JOC The Journal of Organic Chemistry

Article

Metal-free synthesis of 2-aminobenzothiazoles via iodine-catalyzed and oxygen-promoted cascade reactions of isothiocyanatobenzenes with amines

Yuanshuang Xu, Bin Li, Xinying Zhang, and Xuesen Fan

J. Org. Chem., **Just Accepted Manuscript** • DOI: 10.1021/acs.joc.7b01683 • Publication Date (Web): 16 Aug 2017

ACS Publications

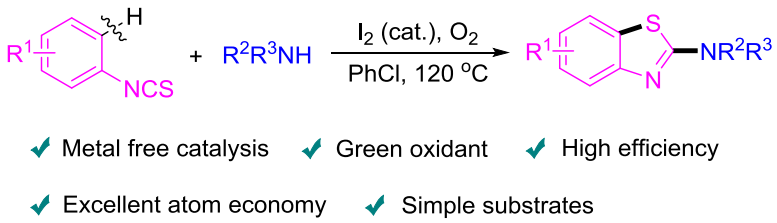
The Journal of Organic Chemistry is published by the American Chemical Society.
1155 Sixteenth Street N.W., Washington, DC 20036

Metal-free synthesis of 2-aminobenzothiazoles *via* iodine-catalyzed and oxygen-promoted cascade reactions of isothiocyanatobenzenes with amines

Yuanshuang Xu, Bin Li, Xinying Zhang*, and Xuesen Fan*

School of Chemistry and Chemical Engineering, Collaborative Innovation Center of Henan Province for Green Manufacturing of Fine Chemicals, Henan Key Laboratory of Organic Functional Molecule and Drug Innovation, Key Laboratory of Green Chemical Media and Reactions, Ministry of Education, Henan Normal University, Xinxiang, Henan 453007, China

E-mail: xinyingzhang@htu.cn; *xuesen.fan@htu.cn*



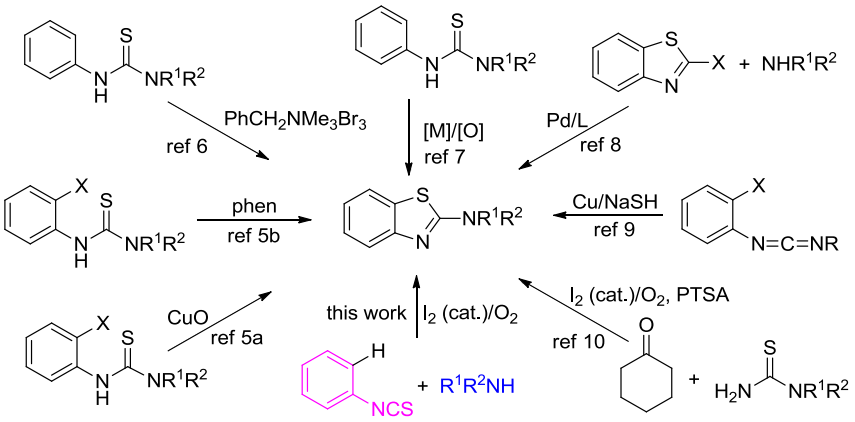
Abstract: In this paper, a highly efficient and sustainable synthesis of 2-aminobenzothiazoles through the cascade reactions of isothiocyanatobenzenes with primary or secondary amines by using iodine as a catalyst and oxygen as an oxidant is presented. Mechanistically, the formation of the title compounds involves the in situ formation of the required benzothiourea intermediate followed by its intramolecular cross dehydrogenative coupling of a C(sp^2)−H bond and a S−H bond. To our knowledge, this should be the first example in which 2-aminobenzothiazoles are efficiently prepared from simple and cheap isothiocyanates and amines under metal free conditions by using iodine as a catalyst and molecular oxygen as an oxidant with water as the byproduct. Compared with literature protocols, this method eliminates the use of *ortho*-halo-substituted precursors, expensive transition metal catalyst, and hazardous oxidant.

INTRODUCTION

2-Aminobenzothiazole constitutes an essential building block of numerous compounds with a broad spectrum of medicinal and pharmaceutical activities such as anti-inflammatory, anti-microbial, anti-tumor, neuroprotective, anti-convulsant, anti-infective, and HIV-1 protease inhibiting, etc.[1] In addition, 2-aminobenzothiazoles have also been frequently used as key intermediates in the synthesis of fine chemicals.[2] Due to their importance, a number of elegant methods for the synthesis of 2-aminobenzothiazoles have been established (Scheme 1),[3] which mainly include: 1) condensation of 2-aminothiophenols with isothiocyanates;[4] 2) Cu-, or phen-catalyzed cyclization of *o*-halobenzothioureas;[5] 3) stoichiometric amount of $PhCH_2NMe_3Br_3$-promoted[6] or transition metal-catalyzed[7] cyclization of benzothioureas; 4) Pd-catalyzed amination of 2-halobenzothiazoles;[8] 5) Cu-catalyzed condensation of carbodiimide with sodium hydrosulfide;[9] 6) iodine-catalyzed condensation and aromatization of cyclohexanone with thiourea;[10] 7) Cu-mediated aerobic three-component reaction of diaminodiaryl disulfide, copper cyanide and an electrophile,[11] etc. While these literature protocols are generally efficient and reliable, some of them still suffer from the need for pre-functionalization of commercial substrates, the use of toxic reagents, expensive metal catalysts and ligands, and the production of hazardous by-products. Therefore, the development of environmentally and economically more sustainable synthetic methods toward 2-aminobenzothiazoles is still highly desirable.

In recent years, iodine-catalyzed or promoted organic reactions have attracted much attention. This is not only due to the inexpensive and green nature of molecular iodine, but also owing to its high efficiency.[12] In particular, the combination of a catalytic amount of iodine with an added oxidant has been widely used in various oxidative carbon−carbon and carbon−heteroatom bonds forming reactions.[13] Meanwhile, cross dehydrogenative coupling (CDC) between the inert C−H/X−H bonds is an appealing strategy in organic synthesis as it provides easy accesses to complex molecules from simple starting materials in a single operation without pre-introduction of special leaving groups. As this strategy can significantly reduce the number of reaction steps, costs, and the amount of wastes, it perfectly fulfills part of the criteria of green chemistry.[14] Inspired by those pioneering studies as mentioned above, and as a continuation of our recent interest in

developing novel methods for the preparation of heterocyclic compounds,[15] we have designed a one-pot synthesis of 2-aminobenzothiazoles directly from the reactions of the commercially available and inexpensive isothiocyanatobenzenes with amines through the in situ formation of a benzothiourea intermediate followed by its intramolecular CDC reaction promoted by a combination of a catalytic amount of iodine with a terminal oxidant (Scheme 1). Herein, we report our detailed study in this aspect.



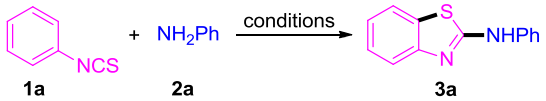
Scheme 1. Different synthetic routes to 2-aminobenzothiazoles

RESULTS AND DISCUSSION

Our study was initiated by treating isothiocyanatobenzene (**1a**) with aniline (**2a**) in the presence of 0.2 equiv of I_2 and 2 equiv of di-*tert*-butyl perioxide (DTBP) in chlorobenzene (PhCl) at 120 ℃ for 12 h. To our delight, from this reaction the desired *N*-phenylbenzo[*d*]thiazol-2-amine (**3a**) was obtained in a yield of 81% (Table 1, entry 1). Then, different oxidants such as *tert*-butyl hydroperoxide (TBHP), H_2O_2, oxone, O_2 and air were tested. We were pleased to find that with oxygen as the oxidant, **3a** could be obtained in 82% yield (entries 1-6). This is a highly promising result on behalf of green and sustainable chemistry since molecular oxygen is considered as an ideal terminal oxidant due to its inexpensive and environmentally friendly characters.[16] While high yields could also be obtained by using peroxides such as DTBP and H_2O_2 as the oxidant, this type of oxidants may suffer from the potential risk of uncontrollable explosive radical reactions. Therefore, we chose O_2 as the oxidant for further screening of the reaction conditions. Among various solvents thus tried, PhCl was found to be more efficient than toluene, DMF and dioxane (entries 7-9 vs 5). In a further aspect, different reaction temperatures were tried, and those higher

or lower than 120 ℃ gave diminished yields of **3a** (entries 10-11). Reducing the amount of I_2 from 0.2 to 0.1 equiv resulted in a sharp decrease in the efficiency, and increasing its amount to 0.5 equiv did not improve the yield of **3a** obviously (entries 12-13). Interestingly, further study showed that when the reaction of **1a** with **2a** was carried out in the presence of 1.0 equiv of I_2 under nitrogen, **3a** was obtained in a yield of 68% (entry 14). Finally, a control experiment indicated that in the absence of iodine, the formation of **3a** was not observed (entry 15).

Table 1. Optimization studies for the preparation of **3a** [a]



1a **2a** **3a**

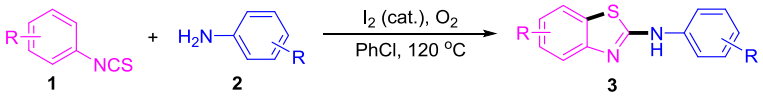
entry	catalyst (equiv)	oxidant (equiv)	solvent	t/ ℃	yield (%)[b]
1	I_2 (0.2)	DTBP (2)	PhCl	120	81
2	I_2 (0.2)	TBHP (2)	PhCl	120	68
3	I_2 (0.2)	H_2O_2 (2)	PhCl	120	86
4	I_2 (0.2)	oxone (2)	PhCl	120	trace
5	I_2 (0.2)	O_2	PhCl	120	82
6	I_2 (0.2)	air	PhCl	120	25
7	I_2 (0.2)	O_2	toluene	120	41
8	I_2 (0.2)	O_2	DMF	120	trace
9	I_2 (0.2)	O_2	dioxane	120	55
10	I_2 (0.2)	O_2	PhCl	100	67
11	I_2 (0.2)	O_2	PhCl	140	75
12	I_2 (0.1)	O_2	PhCl	120	32
13	I_2 (0.5)	O_2	PhCl	120	84
14	I_2 (1.0)	N_2	PhCl	120	68
15	none	O_2	PhCl	120	0

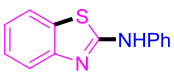
[a] Reaction conditions: **1a** (0.55mmol), **2a** (0.5 mmol), O_2 or N_2 (balloon, 1 atm), solvent (3 mL), 12 h. [b] Isolated yield.

With the optimized reaction conditions in hands, the scope and generality of this 2-aminobenzothiazole-forming reaction were studied. For this purpose, the reactions of diversely substituted isothiocyanatobenzenes (**1**) with aromatic amines (**2**) were firstly studied, and the results were listed in Table 2. It turned out that **1** and **2** bearing either an electron-donating group (EDG) such as methyl or methoxy, or an electron-withdrawing group (EWG) such as fluoro, chloro or trifluoromethyl on the phenyl ring underwent this reaction smoothly to give **3a**-**3j** in

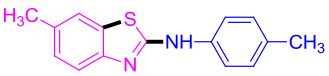
yields ranging from 56-90%, and the electronic nature of the phenyl moiety rendered an obvious effect in that substrates bearing EDG generally gave higher yields than those bearing EWG. This is exemplified by the preparation of **3b**, **3c** *vs* **3d**, **3e**, **3f**. Meanwhile, it was observed that *para*-, *meta*- and *ortho*-substituted **1** and **2** worked well for this reaction, and *meta*-substituted substrate cyclized regioselectively to give the sterically less hindered isomer (**3g** and **3h**). Finally, it was found that naphthalen-1-amine and 1-isothiocyanatonaphthalene could take part in this reaction smoothly to give **3k** in a yield of 78%.

