Supplementary Information

Regioselective C2-Arylation of Imidazo[4,5-b]pyridines.

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1. Synthetic Schemes to Intermediates

Scheme S1. Synthesis of N3-methylimidazo[4,5-b]pyridine, S2.

Scheme S2. Synthesis of N3-SEM and Boc protected imidazo[4,5-b]pyridines.


Scheme S5. Suzuki cross-coupling to 3-((2-methoxyethoxy)methyl)-6-(1-methyl-1H-pyrazol-4-yl)-3H-imidazo[4,5-b]pyridine, S6.


Scheme S8: Investigating the reaction mechanism; C2-deprotonation under C-H arylation conditions.

2. Deprotection of C-H Arylation Products

Table S1. Acid-mediated deprotection of C-H arylation products.

![Reaction Scheme]

Table:

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3. **Kinetic Isotope Experiment**

**Chart S1.** Chart showing conversion versus time for KIE experiments. The 'product formed' is defined as the ratio of product formed to remaining starting material, as measured by LCMS UV-Absorbance at λ254 nm.

**Chart S2.** Initial rate corresponding to 20% conversion.

Kinetic Isotope Effect calculation: 

\[ KIE = \frac{k_H}{k_D} = \frac{0.885}{0.323} = 2.74 \]
4. Experimental for synthesis of intermediates

See main manuscript for general experimental.

\textbf{N2-Methylpyridine-2,3-diamine, S1:} A flask containing N-methyl-3-nitropyridin-2-amine (2 g, 13.1 mmol) and Pd/C (10 \%) (60 mg) was flushed with N\textsubscript{2} and DME (15 mL) added. The mixture was stirred at 40 °C and hydrazine monohydrate (1.8 mL, 40 mmol) was added drop-wise. Upon complete addition the mixture was heated to reflux for 90 minutes. Upon cooling, the mixture was filtered through a bed of celite (upper) and silica (lower). The filter bed was washed with EtOAc:Et\textsubscript{2}O (1:1; 60 mL), the solvent mixture was removed under reduced pressure to yield the product as a purple solid (1.6 g, quant.) which was used without further purification.

\textsuperscript{1}H NMR: (500 MHz, CDCl\textsubscript{3}) \(\delta H\) 7.81 (dd, \(J = 5.1, 1.5\) Hz, 1H), 6.85 (dd, \(J = 7.4, 1.5\) Hz, 1H), 6.54 (dd, \(J = 7.4, 5.1\) Hz, 1H), 4.17 (s, 1H), 3.17 (s, 2H), 3.04 (d, \(J = 2.8\) Hz, 3H); \textsuperscript{13}C NMR: (126 MHz, CDCl\textsubscript{3}) \(\delta C\) 151.2, 139.3, 128.4, 121.8, 113.2, 28.7; LCMS t\textsubscript{R} 0.41 min, \(m/z\) 124 (M+H); Purity (AUC) ≥ 95%; HRMS (M+H)\textsuperscript{+} calculated for \(C_{6}H_{10}N_{3} = 124.0869\), found = 124.0959.

