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# Iodobenzene-Promoted Pd-Catalysed *ortho*-Directed C–H Activation: The Synthesis of Benzothiazoles via Intramolecular Coupling

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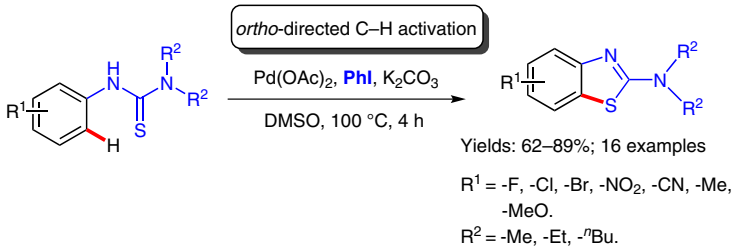


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**Abstract** A series of 2-aminobenzothiazoles were synthesized by a palladium-catalysed oxidative coupling with good yields (62–89%). Iodobenzene was found to be effective as an additive in this intramolecular C–S bond-formation reaction. The directing thiourea group attached to the aryl ring is essential for the activation of the *ortho* C–H bond.

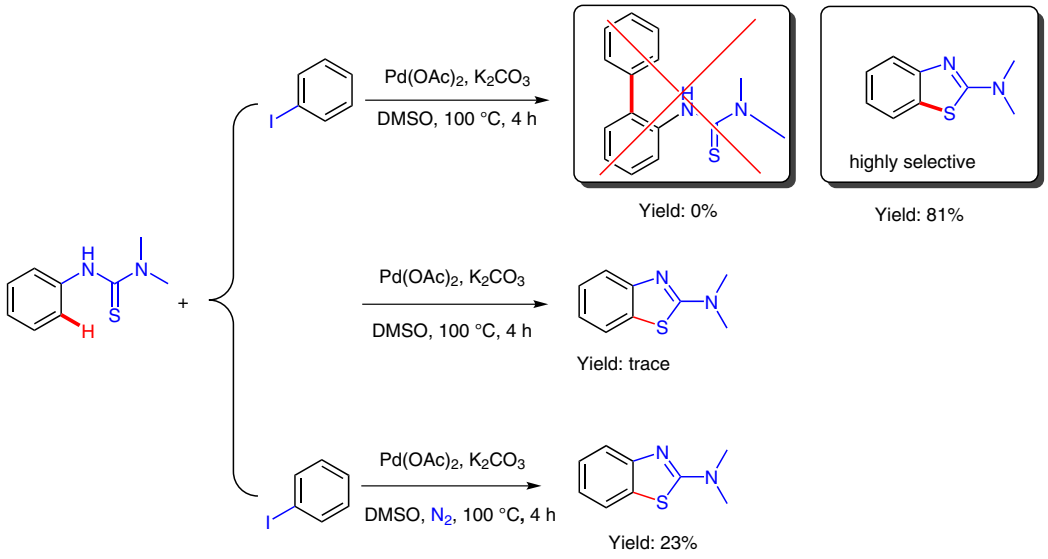
**Key words** palladium, iodobenzene, C–H activation, synthesis, aminobenzothiazole

Benzothiazole derivatives represent an extensive group of heterocyclic compounds, several of which have already found application in the medical sphere as antitumor agents[1] with selective growth inhibitory properties against human cancer cell lines and in agriculture as plant growth regulators (PGR).[2] 2-Aminobenzothiazoles can be obtained through either intermolecular transformations, which are dominated by condensation reactions,[3–7] or intramolecular transformations, which include cross-coupling reactions[8–10] starting from *ortho*-haloaryl thioureas, and oxidative coupling reactions.[11–15] Herein, we present an iodobenzene-promoted Pd-catalysed synthesis of benzothiazoles via intramolecular coupling.