Table 2. Substrate scope for the preparation of **3** (I) [a, b]

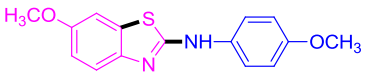




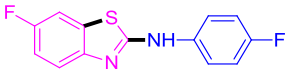
3a, 82%



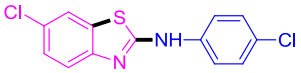
3b, 85%



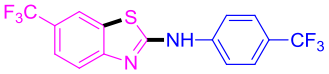
3c, 84%



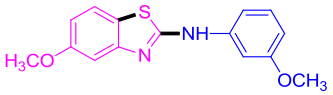
3d, 64%



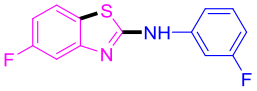
3e, 69%



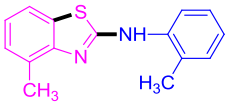
3f, 62%



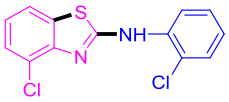
3g, 76%



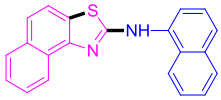
3h, 73%



3i, 90%



3j, 56%



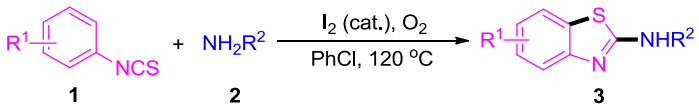
3k, 78%

[a] Reaction conditions: **1** (0.55mmol), **2** (0.5 mmol), I_2 (0.1 mmol), O_2 (balloon, 1 atm), PhCl (3 mL), 120 ℃, 12 h. [b] Isolated yield.

Next, the scope of the amine substrates (**2**) was extended from aromatic primary amines to alkyl primary amines, and the results were listed in Table 3. We were delighted to observe that when diversely substituted isothiocyanates (**1**) were reacted with propan-1-amine, the corresponding products **3l-3o** could be obtained in yields ranging from 62% to 75%. Next, a variety of isothiocyanates (**1**) were let to react with phenylmethanamine. It was shown that functional groups such as methyl, methoxy, chloro, bromo and trifluoromethyl attached on the phenyl moiety in **1** were well tolerated, and both electron-rich and electron-poor phenylisothiocyanates underwent this

cascade reaction successfully to give **3p-3w** in moderate to good yields. To our delight, *o*-methylphenylisothiocyanate was found to be also suitable for this reaction to give the corresponding product (**3u**) in a yield of 74%. Next, (3-fluorophenyl)methanamine, *o*-tolylmethanamine and (2-chlorophenyl)methanamine reacted with **1a** smoothly to give **3x-3z** in moderate yields. When 1-phenylethan-1-amine was reacted with diversely substituted isothiocyanates, the corresponding reactions afforded **3aa-3ee** in 41-68% yields. Notably, from the reaction of naphthalen-1-ylmethanamine, **3ff** could be obtained in a yield of 56%.

Table 3. Substrate scope for the preparation of **3** (II) [a, b]



1 2 3

3l, 68%

3m, 75%

3n, 71%

3o, 62%

3p, 61%

3q, 67%

3r, 60%

3s, 55%

3t, 50%

3u, 74%

3v, 50%

3w, 55%

3x, 56%

3y, 53%

3z, 56%

3aa, 61%

3bb, 64%

3cc, 58%

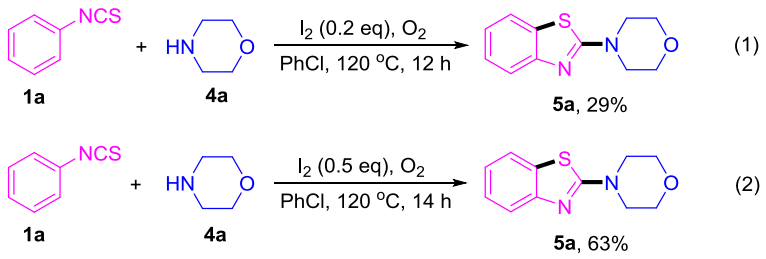
3dd, 41%

3ee, 68%

3ff, 56%

[a] Reaction conditions: **1** (0.55mmol), **2** (0.5 mmol), I_2 (0.1 mmol), O_2 (balloon, 1 atm), PhCl (3 mL), 120 ℃, 12 h. [b] Isolated yield.

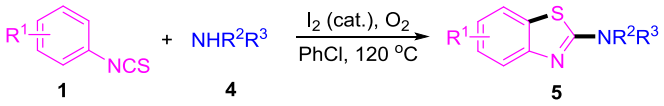
To further expand the substrate scope, morpholine (**4a**), an alkyl secondary amine, was treated with **1a** under the standard reaction conditions used for the synthesis of **3** (Table 1, entry 5). From this reaction, the expected product **5a** was obtained in 29% yield (Scheme 2, 1). To improve the efficiency, several parameters possibly affecting this reaction were screened. After some trials and errors, we were delighted to find that **5a** could be obtained in 63% yield by treating the mixture of **1a** and **4a** with 0.5 equiv of iodine in PhCl under oxygen at 120 ℃ for 14 h (Scheme 2, 2).

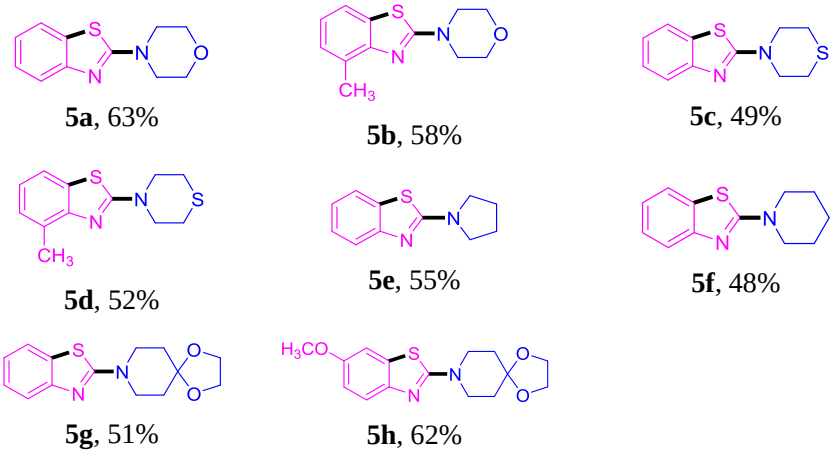


Scheme 2. Synthesis of **5a** under different reaction conditions

Next, the suitability of other secondary amines for this reaction was studied, and the results were listed in Table 4. It was found that in addition to morpholine, thiomorpholine, pyrrolidine, piperidine or functinalized piperidine could also take part in this reaction successfully to give a series of hybrid compounds (**5a**-**5h**) containing both the benzothiazole scaffold and another kind of heterocyclic unit with potential biological and material significance.

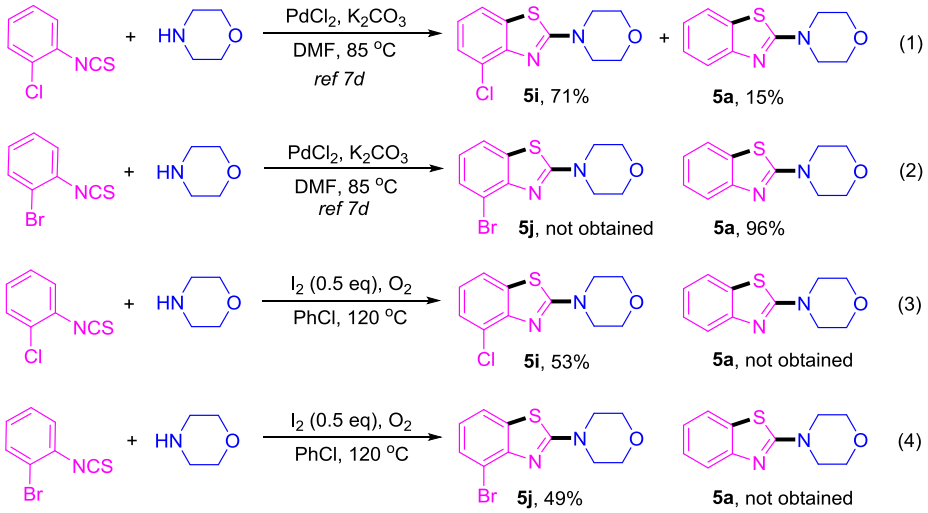
Table 4. Substrate scope for the preparation of **5** [a, b]





[a] Reaction conditions: **1** (0.55mmol), **4** (0.5 mmol), I_2 (0.25mmol), O_2 (balloon, 1 atm), PhCl (3 mL), 120 ℃, 14 h. [b] Isolated yield.

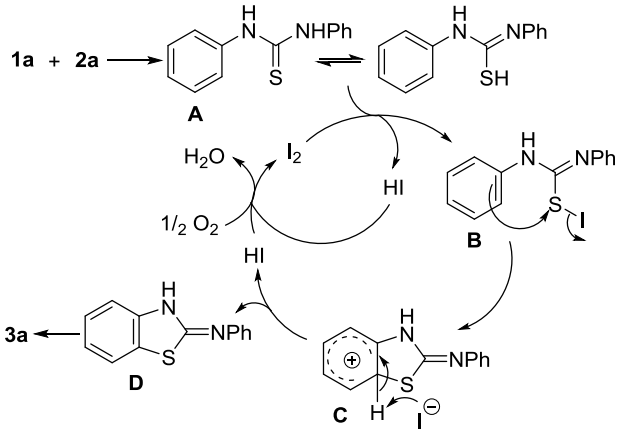
Furthermore, we noted that Patel et al have recently reported an interesting intramolecular arylthiolation of benzothioureas through Pd-catalyzed C−H bond activation or C−X bond breakage.[7d] In that elegant study, they observed that the reaction of 1-chloro-2-isothiocyanato-benzene with morpholine went through both the C−H bond activation and the C−Cl bond breakage pathways to give a mixture of 4-(4-chlorobenzo[*d*]thiazol-2-yl)morpholine (**5i**) and 4-(benzo[*d*]thiazol-2-yl)morpholine (**5a**) in yields of 71% and 15%, respectively (Scheme 3, 1). When 1-bromo-2-isothiocyanatobenzene was used, on the other hand, the reaction exclusively followed a dehalogenative route to give **5a** in an excellent yield of 96%. Meanwhile, the formation of 4-(4-bromobenzo[*d*]thiazol-2-yl)morpholine (**5j**) was not observed (Scheme 3, 2). To compare our method with Patel's protocol, we carried out the reactions of 1-chloro-2-isothiocyanato-benzene and 1-bromo-2-isothiocyanatobenzene with morpholine under the promotion of I_2 and O_2. It turned out that both of them exclusively underwent the C−H bond functionalization pathway to give **5i** (Scheme 3, 3) and **5j** (Scheme 3, 4) in moderate yields. Meanwhile, the formation of **5a**, derived from C−Cl or C−Br bond cleavage, was not observed. These results tell that the method developed in this paper could be considered as a complementary tool to Patel's protocol.