\textbf{3-Methyl-3H-imidazo[4,5-b]pyridine, S2:} To a suspension of \(N^2\)-methylpyridine-2,3-diamine, S1 (1.16 g, 9.4 mmol) in CH\textsubscript{2}Cl\textsubscript{2} (5 mL) was added triethylorthofomrate (10 mL) and acetic acid (1.5 mL). The mixture was reacted under microwave irradiation at 150 °C for 30 min. The residue was purified by flash chromatography; conditions (CH\textsubscript{2}Cl\textsubscript{2}:EtOH:NH\textsubscript{3} (95:4:1) yielding the product as a brown solid (1.17 g, 8.79 mmol, 93 \%). Lit. m.p. 76-78;\textsuperscript{2} Observed m.p. 74-77°C; \textsuperscript{1}H NMR: (500 MHz, CDCl\textsubscript{3}) \(\delta H\) 8.45 (dd, \(J = 4.8, 1.4\) Hz, 1H), 8.10 (dd, \(J = 8.0, 1.4\) Hz, 1H), 8.06 (s, 1H), 7.28-7.23 (m, 1H), 3.96 (s, 3H); \textsuperscript{13}C NMR: (126 MHz, CDCl\textsubscript{3}) \(\delta C\) 147.0, 144.0, 143.8, 134.9, 127.4, 117.6, 29.2; LCMS t\textsubscript{R} = 0.81 mins, \(m/z\) 134 (M+H); Purity (AUC) ≥ 95%; HRMS (M+H)\textsuperscript{+} calculated for \(C_{7}H_{8}N_{3} = 134.0713\), found = 134.0718, (M+Na)\textsuperscript{+} calculated for \(C_{7}H_{7}N_{3}Na = 156.0532\), found = 156.0535.

3-((2-(Trimethylsilyl)ethoxy)methyl)-3H-imidazo[4,5-b]pyridine, S3: Imidazo[4,5-b]pyridine, 3 (1191 mg, 10 mmol) in DMF (100 mL) was cooled to 0 °C in an ice/water bath. To this was added portionwise NaH (480 mg, 12 mmol) and upon complete addition the mixture was stirred for 15 minutes. SEMCl (2.12 mL, 12 mmol) was added dropwise before stirring the mixture at room temperature for 24 h. The mixture was concentrated in vacuo, the residue was taken in 1:1 EtOAc:Cyclohexane (200 mL), washed with water (50 mL), sat. aq. NaCl (3 x 50 mL), dried (MgSO4) and concentrated to give crude product which was purified by column chromatography (10 – 50 % EtOAc in cyclohexane) to afford a yellow oil (1.52g, 61%).

1H NMR: (500 MHz, CDCl3) δH 8.44 (dd, J = 1.4, 8.8 Hz, 1H), 8.21 (s, 1H), 8.10 (dd, J = 1.5, 8.0, 1H), 7.28 (dd, J = 4.8, 8.0 Hz, 1H), 5.70 (s, 2H), 3.65 – 3.61 (m, 2H), 0.95 – 0.92 (m, 2H), -0.05 (s, 9H); 13C NMR: (126 MHz, CDCl3) δC 147.1, 144.7, 144.2, 135.2, 128.1, 118.7, 72.0, 67.1, 17.7, -1.48; LCMS tR = 2.95 mins, m/z = 250 (M+H)+; Purity (AUC) ≥ 95%; HRMS (M+H)+ calculated for C12H20N3OSi = 250.1376, found = 250.1367.