The initial study involved palladium-catalysed *ortho*-directed C–H activation for cross-coupling with iodobenzene. The model reaction we chose was the intermolecular oxidative coupling reaction between 1,1-dimethyl-3-phenylthiourea and iodobenzene. Gratifyingly, the intermolecular cross-coupling product was not detected, and the intramolecular cyclisation product (2-aminobenzothiazole) was furnished with a satisfactory yield of 81% (Scheme 1). The oxidative coupling product could not be obtained when no iodobenzene was present. Much less (23%) intramolecular cyclisation product was formed when the reaction was performed under nitrogen, revealing that atmospheric oxygen was the oxidant, and that iodobenzene was a necessary additive.

Encouraged by these results, we began to optimise the reaction conditions. First, a broad screening of copper and palladium catalysts revealed that copper salts were ineffective (Table1, entries 1–3), but palladium catalysts, for example, $PdBr_2$, $PdCl_2$, $Pd(OAc)_2$ could catalyse the model reaction to give the cyclisation products with 64%, 69% and 81% isolated yields, respectively (Table1, entries 5, 4 and 8). Various other additives, for example, pyridine, ethyldiisopropylamine, KF, CsF and LiCl (Table 1, entries 18–22) that might promote the model reaction were screened, but results showed that these additives were less active than iodobenzene in promoting the intramolecular cyclisation. The additive loading was also investigated, with the optimal additive loading being found to be 0.5 equiv, with 1.0 or 1.5 equiv not improving the yield significantly, and a lower loading (0.1 equiv relative to thiourea) resulted in the yield reducing to 65%.

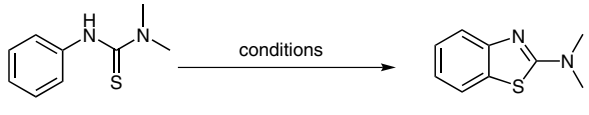
Substituted iodobenzenes proved to be less reactive than iodobenzene (Table 1, entries 8, 16 and 17). A range of bases, such as NaH, $CH_3ONa$, NaOH, KO*t*-Bu, $Cs_2CO_3$, $K_2CO_3$, $Na_2CO_3$ and $NEt_3$ was surveyed and $K_2CO_3$ was found to be the most suitable base for this reaction (Table 1, entries 8–15). Solvent and temperature studies showed that DMSO was the best solvent (Table 1, entries 8, 23–25) and 100 °C was the optimal temperature (Table1, entries 8, 26–28). Under the optimal reaction conditions, various substituted *N*-arylthioureas (**1a–p**) underwent cyclisation smoothly, providing the corresponding 2-aminobenzothiazoles (**2a–p**) in good yields. Substrate scope experiments revealed that arylthioureas bearing electron-withdrawing groups at the *para*- (**1b–h**), *meta*- (**1i**) and *ortho*- (**1j**, **1k**) positions cyclised well, giving 73–89% isolated yields (Table 2, entries




**Scheme 1** Control experiments for the PhI-promoted synthesis of benzothiazole

2–8, 9, 10–11). However, electron-donating *p*-MeO (**1l**), *p*-Me (**1m**) substituents on the *N*-arylthiourea slowed the reaction and decreased the yields (Table 2, entries 12, 13). Presumably due to steric hindrance from the bulky alkylated amino group, the cyclisation yields of **2a**, **2n** and **2o** decreased in turn, and substrate **1o** and **1p**, which bear two butyl groups on the nitrogen (Table 2, entries 15, 16), afforded the products in moderate yields (63% for **1o**, 62% for **1p**).

