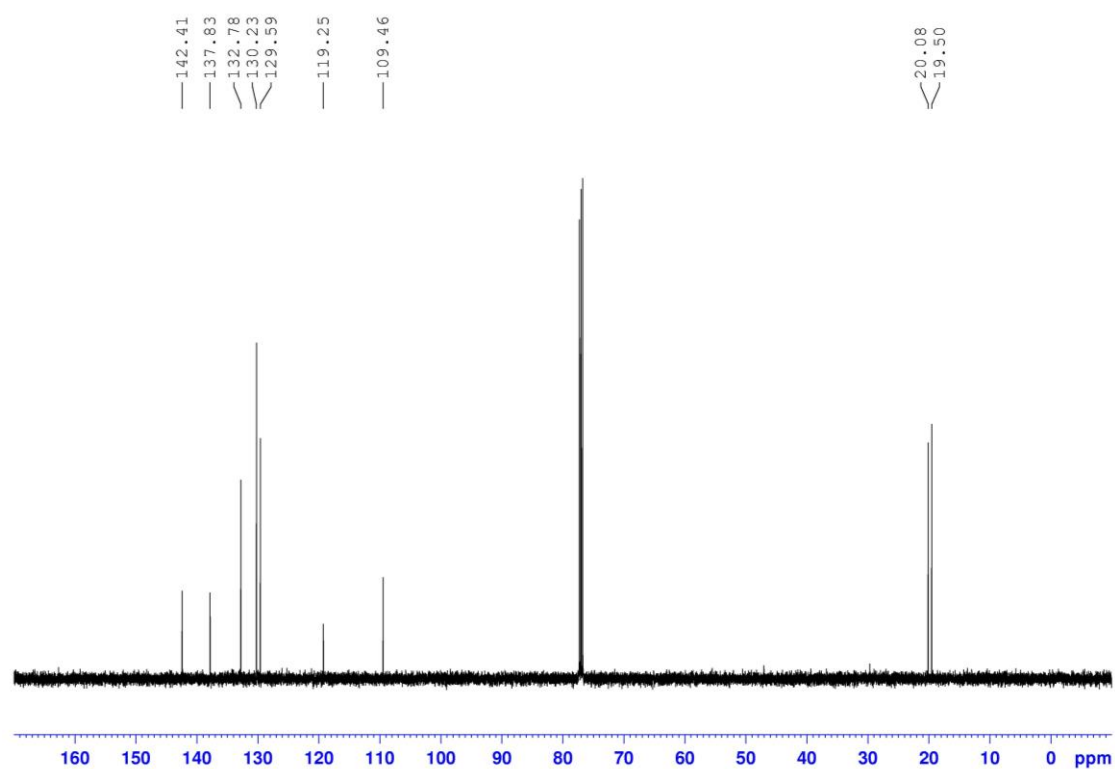
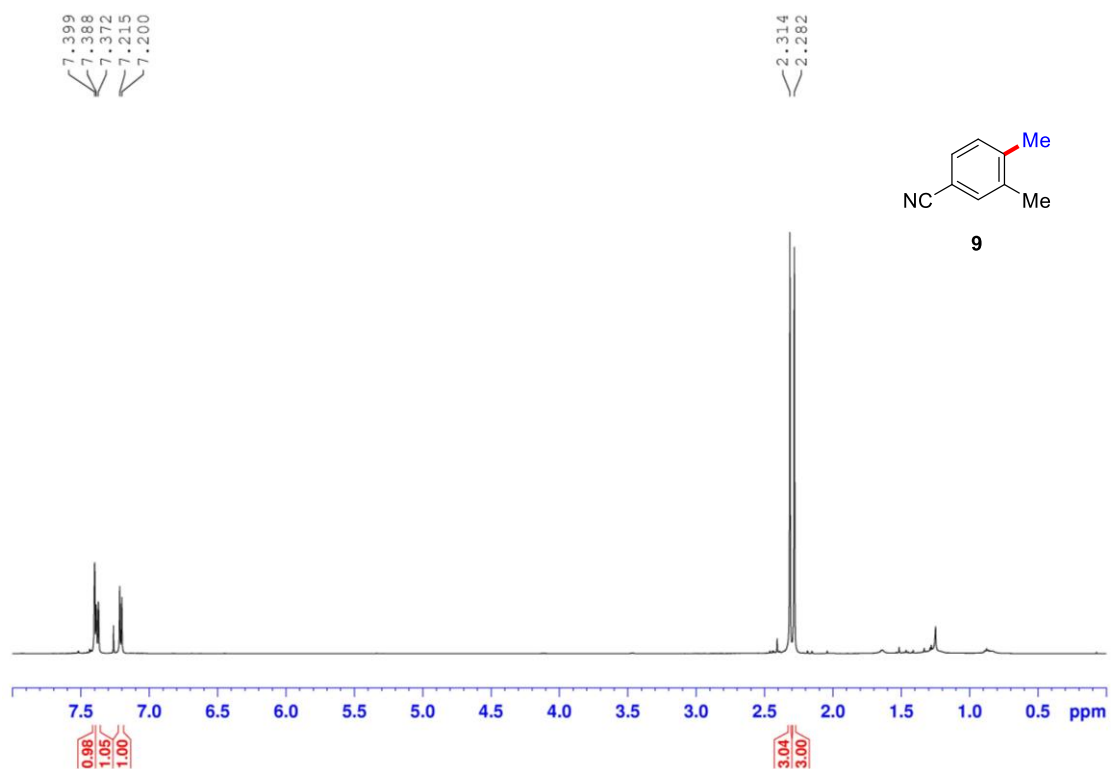


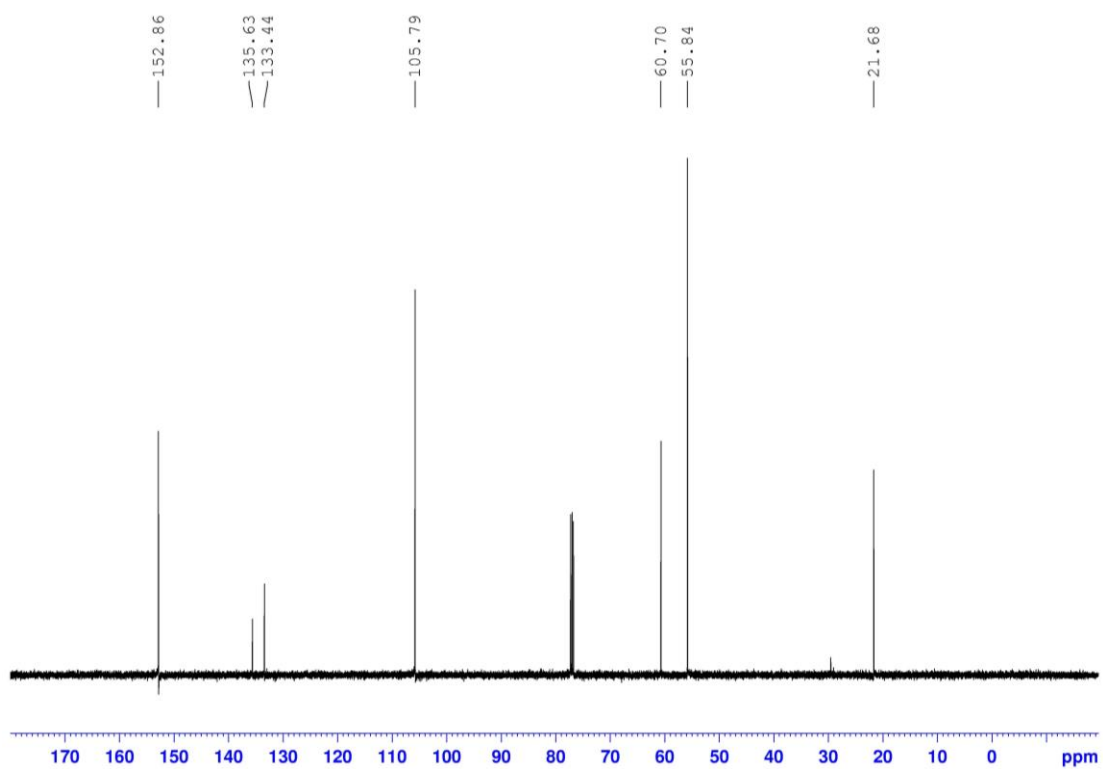
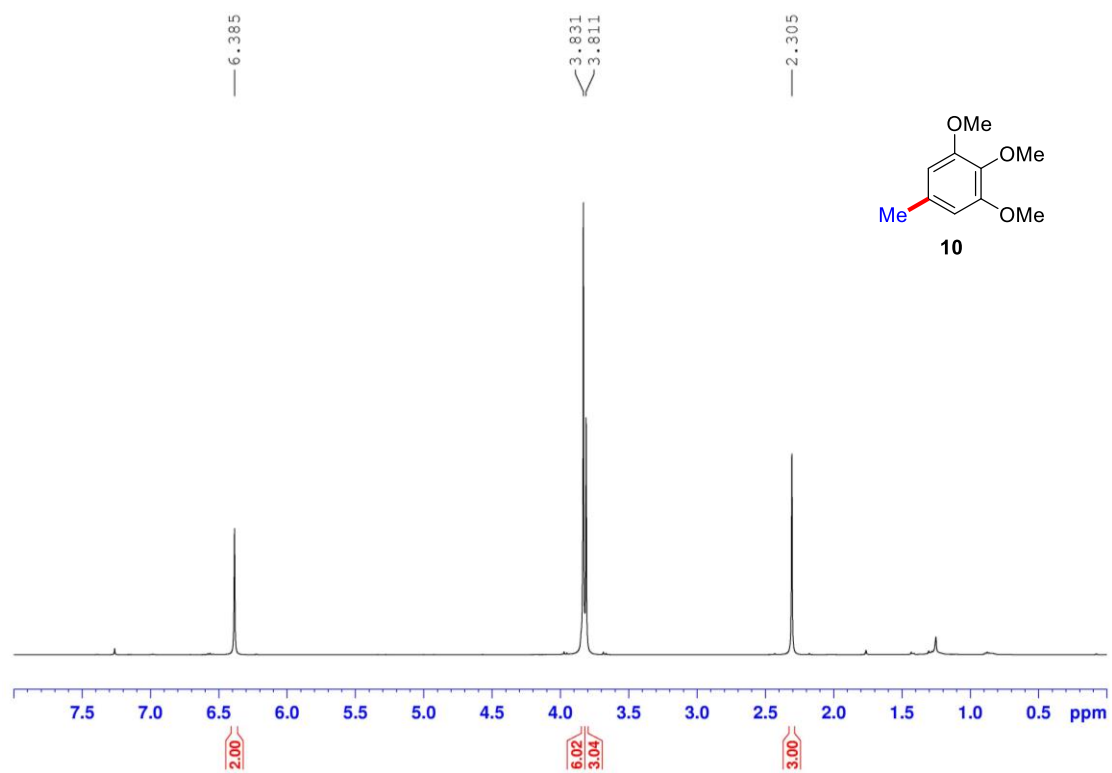
6

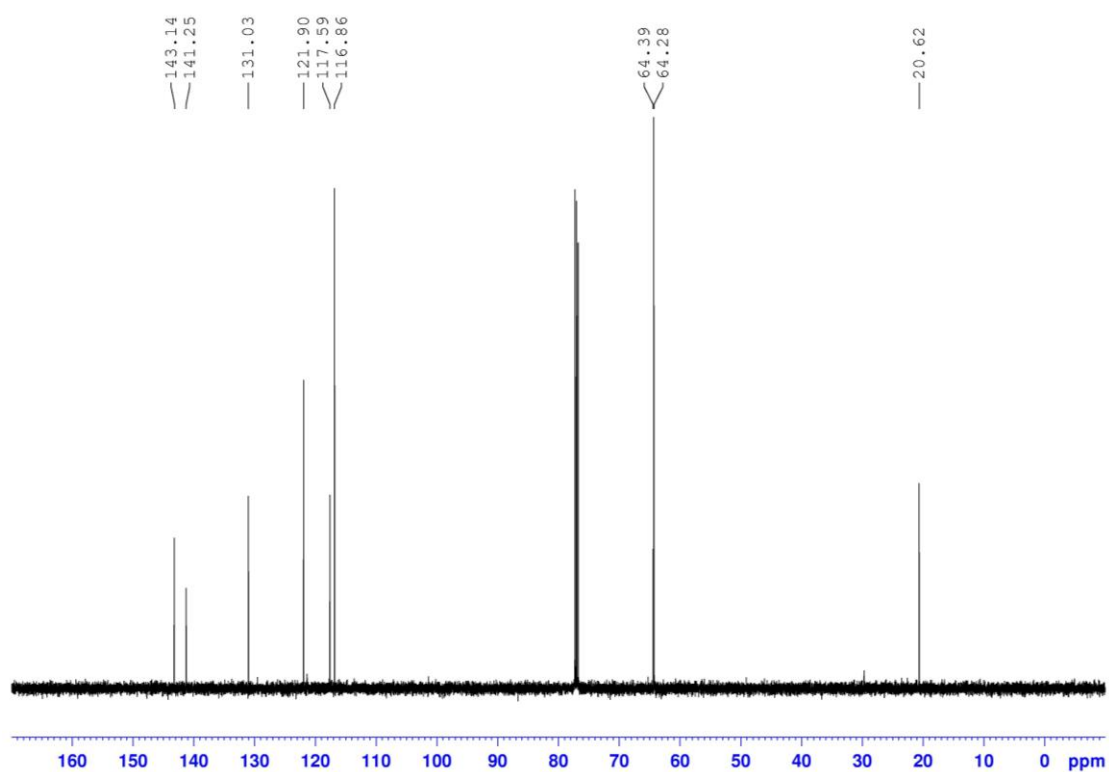
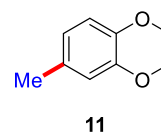
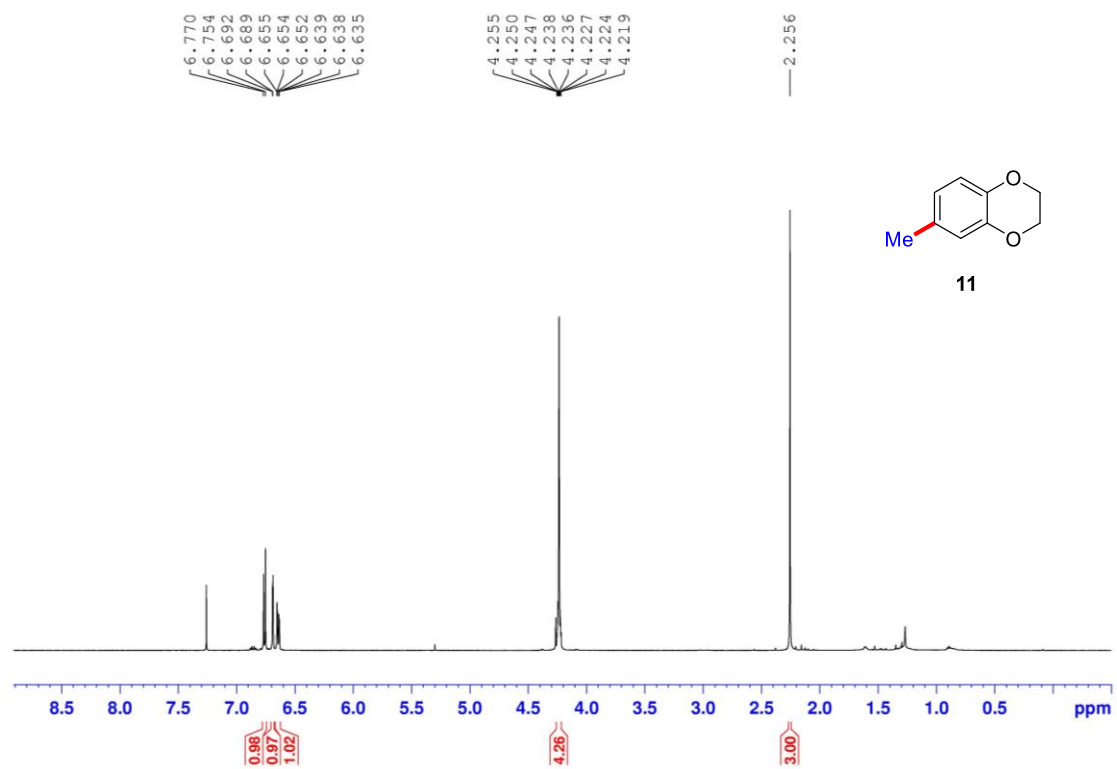