Scheme 3. Different reaction versions of 1-halo-2-isothiocyanatobenzene with morpholine

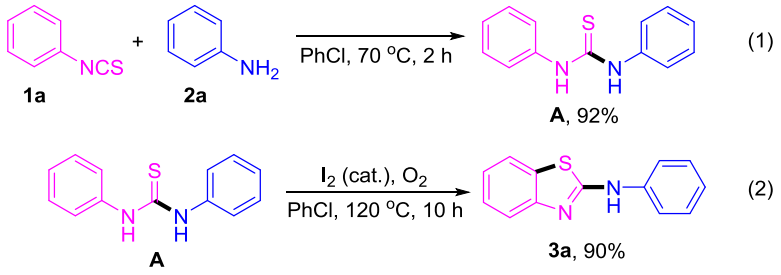
Based on the above observation and previous reports,[13] a plausible mechanism accounting for the formation of **3a** from the reaction of **1a** with **2a** is proposed in Scheme 4. Initially, **1a** condenses with **2a** to afford 1,3-diphenylthiourea (**A**). Then, **A** reacts with iodine to afford

intermediate **B** through the formation of a S−I bond. Next, an intramolecular attack of the π electron of the nucleophilic benzene ring onto the electrophilic S in **B** forms an arenium σ-complex (**C**). Finally, an extrusion of H^+ from **C** assisted by I^- as a base leads to the formation of **3a** *via* intermediate **D**. Meanwhile, oxidation of the *in situ* formed HI by molecular oxygen regenerates I_2 for the next cycle of the reaction.



Scheme 4. Proposed reaction mechanism accounting for the formation of **3a**

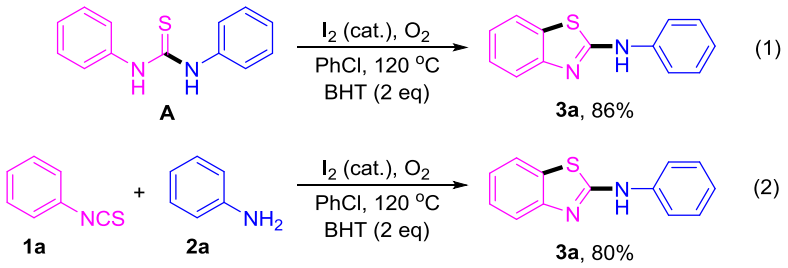
To verify the proposed reaction mechanism, some control experiments were carried out. First, **1a** was treated with **2a** in PhCl at 70 ℃ for 2h. From this reaction, 1,3-diphenylthiourea, the proposed intermediate **A** as shown in Scheme 4, was obtained in a yield of 92% (Scheme 5, 1). When **A** was treated with I_2 in PhCl under an oxygen atmosphere at 120 ℃ for 10 h, **3a** was obtained in a yield of 90% (Scheme 5, 2). These results tell that **A** should be a key intermediate in the formation of **3a** from the reaction of **1a** and **2a**.



Scheme 5. Control experiments (I)

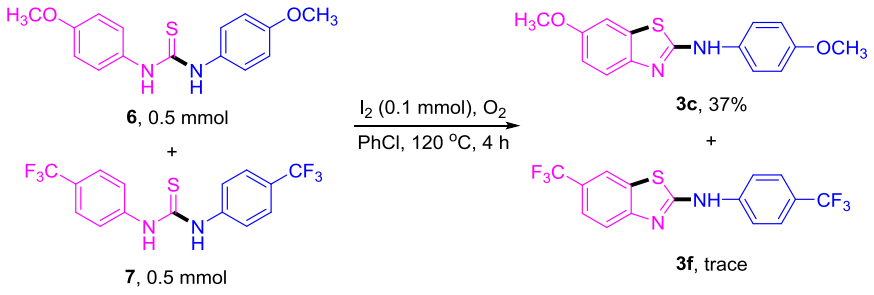
Next, using 2 equiv of butylated hydroxytoluene (BHT) as a free-radical trap was found to have no obvious negative effect on the transformation of **A** toward **3a** (Scheme 6, 1). Moreover, when

2 equiv of BHT were added directly to the reaction of **1a** with **2a** under standard reaction conditions, **3a** could still be obtained in a yield of 80% (Scheme 6, 2), suggesting that a radical reaction pathway might be excluded.



Scheme 6. Control experiments (II)

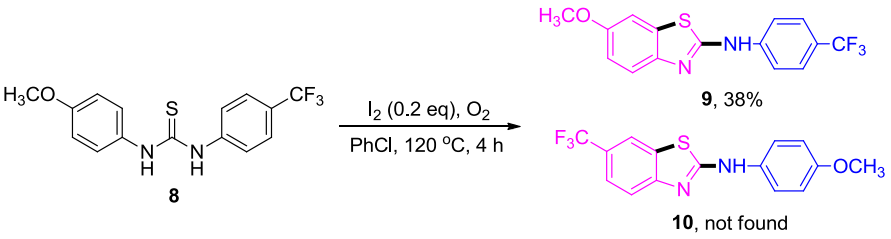
To clarify whether an iodine-catalyzed intramolecular aromatic electrophilic substitution is involved in the formation of **3**, an intermolecular competing experiment was carried out. Thus, a mixture of 1,3-bis(4-methoxyphenyl)thiourea (**6**, 0.5 mmol) and 1,3-bis(4-(trifluoromethyl)-phenyl)thiourea (**7**, 0.5 mmol) were treated with 0.1 mmol of I_2 under an oxygen atmosphere at 120 ℃ for 4 h. From this reaction, **3c**, formed from the reaction of **6**, was obtained in 37% yield. Meanwhile, **3f**, formed from the reaction of **7**, was obtained only in trace amount (Scheme 7). These results indicate that substrate bearing an EDG on the phenyl ring undergoes the cyclization much more rapidly than that bearing an EWG. The higher reactivity of the electron-richer substrate is in consistent with the proposed aromatic electrophilic substitution mechanism with the formation of an arenium σ-complex.



Scheme 7. An intermolecular competing experiment

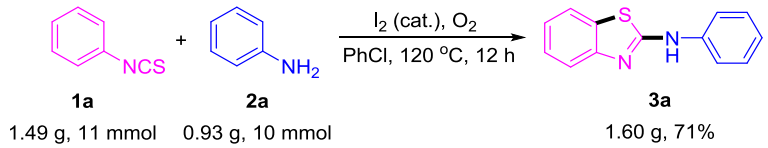
Furthermore, an intramolecular competing experiment was also tried. Thus, 1-(4-methoxy-phenyl)-3-(4-(trifluoromethyl)phenyl)thiourea (**8**) was subjected to I_2 and O_2 in PhCl at 120 ℃ for 4 h. From this reaction, 5-methoxy-*N*-(4-(trifluoromethyl)phenyl)benzo[*d*]thiazol-2-amine (**9**) was

formed in a yield of 38% through the annulation onto the electron-richer benzene ring attached with a methoxy group. Meanwhile, the formation of another possible regioisomer, *N*-(4-methoxyphenyl)-5-(trifluoromethyl)benzo[*d*]thiazol-2-amine (**10**) was not found (Scheme 8). This is in consistent with what has been observed in the intermolecular competing experiment as shown in Scheme 7, and should be considered as another positive evidence in supporting the proposed reaction mechanism as shown in Scheme 4.



Scheme 8. An intramolecular competing experiment

Finally, in order to check the suitability of this new synthetic method in an enlarged scale, 11 mmol of **1a** was treated with 10 mmol of **2a** under standard reaction conditions. From this reaction, **3a** was obtained in a yield of 71% (Scheme 9).



Scheme 9. Gram-scale synthesis of **3a**

CONCLUSION

In summary, a molecular iodine-catalyzed and oxygen-oxidized synthesis of 2-amino benzothiazoles from the cascade reaction of isothiocyanatobenzenes with amines has been developed. Compared with literature reports, notable features of this novel method include: 1) accomplished in the absence of any metal catalyst, 2) starting from commercially available and inexpensive materials, 3) eliminating the need of *ortho*-halo substituted precursors and the use of hazardous oxidant, 4)broad substrate scope, and 5) high efficiency and excellent sustainability. With these advantages, this method is expected to find wide applications in related areas.

EXPERIMENTAL SECTION

1. General Methods.

Commercial reagents were used without further purification. Melting points were recorded with a micro melting point apparatus and uncorrected. The ^{1}H NMR spectra were recorded at 400 MHz or 600 MHz. The ^{13}C NMR spectra were recorded at 100 MHz or 150 MHz. The ^{19}F NMR spectra were recorded at 565 MHz. Chemical shifts were expressed in parts per million (δ) downfield from the internal standard tetramethylsilane, and were reported as s (singlet), d (doublet), t (triplet), dd (doublet of doublet), m (multiplet), br s (broad singlet), etc. The coupling constants *J* were given in Hz. High resolution mass spectra (HRMS) were obtained *via* ESI mode by using a MicrOTOF mass spectrometer. The conversion of starting materials was monitored by thin layer chromatography (TLC) using silica gel plates (silica gel 60 F254 0.25 mm), and components were visualized by observation under UV light (254 and 365 nm).

2. A typical procedure for the synthesis of 3a and spectroscopic data of 3a-3ff

To a 10 mL schlenk tube were added isothiocyanatobenzene (**1a**, 66 uL, 0.55 mmol), aniline (**2a**, 46 uL, 0.5 mmol), I_2 (25.4 mg, 0.1 mmol) and PhCl (3 mL). The mixture was then strirred at 120 ℃ under an oxygen atmosphere for 12 h. Upon completion, the resulting mixture was quenched with saturated aqueous solution of $Na_2S_2O_3$ (10 mL), and extracted with EtOAc (10 mL × 3). The combined organic phase was washed with water and brine, dried over anhydrous Na_2SO_4, and evaporated under reduced pressure. The residue was purified by column chromatography on silica gel with petroleum ether/ethyl acetate (10:1) as the eluent to give **3a** (92.8 mg, 82%). **3b**-**3ff** were obtained in a similar manner.

N-Phenylbenzo[*d*]thiazol-2-amine (**3a**): Eluent: petroleum ether/ethyl acetate (10:1); white solid (92.8 mg, 82%), mp 156-157 ℃ (lit.[17] 158-159 ℃). ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.11-7.19 (m, 2H), 7.30 (t, *J* = 7.6 Hz, 1H), 7.40 (t, *J* = 7.6 Hz, 2H), 7.48-7.54 (m, 3H), 7.61 (d, *J* = 8.4 Hz, 1H), 9.52 (br s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 119.2, 120.7, 120.9, 122.3, 124.5, 126.2, 129.6, 129.8, 140.1, 151.3, 165.4. MS: m/z 227 $[M+H]^+$.

6-Methyl-*N*-(*p*-tolyl)benzo[*d*]thiazol-2-amine (**3b**): Eluent: petroleum ether/ethyl acetate (10:1); white solid (108.1 mg, 85%), mp 163-164 ℃ (lit.[17] 165-166 ℃). ^{1}H NMR (400 MHz, DMSO-d_6) δ: 2.27 (s, 3H), 2.35 (s, 3H), 7.10-7.16 (m, 3H), 7.46 (d, J = 8.4 Hz, 1H), 7.56 (s, 1H), 7.66 (d, J = 8.4 Hz, 2H), 10.28 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6) δ: 20.4, 20.8, 117.8, 118.7, 120.8, 126.9, 129.3, 130.0, 130.8, 131.3, 138.3, 150.1, 160.9. MS: m/z 255 $[M+H]^+$.

