### Metal-Free Oxidative Deamination Cross-Coupling of Imidazoheterocycles with 2-Aminobenzothiazoles

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Abstract A metal-free oxidative deamination-cross-coupling of imidazoheterocycles with 2-aminobenzothiazoles in the presence of tert-butyl nitrite is reported for the first time. This simple protocol tolerates a wide range of functional groups to afford various benzothiazole-imidazoheterocycles in moderate to excellent yields, with the release of nitrogen and water as benign byproducts.

Key words cross-coupling, heterocycles, imidazoles, benzothiazoles, heteroarylation

Imidazoheterocycles are privileged scaffolds with a broad range of biological activities in drug discovery.<sup>1</sup> These compounds have been widely used as antiviral,<sup>2</sup> antibacterial,<sup>3</sup> and anticancer agents,<sup>4</sup> as well as in the treatment of cystic fibrosis.<sup>5</sup> Additionally, imidazoheterocycles can be used as functional materials.<sup>6</sup> Because of their versatility as pharmaceuticals and functional materials, considerable efforts have been made to prepare imidazoheterocyclic cores and to modify imidazoheterocycles.<sup>7,8</sup> As an economical and straightforward synthetic method, the direct C-H arylation of imidazoheterocycles has received much attention.9 However, reports of C-H heteroarylations of imidazoheterocycles remain scarce.

It is also well known that benzothiazoles are useful in the development of drugs and materials.<sup>10,11</sup> Benzothiazole-imidazoheterocycles, formed by coupling of benzothiazoles with imidazoheterocycles, are expected to have significance in medicinal chemistry and in materials science because these compounds potentially possess unique chemical and physical properties due to their highly conjugated heterocyclic structures. Metal-catalyzed C-H activations<sup>12</sup> or oxidative free-radical reactions<sup>13</sup> of benzothiazoles are straightforward pathways to benzothiazole-



imidazoheterocycles. However, metal-catalyzed C-H activations commonly require noble-metal catalysts and excesses of metal oxidants, which are generally expensive and harmful to the environment. These environmental and economic concerns necessitate the development of a metal-free C-H functionalization strategy that meets the guiding principles of green chemistry.<sup>14</sup> We speculated that 1,3-benzothiazol-2-amine might be an alternative reaction partner for the formation of benzothiazole-imidazoheterocycles because it can undergo a Sandmeyer reaction to afford a benzothiazolyl free-radical species.<sup>15</sup> It has also been reported that a variety of transformations can be carried out by using aryl free-radicals formed from aryl diazonium salts.<sup>16,17</sup> However, C-H heteroarylations between two different heterocycles, such as 2-aminobenzothiazoles and imidazoheterocycles through a Meerwein heteroarylation strategy remains to be developed. We therefore decided to develop a simple, practicable, and metal-free method for the oxidative deamination cross-coupling of imidazoheterocycles with 2-aminobenzothiazoles under mild reaction conditions (Figure



Figure 1 Cross-coupling of imidazoheterocycles with 2-aminothiazoles

Optimization studies were performed for the heteroarylation of 6-phenylimidazo[2,1-b][1,3]thiazole (1a) with 1,3benzothiazol-2-amine (2a) as a model reaction (Table 1). Several solvents, including cyclohexane, toluene, DCE, MeNO<sub>2</sub>, and DMF, were examined in the presence of 1.5 equivalents of t-BuONO at 100 °C (Table 1, entries 1-5). The preferred solvent was DCE, which gave product 3a in 34%

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yield, along with a 27% yield of 5-nitroso-6-phenylimidazo[2,1-b][1,3]thiazole as a byproduct (entry 3). To our delight, the addition of a base, such as K<sub>3</sub>PO<sub>4</sub>, K<sub>2</sub>CO<sub>3</sub>, KOAc, NaOAc, or CsOAc, successfully suppressed the nitrosylation of 1a and remarkably improved the yield of 3a to 55-61% (entries 6-10). KOAc was most effective base for this transformation (entry 8), whereas the strong base t-BuOLi was unsuitable for this reaction (entry 11). Generally, organic bases such as Et<sub>3</sub>N, DBU, or DMAP were less effective than inorganic bases (entries 12-14). The use of either one or two equivalents of KOAc gave similar results (entries 8 and 15), whereas the use of 0.5 equivalents of KOAc slightly decreased the yield of **3a** to 56% (entry 16). To improve the yield of **3a** further, the use of two equivalents of **2a** and *t*-BuONO increased the yield of **3a** to 73% (entry 17). It was pleasing to find that performing the reaction at 90 °C slightly enhanced the yield of **3a** to 78% (entry 18), whereas when the reaction was conducted at 80 °C, the yield of 3a decreased to 71% (entry 19). Importantly, a gram-scale reaction also proceeded smoothly to afford product **3a** in 71% vield (entry 18).

With the optimized reaction conditions in hand (Table 1, entry 18), we examined the scope of the heteroarylation of imidazothiazoles with 2-aminobenzothiazoles (Table 2). 6-Arylimidazo[2,1-b][1,3]thiazoles bearing either an electron-withdrawing or an electron-donating group on the benzene ring reacted smoothly to give the corresponding products **3b-g** in moderate to good yields. In comparison with the substrate with a methyl group, the methoxy-substituted substrate was less effective under the standard conditions and gave product 3c in 52% yield. Halo substituents were well tolerated under the standard conditions. For example, the substrate containing a bromo group gave product 3d in 78% yield, whereas that containing a chloro group gave product **3e** in 83% yield. However, the fluorosubstituted substrate was less effective, possibly as a result of the electronegativity of the fluorine atom (product **3f**). Note that various functional groups could be introduced into products **3p**,**r** by disconnection of the carbon-halogen bond. Despite the steric hindrance of the naphthyl group, a 53% yield of **3h** was obtained. We also examined substituent effects on the thiazole ring (3i-m). The substrate with an ester group on the thiazole ring performed well, affording product **3i** in 71% yield. It is noteworthy that further transformation could be made at the ester group. Significantly, benzo[d]imidazo[2,1-b]thiazoles performed particularly well, affording the target products 3k-m in excellent yields. These substrates contain a tricyclic conjugated plane that can stabilize the imidazole ring to facilitate the transformation.

Subsequently, several other 2-aminobenzothiazoles were subjected to this heteroarylation. 2-Aminobenzothiazoles with a methyl or methoxy electron-donating group were well tolerated, giving products **3n** and **3o** in 74% and 75% yield, respectively. Electron-withdrawing substituents



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S N H	Ph +	→NH <sub>2</sub> → base t-BuONO solvent	Ph N N N N S
1a	2a		3a
Entry	Base (equiv)	Solvent	Isolated yield (%)
1	-	cyclohexane	12
2	-	toluene	28
3	-	DCE	34
4	-	MeNO <sub>2</sub>	33
5	-	DMF	11
6	$K_{3}PO_{4}(2)$	DCE	56
7	K <sub>2</sub> CO <sub>3</sub> (2)	DCE	55
8	KOAc (2)	DCE	61
9	NaOAc (2)	DCE	58
10	CsOAc (2)	DCE	59
11	t-BuOLi (2)	DCE	trace
12	Et <sub>3</sub> N (2)	DCE	40
13	DBU (2)	DCE	43
14	DMAP (2)	DCE	45
15	KOAc (1)	DCE	62
16	KOAc (0.5)	DCE	56
17 <sup>b</sup>	KOAc (1)	DCE	73
18 <sup>b,c</sup>	KOAc (1)	DCE	78 (71) <sup>d</sup>
19 <sup>b,e</sup>	KOAc (1)	DCE	71
	A		

<sup>a</sup> Reaction conditions: **1a** (0.2 mmol), **2a** (0.3 mmol), *t*-BuONO (1.5 equiv), solvent (2 mL). 100 °C. 12 h.

