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Switchable and Scalable Heteroarylation of Primary Amines with 2-Chlorobenzothiazoles under Transition-Metal-Free and Solvent-Free Conditions

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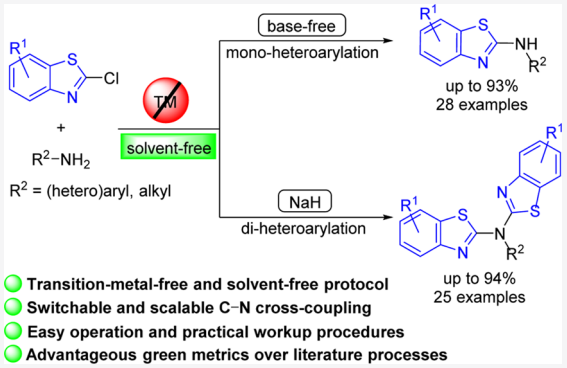
ABSTRACT: 2-Aminobenzothiazoles comprise a valuable structural motif, which prevails in versatile natural products and biologically active compounds. Herein, a switchable and scalable C−N coupling protocol was developed for the synthesis of these compounds from 2-chlorobenzothiazoles and primary amines. Gratifyingly, this protocol was achieved under transition-metal-free and solvent-free conditions. Moreover, introducing an appropriate amount of NaH completely switched the selectivity from mono- toward di-heteroarylation, and further investigations provided a rationale for this new finding. Furthermore, gram-scale synthesis of representative products **3a** and **4a** was realized by applying operationally simple and glovebox-free procedures, which revealed the practical usefulness of this work. Finally, evaluation of the quantitative green metrics provided evidence that our protocol was superior over the literature ones in terms of green chemistry and sustainability.



INTRODUCTION

Benzothiazole and its derivatives are an important class of heterocyclic compounds which have potential applications in numerous areas such as organic chemistry, pharmaceutical industry, and materials science.[1−4] Among these compounds, 2-aminobenzothiazoles have been widely distributed in a number of bioactive molecules.[5] For example, riluzole is an antispasmodic drug mainly used for prolonging the life of patients with amyotrophic lateral sclerosis (ALS).[6,7] Talarozole, an all-trans retinoic acid metabolism blocking agent (RAMBA), can improve the level of endogenous all-trans retinoic acid (RA) in cells. Accordingly, it is commonly used as an effective drug to treat psoriasis, acne, and some other keratinization disorders.[8,9] Besides, compounds bearing the 2-aminobenzothiazole unit also demonstrate anti-tobacco mosaic virus (TMV) activity,[10] antifungal activity,[11] anti-mosquito properties against *Anopheles arabiensis*,[12] and antibacterial activity.[13] Due to the diverse biological and pharmaceutical properties of 2-aminobenzothiazoles, expedient synthetic approaches have been developed for accessing these compounds.

Among the versatile synthetic methods, we paid great attention to traditional C−N cross-coupling strategies,[14−25] which have been utilized to access 2-aminobenzothiazoles via the direct functionalization of the benzothiazole framework. For instance, the C−N cross-coupling of 2-aminobenzothiazole (or its derivatives) with boronic acids,[26,27] aryl halides,[28−36] triflates,[32] or triazenes[37] efficiently afforded the aminated products. Besides, treatment of amines with unsubstituted benzothiazole[38−42] or 2-substituted benzothiazoles[43−52] also enabled the efficient formation of the desired products (Scheme 1a). It was observed that all of the above reactions went through one amination sequence to furnish the mono-heteroarylation products. In our previous work, the corresponding di-heteroarylation products, namely, tertiary amines bearing two benzothiazole units, were selectively prepared from 2-chlorobenzothiazoles and primary aromatic amines for the first time. Interestingly, switchable mono- vs di-heteroarylation was realized via a ligand-controlled Pd-catalyzed strategy (Scheme 1b).[53] Inspired by the above work, we herein aimed to develop a greener and more practical synthetic approach for these molecules. Gratifyingly, a transition-metal-free and solvent-free protocol was obtained to afford either mono- or di-heteroarylation products in a selective manner (Scheme 1c). It was found that heating the two reactants in the absence of any base or additive

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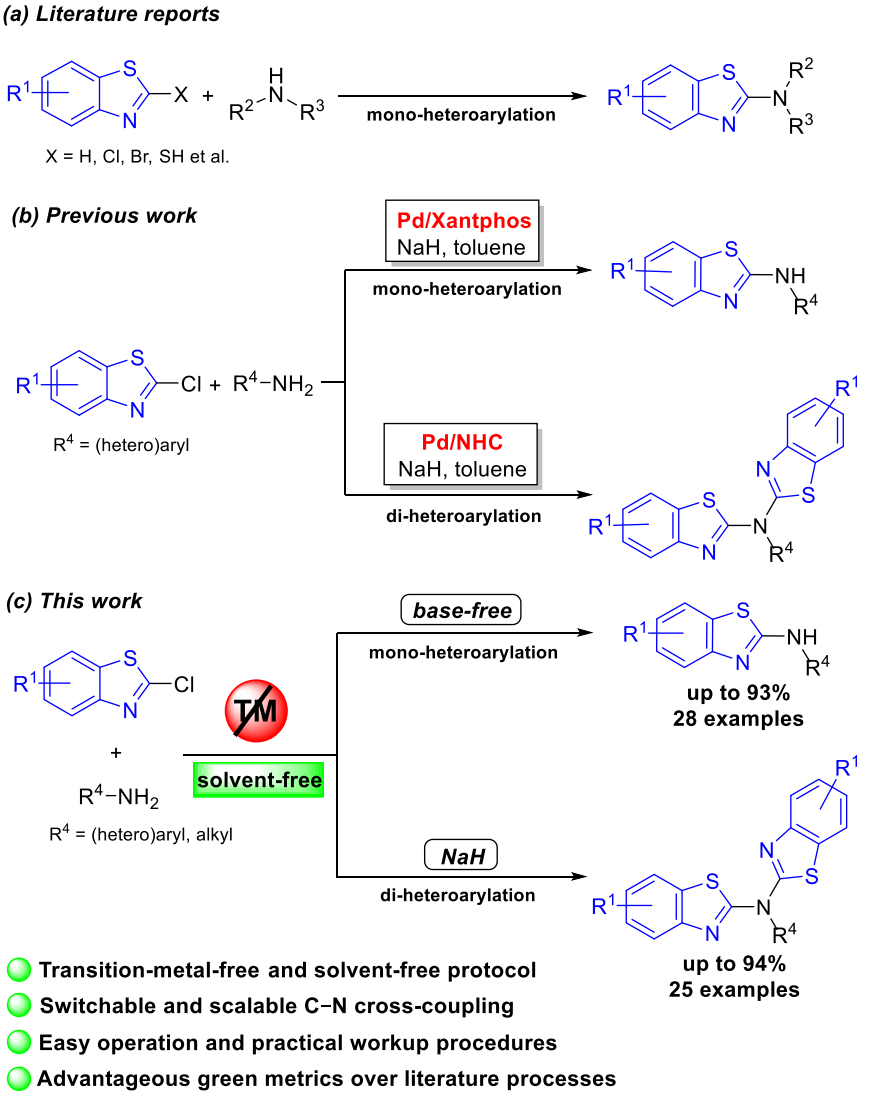
Scheme 1. Design Strategy of This Work: (a) Literature Reports; (b) Previous Work; and (c) This Work



exclusively gave rise to the mono-heteroarylation products, whereas the involvement of an appropriate amount of NaH completely switched the selectivity to the di-heteroarylation counterparts. To further demonstrate the practical potential of our protocol, we carried out gram-scale reactions and optimized the workup procedures. It was also worth emphasizing that the green metrics were calculated to be superior over those of the literature approaches, which implicated the green and sustainable aspects of the current protocol.

RESULTS AND DISCUSSION

2-Chlorobenzothiazole (**1a**) and aniline (**2a**) were selected as the two reactants for optimizations of the reaction conditions (Table S1 in the Supporting Information, Table 1). Our research commenced with the selected conditions in our previous work (as listed in Table S1 in the Supporting Information).[53] In the presence of $Pd(OAc)_2$, NaH, and toluene, Xantphos (or an *N*-heterocyclic carbene precursor) provided **3a** (or **4a**) as the major product (entries 1 and 2), while a ligandless condition led to 51% of **4a** and 5% of **3a** (entry 3). With an aim to identify a greener and more practical protocol for this transformation, further optimizations were conducted (as listed in Table 1). To our delight, Pd was found to be unnecessary for this coupling, with 59% of **4a**, 12% of **3a**, and 16% of unreacted **1a** being observed in the absence of a Pd salt (entry 1). Since organic solvents are the major source of wastes in organic synthesis, we then attempted the same reaction under a solvent-free condition (entry 2). Interestingly, an even better result was obtained in comparison with the toluene-containing reaction (entry 2 vs entry 1). From the perspectives of green chemistry and sustainability, we decided to continue the optimizations without any solvent. Next, different bases were screened to evaluate their effects on the reaction conversion and **4a**/**3a** selectivity (entries 3–20). Among various metal salts, stronger bases including LDA (pK_{aH} = 35.7), *tert*-butoxides (pK_{aH} = 17.0), and hydroxides (pK_{aH} = 15.7) could deliver di-heteroarylation product **4a** to some extent, but they were not as effective as NaH (entries 3–9 vs entry 2). In contrast, weaker bases such as carbonates (pK_{aH} = 10.3) and acetates (pK_{aH} = 4.76) mainly provided mono-heteroarylation product **3a** in low to moderate yield (entries 10–15). Subsequently, organic bases such as 2,2′-bipyridine (bpy), 1,10-phenanthroline (1,10-phen), pyridine (pyr), 1,4-diazabicyclo[2.2.2]octane (DABCO), and diisopropylethylamine (DIPEA) were also

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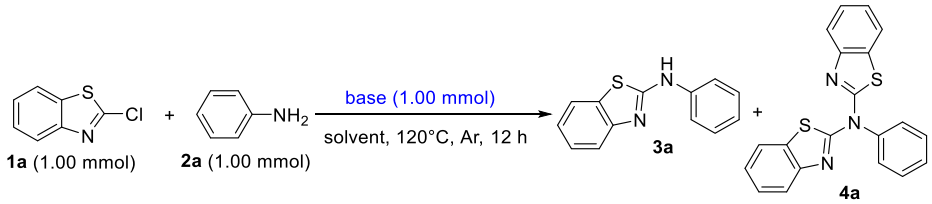
Table 1. Optimization of Reaction Conditions[a]



entry	base	pK_{aH}[b]	solvent	yield (%)[c] 3a	yield (%)[c] 4a	1a (mmol)
1	NaH	~36[d]	toluene	12	59	0.16
2	NaH	~36[d]		3	71	0.05
3	LDA	35.7[e]		4	65	0.08
4	LiO*t*Bu	17.0[e]		2	41	0.45
5	NaO*t*Bu	17.0[e]		5	62	0.18
6	KO*t*Bu	17.0[e]		14	57	0.16
7	LiOH	15.7[e]		8	28	0.57
8	NaOH	15.7[e]		10	8	0.76
9	KOH	15.7[e]		11	18	0.42
10	Na_2CO_3	10.3[e]		6	3	0.82
11	K_2CO_3	10.3[e]		29	4	0.62
12	Cs_2CO_3	10.3[e]		10	5	0.72
13	LiOAc	4.76[e]		31	2	0.56
14	NaOAc	4.76[e]		21	5	0.68
15	KOAc	4.76[e]		25	0	0.62
16	bpy	4.23[e]		71	0	0.18
17	1,10-phen	5.12[e]		65	0	0.26
18	pyr	5.23[e]		76	0	0.15
19	DABCO	8.60[e]		62	0	0.18
20	DIPEA	10.5[e]		67	0	0.23
21				86	5	0.00

[a]A mixture of **1a** (1.00 mmol), **2a** (1.00 mmol), a base (1.00 mmol) or no base, and solvent (2.5 mL) was heated at 120 °C under argon for 12 h. [b]pK_{aH} represents the pK_a values of the conjugate acids.[54] [c]NMR yield using 1,3,5-trimethoxybenzene as an internal standard (average of two consistent runs). [d]In tetrahydrofuran (THF). [e]In water.

attempted (entries 16−20). It was found that only **3a** could be obtained in 62−76% yield, probably due to their weak basicity (pK_{aH} = 4.23−10.5), which could not stimulate the proceeding of the second amination. To our delight, the C−N coupling proceeded smoothly under the base-free condition, affording 86% of **3a** and 5% of **4a** (entry 21). It was obvious that the intrinsic basicity of the added bases was crucial for this transformation. Moreover, they could also serve as additives to interfere the interaction of the two reactants, thus decreasing the viscosity of the reaction mixture so that the reaction efficiency was affected. Therefore, it could be more understandable that the stronger bases stimulated the formation of di-heteroarylation product **4a** (entries 2−9), and the reaction without a base or additive was more efficient than those promoted by the weaker bases (entry 21 vs entries 10−20). Finally, the NaH-promoted and base-free conditions were selected for further investigations, respectively (entries 2 and 21).