**Table 1** Optimization of Model Reaction Conditions[a]

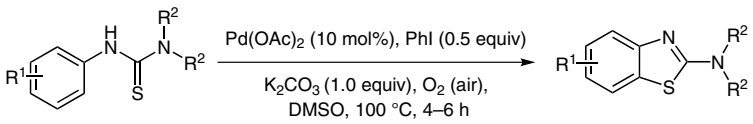



**1a** **2a**

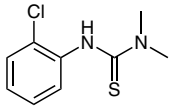
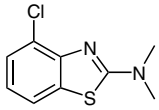
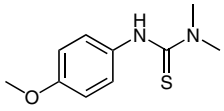
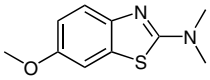
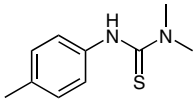
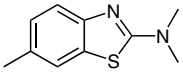
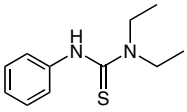
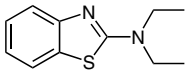
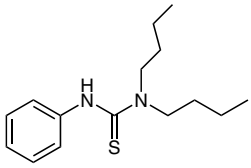
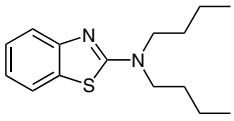
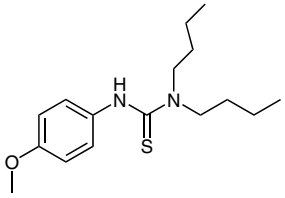
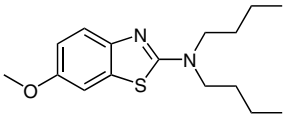
| Entry | Catalyst | Additive | Base | Solvent | Temp. (°C) | Yield (%)[b] |
|---|---|---|---|---|---|---|
| 1 | $Cu(OAc)_2$ | PhI | $K_2CO_3$ | DMSO | 100 | 0 |
| 2 | CuO | PhI | $K_2CO_3$ | DMSO | 100 | 0 |
| 3 | CuI | PhI | $K_2CO_3$ | DMSO | 100 | 0 |
| 4 | $PdCl_2$ | PhI | $K_2CO_3$ | DMSO | 100 | 69 |
| 5 | $PdBr_2$ | PhI | $K_2CO_3$ | DMSO | 100 | 64 |
| 6 | $Pd(dba)_2$ | PhI | $K_2CO_3$ | DMSO | 100 | 54 |
| 7 | $Pd(PPh_3)_4$ | PhI | $K_2CO_3$ | DMSO | 100 | N.R |
| 8 | **$Pd(OAc)_2$** | **PhI** | **$K_2CO_3$** | **DMSO** | **100** | **81** |
| 9 | $Pd(OAc)_2$ | PhI | KO*t*-Bu | DMSO | 100 | N.R |
| 10 | $Pd(OAc)_2$ | PhI | $Cs_2CO_3$ | DMSO | 100 | 56 |
| 11 | $Pd(OAc)_2$ | PhI | $CH_3ONa$ | DMSO | 100 | 58 |
| 12 | $Pd(OAc)_2$ | PhI | $Na_2CO_3$ | DMSO | 100 | 36 |
| 13 | $Pd(OAc)_2$ | PhI | $Et_3N$ | DMSO | 100 | 29 |
| 14 | $Pd(OAc)_2$ | PhI | NaOH | DMSO | 100 | 57 |
| 15 | $Pd(OAc)_2$ | PhI | NaH | DMSO | 100 | 44 |
| 16 | $Pd(OAc)_2$ | 4-iodotoluene | $K_2CO_3$ | DMSO | 100 | 69 |
| 17 | $Pd(OAc)_2$ | 1-iodo-4-nitro-benzene | $K_2CO_3$ | DMSO | 100 | N.R |
| 18 | $Pd(OAc)_2$ | pyridine | $K_2CO_3$ | DMSO | 100 | 19 |
| 19 | $Pd(OAc)_2$ | $(i\text{-}Pr)_2NEt$ | $K_2CO_3$ | DMSO | 100 | 17 |
| 20 | $Pd(OAc)_2$ | KF | $K_2CO_3$ | DMSO | 100 | trace |
| 21 | $Pd(OAc)_2$ | CsF | $K_2CO_3$ | DMSO | 100 | trace |
| 22 | $Pd(OAc)_2$ | LiCl | $K_2CO_3$ | DMSO | 100 | 16 |
| 23 | $Pd(OAc)_2$ | PhI | $K_2CO_3$ | DMF | 100 | 33 |
| 24 | $Pd(OAc)_2$ | PhI | $K_2CO_3$ | DMAC | 100 | 27 |
| 25 | $Pd(OAc)_2$ | PhI | $K_2CO_3$ | $PhCH_3$ | 100 | trace |
| 26 | $Pd(OAc)_2$ | PhI | $K_2CO_3$ | DMSO | 110 | 72 |
| 27 | $Pd(OAc)_2$ | PhI | $K_2CO_3$ | DMSO | 90 | 64 |
| 28 | $Pd(OAc)_2$ | PhI | $K_2CO_3$ | DMSO | 80 | 44 |

