Heterogeneous & Homogeneous & Bio- & Nano-
CHEMCATCHEM
CATALYSIS

# Supporting Information

## Photocatalyst-free, Visible Light Driven, Gold Promoted Suzuki Synthesis of (Hetero)biaryls

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## General Methods

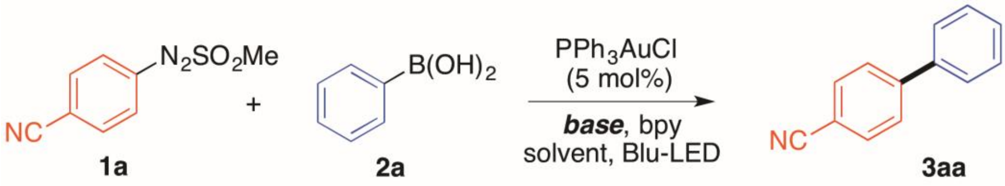
$^{1}$H and $^{13}$C NMR spectra were recorded on a 200 MHz or a 400 MHz spectrometer. Chemical shifts are reported in ppm from TMS with the solvent resonance as the internal standard (deuterochloroform: 7.27 ppm). Data are reported as follows: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, sext = sextet, sept = septet, p = pseudo, b = broad, m = multiplet), coupling constants (Hz). GC-MS spectra were taken by EI ionization at 70 eV on a Hewlett-Packard 5971 with GC injection. They are reported as: *m/z* (rel. intense). Chromatographic purification was done with 240-400 mesh silica gel. Melting points were measured using open glass capillaries in a Bibby Stuart Scientific Melting Point Apparatus SMP 3 and are calibrated by comparison with literature values (Aldrich). Compounds **1a-g** and **1'a** have been prepared by following a known procedure.[1] Boronic acids **2a-g** as well as the catalyst $PPh_3AuCl$ and the employed additives were commercially available and used as received.

**General procedure for the gold catalysed synthesis of (hetero)biaryls 3.** All the following reactions were set up in a 3mL Pyrex vial. To a solution (200 µL, $CH_3CN$:$CH_3OH$ = 3:1, reagent grade) of aryl azosulfone **1** (0.1 mmol, 0.5 M) was added the boronic acid **2** (0.2 mmol, 2 equiv.), NaOAc (0.2 mmol), $PPh_3AuCl$ (5 mol%) and bpy (20 mol%) in sequence. The resulting mixture was then degased via $N_2$-bubbling and the vial irradiated with a 7W or a 1W blue LED while stirring until the complete consumption of the starting substrate **1** (checked by TLC monitoring) the solvent was removed under vacuum and reaction crude purified via flash chromatography.

[1] I. Sapountzis, P. Knochel, *Angew. Chem. Int. Ed.* **2004**, *43*, 897-897; M. Malacarne, S. Protti, M. Fagnoni, *Adv. Synth. Cat. In press*, DOI 10.1002/adsc.201700619

**Optimization of the catalytic system:**

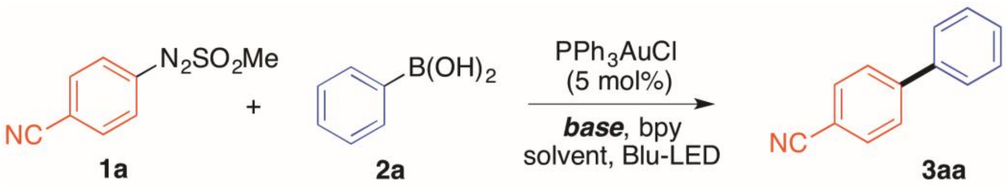
**Table S1: The base**




| Entry | *base* | **3aa** (%Yield)[a] |
|---|---|---|
| 1 | NaOAc | 51 |
| 2 | KOAc | 41 |
| 3 | CsOAc | 43 |
| 4 | $Na_2CO_3$ | 46 |
| 5 | *t*$BuCO_2Na$ | 39 |
| 6 | $NaHCO_3$ | 35 |
| 7 | $Na_2HPO_4$ | 35 |
| 8 | $Li_2CO_3$ | 28 |
| 9 | CsF | 20 |
| 10 | $K_2CO_3$ | 18 |
| 11 | $Cs_2CO_3$ | 11 |
| 12 | *t*BuONa | 0 |
| 13 | -- | 0 |
| 14[b] | TEA | 22 |

*Conditions*: **1a**:**2a**:base:bpy=1:2:2:0.2,rt, 7 W-blue LED, 600μL MeCN, overnight. [a] Isolated yields. [b] 200 μL MeCN.

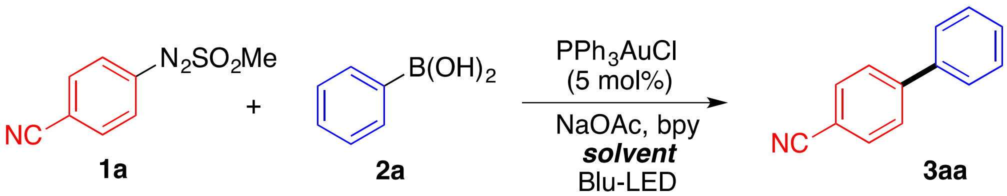
## Table S2: The concentration




| Entry | Base | *Conc. (mol/L)* | **3aa** (% Yield)[a] |
|---|---|---|---|
| 1 | $Na_2CO_3$ | 0.50 | 58 |
| 2 | $Na_2CO_3$ | 1.00 | 48 |
| 3 | $Na_2CO_3$ | 0.17 | 46 |
| 4 | $Na_2CO_3$ | 0.05 | 28 |
| 5 | NaOAc | 0.50 | 56 |
| 6 | NaOAc | 0.17 | 51 |
| 7 | NaOAc | 0.10 | 45 |
| 8 | *t*$BuCO_2Na$ | 0.50 | 48 |
| 9 | *t*$BuCO_2Na$ | 0.17 | 39 |

*Conditions*: **1a**:**2a**:base:bpy = 1:2:2:0.2, rt, 7 W blue-LED, MeCN, overnight. [a] Isolated yields.

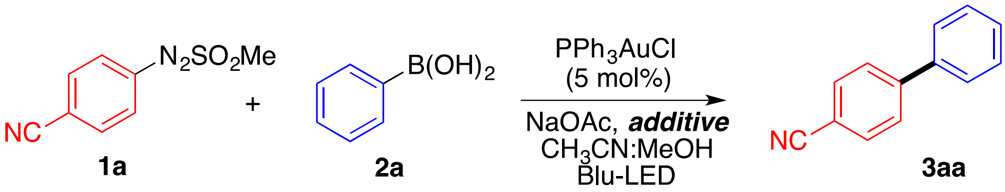
## Table S3: The solvent




| Entry | *Additive* | **3aa** (% Yield)[a] |
|---|---|---|
| 1 | $CH_3CN$/MeOH (3:1) | 61 |
| 2 | $CH_3CN$ | 56 |
| 3 | $CH_3CN/H_2O$ (20:1) | 57 |
| 4 | $CH_3CN/H_2O$ (3:1) | 28 |
| 5 | $CH_3CN$/*t*BuOH (3:1) | 39 |
| 6 | THF | 36 |
| 7 | DMF | 17 |

*Conditions*: **1a**:**2a**:NaOAc:bpy = 1:2:2:0.2, rt, 7 W blue-LED, solvent, overnight. [a] Isolated yields.

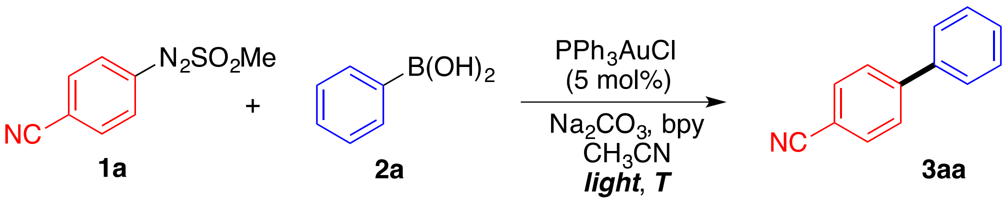
**Table S4: The additive**




| Entry | *additive* | *Loading (mol%)* | **3aa** (% Yield)[a] |
|---|---|---|---|
| 1 | bipyridine | 20 | 61 |
| 2 | 6,6'-$Br_2$-bipyridine | 20 | 53 |
| 3 | 4,4'-$MeO_2$-bipyridine | 20 | 50 |
| 4 | 4,4'-$Ph_2$-bipyridine | 20 | 45 |
| 5 | di-2-pyridyl-methanone | 20 | 41 |
| 6 | 6,6'-$Ph_2$-bipyridine | 20 | 36 |
| 7 | 1,10-phenantroline | 20 | 46 |
| 8 | 4,4'-*t*$Bu_2$-bipyridine | 20 | 36 |
| 9 | 4,4'-$Br_2$-bipyridine | 20 | 28 |
| 10 | 5,5'-$Me_2$-bipyridine | 20 | 17 |
| 11[b] | none | -- | 17 |
| 12 | TEMPO | 120 | 10 |

*Conditions*: **1a**:**2a**:base:bpy = 1:2:2:0.2, rt, 7 W blue-LED, MeCN:MeOH = 3:1, overnight. [a] Isolated yields. [b] Reaction carried out with Tos derivative **1a'**.