<sup>b</sup> **2a** (0.4 mmol, 2 equiv), *t*-BuONO (2 equiv).

<sup>c</sup> At 90 °C.

<sup>d</sup> Gram-scale reaction: **1a** (1 g, 5 mmol), **2a** (10 mmol, 2 equiv), *t*-BuONO

(10 mmol, 2 equiv), KOAc (5 mmol, 1 equiv), DCE (20 mL), 90 °C, 12 h.

At 80 °C.

such as halo groups disfavored the reaction, leading to a decrease in the yield of product (**3p**–**r**). The nitro-substituted substrate was ineffective in this reaction. It was pleasing to find that 1,3-thiazole-2-amine was also suitable for this transformation, providing product **3t** in 57% yield.

The scope of imidazo[1,2-*a*]pyridines was also examined (Table 3). 2-Arylimidazo[1,2-*a*]pyridines with a methyl, methoxy, phenyl, chloro, bromo, or fluoro group on the benzene ring reacted well to afford the corresponding products **5a**-**g** in moderate to good yields. Substrates with methyl groups on the pyridine ring furnished the corresponding products **5h**-**i** in moderate yields. To our delight, both 2-methylimidazo[1,2-*a*]pyridine and 2-ethylimidazo[1,2-*a*]pyridine were compatible with the reaction conditions and gave products **5j** and **5k** in 58 and 51% yield, respectively. It is noteworthy that the reaction of 2-phenylimidazo[1,2-*a*]pyrimidine also proceeded smoothly to give product **5l** in 68% yield. Generally, imidazothiazoles are

# Syn thesis Paper X.-M. Ji et al. Table 2 The Scope of Imidazo[2,1-b]thiazoles<sup>a</sup> KOAc (1 equiv) t-BuONO (2 equiv) DCE, 90 °C, 12 h 2 3 **3b**, 70% **3c**, 52% **3d**, 78% **3e**, 83% **3f**, 63% **3g**, 62% **3h**, 53% **3i**, 68% ó Èt **3j**, 71% **3k**, 93% **3I**, 92% **3m**, 95% **3n**, 74% **30**, 75% **3p**, 53% **3q**, 38%

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**3t**, 57%

NO<sub>2</sub>

**3s**, 0% <sup>a</sup> Reaction conditions: 1 (0.2 mmol), 2 (0.4 mmol), t-BuONO (2 equiv), KOAc (1 equiv), solvent (2 mL), 90 °C, 12 h.

**3r**, 35%

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<sup>a</sup> Reaction conditions: 4 (0.2 mmol), 2 (0.4 mmol), t-BuONO (2 equiv), KOAc (1 equiv), solvent (2 mL), 90 °C, 12 h.

more effective and provide higher yields than imidazopyridines under the standard conditions. Note that the imidazoheterocycles were generally consumed completely, whereas a portion of the 2-aminobenzothiazole was transformed into benzothiazole under the standard conditions. Unfortunately, 1,3-benzoxazole-2-amine was unsuitable for this reaction. Treatment of imidazothiazole **1a** with aniline gave a diazo product rather than a phenylated product in the presence of *t*-BuONO (see Supporting Information). The conjugation of the N=N bond with the benzene ring might stabilize the diazonium salt to facilitate the formation of the diazo compound.

To gain insight into the mechanism, several control experiments were conducted (see Supporting Information). The addition of a radical scavenger such as 1,1-diphenylethylene or TEMPO to the reaction mixture completely suppressed the reaction. In the absence of **1a**, 1,3-benzothiazol-2-amine reacted with *t*-BuONO in the presence of 1,1diphenylethylene or TEMPO to form 1,3-benzothiazole and 1,3-benzothiazol-2(3H)-one. It was demonstrated that benzothiazole did not react with imidazoheterocycle 1a under the standard conditions. These results suggest that the present reaction involves a radical process. On the basis of the present results and previous reports,<sup>16,17</sup> a possible mechanism is proposed in Scheme 1. 1,3-Benzothiazol-2amine reacts initially with *t*-BuONO to yield the diazonium salt **A** in situ; this is followed by a deamination process to generate free radical **B** and nitrogen. Intermediate **B** then reacts with substrate 1a to produce intermediate C. Intermediate C undergoes an electron exchange with another diazonium salt A to afford a carbocation D and another intermediate B. Alternatively, intermediate A might react directly with 1a to form carbocation D. Finally, carbocation D undergoes a dehydrogenation process to afford target product **3a**. It is noteworthy that in the reactions of substrate **1a**, the heteroarylation takes place selectively at the imidazole ring rather than the thiazole ring. This is because the elec-



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Scheme 1 A possible mechanism

tron-rich imidazole ring is more reactive than the thiazole ring and because of greater stability of carbocation **D** as a result of conjugation with the benzene ring.

In summary, a metal-free strategy has been developed for the introduction of benzothiazole moieties onto imidazoheterocycles by oxidative deamination of 2-aminobenzothiazoles. This finding offers a simple and practicable method for the synthesis of a variety of highly conjugated heterocycles that are expected to be significant in pharmaceuticals or materials. This study also opens a new window for the application of the Sandmeyer reaction in C–H heteroarylation.

<sup>1</sup>H and <sup>13</sup>C NMR spectra were measured on a Bruker Avance-III 500 instrument (500 MHz for <sup>1</sup>H, 125 MHz for <sup>13</sup>C NMR) with CDCl<sub>3</sub> or DMSO-*d*<sub>6</sub> as the solvent, and were referenced to internal TMS ( $\delta$  = 0.0 ppm) as the standard. Mass spectra were measured on a Shimadzu GC-MS-QP2010 Plus spectrometer (EI). HRMS (ESI) analyses were performed on a Bruker micrOTOF-Q II instrument. IR spectra were recorded on a Nicolet IS10 spectrophotometer (ATR).

### 2-(6-Phenylimidazo[2,1-*b*][1,3]thiazol-5-yl)-1,3-benzothiazole (3a); Typical Procedure

A 15-mL tube equipped with a Teflon cap and a magnetic stirring bar was charged with substrate **1a** (0.20 mmol). 1,3-Benzothiazol-2-amine (**2a**; 0.40 mmol, 2.0 equiv), KOAc (0.20 mmol, 1.0 equiv), DCE (2 mL), and *t*-BuONO (0.40 mmol, 2.0 equiv) were then added sequentially. The tube was then capped and the mixture was stirred at 90 °C for 12 h. The crude mixture was diluted with EtOAc, filtered through a Celite pad, and washed with EtOAc. The filtrate was concentrated in

vacuo, and the residue was purified by column chromatography (silica gel, hexane-EtOAc) to give a yellow solid; yield: 52.2 mg (78%); mp 166.2-167.1 °C.

IR (ATR): 3106, 2967, 1550, 1530, 1358, 1132, 1099, 867 cm<sup>-1</sup>.

<sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>): δ = 8.75 (d, *J* = 4.5 Hz, 1 H), 7.95 (d, *J* = 8.0 Hz, 1 H), 7.74–7.68 (m, 2 H), 7.67 (d, *J* = 8.0 Hz, 1 H), 7.51–7.49 (m, 3 H), 7.43–7.40 (m, 1 H), 7.29–7.25 (m, 1 H), 6.95 (d, *J* = 4.5 Hz, 1 H).