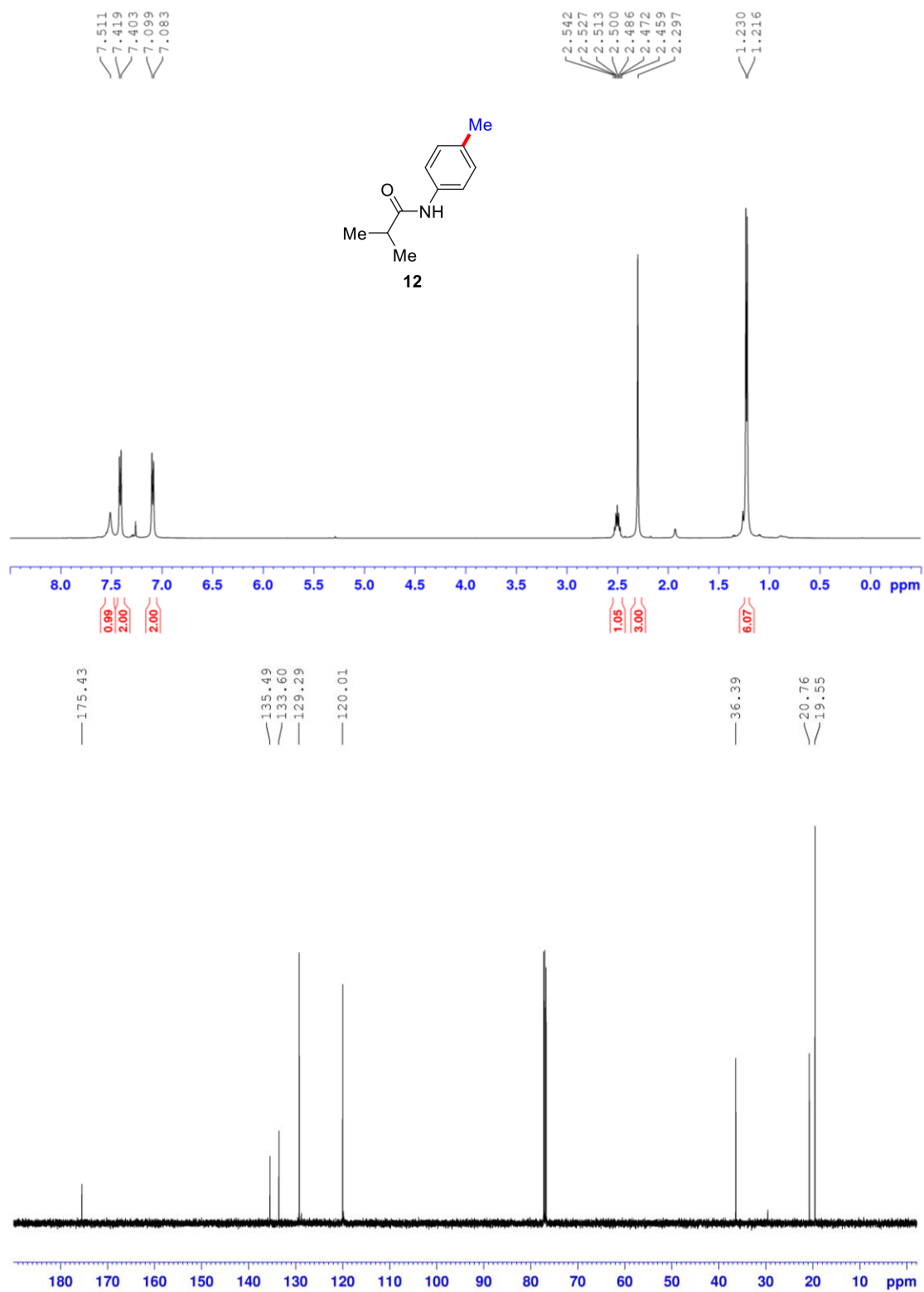


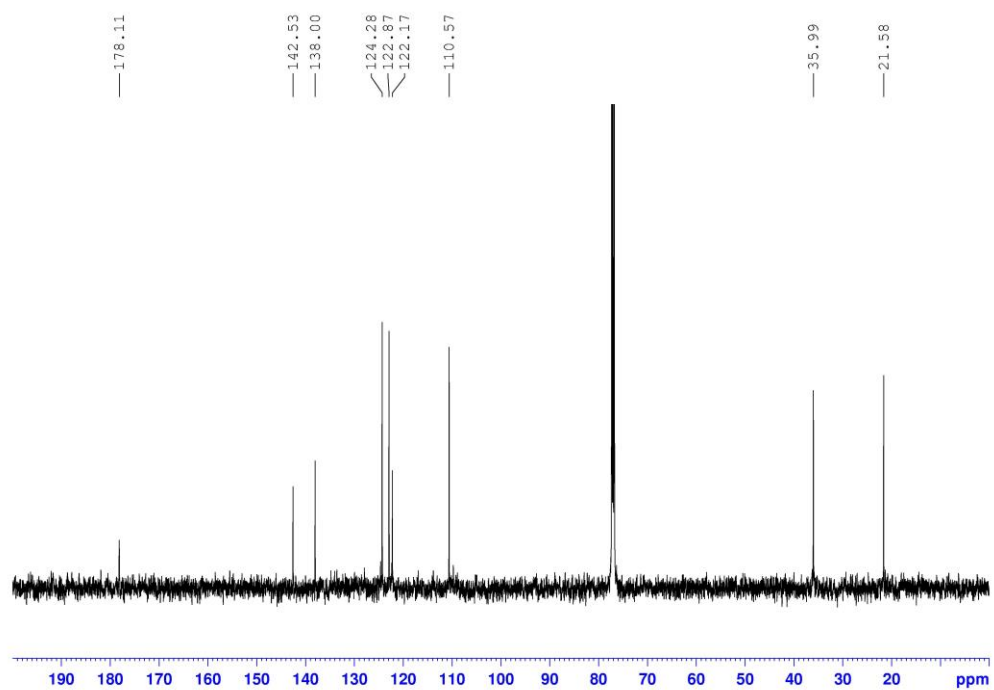
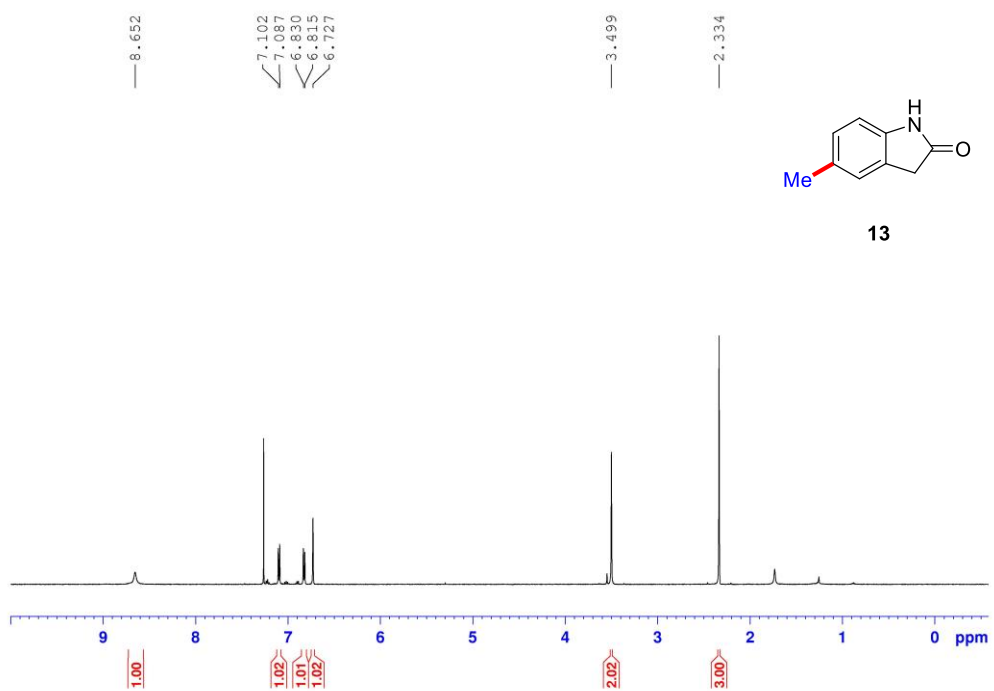


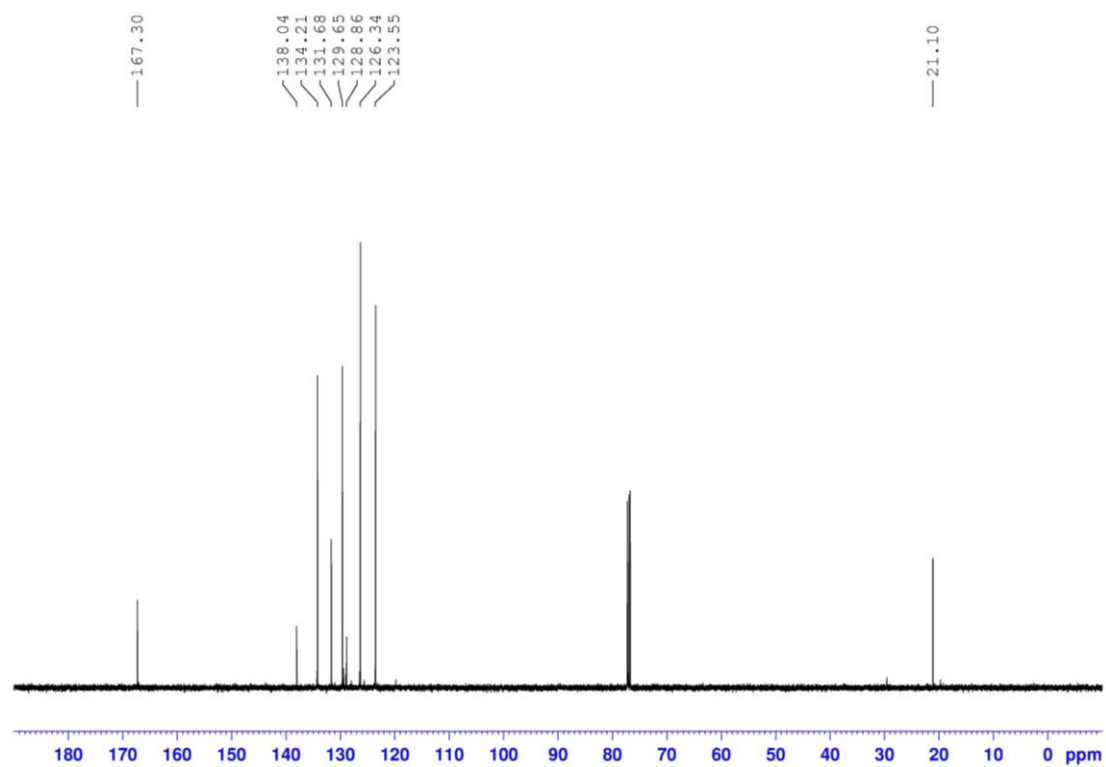
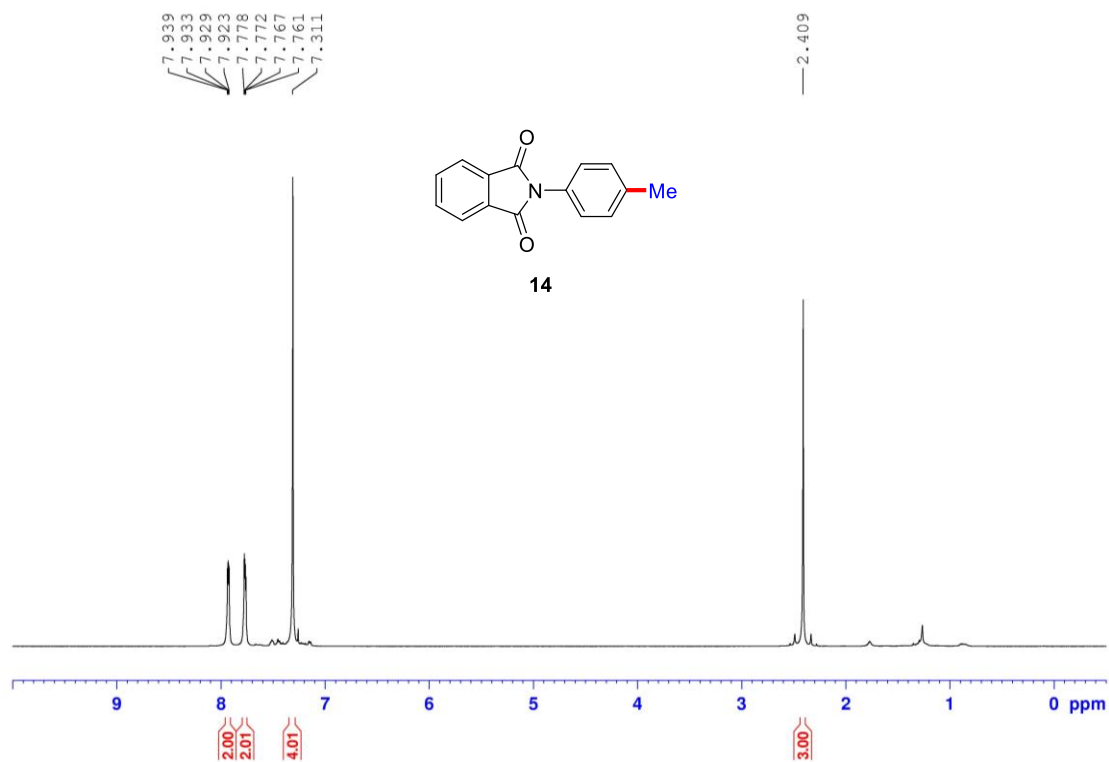