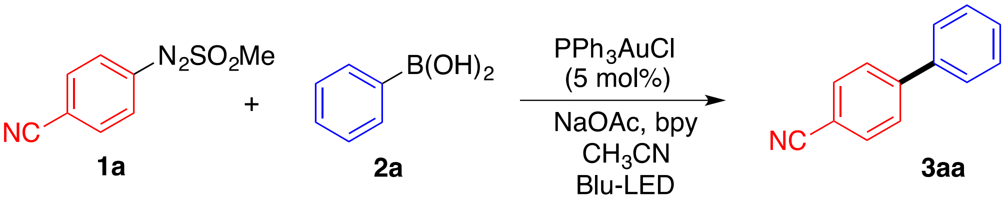
**Table S5: Light and temperature roles**




| Entry | *Light* | *T (°C)* | **3aa** (% Yield)[a] |
|---|---|---|---|
| 1 | 7 W Blue-LED | 25 | 46 |
| 2 | 7 W Blue -LED | 36 | 40 |
| 3 | 24 W Blue -LED | 43 | 36 |
| 4 | 7 W Blue -LED | 15 | 35 |
| 5 | 7 W Blue -LED | -7 | 26 |
| 6 | 7 W White-LED | 25 | 46 |
| 7 | none | 25 | 15 |

*Conditions*: **1a**:**2a**:base:bpy = 1:2:2:0.2, 600 µL $CH_3CN$, overnight. [a] Isolated yields.

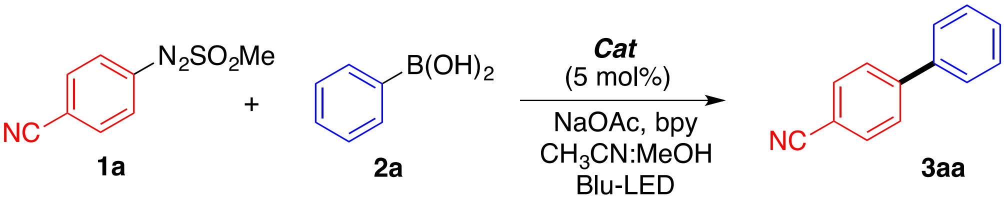
## Table S6: 1a:2a ratio




| **Entry** | **1a:2a** | **3aa** (% Yield)[a] |
|---|---|---|
| 1 | 1:2 | 36 |
| 2 | 2:1 | 46 |
| 3 | 4:1 | 32 |

*Conditions*: **1a**:**2a**:base:bpy = x:y:2:0.2, 600 μL $CH_3CN$, irradiated overnight. [a] Isolated yields.

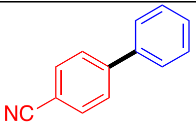
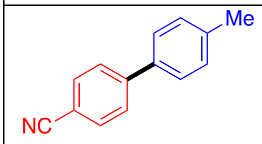
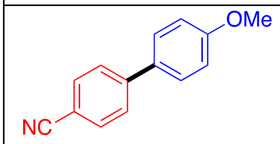
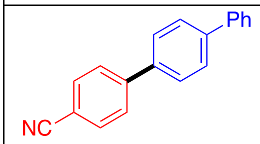
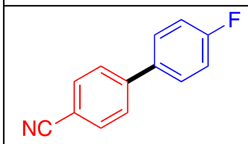
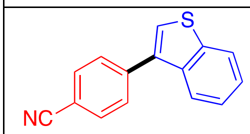
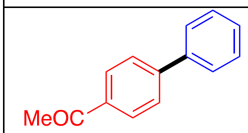
## Table S7: The gold complex



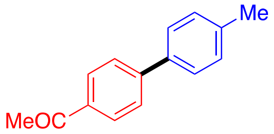
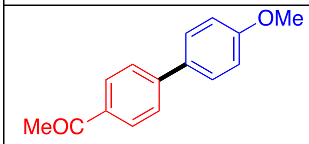
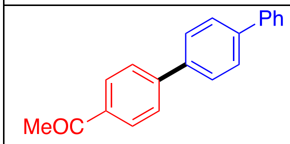
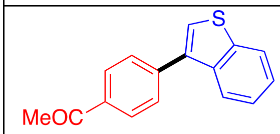
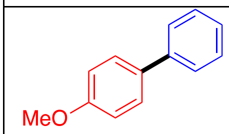
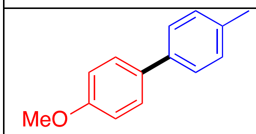
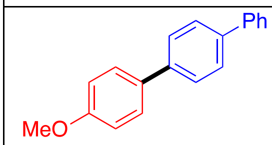
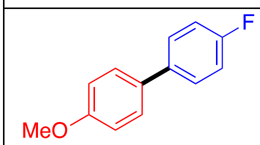
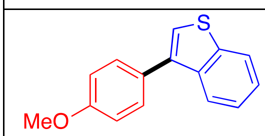

| **Entry** | ***Cat***(mol%) | **3aa** (% Yield)[a] |
|---|---|---|
| 1 | $PPh_3AuCl$ (5) | 61 (65)[b] |
| 2 | $PPh_3AuCl$ (20) | 53 |
| 3 | $PPh_3AuNTf_2$ (5) | 57 |
| 4 | $IPrAuNTf_2$ (5) | 50 |
| 5 | - | < 1 |

*Conditions*: **1a**:**2a**:base:bpy = 1:2:2:0.2, $CH_3CN$:MeOH (3:1, 0.5 M in **1a**), irradiated overnight. [a] Isolated yields. [b] Between brackets NMR-yield.

## Characterization of bi-aryls 3

| | |
|---|---|
|  | **3aa**.[2] Yield: 61% (reaction time = 16 h, 7 W Blue LED). Colourless solid. *c*Hex/EtOAc = 95:5, **MP**: 87-89 °C (lit. MP: 87 ºC ), **GC-MS**: 179 m/z, **$^1$H-NMR** (400 Hz, $CDCl_3$): δ = 7.41-7.45 (m, 1H), 7.48-7.50 (m, 2H), 7.60-7.62 (m, 2H), 7.68-7.75 (m, 4H) ppm.**$^{13}$C-NMR** (100 Hz, $CDCl_3$): δ = 110.9, 118.9, 127.2(2C), 127.7(2C), 128.6, 129.1(2C), 132.6(2C), 139.1, 145.6 ppm. 4,4'-dicyanobiphenyl (**3a'**) was also isolated in 20% yield as the byproduct. **3a'**[3] **GC-MS**: 204 m/z. **$^1$H-NMR** (400 Hz, $CDCl_3$): δ = 7.69 (d, *J* = 8.0 Hz, 4H),7.78 (d, *J* = 8.0 Hz, 4H) ppm. |
|  | **3ab**.[4] Yield: 45%(reaction time = 16 h, 7 W Blue LED). Colourless solid. *c*Hex/EtOAc = 95:5, **MP**: 107-108 °C (lit. MP: 109-110 °C), **GC-MS**: 193 m/z, **$^1$H-NMR** (400 Hz, $CDCl_3$): δ = 2.43 (s, 3H), 7.29 (d, *J* = 7.6 Hz, 2H), 7.50 (d, *J* = 8.0 Hz, 2H), 7.65-7.71 (m, 4H) ppm. |
|  | **3ac**.[2] Yield: 45% (reaction time = 16 h, 7 W Blue LED).Colourless solid. *c*Hex/EtOAc = 95:5; **MP**: 102-105 °C (lit. MP: 104 °C), **GC-MS**: 179 m/z, **$^1$H-NMR** (400 Hz, $CDCl_3$): δ = 3.88 (s, 3H), 7.01 (d, *J* = 8.8 Hz, 2H), 7.57 (d, *J* = 8.8 Hz, 2H), 7.64 (d, *J* = 8.0 Hz, 2H), 7.70 (d, *J* = 8.0 Hz, 2H) ppm. |
|  | **3ad**.[5] Yield: 55% (reaction time = 16 h, 7 W Blue LED). Colourless solid. *c*Hex/EtOAc = 95:5; **MP**: 188-191 °C (lit. MP: 188-190 ºC), **GC-MS**: 255 m/z, **$^1$H-NMR** (400 Hz, $CDCl_3$): δ = 7.38 (t, *J* = 8.0 Hz, 1H), 7.46 (t, *J* = 7.6 Hz, 2H), 7.62-7.73 (m, 10H), ppm. |
|  | **3ae**.[6]Yield: 37% (reaction time = 16 h, 7 W Blue LED). Colourless solid. *c*Hex/EtOAc = 95:5; **MP**: 115-117 °C (lit. MP: 116-118); **GC-MS**: 197 m/z; $^1$H-NMR (400 Hz, $CDCl_3$): 7.17 (t, *J* = 8.7 Hz, 1H), 7.59-7.54 (m, 1H) 7.66-7.62 (m, 1H), 7.76-7.69 (m, 1H). **$^{19}$F-NMR** (377 Hz, $CDCl_3$): δ = -113.2 (m, 1F) ppm. |
|  | **3af**.[7] Yield: 40% (reaction time = 16 h, 7 W Blue LED). Pale red oil. *c*Hex/EtOAc = 95:5; **GC-MS**: 235 m/z; **$^1$H-NMR**(400 Hz, $CDCl_3$): δ = 7.41-7.46 (m, 2H), 7.49 (s, 1H), 7.69-7.72 (m, 2H), 7.75-7.80 (m, 2H), 7.84-7.88 (m, 1H), 7.92-7.96 (m, 1H) ppm. |
|  | **3ba**.[8] Yield: 45% (reaction time = 16 h, 1 W Blue LED). Colourless solid. *c*Hex/EtOAc = 95:5; **MP**: 110-111 °C (lit. MP:109-110 °C); **GC-MS**: 196 m/z; **$^1$H-NMR** (400 Hz, $CDCl_3$): δ = 2.66 (s, 3H) 7.41 (d, *J* = 7.2 Hz, 1H), 7.47-7.50 (m, 2H), 7.63-7.66 (m, 2H),7.69-7.71 (m, 2H), 8.00-8.06 (m, 2H) ppm. |