To attain either **3a** or **4a** in excellent yield, further optimizations were conducted (as listed in Table 2). At the outset, the ratios of **1a**/**2a** were changed (entries 1−10). For the base-free reactions, compared with the ratio of 1.00:1.00, 1.00:0.75−0.50 led to lower **3a**/**4a** selectivity (entries 3−4), whereas 1.00:1.25−1.50 exclusively provided **3a** in excellent yield (entries 5 and 6), with 1.00:1.25 being identified as the optimized ratio (entry 5). In the case of the NaH-involving reactions, gradually increasing the ratio from 1.00:1.00 to 1.50:0.50 facilitated the formation of **4a** (entries 2, 7−10). Specifically, the ratio of 1.25:0.50 was enough to reach the maximum yield (entry 9). Subsequently, the effect of the reaction temperatures was also investigated (entries 5, 9, 11−14). About mono-heteroarylation, lowering the temperature from 120 to 100 °C led to a comparable result (entry 11 vs entry 5), while further reducing it to 80 °C gave rise to **3a** in only 68% yield (entry 12). Therefore, 100 °C was regarded as the most suitable temperature for the selective formation of **3a** (entry 11). For di-heteroarylation, altering the reaction temperature from 120 to 100 °C exclusively gave **4a**, but with a reduced yield of 78% (entry 13). Unfortunately, a mixture of **3a** and **4a** was observed if an even lower temperature of 80 °C was used (entry 14). These results illustrated that selective formation of **3a** or **4a** was realized under transition-metal-free and solvent-free conditions, with entry 9 and entry 11 as the optimized conditions for the mono- and di-heteroarylation, respectively.

After the optimized reaction conditions were achieved, the substrate scope and limitation of this protocol were explored (as shown in Scheme 2). At the beginning, the reactions of **1a** and various anilines were attempted. For the base-free situation, electron-rich products **3b−f** were delivered in excellent yield, while electron-deficient counterparts **3g−n** were afforded in a lower yield of 45−85%. In particular, 4-(trifluoromethyl)aniline (**2l**) and 4-aminobenzonitrile (**2m**) produced desired products **3l** and **3m** in 62 and 45% yield,

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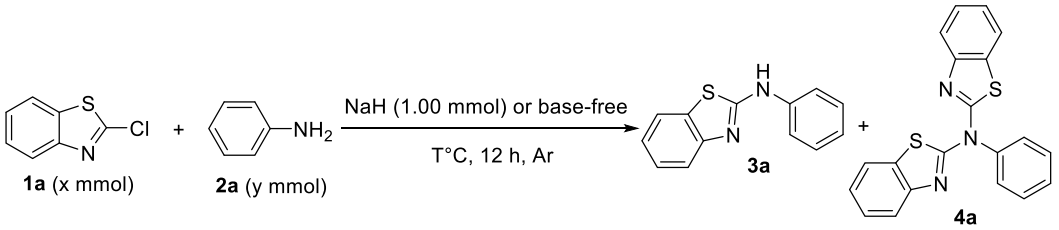
Table 2. Further Screening of Other Parameters



					yield (%)[a]		
entry	*x*	*y*	base	*T*	**3a**	**4a**	**1a** (mmol)
1	1.00	1.00		120	86	5	0.00
2	1.00	1.00	NaH	120	3	71	0.05
3	1.00	0.75		120	45	26	0.18
4	1.00	0.50		120	32	37	0.21
5	1.00	1.25		120	95	0	0.00
6	1.00	1.50		120	96	0	0.00
7	1.00	0.75	NaH	120	0	73	0.08
8	1.00	0.50	NaH	120	0	83	0.00
9	1.25	0.50	NaH	120	0	92 (90[b])	0.16
10	1.50	0.50	NaH	120	0	92	0.39
11	1.00	1.25		100	95 (92[b])	0	0.00
12	1.00	1.25		80	68	0	0.23
13	1.25	0.50	NaH	100	0	78	0.39
14	1.25	0.50	NaH	80	26	52	0.45

[a]NMR yield using 1,3,5-trimethoxybenzene as an internal standard (average of two consistent runs). [b]Isolated yield.

respectively. It seemed that para substituents of anilines had a significant impact on the NaH-promoted reactions. Among the selected electron-donating groups, Me and OMe gave rise to the di-arylation products (**4b−c**) in 91−94% yield. In contrast, the bulkier *i*Pr, *t*Bu, and NMe_2 groups resulted in the expected products (**4d−f**) in 68−76% yield, with the concurrent formation of the mono-heteroarylation counterparts (**3d−f**) in 12−21% yield. As for the investigated electron-deficient groups, two consecutive amination sequences occurred to give products **4g−m** in 21−85% yield. The only exception was the reaction of **1a** with 4-nitroaniline (**2n**), which only afforded mono-heteroarylation product **3n** in 75% yield. In the case of potentially bioactive substructures such as Ph,[55] OPh,[56−58] or NHPh[53] as a para substituent, **3o−q** (or **4o−q**) were isolated in moderate to high yield under the base-free (or NaH-promoted) condition. Afterward, the influence of the substituent positions on the C−N coupling reactions was evaluated. Under the base-free condition, 3-methylaniline (**2r**) and 2-methylaniline (**2s**) displayed comparable reactivity with 4-methylaniline (**2b**). Conversely, **2s** exhibited lower reactivity than **2b** and **2r** under the NaH-promoted condition, with the formation of **4s** in only 52% yield. Moreover, incorporation of different R^1 groups into the benzothiazole framework was attempted. For electron-rich groups such as Me and OMe, excellent yield of mono-heteroarylation products **3t−u** and moderate yield of di-arylated counterparts **4t−u** were obtained for the above-mentioned conditions, respectively. If an electron-withdrawing group (Cl) was used, 56% of **3v** and 21% of **4v** were delivered for the base-free case, whereas only **4v** was isolated in 52% yield for the NaH-promoted case. Probably, the activated substrate (**1v**) facilitated the second amination process under the mono-heteroarylation condition to give a certain amount of di-heteroarylation product **4v**. In our previous work, only **4w** was isolated under either mono- or di-heteroarylation condition for the highly activated substrate (**1w**) bearing an electron-deficient ester group as R^1.[53] Interestingly, the current protocol resulted in **3w** in 93% yield under the base-free condition and **4w** in 85% yield under the NaH-promoted condition. Pleasingly, under the base-free condition, excellent yield and selectivity of **3w** retained even with an excess amount of **1a** or at an elevated temperature (as detailed in Table S2, Supporting Information). Apart from aromatic primary amines, aliphatic substrates **2x−z** were also compatible. Under the base-free condition, desired products **3x−z** were obtained in 91−93% yield. As for the NaH-mediated condition, 63−74% of **4x−z** and 15−16% of **3x−z** were isolated. Finally, heteroaromatic primary amine **2a′** was tried, and only mono-heteroarylation product **3a′** was obtained (25% under the base-free condition and 75% under the NaH-promoted condition).

To rationalize this switchable C−N coupling protocol, additional experiments were carried out. Initially, the reaction progress was monitored at regular time intervals under both conditions (as described in Figure 1). In the absence of a base, 71% of **3a** was detected after 1 h. The yield of **3a** increased simultaneously to 92% by elongating the reaction time to 12 h, while a further increase of the period resulted in a constant yield of **3a** (Figure 1a). It was worth mentioning that no formation of **4a** was detected at all of the tested periods. A similar phenomenon was found for the NaH-mediated reactions, in which the yield of **4a** was gradually increased until a plateau was reached, without the observation of mono-heteroarylation counterpart **3a** (Figure 1b). The results uncovered the excellent selectivity for both conditions. To further clarify this point, control experiments were carried out using **1a** and **3a** as the two coupling reagents (Scheme 3). Expectedly, no reaction occurred for the base-free strategy, whereas 88% of **4a** was isolated for the NaH-containing process. Furthermore, the influence of the NaH amounts on

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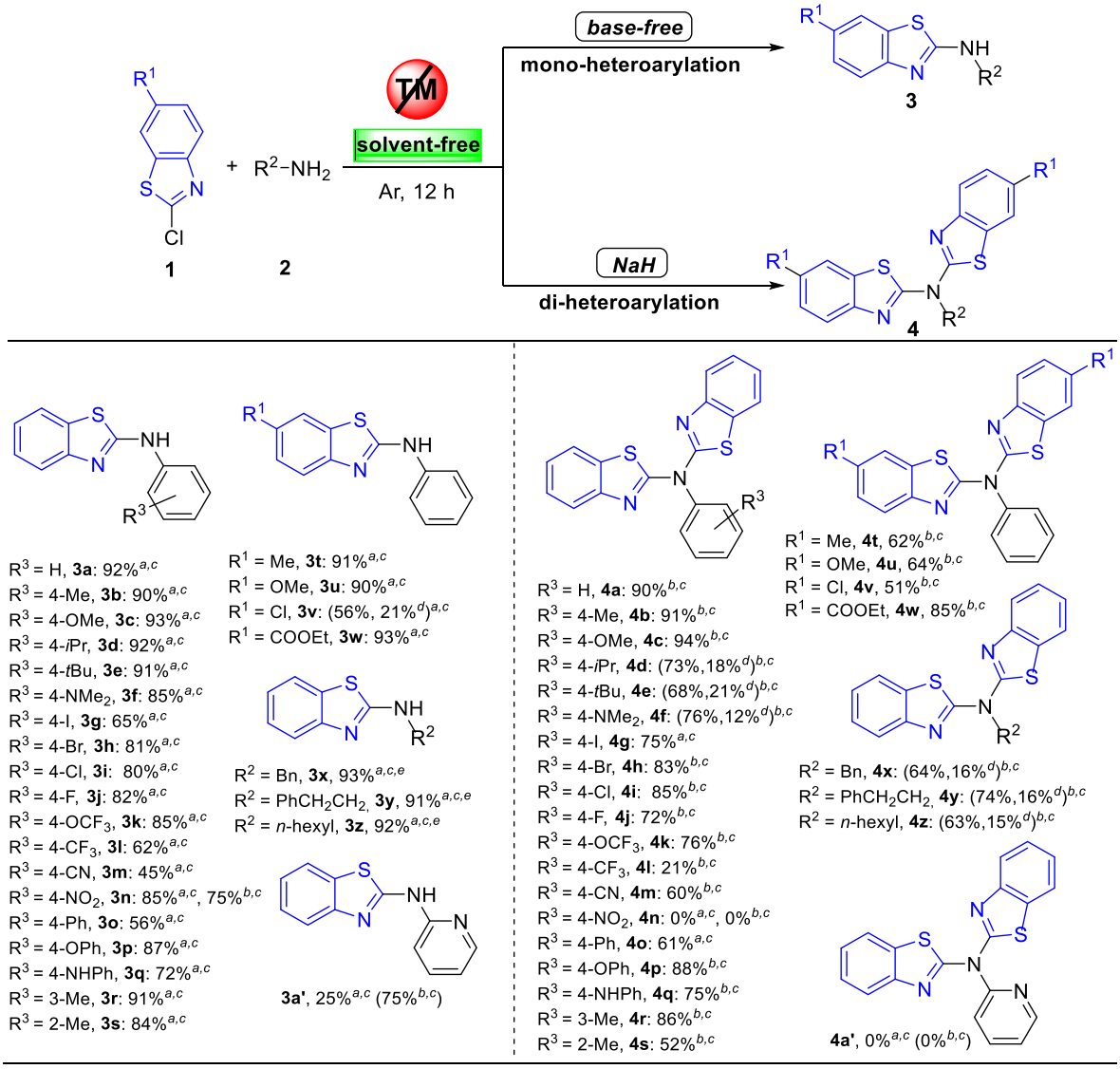
Scheme 2. Substrate Exploration



[a]**1** (1.00 mmol) and **2** (1.25 mmol) were heated at 100°C. [b]**1** (1.25 mmol), **2** (0.50 mmol) and NaH (1.00 mmol) were heated at 120°C. [c]Isolated yield. [d]The yield of the corresponding di- (or mono-)heteroarylation products. [e]**2** (2.00 mmol).