 $^{13}\text{C}$  NMR (125 MHz, CDCl\_3):  $\delta$  = 156.7, 152.7, 152.0, 150.3, 133.5, 133.5, 129.7, 129.2, 128.6, 126.0, 124.8, 122.1, 122.0, 121.0, 118.7, 112.6.

LRMS (EI, 70 eV): m/z (%) = 333 (83), 332 (100), 248 (11), 166 (10), 108 (7).

HRMS (ESI): m/z [M + H]<sup>+</sup> calcd for  $C_{18}H_{12}N_3S_2^+$ : 334.0467; found: 334.0471.

# 2-[6-(4-Tolyl)imidazo[2,1-*b*][1,3]thiazol-5-yl]-1,3-benzothiazole (3b)

Yellow solid; yield: 48.3 mg (70%); mp 138.8–139.5 °C.

IR (ATR): 3068, 2932, 1556, 1523, 1338, 1036, 827 cm<sup>-1</sup>.

<sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>): δ = 8.76 (d, *J* = 4.5 Hz, 1 H), 7.95 (d, *J* = 8.0 Hz, 1 H), 7.68 (d, *J* = 8.0 Hz, 1 H), 7.61 (d, *J* = 8.0 Hz, 2 H), 7.43–7.40 (m, 1 H), 7.32–7.27 (m, 3 H), 6.95 (d, *J* = 4.5 Hz, 1 H), 2.46 (s, 3 H).

 $^{13}\text{C}$  NMR (125 MHz, CDCl<sub>3</sub>):  $\delta$  = 157.0, 152.9, 152.2, 150.8, 139.4, 133.7, 130.8, 129.8, 129.5, 126.2, 124.9, 122.3, 122.2, 121.3, 118.8, 112.7, 21.6.

LRMS (EI, 70 eV): m/z (%) = 347 (73), 346 (100), 281 (13), 207 (29), 173 (9).

HRMS (ESI): m/z [M + H]<sup>+</sup> calcd for  $C_{19}H_{14}N_3S_2^+$ : 348.0624; found: 348.0632.

# 2-[6-(4-Methoxyphenyl)imidazo[2,1-*b*][1,3]thiazol-5-yl]-1,3-ben-zothiazole (3c)

Yellow solid; yield: 37.9 mg (52%); mp 143.7-144.3 °C.

IR (ATR): 3056, 2961, 1545, 1527, 1275, 1179, 860 cm<sup>-1</sup>.

<sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>): δ = 8.78 (d, *J* = 4.5 Hz, 1 H), 7.97 (d, *J* = 8.0 Hz, 1 H), 7.71 (d, *J* = 8.0 Hz, 1 H), 7.66–7.64 (m, 2 H), 7.45–7.42 (m, 1 H), 7.31–7.28 (m, 1 H), 7.07–7.02 (m, 2 H), 6.98 (d, *J* = 4.5 Hz, 1 H), 3.90 (s, 3 H).

 $^{13}\text{C}$  NMR (125 MHz, CDCl\_3):  $\delta$  = 160.7, 157.1, 152.9, 152.1, 150.6, 133.6, 131.2, 126.2, 126.0, 124.9, 122.3, 122.2, 121.2, 118.7, 114.2, 112.5, 55.4.

LRMS (EI, 70 eV): *m*/*z* (%) = 363 (100), 207 (7), 181 (8), 16 (10).

HRMS (ESI): m/z [M + H]<sup>+</sup> calcd for  $C_{19}H_{14}N_3OS_2^+$ : 364.0573; found: 364.0578.

# 2-[6-(4-Bromophenyl)imidazo[2,1-*b*][1,3]thiazol-5-yl]-1,3-benzo-thiazole (3d)

Brown solid; yield: 64.5 mg (78%); mp 205.9–206.5 °C.

IR (ATR): 3110, 2958, 1559, 1538, 1201, 1121, 835 cm<sup>-1</sup>.

<sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>):  $\delta$  = 8.75 (d, *J* = 4.5 Hz, 1 H), 7.98 (d, *J* = 8.0 Hz, 1 H), 7.74 (d, *J* = 8.0 Hz, 1 H), 7.65–7.61 (m, 4 H), 7.47–7.44 (m, 1 H), 7.34–7.31 (m, 1 H), 7.00 (d, *J* = 4.5 Hz, 1 H).

 $^{13}\text{C}$  NMR (125 MHz, CDCl\_3):  $\delta$  = 156.4, 152.9, 152.3, 149.0, 133.6, 132.6, 132.0, 131.5, 126.4, 125.2, 123.7, 122.4, 122.1, 121.3, 118.9, 113.1.

LRMS (EI, 70 eV): *m/z* (%) = 412 (89), 411 (85), 281 (41), 207 (100), 166 (10).

HRMS (ESI):  $m/z \ [M + H]^+$  calcd for  $C_{18}H_{11}BrN_3S_2^+$ : 411.9572; found: 411.9575.

# 2-[6-(4-Chlorophenyl)imidazo[2,1-*b*][1,3]thiazol-5-yl]-1,3-benzo-thiazole (3e)

Yellow solid; yield: 60.9 mg (83%); mp 201.6-202.1 °C.

IR (ATR): 3106, 2961, 1563, 1540, 1202, 1109, 837, 765 cm<sup>-1</sup>.

<sup>1</sup>H NMR (500 MHz,  $CDCl_3$ ):  $\delta = 8.73$  (d, J = 4.5 Hz, 1 H), 7.96 (d, J = 8.0 Hz, 1 H), 7.71 (d, J = 8.0 Hz, 1 H), 7.67 (d, J = 8.0 Hz, 2 H), 7.48–7.42 (m, 3 H), 7.30 (t, J = 7.5 Hz, 1 H), 6.98 (d, J = 4.5 Hz, 1 H).

 $^{13}\text{C}$  NMR (125 MHz, CDCl\_3):  $\delta$  = 156.1, 152.5, 152.0, 148.7, 135.1, 133.3, 131.9, 130.9, 128.7, 126.1, 124.9, 122.1, 121.8, 121.0, 118.6, 112.7.

LRMS (EI, 70 eV): m/z (%) = 367 (95), 366 (100), 207 (27), 281 (13), 166 (10).

HRMS (ESI): m/z [M + H]<sup>+</sup> calcd for  $C_{18}H_{11}CIN_3S_2^+$ : 368.0077; found: 368.0080.

# 2-[6-(4-Fluorophenyl)imidazo[2,1-*b*][1,3]thiazol-5-yl]-1,3-benzo-thiazole (3f)

Yellow solid; yield: 44.1 mg (63%); mp 189.3-190.1 °C.

IR (ATR): 3069, 2938, 1543, 1520, 1231, 1150, 1089, 973 cm<sup>-1</sup>.

<sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>): δ = 8.76 (d, *J* = 4.5 Hz, 1 H), 7.97 (d, *J* = 8.0 Hz, 1 H), 7.72–7.69 (m, 3 H), 7.44 (t, *J* = 7.5 Hz, 1 H), 7.30 (t, *J* = 7.5 Hz, 1 H), 7.19 (t, *J* = 8.5 Hz, 2 H), 6.98 (d, *J* = 4.5 Hz, 1 H).

