Microwave-assisted Silver-catalyzed protodecarboxylation and decarboxylative iodination of aromatic carboxylic acids

Supporting Information

General Information

Anhydrous solvents and deuterated solvents were bought from Energy Chemical Company and used as received. All other chemicals were purchased from a chemical supplier and used as received, unless otherwise stated. TLC was performed on Merck Kieselgel 60 (particle size 40-63 μm) silica under positive pressure.

$^1$H NMR and $^{13}$C NMR spectra were determined by Bruker Ava 400 (400 MHz) instrument with chemical shift values reported in ppm residual solvent peaks: proton, CDCl$_3$: 7.26 ppm and carbon, CDCl$_3$: 77.0 ppm. $^1$H NMR and $^{19}$F NMR are obtained as follows: chemical shift (in ppm on the δ scale), multiplicity (bs = broad singlet, s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet), the coupling constant (J, in Hertz) and integration. $^{13}$C NMR data were obtained as the ppm on the δ scale followed by the interpretation and multiplicity where appropriate.

Microwave heating experiments were performed on CEM Discover-SP Microwave Reactor with max microwave power of 300 W and magnetic frequency of 2.45GHz. Standard Method: Temperature: 100-150°C; Microwave Power: 150 W; Stirring: high.

Gas Chromatography-Mass Spectrometry (GC-MS) was performed on Agilent 5975C Triple Axis GC-MS (EI/CI), equipped with J&W 122-5532 (325°C, 30m×250μm×0.25μm) column.

General procedures for microwave-assisted protodecarboxylation reaction of aromatic carboxylic acid

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\begin{align*}
\text{R} & \quad \text{O} \\
\text{1} & \quad \xrightarrow{\text{Ag(I), K$_2$S$_2$O$_8$}} \\
\text{MeCN, 130°C, Microwave 30 min} & \quad \text{H} \\
\text{2} & \\
\end{align*}
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An oven-dried microwave reaction vial (35 mL) was charged with carboxylic acid (0.50 mmol), silver(I) carbonate (15 mol%), potassium persulfate (2 equiv.) in 4 mL of acetonitrile. The mixture was heated in microwave reactor at 130°C for 30 minutes, then allowed to cool down.

For the measurement of volatile products, chlorobenzene (0.50 mmol) was added into the reaction mixture, and analysis was carried out on GC/MS. Otherwise the reaction mixture was diluted with Et₂O (10 mL) and washed with saturated aqueous NaHCO₃ (10 mL). The aqueous layer was extracted with Et₂O (2×10 mL) and the combined organic layers were dried with anhydrous MgSO₄, then filtered and concentrated under reduced pressure. The crude product was purified by the short silica column and eluted with n-Hexane.

2c, iodobenzene

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Prepared following the general procedure using 2-iodobenzoic acid (124.0 mg, 0.5 mmol) to afford the product as the colorless oil (65.0 mg, 65%).

\(^1\text{H NMR (400MHz, CDCl}_3\): } \delta 7.54 (d, J = 7.8 Hz, 2H), 7.18 (t, J = 7.6 Hz, 1H), 6.96 (t, J = 7.8 Hz, 2H). \(^{13}\text{C NMR (101MHz. CDCl}_3\): } \delta 137.5 (C-H), 130.3 (C-H), 127.5 (C-H), 94.4 (C). Mass spectrum: found 204[M], 77[M-I].

2g, naphthalene,

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Prepared following the general procedure using 1-Naphthoic acid (86.09 mg, 0.5 mmol) to afford naphthalene as white solid (50.0 mg, 77%).

\(^1\text{H NMR (400MHz, CDCl}_3\): } \delta 7.86-7.84 (m, 4H), 7.7.49-7.47 (m, 4H). \(^{13}\text{C NMR (101MHz. CDCl}_3\): } \delta 133.4 (C), 127.9 (C-H), 125.8 (C-H). Mass spectrum: found 128[M].

2i, 2-fluoro bromobenzene
Prepared following the general procedure using 3-bromo-4-fluoro benzoic acid (109.50 mg, 0.5 mmol) to afford 2-fluoro bromobenzene as colorless oil (52.3 mg, 60%).