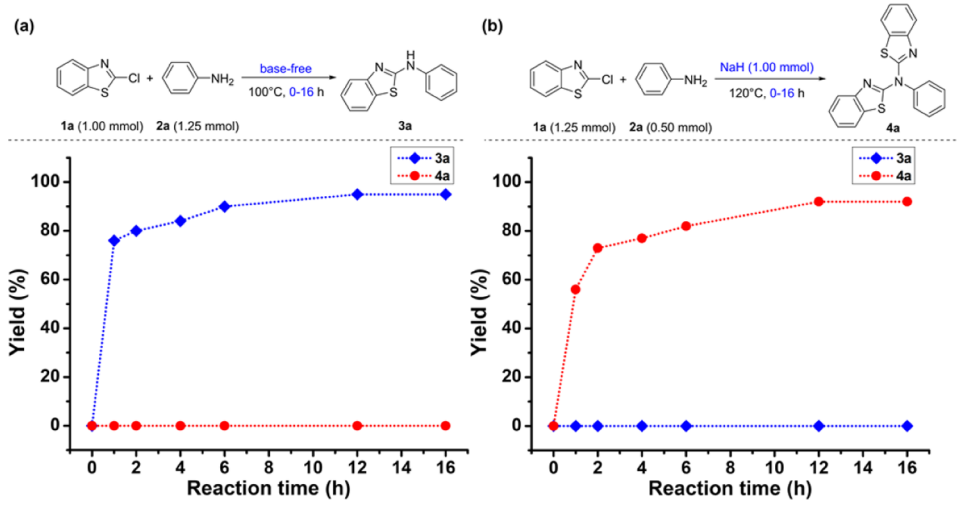


Figure 1. Reaction progress monitored under the (a) base-free and (b) NaH-promoted conditions.

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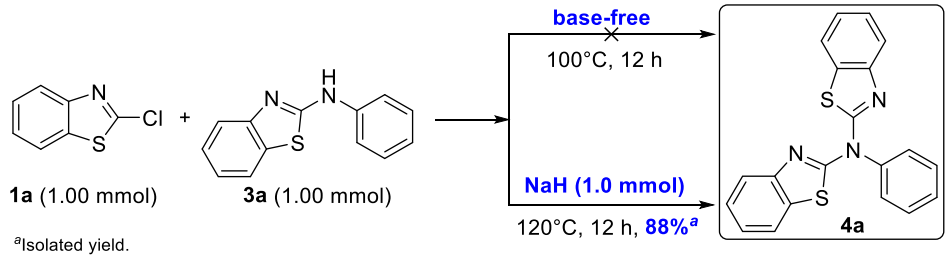
Scheme 3. Treatment of 1a with 3a under either Base-Free or NaH-Promoted Condition



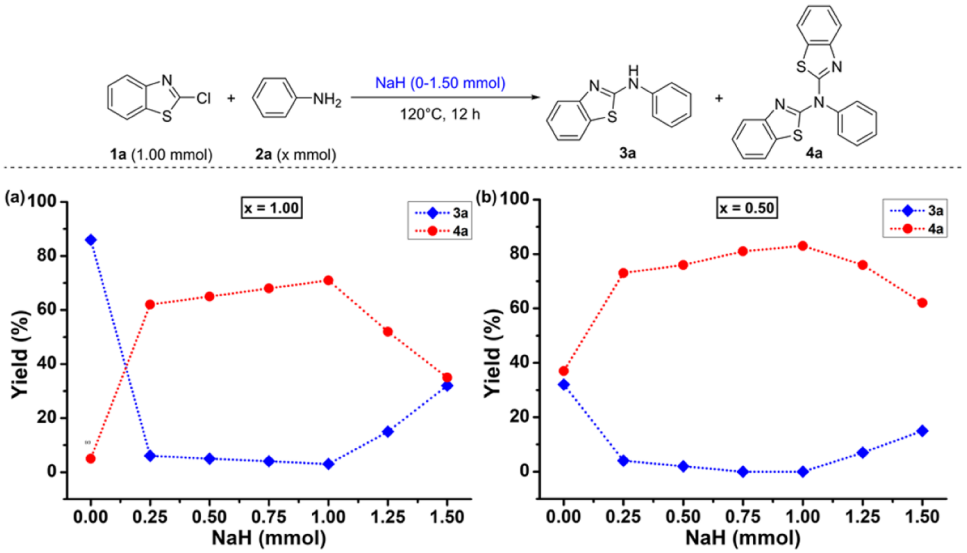
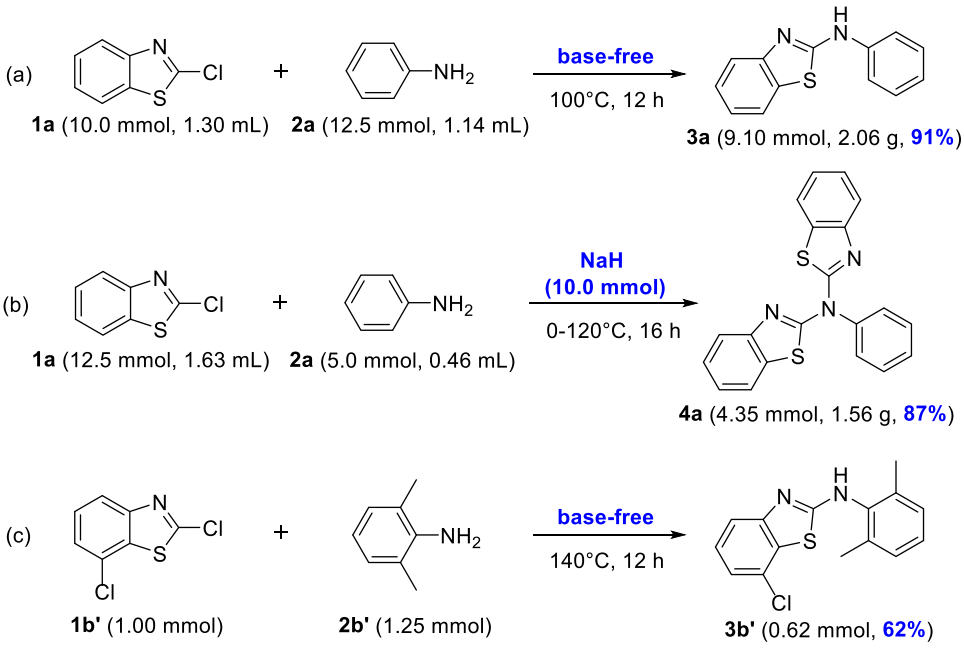


Figure 2. Product distribution between **3a** and **4a** applying different NaH amounts with the **1a**/**2a** ratios of (a) 1.00:1.00, and (b) 1.00:0.50.

Scheme 4. Gram-Scale Production of (a) 3a and (b) 4a; (c) Synthesis of Bioactive Compound 3b′



the product selectivity was investigated (as shown in Figure 2). At a **1a**/**2a** ratio of 1.00:1.00 (exact ratio for mono-heteroarylation), 86% of **3a** and 5% of **4a** were obtained without NaH. Nevertheless, adding 0.25−1.00 mmol of NaH into the reaction mixture led to the formation of **4a** with good selectivity, while even more amounts (1.25−1.50 mmol) resulted in complicated reaction mixtures with lower **4a**/**3a** selectivity (Figure 2a). In the case of a 2.00:1.00 ratio (exact ratio for di-heteroarylation), 37% of **4a** could be obtained, together with 32% of **3a** without NaH. Compared with the 1.00:1.00 ratio, a similar tendency was found if varying amounts of NaH were added (Figure 2b). Even though **4a**

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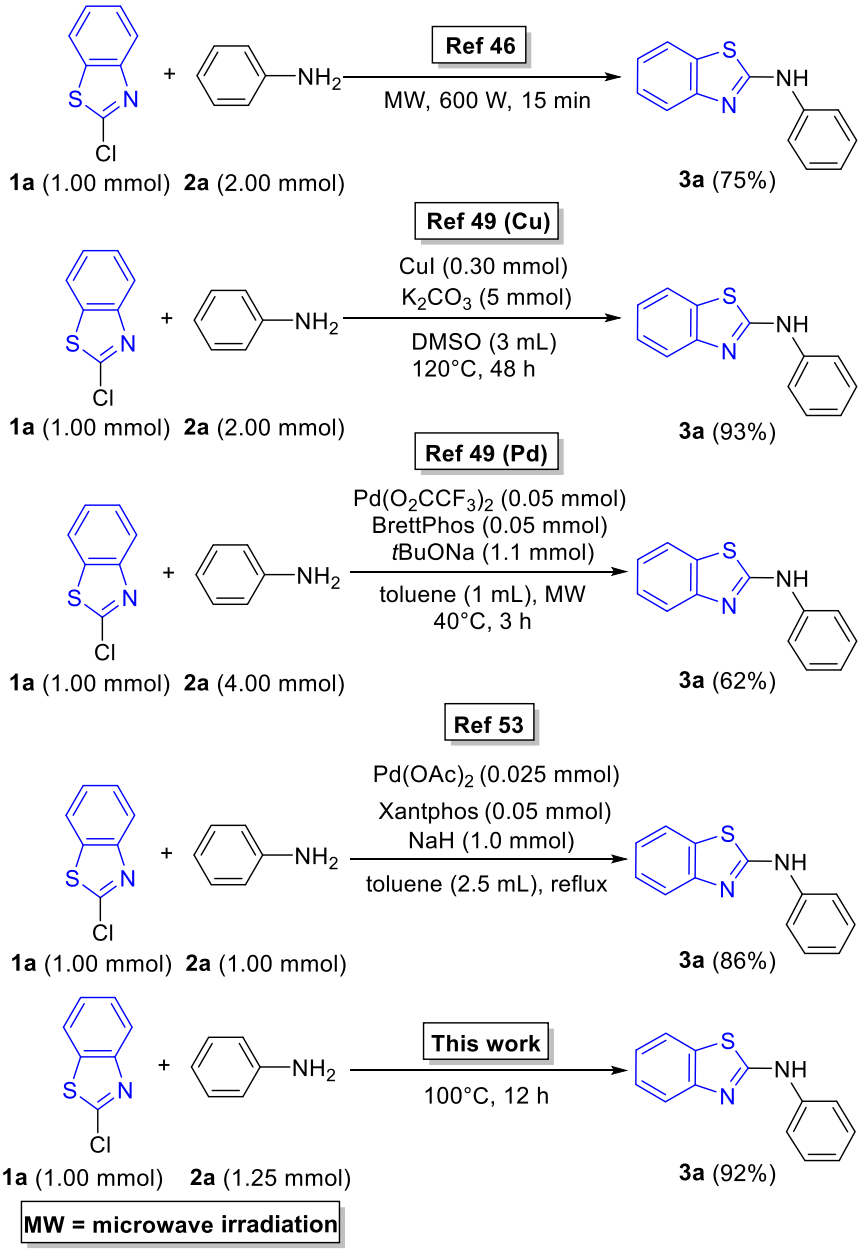
Table 3. Comparison of the Green Metrics between Our Work and the Reported Synthetic Approaches for the Mono-Heteroarylation Reactions



ref	AE (%)	E-factor (kg/kg)	CE (%)	RME (%)	MI (kg/kg)	MP (%)
ref 46	86.1	1.1	51.3	47.7	2.1	47.7
ref 49[a]	86.1	19.9	63.6	59.1	20.9	4.8
ref 49[b]	86.1	8.1	26.0	25.9	9.1	11.0
ref 53	86.1	11.9	86.0	74.1	12.9	7.8
this work	86.1	0.4	82.5	72.8	1.4	72.8

[a]Via Cu catalysis. [b]Via Pd catalysis.

could be generated in the absence of NaH, an appropriate amount of this base was beneficial for acquiring **4a** with excellent selectivity, which is consistent with our previous observation.[25]

From the perspective of industrial application, scalability of a protocol is a key factor. Therefore, gram-scale reactions to produce **3a** and **4a** were performed (as depicted in Scheme 4). For the preparation of **3a**, the identical procedure as the 1 mmol scale reaction was initially adopted (Scheme 4a). However, the hydrochloride salt of **3a**, which was never observed for the smaller-scale reaction, was occasionally obtained. Therefore, 1 M NaOH was added after the reaction to neutralize this possibly generated salt, delivering **3a** (2.06 g) in 91% yield. As for the gram-scale synthesis of **4a**, a modified procedure was applied due to the potential risk caused by the considerably increased amount of NaH (Scheme 4b). Initially, **2a** (5.0 mmol, 0.46 mL) was added dropwisely into a stirred mixture of **1a** (12.5 mmol, 1.63 mL)

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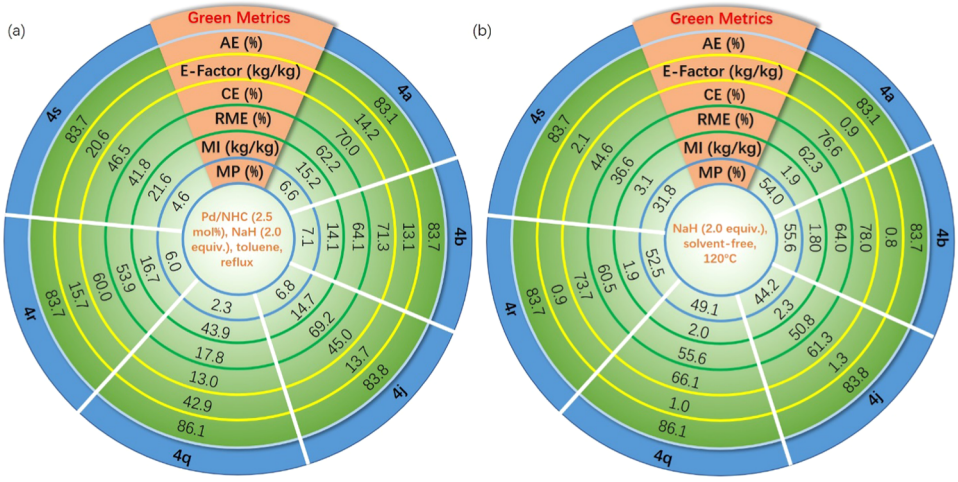

Figure 3. Green metrics for di-heteroarylation utilizing different methodologies: (a) the approach described in ref 53 and (b) this work.

and NaH (0.4 g, 10 mmol, 60% dispersed in mineral oil) at 0 °C. After 1 h, the temperature was increased to 50 °C and the resulting mixture was vigorously stirred at this temperature for 1 h. Subsequently, the mixture was stirred at 80 °C for 2 h and then at 120 °C for another 12 h. Finally, a similar workup procedure with the standard one was utilized to afford desired product **4a** (1.56 g) in 87% yield. It was worth mentioning that both reactions were operationally simple and glovebox-free. Furthermore, the suitability of this protocol for bioactive molecules was also attempted. Pleasingly, compound **3b′** (a potential anticancer agent)[59] was successfully prepared using the newly developed protocol (Scheme 4c).