6-Methoxy-*N*-(4-methoxyphenyl)benzo[*d*]thiazol-2-amine (**3c**): Eluent: petroleum ether/ethyl acetate (10:1); white solid (120.3 mg, 84%), mp 156-157 ℃. ^{1}H NMR (400 MHz, DMSO-d_6) δ: 3.73 (s, 3H), 3.76 (s, 3H), 6.88-6.95 (m, 3H), 7.40 (s, 1H), 7.46 (d, J = 8.8 Hz, 1H), 7.67 (d, J = 8.8 Hz, 2H), 10.10 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6) δ: 55.2, 55.5, 105.3, 113.3, 114.1, 119.2, 119.3, 131.0, 134.2, 146.3, 154.4, 155.0, 160.3. HRMS calcd for $C_{15}H_{15}N_2O_2S$: 287.0849 $[M+H]^+$, found: 287.0854.

6-Fluoro-*N*-(4-fluorophenyl)benzo[*d*]thiazol-2-amine (**3d**): Eluent: petroleum ether/ethyl acetate (10:1); white solid (83.9 mg, 64%), mp 228-230 ℃. ^{1}H NMR (400 MHz, DMSO-d_6) δ: 7.12-7.22 (m, 3H), 7.55-7.59 (m, 1H), 7.71 (dd, J_1 = 8.4 Hz, J_2 = 2.4 Hz, 1H), 7.77-7.81 (m, 2H), 10.49 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6) δ: 107.9 (d, $^{2}J_{C\text{-}F}$ = 27.6 Hz), 113.3 (d, $^{2}J_{C\text{-}F}$ = 24.0 Hz), 115.5 (d, $^{2}J_{C\text{-}F}$ = 22.6 Hz), 119.3 (d, $^{3}J_{C\text{-}F}$ = 7.3 Hz), 119.8 (d, $^{3}J_{C\text{-}F}$ = 8.7 Hz), 131.1 (d, $^{3}J_{C\text{-}F}$ = 10.9 Hz), 137.0 (d, $^{4}J_{C\text{-}F}$ = 2.2 Hz), 148.7, 157.3 (d, $^{1}J_{C\text{-}F}$ = 237.2 Hz), 157.9 (d, $^{1}J_{C\text{-}F}$ = 236.4 Hz), 161.5 (d, $^{4}J_{C\text{-}F}$ = 1.4 Hz). ^{19}F NMR (565 MHz, DMSO-d_6) δ: -120.24, -120.89. HRMS calcd for $C_{13}H_9F_2N_2S$: 263.0449 $[M+H]^+$, found: 263.0459.

6-Chloro-*N*-(4-chlorophenyl)benzo[*d*]thiazol-2-amine (**3e**): Eluent: petroleum ether/ethyl acetate (10:1); white solid (101.8 mg, 69%), mp 226-227 ℃ (lit.[17] 228-229 ℃). ^{1}H NMR (400 MHz, DMSO-d_6) δ: 7.33 (dd, J_1 = 8.8 Hz, J_2 = 2.0 Hz, 1H), 7.40 (d, J = 8.8 Hz, 2H), 7.58(d, J = 8.4 Hz, 1H), 7.80 (d, J = 8.8 Hz, 2H), 7.93 (s, 1H), 10.69 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6) δ: 119.3, 120.3, 120.8, 125.7, 126.1 126.3, 128.8 131.7, 139.3, 150.8, 162.0. MS: m/z 295, 297 $[M+H]^+$.

6-(Trifluoromethyl)-*N*-(4-(trifluoromethyl)phenyl)benzo[*d*]thiazol-2-amine (**3f**): Eluent: petroleum ether/ethyl acetate (10:1); white solid (112.3 mg, 62%), mp 152-153 ℃. ^{1}H NMR (400 MHz, DMSO-d_6) δ: 7.67 (d, *J* = 8.4 Hz, 1H), 7.75 (d, *J* = 8.4 Hz, 2H), 7.81 (d, *J* = 8.4 Hz, 1H), 8.02 (d, *J* = 8.4 Hz, 2H), 8.35 (s, 1H), 11.15 (s, 1H). ^{13}C NMR (150 MHz, DMSO-d_6) δ: 118.4, 119.5 (q, $^{3}J_{C-F}$ = 4.4 Hz), 120.2, 122.9 (q, $^{2}J_{C-F}$ = 31.7 Hz), 123.427 (q, $^{3}J_{C-F}$ = 3.2 Hz), 123.434 (q, $^{2}J_{C-F}$ = 31.8 Hz), 124.9 (q, $^{1}J_{C-F}$ = 270.2 Hz), 125.1 (q, $^{1}J_{C-F}$ = 270.2 Hz), 126.8 (q, $^{3}J_{C-F}$ = 4.4 Hz), 131.3, 143.9, 155.1, 164.5. ^{19}F NMR (565 MHz, DMSO-d_6) δ: -59.57, -60.16. HRMS calcd for $C_{15}H_9F_6N_2S$: 363.0385 $[M+H]^+$, found: 363.0387.

5-Methoxy-*N*-(3-methoxyphenyl)benzo[*d*]thiazol-2-amine (**3g**): Eluent: petroleum ether/ethyl acetate (10:1); yellowish solid (108.8 mg, 76%), mp 157-158 ℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ: 3.77 (s, 3H), 3.80 (s, 3H), 6.70 (d, *J* = 6.8 Hz, 1H), 6.77 (dd, J_1 = 8.4 Hz, J_2 = 2.0 Hz, 1H), 7.05 (d, *J* = 7.2 Hz, 1H), 7.10 (s, 2H), 7.29 (t, *J* = 7.6 Hz, 1H), 7.46 (d, *J* = 8.8 Hz, 1H), 9.53 (br s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 55.4, 55.5, 103.4, 106.2, 109.9, 111.2, 112.6, 121.1, 121.3, 130.3, 141.2, 152.4, 159.1, 160.7, 166.3. HRMS calcd for $C_{15}H_{15}N_2O_2S$: 287.0849 $[M+H]^+$, found: 287.0854.

5-Fluoro-*N*-(3-fluorophenyl)benzo[*d*]thiazol-2-amine **(3h)**: Eluent: petroleum ether/ethyl acetate (10:1); white solid (95.6 mg, 73%), mp 177-179 ℃. ^{1}H NMR (600 MHz, DMSO-d_6) δ: 6.84 (t, *J* = 7.8 Hz, 1H), 7.03 (t, *J* = 9.0 Hz, 1H), 7.36-7.49 (m, 3H), 7.80-7.83 (m,1H), 7.90 (d, *J* = 12.0 Hz, 1H), 10.79 (s, 1H). ^{13}C NMR (150 MHz, DMSO-d_6) δ: 105.3 (d, $^{2}J_{C-F}$ = 26.3 Hz), 106.6 (d, $^{2}J_{C-F}$ = 25.1 Hz), 109.0 (d, $^{2}J_{C-F}$ = 20.9 Hz), 110.5 (d, $^{2}J_{C-F}$ = 24.2 Hz), 114.2, 122.5 (d, $^{3}J_{C-F}$ = 9.8 Hz), 126.1, 130.9 (d, $^{3}J_{C-F}$ = 8.9 Hz), 142.5 (d, $^{3}J_{C-F}$ = 10.8 Hz), 153.5 (d, $^{3}J_{C-F}$ = 12.0 Hz), 161.9 (d, $^{1}J_{C-F}$ = 237.5 Hz), 163.0 (d, $^{1}J_{C-F}$ = 239.6 Hz), 164.0. ^{19}F NMR (565 MHz, DMSO-d_6) δ: -111.54, -116.69. HRMS calcd for $C_{13}H_9F_2N_2S$: 263.0449 $[M+H]^+$, found: 263.0459.

4-Methyl-*N*-(*o*-tolyl)benzo[*d*]thiazol-2-amine (**3i**): Eluent: petroleum ether/ethyl acetate (10:1); white solid (114.5 mg, 90%), mp 131-133 ℃ (lit.[18] 130-132 ℃). ^{1}H NMR (400 MHz, $CDCl_3$) δ: 2.26 (s, 3H), 2.39 (s, 3H), 6.97 (t, *J* = 7.6 Hz, 1H), 7.05 (d, *J* = 7.2 Hz, 1H), 7.17 (t, *J* = 7.6 Hz,

1H), 7.23-7.27 (m, 2H), 7.37 (d, J = 7.6 Hz, 1H), 7.61 (d, J = 8.0 Hz, 1H), 8.83 (br s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 17.9, 18.3, 118.4, 122.0, 124.9, 126.7, 126.9, 127.3, 128.8, 130.0, 131.3, 133.1, 138.7, 151.0, 167.0. MS: m/z 255 $[M+H]^+$.

4-Chloro-*N*-(2-chlorophenyl)benzo[*d*]thiazol-2-amine **(3j)**: Eluent: petroleum ether/ethyl acetate (30:1); white solid (82.3 mg, 56%), mp 116-118 ℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ: 6.97-7.03 (m, 2H), 7.24-7.34 (m, 3H), 7.43 (dd, J_1 = 7.6 Hz, J_2 = 0.8 Hz, 1H), 7.86 (s, 1H), 8.16 (d, J = 8.4 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 119.3, 120.3, 123.4, 123.8, 124.7, 126.6, 128.1, 129.7, 131.5, 136.3, 148.7, 162.9. HRMS calcd for $C_{13}H_9Cl_2N_2S$: 294.9858 $[M+H]^+$, found: 294.9866.

N-(Naphthalen-1-yl)naphtho[1,2-*d*]thiazol-2-amine (**3k**): Eluent: petroleum ether/ethyl acetate (10:1); purple solid (127.3 mg, 78%), mp 179-181 ℃. ^{1}H NMR (600 MHz, DMSO-d_6) δ: 7.45-7.63 (m, 6H), 7.70 (d, J = 7.8 Hz, 1H), 7.85 (d, J = 8.4 Hz, 1H), 7.90 (t, J = 7.8 Hz, 2H), 8.34 (d, J = 7.8 Hz, 1H), 8.43 (d, J = 6.0 Hz, 1H), 8.50 (d, J = 8.4 Hz, 1H), 10.56 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 118.7, 121.6, 121.9, 122.6, 123.7, 125.2, 125.5, 125.9, 126.0, 126.70, 126.74, 126.8, 127.1, 128.0, 128.7, 128.9, 132.2, 134.7, 136.0, 147.5, 168.3. HRMS calcd for $C_{21}H_{15}N_2S$: 327.0950 $[M+H]^+$, found: 327.0951.