$^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 7.63-7.53 (m, 1H), 7.35-7.29 (m, 1H), 7.15 (td, $J = 8.6$, 1.4 Hz, 1H), 7.06 (td, $J = 7.9$, 1.0 Hz, 1H). $^{13}$C NMR (101MHz. CDCl$_3$): $\delta$ 160.37, 157.91, 133.61, 128.95, 125.27, 116.67, 116.45, 109.18, 108.97. Mass spectrum: found 175[M], 95[M-Br].

**2k, 3, 4-Dimethoxy nitrobenzene**

Prepared following the general procedure using 2-nitrobenzoic acid (124.0 mg, 0.5 mmol) to afford as yellow solid (84.5 mg, 92%). $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.93 (d, $J = 8.9$ Hz, 1H), 7.75 (s, 1H), 6.92 (d, $J = 8.9$ Hz, 1H), 3.99 (s, 3H), 3.97 (s, 3H). $^{13}$C NMR (101MHz. CDCl$_3$): $\delta$ 154.5 (C-O), 148.9 (C-O), 141.5 (C-H), 117.8 (C-H), 109.8 (C-H), 106.5 (C-N). Mass spectrum: found 183[M], 137[M-NO$_2$], 107[M-NO$_2$-OCH$_3$].

**Protodecarboxylation reaction, deuterium exchange reaction**
General procedures for microwave-assisted decarboxylative iodination of aromatic carboxylic acid

An oven-dried microwave reaction vial (35 mL) was charged with benzoic acid (0.50 mmol), silver (I) carbonate (25 mol %), potassium persulfate (2 equiv.), sodium carbonate (2 equiv.) and iodine (2 equiv.) in 4 mL acetonitrile. The mixture was heated in microwave reactor at 130°C for 45 minutes, then allowed to cool down, diluted with EtOAc (10 mL) and washed with saturated aqueous Na₂S₂O₈ (10 mL). The resulting mixture was extracted with EtOAc (2×10 mL) and the combined organic layers were dried with anhydrous MgSO₄, then filtered and concentrated under reduced pressure. The crude product was purified by the short silica column and eluted with n-hexane.
3a, 2-Bromo Iodobenzene

[Diagram of 2-Bromo Iodobenzene]

Prepared following the general procedure using 2-bromobenzoic acid (100.0 mg, 0.5 mmol) to afford 2-bromo iodobenzene as yellow oil (137mg, 97%). $^1$H NMR (400 MHz, CDCl$_3$) δ 7.87 (d, $J$ = 7.9 Hz, 1H), 7.63 (d, $J$ = 8.0 Hz, 1H), 7.21 (t, $J$ = 7.7 Hz, 1H), 7.00 (t, $J$ = 7.6 Hz, 1H). $^{13}$C NMR (101MHz. CDCl$_3$): δ 140.4 (C-H), 132.8 (C-H), 129.8 (C-H), 129.5 (C-H), 128.4 (C-Br), 101.2(C-I). Mass spectrum: 283[M], 156[M-I].

3b, 4-Bromo Iodobenzene

[Diagram of 4-Bromo Iodobenzene]

Prepared following the general procedure using 4-bromobenzoic acid (100.0 mg, 0.5 mmol) to afford 4-bromo iodobenzene as yellow oil (102mg, 72%). $^1$H NMR (400 MHz, CDCl$_3$) δ 7.54 (d, $J$ = 7.9 Hz, 2H), 7.23 (d, $J$ = 8.0 Hz, 2H). $^{13}$C NMR (101MHz. CDCl$_3$): δ 139.1 (C-H), 133.5 (C-H), 122.2 (C-H), 92.0 (C-I). Mass spectrum: 283[M], 156[M-I].

3c, 1,2-Diiodobenzene

[Diagram of 1,2-Diiodobenzene]

Prepared following the general procedure using 2-iodobenzoic acid (124.0 mg, 0.5 mmol) to afford 1,2-diiodobenzene as brown oil (163mg, 99%). $^1$H NMR (400 MHz, CDCl$_3$): δ 7.99-7.77 (m, 2H), 7.11-6.89 (m, 2H). $^{13}$C NMR (101MHz. CDCl$_3$): δ 139.5 (C-H), 129.2 (C-H), 107.9 (C-I). Mass spectrum: 330[M], 203[M-I].