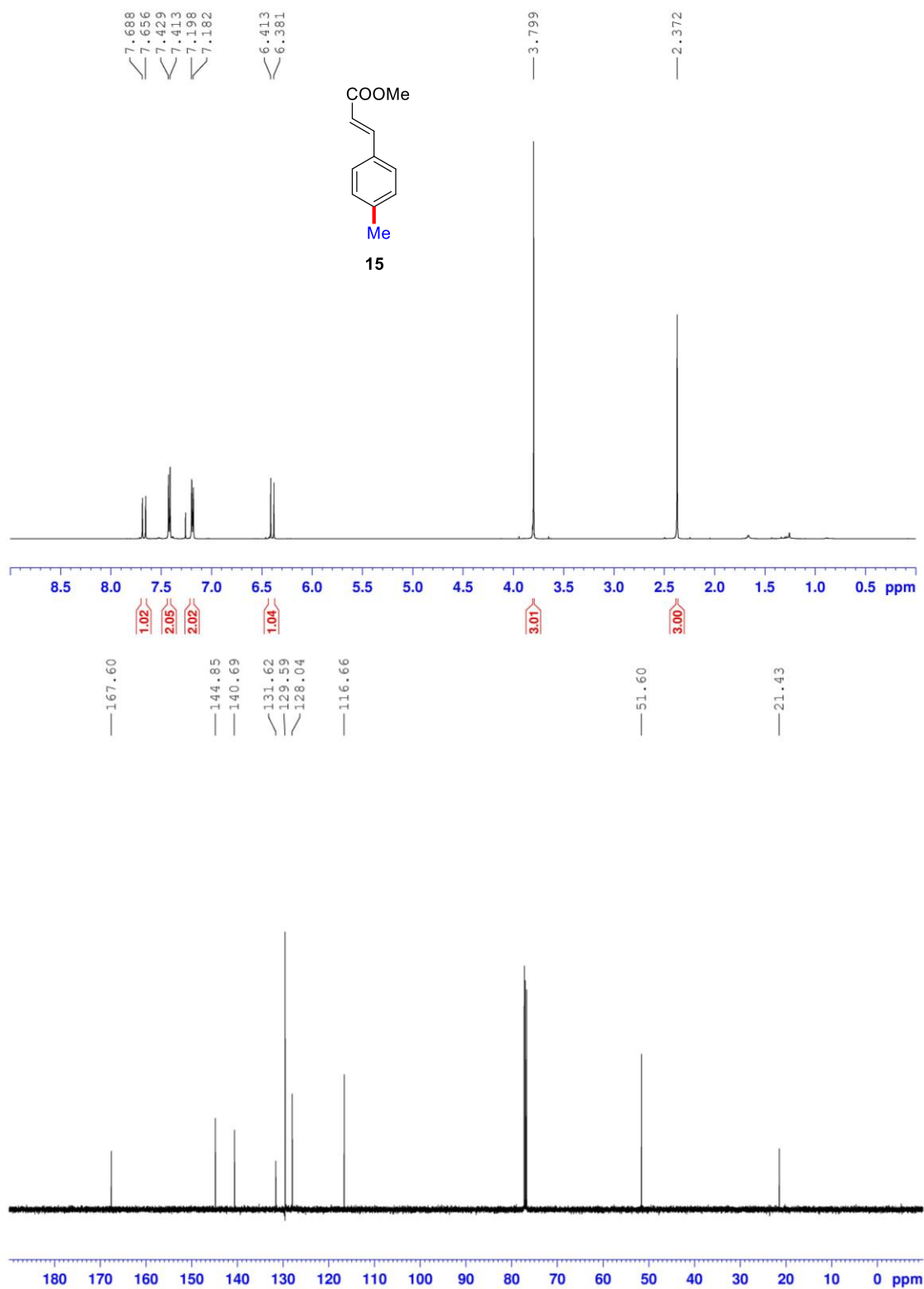


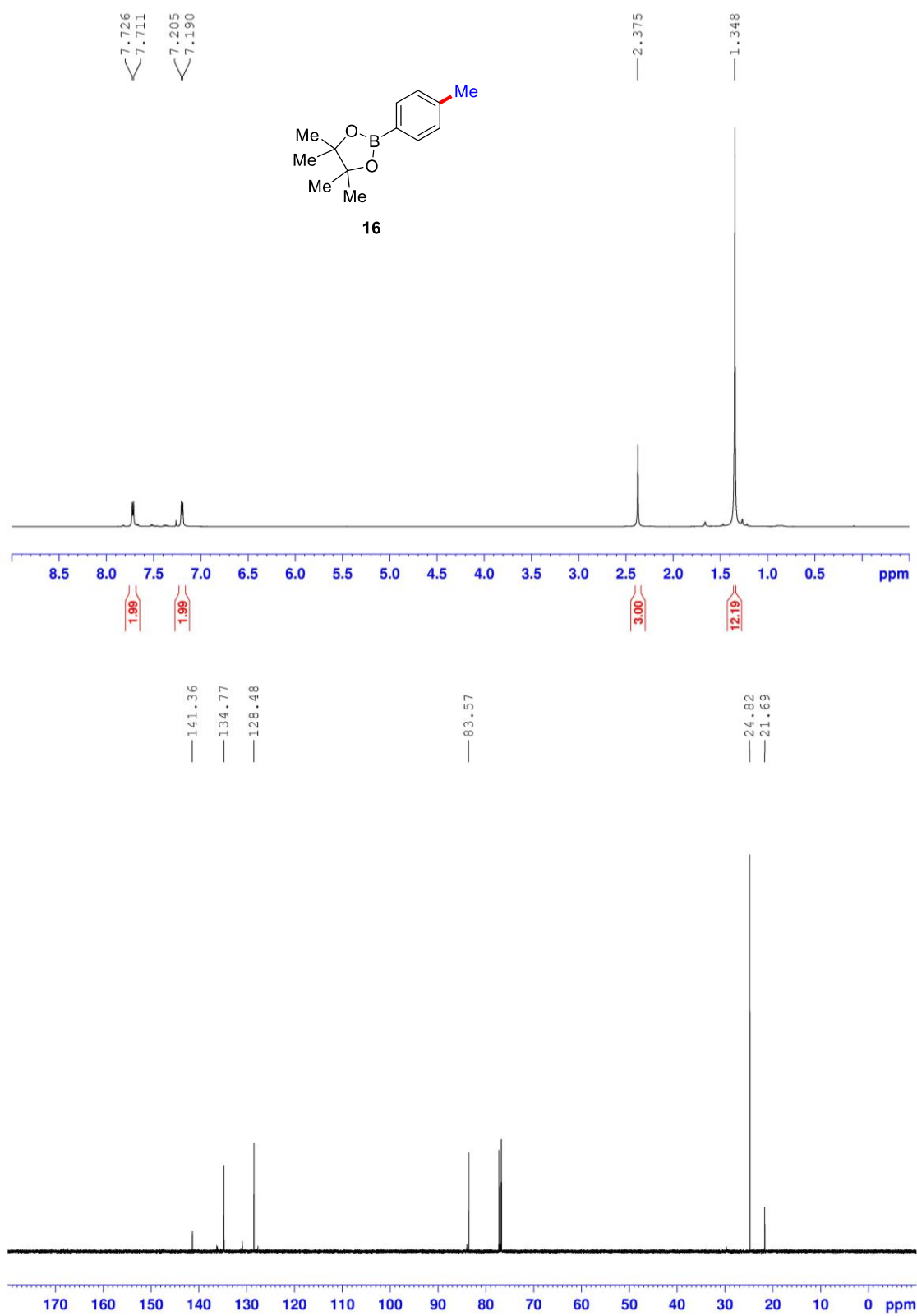


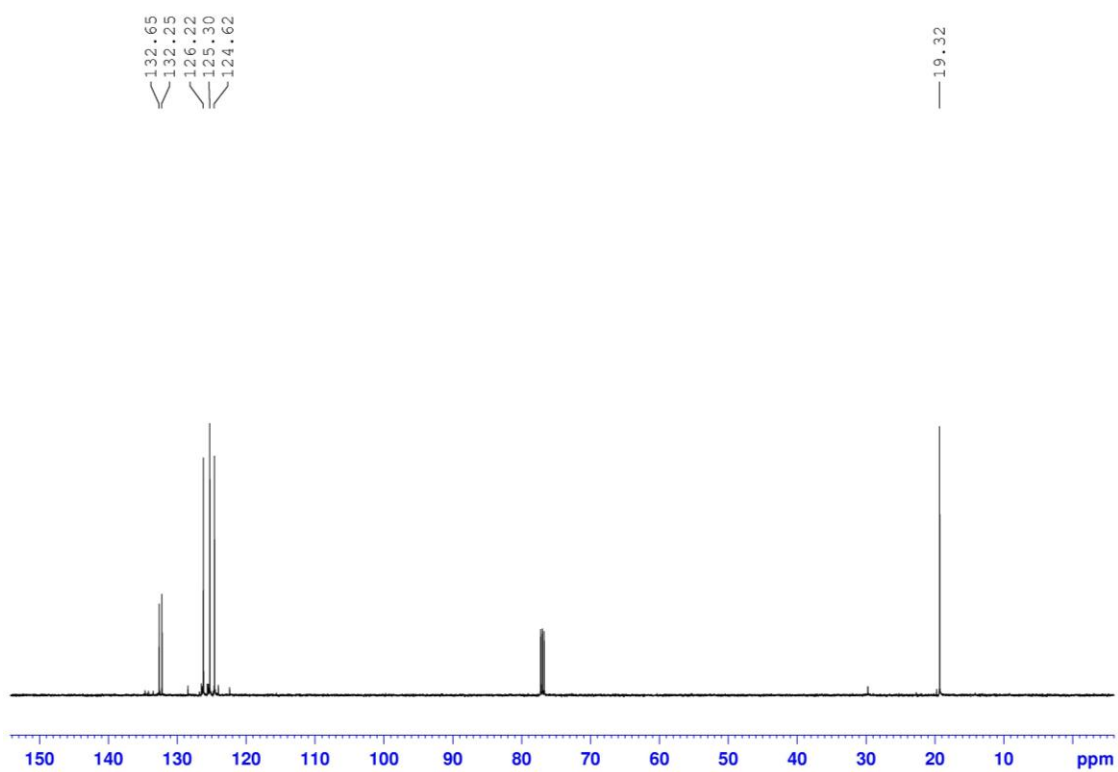
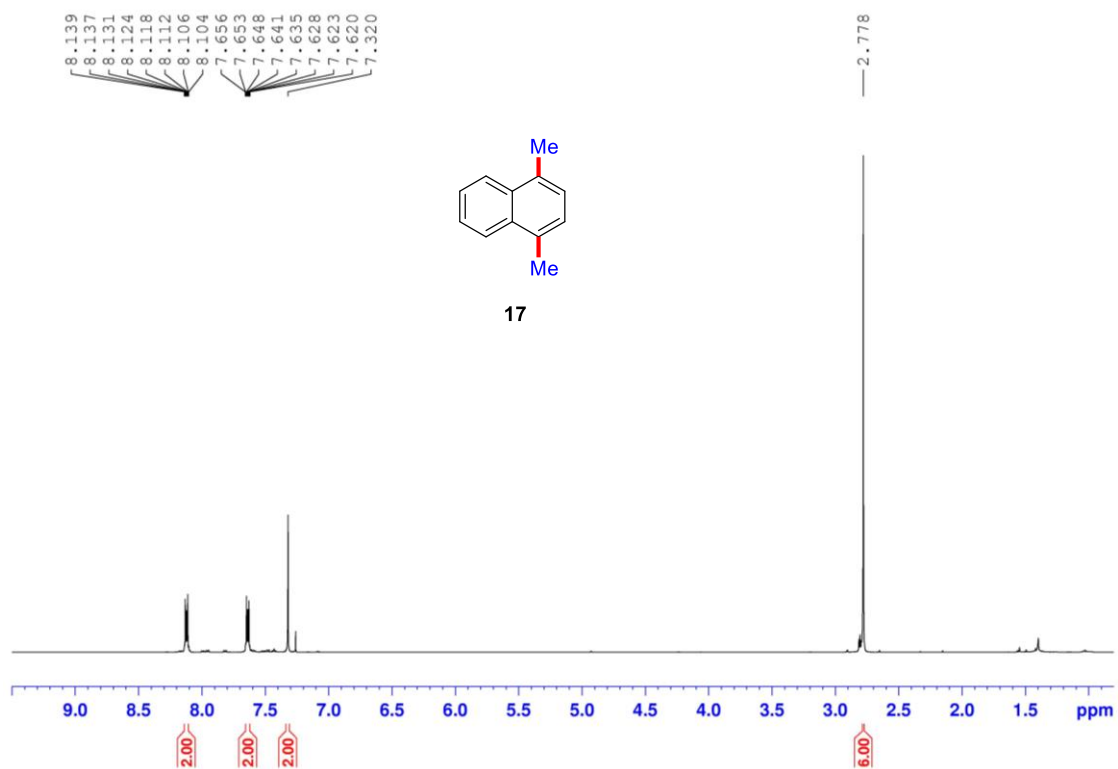