<sup>13</sup>C NMR (125 MHz, CDCl<sub>3</sub>): δ = 163.2 (d,  $J_{C-F}$  = 247.5 Hz), 156.6, 152.9, 152.2, 149.4, 133.6, 131.8 (d,  $J_{C-F}$  = 8.4 Hz), 129.8 (d,  $J_{C-F}$  = 3.3 Hz), 126.3, 125.1, 122.4, 122.1, 121.3, 118.9, 115.8 (d,  $J_{C-F}$  = 21.5 Hz), 112.9.

LRMS (EI, 70 eV): *m/z* (%) = 351 (88), 350 (100), 281 (17), 253 (12), 73 (16).

HRMS (ESI): m/z [M + H]<sup>+</sup> calcd for  $C_{18}H_{11}FN_3S_2^+$ : 352.0373; found: 352.0380.

# 4-[5-(1,3-Benzothiazol-2-yl)imidazo[2,1-*b*][1,3]thiazol-6-yl]benzonitrile (3g)

Yellow solid; yield: 44.3 mg (62%); mp 226.4–227.6 °C.

IR (ATR): 3100, 2921, 2233, 1553, 1507, 1311, 1099, 845 cm<sup>-1</sup>.

<sup>1</sup>H NMR (500 MHz,  $CDCl_3$ ):  $\delta$  = 8.71 (d, *J* = 4.5 Hz, 1 H), 8.01 (d, *J* = 8.0 Hz, 1 H), 7.89 (d, *J* = 8.0 Hz, 2 H), 7.78–7.75 (m, 3 H), 7.48 (t, *J* = 8.0 Hz, 1 H), 7.36 (t, *J* = 8.0 Hz, 1 H), 7.03 (d, *J* = 4.5 Hz, 1 H).

 $^{13}\text{C}$  NMR (125 MHz, CDCl\_3):  $\delta$  = 155.6, 152.6, 152.3, 147.5, 138.1, 133.3, 132.2, 130.2, 126.3, 125.3, 122.4, 121.6, 121.1, 118.9, 118.4, 113.3, 112.6.

LRMS (EI, 70 eV): *m/z* (%) = 358 (96), 357 (100), 281 (6), 179 (7), 73 (8).

HRMS (ESI): m/z [M + H]<sup>+</sup> calcd for  $C_{19}H_{11}N_4S_2^+$ : 359.0420; found: 359.0421.

#### 2-[6-(2-Naphthyl)imidazo[2,1-*b*][1,3]thiazol-5-yl]-1,3-benzothiazole (3h)

Yellow solid; yield: 40.5 mg (53%); mp 215.3–216.2 °C.

IR (ATR): 2952, 1556, 1510, 1269, 1172, 1030, 831 cm<sup>-1</sup>.

<sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>): δ = 8.82 (d, *J* = 4.5 Hz, 1 H), 8.26 (s, 1 H), 7.98 (d, *J* = 8.0 Hz, 2 H), 7.94–7.88 (m, 2 H), 7.82 (dd, *J* = 8.0, 1.5 Hz, 1 H), 7.64 (d, *J* = 8.0 Hz, 1 H), 7.59–7.52 (m, 2 H), 7.45–7.41 (m, 1 H), 7.29–7.26 (m, 1 H), 7.00 (d, *J* = 4.5 Hz, 1 H).

 $^{13}\text{C}$  NMR (125 MHz, CDCl<sub>3</sub>):  $\delta$  = 156.9, 152.9, 152.3, 150.4, 133.8, 133.6, 133.3, 131.0, 129.5, 128.5, 127.9, 127.2, 126.8, 126.5, 126.3, 125.0, 122.3, 122.2, 121.3, 119.1, 112.9.

LRMS (EI, 70 eV): *m/z* (%) = 383 (100), 382 (72), 298 (10), 153 (6), 69 (5).

HRMS (ESI):  $\textit{m/z}~[M + H]^{\scriptscriptstyle +}$  calcd for  $C_{22}H_{14}N_3S_2^{\scriptscriptstyle +}$ : 384.0624; found: 384.0632.

# 2-(2-Methyl-6-phenylimidazo[2,1-*b*][1,3]thiazol-5-yl)-1,3-benzo-thiazole (3i)

Yellow solid; yield: 47.3 mg (68%); mp 127.2-128.4 °C.

IR (ATR): 3113, 2958, 1558, 1529, 1360, 839 cm<sup>-1</sup>.

<sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>): δ = 8.45 (s, 1 H), 7.97 (d, *J* = 8.0 Hz, 1 H), 7.72–7.67 (m, 3 H), 7.49–7.48 (m, 3 H), 7.44–7.40 (m, 1 H), 7.30–7.25 (m, 1 H), 2.51 (s, 3 H).

 $^{13}\text{C}$  NMR (125 MHz, CDCl<sub>3</sub>):  $\delta$  = 157.0, 152.9, 151.6, 149.4, 133.8, 133.7, 129.9, 129.2, 128.7, 126.9, 126.2, 124.9, 122.3, 121.2, 118.6, 14.1.

LRMS (EI, 70 eV): *m/z* (%) = 347 (82), 346 (100), 281 (15), 248 (9), 69 (8).

HRMS (ESI):  $m\!/z$  [M + H]+ calcd for  $C_{19}H_{14}N_3S_2^+\!\!\!:$  348.0624; found: 348.0632.

# Ethyl 5-(1,3-Benzothiazol-2-yl)-6-phenylimidazo[2,1-*b*][1,3]thi-azole-2-carboxylate (3j)

Yellow solid; yield: 57.3 mg (71%); mp 148.5–149.7 °C. IR (ATR): 3060, 2913, 1699, 1560, 1540, 1298, 1099, 936 cm<sup>-1</sup>.

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<sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>): δ = 9.4 (s, 1 H), 8.0 (d, J = 8.2 Hz, 1 H), 7.73–7.72 (m, 2 H), 7.69 (d, J = 8.0 Hz, 1 H), 7.52–7.50 (m, 3 H), 7.45 (t, J = 7.5 Hz, 1 H), 7.30 (t, J = 7.5 Hz, 1 H), 4.45 (q, J = 7.0 Hz, 2 H), 1.44 (t, J = 7.0 Hz, 3 H).

<sup>13</sup>C NMR (125 MHz, CDCl<sub>3</sub>): δ = 161.2, 156.1, 152.7, 152.6, 151.3, 133.5, 133.1, 129.8, 129.7, 128.8, 128.0, 126.3, 125.2, 122.6, 122.2, 121.2, 119.0, 62.3, 14.3.

LRMS (EI, 70 eV): *m/z* (%) = 405 (100), 376 (39), 281 (25), 135 (16), 73 (55).

HRMS (ESI):  $m/z~[M + H]^{\ast}$  calcd for  $C_{21}H_{16}N_{3}O_{2}S_{2}^{\ast}{}^{\ast}{}^{\ast}$  406.0678; found: 406.0671.

#### 3-(1,3-Benzothiazol-2-yl)-2-phenylimidazo[2,1-*b*][1,3]benzothiazole (3k)

Yellow solid; yield: 71.3 mg (93%); mp 201.2-202.3 °C.

IR (ATR): 3073, 2913, 1543, 1503, 1348, 1023, 945 cm<sup>-1</sup>.

<sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>): δ = 8.14 (d, J = 8.0 Hz, 1 H), 8.05–8.03 (m, 1 H), 7.79 (d, J = 8.0 Hz, 1 H), 7.64–7.49 (m, 4 H), 7.39 (t, J = 7.5 Hz, 1 H), 7.30–7.23 (m, 5 H).