[a] Reaction conditions: **1a** (1.0 mmol), catalyst (10% mmol), additive (0.5 equiv), base (1.0 equiv), $O_2$ (air), DMSO (2 mL) for 4–6 h.
[b] Isolated yield.

**Table 2** Iodobenzene-Promoted Pd-Catalysed Synthesis of Benzothiazoles via an Intramolecular Coupling[a]




| Entry | Substrate | Product | Time (h) | Yield (%)[b] |
|---|---|---|---|---|
| 1 | **1a** | **2a** | 4.0 | 81 |
| 2 | **1b** | **2b** | 4.0 | 77 |
| 3 | **1c** | **2c** | 4.0 | 76 |
| 4 | **1d** | **2d** | 4.0 | 74 |
| 5 | **1e** | **2e** | 4.0 | 83 |
| 6 | **1f** | **2f** | 4.0 | 75 |
| 7 | **1g** | **2g** | 4.0 | 87 |
| 8 | **1h** | **2h** | 4.0 | 73 |
| 9 | **1i** | **2i** | 4.0 | 76 |
| 10 | **1j** | **2j** | 4.0 | 74 |

| Entry | Substrate | Product | Time (h) | Yield (%)[b] |
|---|---|---|---|---|
| 11 |  **1k** |  **2k** | 4.0 | 89 |
| 12 |  **1l** |  **2l** | 6.0 | 71 |
| 13 |  **1m** |  **2m** | 6.0 | 73 |
| 14 |  **1n** |  **2n** | 4.0 | 79 |
| 15 |  **1o** |  **2o** | 4.0 | 63 |
| 16 |  **1p** |  **2p** | 6.0 | 62 |

[a] Reaction conditions: **1** (1.0 mmol), catalyst (10% mmol), additive (0.5 mmol), base (1.0 mmol), $O_2$ (air), DMSO (2 mL) for 4–6 h.
[b] Isolated yield.

In summary, we have presented an iodobenzene-promoted Pd-catalysed synthesis of benzothiazoles via an intramolecular coupling. A series of 2-aminobenzothiazoles was synthesised by a palladium-catalysed oxidative coupling in good yields (62–89%). Iodobenzene was found to be an effective additive in this intramolecular C–S bond-formation reaction. A directing group (thiourea) attached to the aryl ring is essential for activation of the *ortho* C–H. This protocol is experimentally simple and shows broad substrate scope, affording the 2-aminobenzothiazoles, and could be attractive in the fields of medicinal chemistry and materials science.

All reactions were carried out in dried glassware with septa. All starting materials were purchased from commercial suppliers. DMSO was dried over molecular sieves. Yields refer to isolated compounds estimated to be >95% pure as determined by $^1$H NMR and capillary GC analysis.