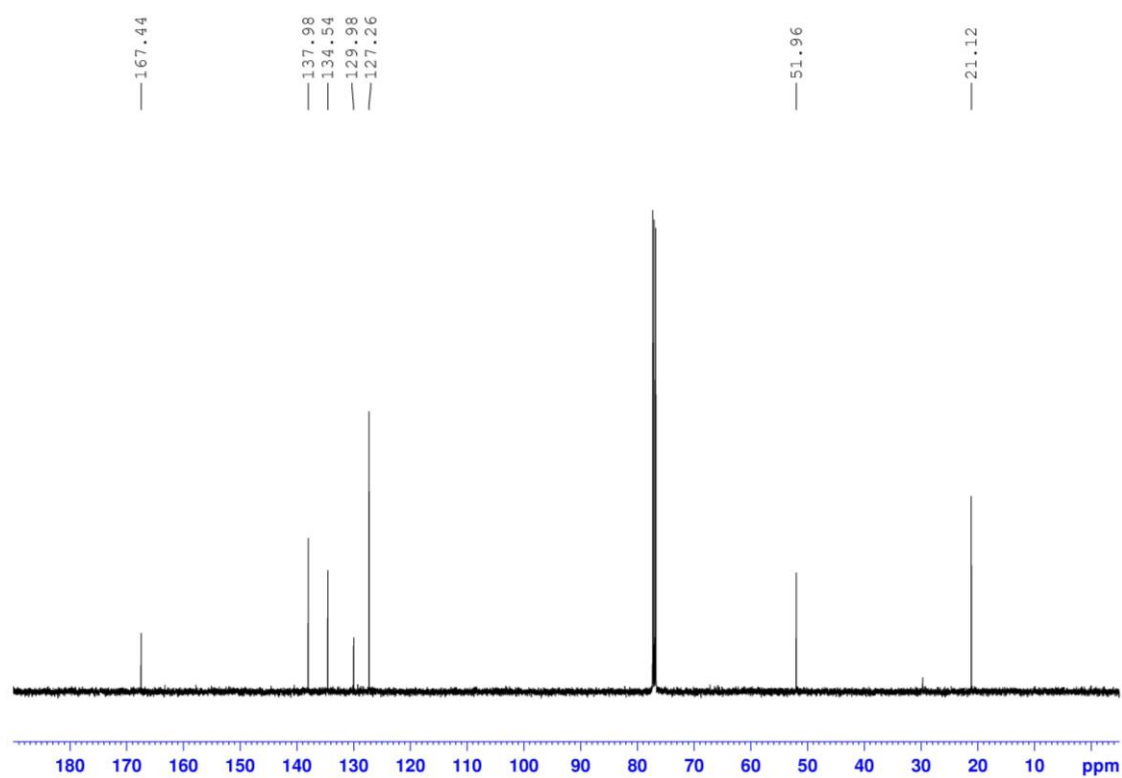
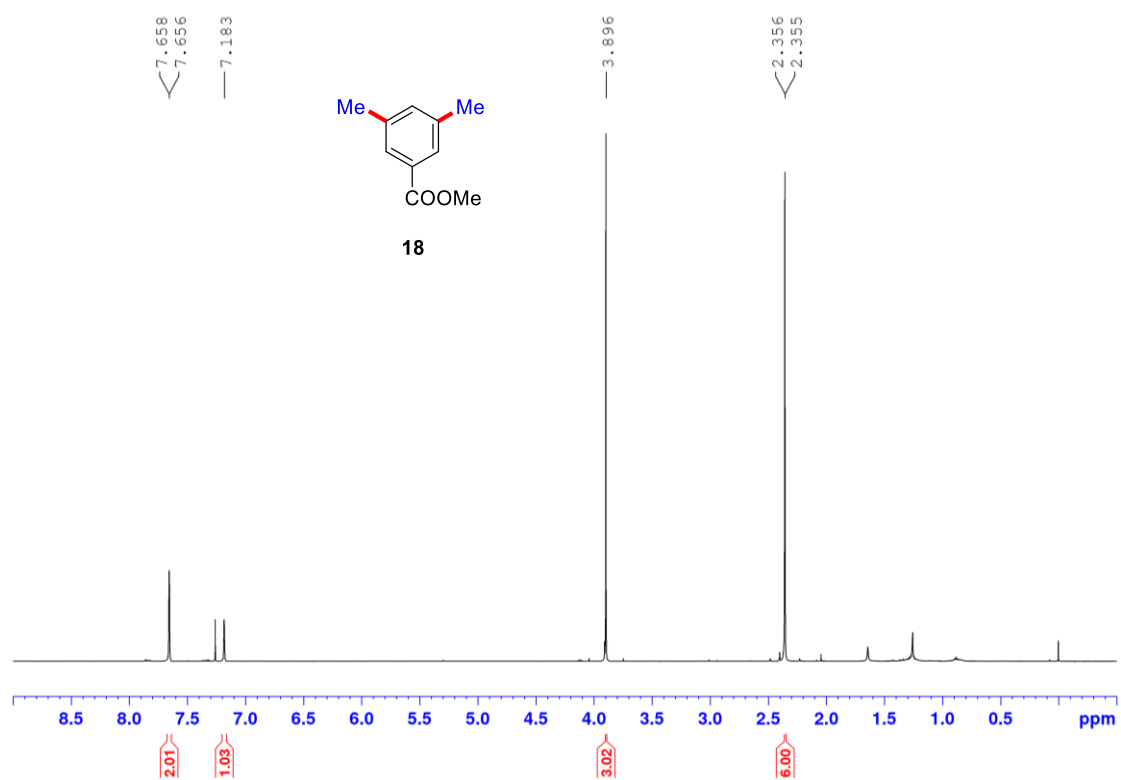


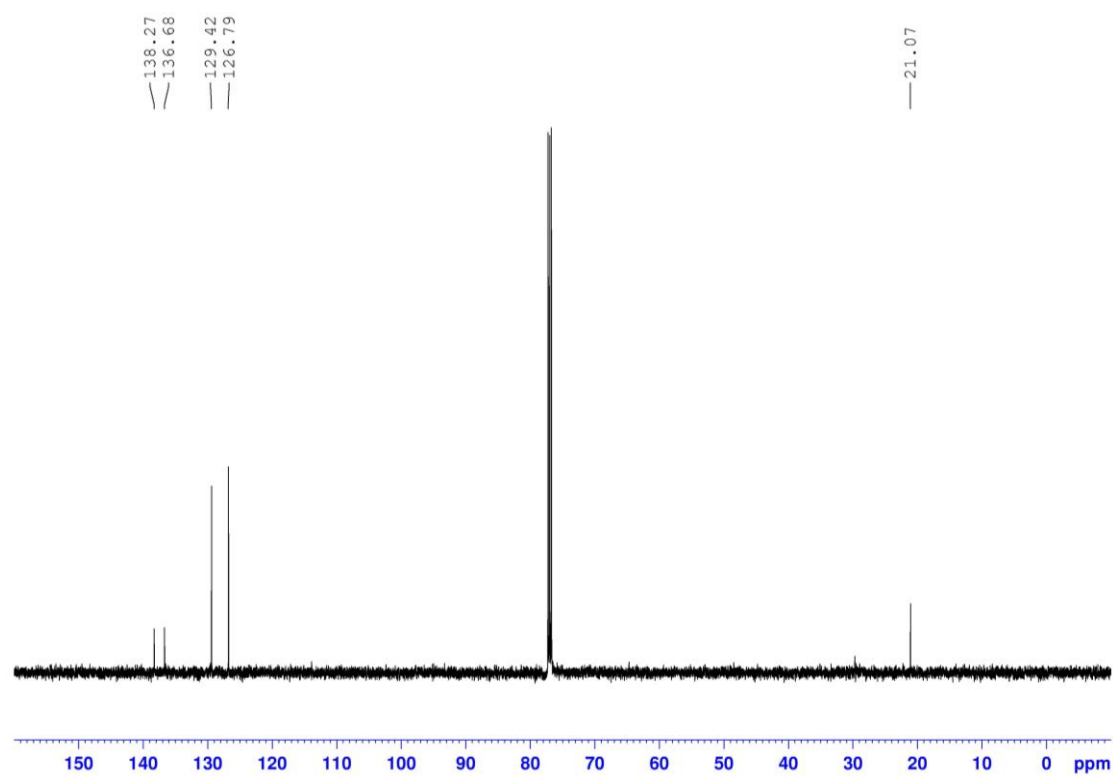
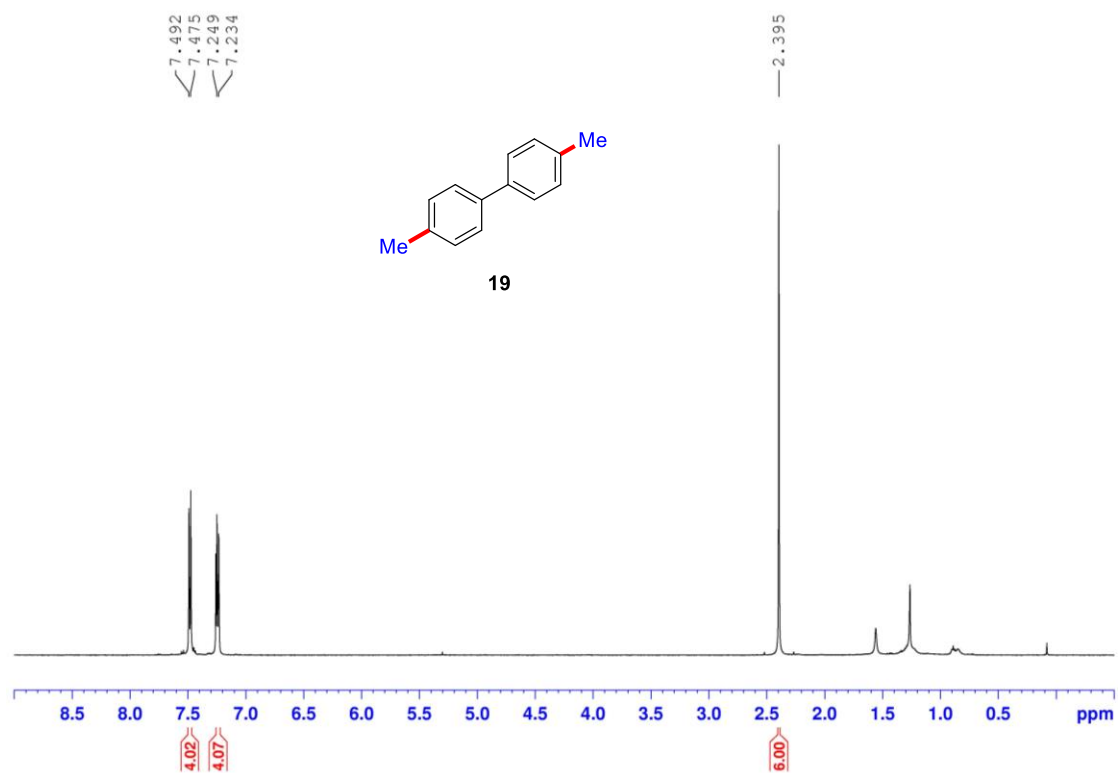


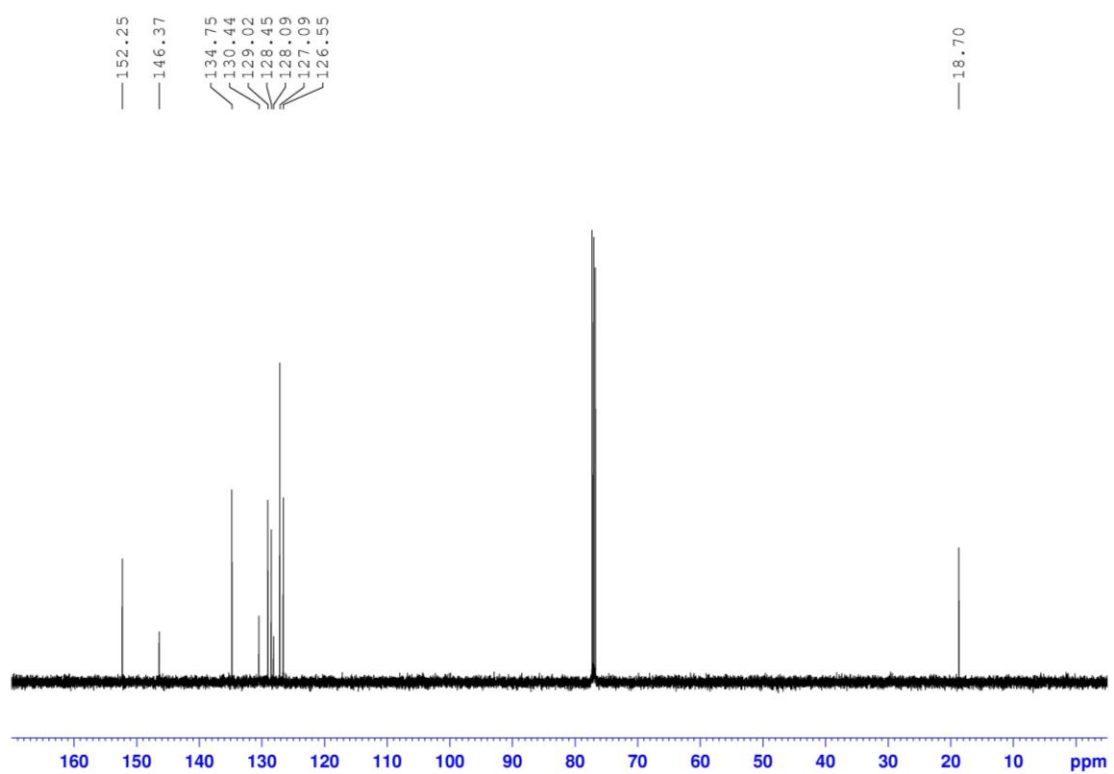
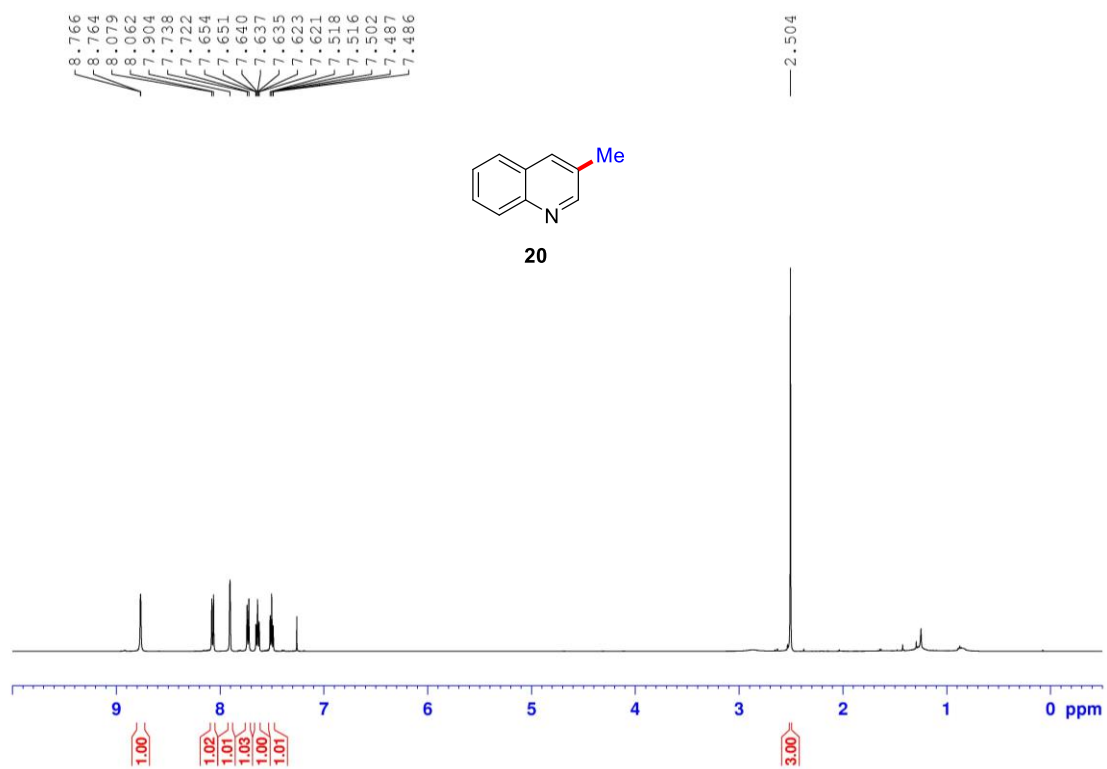