N-Propylbenzo[*d*]thiazol-2-amine (**3l**): Eluent: petroleum ether/ethyl acetate (10:1); white solid (65.4 mg, 68%), mp 77-78 ℃ (lit.[6] 79-80 ℃). ^{1}H NMR (400 MHz, DMSO-d_6) δ: 0.94 (t, J = 7.2 Hz, 3H), 1.57-1.66 (m, 2H), 3.32 (q, J = 6.4 Hz, 2H), 7.00 (t, J = 7.6 Hz, 1H), 7.21 (t, J = 8.0 Hz, 1H), 7.38 (d, J = 8.0 Hz, 1H), 7.65 (d, J = 7.6 Hz, 1H), 8.01 (t, J = 4.8 Hz, 1H). ^{13}C NMR (150 MHz, DMSO-d_6) δ: 11.9, 22.5, 46.2, 118.4, 121.2, 121.3, 125.9, 130.7, 153.2, 166.6. MS: m/z 193 $[M+H]^+$.

6-Methyl-*N*-propylbenzo[*d*]thiazol-2-amine (**3m**): Eluent: petroleum ether/ethyl acetate (10:1); white solid (77.4 mg, 75%), mp 109-110 ℃. ^{1}H NMR (400 MHz, DMSO-d_6) δ: 0.92 (t, J = 7.2 Hz, 3H), 1.55-1.64 (m, 2H), 2.30 (s, 3H), 3.29 (q, J = 6.8 Hz, 2H), 7.00 (d, J = 8.4 Hz, 1H), 7.26 (d, J = 8.0 Hz, 1H), 7.42 (s, 1H), 7.88 (t, J = 5.2 Hz, 1H). ^{13}C NMR (100 MHz, DMSO-d_6) δ: 11.4, 20.7,

22.0, 45.7, 117.5, 120.8, 126.4, 129.7, 130.3, 150.6, 165.5. HRMS calcd for $C_{11}H_{15}N_2S$: 207.0950 $[M+H]^+$, found: 207.0950.

6-Methoxy-*N*-propylbenzo[*d*]thiazol-2-amine (**3n**): Eluent: petroleum ether/ethyl acetate (10:1); white solid (78.9 mg, 71%), mp 205-206 ℃. ^{1}H NMR (400 MHz, DMSO-d_6) δ: 0.93 (t, J = 7.2 Hz, 3H), 1.56-1.65 (m, 2H), 3.29 (q, J = 6.4 Hz, 2H), 3.74 (s, 3H), 6.82 (dd, J_1 = 8.8 Hz, J_2 = 2.4 Hz, 1H), 7.28-7.30 (m, 2H), 7.78 (t, J = 4.8 Hz, 1H). ^{13}C NMR (100 MHz, DMSO-d_6) δ: 11.4, 22.0, 45.7, 55.5, 105.5, 112.8, 118.2, 131.2, 146.8, 154.2, 164.6. HRMS calcd for $C_{11}H_{15}N_2OS$: 223.0900 $[M+H]^+$, found: 223.0876.

6-Chloro-*N*-propylbenzo[*d*]thiazol-2-amine (**3o**): Eluent: petroleum ether/ethyl acetate (10:1); white solid (70.3 mg, 62%), mp 124-126 ℃. ^{1}H NMR (400 MHz, DMSO-d_6) δ: 0.93 (t, J = 7.2 Hz, 3H), 1.56-1.65 (m, 2H), 3.32 (q, J = 6.4 Hz, 2H), 7.22 (dd, J_1 = 8.0 Hz, J_2 = 2.0 Hz, 1H), 7.35 (d, J = 8.8 Hz, 1H), 7.77 (d, J = 2.0 Hz, 1H), 8.14 (t, J = 5.2 Hz, 1H). ^{13}C NMR (100 MHz, DMSO-d_6) δ: 11.3, 21.9, 45.7, 118.7, 120.5, 124.4, 125.6, 131.9, 151.6, 166.7. HRMS calcd for $C_{10}H_{12}ClN_2S$: 227.0404 $[M+H]^+$, found: 227.0414.

N-Benzylbenzo[*d*]thiazol-2-amine (**3p**): Eluent: petroleum ether/ethyl acetate (10:1); white solid (73.3 mg, 61%), mp 157-158 ℃ (lit.[17] 160-161 ℃). ^{1}H NMR (400 MHz, DMSO-d_6) δ: 4.60 (d, J = 6.0 Hz, 2H), 7.02 (t, J = 7.6 Hz, 1H), 7.19-7.28 (m, 2H), 7.33-7.39 (m, 5H), 7.66 (d, J = 8.0 Hz, 1H), 8.50 (t, J = 5.6 Hz, 1H). ^{13}C NMR (100 MHz, DMSO-d_6) δ: 47.2, 118.1, 120.92, 120.95, 125.5, 127.0, 127.4, 128.4, 130.4, 138.9, 152.4, 166.2. MS: m/z 241 $[M+H]^+$.

N-Benzyl-6-methoxybenzo[*d*]thiazol-2-amine (**3q**): Eluent: petroleum ether/ethyl acetate (10:1); white solid (90.6 mg, 67%), mp 133-134 ℃ (lit.[7b] 136-136.5 ℃). ^{1}H NMR (400 MHz, $CDCl_3$) δ: 3.78 (s, 3H), 4.58 (s, 2H), 6.49 (br s, 1H), 6.84 (dd, J_1 = 8.8 Hz, J_2 = 2.8 Hz, 1H), 7.09 (d, J = 2.0 Hz, 1H), 7.26-7.39 (m, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 49.4, 55.9, 105.4, 113.6, 119.2, 127.7, 127.8, 128.8, 131.4, 137.7, 146.5, 155.2, 166.2. MS: m/z 271 $[M+H]^+$.

N-Benzyl-6-chlorobenzo[*d*]thiazol-2-amine (**3r**): Eluent: petroleum ether/ethyl acetate (10:1); white solid (82.4 mg, 60%), mp 204-205 ℃ (lit.[19] 207-208 ℃). ^{1}H NMR (400 MHz, DMSO-d_6) δ:

4.60 (d, *J* = 5.6 Hz, 2H), 7.21-7.28 (m, 2H), 7.33-7.39 (m, 5H), 7.79 (d, *J* = 1.6 Hz, 1H), 8.62 (t, *J* = 5.6 Hz, 1H). ^{13}C NMR (100 MHz, DMSO-d_6) δ: 47.2, 118.9, 120.6, 124.7, 125.6, 127.1, 127.4, 128.4, 132.1, 138.7, 151.4, 166.8. MS: m/z 275 $[M+H]^+$.

N-Benzyl-6-bromobenzo[*d*]thiazol-2-amine (**3s**): Eluent: petroleum ether/ethyl acetate (10:1); white solid (87.8 mg, 55%), mp 210-211 ℃. ^{1}H NMR (400 MHz, DMSO-d_6) δ: 4.59 (d, *J* = 6.0 Hz, 2H), 7.25-7.38 (m, 7H), 7.91 (s, 1H), 8.63 (t, *J* = 5.6 Hz, 1H). ^{13}C NMR (150 MHz, DMSO-d_6) δ: 47.7, 112.8, 120.0, 123.9, 127.6, 127.9, 128.9, 133.1, 139.1, 152.2, 167.3. HRMS calcd for $C_{14}H_{12}BrN_2S$: 318.9905 $[M+H]^+$, found: 318.9899.

N-Benzyl-6-(trifluoromethyl)benzo[*d*]thiazol-2-amine (**3t**): Eluent: petroleum ether/ethyl acetate (10:1); white solid (77.1 mg, 50%), mp 195-196 ℃ (lit.[9] 192.5- 194.7 ℃). ^{1}H NMR (400 MHz, DMSO-d_6) δ: 4.65 (d, *J* = 5.6 Hz, 2H), 7.28 (t, *J* = 7.2 Hz, 1H), 7.34-7.41 (m, 4H), 7.50-7.55 (m, 2H), 8.14 (s, 1H), 8.89 (t, *J* = 5.6 Hz, 1H). ^{13}C NMR (100 MHz, DMSO-d_6) δ: 47.3, 117.9, 118.6 (q, $^3J_{C-F}$ = 3.6 Hz), 121.1 (q, $^2J_{C-F}$ = 32.0 Hz), 122.6 (q, $^3J_{C-F}$ = 3.6 Hz), 124.8 (q, $^1J_{C-F}$ = 269.9 Hz), 127.2, 127.4, 128.4, 131.1, 138.4, 155.4, 168.8. ^{19}F NMR (565 MHz, DMSO-d_6) δ: -59.20. MS: m/z 309 $[M+H]^+$.

N-Benzyl-4-methylbenzo[*d*]thiazol-2-amine (**3u**): Eluent: petroleum ether/ethyl acetate (10:1); white solid (94.1 mg, 74%), mp 110-112 ℃ (lit.[7b] 112-113 ℃). ^{1}H NMR (400 MHz, $CDCl_3$) δ: 2.53 (s, 3H), 4.53 (s, 2H), 6.43 (br s, 1H), 6.96 (t, *J* = 8.0 Hz, 1H), 7.08 (d, *J* = 7.2 Hz, 1H), 7.23-7.33 (m, 5H), 7.38 (d, *J* = 7.6 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 18.5, 49.6, 118.4, 121.5, 126.8, 127.6, 127.8, 128.7, 128.8, 130.3, 137.7, 151.4, 167.2. MS: m/z 255 $[M+H]^+$.

N-Benzyl-4-chlorobenzo[*d*]thiazol-2-amine (**3v**): Eluent: petroleum ether/ethyl acetate (10:1); white solid (68.7 mg, 50%), mp 126-128 ℃. ^{1}H NMR (400 MHz, DMSO-d_6) δ: 4.62 (d, *J* = 5.6 Hz, 2H), 7.01 (t, *J* = 7.6 Hz, 1H), 7.26-7.32 (m, 2H), 7.36 (t, *J* = 7.2 Hz, 2H), 7.42 (d, *J* = 7.6 Hz, 2H), 7.65 (d, *J* = 8.0 Hz, 1H), 8.83 (t, *J* = 5.2 Hz, 1H). ^{13}C NMR (100 MHz, DMSO-d_6) δ: 47.5, 119.9, 121.58, 121.63, 125.7, 127.2, 127.6, 128.4, 131.7, 138.4, 149.1, 167.0. HRMS calcd for $C_{14}H_{12}ClN_2S$: 275.0404 $[M+H]^+$, found: 275.0395.

N-Benzyl-4-bromobenzo[*d*]thiazol-2-amine (**3w**): Eluent: petroleum ether/ethyl acetate (10:1); white solid (87.8 mg, 55%), mp 131-132 ℃. ^{1}H NMR (400 MHz, DMSO-d_6) δ: 4.60 (d, *J* = 6.0 Hz, 2H), 6.93 (t, *J* = 8.0 Hz, 1H), 7.25-7.29 (m, 1H), 7.35 (t, *J* = 8.0 Hz, 2H), 7.41-7.45 (m, 3H), 7.67 (d, *J* = 7.6 Hz, 1H), 8.84 (br s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6) δ: 47.5, 110.7, 120.4, 122.0, 127.2, 127.7, 128.4, 128.7, 131.1, 138.4, 150.4, 166.6. HRMS calcd for $C_{14}H_{12}BrN_2S$: 318.9899 $[M+H]^+$, found: 318.9889.