[2] M. Amatore, C. Gosmini, *Angew.Chem. Int. Ed.* **2008**, *47*, 2089-2092.
[3]G. Cahiez, C. Chaboche, F. Mahuteau-Betzer, M. Ahr, *Org. Lett.* **2005**, *7*, 1943-1946.
[4] Y.-X., Luan, T. Zhang, W.-W. Yao, K. Lu, L.-Y. Kong, M.-C. Ye, *J. Am. Chem. Soc.* **2017**, *139*, 1786-1789.
[5] D. Qiu, H, Meng, L. Jin, S. Wang, S.-B. Tang, X. Wang, F.-Y. Mo, Y. Zhang, J.-B. Wang, *Angew.Chem. Int. Ed.* **2013**, *44*, 11581-11584.
[6] S. Bernhardt, G. Manolikakes, T. Kunz, P. Knochel, *Angew. Chem. Int. Ed.* **2011**, *50,* 9205-9209.
[7] K. Yuan, H. Doucet, *Chem. Sci.*, **2013**, *5*, 392-396.
[8] I. J. S. Fairlamb, A. R. Kapdi, A. F. Lee, *Org. Lett.* **2004**,*6*, 4435-4438.

| | |
|---|---|
|  | **3bb**.[9] Yield: 31% (reaction time = 40 h, 1 W Blue LED). White solid. *c*Hex/EtOAc = 93:7; **MP**: 116-117 °C (lit. MP: 116-118 °C); **GC-MS**: 210 m/z; **$^1$H-NMR** (400 Hz, $CDCl_3$): δ = 2.39 (s, 3H), 2.63 (s, 3H), 7.24 (d, *J* = 7.8 Hz, 2H), 7.51 (d, *J* = 8,0 Hz, 2H), 7.65 (d, *J* = 7.8 Hz, 2H), 8.00 (d, *J* = 8.0 Hz, 2H) ppm. |
|  | **3bc**.[6] Yield: 31% (reaction time = 16 h, 1 W Blue LED).White solid. *c*Hex/EtOAc = 9:1; **MP**: 155-157 °C (lit. MP: 156-157 °C); **GC-MS**: 226 m/z; **$^1$H-NMR** (400 Hz, $CDCl_3$): δ = 2.64 (s, 3H), 3.88 (s, 3H), 7.00 (dd, *J* = 2.0, 6.8 Hz, 2H), 7.58 (dd, *J* = 2.0, 6.8 Hz, 2H), 7.65 (dd, *J* = 2.0, 8.0 Hz, 2H), 8.01 (dd, *J* = 2.0, 8.0 Hz, 2H) ppm. |
|  | **3bd**.[10] Yield: 35% (by $^1$H-NMR, as a mixture with *p*-quarter phenyl, reaction time = 16 h, 7 W Blue LED). White solid, MP: 234-237 °C (lit. MP: 237-238 °C), *c*Hex/EtOAc = 95:5; **GC-MS**: 272 m/z; **$^1$H-NMR** (400, Hz, $CDCl_3$): δ= 2.66 (s, 3H), 7.39 (d, *J* = 7.4 Hz, 1H), 7.48 (t, *J* = 7.4 Hz, 2H), 7.65-7.68 (m, 2H),7.71-7.73 (m, 4H), 7.73-7.76 (m, 2H), 8.06 (d, *J* = 8.4 Hz, 2H) ppm. |
|  | **3bf**.[11] Yield: 48% (reaction time = 16 h, 7 W Blue LED). Red solid . *c*Hex/EtOAc = 9:1; **MP**: 76-78 °C (lit. MP: 77-78°C); **GC-MS**: 252 m/z; **$^1$H-NMR** (400 Hz, $CDCl_3$): δ = 2.68 (s, 3 H), 7.42-7.44 (m, 2H), 7.51 (s, 1H), 7.71 (d, *J* = 8.0 Hz, 2H), 7.91-7.96 (m, 2H), 8.06 (d, 2H, *J* = 8.4 Hz) ppm. |
|  | **3ca**.[9] Yield: 40% (reaction time = 16 h, 1 W Blue LED). White solid, MP: 77-79 °C (lit. MP: 77-78°C). *c*Hex/EtOAc = 98:2; **GC-MS**: 184 m/z. **$^1$H-NMR** (400 Hz, $CDCl_3$): δ = 3.87 (s, 3H), 7.00 (d, *J* = 8.8 Hz, 2H), 7.32 (d, *J* = 7.4 Hz, 1H), 7.43 (t, *J* = 8.0 Hz, 2H), 7.53-7.58 (m, 4H) ppm. |
|  | **3cb**.[4] Yield: 28% (reaction time = 16 h, 1 W Blue LED). Light yellow solid. *c*Hex/DCM = 97:3; **MP**: 107-109 °C (lit. MP: 107-108°C); **GC-MS**: 198 m/z; **$^1$H-NMR** (400 Hz, $CDCl_3$): δ = 2.39 (s, 3H), 3.86 (s, 3H), 6.97 (d, *J* = 8.8 Hz, 2H), 7.23 (d, *J* = 7.8 Hz, 2H), 7.45 (d, *J* = 7.8 Hz. 2 H), 7.51 (d, *J* = 8.8 Hz, 2H) ppm. |
|  | **3cd**.[12] Yield: 38% (reaction time = 16 h, 1 W Blue LED). White solid. *c*Hex/DCM = 9:1; **MP**: 222-224 °C (lit. MP: 221-224°C); **GC-MS**: 260 m/z;**$^1$H-NMR** (400 Hz, $CDCl_3$): δ = 3.88 (s, 3H), 7.01 (d, *J* = 9.2 Hz, 2H), 7.36 (t, *J* = 7.4 Hz, 1H), 7.47 (t, *J* = 7.6 Hz, 2H),7.59 (d, *J* = 9.2 Hz, 2H), 7.63-7.75 (m, 6H) ppm. |
|  | **3ce**.[13] Yield: 55% (reaction time = 16 h, 1 W Blue LED). Pale yellow solid. *c*Hex/EtOAc = 30:1; **MP**: 91-22 °C (lit. MP: 90-91°C); **GC-MS**: 202 m/z; **$^1$H-NMR** (400 Hz, $CDCl_3$): δ = 3.86 (s, 3H), 6.98 (d, *J* = 8.8 Hz, 2H), 7.11 (d, *J* = 8.4 Hz, 2H), 7.47-7.52 (m, 2H) ppm. **$^{19}$F-NMR** (377 Hz, $CDCl_3$): δ = -116.9 (m, 1F) ppm. |
|  | **3cf**.[11] Yield: 44% (reaction time = 16 h, 1 W Blue LED). Coulorless oil. *c*Hex/EtOAc = 9:1; **GC-MS:** 240 m/z; **$^1$H-NMR** (400 Hz, $CDCl_3$): δ = 3.89 (s, 3H), 7.03 (d, *J* = 6.4 Hz, 2H), 7.34 (s, 1H), 7.38-7.41 (m, 2H), 7.51 (d, *J* = 6.4 Hz, 2H),7.89-7.94 (m, 2H) |

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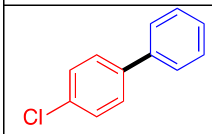
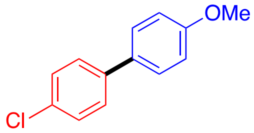
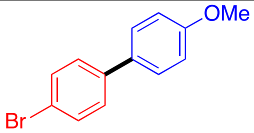
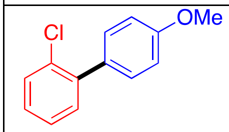
| | |
|---|---|
| | ppm. |
|  | **3da**.[14] Yield: 40% (reaction time = 16 h, 1 W Blue LED). Orange solid. *c*Hex/DCM = 96:4; **MP:** 78-80 °C (lit. MP: 78-79 °C); **GC-MS**: 208 m/z; **$^1$H-NMR** (400 Hz, $CDCl_3$): δ = 3.85 (s, 3H), 6.96-6.99 (m, 2H), 7.36-7.39 (m, 2H), 7.46-7.51 (m, 4H) ppm. |
|  | **3dc**.[15] Yield: 44% (reaction time = 16 h, 1 W Blue LED). Orange solid. *c*Hex/EtOAc = 80:3; **MP:** 108-110 °C (lit. MP: 111.1-111.3 °C); **GC-MS**: 218 m/z; **$^1$H-NMR** (400 Hz, $CDCl_3$): δ = 3.62 (s, 3H), 6.98 (d, J = 9.2 Hz, 2H), 7.38 (d, *J* = 9.2 Hz, 2H), 7.47-7.51 (m, 4H) ppm. |
|  | **3ec**.[16] Yield: 39% (reaction time = 19 h, 1 W Blue LED). White solid. *c*Hex/EtOAc = 95:5; **MP:** 137-138 °C (lit. MP: 136-138 °C); **GC-MS**: 262 m/z; **$^1$H-NMR** (400 Hz, $CDCl_3$): δ = 3.86 (s, 3H), 6.98 (d, *J* = 8.8 Hz, 2H), 7.42 (d, *J* = 8.8 Hz, 2H), 7.49 (d, *J* = 8.8 Hz, 2H), 7.54 (d, *J* = 8.6 Hz, 2H) ppm. |
|  | **3fc**.[17] Yield: 28% (reaction time = 16 h, 1 W Blue LED). Red oil. *n*Hex/$Et_2O$ = 100:1; **GC-MS**: 218 m/z; **$^1$H-NMR** (400 Hz, $CDCl_3$): δ = 3.87 (s, 3H), 6.98 (d, *J* = 9.2 Hz, 2H), 7.28-7.36 (m, 3H), 7.40 (d, *J* = 9.2 Hz, 2H), 7.46-7.48 (m, 1H) ppm. |