 tert-Butyl 3H-imidazo[4,5-b]pyridine-3-carboxylate, S4: To a stirred suspension of imidazo[4,5-b]pyridine, 3 (1191 mg, 10 mmol), Et3N (334 µL, 2.4 mmol) and DMAP (24 mg, 0.2 mmol) in THF (10 mL) at r.t. under an N2 atmosphere, was added Boc2O (2M in THF) (1.1 mL, 2.2 mmol). The mixture was heated to 65 ºC for 1 hour. Upon cooling the mixture was concentrated in vacuo and purified by flash column chromatography (20-40% EtOAc in cyclohexane) to yield a white solid (951 mg, 43%). Observed m.p. = 90 – 92 ºC; 1H NMR: (500 MHz, CDCl3) δH 8.67 (s, 1H), 8.62 (dd, J = 4.8, 1.6 Hz, 1H), 8.29 (dd, J = 8.1, 1.6 Hz, 1H), 7.35 (dd, J = 8.1, 4.8 Hz, 1H), 1.72 (s, 9H); 13C NMR: (126 MHz, CDCl3) δC 156.5, 147.4, 146.5, 144.1, 124.2, 122.6, 120.2, 85.6, 28.0; LCMS tR = 2.54 mins, m/z = 164 (loss of t-Bu, M+H)+; Purity (AUC) ≥ 95%; HRMS (M+H)+ calculated for C11H14N3O2 = 220.1081, found = 220.1077, also 164.0626 (loss of tert-butyl).
**6-Bromo-3H-imidazo[4,5-b]pyridine, 4:** A solution of 5-bromopyridine-2,3-diamine (500 mg, 2.66 mmol), triethylorthoformate (5 mL), acetic acid (0.75 mL) and CH₂Cl₂ (2.5 mL) was irradiated in a µW at 150 °C for 30 mins. The solvents were removed under reduced pressure and the residue was purified by Biotage SP1 (50 g SNAP column, 40 mL/min, 3 CV Cyclohexane, 9 CV 0-10 % MeOH in CH₂Cl₂). The product was obtained as a cream solid (358 mg, 69 %). Lit. m.p. 322-229; Observed m.p. 229-231˚C; ¹H NMR (CD₃OD, 500MHz) δH 8.48 (d, J = 2.1 Hz, 1H), 8.42 (s, 1H), 8.23 (d, J = 2.1 Hz, 1H); ¹³C NMR (CD₃OD, 126 MHz) δC 149.6, 145.0, 144.9, 126.0, 113.5, one q C does not appear; LCMS tᵣ 1.74 min, m/z 197, 199 (M+H)⁺ bromine isotopic pattern; Purity (AUC) ≥ 95%; HRMS (M+H)⁺ calculated for C₆H₅N₃Br = 197.9661, found = 197.9670; CHN Microanalysis calculated for C₆H₄BrN₃ = C, 36.39; H, 2.04; N, 21.22%, observed = C, 36.33; H, 2.06; N, 21.16%.

**3-((2-Methoxyethoxy)methyl)-6-phenyl-3H-imidazo[4,5-b]pyridine, S5:** 6-Bromo-3-((2-methoxyethoxy)methyl)-3H-imidazo[4,5-b]pyridine, 7a (589 mg, 2.0 mmol), phenyl boronic acid (488 mg, 4.0 mmol), K₂CO₃ (4.0 ml, 1 M, 4.0 mmol), Pd(OAc)₂ (18 mg, 4 mol%) and nBuPAd₂ (57 mg, 8 mol%) were dissolved in DME (5.0 ml) and heated in a microwave reactor at 150 °C for 1 h. The mixture was diluted with ethyl acetate (100 mL) and washed with H₂O. The crude mixture was concentrated in vacuo and purified on Biotage SP1 (12g SINGLE StEP column, 15 mL/min, 3 CV CH₂Cl₂ then 12 CV 0-100% (5% MeOH in CH₂Cl₂)) to afford product as an orange oil (521 mg, 92%). ¹H NMR (500 MHz, CDCl₃) δH 8.66 (d, J = 1.9 Hz, 1H), 8.28 (s, 1H), 8.27 (d, J = 1.9 Hz, 1H), 7.65 - 7.61 (m, 2H), 7.53 – 7.47 (m, 2H), 7.44 – 7.38 (m, 1H), 5.80 (s, 2H), 3.78 – 3.73 (m, 2H), 3.56 – 3.51 (m, 2H), 3.36 (s, 3H); ¹³C NMR (126 MHz, CDCl₃) δC 146.6, 144.9, 144.2, 138.6, 135.3, 133.0, 129.1, 127.6, 127.5 126.5, 73.0, 71.6, 68.9, 59.1; LCMS tᵣ = 2.74 min, m/z 284 (M+H)⁺; Purity (AUC) ≥ 95%; HRMS (M+H)⁺ calculated for C₁₆H₁₈N₃O₂ = 284.1394, found = 284.1388.