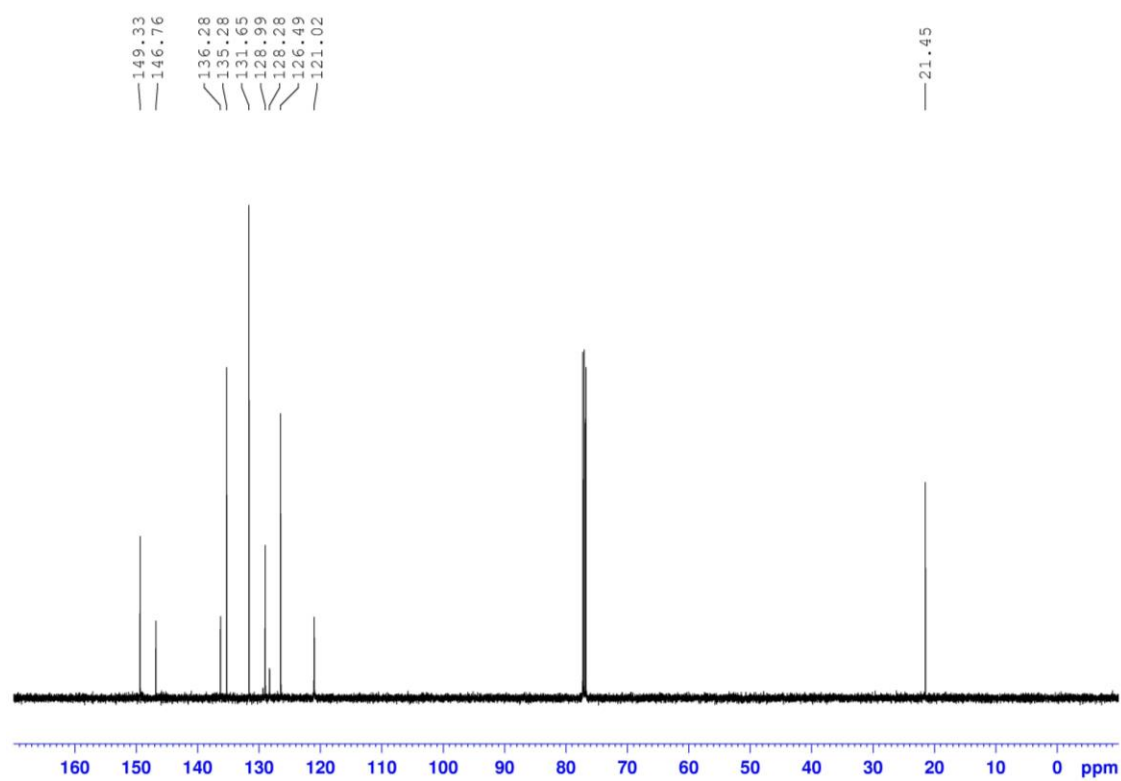
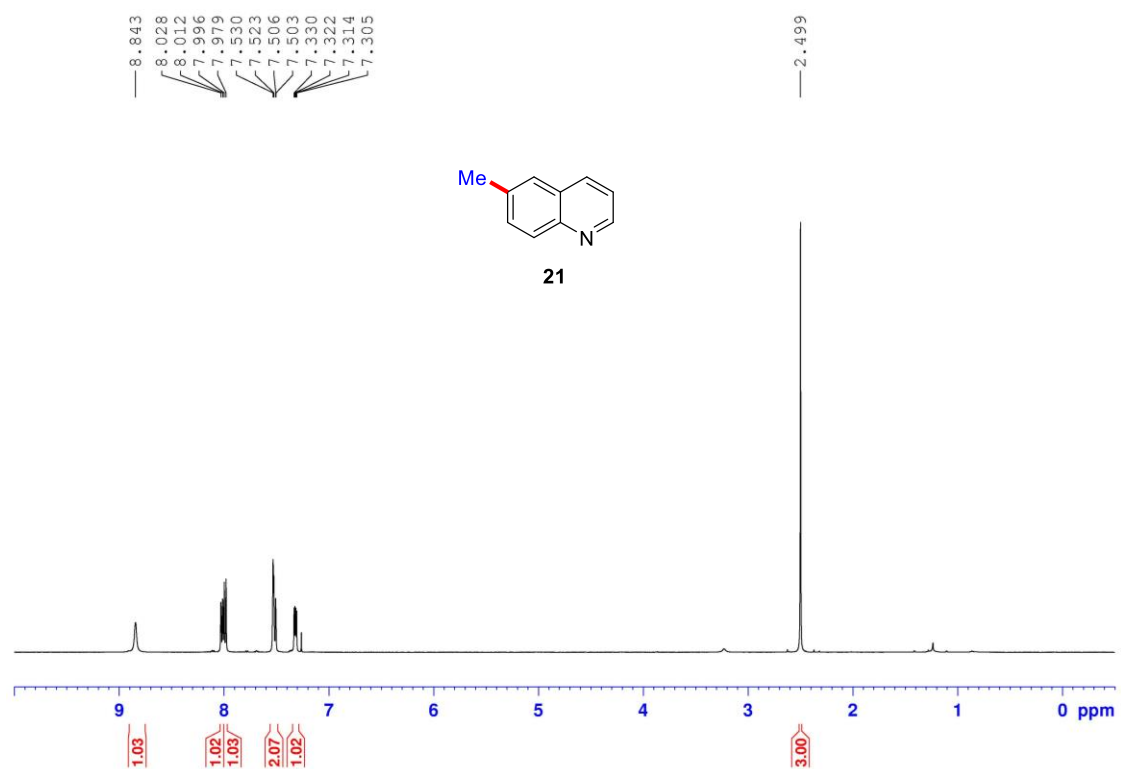


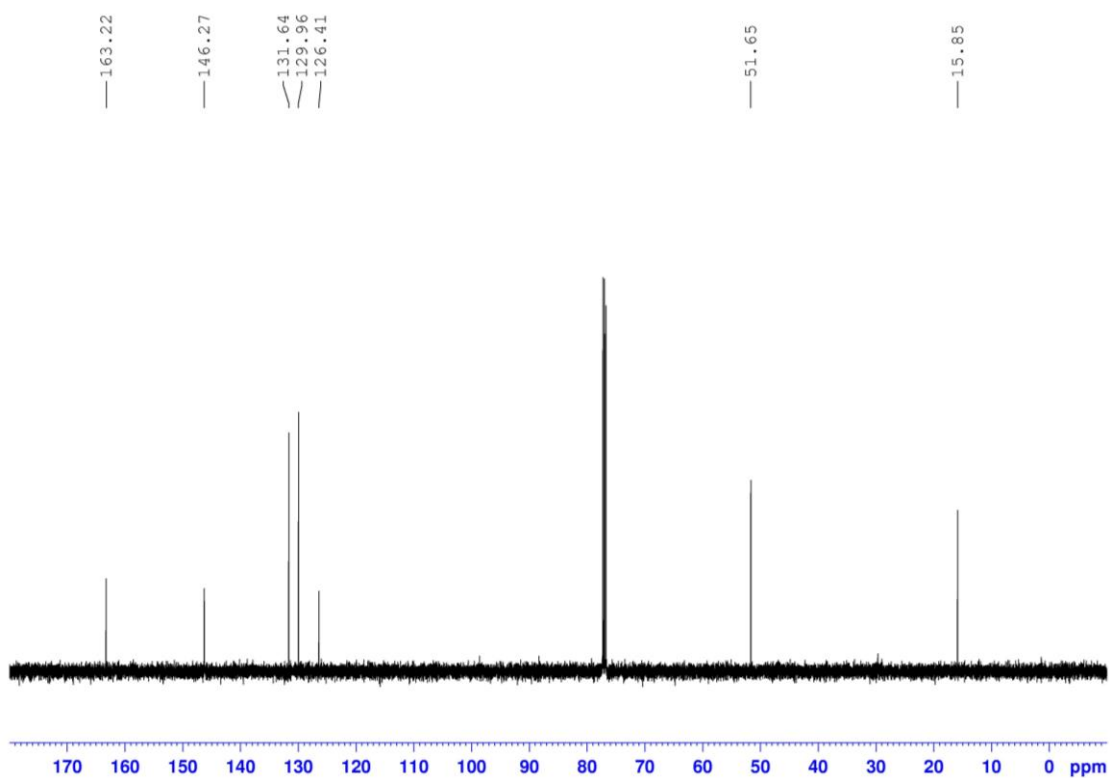
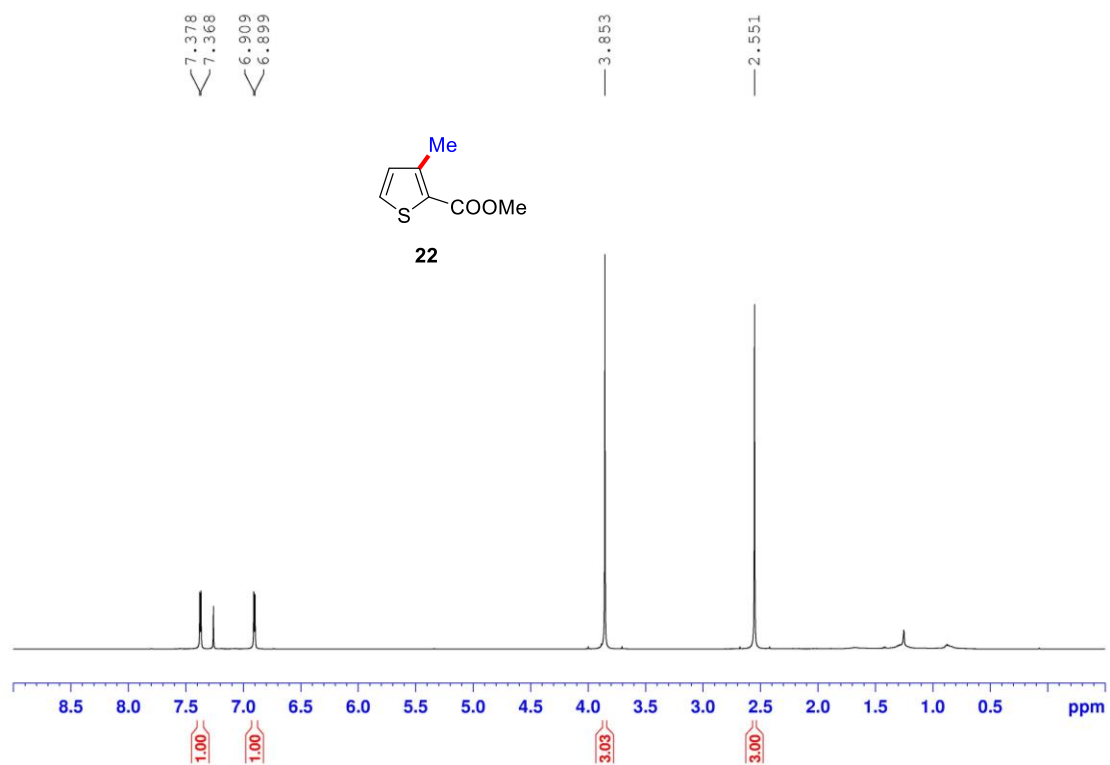


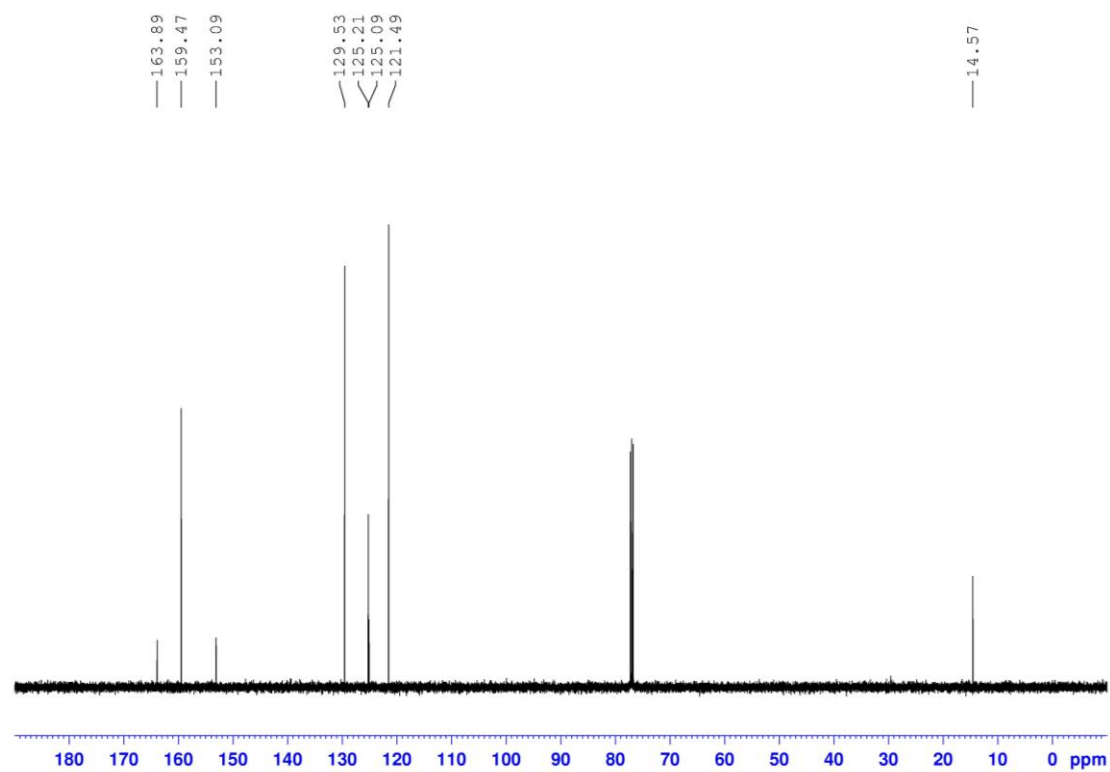
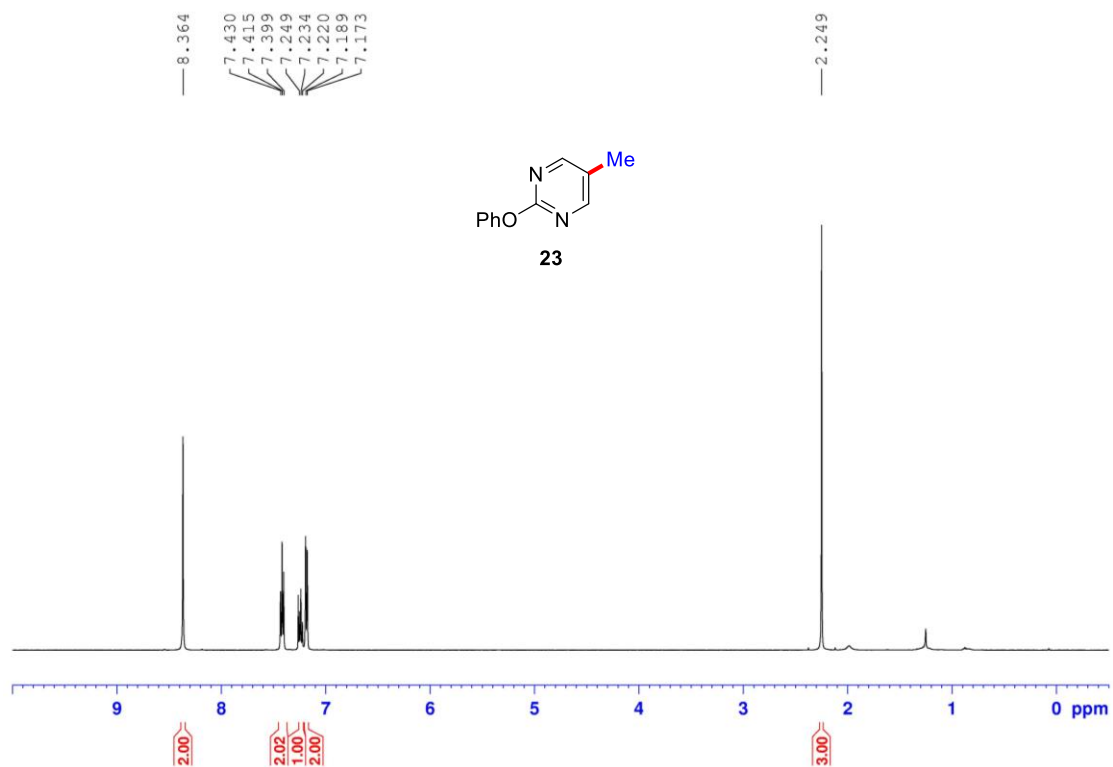