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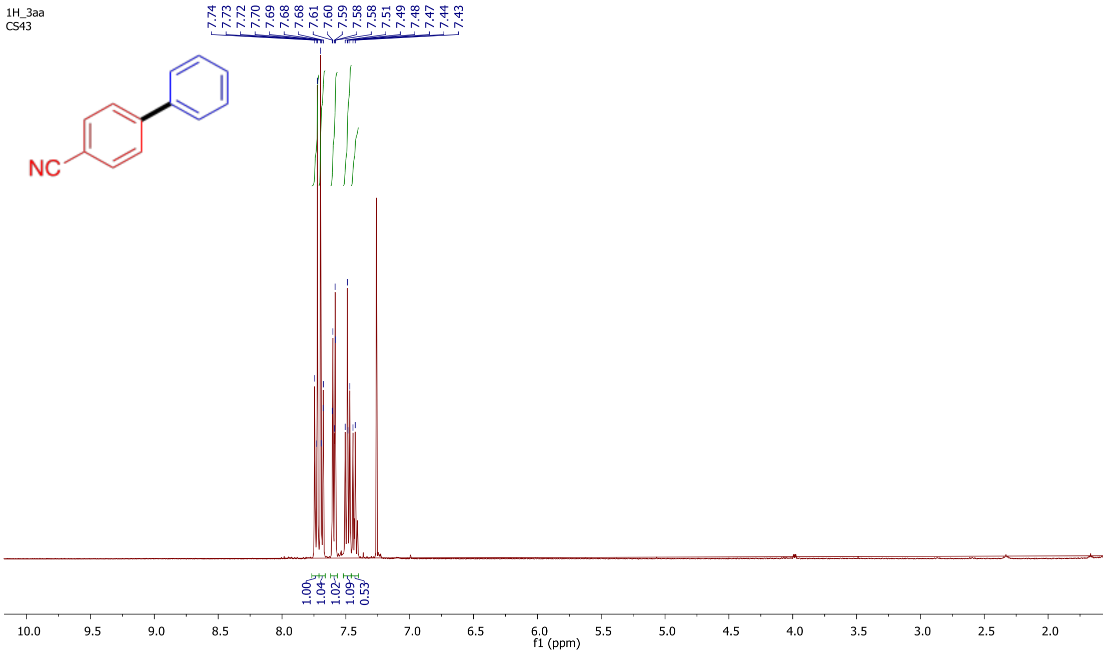
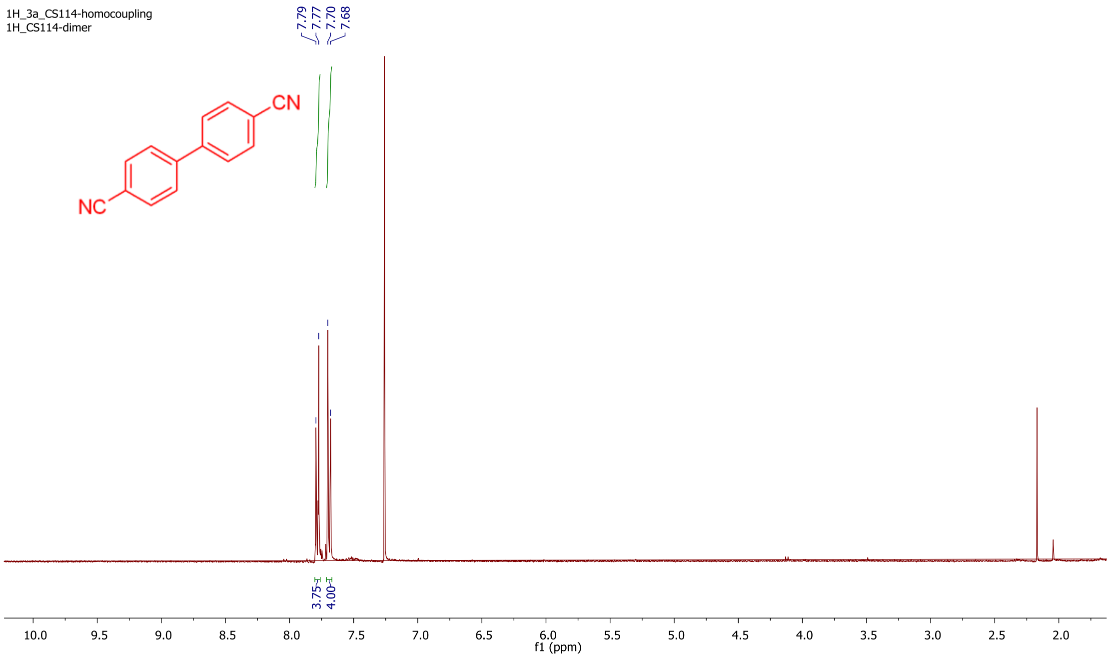
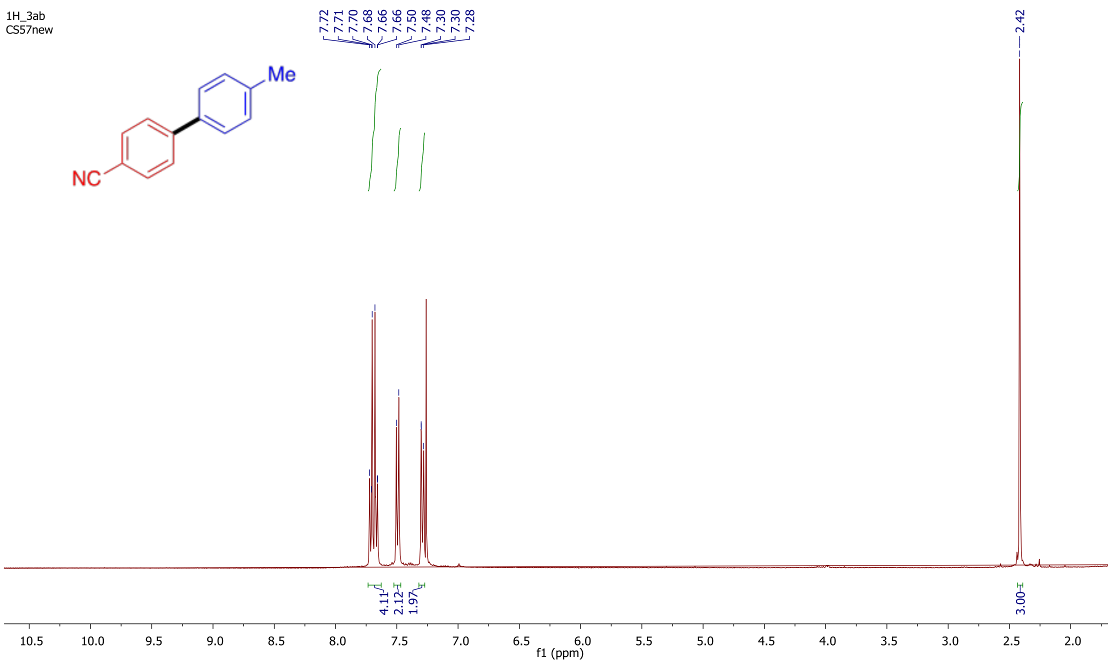
**[1]H NMR spectra of compounds 3.**