 $^{13}\text{C}$  NMR (125 MHz, CDCl<sub>3</sub>):  $\delta$  = 156.7, 152.9, 150.0, 149.5, 135.9, 133.2, 133.1, 130.0, 128.9, 128.4, 128.3, 126.3, 125.9, 125.6, 124.9, 123.8, 123.4, 121.5, 118.3, 115.6.

LRMS (EI, 70 eV): *m/z* (%) = 383 (87), 382 (100), 281 (19), 191 (17), 73 (19).

HRMS (ESI): m/z [M + H]<sup>+</sup> calcd for  $C_{22}H_{14}N_3S_2^+$ : 384.0624; found: 384.0629.

#### 3-(1,3-Benzothiazol-2-yl)-7-methyl-2-phenylimidazo[2,1b][1,3]benzothiazole (3l)

Yellow solid; yield: 72.9 mg (92%); mp 203.7–204.5  $^{\circ}\text{C}.$ 

IR (ATR): 3035, 2956, 1527, 1458, 1230, 1031, 915 cm<sup>-1</sup>.

<sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>): δ = 8.20 (d, *J* = 8.0 Hz, 1 H), 8.01 (d, *J* = 8.0 Hz, 1 H), 7.86 (d, *J* = 8.0 Hz, 1 H), 7.64–7.63 (m, 2 H), 7.60–7.56 (m, 1 H), 7.49 (s, 1 H), 7.47–7.44 (m, 1 H), 7.37–7.36 (m, 3 H), 7.12 (d, *J* = 8.0 Hz, 1 H), 2.43 (s, 3 H).

 $^{13}\text{C}$  NMR (125 MHz, CDCl<sub>3</sub>):  $\delta$  = 156.8, 152.9, 149.9, 149.2, 135.9, 135.1, 133.1, 131.1, 130.0, 128.9, 128.3, 128.3, 127.0, 126.2, 125.6, 123.8, 123.3, 121.5, 118.3, 115.3, 21.0.

LRMS (EI, 70 eV): *m*/*z* (%) = 397 (88), 396 (100), 248 (11), 121 (7), 77 (6).

HRMS (ESI): m/z [M + H]<sup>+</sup> calcd for  $C_{23}H_{16}N_3S_2^+$ : 398.0780; found: 398.0788.

#### 3-(1,3-Benzothiazol-2-yl)-7-chloro-2-phenylimidazo[2,1b][1,3]benzothiazole (3m)

Yellow solid; yield: 79.2 mg (95%); mp 119.8-120.5 °C.

IR (ATR): 3106, 2913, 1540, 1510, 1102, 803 cm<sup>-1</sup>.

<sup>1</sup>H NMR (500 MHz,  $CDCl_3$ ):  $\delta$  = 8.27 (d, *J* = 9.0 Hz, 1 H), 8.17 (d, *J* = 8.0 Hz, 1 H), 7.83 (d, *J* = 8.0 Hz, 1 H), 7.66–7.61 (m, 3 H), 7.58–7.55 (m, 1 H), 7.46–7.43 (m, 1 H), 7.39–7.36 (m, 3 H), 7.29 (dd, *J* = 9.0, 2.0 Hz, 1 H).

 $^{13}\text{C}$  NMR (125 MHz, CDCl<sub>3</sub>):  $\delta$  = 156.7, 153.0, 150.2, 150.1, 136.0, 133.2, 132.2, 131.7, 130.8, 129.3, 128.9, 128.6, 126.6, 126.5, 126.0, 123.6, 123.5, 121.7, 119.1, 117.0.

LRMS (EI, 70 eV): *m/z* (%) = 418 (6), 416 (100), 207 (8), 191 (9), 69 (12).

HRMS (ESI):  $m/z~[M + H]^{+}$  calcd for  $C_{22}H_{13}CIN_{3}S_{2}^{+}$ : 418.0234; found: 418.0240.

# 6-Methyl-2-(6-phenylimidazo[2,1-*b*][1,3]thiazol-5-yl)-1,3-benzo-thiazole (3n)

Yellow solid; yield: 51.3 mg (74%); mp 182.3–183.6 °C.

IR (ATR): 3013, 2967, 1587, 1526, 1350, 1030, 835 cm<sup>-1</sup>.

<sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>): δ = 8.74 (d, *J* = 4.5 Hz, 1 H), 7.84 (d, *J* = 8.5 Hz, 1 H), 7.74–7.72 (m, 2 H), 7.50–7.47 (m, 4 H), 7.26–7.22 (m, 1 H), 6.96 (d, *J* = 4.5 Hz, 1 H), 2.43 (s, 3 H).

 $^{13}\text{C}$  NMR (125 MHz, CDCl\_3):  $\delta$  = 155.9, 152.0, 151.0, 150.1, 135.2, 133.9, 133.8, 130.0, 129.3, 128.7, 127.8, 122.1, 121.9, 121.0, 118.9, 112.7, 21.6.

LRMS (EI, 70 eV): *m/z* (%) = 347 (82), 346 (100), 281 (26), 208 (13), 73 (48).

HRMS (ESI): m/z [M + H]<sup>+</sup> calcd for  $C_{19}H_{14}N_3S_2^+$ : 348.0624; found: 348.0626.

# 6-Methoxy-2-(6-phenylimidazo[2,1-*b*]thiazol-5-yl)benzo[d]thiazole (30)

Yellow solid; yield: 54.6 mg (75%); mp 188.5-189.2 °C.

IR (ATR): 3113, 2973, 1596, 1531, 1026, 827 cm<sup>-1</sup>.

<sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>): δ = 8.69 (d, *J* = 4.5 Hz, 1 H), 7.83 (d, *J* = 9.0 Hz, 1 H), 7.73–7.71 (m, 2 H), 7.50–7.48 (m, 3 H), 7.14 (d, *J* = 2.5 Hz, 1 H), 7.02 (dd, *J* = 9.0, 2.5 Hz, 1 H), 6.94 (d, *J* = 4.5 Hz, 1 H), 3.80 (s, 3 H). <sup>13</sup>C NMR (125 MHz, CDCl<sub>3</sub>): δ = 157.7, 154.6, 151.8, 149.8, 147.4, 135.1, 133.8, 129.9, 129.2, 128.7, 122.9, 122.0, 118.8, 115.4, 112.6, 104.0, 55.8.

LRMS (EI, 70 eV): *m/z* (%) = 363 (100), 181 (10), 160 (10), 95 (16), 69 (8).

HRMS (ESI): m/z [M + H]<sup>+</sup> calcd for  $C_{19}H_{14}N_3OS_2^+$ : 364.0573; found: 364.0578.

# 6-Bromo-2-(6-phenylimidazo[2,1-*b*][1,3]thiazol-5-yl)-1,3-benzo-thiazole (3p)

Brown solid; yield: 43.9 mg (53%); mp 172.6-173.5 °C.

IR (ATR): 3115, 2968, 1539, 1352, 1097, 831 cm<sup>-1</sup>.

<sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>): δ = 8.71 (d, *J* = 4.5 Hz, 1 H), 8.08 (d, *J* = 2.0 Hz, 1 H), 7.71–7.69 (m, 2 H), 7.52–7.50 (m, 4 H), 7.36 (dd, *J* = 8.0, 2.0 Hz, 1 H), 6.99 (d, *J* = 4.5 Hz, 1 H).

 $^{13}\text{C}$  NMR (125 MHz, CDCl\_3):  $\delta$  = 158.4, 154.1, 152.6, 151.2, 133.5, 132.4, 129.9, 129.6, 128.9, 127.9, 125.1, 122.2, 122.1, 120.0, 118.6, 113.1.