3d, 1, 4-Diiodobenzene
Prepared following the general procedure using 4-iodobenzoic acid (124.0 mg, 0.5 mmol) to afford 1, 4-diiodobenzene as brown oil (124 mg, 75%). \( ^1H \) NMR (400 MHz, CDCl\(_3\)) \( \delta \ 7.41 \) (s, 4H). \( ^{13}C \) NMR (101MHz. CDCl\(_3\)): \( \delta \ 139.3 \) (C-H), 93.3 (C-I). Mass spectrum: 330[M], 203[M-I].

3f, 4-Nitro Iodobenzene

Prepared following the general procedure using 4-nitrobenzoic acid (83.5 mg, 0.5 mmol) to afford 2-nitro iodobenzene as white solid (84 mg, 68%). \( ^1H \) NMR (400 MHz, CDCl\(_3\)) \( \delta \ 7.94 \) (d, \( J = 7.7 \) Hz, 1H), 7.30 (t, \( J = 7.8 \) Hz, 1H). \( ^{13}C \) NMR (101MHz. CDCl\(_3\)): \( \delta \ 141.9 \) (C-H), 133.4 (C-H), 129.0 (C-H), 128.5 (C-H), 125.4 (C-NO\(_2\)), 86.2(C-I). Mass spectrum: 249[M], 203[M-NO\(_2\)], 76[M-I-NO\(_2\)].

3g, 1-Iodonaphthalene

Prepared following the general procedure using 1-Naphthoic acid (86.1 mg, 0.5 mmol) to afford 2-iodonaphthalene as colorless oil (92 mg, 73%). \( ^1H \) NMR (400 MHz, CDCl\(_3\)) \( \delta \ 7.84 \) (d, \( J = 8.2 \) Hz, 1H), 7.77 (d, \( J = 7.7 \) Hz, 1H), 7.58 (t, \( J = 7.5 \) Hz, 1H), 7.52 (t, \( J = 7.4 \) Hz, 1H). \( ^{13}C \) NMR
(101MHz. CDCl₃): δ 137.5 (C-H), 134.4 (C-H), 134.2 (C-H), 132.2 (C-H), 129.0 (C-H), 128.6 (C-H), 127.7 (C-H), 126.9 (C-H), 126.7 (C-H), 99.6 (C-I). Mass spectrum: 254[M], 127[M-I].

3h, 2-Iodonaphthalene

![2-Iodonaphthalene](image)

Prepared following the general procedure using 2-Naphthoic acid (86.1 mg, 0.5 mmol) to afford 2-iodonaphthalene as brown oil (71 mg, 56%). ¹H NMR (400 MHz, CDCl₃) δ 8.24 (s, 1H), 7.80 (m, 1H), 7.78 (d, J = 7.7 Hz, 2H), 7.57 (d, J = 7.5 Hz, 1H), 7.49 (m, 2H). ¹³C NMR (101MHz. CDCl₃): δ 136.6 (C-H), 135.0 (C-H), 134.4 (C-H), 132.1 (C-H), 129.5 (C-H), 127.9 (C-H), 126.8 (C-H), 126.7 (C-H), 126.5 (C-H), 91.5 (C-I). Mass spectrum: 254[M], 127[M-I].

3i, 3-bromo-4-fluoro-iodobenzene

![3-bromo-4-fluoro-iodobenzene](image)

Prepared following the general procedure using 3-bromo-4-fluoro-benzoic acid (109.5 mg, 0.5 mmol) to afford 3-bromo-4-fluoro-iodobenzene as yellow oil (120 mg, 80%). ¹H NMR (400 MHz, CDCl₃) δ 7.87 (d, J = 6.2 Hz, 1H), 7.57 (s, 1H), 6.88 (t, J = 8.4 Hz, 1H). ¹³C NMR (101MHz. CDCl₃): δ 160.5 (C-H), 158.0 (C-H), 141.5 (C-H), 137.9 (C-H), 118.3 (C-F), 110.5 (C-Br), 87.1 (C-I). Mass spectrum: 300[M], 173[M-I], 94[M-I-Br].