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7.66
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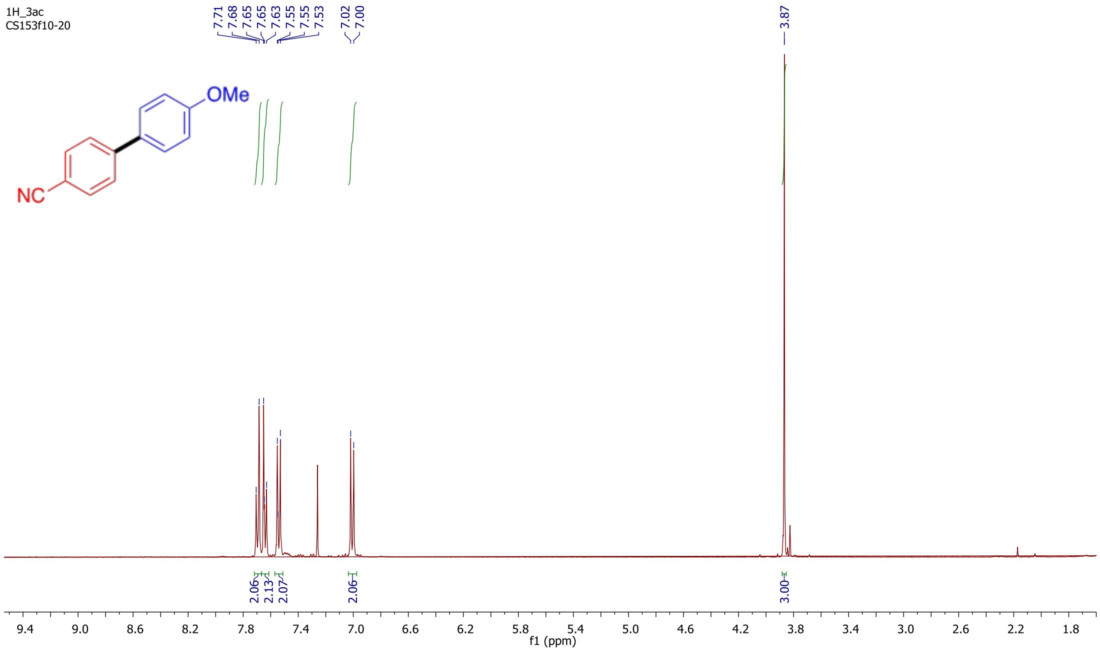
1.97
3.00
f1 (ppm)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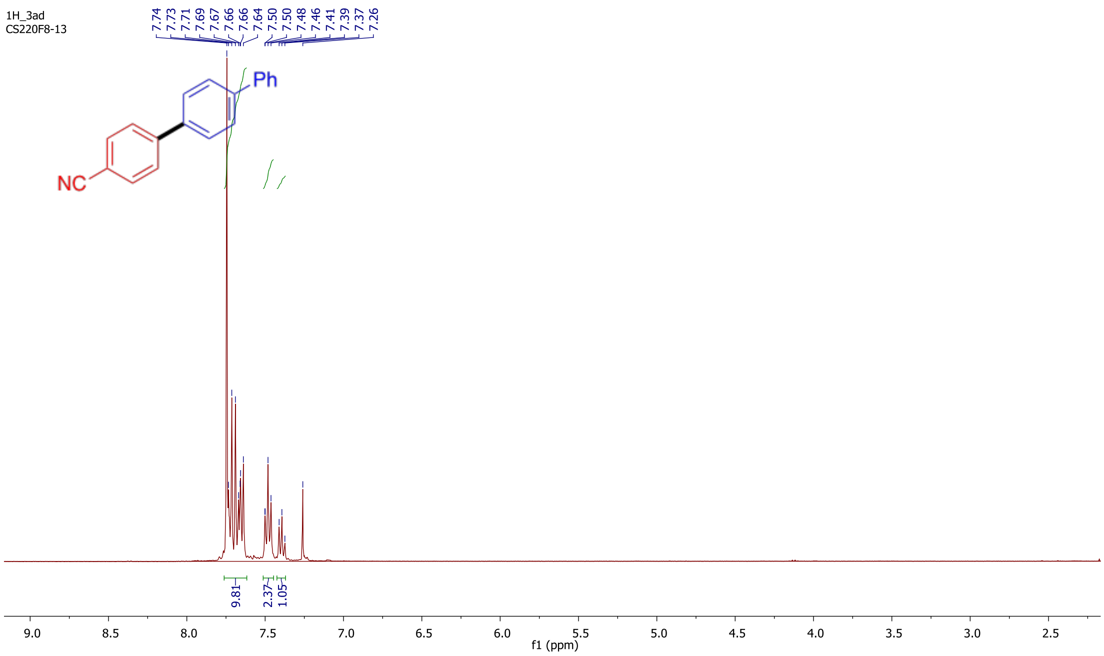
7.00
3.87
2.06
2.13
2.07
2.06
3.00
f1 (ppm)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7.48
7.46
7.41
7.39
7.37
7.26
Ph
NC
9.81
2.37
1.05
9.0
8.5
8.0
7.5
7.0
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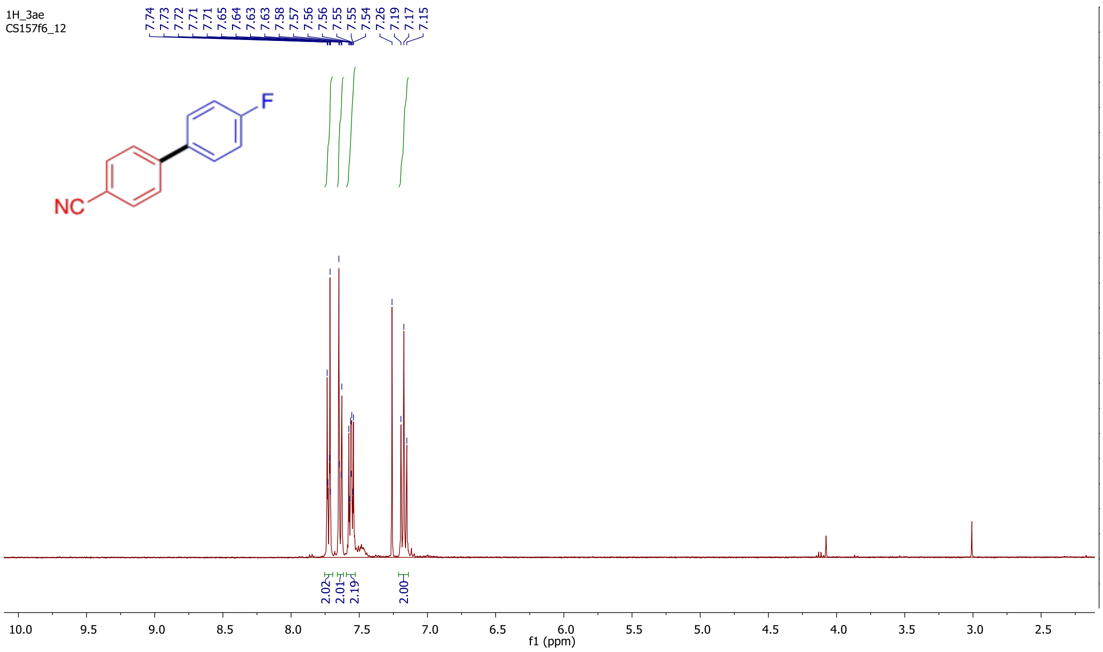
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
f1 (ppm)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7.64
7.63
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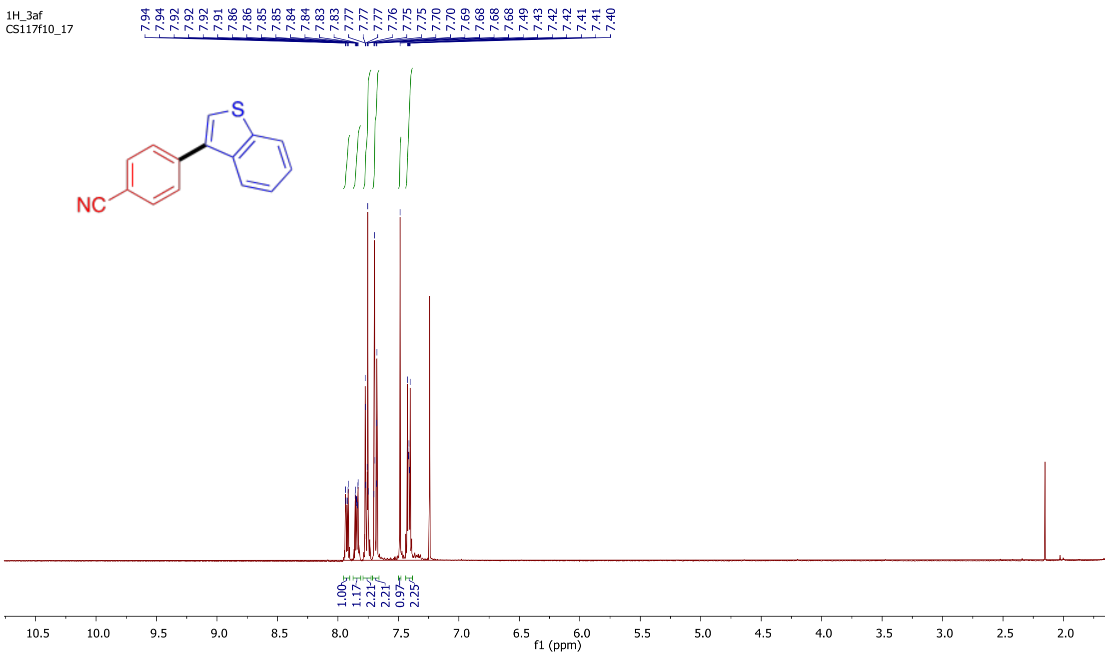
7.57
7.56
7.55
7.55
7.54
7.26
7.19
7.17
7.15
F
NC
2.02
2.01
2.19
2.00
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