LRMS (EI, 70 eV): *m/z* (%) = 412 (100), 410 (81), 331 (10), 207 (10), 107 (12).

HRMS (ESI):  $m/z \ [M + H]^+$  calcd for  $C_{18}H_{11}BrN_3S_2^+$ : 411.9572; found: 411.9579.

# 6-Chloro-2-(6-phenylimidazo[2,1-*b*][1,3]thiazol-5-yl)-1,3-benzo-thiazole (3q)

Yellow solid; yield: 28.0 mg (38%); mp 217.3–218.1 °C.

IR (ATR): 2971, 1556, 1543, 1228, 1135, 881, 766 cm<sup>-1</sup>.

<sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>): δ = 8.76 (d, *J* = 4.5 Hz, 1 H), 7.87 (d, *J* = 8.5 Hz, 1 H), 7.72–7.71 (m, 2 H), 7.66 (d, *J* = 2.0 Hz, 1 H), 7.53–7.52 (m, 3 H), 7.40 (dd, *J* = 8.5, 2.0 Hz, 1 H), 7.03 (d, *J* = 4.5 Hz, 1 H).

 $^{13}\text{C}$  NMR (125 MHz, CDCl<sub>3</sub>):  $\delta$  = 157.0, 152.1, 151.1, 150.6, 134.5, 133.2, 130.3, 129.6, 129.2, 128.5, 126.7, 122.6, 121.8, 120.5, 118.2, 112.7.

LRMS (EI, 70 eV): *m/z* (%) = 367 (88), 366 (100), 282 (7), 183 (9), 107 (5).

HRMS (ESI):  $m/z \ [M + H]^+$  calcd for  $C_{18}H_{11}CIN_3S_2^+$ : 368.0077; found: 368.0085.

# 6-Fluoro-2-(6-phenylimidazo[2,1-*b*][1,3]thiazol-5-yl)-1,3-benzo-thiazole (3r)

Yellow solid; yield: 24.8 mg (35%); mp 171.7-172.5 °C.

IR (ATR): 3061, 2942, 1539, 1231, 1142, 982, 758 cm<sup>-1</sup>.

<sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>): δ = 8.70 (d, J = 4.5 Hz, 1 H), 7.87 (dd, J = 9.0, 5.0 Hz, 1 H), 7.71–7.69 (m, 2 H), 7.51–7.49 (m, 3 H), 7.34 (dd, J = 8.0, 2.5 Hz, 1 H), 7.16–7.12 (m, 1 H), 6.97 (d, J = 4.5 Hz, 1 H).

<sup>13</sup>C NMR (125 MHz, CDCl<sub>3</sub>): δ = 160.0 (d,  $J_{C-F}$  = 244.0 Hz), 156.3 (d,  $J_{C-F}$  = 3.1 Hz), 152.0, 150.3, 149.2 (d,  $J_{C-F}$  = 3.1 Hz), 134.4 (d,  $J_{C-F}$  = 11.1 Hz), 133.2, 129.6, 129.2, 128.5, 122.8 (d,  $J_{C-F}$  = 9.3 Hz), 121.7, 118.3, 114.4 (d,  $J_{C-F}$  = 24.5 Hz), 112.6, 107.2 (d,  $J_{C-F}$  = 26.8 Hz).

LRMS (EI, 70 eV): *m*/*z* (%) = 351 (90), 350 (100), 306 (8), 279 (3), 103 (8).

HRMS (ESI): m/z [M + H]<sup>+</sup> calcd for C<sub>18</sub>H<sub>11</sub>FN<sub>3</sub>S<sub>2</sub><sup>+</sup>: 352.0373; found: 352.0386.

#### 6-Phenyl-5-(1,3-thiazol-2-yl)imidazo[2,1-b][1,3]thiazole (3t)

Yellow solid; yield: 32.5 mg (57%); mp 127.9-128.6 °C.

IR (ATR): 2972, 1550, 1352, 1230, 1126, 1055, 967 cm<sup>-1</sup>.

<sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>): δ = 8.55 (d, *J* = 4.5 Hz, 1 H), 7.79 (d, *J* = 3.0 Hz, 1 H), 7.71–7.69 (m, 2 H), 7.50–7.41 (m, 3 H), 7.11 (d, *J* = 3.0 Hz, 1 H), 6.92 (d, *J* = 4.5 Hz, 1 H).

 $^{13}\text{C}$  NMR (125 MHz, CDCl<sub>3</sub>):  $\delta$  = 157.4, 151.2, 148.3, 142.2, 134.0, 129.6, 129.0, 128.7, 121.6, 118.8, 116.9, 112.4.

LRMS (EI, 70 eV): *m/z* (%) = 283 (57), 282 (100), 198 (6), 103 (5), 57 (5).

HRMS (ESI): m/z [M + H]<sup>+</sup> calcd for  $C_{14}H_{10}N_3S_2^+$ : 284.0311; found: 284.0316.

#### 2-(2-Phenylimidazo[1,2-a]pyridin-3-yl)-1,3-benzothiazole (5a)

Yellow solid; yield: 46.9 mg (72%); mp 162.2-163.1 °C.

IR (ATR): 3069, 2958, 1545, 1522 1292, 1090, 820 cm<sup>-1</sup>.

<sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>): δ = 9.99 (d, *J* = 7.0 Hz, 1 H), 8.05 (d, *J* = 8.0 Hz, 1 H), 7.77–7.70 (m, 4 H), 7.53–7.50 (m, 3 H), 7.47–7.41 (m, 2 H), 7.31 (t, *J* = 7.5 Hz, 1 H), 7.07 (t, *J* = 6.5 Hz, 1 H).

 $^{13}\text{C}$  NMR (125 MHz, CDCl<sub>3</sub>):  $\delta$  = 157.7, 153.0, 150.5, 146.5, 133.8, 133.8, 130.2, 129.4, 128.7, 128.1, 127.4, 126.2, 125.0, 122.5, 121.1, 117.4, 116.1, 113.9.

LRMS (EI, 70 eV): *m/z* (%) = 327 (88), 326 (100), 253 (6), 163 (12), 73 (16).

HRMS (ESI): m/z [M + H]<sup>+</sup> calcd for C<sub>20</sub>H<sub>14</sub>N<sub>3</sub>S<sup>+</sup>: 328.0903; found: 328.0905.

#### 2-[2-(4-Tolyl)imidazo[1,2-a]pyridin-3-yl]-1,3-benzothiazole (5b)

Yellow solid; yield: 46.3 mg (68%); mp 225.8–226.5 °C. IR (ATR): 2978, 1540, 1515, 1269, 1198, 1072, 835 cm<sup>-1</sup>. <sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>): δ = 9.99 (d, *J* = 7.0 Hz, 1 H), 8.04 (d, *J* = 8.0 Hz, 1 H), 7.75–7.70 (m, 2 H), 7.61 (d, *J* = 8.0 Hz, 2 H), 7.47–7.38 (m, 2 H), 7.32–7.29 (m, 3 H), 7.07–7.04 (m, 1 H), 2.47 (s, 3 H).

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 $^{13}\text{C}$  NMR (125 MHz, CDCl\_3):  $\delta$  = 157.6, 152.7, 150.4, 146.2, 139.2, 133.6, 130.6, 129.8, 129.2, 127.9, 127.0, 125.9, 124.7, 122.2, 120.9, 117.1, 115.8, 113.6, 21.4.