Finally, the green and sustainable level of this protocol was examined using the quantitative green metrics, which include atom economy (AE), E-factor, carbon efficiency (CE), reaction mass efficiency (RME), mass intensity (MI), and mass productivity (MP).[60,61] Accordingly, the above-mentioned green metrics of this work and the literature protocols were calculated (as detailed in Tables S3 and S4 in the Supporting Information). For mono-heteroarylation, compound **3a** was selected as an example to elucidate the calculated parameters (as listed in Table 3). AE is a theoretical number that only considers the substances in the chemical equation. Since these methods contain the same equation, an identical value of 86.1% was determined for all of them. Meanwhile, the E-factor, which takes the generated wastes from all of the reagents into account, was examined. To our delight, the E-factor in this work is much lower than the literature approaches, implying that our process exhibited less negative influence on the environment aspect. This result was evidently attributed to the solvent-free and base-free features of our process. Compared with the CE and RME values from the literature, comparable or better results were obtained for the present work, demonstrating good efficiency of the current mono-heteroarylation process. In addition, the values of the other mass-related metrics (MI and MP) also exhibited the advantage of this base-free process over the reported ones in terms of greenness and sustainability. With regard to di-heteroarylation, these parameters of the only literature example and the present work were also presented (as shown in Figure 3). For the same reason, the AE values for each product are identical. It appeared that the two protocols possessed similar CE and RME values, which indicated that they have comparable efficiency. Due to the absence of solvents and transition-metal catalysts, the E-factor values of this protocol (0.8−2.1, Figure 3b) are much lower than those in the literature (13.1−42.9, Figure 3a). Besides, this NaH-mediated process displayed significantly better performance than the reported synthetic route regarding the MI and MP values, which reflect the relationship between the product mass and the total input mass. Based on these findings, we envisioned that both mono- and di-heteroarylation processes in the present work were greener and more sustainable than the reported ones.

CONCLUSIONS

In summary, a switchable and scalable protocol was developed for the C−N cross-coupling of 2-chlorobenzothiazoles and primary amines. Notably, this protocol was realized in the absence of transition metals and solvents. After screening of various reaction conditions, the base-free and NaH-promoted conditions were identified to selectively deliver the desired mono- and di-heteroarylation products, respectively. Furthermore, additional investigations were performed to provide the rationale for this switchable C−N coupling protocol. The experimental results advocated the essence of NaH (with a suitable amount) in completely tuning the selectivity from mono- to di-heteroarylation. To demonstrate the practical value of the newly developed protocol, gram-scale synthesis of **3a** and **4a** was accomplished in a facile and efficient manner, without the necessity of using a glovebox for reaction setup. In view of the quantitative green metrics, both mono- and di-heteroarylation processes of this protocol displayed relatively greener and more sustainable levels than the literature processes.

EXPERIMENTAL SECTION

General Information. All of the reactions were carried out using standard Schlenk techniques unless otherwise mentioned. Nuclear magnetic resonance (NMR, including ^{1}H NMR, ^{13}C NMR, and ^{19}F NMR) spectra were recorded on a Bruker Avance 500 spectrometer in $CDCl_3$ or DMSO-d_6, with tetramethylsilane (TMS) as an internal reference. Multiplicities were designated using the following abbreviations: s = singlet, d = doublet, t = triplet, q = quartet, p = pentet, hept = heptet, m = multiplet, dd = doublet of doublets, dt = doublet of triplets, td = triplet of doublets, ddd = doublet of doublets of doublets. Melting points were taken on a Buchi M-560 melting point apparatus without calibration. High-resolution mass spectrometry (HRMS) analyses were done with a Thermo Fisher Q Exactive

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UHMR Orbitrap instrument. Ultrasonic radiation was performed with a Kunshan Shumei KQ-50E ultrasonic cleaner. All of the common reagents, including 2-chlorobenzothiazoles and primary amines, were purchased from commercial suppliers and used as received. The pK_{aH} values of LDA,[62] bpy,[54] 1,10-phen,[54] pyr,[54] DABCO,[63] and DIPEA[64] could be found from the corresponding references, while those of the other bases were derived from the following link: https://organicchemistrydata.org/hansreich/resources/pka/#pka_general.

General Procedures for the C−N Cross-Coupling of 2-Chlorobenzothiazoles and Primary Amines. *Under the Base-Free Condition.* 2-Chlorobenzothiazole or its derivative (**1**, 1.00 mmol) and a primary amine (**2**, 1.25 mmol) were added into a 25 mL Schlenk flask, which was then capped with a rubber septum. The flask was subjected to three cycles of evacuation-backfilling with argon and heated at 100 °C for 12 h. Subsequently, the resultant solid was washed with cold hexane (3 × 5 mL) to afford the mono-heteroarylation products (**3**). If the products were not pure enough, column chromatography (hexane/ethyl acetate = 7:1−3:1) was required to deliver the desired pure products. For the gram-scale reaction, a mixture of **1a** (1.3 mL, 10.0 mmol) and **2a** (1.2 mL, 12.5 mmol) was heated at 100 °C for 12 h. After the reaction, 1 M NaOH (10 mL) was slowly added while stirring and the suspension was placed under ultrasonic radiation for 30 min. The resultant solid was collected via vacuum filtration, washed with cold hexane (3 × 10 mL), and dried in an oven to afford product **3a** in 91% yield (2.06 g, 9.10 mmol).

Under the NaH-Promoted Condition. The procedure was similar to that under the base-free condition, with a mixture of **1** (1.00 mmol), NaH (40.0 mg, 1.00 mmol, 60% dispersed in mineral oil), and **2** (1.25 mmol) being heated at 120 °C for 12 h. For the workup process, the reaction was quenched with ice water (10 mL, dropwise). Subsequently, the resultant solid was collected, washed with water (3 × 5 mL) and cold hexane (3 × 5 mL), and dried in an oven to afford the di-heteroarylation products (**4**). For the impure products, column chromatography (hexane/ethyl acetate = 20:1−4:1) was required to deliver the desired pure products. For the gram-scale reaction, an optimized procedure was adopted due to the potential risk from the larger amount of NaH. At 0 °C, **2a** (1.14 mL, 12.5 mmol) was added dropwisely to a stirred mixture of **1a** (1.30 mL, 10.0 mmol) and NaH (0.40 g, 10.0 mmol), and the mixture was stirred at this temperature for 1 h, then at 50 °C for 1 h, 80 °C for 2 h, and 120 °C for 12 h. After the reaction, ice water (25 mL) was added dropwisely while stirring and the suspension was placed under ultrasonic radiation for 1 h. The resultant solid was collected via vacuum filtration and washed with water (3 × 15 mL) and cold hexane (3 × 15 mL) to afford product **4a** in 87% yield (1.56 g, 4.35 mmol).

Calculations of NMR Yield and Green Metrics. After the reaction was completed, the Schlenk flask was cooled down to room temperature (for the reaction using LiO*t*Bu, NaO*t*Bu, KO*t*Bu, LDA, or NaH as a promoter, ice water was added dropwise to quench the reaction). Subsequently, 1,3,5-trimethoxybenzene (84.0 mg, 0.5 mmol) and $CDCl_3$ (∼3.0 mL) were added, with 0.5 mL of the upper solution being transferred to an NMR tube for NMR analysis. Besides, the green metrics of the selected references and this work were calculated based on the literature methods.[60,61]

Characterization Data for Compounds 3 and 4. *N-Phenylbenzo[d]thiazol-2-amine (**3a**).*[53] The crude product was purified by column chromatography (hexane/ethyl acetate = 7:1). White solid, mp 158.9−160.0 °C. Isolated yield: 92% (208.2 mg, under the base-free condition). ^{1}H NMR (500 MHz, DMSO-d_6) δ 10.48 (s, 1H), 7.90−7.74 (m, J = 10.0 Hz, 3H), 7.62 (d, J = 7.7 Hz, 1H), 7.46−7.28 (m, 3H), 7.20−7.10 (m, 1H), 7.10−6.98 (m, 1H). ^{13}C{^{1}H} NMR (126 MHz, DMSO-d_6) δ 162.1, 152.6, 141.1, 130.5, 129.4, 126.3, 122.7, 122.5, 121.5, 119.7, 118.3. HRMS (ESI): calcd for $C_{13}H_{11}N_2S$ $[M + H]^+$: 227.0638; found: 227.0637.

*N-(p-Tolyl)benzo[d]thiazol-2-amine (**3b**).*[53] The crude product was purified by column chromatography (hexane/ethyl acetate = 7:1). White solid, mp 182.4−182.9 °C. Isolated yield: 90% (216.3 mg, under the base-free condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.87 (s, 1H), 7.60 (d, J = 7.8 Hz, 1H), 7.52 (d, J = 8.0 Hz, 1H), 7.40−7.33 (m, 2H), 7.30 (t, J = 7.7 Hz, 1H), 7.21 (d, J = 7.8 Hz, 2H), 7.12 (t, J = 7.6 Hz, 1H), 2.37 (s, 3H). ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 165.7, 151.5, 137.3, 134.5, 130.1, 129.9, 126.0, 122.1, 121.1, 120.8, 119.1, 20.9. HRMS (ESI): calcd for $C_{14}H_{13}N_2S$ $[M + H]^+$: 241.0794; found: 241.0793.

*N-(4-Methoxyphenyl)benzo[d]thiazol-2-amine (**3c**).* The crude product was purified by column chromatography (hexane/ethyl acetate = 7:1). White solid, mp 161.6−162.6 °C. Isolated yield: 93% (238.4 mg, under the base-free condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.96 (s, 1H), 7.57 (d, J = 7.8 Hz, 1H), 7.46 (d, J = 8.0 Hz, 1H), 7.41 (d, J = 8.8 Hz, 2H), 7.28 (t, J = 7.7 Hz, 1H), 7.10 (t, J = 7.6 Hz, 1H), 6.96 (d, J = 8.8 Hz, 2H), 3.84 (s, 3H). ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 167.1, 157.4, 151.7, 133.0, 129.9, 126.0, 124.1, 121.9, 120.8, 118.9, 114.8, 55.5. HRMS (APCI): calcd for $C_{14}H_{13}N_2OS$ $[M + H]^+$: 257.0743; found: 257.0740.

*N-(4-Isopropylphenyl)benzo[d]thiazol-2-amine (**3d**).* The crude product was purified by column chromatography (hexane/ethyl acetate = 7:1). White solid, mp 245.8−247.2 °C. Isolated yield: 92% (246.9 mg, under the base-free condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.71 (s, 1H), 7.61 (d, J = 7.7 Hz, 1H), 7.56 (d, J = 8.2 Hz, 1H), 7.40 (d, J = 8.5 Hz, 2H), 7.34−7.28 (m, 1H), 7.26 (dd, J = 6.8, 1.8 Hz, 2H), 7.13 (td, J = 7.6, 1.3 Hz, 1H), 2.93 (hept, J = 6.8 Hz, 1H), 1.27 (d, J = 6.9 Hz, 6H). ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 165.3, 151.5, 145.4, 137.5, 130.0, 127.5, 126.1, 122.2, 120.8, 120.6, 119.2, 33.6, 24.0. HRMS (APCI): calcd for $C_{16}H_{17}N_2S$ $[M + H]^+$: 269.1107; found: 269.1104.