N-(3-Fluorobenzyl)benzo[*d*]thiazol-2-amine (**3x**): Eluent: petroleum ether/ethyl acetate (10:1); white solid (72.3 mg, 56%), mp 141-143 ℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ: 4.62 (s, 2H), 6.98 (t, *J* = 8.0 Hz, 1H), 7.05-7.12 (m, 2H), 7.17 (d, *J* = 7.2 Hz, 2H), 7.23-7.32 (m, 2H), 7.37 (d, *J* = 8.0 Hz, 1H), 7.56 (d, *J* = 8.0 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 48.8 (d, $^{4}J_{C\text{-}F}$ = 2.1 Hz), 114.5 (d, $^{2}J_{C\text{-}F}$ = 21.8 Hz), 114.7 (d, $^{2}J_{C\text{-}F}$ = 21.1 Hz), 118.8, 120.9, 121.7, 123.1 (d, $^{4}J_{C\text{-}F}$ = 3.0 Hz), 126.1, 130.3, 130.4 (d, $^{3}J_{C\text{-}F}$ = 8.7 Hz), 140.2 (d, $^{3}J_{C\text{-}F}$ = 6.6 Hz), 152.1, 163.1 (d, $^{1}J_{C\text{-}F}$ = 245.2 Hz), 167.9. ^{19}F NMR (565 MHz, $CDCl_3$) δ: -112.36. HRMS calcd for $C_{14}H_{12}FN_2S$: 259.0700 $[M+H]^+$, found: 259.0707.

N-(2-Methylbenzyl)benzo[*d*]thiazol-2-amine (**3y**): Eluent: petroleum ether/ethyl acetate (10:1); yellowish solid (67.4 mg, 53%), mp 154-155 ℃ (lit.[7b] 157- 158 ℃). ^{1}H NMR (400 MHz, $CDCl_3$) δ: 2.36 (s, 3H), 4.58 (s, 2H), 6.60 (br s, 1H), 7.05 (t, *J* = 7.6 Hz, 1H), 7.15-7.25 (m, 4H), 7.33-7.36 (m, 2H), 7.55 (d, *J* = 7.6 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 19.1, 47.6, 118.8, 120.9, 121.5, 126.0, 126.4, 128.1, 128.5, 130.3, 130.7, 135.2, 136.6, 152.3, 167.6. MS: m/z 255 $[M+H]^+$.

N-(2-Chlorobenzyl)benzo[*d*]thiazol-2-amine (**3z**): Eluent: petroleum ether/ethyl acetate (10:1); white solid (76.9 mg, 56%), mp 134-135 ℃ (lit.[20] 134.7-135.2 ℃). ^{1}H NMR (400 MHz, $CDCl_3$) δ: 4.71 (s, 2H), 7.03-7.08 (m, 2H), 7.17-7.25 (m, 3H), 7.36-7.40 (m, 2H), 7.47-7.50 (m, 1H), 7.54 (d, *J* = 8.0 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 47.1, 118.8, 120.9, 121.6, 126.0, 127.1, 129.1, 129.5, 129.7, 130.4, 133.6, 135.1, 152.2, 167.9. MS: m/z 275 $[M+H]^+$.

N-(1-Phenylethyl)benzo[*d*]thiazol-2-amine (**3aa**): Eluent: petroleum ether/ethyl acetate (10:1); white solid (77.6 mg, 61%), mp 131-132 ℃ (lit.[7b] 132- 134 ℃). ^{1}H NMR (400 MHz, DMSO-d_6) δ:

1.50 (d, *J* = 6.8 Hz, 3H), 5.03-5.10 (m, 1H), 6.99 (t, *J* = 7.2 Hz, 1H), 7.17-7.24 (m, 2H), 7.31-7.37 (m, 3H), 7.42 (d, *J* = 7.6 Hz, 2H), 7.64 (d, *J* = 7.6 Hz, 1H), 8.54 (d, *J* = 7.6 Hz, 1H). ^{13}C NMR (100 MHz, DMSO-d_6) δ: 23.1, 53.4, 118.1, 120.8, 120.9, 125.5, 126.0, 126.8, 128.3, 130.3, 144.4, 152.5, 165.3. MS: m/z 255 $[M+H]^+$.

6-Methyl-*N*-(1-phenylethyl)benzo[*d*]thiazol-2-amine (**3bb**): Eluent: petroleum ether/ethyl acetate (10:1); yellowish solid (85.9 mg, 64%), mp 106-107 ℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ: 1.57 (d, *J* = 6.8 Hz, 3H), 2.33 (s, 3H), 4.73 (q, *J* = 6.8 Hz, 1H), 7.03 (d, *J* = 8.4 Hz, 1H), 7.09 (br s, 1H), 7.21-7.26 (m, 1H), 7.28-7.32 (m, 3H), 7.35-7.38 (m, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 21.2, 23.8, 55.6, 118.4, 120.9, 126.2, 127.1, 127.6, 128.8, 130.7, 131.1, 143.3, 149.9, 167.1. HRMS calcd for $C_{16}H_{17}N_2S$: 269.1107 $[M+H]^+$, found: 269.1112.

6-Methoxy-*N*-(1-phenylethyl)benzo[*d*]thiazol-2-amine (**3cc**): Eluent: petroleum ether/ethyl acetate (10:1); white solid (82.5 mg, 58%), mp 125-127 ℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ: 1.59 (d, *J* = 6.4 Hz, 3H), 3.76 (s, 3H), 4.76 (q, *J* = 6.8 Hz, 1H), 6.68 (br s, 1H), 6.85 (dd, J_1 = 8.8 Hz, J_2 = 2.4 Hz, 1H), 7.06 (d, *J* = 2.8 Hz, 1H), 7.24-7.27 (m, 1H), 7.32 (t, *J* = 7.2 Hz, 2H), 7.38 (d, *J* = 8.4 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 23.8, 55.5, 55.9, 105.4, 113.5, 119.2, 126.2, 127.6, 128.8, 131.6, 143.2, 146.3, 155.0, 165.9. HRMS calcd for $C_{16}H_{17}N_2OS$: 285.1056 $[M+H]^+$, found: 285.1054.

N-(1-Phenylethyl)-6-(trifluoromethyl)benzo[*d*]thiazol-2-amine (**3dd**): Eluent: petroleum ether/ ethyl acetate (10:1); yellowish solid (66.1 mg, 41%), mp 120-122 ℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ: 1.63 (d, *J* = 6.8 Hz, 3H), 4.78 (q, *J* = 6.4 Hz, 1H), 7.21-7.39 (m, 6H), 7.48 (s, 2H), 7.78 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 23.5, 55.8, 118.3 (q, $^3J_{C\text{-}F}$ = 3.6 Hz), 118.5, 123.2 (q, $^3J_{C\text{-}F}$ = 3.6 Hz), 123.4 (q, $^2J_{C\text{-}F}$ = 32.8 Hz), 124.6 (q, $^1J_{C\text{-}F}$ = 269.9 Hz), 126.1, 127.9, 128.9, 130.7, 142.3, 154.5, 169.5. ^{19}F NMR (565 MHz, $CDCl_3$) δ: -60.94. HRMS calcd for $C_{16}H_{14}F_3N_2S$: 323.0824 $[M+H]^+$, found: 323.0833.

4-Methyl-*N*-(1-phenylethyl)benzo[*d*]thiazol-2-amine (**3ee**): Eluent: petroleum ether/ethyl acetate (10:1); yellowish oil (91.2 mg, 68%). ^{1}H NMR (400 MHz, $CDCl_3$) δ: 1.52 (d, *J* = 6.8 Hz,

3H), 2.55 (s, 3H), 4.70 (q, *J* = 6.4 Hz, 1H), 6.16 (br s, 1H), 6.93 (t, *J* = 7.6 Hz, 1H), 7.07 (d, *J* = 7.2 Hz, 1H), 7.21-7.24 (m, 1H), 7.29 (t, *J* = 7.6 Hz, 2H), 7.34 (d, *J* = 7.6 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 18.5, 23.6, 55.6, 118.4, 121.4, 126.2, 126.8, 127.7, 128.7, 128.8, 130.5, 143.0, 151.1, 166.3. HRMS calcd for $C_{16}H_{17}N_2S$: 269.1107 $[M+H]^+$, found: 269.1111.

N-(Naphthalen-1-ylmethyl)benzo[*d*]thiazol-2-amine (**3ff**): Eluent: petroleum ether/ethyl acetate (10:1); white solid (81.3 mg, 56%), mp 148-149 ℃ (lit.[20] 150.1- 150.8 ℃). ^{1}H NMR (400 MHz, $CDCl_3$) δ: 4.93 (s, 2H), 6.44 (br s, 1H), 6.97 (t, *J* = 7.6 Hz, 1H), 7.15 (t, *J* = 7.6 Hz, 1H), 7.28-7.32 (m, 2H), 7.38-7.46 (m, 4H), 7.71 (d, *J* = 8.4 Hz, 1H), 7.76-7.78 (m, 1H), 7.91-7.93 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 47.5, 118.9, 120.9, 121.6, 123.4, 125.5, 126.0, 126.1, 126.5, 126.7, 128.9, 130.4, 131.4, 132.6, 133.9, 152.3, 167.3. MS: m/z 291 $[M+H]^+$.

3. A typical procedure for the synthesis of 5a and spectroscopic data of 5a-5j

To a 10 mL schlenk tube were added isothiocyanatobenzene (**1a**, 66 uL, 0.55 mmol), morpholine (**4a**, 44 uL, 0.5 mmol), I_2 (64.5 mg, 0.25 mmol) and PhCl (3 mL). The mixture was then strirred at 120 ℃ under an oxygen atmosphere for 14 h. Upon completion, the resulting mixture was quenched with saturated aqueous solution of $Na_2S_2O_3$ (10 mL), and extracted with EtOAc (10 mL × 3). The combined organic phase was washed with water and brine, dried over anhydrous Na_2SO_4, and evaporated under reduced pressure. The residue was purified by column chromatography on silica gel with petroleum ether/ethyl acetate (10:1) as the eluent to give **5a** (69.4 mg, 63%). **5b-5j** were obtained in a similar manner.

4-(Benzo[*d*]thiazol-2-yl)morpholine (**5a**): Eluent: petroleum ether/ethyl acetate (10:1); white solid (69.4 mg, 63%), mp 117-118 ℃ (lit.[7b] 119-120 ℃). ^{1}H NMR (400 MHz, $CDCl_3$) δ: 3.62 (t, *J* = 4.8 Hz, 4H), 3.83 (t, *J* = 4.8 Hz, 4H), 7.10 (t, *J* = 7.6 Hz, 1H), 7.31 (t, *J* = 8.0 Hz, 1H), 7.56-7.62 (m, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 48.5, 66.3, 119.4, 120.8, 121.7, 126.1, 130.6, 152.5, 169.0. MS: m/z 221 $[M+H]^+$.

4-(4-Methylbenzo[*d*]thiazol-2-yl)morpholine (**5b**): Eluent: petroleum ether/ethyl acetate (10:1); white solid (68.0 mg, 58%), mp 140-142 ℃ (lit.[18] 143-146 ℃). ^{1}H NMR (400 MHz, $CDCl_3$) δ:

2.56 (s, 3H), 3.62 (t, *J* = 4.8 Hz, 4H), 3.83 (t, *J* = 4.8 Hz, 4H), 7.00 (t, *J* = 7.6 Hz, 1H), 7.12 (d, *J* = 7.6 Hz, 1H), 7.45 (d, *J* = 7.6 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 18.2, 48.5, 66.3, 118.2, 121.5, 126.8, 129.3, 130.5, 151.6, 168.1. MS: m/z 235 $[M+H]^+$.