LRMS (EI, 70 eV): *m/z* (%) = 341 (80), 340 (100), 253 (8), 135 (6), 73 (15).

HRMS (ESI):  $\ensuremath{\textit{m/z}}\xspace$  [M + H]^+ calcd for  $C_{21}H_{16}N_3S^*$ : 342.1059; found: 342.1055.

### 2-[2-(4-Methoxyphenyl)imidazo[1,2-*a*]pyridin-3-yl]-1,3-benzo-thiazole (5c)

Brown solid; yield: 39.9 mg (56%); mp 229.3–230.2 °C. IR (ATR): 3071, 2965, 1539, 1517, 1073, 952, 832 cm<sup>-1</sup>.

<sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>): δ = 9.89 (d, J = 7.0 Hz, 1 H), 7.94 (d, J = 8.0 Hz, 1 H), 7.65–7.61 (m, 2 H), 7.55 (d, J = 9.0 Hz, 2 H), 7.36–7.29 (m, 2

H), 7.22–7.19 (m, 1 H), 6.95–6.94 (m, 3 H), 3.80 (s, 3 H).  $^{13}$ C NMR (125 MHz, CDCl<sub>3</sub>):  $\delta$  = 160.7, 157.8, 152.9, 150.3, 146.4, 133.7, 131.5, 128.1, 127.3, 126.1, 125.9, 124.9, 122.4, 121.1, 117.2, 115.9, 114.2, 113.7, 55.4.

LRMS (EI, 70 eV): *m/z* (%) = 357 (100), 356 (97), 281 (39), 207 (75), 73 (56).

HRMS (ESI): m/z [M + H]<sup>+</sup> calcd for  $C_{21}H_{16}N_3OS^+$ : 358.1009; found: 358.1011.

### 2-(2-Biphenyl-4-ylimidazo[1,2-*a*]pyridin-3-yl)-1,3-benzothiazole (5d)

Yellow solid; yield: 45.3 mg (56%); mp 239.2-240.0 °C.

IR (ATR): 3059, 2962, 1538, 1509, 1120, 935, 829 cm<sup>-1</sup>.

<sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>): δ = 9.97 (d, *J* = 7.0 Hz, 1 H), 8.05 (d, *J* = 8.1 Hz, 1 H), 7.81–7.70 (m, 8 H), 7.48–7.36 (m, 5 H), 7.30 (t, *J* = 8.0 Hz, 1 H), 7.06 (t, *J* = 6.9 Hz, 1 H).

 $^{13}\text{C}$  NMR (125 MHz, CDCl\_3):  $\delta$  = 157.4, 152.8, 149.7, 146.3, 141.9, 140.4, 133.6, 132.4, 130.4, 128.7, 127.9, 127.5, 127.3, 127.2, 127.0, 126.0, 124.9, 122.3, 121.0, 117.1, 115.8, 113.7.

LRMS (EI, 70 eV): *m/z* (%) = 403 (81), 402 (100), 326 (6), 281 (7), 78 (7).

HRMS (ESI): m/z [M + H]<sup>+</sup> calcd for C<sub>26</sub>H<sub>18</sub>N<sub>3</sub>S<sup>+</sup>: 404.1216; found: 404.1216.

#### 2-[2-(4-Bromophenyl)imidazo[1,2-*a*]pyridin-3-yl]-1,3-benzothiazole (5e)

Brown solid; yield: 47.2 mg (58%); mp 228.5–229.6 °C.

IR (ATR): 3035, 2957, 1550, 1523, 1269, 1091, 1030, 826, 687 cm<sup>-1</sup>.

 $^1\text{H}$  NMR (500 MHz, CDCl<sub>3</sub>):  $\delta$  = 9.93 (d, J = 7.0 Hz, 1 H), 8.06 (d, J = 8.0 Hz, 1 H), 7.76–7.74 (m, 2 H), 7.65–7.60 (m, 4 H), 7.50–7.42 (m, 2 H), 7.36–7.37 (m, 1 H), 7.10–7.07 (m, 1 H).

 $^{13}\text{C}$  NMR (125 MHz, CDCl<sub>3</sub>):  $\delta$  = 156.9, 152.7, 148.6, 146.2, 133.5, 132.4, 131.7, 131.6, 127.8, 127.3, 126.1, 125.0, 123.7, 122.4, 121.0, 117.1, 115.8, 113.8.

LRMS (EI, 70 eV): *m/z* (%) = 406 (75), 281 (55), 207 (100), 135 (23), 69 (12).

HRMS (ESI):  $m/z \ [M + H]^+$  calcd for  $C_{20}H_{13}BrN_3S^+$ : 406.0008; found: 406.0013.

#### 2-[2-(4-Chlorophenyl)imidazo[1,2-*a*]pyridin-3-yl]-1,3-benzothiazole (5f)

Yellow solid; yield: 50.5 mg (70%); mp 212.5–213.6 °C.

IR (ATR): 3120, 2962, 1539, 1509, 1373, 1215, 1093, 985, 718 cm<sup>-1</sup>.

<sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>): δ = 9.94 (d, *J* = 7.0 Hz, 1 H), 8.06 (d, *J* = 8.5 Hz, 1 H), 7.75 (d, *J* = 8.5 Hz, 2 H), 7.67 (d, *J* = 8.4 Hz, 2 H), 7.49–7.42 (m, 4 H), 7.34 (t, *J* = 7.5 Hz, 1 H), 7.08 (t, *J* = 7.0 Hz, 1 H).

 $^{13}\text{C}$  NMR (125 MHz, CDCl\_3):  $\delta$  = 156.9, 152.7, 148.6, 146.2, 135.3, 133.4, 132.0, 131.3, 128.7, 127.7, 127.3, 126.0, 124.9, 122.3, 120.9, 117.1, 115.8, 113.7.

LRMS (El, 70 eV): m/z (%) = 361 (81), 360 (100), 281 (35), 253 (17), 163 (21).

HRMS (ESI): m/z [M + H]<sup>+</sup> calcd for C<sub>20</sub>H<sub>13</sub>ClN<sub>3</sub>S<sup>+</sup>: 362.0513; found: 362.0518.

#### 2-[2-(4-Fluorophenyl)imidazo[1,2-*a*]pyridin-3-yl]-1,3-benzothiazole (5g)

Yellow solid; yield: 38.8 mg (56%); mp 196.2-197.1 °C.

IR (ATR): 3052, 2957, 1539, 1350, 121, 1091, 979 cm<sup>-1</sup>.

<sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>): δ = 9.98 (d, *J* = 7.5 Hz, 1 H), 8.06 (d, *J* = 8.1 Hz, 1 H), 7.76–7.69 (m, 4 H), 7.49–7.43 (m, 2 H), 7.34 (t, *J* = 7.5 Hz, 1 H), 7.21 (t, *J* = 8.4 Hz, 2 H), 7.09 (t, *J* = 7.0 Hz, 1 H).

<sup>13</sup>C NMR (125 MHz, CDCl<sub>3</sub>): δ = 163.7 (d,  $J_{C-F}$  = 247.3 Hz), 157.4, 152.9, 149.3, 146.4, 133.7, 132.1 (d,  $J_{C-F}$  = 8.4 Hz), 129.9, 128.1, 127.4, 126.3, 125.1, 122.5, 121.1, 117.4, 116.1, 115.8 (d,  $J_{C-F}$  = 21.6 Hz), 113.9.

LRMS (EI, 70 eV): *m/z* (%) = 345 (73), 344 (100), 208 (9), 172 (15), 78 (11).