*N-(4-(tert-Butyl)phenyl)benzo[d]thiazol-2-amine (**3e**).*[53] The crude product was purified by column chromatography (hexane/ethyl acetate = 7:1). White solid, mp 136.1−137.6 °C. Isolated yield: 91% (257.0 mg, under the base-free condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.70 (s, 1H), 7.61 (d, J = 7.9 Hz, 1H), 7.57 (d, J = 8.1 Hz, 1H), 7.41 (s, 4H), 7.32 (t, J = 7.7 Hz, 1H), 7.14 (t, J = 7.6 Hz, 1H), 1.34 (s, 9H). ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 165.2, 151.5, 147.5, 137.2, 129.9, 126.4, 126.1, 122.2, 120.8, 120.2, 119.2, 34.4, 31.4. HRMS (ESI): calcd for $C_{17}H_{19}N_2S$ $[M + H]^+$: 283.1263; found: 283.1262.

*N^1-(Benzo[d]thiazol-2-yl)-N^4,N^4-dimethylbenzene-1,4-diamine (**3f**).* The crude product was purified by column chromatography (hexane/ethyl acetate = 5:1). White solid, mp 187.0−188.2 °C. Isolated yield: 85% (229.0 mg, under the base-free condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.20 (s, 1H), 7.55 (d, J = 7.9 Hz, 1H), 7.49 (d, J = 8.1 Hz, 1H), 7.31 (d, J = 8.4 Hz, 2H), 7.28 (d, J = 7.5 Hz, 1H), 7.08 (t, J = 7.6 Hz, 1H), 6.76 (d, J = 8.4 Hz, 2H), 2.98 (s, 6H). ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 168.0, 152.1, 149.0, 130.2, 129.0, 125.9, 124.8, 121.7, 120.7, 118.9, 113.2, 40.7. HRMS (APCI): calcd for $C_{15}H_{16}N_3S$ $[M + H]^+$: 270.1059; found: 270.1055.

*N-(4-Iodophenyl)benzo[d]thiazol-2-amine (**3g**).* The crude product was purified by column chromatography (hexane/ethyl acetate = 7:1). Light pink solid, mp 208.9−209.6 °C. Isolated yield: 65% (228.9 mg, under the base-free condition). ^{1}H NMR (500 MHz, DMSO-d_6) δ 10.58 (s, 1H), 7.82 (d, J = 7.6 Hz, 1H), 7.74−7.55 (m, 5H), 7.33 (t, J = 7.4 Hz, 1H), 7.17 (t, J = 7.4 Hz, 1H). ^{13}C{^{1}H} NMR (126 MHz, DMSO-d_6) δ 161.7, 152.4, 140.9, 138.0, 130.5, 126.4, 123.0, 121.6, 120.4, 119.9, 85.3. HRMS (APCI): calcd for $C_{13}H_{10}IN_2S$ $[M + H]^+$: 352.9604; found: 352.9602.

*N-(4-Bromophenyl)benzo[d]thiazol-2-amine (**3h**).* The crude product was purified by column chromatography (hexane/ethyl acetate = 7:1). White solid, mp 219.0−219.8 °C. Isolated yield: 81% (247.2 mg, under the base-free condition). ^{1}H NMR (500 MHz, DMSO-d_6) δ 10.61 (s, 1H), 7.82 (dd, J = 7.9, 1.2 Hz, 1H), 7.80−7.76 (m, 2H), 7.62 (d, J = 8.0 Hz, 1H), 7.54 (d, J = 8.8 Hz, 2H), 7.34 (td, J = 7.8, 1.3 Hz, 1H), 7.18 (td, J = 7.6, 1.1 Hz, 1H). ^{13}C{^{1}H} NMR (126 MHz, DMSO-d_6) δ 161.7, 152.4, 140.4, 132.2, 130.5, 126.4, 123.0, 121.6, 120.1, 119.8, 113.7. HRMS (APCI): calcd for $C_{13}H_{10}BrN_2S$ $[M + H]^+$: 304.9743; found: 304.9740.

*N-(4-Chlorophenyl)benzo[d]thiazol-2-amine (**3i**).* The crude product was purified by column chromatography (hexane/ethyl acetate = 7:1). White solid, mp 205.0−206.1 °C. Isolated yield: 80%

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(208.6 mg, under the base-free condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.65 (d, J = 5.5 Hz, 1H), 7.63 (d, J = 5.8 Hz, 1H), 7.52−7.47 (m, 2H), 7.38−7.34 (m, 3H), 7.19 (t, J = 7.6 Hz, 1H). $^{13}C\{^1H\}$ NMR (126 MHz, $CDCl_3$) δ 163.0, 151.4, 138.3, 130.0, 129.5, 129.1, 126.3, 122.9, 120.9, 120.8, 119.8. HRMS (APCI): calcd for $C_{13}H_{10}ClN_2S$ $[M + H]^+$: 261.0248; found: 261.0247.

*N-(4-Fluorophenyl)benzo[d]thiazol-2-amine (**3j**).*[53] The crude product was purified by column chromatography (hexane/ethyl acetate = 7:1). White solid, mp 202.2−202.6 °C. Isolated yield: 82% (200.3 mg, under the base-free condition). ^{1}H NMR (500 MHz, DMSO-d_6) δ 10.51 (s, 1H), 7.81 (t, J = 7.0 Hz, 3H), 7.59 (d, J = 8.0 Hz, 1H), 7.33 (t, J = 7.6 Hz, 1H), 7.22 (t, J = 8.5 Hz, 2H), 7.16 (t, J = 7.5 Hz, 1H). $^{13}C\{^1H\}$ NMR (126 MHz, DMSO-d_6) δ 162.1, 157.8 (d, J = 238.5 Hz), 152.5, 137.6, 130.4, 126.4, 122.8, 121.5, 119.8 (d, J = 7.7 Hz), 119.7, 116.0 (d, J = 22.3 Hz). $^{19}F\{^1H\}$ NMR (471 MHz, $CDCl_3$) δ −117.6. HRMS (ESI): calcd for $C_{13}H_{10}FN_2S$ $[M + H]^+$: 245.0543; found: 245.0542.

*N-(4-(Trifluoromethoxyl)phenyl)benzo[d]thiazol-2-amine (**3k**).* The crude product was purified by column chromatography (hexane/ethyl acetate = 7:1). White solid, mp 172.8−173.2 °C. Isolated yield: 85% (263.7 mg, under the base-free condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.27 (s, 1H), 7.65 (d, J = 7.8 Hz, 1H), 7.61 (d, J = 8.1 Hz, 1H), 7.59−7.54 (m, 2H), 7.36 (t, J = 7.7 Hz, 1H), 7.25 (d, J = 9.1 Hz, 2H), 7.19 (t, J = 7.6 Hz, 1H). $^{13}C\{^1H\}$ NMR (126 MHz, $CDCl_3$) δ 163.5, 151.4, 145.1, 138.5, 130.0, 126.3, 122.8, 122.3, 120.9, 120.8, 120.5 (q, J = 259.6 Hz), 119.7. $^{19}F\{^1H\}$ NMR (471 MHz, $CDCl_3$) δ −58.1. HRMS (APCI): calcd for $C_{14}H_{10}F_3N_2OS$ $[M + H]^+$: 311.0460; found: 311.0455.

*N-(4-(Trifluoromethyl)phenyl)benzo[d]thiazol-2-amine (**3l**).*[53] The crude product was purified by column chromatography (hexane/ethyl acetate = 7:1). White solid, mp 191.4−192.7 °C. Isolated yield: 62% (182.5 mg, under the base-free condition). ^{1}H NMR (500 MHz, DMSO-d_6) δ 10.90 (s, 1H), 8.00 (d, J = 8.3 Hz, 2H), 7.87 (d, J = 7.8 Hz, 1H), 7.73 (d, J = 8.3 Hz, 2H), 7.68 (d, J = 8.0 Hz, 1H), 7.38 (t, J = 7.6 Hz, 1H), 7.22 (t, J = 7.5 Hz, 1H). $^{13}C\{^1H\}$ NMR (126 MHz, DMSO-d_6) δ 161.6, 152.2, 144.4, 130.6, 126.8 (q, J = 3.8 Hz), 126.5, 125.1 (q, J = 270.8 Hz), 123.3, 122.2 (q, J = 31.9 Hz), 121.7, 120.2, 117.9. $^{19}F\{^1H\}$ NMR (471 MHz, $CDCl_3$) δ −61.9. HRMS (ESI): calcd for $C_{14}H_{10}F_3N_2S$ $[M + H]^+$: 295.0511; found: 295.0510.

*4-(Benzo[d]thiazol-2-ylamino)benzonitrile (**3m**).* The crude product was purified by column chromatography (hexane/ethyl acetate = 4:1). White solid, mp 198.2−199.4 °C. Isolated yield: 45% (113.1 mg, under the base-free condition). ^{1}H NMR (500 MHz, DMSO-d_6) δ 10.99 (s, 1H), 7.98 (d, J = 8.7 Hz, 2H), 7.88 (d, J = 7.8 Hz, 1H), 7.82 (d, J = 8.7 Hz, 2H), 7.70 (d, J = 8.0 Hz, 1H), 7.38 (t, J = 7.7 Hz, 1H), 7.23 (t, J = 7.6 Hz, 1H). $^{13}C\{^1H\}$ NMR (126 MHz, DMSO-d_6) δ 161.3, 152.1, 144.9, 134.0, 130.6, 126.6, 123.5, 121.8, 120.3, 119.8, 118.1, 103.7. HRMS (APCI): calcd for $C_{14}H_{10}N_3S$ $[M + H]^+$: 252.0590; found: 252.0586.

*N-(4-Nitrophenyl)benzo[d]thiazol-2-amine (**3n**).* The crude product was purified by column chromatography (hexane/ethyl acetate = 7:1). Yellow solid, mp 225.7−227.0 °C. Isolated yield: 85% (230.6 mg, under the base-free condition) and 75% (101.7 mg, under the NaH-promoted condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.28 (d, J = 9.1 Hz, 2H), 7.78 (dd, J = 8.5, 3.9 Hz, 3H), 7.72 (d, J = 7.9 Hz, 1H), 7.43 (t, J = 7.6 Hz, 1H), 7.28 (d, J = 7.7 Hz, 1H). $^{13}C\{^1H\}$ NMR (126 MHz, $CDCl_3$) δ 160.3, 151.3, 145.3, 142.5, 130.4, 126.6, 125.7, 123.8, 121.0, 120.8, 117.3. HRMS (APCI): calcd for $C_{13}H_{10}N_3O_2S$ $[M + H]^+$: 272.0488; found: 272.0486.

*N-([1,1′-Biphenyl]-4-yl)benzo[d]thiazol-2-amine (**3o**).* The crude product was purified by column chromatography (hexane/ethyl acetate = 7:1). White solid, mp 224.0−224.5 °C. Isolated yield: 56% (169.3 mg, under the base-free condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.70−7.55 (m, 8H), 7.45 (t, J = 7.7 Hz, 2H), 7.39−7.32 (m, 2H), 7.18 (t, J = 7.6 Hz, 1H). $^{13}C\{^1H\}$ NMR (126 MHz, $CDCl_3$) δ 163.5, 151.5, 140.4, 138.9, 137.0, 130.2, 128.8, 128.2, 127.2, 126.8, 126.2, 122.7, 120.9, 119.9, 119.7. HRMS (APCI): calcd for $C_{19}H_{15}N_2S$ $[M + H]^+$: 303.0950; found: 303.0948.

*N-(4-Phenoxyphenyl)benzo[d]thiazol-2-amine (**3p**).*[53] The crude product was purified by column chromatography (hexane/ethyl acetate = 4:1). White solid, mp 158.2−159.5 °C. Isolated yield: 87% (277.0 mg, under the base-free condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.41 (s, 1H), 7.61 (d, J = 7.9 Hz, 1H), 7.56 (d, J = 8.1 Hz, 1H), 7.48 (d, J = 8.7 Hz, 2H), 7.39−7.28 (m, 3H), 7.19−7.09 (m, 2H), 7.06 (d, J = 9.0 Hz, 2H), 7.04 (d, J = 8.5 Hz, 2H). $^{13}C\{^1H\}$ NMR (126 MHz, $CDCl_3$) δ 165.2, 157.3, 154.1, 151.6, 135.2, 130.0, 129.8, 126.1, 123.3, 122.7, 122.3, 120.8, 120.0, 119.3, 118.7. HRMS (ESI): calcd for $C_{19}H_{15}N_2OS$ $[M + H]^+$: 319.0900; found: 319.0898.