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3-((2-Methoxyethoxy)methyl)-6-(1-methyl-1H-pyrazol-4-yl)-3H-imidazo[4,5-b]pyridine, **S6**: 6-Bromo-3-((2-methoxyethoxy)methyl)-3H-imidazo[4,5-b]pyridine, 7a (1.0 M in DMF, 0.25 mL, 0.25 mmol), 1-methylpyrazole-4-boronic acid pinacol ester (78 mg, 0.375 mmol), Pd(OAc)$_2$ (2.2 mg, 0.01 mmol) and nBuPAd$_2$ (7 mg, 0.02 mmol) were taken in 1.0 M aq. K$_2$CO$_3$ (0.5 mL, 0.5 mmol) and DME (0.75 mL), the combined reagents were irradiated in µW at 150 °C for 1 h. The mixture was filtered through a bed of celite (top layer) and silica (bottom layer), eluting with CHCl$_3$/MeOH affording crude product which was purified on Biotage SP1 (12g SINGLE StEp column, 15 mL/min, 0 – 5% MeOH in CH$_2$Cl$_2$) to afford the product as a brown oil (62 mg, 86%). $^1$H NMR: (500 MHz, CDCl$_3$) δ$_H$ 8.60 (d, $J = 2.0$ Hz, 1H), 8.30 (s, 1H), 8.16 (d, $J = 2.0$ Hz, 1H), 7.83 (d, $J = 0.9$ Hz, 1H), 7.70 (d, $J = 0.9$ Hz, 1H), 5.80 (s, 2H), 4.01 (s, 3H), 3.78 – 3.70 (m, 2H), 3.57 – 3.52 (m, 2H), 3.37 (s, 3H); $^{13}$C NMR: (126 MHz, CDCl$_3$) δ$_C$ 145.7, 144.5, 143.1, 136.9, 127.1, 124.9, 124.5, 120.3, 73.1, 71.6, 69.0, 59.1, 39.2; LCMS $t_R$ = 2.06 mins, $m/z =$ 288 (M+H)$^+$; Purity (AUC) ≥ 95%; HRMS (M+H)$^+$ calculated for C$_{14}$H$_{18}$N$_5$O$_2$ = 288.1455, found = 288.1459.

3-((2-Methoxyethoxy)methyl)-N,N-dimethyl-3H-imidazo[4,5-b]pyridine-6-carboxamide, **S7**: 6-Bromo-3-((2-methoxyethoxy)methyl)-3H-imidazo[4,5-b]pyridine, 7a (1.0 M in DMF, 0.25 mL, 0.25 mmol), dimethylamine (2.0 M in THF, 625 µL, 1.25 mmol), Herrmann's Palladacycle (6 mg, 0.00625 mmol), [(t-Bu)$_3$PH]BF$_4$ (5 mg, 0.0175 mmol), Mo(CO)$_6$ (66 mg, 0.25 mmol) and DBU (1.0 M in THF, 0.75 mL, 0.75 mmol) were combined in 1,4-dioxane (2.5 mL) and irradiated in µW at 140 °C for 1 h. The reaction mixture was filtered through a bed of celite (top layer) and silica (bottom layer) with CHCl$_3$/MeOH to afford crude product. Purification using Biotage SP1 (10g SNAP, 15 mL/min, 0 – 5% MeOH in CH$_2$Cl$_2$) afforded the product as a brown oil (60 mg, 86%). $^1$H NMR: (500 MHz, CDCl$_3$) δ$_H$ 8.57 (d, $J = 1.9$ Hz, 1H), 8.32 (s, 1H), 8.18 (d, $J = 1.9$ Hz, 1H), 5.80 (s, 2H), 3.78 – 3.70 (m, 2H), 3.56 – 3.51 (m, 2H), 3.36 (s, 3H), 3.19 (bs, 3H), 3.09 (bs, 3H); $^{13}$C NMR: (126 MHz, CDCl$_3$) δ$_C$ 169.6, 147.5, 145.6, 144.2, 134.3, 127.6, 127.2, 73.0, 71.5, 69.0, 59.1, 39.9, 35.7; LCMS $t_R$ = 1.62 mins, $m/z =$ 279.
(M+H)+; Purity (AUC) ≥ 95%; HRMS (M+H)+ calculated for C_{13}H_{19}N_{4}O_{3} = 279.1452, found = 279.1455.