HRMS (ESI): m/z [M + H]<sup>+</sup> calcd for  $C_{20}H_{13}FN_3S^+$ : 346.0809; found: 346.0813.

# 2-(7-Bethyl-2-phenylimidazo[1,2-*a*]pyridin-3-yl)benzo[d]thiazole (5h)

Yellow solid; yield: 41.9 mg (61%); mp 188.3–189.5 °C.

IR (ATR): 3075, 2958, 1552, 1270, 1095, 836 cm<sup>-1</sup>.

<sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>): δ = 9.86 (d, *J* = 7.0 Hz, 1 H), 8.02 (d, *J* = 8.0 Hz, 1 H), 7.72–7.68 (m, 3 H), 7.51–7.42 (m, 5 H), 7.28 (t, *J* = 7.0 Hz, 1 H), 6.89 (d, *J* = 7.0 Hz, 1 H), 2.48 (s, 3 H).

 $^{13}\text{C}$  NMR (125 MHz, CDCl\_3):  $\delta$  = 157.8, 153.0, 150.5, 147.0, 138.7, 134.0, 133.7, 130.2, 129.4, 128.7, 127.4, 126.1, 124.9, 122.4, 121.1, 116.4, 115.9, 115.7, 21.5.

LRMS (EI, 70 eV): *m/z* (%) = 341 (81), 340 (100), 207 (4), 170 (11), 65 (5).

HRMS (ESI):  $\textit{m/z}~[M + H]^{*}$  calcd for  $C_{21}H_{16}N_{3}S^{*}\!\!:$  342.1059; found: 342.1065.

#### 2-(6-Methyl-2-phenylimidazo[1,2-*a*]pyridin-3-yl)-1,3-benzothiazole (5i)

Yellow solid; yield: 42.5 mg (62%); mp 191.0–192.2 °C.

IR (ATR): 3073, 2961, 1543, 1513, 1271, 1089, 819 cm<sup>-1</sup>.

<sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>): δ = 9.73 (s, 1 H), 8.08 (d, J = 8.0 Hz, 1 H), 7.73–7.66 (m, 4 H), 7.52–7.46 (m, 4 H), 7.34–7.28 (m, 2 H), 2.48 (s, 3 H).

 $^{13}\text{C}$  NMR (125 MHz, CDCl<sub>3</sub>):  $\delta$  = 157.6, 152.7, 149.7, 145.2, 133.6, 130.2, 129.9, 129.0, 128.4, 125.8, 125.4, 124.7, 123.5, 122.2, 120.8, 116.3, 115.5, 18.4.

LRMS (EI, 70 eV): *m*/*z* (%) = 341 (81), 340 (100), 207 (6), 170 (11), 65 (7).

HRMS (ESI):  $\textit{m/z}~[M + H]^{*}$  calcd for  $C_{21}H_{16}N_{3}S^{*}\!\!:$  342.1059; found: 342.1059.

#### 2-(2-Methylimidazo[1,2-a]pyridin-3-yl)-1,3-benzothiazole (5j)

Yellow solid; yield: 30.7 mg (58%); mp 137.2–138.3 °C.

IR (ATR): 2926, 1557, 1540, 1510, 1349, 1235, 1031, 915 cm<sup>-1</sup>.

<sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>): δ = 10.08 (dd, *J* = 6.0, 1.0 Hz, 1 H), 8.04 (d, *J* = 8.0 Hz, 1 H), 7.92–7.88 (m, 1 H), 7.66 (d, *J* = 8.5 Hz, 1 H), 7.51–7.48 (m, 1 H), 7.40–7.34 (m, 2 H), 7.05–7.02 (m, 1 H), 2.83 (s, 3 H).

 $^{13}\text{C}$  NMR (125 MHz, CDCl<sub>3</sub>):  $\delta$  = 157.3, 153.1, 147.8, 146.1, 133.3, 128.4, 127.1, 126.4, 124.7, 122.4, 121.1, 116.5, 113.6, 16.6.

LRMS (EI, 70 eV): m/z (%) = 265 (80), 264 (100), 135 (7), 133 (7), 78 (17).

HRMS (ESI): m/z [M + H]<sup>+</sup> calcd for C<sub>15</sub>H<sub>12</sub>N<sub>3</sub>S<sup>+</sup>: 266.0746; found: 266.0749.

#### 2-(2-Ethylimidazo[1,2-a]pyridin-3-yl)-1,3-benzothiazole (5k)

Yellow solid; yield: 28.3 mg (51%); mp 140.9–141.7 °C. IR (ATR): 3033, 2967, 1537, 1440, 1238, 1029, 910 cm<sup>-1</sup>.

<sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>):  $\delta$  = 10.07 (d, J = 7.0 Hz, 1 H), 8.05 (d, J = 8.0 Hz, 1 H), 7.90 (d, J = 8.0 Hz, 1 H), 7.69 (d, J = 9.0 Hz, 1 H), 7.49 (t, J = 7.5 Hz, 1 H), 7.37 (q, J = 7.0 Hz, 2 H), 7.02 (t, J = 7.0 Hz, 1 H), 3.22 (q, J = 7.5 Hz, 2 H), 1.51 (t, J = 7.5 Hz, 3 H).

 $^{13}\text{C}$  NMR (125 MHz, CDCl\_3):  $\delta$  = 156.8, 152.9, 152.8, 146.0, 133.0, 128.1, 126.7, 126.1, 124.4, 122.2, 120.8, 116.4, 115.5, 113.21, 23.0, 12.9.

LRMS (EI, 70 eV): *m/z* (%) = 279 (100), 207 (18), 186 (10), 78 (22), 73 (11).

HRMS (ESI):  $m/z \ [M + Na]^+$  calcd for  $C_{16}H_{13}N_3NaS^+$ : 302.0722; found: 302.0712.

#### 3-(1,3-Benzothiazol-2-yl)-2-phenylimidazo[1,2-*a*]pyrimidine (51)

Yellow solid; yield: 44.5 mg (68%); mp 232.3–233.1 °C.

IR (ATR): 3119, 2908, 1545, 1507, 1377, 1228, 933 cm<sup>-1</sup>.

<sup>1</sup>H NMR (500 MHz,  $CDCl_3$ ):  $\delta$  = 10.28 (dd, *J* = 7.0, 2.0 Hz, 1 H), 8.72 (dd, *J* = 4.0, 2.0 Hz, 1 H), 8.02 (d, *J* = 8.0 Hz, 1 H), 7.77 (dd, *J* = 8.0, 2.0 Hz, 2 H), 7.71 (d, *J* = 7.8 Hz, 1 H), 7.57–7.50 (m, 3 H), 7.48–7.43 (m, 1 H), 7.37–7.29 (m, 1 H), 7.12 (dd, *J* = 7.0, 4.0 Hz, 1 H).

 $^{13}\text{C}$  NMR (125 MHz, CDCl<sub>3</sub>):  $\delta$  = 157.0, 152.6, 151.9, 151.6, 149.2, 136.0, 133.6, 133.1, 130.2, 129.8, 128.8, 126.4, 125.4, 122.6, 121.2, 114.5, 110.1.

LRMS (EI, 70 eV): *m/z* (%) = 328 (85), 327 (100), 208 (8), 135 (7), 73 (28).

HRMS (ESI): m/z [M + H]<sup>+</sup> calcd for  $C_{19}H_{13}N_4S^+$ : 329.0855; found: 329.0863.

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#### **Supporting Information**

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