*N^1-(Benzo[d]thiazol-2-yl)-N^4-phenylbenzene-1,4-diamine (**3q**).*[53] The crude product was purified by column chromatography (hexane/ethyl acetate = 3:1). White solid, mp 182.0−183.4 °C. Isolated yield: 72% (228.5 mg, under the base-free condition). ^{1}H NMR (500 MHz, DMSO-d_6) δ 10.28 (s, 1H), 8.05 (s, 1H), 7.76 (d, J = 7.7 Hz, 1H), 7.66 (d, J = 8.3 Hz, 2H), 7.54 (d, J = 7.9 Hz, 1H), 7.30 (t, J = 7.5 Hz, 1H), 7.20 (t, J = 7.5 Hz, 2H), 7.11 (d, J = 7.7 Hz, 3H), 7.02 (d, J = 7.8 Hz, 2H), 6.76 (t, J = 7.1 Hz, 1H). $^{13}C\{^1H\}$ NMR (126 MHz, DMSO-d_6) δ 162.5, 152.8, 144.8, 138.6, 134.3, 130.4, 129.6, 126.3, 122.3, 121.4, 119.9, 119.3, 119.2, 119.0, 116.0. HRMS (ESI): calcd for $C_{19}H_{16}N_3S$ $[M + H]^+$: 318.1059; found: 318.1059.

*N-(m-Tolyl)benzo[d]thiazol-2-amine (**3r**).*[53] The crude product was purified by column chromatography (hexane/ethyl acetate = 7:1). White solid, mp 122.6−123.7 °C. Isolated yield: 91% (218.7 mg, under the base-free condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.37 (s, 1H), 7.61 (d, J = 7.8 Hz, 1H), 7.54 (d, J = 8.1 Hz, 1H), 7.29 (d, J = 7.6 Hz, 4H), 7.13 (t, J = 7.6 Hz, 1H), 6.99 (d, J = 6.3 Hz, 1H), 2.37 (s, 3H). $^{13}C\{^1H\}$ NMR (126 MHz, $CDCl_3$) δ 165.4, 151.2, 139.9, 139.6, 129.7, 129.4, 126.0, 125.3, 122.2, 121.3, 120.8, 119.1, 117.5, 21.5. HRMS (ESI): calculated for $C_{14}H_{13}N_2S$ $[M + H]^+$: 241.0794; found: 241.0793.

*N-(o-Tolyl)benzo[d]thiazol-2-amine (**3s**).*[53] The crude product was purified by column chromatography (hexane/ethyl acetate = 7:1). White solid, mp 119.8−121.1 °C. Isolated yield: 84% (201.9 mg, under the base-free condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.92 (s, 1H), 7.63 (d, J = 7.7 Hz, 1H), 7.55 (d, J = 7.8 Hz, 1H), 7.37 (d, J = 8.0 Hz, 1H), 7.34−7.21 (m, 4H), 7.08 (t, J = 7.5 Hz, 1H), 2.36 (s, 3H). $^{13}C\{^1H\}$ NMR (126 MHz, $CDCl_3$) δ 167.4, 151.6, 138.3, 132.7, 131.3, 130.0, 127.2, 126.5, 126.0, 124.5, 121.9, 120.8, 118.7, 17.9. HRMS (ESI): calcd for $C_{14}H_{13}N_2S$ $[M + H]^+$: 241.0794; found: 241.0793.

*6-Methyl-N-phenylbenzo[d]thiazol-2-amine (**3t**).*[53] The crude product was purified by column chromatography (hexane/ethyl acetate = 7:1). White solid, mp 166.5−167.3 °C. Isolated yield: 91% (218.7 mg, under the base-free condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.39 (s, 1H), 7.48 (dd, J = 7.7, 4.6 Hz, 3H), 7.43 (s, 1H), 7.39 (t, J = 7.5 Hz, 2H), 7.14 (t, J = 7.0 Hz, 2H), 2.41 (s, 3H). $^{13}C\{^1H\}$ NMR (126 MHz, $CDCl_3$) δ 163.6, 149.3, 139.9, 132.3, 130.0, 129.5, 127.4, 124.1, 120.8, 119.9, 119.0, 21.3. HRMS (ESI): calcd for $C_{14}H_{13}N_2S$ $[M + H]^+$: 241.0794; found: 241.0792.

*6-Methoxy-N-phenylbenzo[d]thiazol-2-amine (**3u**).*[53] The crude product was purified by column chromatography (hexane/ethyl acetate = 5:1). White solid, mp 115.5−116.6 °C. Isolated yield: 90% (230.7 mg, under the base-free condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.60 (s, 1H), 7.53−7.44 (m, 3H), 7.43−7.35 (m, 2H), 7.19−7.10 (m, 2H), 6.93 (dt, J = 8.8, 1.9 Hz, 1H), 3.83 (s, 3H). $^{13}C\{^1H\}$ NMR (126 MHz, $CDCl_3$) δ 162.7, 155.7, 145.6, 140.0, 130.9, 129.5, 123.9, 119.8, 119.8, 113.9, 105.1, 55.9. HRMS (ESI): calcd for $C_{14}H_{13}N_2OS$ $[M + H]^+$: 257.0743; found: 257.0742.

*6-Chloro-N-phenylbenzo[d]thiazol-2-amine (**3v**).*[53] The crude product was purified by column chromatography (hexane/ethyl acetate = 7:1). White solid, mp 191.0−191.8 °C. Isolated yield: 56% of **3v** (146.0 mg) and 21% of di-heteroarylation counterpart **4v** (45.0 mg, under the base-free condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.07 (s, 1H), 7.59 (s, 1H), 7.49 (dd, J = 8.6, 3.3 Hz, 3H), 7.41 (t, J = 7.7 Hz, 2H), 7.29 (d, J = 8.7 Hz, 1H), 7.18 (t, J = 7.4 Hz, 1H). $^{13}C\{^1H\}$ NMR (126 MHz, $CDCl_3$) δ 164.3, 150.2, 139.4, 131.3, 129.6, 127.7, 126.7, 124.6, 120.5, 120.2, 120.1. HRMS (ESI): calcd for $C_{13}H_{10}ClN_2S$ $[M + H]^+$: 261.0248; found: 261.0247.

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*Ethyl 2-(phenylamino)benzo[d]thiazole-6-carboxylate (**3w**).* The crude product was purified by column chromatography (hexane/ethyl acetate = 7:1). White solid, mp 155.5−156.0 °C. Isolated yield: 93% (277.5 mg, under the base-free condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.87 (s, 1H), 8.34 (d, J = 1.6 Hz, 1H), 8.02 (dd, J = 8.5, 1.7 Hz, 1H), 7.54 (d, J = 8.5 Hz, 1H), 7.53−7.49 (m, 2H), 7.44 (t, J = 7.9 Hz, 2H), 7.22 (t, J = 7.4 Hz, 1H), 4.39 (q, J = 7.1 Hz, 2H), 1.40 (t, J = 7.1 Hz, 3H). ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 167.4, 166.3, 155.1, 139.3, 129.8, 129.7, 127.9, 125.1, 124.5, 122.9, 120.8, 118.6, 60.9, 14.4. HRMS (APCI): calcd for $C_{16}H_{15}N_2O_2S$ [M + H]$^+$: 299.0849; found: 299.0844.

*N-Benzylbenzo[d]thiazol-2-amine (**3x**).* The crude product was purified by column chromatography (hexane/ethyl acetate = 5:1). White solid, mp 163.2−163.9 °C. Isolated yield: 93% (223.5 mg, under the base-free condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.57 (dd, J = 7.9, 1.3 Hz, 1H), 7.47 (dd, J = 8.1, 1.1 Hz, 1H), 7.40 (d, J = 7.0 Hz, 2H), 7.35 (t, J = 7.3 Hz, 2H), 7.33−7.26 (m, 2H), 7.08 (td, J = 7.6, 1.2 Hz, 1H), 6.17 (s, 1H), 4.63 (s, 2H). ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 167.4, 152.3, 137.4, 130.5, 128.8, 127.9, 127.7, 126.0, 121.6, 120.8, 119.0, 49.4. HRMS (APCI): $C_{14}H_{13}N_2S$ [M + H]$^+$: calcd for 241.0794; found: 241.0791.

*N-Phenethylbenzo[d]thiazol-2-amine (**3y**).* The crude product was purified by column chromatography (hexane/ethyl acetate = 5:1). White solid, mp 144.1−144.3 °C. Isolated yield: 91% (231.5 mg, under the base-free condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.58 (dd, J = 7.9, 1.2 Hz, 1H), 7.52 (dd, J = 8.1, 1.0 Hz, 1H), 7.34−7.27 (m, 3H), 7.26−7.21 (m, 3H), 7.08 (td, J = 7.6, 1.2 Hz, 1H), 5.58 (s, 1H), 3.69 (t, J = 6.9 Hz, 2H), 2.99 (t, J = 6.9 Hz, 2H). ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 167.2, 152.4, 138.3, 130.4, 128.8, 128.7, 126.7, 125.9, 121.5, 120.8, 118.9, 46.5, 35.6. HRMS (APCI): calcd for $C_{15}H_{15}N_2S$ [M + H]$^+$: 255.0950; found: 255.0947.

*N-Hexylbenzo[d]thiazol-2-amine (**3z**).* The crude product was purified by column chromatography (hexane/ethyl acetate = 5:1). White solid, mp 63.1−63.3 °C. Isolated yield: 92% (215.6 mg, under the base-free condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.58 (d, J = 7.8 Hz, 1H), 7.52 (d, J = 8.0 Hz, 1H), 7.28 (td, J = 7.8, 1.2 Hz, 1H), 7.07 (td, J = 7.6, 1.1 Hz, 1H), 5.70 (s, 1H), 3.40 (t, J = 7.1 Hz, 2H), 1.68 (p, J = 7.3 Hz, 2H), 1.46−1.36 (m, 2H), 1.34−1.26 (m, 4H), 0.94−0.84 (m, 3H). ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 167.6, 152.5, 130.4, 125.9, 121.4, 120.7, 118.8, 45.7, 31.4, 29.5, 26.5, 22.5, 14.0. HRMS (APCI): calcd for $C_{13}H_{19}N_2S$ [M + H]$^+$: 235.1263; found: 235.1261.

*N-(Pyridin-2-yl)benzo[d]thiazol-2-amine (**3a′**).*[53] The crude product was purified by column chromatography (hexane/ethyl acetate = 3:1). White solid, mp 238.7−239.4 °C. Isolated yield: 25% (56.8 mg, under the base-free condition), 75% (85.2 mg, under the NaH-promoted condition). ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.55 (s, 1H), 8.34 (d, J = 5.0 Hz, 1H), 7.89 (d, J = 7.8 Hz, 1H), 7.76 (t, J = 7.8 Hz, 1H), 7.61 (d, J = 8.0 Hz, 1H), 7.36 (t, J = 7.7 Hz, 1H), 7.18 (dd, J = 13.4, 7.6 Hz, 2H), 7.00 (t, J = 6.2 Hz, 1H). ^{13}C{^{1}H} NMR (126 MHz, DMSO-d_6) δ 159.8, 152.1, 149.9, 147.0, 138.8, 132.1, 126.2, 122.5, 121.6, 119.6, 117.3, 111.7. HRMS (ESI): calcd for $C_{12}H_{10}N_3S$ [M + H]$^+$: 228.0590; found: 228.0589.

*7-Chloro-N-(2,6-dimethylphenyl)benzo[d]thiazol-2-amine (**3b′**).*[59] The crude product was purified by column chromatography (hexane/ethyl acetate = 7:1). White solid, mp 196.2−197.5 °C. Isolated yield: 62% (179.0 mg, under the base-free condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.07 (s, 1H), 7.27−7.24 (m, 1H), 7.23−7.19 (m, 2H), 7.19−7.14 (m, 2H), 7.06−7.01 (m, 1H), 2.37 (s, 6H). ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 169.7, 153.0, 137.3, 136.5, 130.4, 129.1, 128.7, 126.9, 126.3, 121.2, 116.5, 18.1. HRMS (ESI): calcd for $C_{15}H_{14}ClN_2S$ [M + H]$^+$: 289.0561; found: 289.0560.

*N-(Benzo[d]thiazol-2-yl)-N-phenylbenzo[d]thiazol-2-amine (**4a**).*[53] The crude product was purified by column chromatography (hexane/ethyl acetate = 5:1). White solid, mp 201.9−203.3 °C. Isolated yield: 90% (161.8 mg, under the NaH-promoted condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.79 (d, J = 8.1 Hz, 2H), 7.71 (d, J = 7.9 Hz, 2H), 7.68−7.58 (m, 3H), 7.55 (d, J = 7.4 Hz, 2H), 7.39 (t, J = 7.7 Hz, 2H), 7.24 (t, J = 7.6 Hz, 2H). ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 162.8, 150.1, 141.7, 132.4, 130.5, 129.9, 129.3, 126.1, 123.5, 121.2, 120.7. HRMS (APCI): calcd for $C_{20}H_{14}N_3S_2$ [M + H]$^+$: 360.0624; found: 360.0617.

