Organic photoredox catalysis enabled cross-coupling of arenediazonium and sulfinate salts: synthesis of (un)symmetrical diaryl/alkyl aryl sulfones

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General Information: Reagents were obtained from commercial suppliers, and used without further purification unless otherwise specified by a reference. All reactions were performed under a nitrogen atmosphere. Organic solutions were concentrated using a Buchi rotary evaporator. Column chromatography was carried out over silica gel (Merck 100–200 mesh) and TLC was performed using silica gel GF254 (Merck) plates. $^1$H NMR spectra were recorded on a Bruker AVII 400 spectrometer in CDCl$_3$ using TMS as internal reference with chemical shift value being reported in ppm. All coupling constants ($J$) are reported in Hertz (Hz). $^{13}$C NMR spectra were recorded on the same instrument at 100 MHz in CDCl$_3$ and TMS was used as internal reference. Mass (EI) spectra were recorded on a JEOL D-300 mass spectrometer.

Typical procedure for VLPC enabled arylation of sulfinate salts
A solution of arenediazonium salt 1 (1.0 mmol), sulfinate salt 2 (1.3 mmol) and eosin Y (1 mol%) in CH$_3$CN/H$_2$O (10:1, 5 mL) was irradiated with visible-light (green light emitting diodes (LEDs), $\lambda_{\text{max}} = 535$ nm, 2.5 W) under a nitrogen atmosphere with stirring at rt for 8-18 h (Table 2 and 3). After completion of the reaction (monitored by TLC), water (5 mL) was added and the mixture was extracted with ethyl acetate (3 × 5 mL). The combined organic phase was dried over anhydrous Na$_2$SO$_4$, filtered, and concentrated under reduced pressure. The resulting crude product was purified by silica gel chromatography using a mixture of hexane/ethyl acetate (9:1) as eluent to afford an analytically pure sample of product 3/4.
Typical procedure for one-pot VLPC enabled sulfonylation of anilines
To solution containing 1.0 mmol of aniline derivative 5 and 1 mol% of eosin Y in CH$_3$CN/H$_2$O 10:1 (5 mL) was successively added 0.2 mmol of methanesulfonic acid, 1.5 mmol of tert-butyl nitrite and 1.3 mmol of sulfinate salt 2a under irradiation with visible-light (green light emitting diodes (LEDs), $\lambda_{\text{max}}$ = 535 nm, 2.5 W) and nitrogen atmosphere with stirring at rt for 10-13 h (Table 4). After completion of the reaction (monitored by TLC), water (5 mL) was added and the mixture was extracted with ethyl acetate (3 × 5 mL). The combined organic phase was dried over anhydrous Na$_2$SO$_4$, filtered, and concentrated under reduced pressure. The resulting crude product was purified by silica gel chromatography using a mixture of hexane/ethyl acetate (9:1) as eluent to afford an analytically pure sample of product 3.

Light turn-ON/OFF experiment
The model reaction was alternatively irradiated with green LED ($\lambda_{\text{max}}$ = 535 nm, 2.50 W) and kept in the dark in two-hour intervals. The yield was determined by flash chromatography. The result has been shown in Fig. 1.

![Light turn-ON/OFF experiment](image)

Fig. 1. Light turn-ON/OFF experiment.
Radical trapping experiment

1,1-Diphenylethylene (0.4 mmol, 2.0 equiv.) was added to the model reaction. The crude mixture of the reaction was detected by GC-MS. Products 3j, 7 and 8 were detected, as shown in Fig. 2 and Fig. 3.

![Diagram with chemical structures and GC traces]

Fig. 2. GC of products 3j, 7 and 8.
Fig. 3. MS (EI) of products 7 and 8.