3-((2-Methoxyethoxy)methyl)-6-methyl-3H-imidazo[4,5-b]pyridine. **S8:**

6-Bromo-3-((2-methoxyethoxy)methyl)-3H-imidazo[4,5-b]pyridine, **7a** (589 mg, 2.0 mmol), methylboronic acid (239 mg, 4.0 mmol), CsF (636 mg, 4.0 mmol), Pd(OAc)$_2$ (18 mg, 4 mol%) and nBuPAd$_2$ (57 mg, 8 mol%) were dissolved in DME (5.0 ml) and heated in a microwave reactor at 150 °C for 1 h. The crude mixture was concentrated in vacuo and purified by column chromatography (CH$_2$Cl$_2$ to EtOH:CH$_2$Cl$_2$ 10:90) to afford the product as a yellow oil (354 mg, 80%); $^1$H NMR (500 MHz, CDCl$_3$) $\delta$H 8.27 (d, $J$ = 1.8 Hz, 1H), 8.19 (s, 1H), 7.90 (d, $J$ = 1.8 Hz, 1H), 5.75 (s, 2H), 3.72 – 3.70 (m, 2H), 3.52 – 3.50 (m, 2H), 3.36 (s, 3H), 2.50 (s, 3H); $^{13}$C NMR (126 MHz, CDCl$_3$) $\delta$C 145.6, 145.5, 144.2, 135.1, 128.4, 128.1, 72.9, 71.5, 68.8, 59.0, 18.6; LCMS $t_R$ = 1.62 min, $m/z$ = 222 (M+H)+; Purity (AUC) ≥ 95%; HRMS (M+H)+ calculated for C$_{13}$H$_{19}$N$_{4}$O$_{3}$ = 279.1452, found = 279.1455.