3j, 3-chloro-4-fluoro-iodobenzene

Prepared following the general procedure, using 3-chloro-4-fluoro-benzoic acid (87.0 mg, 0.5mmol). Yield of 83% was measured by GC/MS.

3k, 2-Nitro-3,4-dimethoxy Iodobenzene
Prepared following the general procedure using 2-nitro-3, 4-dimethoxy benzoic acid (113.6 mg, 0.5 mmol) to afford 2-nitro-3,4-dimethoxy iodobenzene as yellow solid (131 mg, 85%). $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.63(s, 1H), 7.42 (s, 1H), 3.98(s, 3H), 3.96(s, 3H). $^{13}$C NMR (101MHz. CDCl$_3$): $\delta$ 152.8 (C-O), 149.1 (C-O), 145.1 (C-N), 123.1 (C-H), 109.0 (C-H), 77.2(C-I), 56.7 (C-3H), 56.4 (C-3H). Mass spectrum: 309[M], 263[M-NO$_2$], 236[M-NO$_2$-OCH$_3$].

3l, 3-iodo-5-bromopyridine

Prepared following the general procedure using 5-Bromonicotinic acid (100.0 mg, 0.5 mmol). The yield of 63% was measured by GC/MS.

3m, 1-iodo-3-methoxybenzene

Prepared following the general procedure using 3-methoxybenzoic acid (76.0 mg, 0.5 mmol). The product was analyzed by GC/MS, as a mixture of di-, triiodio substituted products, and the combined yield was 97%.

3n, 2,4-diiodo-1-methoxybenzene

Prepared following the general procedure using 4-methoxybenzoic acid (76.0 mg, 0.5 mmol). The product was analyzed by GC/MS to give the yield of 86%.

3o, 3-Trifluoromethyl Iodobenzene
Prepared following the general procedure using 3-trifluoromethyl benzoic acid (95.0 mg, 0.5 mmol) to afford 3-trifluoromethyl iodobenzene as brown solid (125 mg, 92%). $^1$H NMR (400 MHz, CDCl$_3$) δ 8.41 (d, $J = 7.9$ Hz, 1H), 8.33 (d, $J = 8.0$ Hz, 1H), 7.91 (t, $J = 7.7$ Hz, 1H), 7.67 (t, $J = 7.6$ Hz, 1H). Mass spectrum: 272[M], 145[M-I].

3p, 4-Trifluoromethyl Iodobenzene

Prepared following the general procedure using 4-trifluoromethyl benzoic acid (95.0 mg, 0.5 mmol) to afford 4-trifluoromethyl iodobenzene as brown solid (102 mg, 75%). $^1$H NMR (400 MHz, CDCl$_3$) δ 8.26 (d, $J = 7.9$ Hz, 2H), 7.78 (d, $J = 8.0$ Hz, 2H). Mass spectrum: 272[M], 145[M-I].

3q, 2-Fluoro Iodobenzene

Prepared following the general procedure using 2-fluorobenzoic acid (70.1 mg, 0.5 mmol) to afford 2-fluoro iodobenzene as brown solid (100 mg, 90%). $^1$H NMR (400 MHz, CDCl$_3$) δ 8.04 (d, $J = 7.9$ Hz, 1H), 7.58 (d, $J = 8.0$ Hz, 1H), 7.23 (t, $J = 7.7$ Hz, 1H), 7.21-7.09 (t, $J = 7.6$ Hz, 1H). Mass spectrum: 222[M], 95[M-I].

3r, 4-Fluoro Iodobenzene

Prepared following the general procedure using 4-fluorobenzoic acid (70.1 mg, 0.5 mmol) to afford 2-fluoro iodobenzene as brown solid (72 mg, 65%). $^1$H NMR (400 MHz, CDCl$_3$) δ 8.16 (dd, $J = 7.4$ Hz, 2H), 7.18 (t, $J = 8.3$ Hz, 2H), $^{13}$C NMR (101 MHz, CDCl$_3$): δ 161.7 (C-F), 132.9 (C-H), 115.9 (C-H), 84.3 (C-I). Mass spectrum: 222[M], 95[M-I].