### Typical Procedure for the Preparation of 2-Aminobenzothiazoles in the Presence of Iodobenzene and Palladium Diacetate

1,1-Dimethyl-3-phenylthiourea (1.0 mml), $Pd(OAc)_2$ (10% mmol), $K_2CO_3$ (1.0 mmol), iodobenzene (0.5 mmol) were placed in a dried tube equipped with a septum and magnetic stirrer bar, and DMSO (2 mL) was then added. The mixture was stirred at 100 °C and the reaction was followed by TLC until the starting material was consumed (ca. 4–6 h). The reaction was cooled to r.t., quenched with sat. $NH_4Cl$ solution (5 mL) and then extracted with EtOAc (10 mL). The organic extract was dried over anhydrous $Na_2SO_4$, filtered and evaporated under vacuum. The residue was purified by flash column chromatography with a solvent system as described below to afford the desired product.

**N,N-Dimethylbenzo[*d*]thiazol-2-amine (Table 2, entry 1, 2a)**

The residue was purified by flash chromatography on silica gel (EtOAc/PE = 1:3) to give the target compound **2a** (144 mg, 81%) as a dark-yellow solid; mp 82–84 °C.

$^1$H NMR (400 MHz, $CDCl_3$): δ = 7.6 (t, *J* = 7.6 Hz, 2 H), 7.33 (t, *J* = 8.0 Hz, 1 H), 7.10 (t, *J* = 7.6 Hz, 1 H), 3.23 (s, 6 H).

$^{13}$C NMR (100 MHz, $CDCl_3$): δ = 168.77, 153.08, 131.01, 125.98, 120.96, 120.66, 110.72, 40.22.

HRMS (ESI): *m*/*z* calcd for $C_9H_{10}N_2S$: 178.0565; found: 178.0543.

**6-Bromo-N,N-dimethylbenzo[*d*]thiazol-2-amine (Table 2, entry 2, 2b)**

The residue was purified by flash chromatography on silica gel (EtOAc/PE = 1:3) to give the target compound **2b** (198 mg, 77%) as a fawn solid; mp 109–112 °C.

$^1$H NMR (400 MHz, $CDCl_3$): δ = 7.66 (s, 1 H), 7.40–7.33 (m, 2 H), 3.17 (s, 6 H).

$^{13}$C NMR (100 MHz, $CDCl_3$): δ = 168.81, 151.97, 132.61, 129.16, 123.11, 119.81, 113.20, 40.29.

HRMS (ESI): *m*/*z* calcd for $C_9H_{10}N_2S$: 255.9670; found: 255.9681.

**6-Nitro-N,N-dimethylbenzo[*d*]thiazol-2-amine (Table 2, entry 3, 2c)**

The residue was purified by flash chromatography on silica gel (EtOAc/PE = 1:1) to give the target compound **2c** (169 mg, 76%) as a bright-yellow solid; mp 209–211 °C.

$^1$H NMR (400 MHz, $CDCl_3$): δ = 8.44 (s, 1 H), 8.14 (d, *J* = 8.8 Hz, 1 H), 7.46 (d, *J* = 8.8 Hz, 1 H), 3.23 (s, 6 H).

$^{13}$C NMR (100 MHz, $CDCl_3$): δ = 172.03, 158.37, 141.34, 131.21, 122.62, 117.79, 117.24, 40.43.

HRMS (ESI): *m*/*z* calcd for $C_9H_{10}N_2S$: 223.0415; found: 224.0420.

**6-Nitrile-N,N-dimethylbenzo[*d*]thiazol-2-amine (Table 2, entry 4, 2d)**

The residue was purified by flash chromatography on silica gel (EtOAc/PE = 1:1) to give the target compound **2d** (150 mg, 74%) as a grey solid; mp 162–164 °C.

$^1$H NMR (400 MHz, $CDCl_3$): δ = 7.79 (s, 1 H), 7.47 (s, 2 H), 3.30 (s, 6 H).

$^{13}$C NMR (100 MHz, $CDCl_3$): δ = 170.97, 156.53, 131.63, 130.03, 124.75, 119.73, 118.76, 103.15.

HRMS (ESI): *m*/*z* calcd for $C_9H_{10}N_2S$: 203.0517; found: 203.0519.