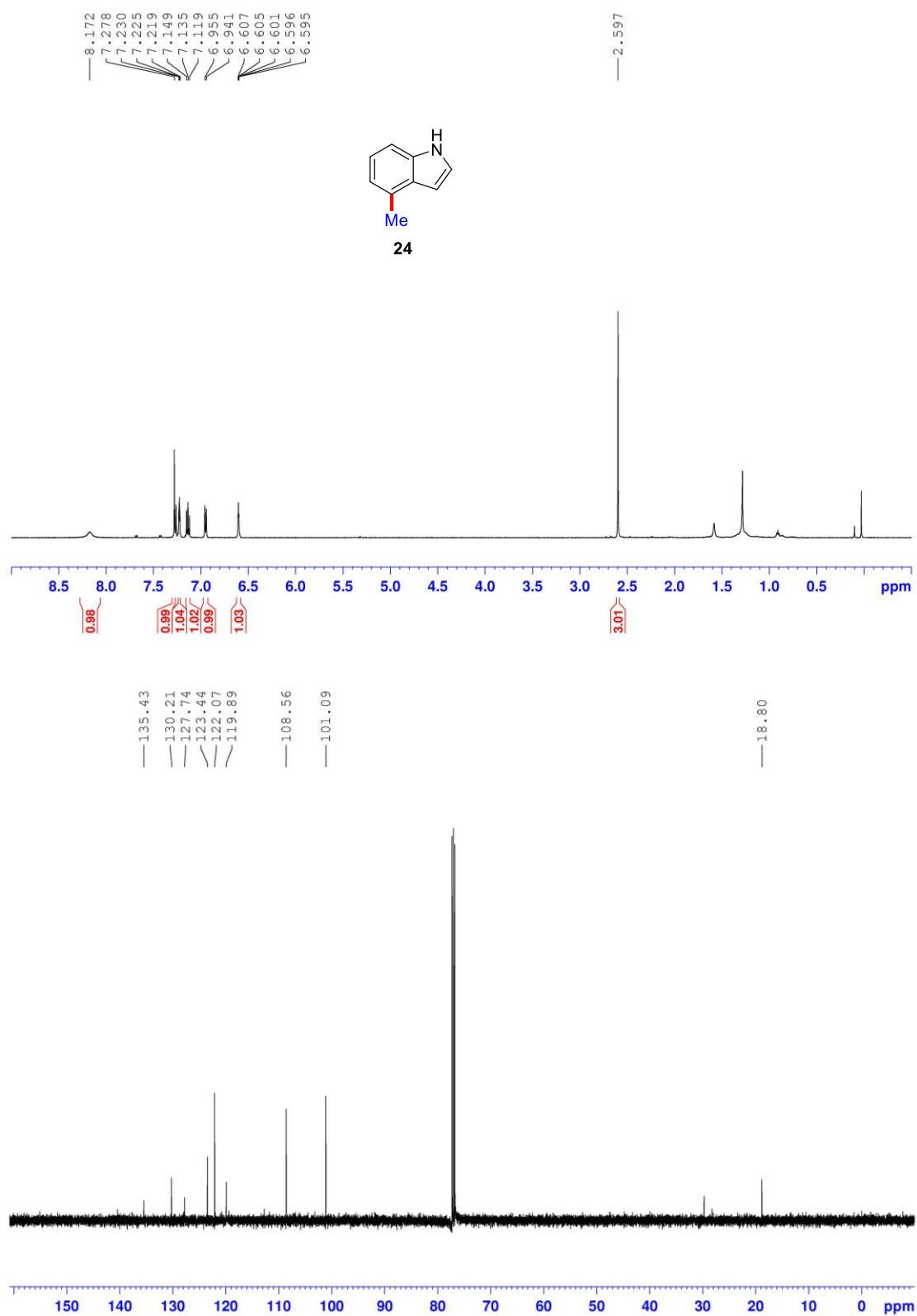


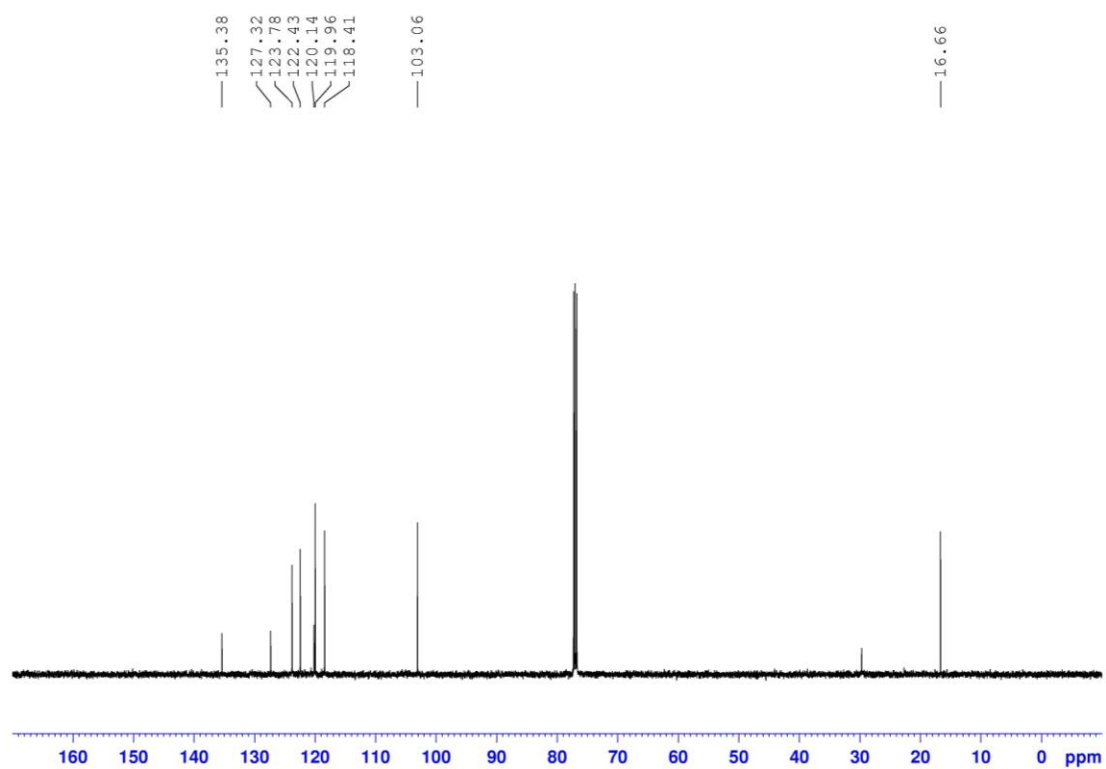
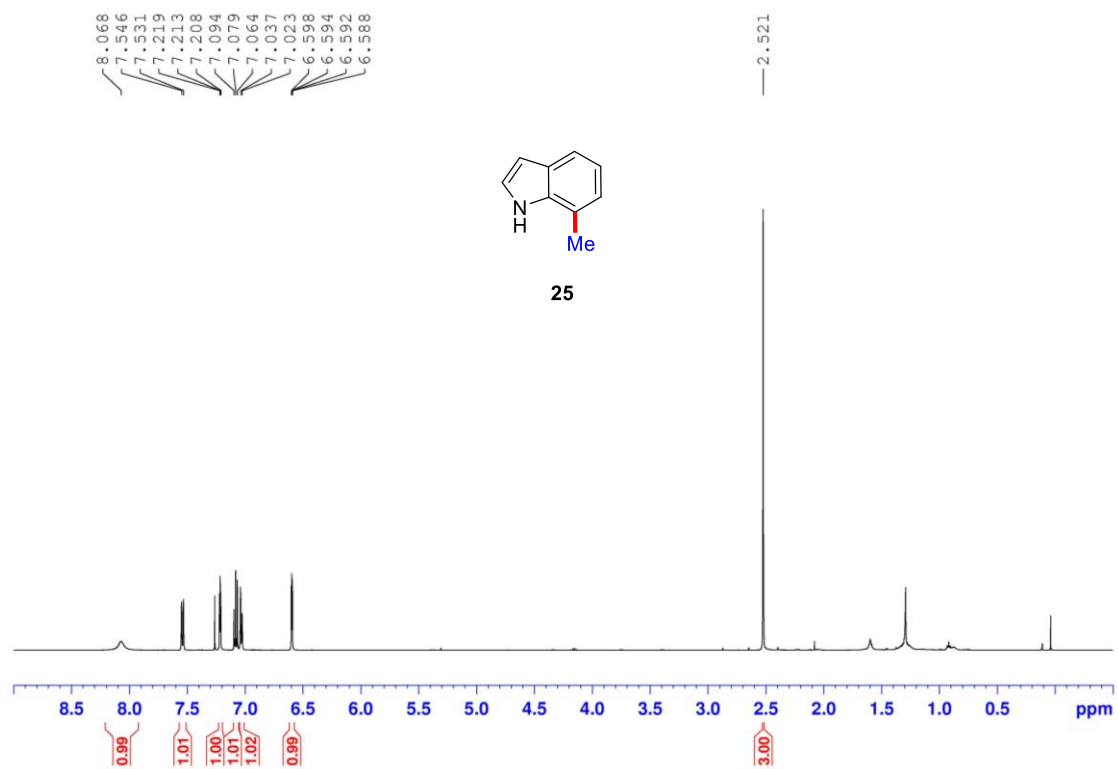