f1 (ppm)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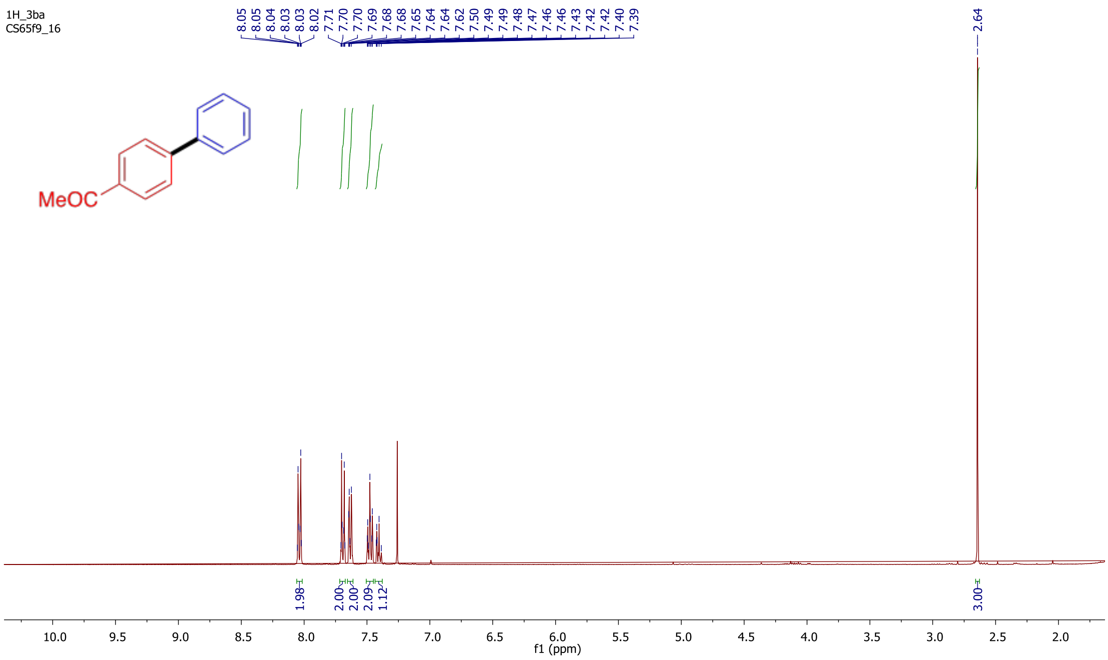
S
NC
1.00 1.17 2.21 2.21 0.97 2.25
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0
f1 (ppm)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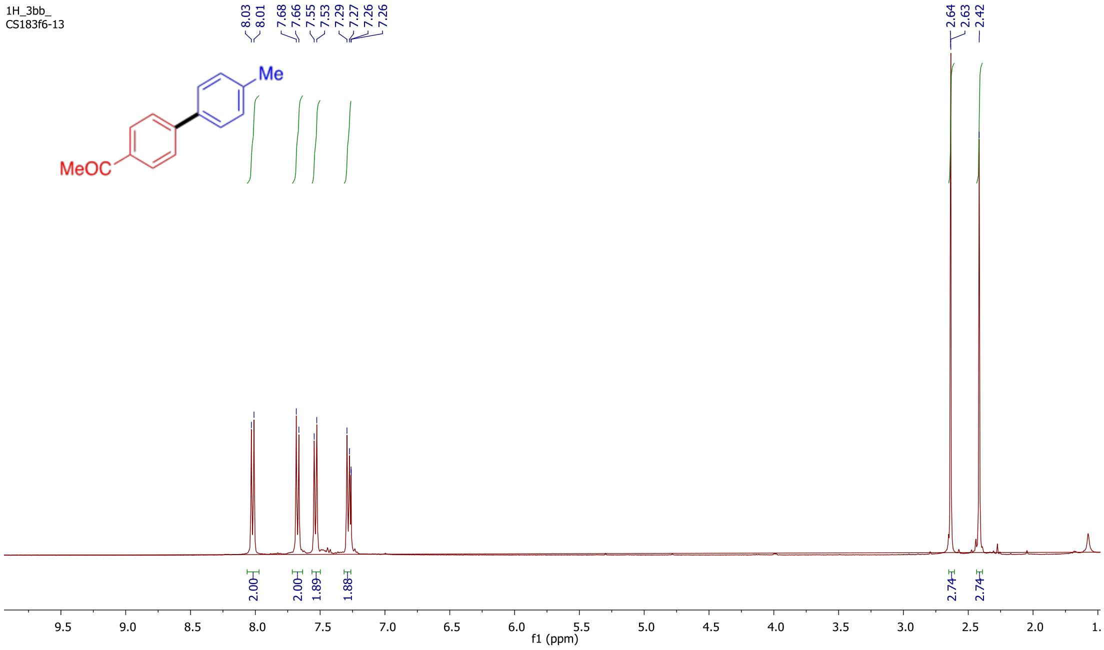
2.64
MeOC
1.98 2.00 2.00 2.09 1.12 3.00
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0
f1 (ppm)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7.55
7.53
7.29
7.27
7.26
7.26
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2.63
2.42
2.00
2.00
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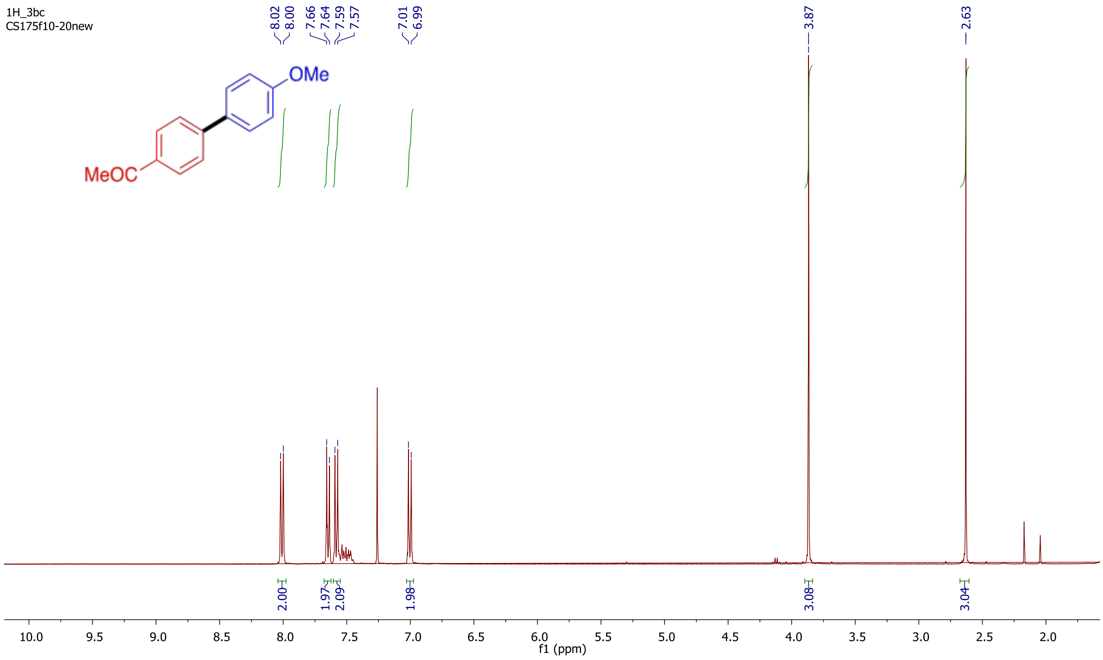
2.74
2.74
f1 (ppm)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8.00
7.66
7.64
7.59
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7.01
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3.87
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2.00