**6-Chloro-N,N-dimethylbenzo[*d*]thiazol-2-amine (Table 2, entry 5, 2e)**

The residue was purified by flash chromatography on silica gel (EtOAc/PE = 1:3) to give the target compound **2e** (175 mg, 83%) as a brown solid; mp 102–104 °C.

$^1$H NMR (400 MHz, $CDCl_3$): δ = 7.46 (s, 1 H), 7.38 (d, *J* = 8.8 Hz, 1 H), 7.17 (d, *J* = 8.4, 1 H), 3.08 (s, 6 H).

$^{13}$C NMR (100 MHz, $CDCl_3$): δ = 168.83, 151.72, 132.19, 126.38, 125.97, 120.29, 119.33, 40.36.

HRMS (ESI): *m*/*z* calcd for $C_9H_{10}N_2S$; 212.0175; found: 212.0182.

**6-Fluoro-N,N-dimethylbenzo[*d*]thiazol-2-amine (Table 2, entry 6, 2f)**

The residue was purified by flash chromatography on silica gel (EtOAc/PE = 1:3) to give the target compound **2f** (147 mg, 75%) as a white solid; mp 118–120 °C.

$^1$H NMR (400 MHz, $CDCl_3$): δ = 7.40–7.37 (m, 1 H), 7.19 (d, *J* = 8.0 Hz, 1 H), 6.92 (t, *J* = 8.0 Hz, 1 H), 3.03 (6 H).

$^{13}$C NMR (100 MHz, $CDCl_3$): δ = 168.33, 157.85 (d, $^1J_{C-F}$ = 237.9 Hz), 149.34, 131.52 (d, $^3J_{C-F}$ = 10.6 Hz), 119.04 (d, $^3J_{C-F}$ = 8.6 Hz), 113.57 (d, $^2J_{C-F}$ = 23.5 Hz), 107.40 (d, $^2J_{C-F}$ = 26.8 Hz), 40.22.

HRMS (ESI): *m*/*z* calcd for $C_9H_{10}N_2S$: 196.0470; found: 196.0468.

**6-Chloro-N,N-diethylbenzo[*d*]thiazol-2-amine (Table 2, entry 7, 2g)**

The residue was purified by flash chromatography on silica gel (EtOAc/PE = 1:4) to give the target compound **2g** (209 mg, 87%) as a pale-yellow syrup.

$^1$H NMR (400 MHz, $CDCl_3$): δ = 7.40 (s, 1 H), 7.26 (d, *J* = 8.8 Hz, 1 H), 7.09 (d, *J* = 8.4 Hz, 1 H), 3.46–3.40 (m, 4 H), 1.16 (t, *J* = 7.2 Hz, 6 H).

$^{13}$C NMR (100 MHz, $CDCl_3$): δ = 167.37, 151.76, 131.72, 126.16, 125.63, 120.13, 119.04, 45.46, 12.82.

HRMS (ESI): *m*/*z* calcd for $C_9H_{10}N_2S$: 240.0488; found: 240.0475.

**6-Bromo-N,N-diethylbenzo[*d*]thiazol-2-amine (Table 2, entry 8, 2h)**

The residue was purified by flash chromatography on silica gel (EtOAc/PE = 1:4) to give the target compound **2h** (208 mg, 73%) as a pale-yellow syrup.

$^1$H NMR (400 MHz, $CDCl_3$): δ = 7.63 (s, 1 H), 7.36–7.31 (m, 2 H), 3.54–3.49 (m, 4 H), 1.24 (t, *J* = 7.2 Hz, 6 H).

$^{13}$C NMR (100 MHz, $CDCl_3$): δ = 167.40, 152.09, 132.21, 129.00, 122.98, 119.58, 112.90, 45.58, 1.07.

HRMS (ESI): *m*/*z* calcd for $C_9H_{10}N_2S$: 283.9983; found: 283.9976.