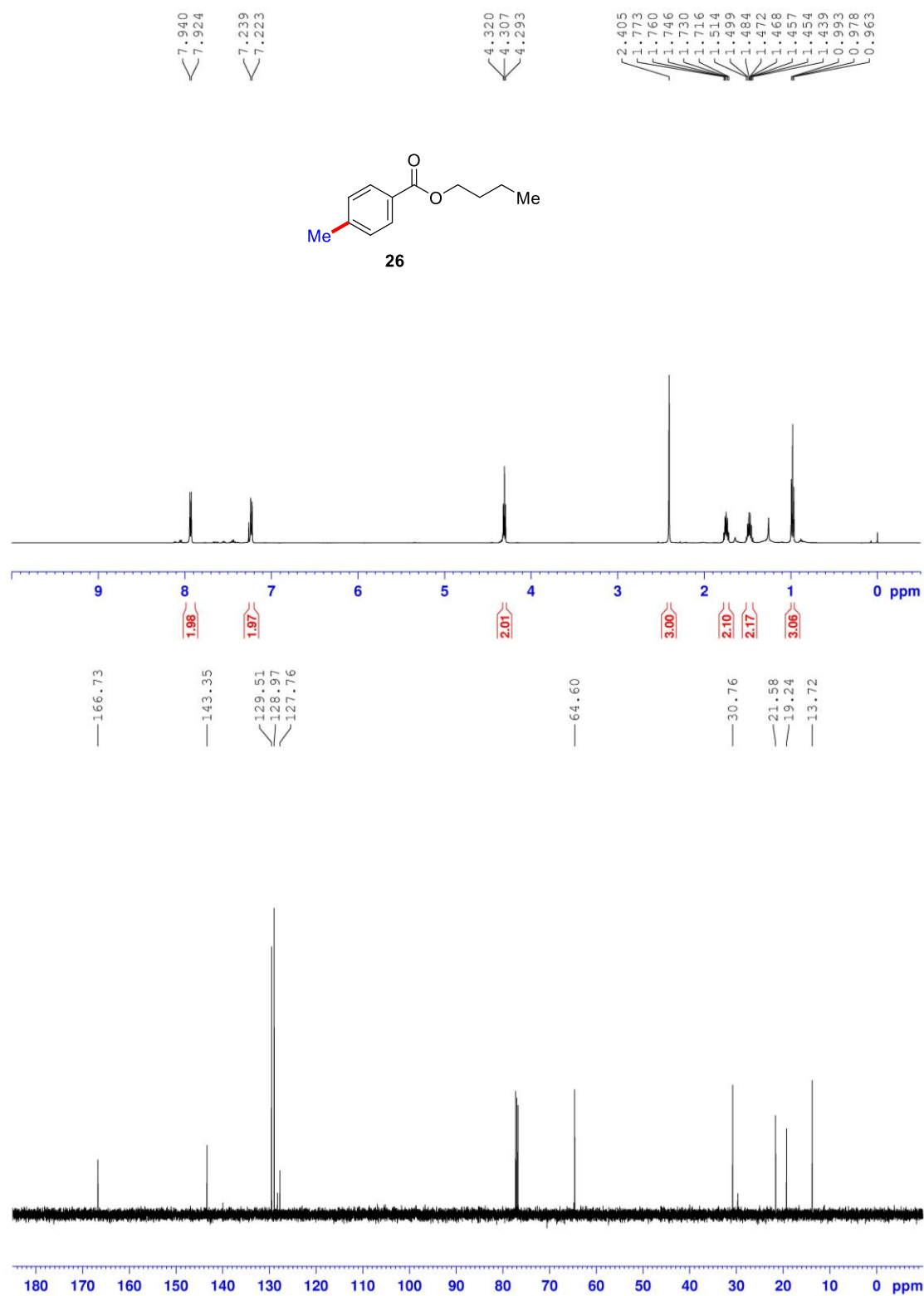


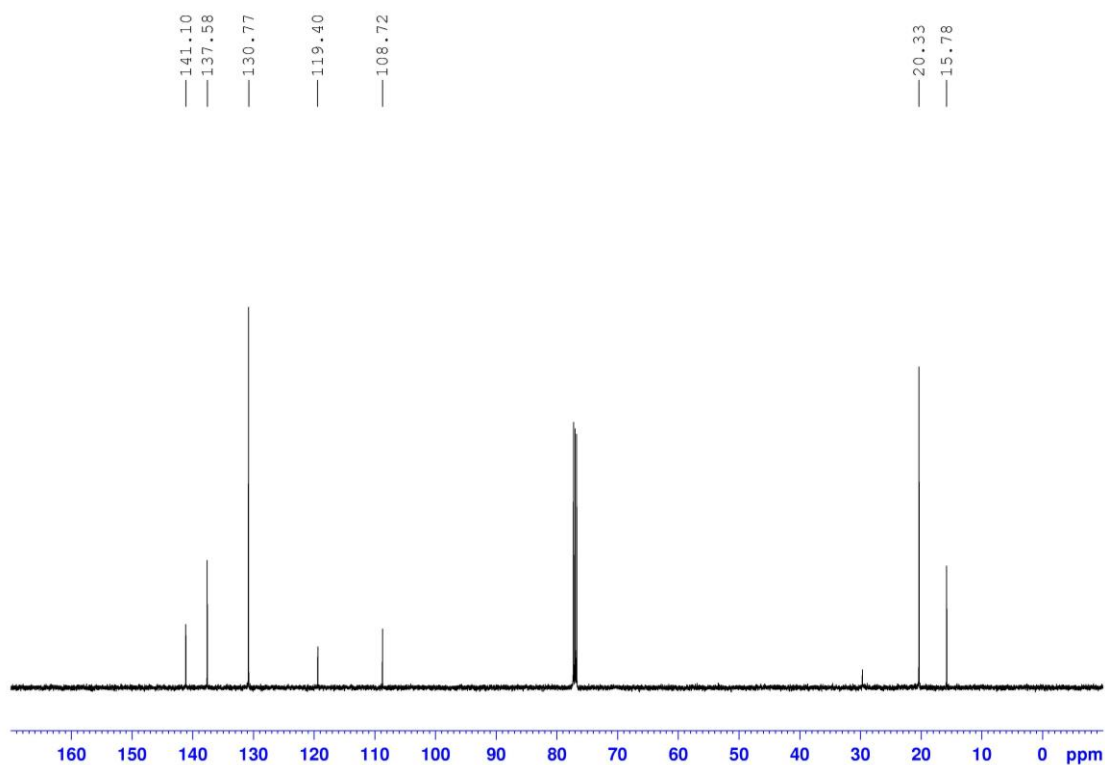
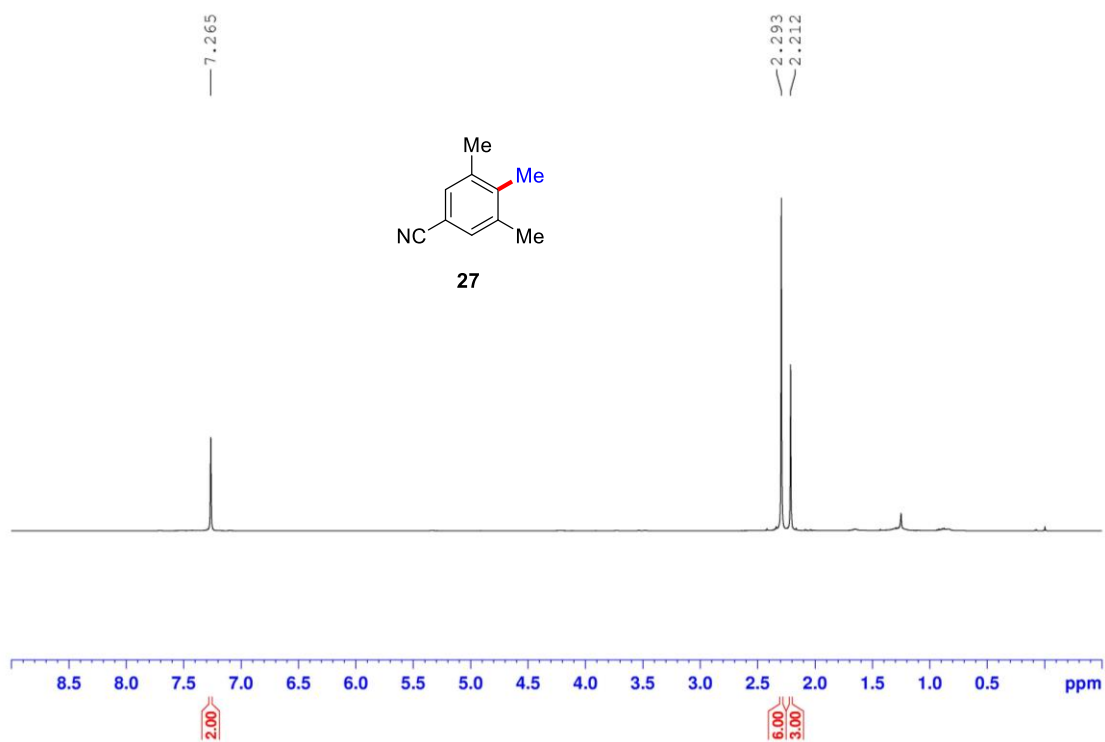


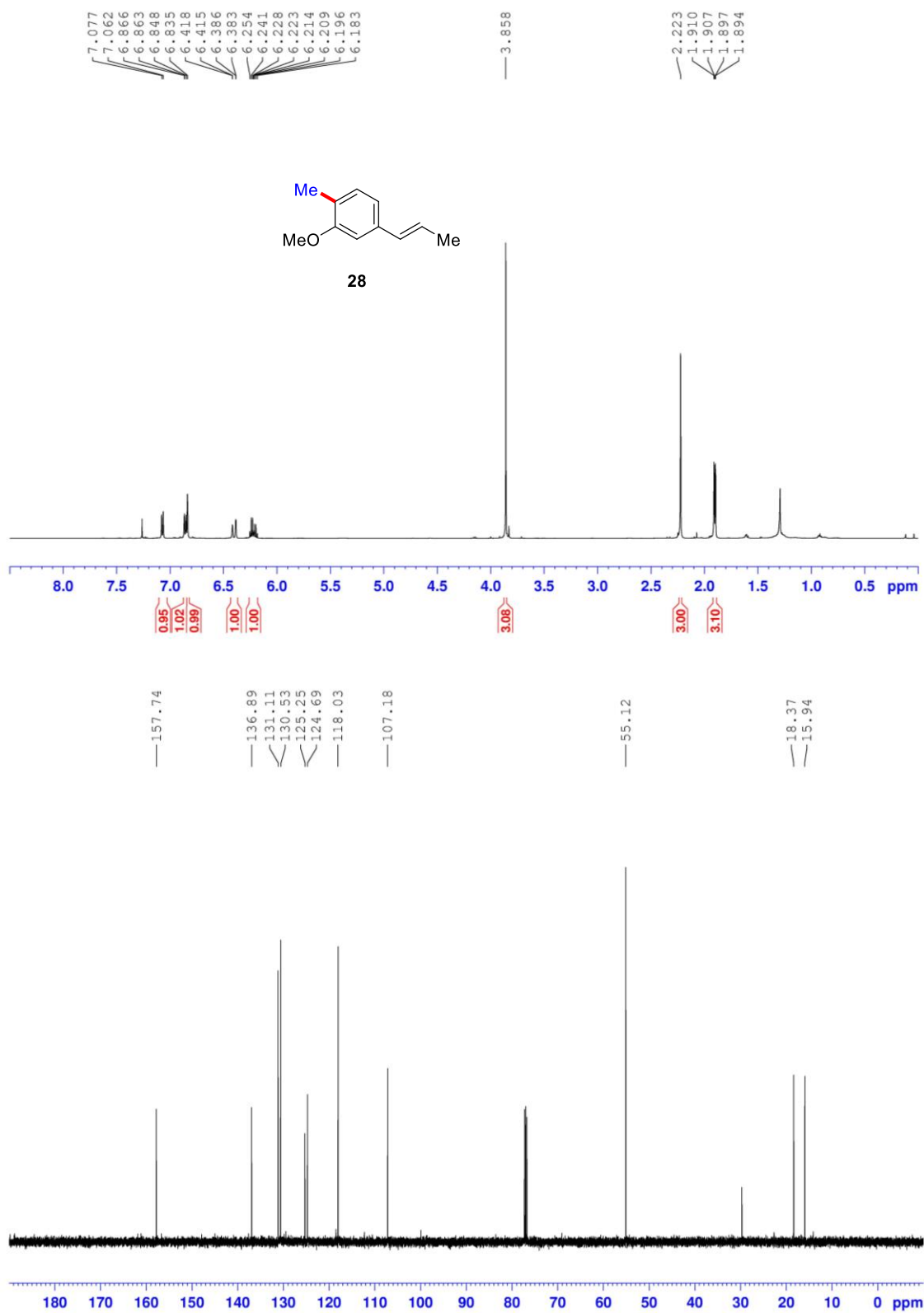


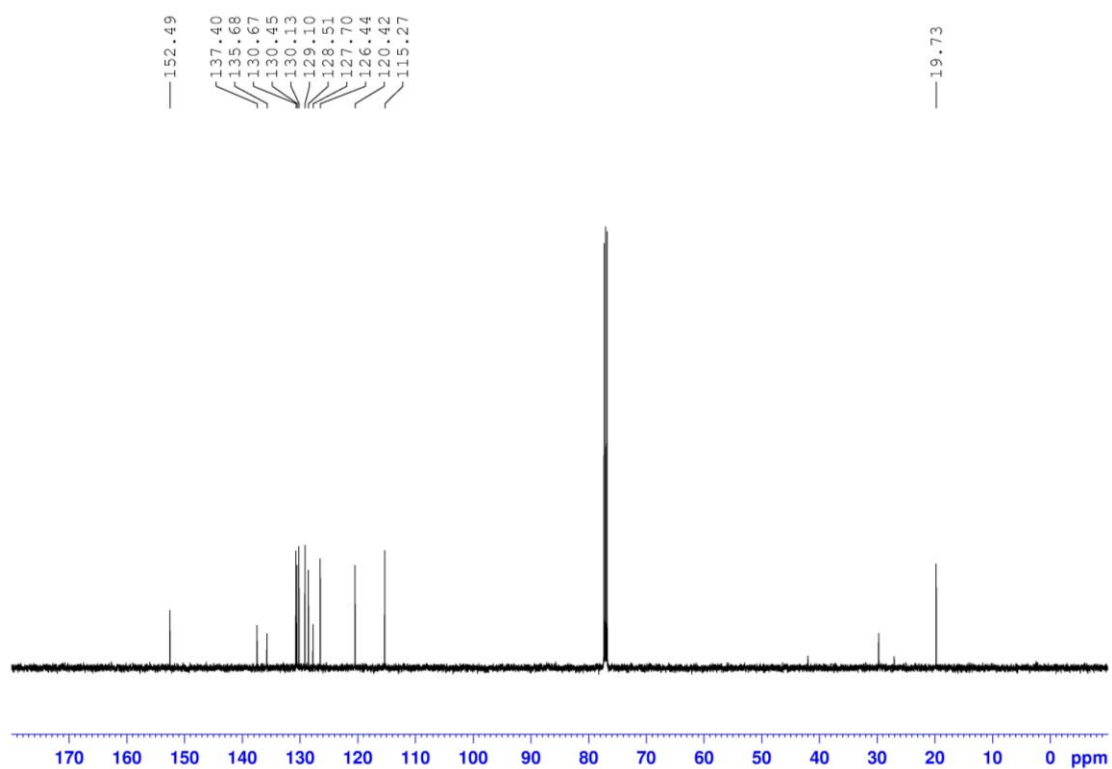
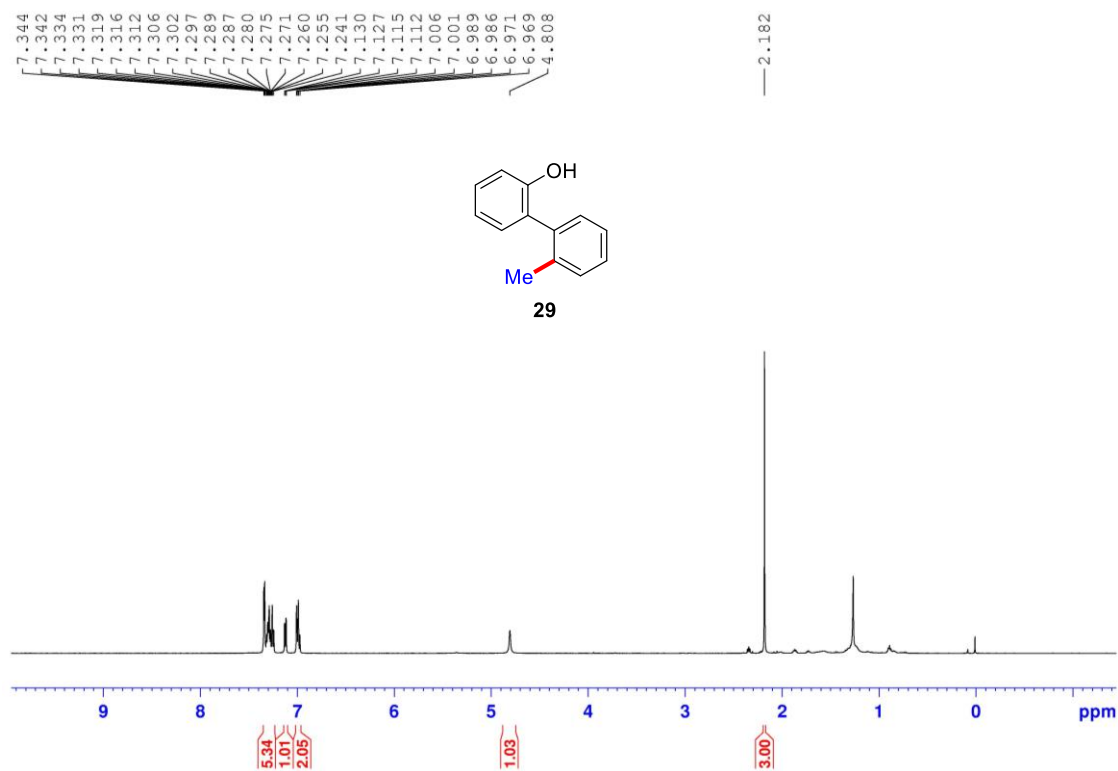