Spectroscopic and analytical data for compounds 3

\[
\text{O} \quad \text{O} \\
\text{MeO} \\
\text{O} \quad \text{O} \\
\text{MeO}
\]

1-methyl-4-(phenylsulfonyl)benzene,\textsuperscript{1,3} 3a, yield 85%

\textsuperscript{1}H NMR (400 MHz, CDCl\textsubscript{3}) δ 7.99 – 7.86 (m, 2H), 7.80 (d, J = 8.3 Hz, 2H), 7.59 – 7.43 (m, 3H), 7.31 (d, J = 8.0 Hz, 2H), 2.39 (s, 3H). \textsuperscript{13}C NMR (100 MHz, CDCl\textsubscript{3}) δ 144.1, 142.0, 138.5, 132.9, 130.0, 129.1, 127.7, 127.5, 21.5. HRMS (EI); Mass calcd for C\textsubscript{13}H\textsubscript{12}O\textsubscript{2}S [M]\textsuperscript{+}: 232.0558; found 232.0562.

\[
\text{O} \quad \text{O} \\
\text{MeO} \\
\text{O} \quad \text{O} \\
\text{MeO}
\]

1-methoxy-4-tosylbenzene,\textsuperscript{1,3,5} 3b, yield 72%

\textsuperscript{1}H NMR (400 MHz, CDCl\textsubscript{3}) δ 7.87 – 7.85 (d, J = 8.8 Hz, 2H), 7.80 – 7.78 (d, J = 8.2 Hz, 2H), 7.28 – 7.26 (d, J = 7.9 Hz, 2H), 6.96 – 6.94 (d, J = 8.8 Hz, 2H), 3.83 (s, 3H), 2.38 (s, 3H). \textsuperscript{13}C NMR (100 MHz, CDCl\textsubscript{3}) δ 163.2, 143.7, 139.3, 133.5, 129.7, 129.6, 127.3, 114.4, 55.6, 21.4. HRMS (EI); Mass calcd for C\textsubscript{14}H\textsubscript{14}O\textsubscript{3}S [M]\textsuperscript{+}: 262.0664; found 262.0662.
1-methoxy-3-tosylbenzene, $^1$ 3c, yield 74%

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.82 (d, $J$ = 8.2 Hz, 2H), 7.50-7.28 (m, 5H), 7.04 (m, 1H), 3.82 (s, 3H), 2.39 (s, 3H). $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 159.9, 144.2, 143.0, 138.5, 130.3, 130.0, 127.7, 119.7, 119.3, 112.1, 55.6, 21.5. HRMS (EI); Mass calcd for C$_{14}$H$_{14}$O$_3$S [M]$^+$: 262.0664; found 262.0661.

1-methyl-4-tosylbenzene,$^{1,5}$ 3d, yield 75%

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.80 (d, $J$ = 8.3 Hz, 4H), 7.25 (d, $J$ = 8.3 Hz, 4H), 2.39 (s, 6H). $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 144.0, 139.0, 129.8, 127.5, 21.6. HRMS (EI); Mass calcd for C$_{14}$H$_{14}$O$_2$S [M]$^+$: 246.0715; found 246.0713.

4-tosylphenol,$^2$ 3e, yield 73%

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.77 (d, $J$ = 8.2 Hz, 4H), 7.23 (d, $J$ = 9.0 Hz, 2H), 6.85 (d, $J$ = 8.4 Hz, 2H), 6.53 (s, 1H), 2.38 (s, 3H). $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 160.1, 143.9, 139.2, 133.1, 130.0, 129.8, 127.3, 116.2, 21.5. HRMS (EI); Mass calcd for C$_{13}$H$_{12}$O$_3$S [M]$^+$: 248.0507; found 248.0508.

1-Fluoro-4-tosylbenzene,$^{4,5}$ 3f, yield 91%

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.99 – 7.93 (m, 2H), 7.82 – 7.79 (m, 2H), 7.31 – 7.29 (m, 2H), 7.21 – 7.14 (m, 2H), 2.38 (s, 3H). $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 165.2 (d, $J_{CF}$ = 255.5 Hz), 144.3,
138.6, 138.0, 130.2 (d, \( J_{CF} = 9.4 \) Hz), 130.0, 127.7, 116.4 (d, \( J_{CF} = 22.6 \) Hz), 21.6. HRMS (EI); Mass calcd for \( \text{C}_{13}\text{H}_{11}\text{FO}_2\text{S} \) [M]+: 250.0464; found 250.0469.