2-Thiomorpholinobenzo[*d*]thiazole (**5c**): Eluent: petroleum ether/ethyl acetate (10:1); white solid (57.9 mg, 49%), mp 92-94 ℃ (lit.[21] 92-93 ℃). ^{1}H NMR (400 MHz, $CDCl_3$) δ: 2.73-2.76 (m, 4H), 3.95-3.98 (m, 4H), 7.08 (t, *J* = 7.6 Hz, 1H), 7.30 (t, *J* = 7.6 Hz, 1H), 7.54 (d, *J* = 8.0 Hz, 1H), 7.60 (d, *J* = 7.6 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 26.6, 51.2, 119.1, 120.7, 121.6, 126.1, 130.7, 152.6, 168.1. MS: m/z 237 $[M+H]^+$.

4-Methyl-2-thiomorpholinobenzo[*d*]thiazole (**5d**): Eluent: petroleum ether/ethyl acetate (10:1); yellowish solid (65.1 mg, 52%), mp 80-82 ℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ: 2.55 (s, 3H), 2.72-2.75 (m, 4H), 3.95-3.97 (m, 4H), 6.98 (t, *J* = 7.6 Hz, 1H), 7.10 (d, *J* = 7.2 Hz, 1H), 7.43 (d, *J* = 7.6 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 18.3, 26.6, 51.1, 118.1, 121.4, 126.8, 129.1, 130.5, 151.7, 167.2. HRMS calcd for $C_{12}H_{15}N_2S_2$: 251.0671 $[M+H]^+$, found: 251.0687.

2-(Pyrrolidin-1-yl)benzo[*d*]thiazole (**5e**): Eluent: petroleum ether/ethyl acetate (10:1); white solid (56.2 mg, 55%), mp 101-102 ℃ (lit.[22] 102-103 ℃). ^{1}H NMR (400 MHz, $CDCl_3$) δ: 2.03-2.07 (m, 4H), 3.56 (t, *J* = 6.0 Hz, 4H), 7.03 (t, *J* = 7.2 Hz, 1H), 7.28 (t, *J* = 7.6 Hz, 1H), 7.58 (d, *J* = 7.6 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 25.7, 49.5, 118.7, 120.66, 120.69, 125.9, 130.8, 153.4, 165.4. MS: m/z 205 $[M+H]^+$.

2-(Piperidin-1-yl)benzo[*d*]thiazole (**5f**): Eluent: petroleum ether/ethyl acetate (10:1); white solid (52.4 mg, 48%), mp 94-95 ℃ (lit.[22] 95-98 ℃). ^{1}H NMR (400 MHz, $CDCl_3$) δ: 1.68 (s, 6H), 3.58-3.60 (m, 4H), 7.04 (t, *J* = 7.6 Hz, 1H), 7.25-7.29 (m, 1H), 7.53 (d, *J* = 8.0 Hz, 1H), 7.57 (d, *J* = 8.0 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 24.3, 25.3, 49.6, 118.8, 120.6, 121.1, 125.9, 130.7, 153.0, 168.9. MS: m/z 219 $[M+H]^+$.

8-(Benzo[*d*]thiazol-2-yl)-1,4-dioxa-8-azaspiro[4.5]decane (**5g**): Eluent: petroleum ether/ethyl acetate (10:1); white solid (70.5 mg, 51%), mp 117-119 ℃ (lit.[7a] 118.5-121 ℃). ^{1}H NMR (400 MHz, $CDCl_3$) δ: 1.84 (t, *J* = 5.6 Hz, 4H), 3.75 (t, *J* = 5.6 Hz, 4H), 4.00 (s, 4H), 7.07 (t, *J* = 8.0 Hz,

1H), 7.26-7.31 (m, 1H), 7.54 (d, *J* = 8.0 Hz, 1H), 7.59 (d, *J* = 7.6 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 34.4, 46.8, 64.5, 106.9, 119.0, 120.7, 121.4, 126.0, 131.0, 152.9, 168.3. MS: m/z 277 $[M+H]^+$.

8-(6-Methoxybenzo[*d*]thiazol-2-yl)-1,4-dioxa-8-azaspiro[4.5]decane (**5h**): Eluent: petroleum ether/ethyl acetate (10:1); yellowish solid (95.0 mg, 62%), mp 104-106 ℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ: 1.83 (t, *J* = 5.6 Hz, 4H), 3.71 (t, *J* = 5.6 Hz, 4H), 3.81 (s, 3H), 4.00 (s, 4H), 6.89 (dd, J_1 = 8.8 Hz, J_2 = 2.4 Hz, 1H), 7.14 (d, *J* = 2.4 Hz, 1H), 7.44 (d, *J* = 8.8 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 34.3, 46.8, 55.9, 64.5, 105.2, 107.0, 113.6, 119.4, 132.0, 147.1, 155.0, 166.9. HRMS calcd for $C_{15}H_{19}N_2O_3S$: 307.1111 $[M+H]^+$, found: 307.1110.

4-(4-Chlorobenzo[*d*]thiazol-2-yl)morpholine (**5i**): Eluent: petroleum ether/ethyl acetate (10:1); white solid (67.5 mg, 53%), mp 110-112 ℃ (lit.[7f] 112-113 ℃). ^{1}H NMR (400 MHz, $CDCl_3$) δ: 3.65 (t, *J* = 5.2 Hz, 4H), 3.82 (t, *J* = 4.8 Hz, 4H), 7.00 (t, *J* = 8.0 Hz, 1H), 7.32 (d, *J* = 8.0 Hz, 1H), 7.48 (d, *J* = 8.0 Hz, 1H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 48.4, 66.2, 119.3, 122.0, 123.7, 126.4, 131.8, 149.6, 169.0. MS: m/z 255 $[M+H]^+$.

4-(4-Bromobenzo[*d*]thiazol-2-yl)morpholine (**5j**): Eluent: petroleum ether/ethyl acetate (10:1); yellow solid (73.3 mg, 49%), mp 79-80 ℃ (lit.[7f] 81-85 ℃). ^{1}H NMR (400 MHz, $CDCl_3$) δ: 3.64 (t, *J* = 5.2 Hz, 4H), 3.82 (t, *J* = 4.8 Hz, 4H), 6.93 (t, *J* = 8.0 Hz, 1H), 7.48 (d, *J* = 7.6 Hz, 1H), 7.52 (d, *J* = 7.6 Hz, 1H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 48.4, 66.2, 112.5, 119.9, 122.4, 129.5, 131.1, 150.8, 168.6. MS: m/z 299, 301 $[M+H]^+$.

4. Control experiments (I)

4.1. To a 10 mL reaction tube were added **1a** (66 uL, 0.55 mmol), **2a** (46 uL, 0.5 mmol) and PhCl (3 mL). The tube was then sealed, and the mixture was stirred at 70 ℃ for 2 h. Upon completion, the resulting mixture was evaporated under reduced pressure, and the residue was purified by column chromatography on silica gel with petroleum ether/ethyl acetate (3:1) as the eluent to give **A** (105.0 mg, 92%).

1,3-Diphenylthiourea (**A**): Eluent: petroleum ether/ethyl acetate (3:1); white solid (105.0 mg, 92%), mp 153-154 ℃ (lit.[23] 154-155 ℃). ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.17-7.21 (m, 2H), 7.29-7.34 (m, 8H), 8.07 (br s, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ: 125.3, 127.1, 129.6, 137.2, 179.8. MS: m/z 229 $[M+H]^+$.

4.2. To a 10 mL schlenk tube were added **A** (114.2 mg, 0.5 mmol), I_2 (25.4 mg, 0.1 mmol) and PhCl (3.0 mL). Then, the mixture was strirred at 120 ℃ under an oxygen atmosphere for 10 h. Upon completion, the resulting mixture was quenched with saturated aqueous solution of $Na_2S_2O_3$ (10 mL), and extracted with EtOAc (10 mL × 3). The combined organic phase was washed with water and brine, dried over anhydrous Na_2SO_4, and evaporated under reduced pressure. The residue was purified by column chromatography on silica gel with petroleum ether/ethyl acetate (10:1) as the eluent to give **3a** (101.8 mg, 90%).

5. Control experiments (II)

5.1. To a 10 mL schlenk tube were added **A** (114.2 mg, 0.5 mmol), I_2 (25.4 mg, 0.1 mmol), BHT (220.4 mg, 1.0 mmol) and PhCl (3 mL). The mixture was then strirred at 120 ℃ under an oxygen atmosphere for 10 h. Upon completion, the resulting mixture was quenched with saturated aqueous solution of $Na_2S_2O_3$ (10 mL), and extracted with EtOAc (10 mL × 3). The combined organic phase was washed with water and brine, dried over anhydrous Na_2SO_4, and evaporated under reduced pressure. The residue was purified by column chromatography on silica gel with petroleum ether/ethyl acetate (10:1) as the eluent to give **3a** (97.3 mg, 86%).

5.2. To a 10 mL schlenk tube were added isothiocyanatobenzene (**1a**, 66 uL, 0.55 mmol), aniline (**2a**, 46 uL, 0.5 mmol), I_2 (25.4 mg, 0.1 mmol), BHT (220.4 mg, 1.0 mmol) and PhCl (3 mL). The mixture was then strirred at 120 ℃ under an oxygen atmosphere for 12 h. Upon completion, the resulting mixture was quenched with saturated aqueous solution of $Na_2S_2O_3$ (10 mL), and extracted with EtOAc (10 mL × 3). The combined organic phase was washed with water and brine, dried over anhydrous Na_2SO_4, and evaporated under reduced pressure. The residue was purified by

column chromatography on silica gel with petroleum ether/ethyl acetate (10:1) as the eluent to give **3a** (90.5 mg, 80%).

6. An intermolecular competing experiment

To a 10 mL schlenk tube were added 1,3-bis(4-methoxyphenyl)thiourea (**6**, 144.2 mg, 0.5 mmol), 1,3-bis(4-(trifluoromethyl)phenyl)thiourea (**7**, 182.2 mg, 0.5 mmol), I_2 (25.4 mg, 0.1 mmol) and PhCl (5 mL). The mixture was then strirred at 120 ℃ under an oxygen atmosphere for 4 h. Then, the resulting mixture was quenched with saturated aqueous solution of $Na_2S_2O_3$ (10 mL), and extracted with EtOAc (10 mL × 3). The combined organic phase was washed with water and brine, dried over anhydrous Na_2SO_4, and evaporated under reduced pressure. The residue was purified by column chromatography on silica gel with petroleum ether/ethyl acetate (10:1) as the eluent to give **3c** (53.0 mg, 37%).

7. An intramolecular competing experiment

To a 10 mL schlenk tube were added 1-(4-methoxyphenyl)-3-(4-(trifluoromethyl)phenyl)-thiourea (**8**, 163.2 mg, 0.5 mmol), I_2 (25.4 mg, 0.1 mmol) and PhCl (3 mL). The mixture was then strirred at 120 ℃ under an oxygen atmosphere for 4 h. Then, the resulting mixture was quenched with saturated aqueous solution of $Na_2S_2O_3$ (10 mL), and extracted with EtOAc (10 mL × 3). The combined organic phase was washed with water and brine, dried over anhydrous Na_2SO_4, and evaporated under reduced pressure. The residue was purified by column chromatography on silica gel with petroleum ether/ethyl acetate (10:1) as the eluent to give **9** (61.6 mg, 38%).

