A highly efficient TBAF-promoted intramolecular cyclization of \( \text{gem} \)-dibromoolefins for the synthesis of 2-bromobenzofurans(thiophenes)

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1. Physical measurements and materials

All \( ^1\text{H} \) NMR and \( ^{13}\text{C} \) NMR spectra were recorded on a 400 MHz Bruker FT-NMR spectrometers. All chemical shifts are given as \( \delta \) value (ppm) with reference to tetramethylsilane (TMS) as an internal standard. High resolution mass spectroscopy data of the product were collected on a Waters Micromass GCT instrument. Products were purified by flash chromatography on 100–200 mesh silica gels, SiO\textsubscript{2}. Unless otherwise noted, the chemicals and solvents were purchased from commercial suppliers either from Aldrich, USA or Shanghai Chemical Company, China and were used without purification prior to use.
2. Typical procedure for the intramolecular cyclization

A Schlenk tube with a magnetic stirring bar was charged with 2-(gem-dibromovinyl)phenol (1a), TBAF (1.0 M solution in THF, 1.0 mL, 1.0 mmol), and THF (1.0 mL). The reaction mixture was stirred for 10 min at room temperature, and then heated at 45 °C for 4 h. After the reaction mixture was cooled to ambient temperature, the solvent was removed under reduced pressure. The residue was purified by flash chromatography on silica gel (eluant: hexane/ethyl acetate) to give the intramolecular cyclization product, 2-bromobenzofuran (2a, 195 mg, 99% yield).

3. Optimization of partial reaction conditions

Table The effect of solvent on the intramolecular cyclization of 2-(gem-dibromovinyl)phenol (1a)\textsuperscript{a}

<table>
<thead>
<tr>
<th>Entry</th>
<th>Solvent</th>
<th>Yield (%)\textsuperscript{b}</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>THF</td>
<td>99</td>
</tr>
<tr>
<td>2</td>
<td>CH\textsubscript{3}CN</td>
<td>98</td>
</tr>
<tr>
<td>3</td>
<td>DMF</td>
<td>99</td>
</tr>
<tr>
<td>4</td>
<td>DMSO</td>
<td>97</td>
</tr>
<tr>
<td>5</td>
<td>1,4-Dioxane</td>
<td>96</td>
</tr>
<tr>
<td>6</td>
<td>Toluene</td>
<td>81</td>
</tr>
<tr>
<td>7</td>
<td>H\textsubscript{2}O</td>
<td>NR</td>
</tr>
<tr>
<td>8</td>
<td>CH\textsubscript{3}CH\textsubscript{2}OH</td>
<td>NR</td>
</tr>
<tr>
<td>9</td>
<td>CH\textsubscript{3}CH\textsubscript{2}CH\textsubscript{2}OH</td>
<td>NR</td>
</tr>
</tbody>
</table>

\textsuperscript{a} Reaction conditions: 2-(gem-dibromovinyl)phenol (1a, 1.0 mmol), TBAF (1.0 mmol), solvent (2.0 mL) at 45 °C for 4 h. \textsuperscript{b} Isolated yield.

4. Further transformation of 2-bromobenzofuran

When the prepared 2-bromobenzofuran (2a) reacted with phenylboronic acid and phenylacetylene under the classic Suzuki reaction conditions (See: S. Thielges, E. Meddah, P. Bisseret, J. Eustache, Tetrahedron Lett. 2004, 45, 907–910) and Sonogashira reaction conditions (See: M. Nagamochi, Y.-Q. Fang, M. Lautens, Org. Lett. 2007, 9, 2955–2958), the corresponding cross-coupling product 3a and 4a were isolated in 90%, and 92% yields, respectively.
5. Characterization data for the intramolecular cyclization products

2a (Colorless oil):¹ \( ^1H \) NMR (400 Hz, CDCl₃): \( \delta = 7.43 - 7.50 \) (m, 2H), 7.19 - 7.26 (m, 2H), 6.71 (s, 1H); \(^{13}C\) NMR (100 Hz, CDCl₃): \( \delta = 155.7, 128.7, 128.2, 124.2, 123.3, 120.1, 110.9, 108.2 \).

2b (White solid, m.p. 41 - 43 °C):¹ \( ^1H \) NMR (400 Hz, CDCl₃): \( \delta = 7.48 \) (d, \( J = 1.2 \) Hz, 1H), 7.37 (d, \( J = 8.8 \) Hz, 1H), 7.23 (dd, \( J_1 = 8.8 \) Hz, \( J_2 = 1.2 \) Hz, 1H), 6.69 (s, 1H); \(^{13}C\) NMR (100 Hz, CDCl₃): \( \delta = 154.1, 129.9, 129.8, 129.1, 124.4, 119.6, 111.8, 108.0 \).