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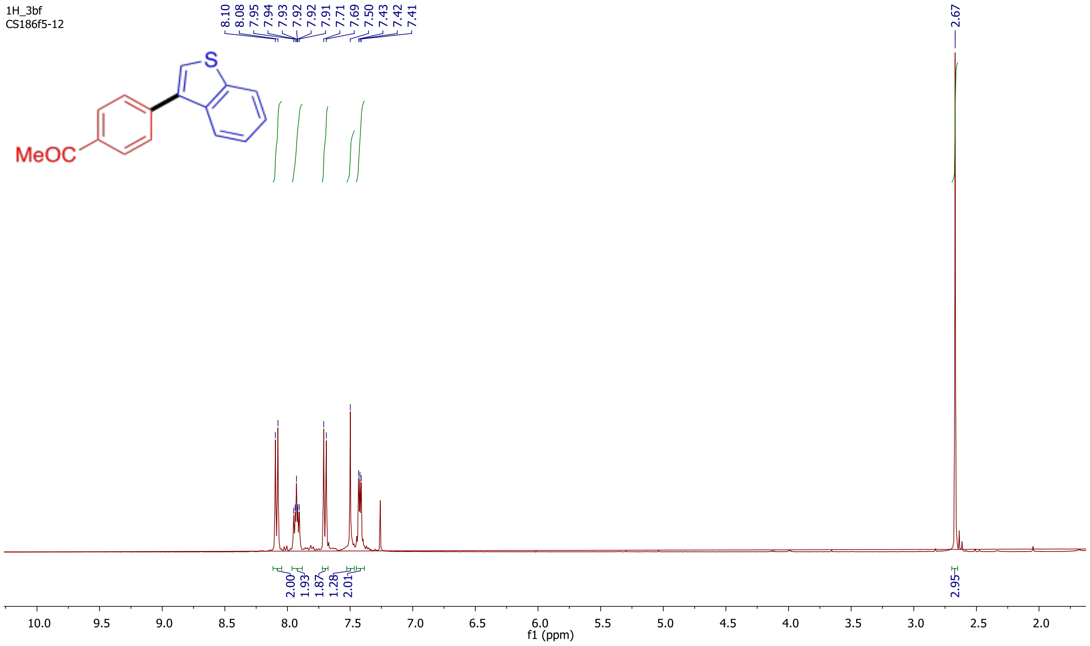
2.09
1.98
3.08
3.04
f1 (ppm)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7.69
7.50
7.43
7.42
7.41
2.67
S
MeOC
2.00
1.93
1.87
1.28
2.01
2.95
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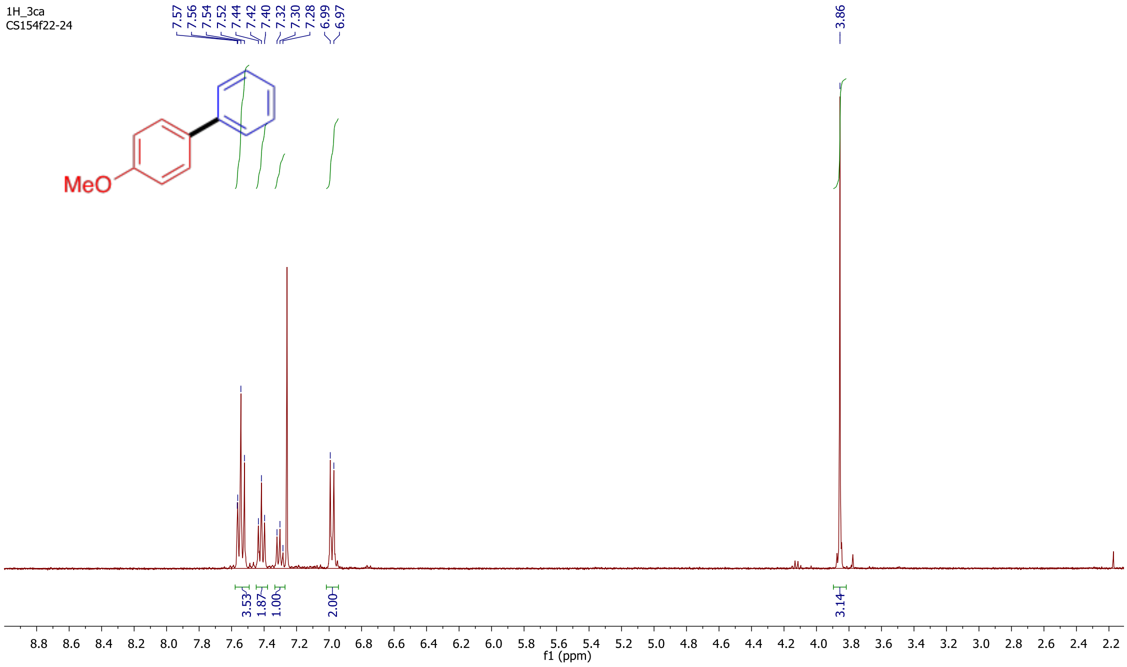
f1 (ppm)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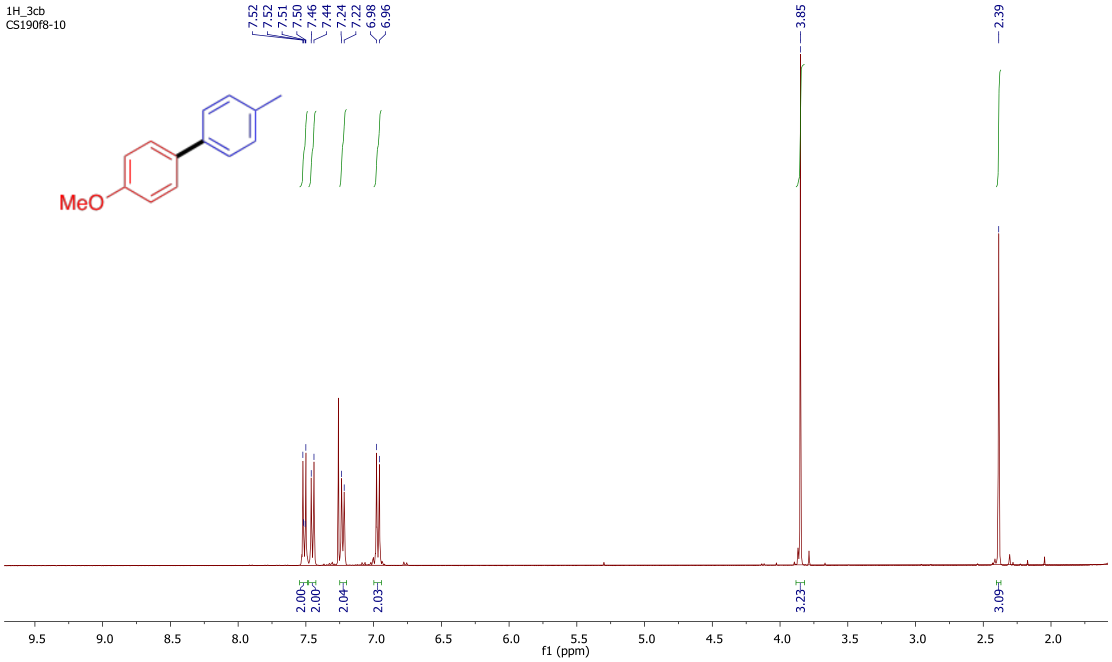
7.28
6.99
6.97
3.86
MeO
3.53
1.87
1.00
2.00
3.14
8.8 8.6 8.4 8.2 8.0 7.8 7.6 7.4 7.2 7.0 6.8 6.6 6.4 6.2 6.0 5.8 5.6 5.4 5.2 5.0 4.8 4.6 4.4 4.2 4.0 3.8 3.6 3.4 3.2 3.0 2.8 2.6 2.4 2.2
f1 (ppm)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2.03
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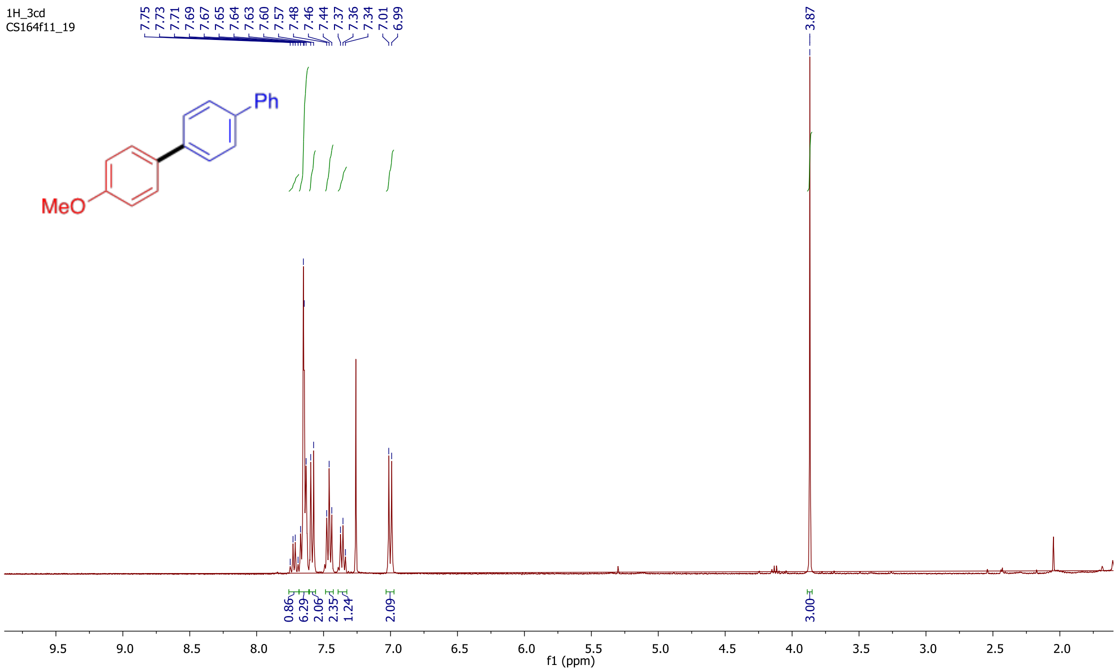
3.09
f1 (ppm)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7.46
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7.36
7.34
7.01