**4-Bromo-N,N-diethylbenzo[*d*]thiazol-2-amine (Table 2, entry 9, 2i)**

The residue was purified by flash chromatography on silica gel (EtOAc/PE = 1:3) to give the target compound **2i** (188 mg, 73%) as a white solid; mp 116–118 °C.

$^1$H NMR (400 MHz, $CDCl_3$): δ = 7.62 (s, 1 H), 7.32 (d, *J* = 8.4 Hz, 1 H), 7.06 (d, *J* = 8.4 Hz, 1 H), 3.08 (s, 6 H).

$^{13}$C NMR (100 MHz, $CDCl_3$): δ = 169.56, 154.61, 129.97, 123.55, 121.61, 119.41, 40.16.

HRMS (ESI): *m*/*z* calcd for $C_9H_{10}N_2S$: 255.9670; found: 255.9678.

**4-Nitro-N,N-dimethylbenzo[*d*]thiazol-2-amine (Table 2, entry 10, 2j)**

The residue was purified by flash chromatography on silica gel (EtOAc/PE = 1:3) to give the target compound **2j** (166 mg, 74%) as a brown solid; mp 199–201 °C.

$^1$H NMR (400 MHz, $CDCl_3$): δ = 7.98 (d, *J* = 8.4 Hz, 1 H), 7.74 (d, *J* = 7.6 Hz, 1 H), 7.02 (t, *J* = 8.0 Hz, 1 H), 3.24 (s, 6 H).

$^{13}$C NMR (100 MHz, $CDCl_3$): δ = 171.10, 147.23, 138.66, 135.14, 125.80, 122.49, 119.42, 40.29.

HRMS (ESI): *m*/*z* calcd for $C_9H_{10}N_2S$: 223.0415; found: 224.0409.

**4-Chloro-*N*,*N*-dimethylbenzo[*d*]thiazol-2-amine (Table 2, entry 11, 2k)**

The residue was purified by flash chromatography on silica gel (EtOAc/PE = 1:3) to give the target compound **2k** (188 mg, 89%) as a white solid; mp 95–96 °C.

$^1$H NMR (400 MHz, $CDCl_3$): δ = 7.41 (d, *J* = 8.0 Hz, 1 H), 7.26 (d, *J* = 8.0 Hz, 1 H), 6.90 (t, *J* = 7.6 Hz, 1 H), 3.12 (s, 6 H).

$^{13}$C NMR (100 MHz, $CDCl_3$): δ = 168.80, 150.21, 132.34, 126.18, 122.98, 121.18, 119.14, 40.15.

HRMS (ESI): *m*/*z* calcd for $C_9H_{10}N_2S$: 212.0175; found: 212.0184.

**6-Methoxy-*N*,*N*-dimethylbenzo[*d*]thiazol-2-amine (Table 2, entry 12, 2l)**

The residue was purified by flash chromatography on silica gel (EtOAc/PE = 1:1) to give the target compound **2l** (148 mg, 71%) as a pale-yellow solid; mp 90–92 °C.

$^1$H NMR (400 MHz, $CDCl_3$): δ = 7.43 (d, *J* = 8.8 Hz, 1 H), 7.09 (s, 1 H), 8.85 (d, *J* = 8.4 Hz, 1 H), 3.75 (s, 3 H), 3.10 (s, 6 H).

$^{13}$C NMR (100 MHz, $CDCl_3$): δ = 167.43, 154.66, 147.22, 131.86, 119.06, 113.49, 105.23, 55.87, 40.21.

HRMS (ESI): *m*/*z* calcd for $C_9H_{10}N_2S$: 208.0670; found: 208.0682.

***N*,*N*,6-Trimethylbenzo[*d*]thiazol-2-amine (Table 2, entry 13, 2m)**

The residue was purified by flash chromatography on silica gel (EtOAc/PE = 1:1) to give the target compound **2m** (126 mg, 73%) as a red-brown solid; mp 96–98 °C.