6-Methoxy-*N*-(4-(trifluoromethyl)phenyl)benzo[*d*]thiazol-2-amine (**9**): Eluent: petroleum ether/ ethyl acetate (10:1); white solid (61.6 mg, 38%), mp 182-183 ℃. ^{1}H NMR (400 MHz, DMSO-d_6) δ: 3.79 (s, 3H), 6.96 (dd, J_1 = 8.4 Hz, J_2 = 2.0 Hz, 1H), 7.49 (s, 1H), 7.57 (d, J = 8.8 Hz, 1H), 7.70 (d, J = 8.8 Hz, 2H), 7.95 (d, J = 8.8 Hz, 2H), 10.72 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6) δ: 55.6, 105.3, 113.8, 117.1, 120.1, 121.4 (q, $^2J_{C\text{-}F}$ = 32.0 Hz), 124.6 (q, $^1J_{C\text{-}F}$ = 269.8 Hz), 126.3 (q, $^3J_{C\text{-}F}$ = 3.7 Hz), 131.3, 144.0, 145.7, 155.6, 159.2. ^{19}F NMR (565 MHz, DMSO-d_6) δ: -59.98. HRMS calcd for $C_{15}H_{12}F_3N_2OS$: 325.0617 $[M+H]^+$, found: 325.0619.

8. Gram-scale synthesis of 3a

To a 50 mL round-bottom flask were added **1a** (1.31 mL, 11 mmol), **2a** (0.91 mL, 10 mmol), I_2 (0.51 g, 2 mmol) and PhCl (25 mL). The mixture was then strirred at 120 ^{o}C under an oxygen atmosphere for 12 h. Upon completion, the resulting mixture was quenched with saturated aqueous solution of $Na_2S_2O_3$ (10 mL), and extracted with EtOAc (10 mL × 3). The combined organic phase was washed with water and brine, dried over anhydrous Na_2SO_4, and evaporated under reduced pressure. The residue was purified by column chromatography on silica gel with petroleum ether/ethyl acetate (10:1) as the eluent to give **3a** (1.60 g, 71%).

Acknowledgments. We are grateful to the National Natural Science Foundation of China (NSFC) (grant number 21572047), Program for Innovative Research Team in Science and Technology in Universities of Henan Province (15IRTSTHN003), and Program for Science and Technology Innovation Talents in Universities of Henan Province (15HASTIT005) for financial support.

Supporting Information. Copies of ^{1}H, ^{13}C and ^{19}F NMR spectra. This material is available free of charge *via* the Internet at http://pubs.acs.org.

References

(1) (a) Fajkusova, D.; Pesko, M.; Keltosova, S.; Guo, J.; Oktabec, Z.; Vejsova, M.; Kollar, P.; Coffey, A.; Csollei, J.; Kralova, K.; Jampilek, J. *Bioorg. Med. Chem.* **2012**, *20*, 7059. (b) Chikhale, R.; Menghani, S.; Babu, R.; Bansode, R.; Bhargavi, G.; Karodia, N.; Rajasekharan, M. V.; Paradkar, A.; Khedekar, P. *Eur. J. Med. Chem.* **2015**, *96*, 30. (c) Ghosh, A. K.; Rao, K. V.; Nyalapatla, P. R.; Osswald, H. L.; Martyr, C. D.; Aoki, M.; Hayashi, H.; Agniswamy, J.; Wang, Y.-F.; Bulut, H.; Das, D.; Weber, I. T.; Mitsuya, H. *J. Med. Chem.* **2017**, *60*, 4267.

(2) (a) Jian, R.; Wang, P.; Duan, W.; Wang, J.; Zheng, X.; Weng, J. *Ind. Eng. Chem. Res.* **2016**, *55*, 11520. (b) Zhang, J.; Lu, X.; Li, T.; Wang, S.; Zhong, G. *J. Org. Chem.* **2017**, *82*, 5222.

(3) Shen, C.; Zhang, P.; Sun, Q.; Bai, S.; Hor, T. S. A.; Liu, X. *Chem. Soc. Rev.* **2015**, *44*, 291 and references cited therein.

(4) Zhang, X.; Jia, X.; Wang, J.; Fan, X. *Green Chem.* **2011**, *13*, 413.

(5) (a) Rout, S. K.; Guin, S.; Nath, J.; Patel, B. K. *Green Chem.* **2012**, *14*, 2491. (b) Zhang, W.; Yue, Y.; Yu, D.; Song, L.; Xu, Y.-Y.; Tian, Y.-J.; Guo, Y.-J. *Adv. Synth. Catal.* **2012**, *354*, 2283. (c) Yao, Y.; Liu, H.; Wu, Y.; Cai, M. *Appl. Organometal. Chem.* **2013**, *27*, 109. (d) Liu, J.; Zhang, X.; Yang, J.; Wang, L. *Appl. Organometal. Chem.* **2014**, *28*, 198 and references cited therein.

(6) Jordan, A. D.; Luo, C.; Reitz, A. B. *J. Org. Chem.* **2003**, *68*, 8693.

(7) (a) Joyce, L. L.; Batey, R. A. *Org. Lett.* **2009**, *11*, 2792. (b) Inamoto, K.; Hasegawa, C.; Kawasaki, J.; Hiroya, K.; Doi, T. *Adv. Synth. Catal.* **2010**, *352*, 2643. (c) Wang, H.; Wang, L.; Shang, J.; Li, X.; Wang, H.; Gui, J.; Lei, A. *Chem. Commun.***2012**, *48*, 76. (d) Sahoo, S. K.; Banerjee, A.; Chakraborty, S.; Patel, B. K. *ACS Catal.* **2012**, *2*, 544. (e) Banerjee, A.; Santra, S. K.; Rout, S. K.; Patel, B. K. *Tetrahedron* **2013**, *69*, 9096. (f) Sharma, S.; Pathare, R. S.; Maurya, A. K.; Gopal, K.; Roy, T. K.; Sawant, D. M.; Pardasani, R. T. *Org. Lett.* **2016**, *18*, 356.

(8) Toulot, S.; Heinrich, T.; Leroux, F. R. *Adv. Synth. Catal.* **2013**, *355*, 3263.

(9) Zeng, W.; Dang, P.; Zhang, X.; Liang,Y.; Peng, C. *RSC Adv.* **2014**, *4*, 31003.

(10) Zhao, J.; Huang, H.; Wu, W.; Chen, H.; Jiang, H. *Org. Lett.* **2013**, *15*, 2604.

(11) Castanheiro, T.; Suffert, J.; Gulea, M.; Donnard, M. *Org. Lett.* **2016**, *18*, 2588.

(12) (a) Hao, W.-J.; Wang, S.-Y.; Ji, S.-J. *ACS Catal.* **2013**, *3*, 2501. (b) Sun, J.; Qiu, J.-K.; Zhu, Y.-L.; Guo, C.; Hao, W.-J.; Jiang, B.; Tu, S.-J. *J. Org. Chem.* **2015**, *80*, 8217. (c) von der Heiden, D.; Bozkus, S.; Klussmann, M.; Breugst, M. *J. Org. Chem.* **2017**, *82*, 4037. (d) Zhang, Z.; Pi, C.; Tong, H.; Cui, X.; Wu, Y. *Org. Lett.* **2017**, *19*, 440. (e) Wang, B.; Meng, Y.; Zhou, Y.; Ren, L.; Wu, J.; Yu, W.; Chang, J. *J. Org. Chem.* **2017**, 82, 5898.

(13) (a) Yang, D.; Yan, K.; Wei, W.; Zhao, J.; Zhang, M.; Sheng, X.; Li, G.; Lu, S.; Wang, H. *J. Org. Chem.* **2015**, *80*, 6083. (b) Beuleaw, D.; Udomsasporn, K.; Yotphan, S. *J. Org. Chem.* **2015**, *80*, 3447. (c) Luo, W.-K.; Shi, X.; Zhou, W.; Yang, L. *Org. Lett.* **2016**, *18*, 2036. (d)

Wang, Y.; Jiang, C.-M.; Li, H.-L.; He, F.-S.; Luo, X.; Deng, W.-P. *J. Org. Chem.* **2016**, *81*, 8653. (e) Siddaraju, Y.; Prabhu, K. R. *J. Org. Chem.* **2017**, *82*, 3084. (f) Fan, W.; Yang, Z.; Jiang, B.; Li, G. *Org. Chem. Front.* **2017**, *4*, 1091. (i) Fan, W.; Li, Q.; Li, Y.; Sun, H.; Jiang, B.; Li, G. *Org. Lett.* **2016**, *18*, 1219. (g) Yang, D.; Sun, P.; Wei, W.; Meng, L.; He, L.; Fang, B.; Jiang, W.; Wang, H. *Org. Chem. Front.* **2016**, *3*, 1457. (h) Wu, W.; An, Y.; Li, J.; Yang, S.; Zhu, Z.; Jiang, H. *Org. Chem. Front.* DOI: 10.1039/c7qo00326a. (i) Li, X.-F.; Cui, S.-L.; Wang, Y.-G. *Tetrahedron Lett.* **2006**, *47*, 3127.

(14) Cheng, D.; Wu, L.; Lv, H.; Xu, X.; Yan, J. *J. Org. Chem.* **2017**, *82*, 1610 and references cited therein.

(15) (a) Fan, X.; Yan, M.; Wang, Y.; Zhang, X. *J. Org. Chem.* **2015**, *80*, 10536. (b) Li, B.; Zhang, B.; Zhang, X.; Fan, X. *J. Org. Chem.* **2016**, *81*, 9530. (c) Zhang, B.; Li, B.; Zhang, X.; Fan, X. *Org. Lett.* **2017**, *19*, 2294. (d) Wang, Z.; Chen, G.; Zhang, X.; Fan, X. *Org. Chem. Front.* **2017**, *4*, 612. (e) Li, B.; Zhang, B.; Zhang, X.; Fan, X. *Chem. Commun.* **2017**, *53*, 1297.

(16) (a) Shi, Z.; Zhang, C.; Tang, C.; Jiao, N. *Chem. Soc. Rev.* **2012**, *41*, 3381. (b) Parmeggiani, C.; Matassini, C.; Cardona, F. *Green Chem.* **2017**, *19*, 2030. (c) Gulzar, N.; Schweitzer-Chaput, B.; Klussmann, M. *Catal. Sci. Technol.* **2014**, *4*, 2778.

(17) Zhao, N.; Liu, L.; Wang, F.; Li, J.; Zhang, W. *Adv. Synth. Catal.* **2014**, *356*, 2575.

(18) He, Y. M.; Li, J.; Luo, S.; Huang, J. B.; Zhu, Q. *Chem. Commun.* **2016**, *52*, 8444.

(19) Finch, N.; Ricca, Jr., S.; Werner, L. H. *J. Org. Chem.* **1980**, *45*, 3416.

(20) Li, F.; Shan, H. X.; Kang, Q. K.; Chen, L. *Chem. Commun.* **2011**, *47*, 5058.

(21) Zhao, H.; He, W.; Yao, R. Y.; Cai, M. Z. *Adv. Synth. Catal.* **2014**, *356*, 3092.

(22) Khatun, N.; Jamir, L.; Ganesh, M.; Patel, B. K. *RSC Adv.* **2012**, *2*, 11557.

(23) Zhang, Z.; Wu, H. H.; Tan, Y. J. *RSC Adv.* **2013**, *3*, 16940.