*N-(Benzo[d]thiazol-2-yl)-N-(p-tolyl)benzo[d]thiazol-2-amine (**4b**).*[53] The crude product was purified by column chromatography (hexane/ethyl acetate = 5:1). White solid, mp 189.1−190.4 °C. Isolated yield: 91% (169.9 mg, under the NaH-promoted condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.80 (d, J = 8.1 Hz, 2H), 7.71 (d, J = 7.9 Hz, 2H), 7.43 (s, 4H), 7.39 (t, J = 7.7 Hz, 2H), 7.26−7.23 (m, 2H), 2.50 (s, 3H). ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 163.0, 150.1, 140.1, 139.2, 132.5, 131.1, 129.0, 126.0, 123.4, 121.2, 120.7, 21.5. HRMS (APCI): calcd for $C_{21}H_{16}N_3S_2$ [M + H]$^+$: 374.0780; found: 374.0776.

*N-(Benzo[d]thiazol-2-yl)-N-(4-methoxyphenyl)benzo[d]thiazol-2-amine (**4c**).* The crude product was purified by column chromatography (hexane/ethyl acetate = 4:1). White solid, mp 206.5−207.3 °C. Isolated yield: 94% (183.1 mg, under the NaH-promoted condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.80 (d, J = 8.1 Hz, 2H), 7.72 (dd, J = 7.9, 1.2 Hz, 2H), 7.46 (d, J = 8.9 Hz, 2H), 7.39 (ddd, J = 8.3, 7.2, 1.2 Hz, 2H), 7.26−7.23 (m, 2H), 7.12 (d, J = 8.9 Hz, 2H), 3.92 (s, 3H). ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 163.3, 160.4, 150.2, 134.5, 132.5, 130.5, 126.1, 123.4, 121.2, 120.7, 115.6, 55.6. HRMS (APCI): calcd for $C_{21}H_{16}N_3OS_2$ [M + H]$^+$: 390.0729; found: 390.0726.

*N-(Benzo[d]thiazol-2-yl)-N-(4-isopropylphenyl)benzo[d]thiazol-2-amine (**4d**).* The crude product was purified by column chromatography (hexane/ethyl acetate = 7:1). White solid, mp 210.1−210.9 °C. Isolated yield: 73% of **4d** (146.6 mg) and 18% of mono-heteroarylation counterpart **3d** (24.2 mg, under the NaH-promoted condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.80 (d, J = 8.1 Hz, 2H), 7.71 (d, J = 7.8 Hz, 2H), 7.52−7.43 (m, 4H), 7.39 (t, J = 7.7 Hz, 2H), 7.26−7.22 (m, 2H), 3.06 (hept, J = 7.0 Hz, 1H), 1.37 (d, J = 6.8 Hz, 6H). ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 163.1, 150.7, 150.1, 139.4, 132.5, 128.9, 128.5, 126.0, 123.4, 121.2, 120.7, 34.0, 23.9. HRMS (APCI): calcd for $C_{23}H_{20}N_3S_2$ [M + H]$^+$: 402.1093; found: 402.1090.

*N-(Benzo[d]thiazol-2-yl)-N-(4-(tert-butyl)phenyl)benzo[d]-thiazol-2-amine (**4e**).*[53] The crude product was purified by column chromatography (hexane/ethyl acetate = 20:1). White solid, mp 272.7−274.1 °C. Isolated yield: 68% of **4e** (141.3 mg) and 21% of mono-heteroarylation counterpart **3e** (29.7 mg, under the NaH-promoted condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.80 (d, J = 8.1 Hz, 2H), 7.72 (d, J = 7.9 Hz, 2H), 7.63 (d, J = 8.1 Hz, 2H), 7.46 (d, J = 8.1 Hz, 2H), 7.39 (t, J = 7.7 Hz, 2H), 7.24 (t, J = 5.9 Hz, 2H), 1.43 (s, 9H). ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 163.1, 153.0, 150.1, 139.1, 132.5, 128.6, 127.4, 126.0, 123.4, 121.2, 120.7, 35.0, 31.4. HRMS (APCI): calcd for $C_{24}H_{22}N_3S_2$ [M + H]$^+$: 416.1250; found: 416.1245.

*N^1,N^1-bis(Benzo[d]thiazol-2-yl)-N^4,N^4-dimethylbenzene-1,4-diamine (**4f**).* The crude product was purified by column chromatography (hexane/ethyl acetate = 4:1). White solid, mp 278.7−280.1 °C. Isolated yield: 76% of **4f** (153.0 mg) and 12% of mono-heteroarylation counterpart **3f** (16.2 mg, under the NaH-promoted condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.80 (d, J = 8.1 Hz, 2H), 7.70 (d, J = 7.9 Hz, 2H), 7.43−7.33 (m, 4H), 7.23 (t, J = 7.8 Hz, 2H), 6.86 (d, J = 8.5 Hz, 2H), 3.07 (s, 6H). ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 163.9, 150.9, 150.4, 132.6, 130.4, 129.7, 125.9, 123.2, 121.2, 120.7, 112.8, 40.3. HRMS (APCI): calcd for $C_{22}H_{19}N_4S_2$ [M + H]$^+$: 403.1046; found: 403.1042.

*N-(Benzo[d]thiazol-2-yl)-N-(4-iodophenyl)benzo[d]thiazol-2-amine (**4g**).* The crude product was purified by column chromatography (hexane/ethyl acetate = 20:1). White solid, mp 241.1−241.9 °C. Isolated yield: 75% (182.0 mg, under the NaH-promoted condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.97 (d, J = 8.1 Hz, 2H), 7.80 (d, J = 8.1 Hz, 2H), 7.73 (d, J = 7.8 Hz, 2H), 7.41 (t, J = 7.7 Hz, 2H), 7.31 (d, J = 8.1 Hz, 2H), 7.27 (d, J = 7.5 Hz, 2H). ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 162.4, 150.0, 141.3, 139.8, 132.4, 131.3, 126.2, 123.7, 121.3, 120.8, 95.9. HRMS (APCI): calcd for $C_{20}H_{13}IN_3S_2$ [M + H]$^+$: 485.9590; found: 485.9586.

*N-(Benzo[d]thiazol-2-yl)-N-(4-bromophenyl)benzo[d]thiazol-2-amine (**4h**).* The crude product was purified by column

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chromatography (hexane/ethyl acetate = 20:1). White solid, mp 224.5−225.5 °C. Isolated yield: 83% (181.9 mg, under the NaH-promoted condition). ^{1}H NMR (500 MHz, DMSO-d_6) δ 7.99 (dd, J = 8.0, 1.1 Hz, 2H), 7.92 (d, J = 8.5 Hz, 2H), 7.76 (d, J = 8.1 Hz, 2H), 7.73 (d, J = 8.5 Hz, 2H), 7.46 (td, J = 7.8, 1.2 Hz, 2H), 7.32 (td, J = 7.7, 1.1 Hz, 2H). ^{13}C{^{1}H} NMR (126 MHz, DMSO-d_6) δ 162.7, 149.9, 141.1, 134.1, 132.3, 126.9, 124.1, 123.9, 122.1, 121.0. HRMS (APCI): calcd for $C_{20}H_{13}BrN_3S_2$ [M + H]$^+$: 437.9729; found: 437.9727.

*N-(Benzo[d]thiazol-2-yl)-N-(4-chlorophenyl)benzo[d]thiazol-2-amine (**4i**).* The crude product was purified by column chromatography (hexane/ethyl acetate = 20:1). White solid, mp 197.0−197.6 °C. Isolated yield: 85% (167.4 mg, under the NaH-promoted condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.79 (d, J = 8.1 Hz, 2H), 7.73 (d, J = 7.8 Hz, 2H), 7.60 (d, J = 8.6 Hz, 2H), 7.49 (d, J = 8.6 Hz, 2H), 7.41 (t, J = 7.7 Hz, 2H), 7.29−7.22 (m, 2H). ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 162.5, 150.0, 140.0, 135.9, 132.4, 130.8, 130.7, 126.2, 123.7, 121.3, 120.8. HRMS (APCI): calcd for $C_{20}H_{13}ClN_3S_2$ [M + H]$^+$: 394.0234; found: 394.0234.

*N-(Benzo[d]thiazol-2-yl)-N-(4-fluorophenyl)benzo[d]thiazol-2-amine (**4j**).*[53] The crude product was purified by column chromatography (hexane/ethyl acetate = 20:1). White solid, mp 199.6−201.0 °C. Isolated yield: 72% (135.9 mg, under the NaH-promoted condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.79 (d, J = 8.2 Hz, 2H), 7.72 (d, J = 8.0 Hz, 2H), 7.53 (dd, J = 8.5, 4.9 Hz, 2H), 7.40 (t, J = 7.7 Hz, 2H), 7.31 (t, J = 8.4 Hz, 2H), 7.25 (t, J = 7.7 Hz, 2H). ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 163.1 (d, J = 250.4 Hz), 162.7, 150.0, 137.5 (d, J = 3.2 Hz), 132.4, 131.4 (d, J = 8.9 Hz), 126.2, 123.6, 121.5, 120.8, 117.5 (d, J = 23.0 Hz). ^{19}F{^{1}H} NMR (471 MHz, $CDCl_3$) δ −110.0. HRMS (APCI): calcd for $C_{20}H_{13}FN_3S_2$ [M + H]$^+$: 378.0529; found: 378.0524.

*N-(Benzo[d]thiazol-2-yl)-N-(4-(trifluoromethoxy)phenyl)benzo-[d]thiazol-2-amine (**4k**).* The crude product was purified by column chromatography (hexane/ethyl acetate = 20:1). White solid, mp 172.0−172.3 °C. Isolated yield: 76% (168.5 mg, under the NaH-promoted condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.80 (d, J = 8.1 Hz, 2H), 7.74 (d, J = 7.9 Hz, 2H), 7.64−7.57 (m, 2H), 7.47 (d, J = 8.7 Hz, 2H), 7.42 (t, J = 7.7 Hz, 2H), 7.28 (d, J = 7.7 Hz, 2H). ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 162.5, 150.0, 149.9, 139.7, 132.4, 131.2, 126.3, 123.9, 123.7, 122.6, 121.5, 121.3, 120.8, 119.4, 117.3. ^{19}F{^{1}H} NMR (471 MHz, $CDCl_3$) δ −57.7. HRMS (APCI): calcd for $C_{21}H_{13}F_3N_3OS_2$ [M + H]$^+$: 444.0447; found: 444.0441.

*N-(Benzo[d]thiazol-2-yl)-N-(4-(trifluoromethyl)phenyl)benzo[d]-thiazol-2-amine (**4l**).*[53] The crude product was purified by column chromatography (hexane/ethyl acetate = 5:1). White solid, mp 230.7−231.9 °C. Isolated yield: 21% (44.9 mg, under the NaH-promoted condition). ^{1}H NMR (500 MHz, DMSO-d_6) δ 8.11 (d, J = 8.1 Hz, 2H), 8.04 (d, J = 8.1 Hz, 2H), 7.99 (d, J = 7.9 Hz, 2H), 7.75 (d, J = 8.1 Hz, 2H), 7.45 (t, J = 7.7 Hz, 2H), 7.32 (t, J = 7.6 Hz, 2H). ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 162.1, 149.9, 144.5, 132.4, 131.8 (q, J = 33.0 Hz), 130.1, 127.6 (q, J = 3.7 Hz), 126.3, 123.8, 123.7 (q, J = 272.6 Hz), 121.3, 120.8. ^{19}F{^{1}H} NMR (471 MHz, DMSO-d_6) δ −61.1. HRMS (APCI): calcd for $C_{21}H_{13}F_3N_3S_2$ [M + H]$^+$: 428.0497; found: 428.0493.

*4-(Bis(benzo[d]thiazol-2-yl)amino)benzonitrile (**4m**).* The crude product was purified by column chromatography (hexane/ethyl acetate = 10:1). White solid, mp 229.3−230.6 °C. Isolated yield: 60% (115.3 mg, under the NaH-promoted condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.99−7.89 (m, 2H), 7.79 (d, J = 8.1 Hz, 2H), 7.75 (d, J = 8.0 Hz, 2H), 7.71 (d, J = 8.5 Hz, 2H), 7.43 (t, J = 7.7 Hz, 2H), 7.29 (t, J = 7.6 Hz, 2H). ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 161.8, 149.8, 145.2, 134.3, 132.3, 130.5, 126.4, 124.0, 121.4, 120.9, 117.9, 113.8. HRMS (APCI): calcd for $C_{21}H_{13}N_4S_2$ [M + H]$^+$: 385.0576; found: 385.0569.