$^1$H NMR (400 MHz, $CDCl_3$): δ = 7.43 (d, *J* = 8.0 Hz, 1 H), 7.09 (d, *J* = 4.0 Hz, 1 H), 6.85 (d, *J* = 8.8 Hz, 1 H), 3.76 (s, 3 H), 3.10 (s, 6 H).

$^{13}$C NMR (100 MHz, $CDCl_3$): δ = 168.25, 150.92, 131.06, 130.61, 127.11, 120.72, 118.34, 40.19, 21.21.

HRMS (ESI): *m*/*z* calcd for $C_9H_{10}N_2S$: 192.0721; found: 172.0729.

***N*,*N*-Diethylbenzo[*d*]thiazol-2-amine (Table 2, entry 14, 2n)**

The residue was purified by flash chromatography on silica gel (EtOAc/PE = 1:4) to give the target compound **2n** (163 mg, 79%) as a pale-yellow syrup.

$^1$H NMR (400 MHz, $CDCl_3$): δ = 7.59 (t, *J* = 8.0 Hz, 2 H), 7.26 (t, *J* = 7.2 Hz, 1 H), 7.01 (t, *J* = 7.6 Hz, 1 H), 3.57–3.51 (m, 4 H), 1.26 (t, *J* = 7.2 Hz, 6 H).

$^{13}$C NMR (100 MHz, $CDCl_3$): δ = 167.30, 130.24, 125.93, 120.88, 120.56, 118.45, 45.54, 12.87.

HRMS (ESI): *m*/*z* calcd for $C_9H_{10}N_2S$: 206.0878; found: 208.0885.

***N*,*N*-Dibutylbenzo[*d*]thiazol-2-amine (Table 2, entry 15, 2o)**

The residue was purified by flash chromatography on silica gel (EtOAc/PE = 1:10) to give the target compound **2o** (165 mg, 63%) as a colourless viscous oil.

$^1$H NMR (400 MHz, $CDCl_3$): δ = 7.54 (t, *J* = 8.0 Hz, 2 H), 7.25 (t, *J* = 8.0 Hz, 1 H), 7.01 (t, *J* = 8.0 Hz, 1 H), 3.48 (t, *J* = 8.0 Hz, 4 H), 1.70–1.63 (m, 4 H), 1.42–1.33 (m, 4 H), 0.96 (t, *J* = 8.0 Hz, 6 H).

$^{13}$C NMR (100 MHz, $CDCl_3$): δ = 167.90, 153.06, 130.52, 125.82, 120.71, 120.47, 118.51, 51.05, 29.64, 20.15, 13.96.

HRMS (ESI): *m*/*z* calcd for $C_9H_{10}N_2S$: 262.1504; found: 262.1497.

**6-Methoxy-*N*,*N*-dibutylbenzo[*d*]thiazol-2-amine (Table 2, entry 16, 2p)**

The residue was purified by flash chromatography on silica gel (EtOAc/PE = 1:7) to give the target compound **2p** (180 mg, 62%) as a pale-yellow syrup.

$^1$H NMR (400 MHz, $CDCl_3$): δ = 7.41 (d, *J* = 8.8 Hz, 1 H), 7.09 (s, 1 H), 6.84 (d, *J* = 9.2 Hz, 1 H), 3.76 (s, 3 H), 3.43 (t, *J* = 7.6 Hz, 4 H), 1.67–1.60 (m, 4 H), 1.38–1.32 (m, 4 H), 0.94 (t, *J* = 7.2 Hz, 6 H).

$^{13}$C NMR (100 MHz, $CDCl_3$): δ = 166.52, 154.50, 147.46, 131.50, 118.83, 113.19, 105.21, 55.88, 50.92, 26.69, 20.16, 13.96.

HRMS (ESI): *m*/*z* calcd for $C_9H_{10}N_2S$: 292.1609; found: 292.1615.

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## Supporting Information

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