![Structure](image)

1-(4-chlorophenylsulfonyl)-4-methylbenzene,\(^1\) \(^2\) 3g, yield 88%

\(^1\text{H NMR}\) (400 MHz, CDCl\(_3\)) \( \delta \) 7.85 (d, \( J = 8.5 \) Hz, 2H), 7.79 (d, \( J = 8.1 \) Hz, 2H), 7.41 (d, \( J = 8.5 \) Hz, 2H), 7.29 (d, \( J = 8.0 \) Hz, 2H), 2.39 (s, 3H). \(^{13}\text{C NMR}\) (100 MHz, CDCl\(_3\)) \( \delta \) 144.5, 140.4, 139.6, 138.1, 130.2, 129.5, 128.9, 127.7, 21.6. HRMS (EI); Mass calcd for \( \text{C}_{13}\text{H}_{11}\text{ClO}_2\text{S} \) [M]+: 266.0168; found 266.0170.

![Structure](image)

1-(3-chlorophenylsulfonyl)-4-methylbenzene,\(^1\) 3h, yield 86%

\(^1\text{H NMR}\) (400 MHz, CDCl\(_3\)) \( \delta \) 7.91-7.80 (m, 2H), 7.43-7.29 (m, 6H), 2.39 (s, 3H). \(^{13}\text{C NMR}\) (100 MHz, CDCl\(_3\)) \( \delta \) 144.7, 143.6, 137.8, 135.4, 133.2, 130.6, 130.2, 127.8, 127.5, 125.4, 21.6. HRMS (EI); Mass calcd for \( \text{C}_{13}\text{H}_{11}\text{ClO}_2\text{S} \) [M]+: 266.0168; found 266.0171.

![Structure](image)

1-Methyl-4-((4-nitrophenyl)sulfonyl)benzene,\(^3\) 3i, yield 94%

\(^1\text{H NMR}\) (400 MHz, CDCl\(_3\)) \( \delta \) 8.35 (d, \( J = 8.7 \) Hz, 2H), 8.12 (d, \( J = 8.7 \) Hz, 2H), 7.85 (d, \( J = 8.3 \) Hz, 2H), 7.34 (d, \( J = 8.1 \) Hz, 2H), 2.43 (s, 3H). \(^{13}\text{C NMR}\) (100 MHz, CDCl\(_3\)) \( \delta \) 150.2, 147.8, 145.5, 137.0, 130.3, 128.7, 128.1, 124.3, 21.6. HRMS (EI); Mass calcd for \( \text{C}_{13}\text{H}_{11}\text{NO}_4\text{S} \) [M]+: 277.0409; found 277.0406.

![Structure](image)

4-tosylbenzonitrile,\(^2\) \(^5\) 3j, yield 93%
\[ \text{\textit{H} NMR (400 MHz, CDCl}_3) \ \delta \ 8.04 \ (d, J = 8.4 \text{ Hz}, 2H), \ 7.83 \ (d, J = 8.2 \text{ Hz}, 2H), \ 7.78 \ (d, J = 8.3 \text{ Hz}, 2H), \ 7.33 \ (d, J = 8.1 \text{ Hz}, 2H), \ 2.43 \ (s, 3H). \]

\[ \text{\textit{C} NMR (100 MHz, CDCl}_3) \ \delta \ 146.2, 145.2, 137.2, 133.0, 130.3, 128.2, 128.0, 117.2, 116.7, 21.6. \]

HRMS (EI); Mass calcd for C\textsubscript{14}H\textsubscript{11}NO\textsubscript{2}S [M]^+: 257.0510; found 257.0513.

\[ \text{3-tosylbenzonitrile,}^{2,5} \text{ 3k, yield 87\%} \]

\[ \text{\textit{H} NMR (400 MHz, CDCl}_3) \ \delta \ 8.23–8.08 \ (m, 2H), \ 7.88–7.76 \ (m, 3H), \ 7.65 \ (t, J = 7.9 \text{ Hz}, 1H), \ 7.33 \ (d, J = 8.0 \text{ Hz}, 2H), \ 2.41 \ (s, 3H). \]

\[ \text{\textit{C} NMR (100 MHz, CDCl}_3) \ \delta \ 145.2, 143.9, 137.1, 136.0, 131.3, 131.2, 130.3, 128.0, 117.0, 113.8, 21.6. \]

HRMS (EI); Mass calcd for C\textsubscript{14}H\textsubscript{11}NO\textsubscript{2}S [M]^+: 257.0510; found 257.0512.