*N-([1,1′-Biphenyl]-4-yl)-N-(benzo[d]thiazol-2-yl)benzo[d]thiazol-2-amine (**4o**).* The crude product was purified by column chromatography (hexane/ethyl acetate = 10:1). White solid, mp 257.0−257.5 °C. Isolated yield: 61% (132.8 mg, under the NaH-promoted condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.85 (d, J = 8.4 Hz, 2H), 7.82 (d, J = 8.1 Hz, 2H), 7.74 (d, J = 7.9 Hz, 2H), 7.71 (d, J = 7.2 Hz, 2H), 7.62 (d, J = 8.4 Hz, 2H), 7.51 (t, J = 7.6 Hz, 2H), 7.46−7.37 (m, 3H), 7.30−7.24 (m, 2H). ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 162.9, 150.1, 142.8, 140.8, 139.9, 132.5, 129.6, 129.1, 128.9, 128.0, 127.3, 126.1, 123.5, 121.3, 120.8. HRMS (APCI): calcd for $C_{26}H_{18}N_3S_2$ [M + H]$^+$: 436.0937; found: 436.0927.

*N-(Benzo[d]thiazol-2-yl)-N-(4-phenoxyphenyl)benzo[d]thiazol-2-amine (**4p**).*[53] The crude product was purified by column chromatography (hexane/ethyl acetate = 5:1). White solid, mp 217.5−219.0 °C. Isolated yield: 88% (198.7 mg, under the NaH-promoted condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.80 (d, J = 8.1 Hz, 2H), 7.72 (d, J = 7.9 Hz, 2H), 7.47 (d, J = 8.3 Hz, 2H), 7.45−7.35 (m, 4H), 7.28−7.21 (m, 3H), 7.20−7.16 (m, 4H). ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 163.1, 158.8, 155.9, 150.1, 136.1, 132.5, 130.8, 130.0, 126.1, 124.4, 123.5, 121.2, 120.8, 120.1, 119.4. HRMS (APCI): calcd for $C_{26}H_{18}N_3OS_2$ [M + H]$^+$: 452.0886; found: 452.0874.

*N^1,N^1-bis(Benzo[d]thiazol-2-yl)-N^4-phenylbenzene-1,4-diamine (**4q**).*[53] The crude product was purified by column chromatography (hexane/ethyl acetate = 5:1). White solid, mp 202.7−203.8 °C. Isolated yield: 75% (169.0 mg, under the NaH-promoted condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.82 (d, J = 8.1 Hz, 2H), 7.73 (d, J = 7.9 Hz, 2H), 7.45−7.30 (m, 6H), 7.26 (s, 2H), 7.24−7.19 (m, 4H), 7.04 (t, J = 7.4 Hz, 1H), 6.12 (s, 1H). ^{13}C{^{1}H} NMR (126 MHz, DMSO-d_6) δ 163.6, 150.1, 145.7, 142.7, 133.0, 132.5, 130.6, 129.8, 126.8, 123.9, 122.0, 121.5, 120.9, 118.8, 116.9. HRMS (APCI): calcd for $C_{26}H_{19}N_4S_2$ [M + H]$^+$: 451.1046; found: 451.1037.

*N-(Benzo[d]thiazol-2-yl)-N-(m-tolyl)benzo[d]thiazol-2-amine (**4r**).*[53] The crude product was purified by column chromatography (hexane/ethyl acetate = 20:1). White solid, mp 194.9−195.8 °C. Isolated yield: 86% (160.6 mg, under the NaH-promoted condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.80 (d, J = 8.1 Hz, 2H), 7.72 (d, J = 7.9 Hz, 2H), 7.52 (t, J = 7.9 Hz, 1H), 7.40 (t, J = 7.7 Hz, 3H), 7.35 (d, J = 7.0 Hz, 2H), 7.26−7.23 (m, 2H), 2.47 (s, 3H). ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 162.9, 150.1, 141.6, 140.6, 132.5, 130.8, 130.2, 129.7, 126.2, 126.1, 123.4, 121.2, 120.7, 21.5. HRMS (APCI): calcd for $C_{21}H_{16}N_3S_2$ [M + H]$^+$: 374.0780; found: 374.0777.

*N-(Benzo[d]thiazol-2-yl)-N-(o-tolyl)benzo[d]thiazol-2-amine (**4s**).*[53] The crude product was purified by column chromatography (hexane/ethyl acetate = 20:1). White solid, mp 193.4−194.3 °C. Isolated yield: 52% (97.1 mg, under the NaH-promoted condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.80 (d, J = 8.1 Hz, 2H), 7.73 (d, J = 7.9 Hz, 2H), 7.56−7.44 (m, 4H), 7.40 (t, J = 7.7 Hz, 2H), 7.25 (t, J = 7.6 Hz, 2H), 2.19 (s, 3H). ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 162.2, 150.3, 140.6, 137.4, 132.5, 132.2, 130.4, 129.5, 128.1, 126.1, 123.4, 121.2, 120.8, 17.5. HRMS (APCI): calcd for $C_{21}H_{16}N_3S_2$ [M + H]$^+$: 374.0780; found: 374.0775.

*6-Methyl-N-(6-methylbenzo[d]thiazol-2-yl)-N-phenylbenzo[d]-thiazol-2-amine (**4t**).*[53] The crude product was purified by column chromatography (hexane/ethyl acetate = 20:1). White solid, mp 192.2−193.3 °C. Isolated yield: 62% (120.1 mg, under the NaH-promoted condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.67 (d, J = 8.3 Hz, 2H), 7.65−7.57 (m, 3H), 7.54 (d, J = 7.6 Hz, 2H), 7.50 (s, 2H), 7.20 (d, J = 8.2 Hz, 2H), 2.44 (s, 6H). ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 162.1, 148.1, 141.8, 133.3, 132.5, 130.4, 129.8, 129.4, 127.4, 120.8, 120.6, 21.5. HRMS (APCI): calcd for $C_{22}H_{18}N_3S_2$ [M + H]$^+$: 388.0937; found: 388.0930.

*6-Methoxy-N-(6-methoxybenzo[d]thiazol-2-yl)-N-phenylbenzo-[d]thiazol-2-amine (**4u**).*[53] The crude product was purified by column chromatography (hexane/ethyl acetate = 4:1). White solid, mp 165.4−166.3 °C. Isolated yield: 64% (134.2 mg, under the NaH-promoted condition). ^{1}H NMR (500 MHz, DMSO-d_6) δ 7.77−7.68 (m, 5H), 7.67 (d, J = 8.9 Hz, 2H), 7.61 (d, J = 1.5 Hz, 2H), 7.07 (dd, J = 8.8, 1.5 Hz, 2H), 3.84 (s, 6H). ^{13}C{^{1}H} NMR (126 MHz, DMSO-d_6) δ 161.1, 156.4, 144.2, 141.9, 133.6, 131.0, 130.4, 130.0, 121.5, 115.1, 105.5, 56.1. HRMS (APCI): calcd for $C_{22}H_{18}N_3O_2S_2$ [M + H]$^+$: 420.0835; found: 420.0827.

*6-Chloro-N-(6-chlorobenzo[d]thiazol-2-yl)-N-phenylbenzo[d]-thiazol-2-amine (**4v**).*[53] The crude product was purified by column chromatography (hexane/ethyl acetate = 20:1). White solid, mp

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244.2−245.3 °C. Isolated yield: 51% (109.2 mg, under the NaH-promoted condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.73−7.59 (m, 7H), 7.53 (d, J = 6.9 Hz, 2H), 7.36 (d, J = 8.6 Hz, 2H). $^{13}C\{^1H\}$ NMR (126 MHz, $CDCl_3$) δ 162.8, 148.6, 141.2, 133.6, 130.6, 130.3, 129.2, 129.0, 126.8, 122.1, 120.4. HRMS (APCI): calcd for $C_{20}H_{12}Cl_2N_3S_2$ $[M + H]^+$: 427.9844; found: 427.9839.

*Diethyl 2,2′-(phenylazanediyl)bis(benzo[d]thiazole-6-carboxylate) (**4w**).*[53] The crude product was purified by column chromatography (hexane/ethyl acetate = 4:1). White solid, mp 239.1−239.9 °C. Isolated yield: 85% (214.0 mg, under the NaH-promoted condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.45 (s, 2H), 8.10 (d, J = 8.5 Hz, 2H), 7.80 (d, J = 8.6 Hz, 2H), 7.72−7.62 (m, 3H), 7.56 (d, J = 7.0 Hz, 2H), 4.40 (q, J = 7.1 Hz, 4H), 1.42 (t, J = 7.1 Hz, 6H). $^{13}C\{^1H\}$ NMR (126 MHz, $CDCl_3$) δ 166.2, 165.0, 153.3, 141.1, 132.4, 130.7, 130.4, 129.1, 127.7, 125.8, 123.0, 120.9, 61.1, 14.4. HRMS (APCI): calcd for $C_{26}H_{22}N_3O_4S_2$ $[M + H]^+$: 504.1046; found: 504.1037.

*N-(Benzo[d]thiazol-2-yl)-N-benzylbenzo[d]thiazol-2-amine (**4x**).* The crude product was purified by column chromatography (hexane/ethyl acetate = 20:1). White solid, mp 184.9−185.4 °C. Isolated yield: 64% of **4x** (119.5 mg) and 16% of mono-heteroarylation counterpart **3x** (19.2 mg, under the NaH-promoted condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.84 (d, J = 8.1 Hz, 2H), 7.77 (d, J = 7.8 Hz, 2H), 7.45−7.40 (m, 4H), 7.33−7.29 (m, 2H), 7.28−7.25 (m, 3H), 5.77 (s, 2H). $^{13}C\{^1H\}$ NMR (126 MHz, $CDCl_3$) δ 161.9, 149.8, 135.4, 132.4, 128.7, 127.8, 127.2, 126.2, 123.4, 121.0, 120.9, 54.8. HRMS (APCI): calcd for $C_{21}H_{16}N_3S_2$ $[M + H]^+$: 374.0780; found: 374.0777.

*N-(Benzo[d]thiazol-2-yl)-N-phenethylbenzo[d]thiazol-2-amine (**4y**).* The crude product was purified by column chromatography (hexane/ethyl acetate = 20:1). White solid, mp 164.6−165.1 °C. Isolated yield: 74% of **4y** (143.4 mg) and 16% of mono-heteroarylation counterpart **3y** (20.3 mg, under the NaH-promoted condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.87 (d, J = 8.0 Hz, 2H), 7.80 (dd, J = 7.9, 1.1 Hz, 2H), 7.45 (t, J = 7.7 Hz, 2H), 7.41 (d, J = 7.1 Hz, 2H), 7.36 (t, J = 7.5 Hz, 2H), 7.31−7.25 (m, 3H), 4.66−4.57 (m, 2H), 3.33−3.24 (m, 2H). $^{13}C\{^1H\}$ NMR (126 MHz, $CDCl_3$) δ 161.3, 150.1, 138.0, 132.1, 129.1, 128.7, 126.8, 126.2, 123.3, 121.0, 120.9, 54.4, 33.6. HRMS (APCI): calcd for $C_{22}H_{18}N_3S_2$ $[M + H]^+$: 388.0937; found: 388.0932.

*N-(Benzo[d]thiazol-2-yl)-N-hexylbenzo[d]thiazol-2-amine (**4z**).* The crude product was purified by column chromatography (hexane/ethyl acetate = 20:1). White solid, mp 105.4−105.8 °C. Isolated yield: 63% of **4z** (115.8 mg) and 15% of mono-heteroarylation counterpart **3z** (17.6 mg, under the NaH-promoted condition). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.84 (d, J = 8.1 Hz, 2H), 7.80 (d, J = 8.2 Hz, 2H), 7.44 (t, J = 7.7 Hz, 2H), 7.29−7.26 (m, 2H), 4.48−4.40 (m, 2H), 2.05−1.92 (m, 2H), 1.53−1.46 (m, 2H), 1.43−1.30 (m, 4H), 7.84 (d, J = 8.1 Hz, 3H). $^{13}C\{^1H\}$ NMR (126 MHz, $CDCl_3$) δ 161.5, 150.1, 132.1, 126.1, 123.2, 120.9, 120.8, 52.9, 31.4, 27.3, 26.4, 22.6, 14.0. HRMS (APCI): calcd for $C_{20}H_{22}N_3S_2$ $[M + H]^+$: 368.1250; found: 368.1249.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge at https://pubs.acs.org/doi/10.1021/acs.joc.1c01019.

Supplementary results; detailed calculated green metrics and original NMR spectra of all target compounds; optimization of reaction conditions; and reactions of ethyl 2-chlorobenzo[*d*]thiazole-6-carboxylate (**1w**) and aniline (**2a**) under the base-free condition (PDF)

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Notes

The authors declare no competing financial interest.

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