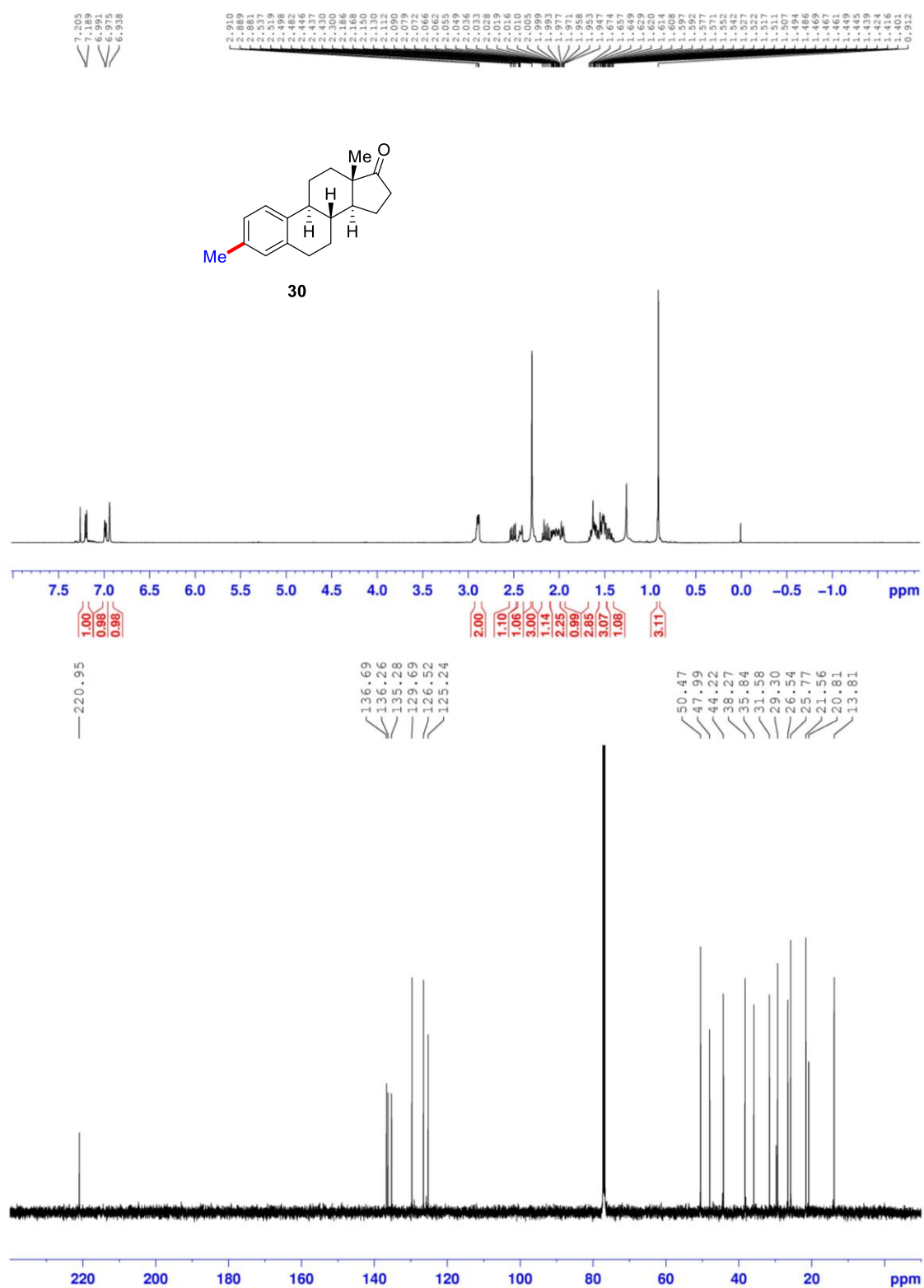


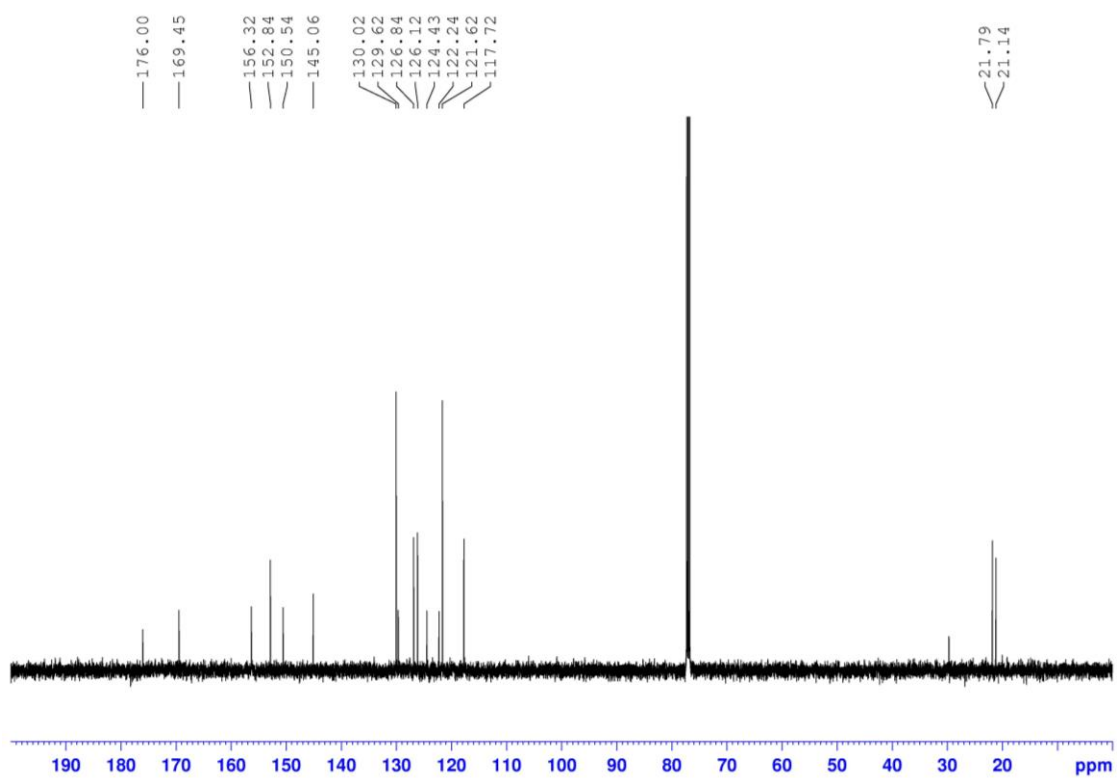
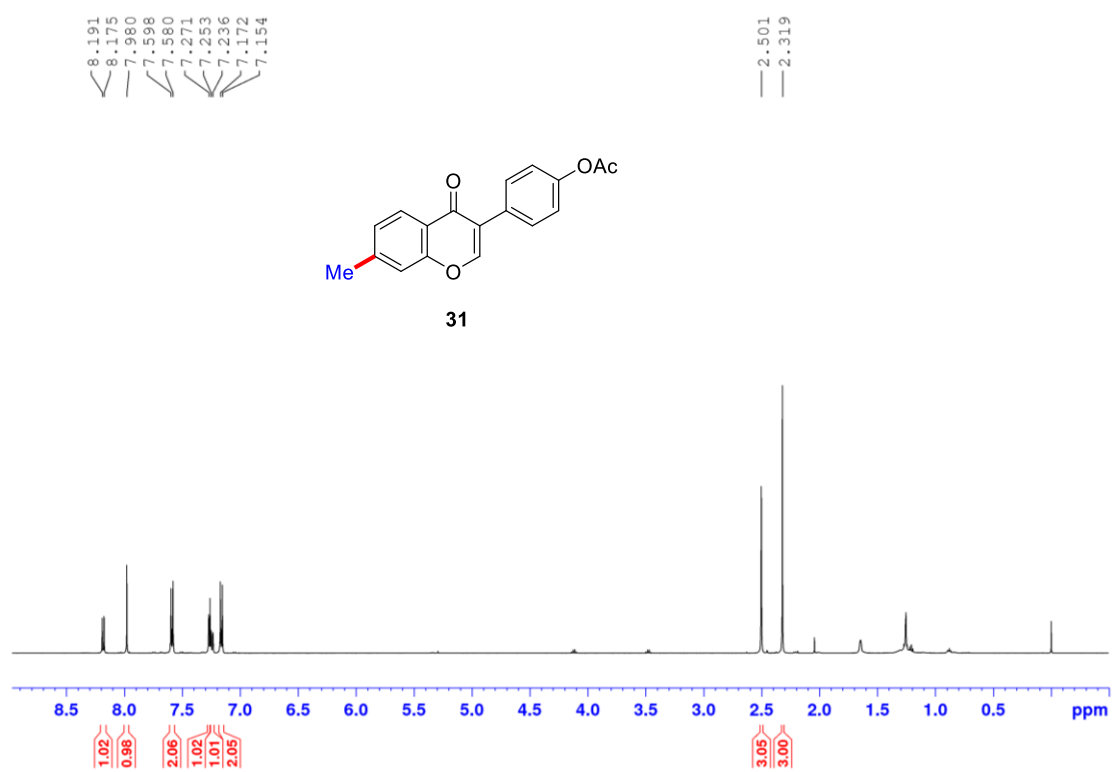


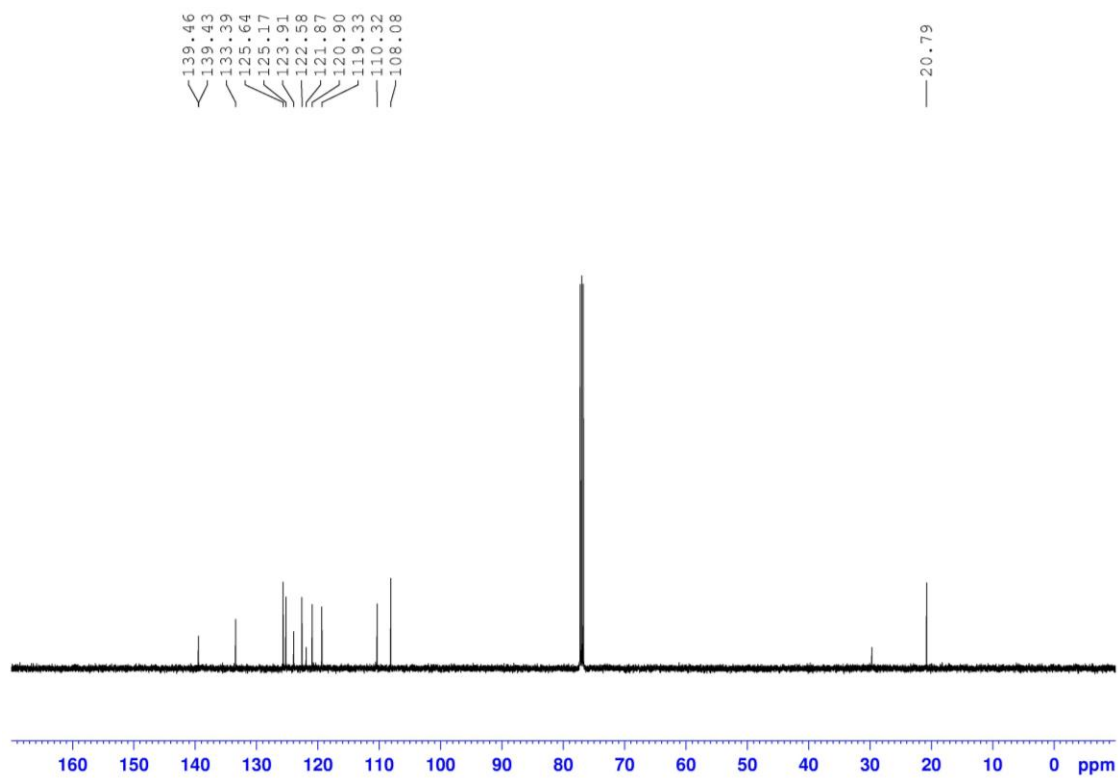
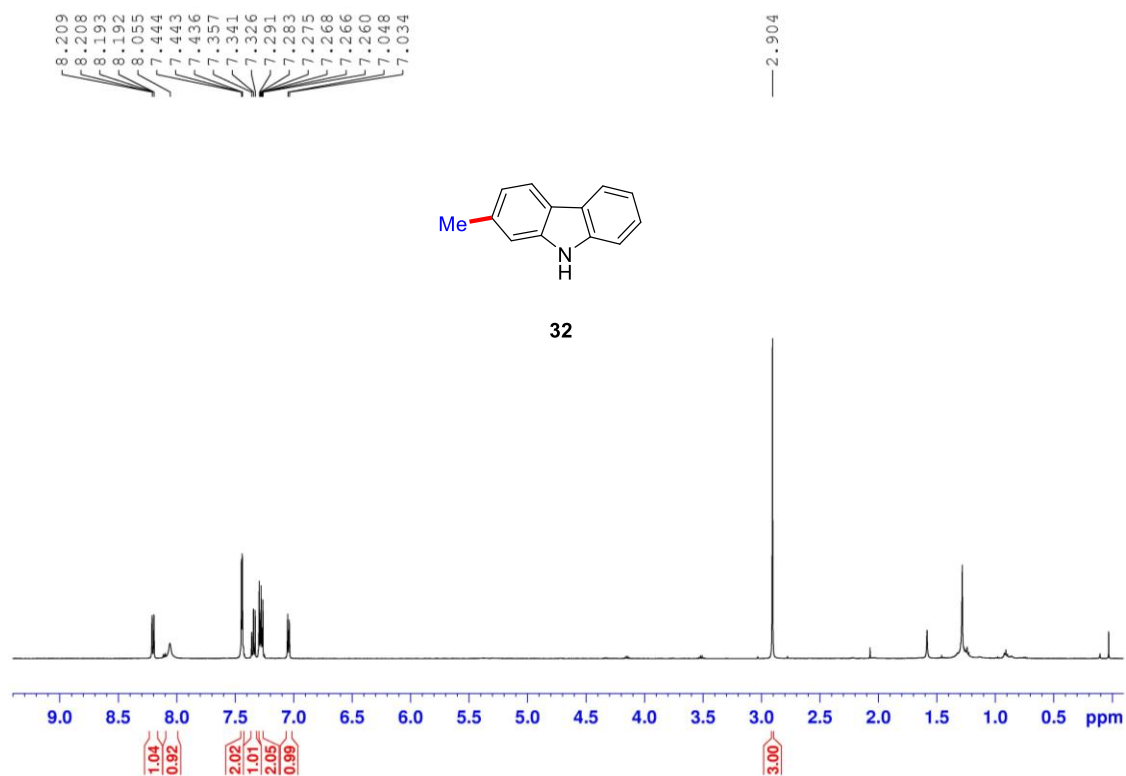












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