2c (Yellow solid, m.p. 55 - 58 °C):¹ \( ^1H \) NMR (400 Hz, CDCl₃): \( \delta = 7.64 \) (d, \( J = 0.8 \) Hz, 1H), 7.31 - 7.38 (m, 2H), 6.69 (s, 1H); \(^{13}C\) NMR (100 Hz, CDCl₃): \( \delta = 154.4, 130.5, 129.7, 127.1, 122.7, 116.6, 112.3, 107.8 \).

2d (White solid, m.p. 70 - 72 °C): \( ^1H \) NMR (400 Hz, CDCl₃): \( \delta = 7.37 \) (d, \( J = 1.6 \) Hz, 1H), 7.23 (d, \( J = 8.8 \) Hz, 1H), 7.12 (m, 2H), 6.75 (s, 1H); \(^{13}C\) NMR (100 Hz, CDCl₃): \( \delta = 154.4, 130.5, 129.7, 127.1, 122.7, 116.6, 112.3, 107.8 \).

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¹ Electronic Supplementary Material (ESI) for Chemical Communications.
1H), 7.26 (d, $J = 1.2$ Hz, 1H), 6.72 (s, 1H); $^{13}$C NMR (100 Hz, CDCl$_3$): $\delta = 150.2$, 130.8, 130.8, 129.4, 124.5, 118.3, 116.9, 108.7. HRMS (EI): calcd for C$_8$H$_3$BrCl$_2$O, 263.8742; found, 263.8744.

![Chemical structure](image)

2e (Yellow solid, m.p. 87–89 °C): $^1$H NMR (400 Hz, CDCl$_3$): $\delta = 7.59$ (d, $J = 1.6$ Hz, 1H), 7.57 (d, $J = 1.2$ Hz, 1H), 6.76 (s, 1H); $^{13}$C NMR (100 Hz, CDCl$_3$): $\delta = 152.0$, 131.1, 130.7, 129.7, 121.9, 116.8, 108.7, 104.2. HRMS (EI): calcd for C$_8$H$_3$Br$_3$O, 351.7730; found, 351.7734.

![Chemical structure](image)

2f (Yellow solid, m.p. 80–82 °C): $^1$H NMR (400 Hz, CDCl$_3$): $\delta = 7.44$–7.42 (m, 2H), 6.76 (s, 1H). $^{13}$C NMR (100 Hz, CDCl$_3$): $\delta = 151.7, 130.8, 130.4, 129.7, 127.2, 118.9, 108.9, 103.8$. HRMS (EI): calcd for C$_8$H$_3$Br$_2$ClO, 307.8237; found, 307.8239.

![Chemical structure](image)

2g (White solid, m.p. 76–78 °C): $^1$H NMR (400 Hz, CDCl$_3$): $\delta = 7.25$ (d, $J = 1.6$ Hz, 1H), 6.90 (d, $J = 1.2$ Hz, 1H), 6.66 (s, 1H), 3.99 (s, 3H); $^{13}$C NMR (100 Hz, CDCl$_3$): $\delta = 145.0, 144.1, 131.4, 129.3, 116.7, 115.0, 110.2, 108.1, 56.4$. HRMS (EI): calcd for C$_9$H$_6$Br$_2$O$_2$, 303.8734; found, 303.8735.

![Chemical structure](image)

2h (Yellow solid, m.p. 94–96 °C): $^1$H NMR (400 Hz, CDCl$_3$): $\delta = 8.46$ (d, $J = 2.0$ Hz, 1H), 8.22 (dd, $J_1 = 9.2$ Hz, $J_2 = 2.0$ Hz, 1H), 7.56 (d, $J = 8.8$ Hz, 1H), 6.91 (s, 1H); $^{13}$C
NMR (100 Hz, CDCl₃): δ = 158.3, 144.6, 131.9, 129.0, 120.1, 116.5, 111.3, 109.2. HRMS (EI): calcd for C₈H₃BrNO₃, 240.9372; found, 240.9375.

2i (Colorless oil):¹ ¹H NMR (400 Hz, CDCl₃): δ = 7.37 (d, J = 8.4 Hz, 1H), 7.00 (d, J = 1.2 Hz, 1H), 6.88 (dd, J₁ = 8.0 Hz, J₂ = 2.0 Hz, 1H), 6.65 (s, 1H), 3.85 (s, 3H); ¹³C NMR (100 Hz, CDCl₃): δ = 157.8, 156.6, 126.0, 122.0, 120.1, 112.2, 108.0, 95.7, 55.7.

2j (Colorless oil):¹ ¹H NMR (400 Hz, CDCl₃): δ = 7.16 (t, J = 8.0 Hz, 1H), 7.10 (d, J = 7.6 Hz, 1H), 6.78 (d, J = 8.0 Hz, 1H), 6.72 (s, 1H), 4.01 (s, 3H); ¹³C NMR (100 Hz, CDCl₃): δ = 145.1, 144.7, 130.3, 128.1, 124.1, 112.3, 108.6, 106.5, 56.1.

2k (Colorless oil):¹ ¹H NMR (400 Hz, CDCl₃): δ = 8.01 (d, J = 8.0 Hz, 1H), 7.90 (d, J = 8.4 Hz, 1H), 7.66 (d, J = 8.8 Hz, 1H), 7.54–7.58 (m, 2H), 7.46–7.50 (t, J = 7.6 Hz, 1H), 7.16 (s, 1H); ¹³C NMR (100 Hz, CDCl₃): δ = 153.4, 130.3, 128.7, 126.6, 126.6, 126.3, 125.1, 124.9, 124.1, 123.3, 111.7, 107.4.

2l (Colorless oil):¹¹H NMR (400 Hz, CDCl₃): δ = 7.38–7.36 (m, 1H), 7.18–7.17 (m, 2H), 6.72 (s, 1H), 1.52 (s, 9H); ¹³C NMR (100 Hz, CDCl₃): δ = 154.2, 134.6, 129.3, 127.1, 123.3, 121.0, 118.0, 108.1, 34.3, 29.8. HRMS (EI): calcd for C₁₂H₁₃BrO,
2m (Colorless oil): $^1$H NMR (400 Hz, CDCl$_3$): $\delta = 7.52-7.44$ (m, 2H), 7.31-7.24 (m, 2H), 6.60 (s, 1H); $^{13}$C NMR (100 Hz, CDCl$_3$): $\delta = 154.1, 141.4, 128.3, 124.2, 123.4, 120.2, 110.9, 103.1$. HRMS (EI): calcd for C$_8$H$_5$ClO, 152.0028; found, 152.0029.

2n (Colorless oil): $^1$H NMR (400 Hz, CDCl$_3$): $\delta = 7.75-7.69$ (m, 2H), 7.36-7.30 (m, 3H); $^{13}$C NMR (100 Hz, CDCl$_3$): $\delta = 141.0, 139.5, 126.6, 124.7, 124.5, 122.7, 121.6, 115.4$.

2o (White solid, m.p. 35–37 $^\circ$C): $^1$H NMR (400 Hz, CDCl$_3$): $\delta = 7.60$ (d, $J = 8.0$ Hz, 1H), 7.51 (s, 1H), 7.32 (d, $J = 7.6$ Hz, 1H), 7.24 (t, $J = 8.0$ Hz, 1H); $^{13}$C NMR (100 Hz, CDCl$_3$): $\delta = 141.9, 137.9, 127.7, 125.1, 125.0, 124.7, 120.0, 116.6$.

2p (White solid, m.p. 55–57 $^\circ$C): $^1$H NMR (400 Hz, CDCl$_3$): $\delta = 7.80$ (d, $J = 2.0$ Hz, 1H), 7.55 (d, $J = 8.4$ Hz, 1H), 7.41 (dd, $J_1 = 8.0$ Hz, $J_2 = 2.0$ Hz, 1H), 7.23 (s, 1H); $^{13}$C NMR (100 Hz, CDCl$_3$): $\delta = 140.9, 139.4, 127.4, 125.7, 125.2, 122.7, 118.8, 117.2$.

2q (White solid, m.p. 48–50 $^\circ$C): $^1$H NMR (400 Hz, CDCl$_3$): $\delta = 7.84$ (s, 1H), 7.51 (d, $J = 8.4$ Hz, 1H), 7.42 (dd, $J_1 = 8.4$ Hz, $J_2 = 1.6$ Hz, 1H), 7.26 (s, 1H); $^{13}$C NMR (100 Hz, CDCl$_3$): $\delta = 154.1, 141.4, 128.3, 124.2, 123.4, 120.2, 110.9, 103.1$. HRMS (EI): calcd for C$_8$H$_5$ClO, 152.0028; found, 152.0029.
Hz, CDCl₃): δ = 142.2, 138.2, 128.2, 126.2, 124.0, 123.7, 118.4, 115.9.

6. ¹H NMR, ¹³C NMR spectra and HRMS data
7. References