6-Cyclopropyl-3-((2-methoxyethoxy)methyl)-3H-imidazo[4,5-b]pyridine. **S9:**

6-Bromo-3-((2-methoxyethoxy)methyl)-3H-imidazo[4,5-b]pyridine, **7a** (589 mg, 2.0 mmol), cyclopropylboronic acid (344 mg, 4.0 mmol), CsF (636 mg, 4.0 mmol), Pd(OAc)$_2$ (18 mg, 4 mol%) and nBuPAd$_2$ (57 mg, 8 mol%) were dissolved in DME (5.0 ml) and heated in a microwave reactor at 150 °C for 1 h. The crude mixture was concentrated in vacuo and purified by column chromatography (CH$_2$Cl$_2$ to EtOH: CH$_2$Cl$_2$ 10:90) to afford the product as a yellow oil (440 mg, 89%); $^1$H NMR (500 MHz, CDCl$_3$) $\delta$H 8.36 (d, $J$ = 2.0 Hz, 1H), 8.08 (s, 1H), 7.45 (d, $J$ = 2.0 Hz, 1H), 5.57 (s, 2H), 3.54 – 3.48 (m, 2H), 3.47 – 3.42 (m, 2H), 3.28 (s, 3H), 2.00 (ddd, $J$ = 8.5, 5.2, 3.4 Hz, 1H), 1.04 – 0.96 (m, 2H), 0.70 (dt, $J$ = 6.4, 4.8 Hz, 2H); $^{13}$C NMR (126 MHz, CDCl$_3$) $\delta$C 155.1, 145.0, 144.6, 134.9, 125.9, 115.1, 75.4, 71.7, 67.7, 59.0, 13.4, 9.1; LCMS $t_R$ = 1.95 min, $m/z$ = 248 (M+H)+; Purity (AUC) ≥ 95%; HRMS (M+H)+ calculated for C$_{13}$H$_{18}$N$_{3}$O$_{2}$ = 248.1394, found = 248.1394.
3-((2-Methoxyethoxy)methyl)-7-methyl-3H-imidazo[4,5-b]pyridine. S10: 7-Chloro-3-((2-methoxyethoxy)methyl)-3H-imidazo[4,5-b]pyridine, 8a (1.0M in DMF, 0.2 mL, 0.2 mmol), methylboronic acid (18 mg, 0.3 mmol), CsF (60 mg, 0.4 mmol), Pd(OAc)$_2$ (2.2 mg, 5 mol%) and nBuPAd$_2$ (7.2 mg, 10 mol%) were dissolved in DME (1.0 ml) and heated in a microwave reactor at 150 °C for 2.5 h. The reaction mixture was filtered through a plug of silica (bottom layer) and celite (top layer), eluting with CHCl$_3$ & MeOH. The filtrate was concentrated in vacuo and purified by column chromatography (0 – 5% MeOH in CH$_2$Cl$_2$) to afford the product as a yellow oil (35 mg, 80%). $^1$H NMR: (500 MHz, CDCl$_3$) $\delta$H 8.32 (d, $J$ = 4.9 Hz, 1H), 8.29 (s, 1H), 7.12 (dd, $J$ = 4.9 0.8 Hz, 1H), 5.78 (s, 2H), 3.75 – 3.71 (m, 2H), 3.54 – 3.50 (m, 2H), 3.35 (s, 3H), 2.73 (d, $J$ = 0.8 Hz, 3H); $^{13}$C NMR: (126 MHz, CDCl$_3$) $\delta$C 146.2, 144.8, 142.9, 139.9, 134.2, 120.1, 73.2, 71.5, 68.9, 59.1, 16.3; LCMS t$_R$ = 1.96 mins, $m/z$ = 222 (M+H)$^+$; Purity (AUC) ≥ 95%; HRMS (M+H)$^+$ calculated for C$_{11}$H$_{16}$N$_3$O$_2$ = 222.1237, found = 222.1240.
5. NMR Spectra

5.1 Spectra of intermediates

$^1$H NMR:

![NMR Spectrum](image1)

$^{13}$C NMR:

![NMR Spectrum](image2)
$^1$H NMR:

$^{13}$C NMR:
$^1$H NMR:

$^{13}$C NMR:
$^1$H NMR:

![1H NMR spectrum of compound 6b]

$^{13}$C NMR:

![13C NMR spectrum of compound 6b]
2D NMR – HMBC Experiment

**N3 MEM, 4a** – N-CH$_2$-O correlates to C3a and C2 and not C7a.

**N1 MEM, 4b** – N-CH$_2$-O correlates to C7a and C2 and not C3a.
$^1$H NMR:

$^{13}$C NMR:
**$^1$H NMR:**

![1H NMR spectrum](image)

**$^{13}$C NMR:**

![13C NMR spectrum](image)
2D NMR – HMBC Experiment

6-Br N3 MEM, 5a – N-CH$_2$-O does not show correlation to either quaternary C, but it does to C2 - inconclusive.

6-Br N1 MEM, 5b – However, the N1 regioisomer is easily distinguished as the N-CH$_2$-O correlates to C7a and C2 and not C3a.
$^1$H NMR:

$^{13}$C NMR:
$^1$H NMR:

$^{13}$C NMR:
2D NMR – HMBC Experiment

7-Cl N3 MEM, 6a – N-CH$_2$-O correlates to C3a and C2 and not C7a.