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Ph
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2.35
1.24
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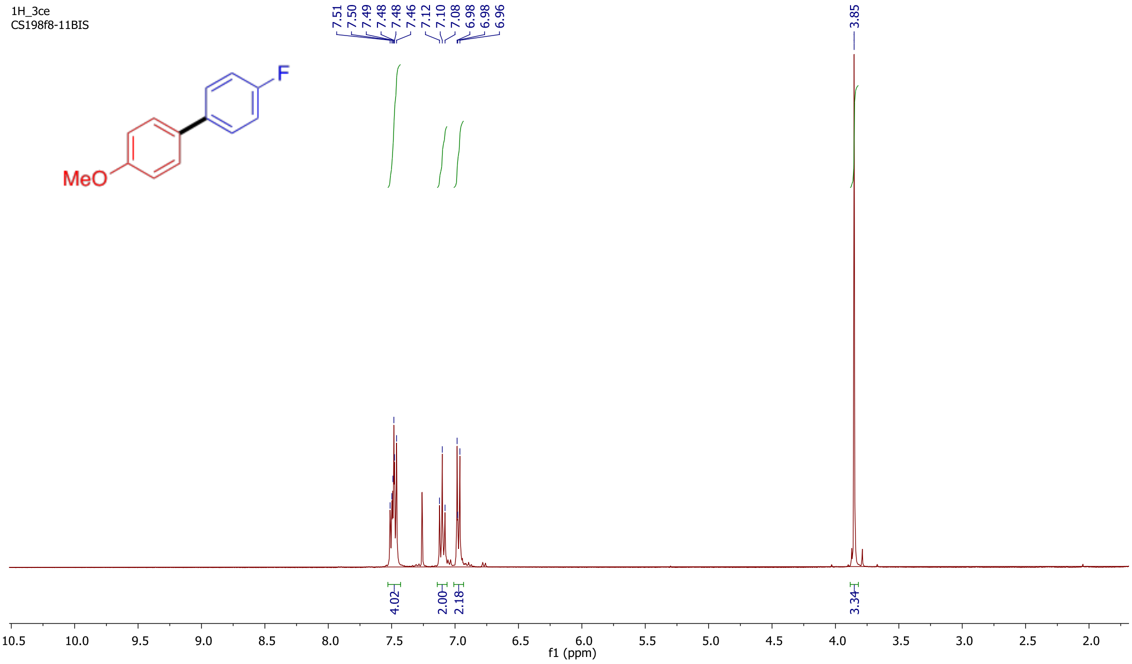
3.00
f1 (ppm)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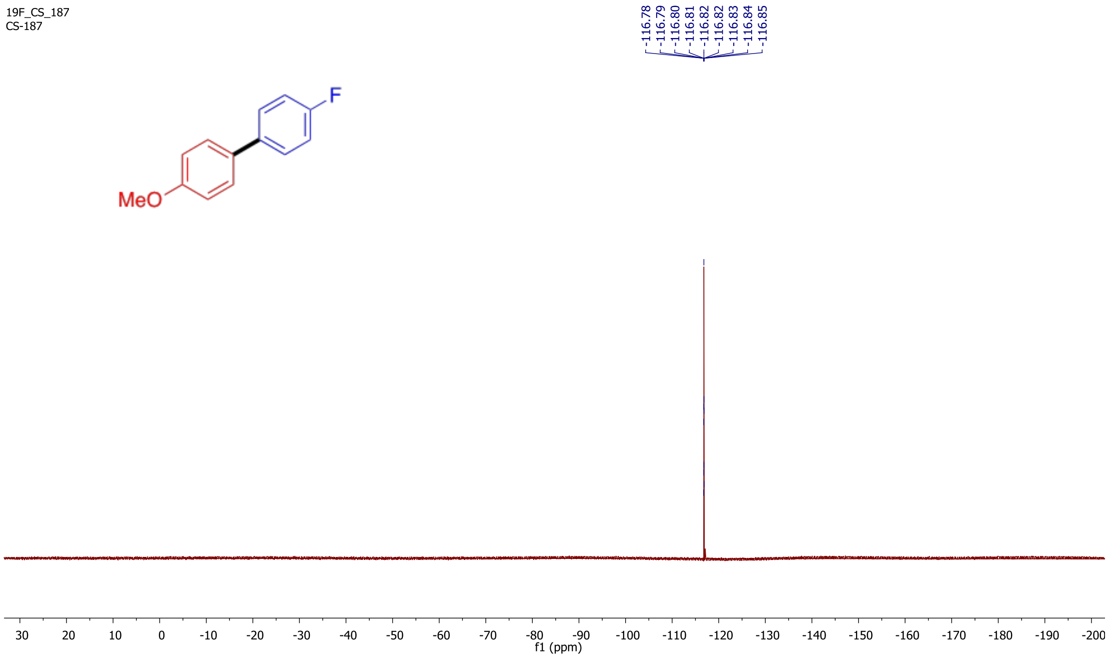
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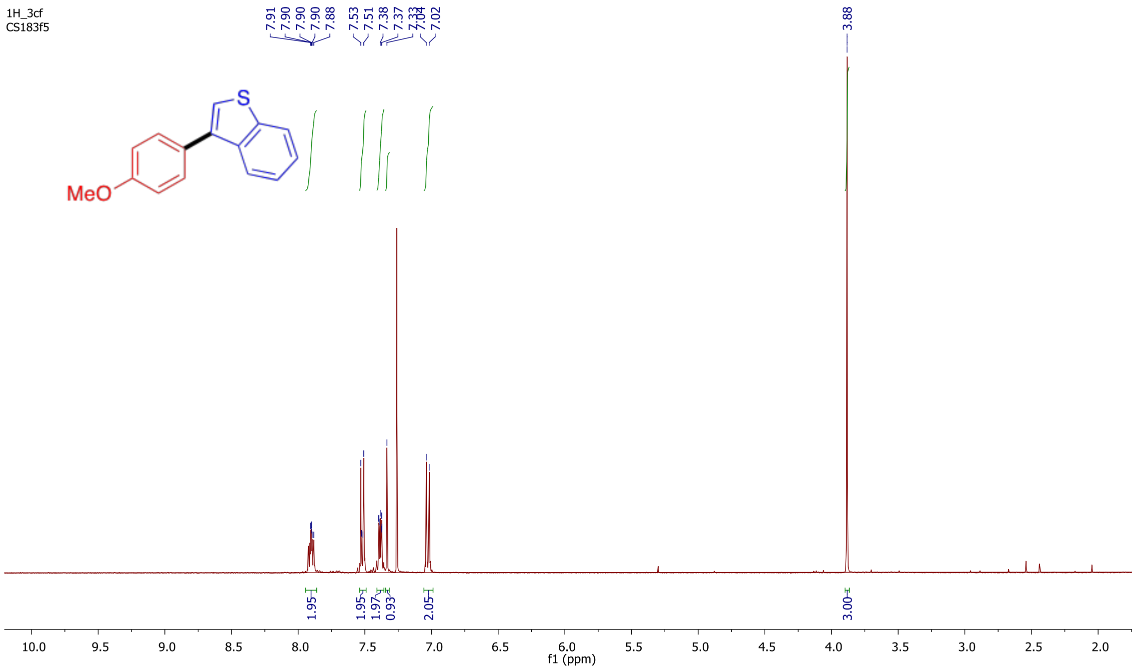
f1 (ppm)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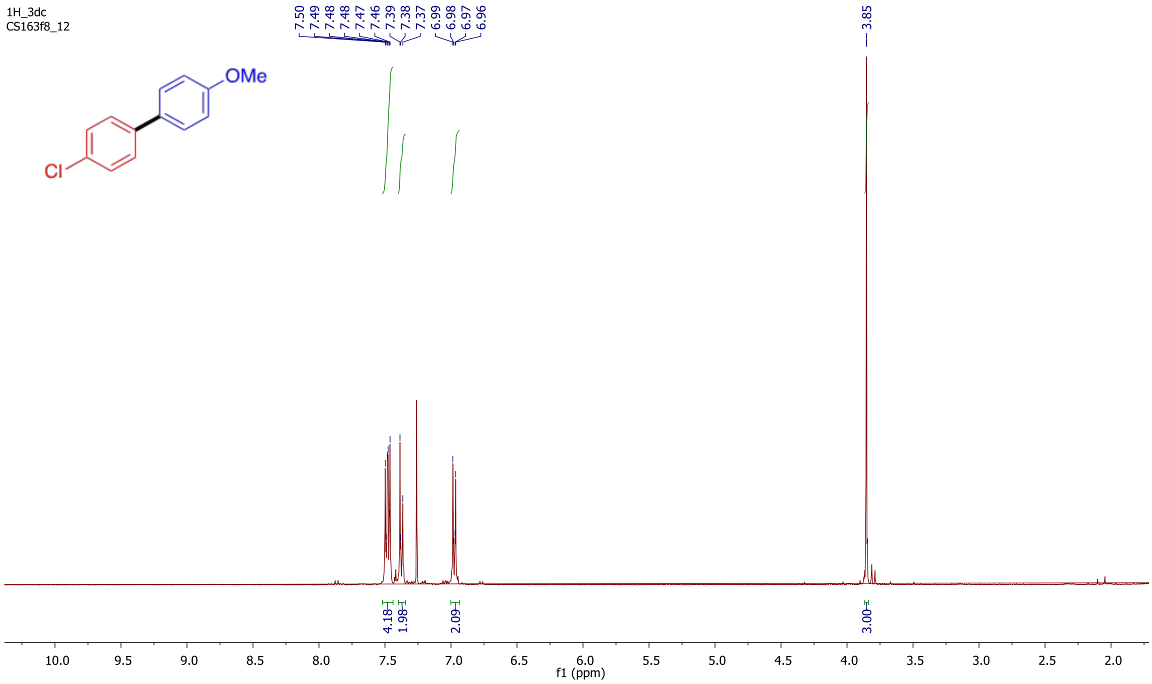
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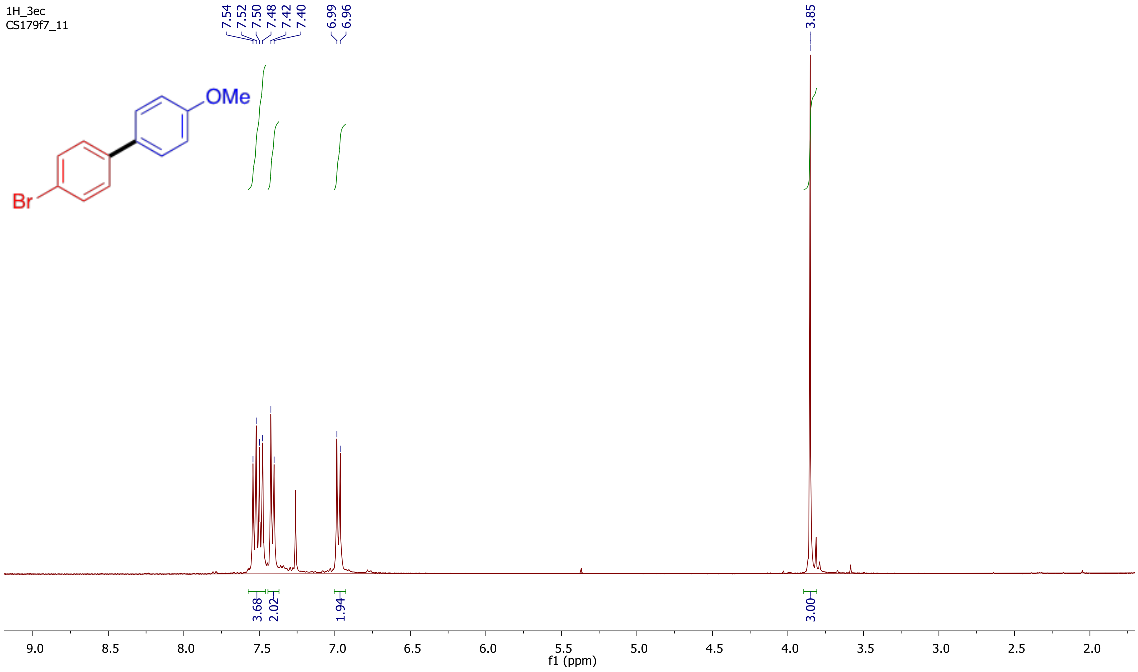
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Br
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1.94
3.00
9.0
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8.0
7.5
7.0
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6.0
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4.0
3.5
3.0
2.5
2.0
f1 (ppm)