\[ \text{2-Tosylbenzonitrile,} \text{ 3l, yield 88\%} \]

\[ \text{\textit{H} NMR (400 MHz, CDCl}_3) \ \delta \ 8.35–8.27 \ (m, 1H), \ 7.97 \ (d, J = 8.2 \text{ Hz}, 2H), \ 7.86–7.77 \ (m, 2H), \ 7.72–7.62 \ (m, 1H), \ 7.33 \ (d, J = 8.1 \text{ Hz}, 2H), \ 2.43 \ (s, 3H). \]

\[ \text{\textit{C} NMR (100 MHz, CDCl}_3) \ \delta \ 145.3, 144.1, 136.5, 135.6, 133.2, 133.0, 130.1, 129.6, 128.7, 115.6, 111.2, 21.6. \]

HRMS (EI); Mass calcd for C\textsubscript{14}H\textsubscript{11}NO\textsubscript{2}S [M]^+: 257.0510; found 257.0509.

\[ \text{2-tosynaphthalene,} \text{ 3m, yield 78\%} \]

\[ \text{\textit{H} NMR (400 MHz, CDCl}_3) \ \delta \ 8.58 \ (s, 1H), \ 8.01 – 7.79 \ (m, 6H), \ 7.67 – 7.53 \ (m, 2H), \ 7.29 \ (d, J = 8.4 \text{ Hz}, 2H), \ 2.37 \ (s, 3H). \]

\[ \text{\textit{C} NMR (100 MHz, CDCl}_3) \ \delta \ 144.1, 138.8, 138.7, 134.9, 129.8, 129.6, 129.4, 129.1, 128.8, 127.9, 127.7, 127.5, 122.5, 21.5. \]

HRMS (EI); Mass calcd for C\textsubscript{17}H\textsubscript{14}O\textsubscript{2}S [M]^+: 282.0715; found 282.0718.
1,2-dichloro-4-tosylbenzene, \(^1\) 3n, yield 92%

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 8.01 - 7.74 (m, 3H), 7.57 - 7.53 (d, \(J = 8.8\) Hz, 2H), 7.32 - 7.29 (d, \(J = 7.6\) Hz, 2H), 2.40 (s, 3H). \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 144.9, 141.8, 138.0, 137.6, 131.4, 130.9, 130.1, 129.4, 128.6, 127.8, 21.5. \(\text{HRMS (EI)}\); Mass calcd for C\(_{13}\)H\(_{10}\)Cl\(_2\)O\(_2\)S [M]\(^+\): 299.9779; found 299.9776.

1,3-dichloro-5-tosylbenzene, \(^1\) 3o, yield 91%

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 7.79 - 7.75 (m, 3H), 7.49 - 7.30 (m, 4H), 2.41 (s, 3H). \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 145.2, 144.8, 137.1, 136.2, 133.0, 130.3, 128.0, 125.8, 21.6. \(\text{HRMS (EI)}\); Mass calcd for C\(_{13}\)H\(_{10}\)Cl\(_2\)O\(_2\)S [M]\(^+\): 299.9779; found 299.9777.

Sulfonyldibenzene, \(^3,4\) 4a, yield 92%

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 7.98 - 7.93 (m, 2H), 7.59 - 7.56 (m, 2H), 7.53 - 7.45 (m, 4H). \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 141.7, 133.2, 129.4, 127.7. \(\text{HRMS (EI)}\); Mass calcd for C\(_{12}\)H\(_{10}\)O\(_2\)S [M]\(^+\): 218.0402; found 218.0401.

1-Methoxy-4-(phenylsulfonyl)benzene, \(^3,4\) 4b, yield 88%

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 7.93 - 7.90 (m, 2H), 7.89 - 7.86 (m, 2H), 7.58 - 7.43 (m, 3H), 6.98 - 6.95 (m, 2H), 3.84 (s, 3H). \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 164.4, 142.4, 133.3, 133.0, 130.1,
129.2, 127.3, 114.6, 55.7. HRMS (EI); Mass calcd for C_{13}H_{12}O_{3}S [M]^+: 248.0507; found 248.0509.

![Structure](image)

1-Fluoro-4-(phenylsulfonyl)benzene,\textsuperscript{3,4} 4c, yield 95%

\textsuperscript{1}H NMR (400 MHz, CDCl\textsubscript{3}) \(\delta\) 8.00 – 7.91 (m, 4H), 7.61 – 7.54 (m, 1H), 7.55 – 7.50 (m, 2H), 7.21 – 7.14 (m, 2H). \textsuperscript{13}C NMR (100 MHz, CDCl\textsubscript{3}) \(\delta\) 165.4 (d, \(J_{CF} = 256.0\) Hz), 141.6, 137.8, 133.4, 130.5 (d, \(J_{CF} = 9.6\) Hz), 129.3, 127.6, 116.7 (d, \(J_{CF} = 23.2\) Hz). HRMS (EI); Mass calcd for C_{12}H_{9}FO_{2}S [M]^+: 236.0307; found 236.0305.

![Structure](image)

4-(phenylsulfonyl)benzonitrile,\textsuperscript{3} 4d, yield 93%

\textsuperscript{1}H NMR (400 MHz, CDCl\textsubscript{3}) \(\delta\) 8.07 – 8.00 (m, 2H), 7.97 – 7.91 (m, 2H), 7.83 – 7.76 (m, 2H), 7.65 – 7.50 (m, 3H). \textsuperscript{13}C NMR (100 MHz, CDCl\textsubscript{3}) \(\delta\) 146.0, 140.3, 134.1, 133.2, 129.8, 128.4, 128.1, 117.3, 117.0. HRMS (EI); Mass calcd for C_{13}H_{9}NO_{2}S [M]^+: 243.0354; found 243.0355.

![Structure](image)

1-(4-methoxyphenylsulfonyl)-4-methoxybenzene,\textsuperscript{3} 4e, yield 78%

\textsuperscript{1}H NMR (400 MHz, CDCl\textsubscript{3}) \(\delta\) 7.89 – 7.79 (m, 4H), 7.03 – 6.92 (m, 4H), 3.85 (s, 6H). \textsuperscript{13}C NMR (100 MHz, CDCl\textsubscript{3}) \(\delta\) 163.3, 134.2, 129.7, 114.7, 55.7. HRMS (EI); Mass calcd for C_{14}H_{14}O_{4}S [M]^+: 278.0613; found 278.0615.
1-Fluoro-4-((4-methoxyphenyl)sulfonyl)benzene,\(^4\) 4f, yield 84%

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta \) 7.96 – 7.91 (m, 2H), 7.88 – 7.83 (m, 2H), 7.17 – 7.12 (m, 2H), 7.00 – 6.93 (m, 2H), 3.84 (s, 3H). \(^13\)C NMR (100 MHz, CDCl\(_3\)) \(\delta \) 165.2 (d, \(J_{CF} = 255.4 \) Hz), 163.4, 138.5 (d, \(J_{CF} = 3.2 \) Hz), 132.9, 130.1 (d, \(J_{CF} = 9.5 \) Hz), 129.9, 116.4 (d, \(J_{CF} = 22.8 \) Hz), 114.7, 55.7. HRMS (EI); Mass calcd for C\(_{13}\)H\(_{11}\)FO\(_3\)S [M\(^+\)]: 266.0413; found 266.0411.

\[\text{MeO} \quad \text{SO}_2 \quad \text{Cl} \]

1-Chloro-4-((4-methoxyphenyl)sulfonyl)benzene,\(^4\) 4g, yield 80%

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta \) 7.88 – 7.83 (m, 4H), 7.45 – 7.41 (m, 2H), 6.98 – 6.93 (m, 2H), 3.83 (s, 3H). \(^13\)C NMR (100 MHz, CDCl\(_3\)) \(\delta \) 163.5, 141.0, 139.3, 132.6, 129.9, 129.4, 128.6, 114.7, 55.5. HRMS (EI); Mass calcd for C\(_{13}\)H\(_{11}\)ClO\(_3\)S [M\(^+\)]: 282.0117; found 282.0118.

\[\text{MeO} \quad \text{SO}_2 \]

1-methoxy-4-(methylsulfonyl)benzene,\(^3\) 4h, yield 48%

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta \) 7.92–7.81 (m, 2H), 7.07–6.95 (m, 2H), 3.90 (s, 3H), 3.05 (s, 3H). \(^13\)C NMR (100 MHz, CDCl\(_3\)) \(\delta \) 163.9, 132.4, 129.5, 114.6, 55.8, 45.1. HRMS (EI); Mass calcd for C\(_8\)H\(_7\)NO\(_2\)S [M\(^+\)]: 186.0351; found 186.0349.

\[\text{NC} \quad \text{SO}_2 \]

4-(Methylsulfonyl)benzonitrile,\(^5\) 4i, yield 60%

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta \) 8.08 (d, \(J = 8.5 \) Hz, 2H), 7.92 (d, \(J = 8.5 \) Hz, 2H), 3.08 (s, 3H). \(^13\)C NMR (100 MHz, CDCl\(_3\)) \(\delta \) 144.5, 133.2, 128.3, 117.6, 117.1, 44.1. HRMS (EI); Mass calcd for C\(_8\)H\(_7\)NO\(_2\)S [M\(^+\)]: 181.0192; found 181.0194.
4-(Ethylsulfonyl)benzonitrile,\textsuperscript{5} 4j, yield 62%

\textsuperscript{1}H NMR (400 MHz, CDCl\textsubscript{3}) \(\delta \) 8.03 (d, \( J = 8.4 \) Hz, 2H), 7.90 (d, \( J = 8.4 \) Hz, 2H), 3.13 (q, \( J = 7.2 \) Hz, 2H), 1.32 (t, \( J = 7.2 \) Hz, 3H). \textsuperscript{13}C NMR (100 MHz, CDCl\textsubscript{3}) \(\delta \) 142.7, 133.1, 129.1, 117.5, 117.0, 50.5, 7.2. HRMS (EI); Mass calcd for C\textsubscript{9}H\textsubscript{9}NO\textsubscript{2}S [M]\textsuperscript{+}: 195.0349; found 195.0347.

4-(Cyclopropylsulfonyl)benzonitrile,\textsuperscript{5} 4k, yield 58%

\textsuperscript{1}H NMR (400 MHz, CDCl\textsubscript{3}) \(\delta \) 8.01 (d, \( J = 8.3 \) Hz, 2H), 7.87 (d, \( J = 8.3 \) Hz, 2H), 2.44–2.55 (m, 1H), 1.50–1.37 (m, 2H), 1.19–1.07 (m, 2H). \textsuperscript{13}C NMR (100 MHz, CDCl\textsubscript{3}) \(\delta \) 144.8, 132.9, 128.3, 117.1, 116.1, 32.6, 6.4. HRMS (EI); Mass calcd for C\textsubscript{10}H\textsubscript{9}NO\textsubscript{2}S [M]\textsuperscript{+}: 207.0349; found: 207.0351.

References


\textit{Copies of \textsuperscript{1}H and \textsuperscript{13}C-NMR spectra of compounds 3a-o ad 4a-k.}
$^{13}$C-NMR Spectrum

$^{1}$H-NMR Spectrum
\[ ^1H\text{-NMR Spectrum} \]

\[ ^{13}C\text{-NMR Spectrum} \]
$\text{H-NMR Spectrum}$

$\text{C-NMR Spectrum}$
$^1$H-NMR Spectrum

$^{13}$C-NMR Spectrum
$^{1}H$-NMR Spectrum

$^{13}$C-NMR Spectrum
$^{1}H$-NMR Spectrum

$^{13}C$-NMR Spectrum
$^{1}H$-NMR Spectrum

$^{13}C$-NMR Spectrum
$^1$H-NMR Spectrum

$^{13}$C-NMR Spectrum
$^1$H-NMR Spectrum

$^{13}$C-NMR Spectrum
$^{1}H$-NMR Spectrum

$^{13}C$-NMR Spectrum
$^1$H-NMR Spectrum
$^{13}$C-NMR Spectrum

$^{1}H$-NMR Spectrum
H-NMR Spectrum

13C-NMR Spectrum
$^{1}$H-NMR Spectrum

$^{13}$C-NMR Spectrum
$^{1}$H-NMR Spectrum

$^{13}$C-NMR Spectrum
$^1$H-NMR Spectrum

$^{13}$C-NMR Spectrum
$^{1}H$-NMR Spectrum

$^{13}C$-NMR Spectrum
$^{1}H$-NMR Spectrum

$^{13}C$-NMR Spectrum
$^1$H-NMR Spectrum

$^{13}$C-NMR Spectrum