7-Cl N1 MEM, 6b – N-CH$_2$-O correlates to C7a and C2 and not C3a.
\( ^1H \text{NMR:} \)

\[
\text{S3}
\]

\( ^{13}C \text{NMR:} \)

\[
\text{S3}
\]
$^1$H NMR:

$^{13}$C NMR:
$^{1}H$ NMR:

$^{13}C$ NMR:
$^{1}H$ NMR:

$^{13}C$ NMR:
$^1$H NMR:

![NMR spectrum for S8](image)

$^{13}$C NMR:

![NMR spectrum for S8](image)
$^1$H NMR:

$^{13}$C NMR:
$^{1}$H NMR:

![1H NMR spectrum of compound S10](image)

$^{13}$C NMR:

![13C NMR spectrum of compound S10](image)
5.2 Spectra of C-H arylation products

$^1$H NMR:

$^{13}$C NMR:
$^{1}\text{H} \text{NMR}$:

$^{13}\text{C} \text{NMR}$:
$^1$H NMR:

$^{13}$C NMR:
$^{1}H$ NMR:

$^{13}C$ NMR:

$^{13}C$ peak for $\text{Si(CH}_3)_3$ assigned from HSQC experiment, $\delta_C = -1.2$ ppm.
$^1$H NMR:

$^{13}$C NMR:
$^1$H NMR:

$^{13}$C NMR, DEPT135:
$^{19}\text{F NMR:}$

$^{1}\text{H NMR:}$
$^{13}$C NMR:

$^{1}$H NMR:
$^{13}$C NMR:

![Carbon NMR spectrum](image)

$^{19}$F NMR:

![Fluorine NMR spectrum](image)
$^1$H NMR:

$^{13}$C NMR:
$^1$H NMR:

$^{13}$C NMR:
$^1$H NMR:

$^{13}$C NMR:
$^{19}$F NMR:

![NMR Spectrum](image-url)
$^1$H NMR:

$^{13}$C NMR:
$^1$H NMR:

$^{13}$C NMR, DEPT135:
$^{1}$H NMR:

$^{13}$C NMR, DEPT135:
$^1$H NMR:

$^{13}$C NMR:
$^1$H NMR:

$^{13}$C NMR:
$^{19}$F NMR:
$^1$H NMR:

16b

$^{13}$C NMR:
$^1$H NMR:

$^{13}$C NMR:
$^1$H NMR:

$^{13}$C NMR:
$^1$H NMR:

$^{13}$C NMR:
$^{19}$F NMR:

$^1$H NMR:
$^{13}$C NMR:

![13C NMR spectrum]

$^{19}$F NMR:

![19F NMR spectrum]
$^1$H NMR:

$^{13}$C NMR:
$^1$H NMR:

$^{13}$C NMR:
$^{19}\text{F NMR:}$
$^1$H NMR:

$^{13}$C NMR:
$^{1}H$ NMR:

![1H NMR spectrum](image)

$^{13}C$ NMR:

![13C NMR spectrum](image)
5.3 Spectra of deprotected C2-arylated products

$^1$H NMR:

![1H NMR spectrum of compound 9]

$^{13}$C NMR:

![$^{13}$C NMR spectrum of compound 9]
$^1$H NMR:

15b

$^{13}$C NMR:

15b
$^1$H NMR:

![H NMR spectrum of 15c](image1)

$^{13}$C NMR:

![C NMR spectrum of 15c](image2)
$^{19}$F NMR:

$^{1}$H NMR:
$^{13}$C NMR:

![Carbon NMR spectrum](image1)

$^{1}$H NMR:

![Hydrogen NMR spectrum](image2)
$^{13}$C NMR:

$^{19}$F NMR:
$^1$H NMR:

$^{13}$C NMR:
$^1$H NMR:

$^{13}$C NMR:
$^{1}$H NMR:

$^{13}$C NMR:
$^{19}$F NMR:

![Chemical structure and NMR spectrum](image)
$^1$H NMR:

$^{13}$C NMR:
$^1$H NMR:

![1H NMR spectrum](image1)

$^{13}$C NMR:

![13C NMR spectrum](image2)
$^1$H NMR:

![1H NMR spectrum for compound 15k](image)

$^{13}$C NMR, DEPT:

![$^{13}$C NMR spectrum for compound 15k](image)
$^1$H NMR:

$^{13}$C NMR: