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Practical synthesis and applications of benzoboroxoles

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Dedicated to the memory of Professor Herbert C. Brown (1912–2004)

Abstract—A convenient one-pot synthesis of benzoboroxoles has been developed via the reaction of *o*-bromobenzyl alcohols with NaH, ^{n}BuLi, and B(O^{i}Pr)$_3$ followed by acidic hydrolysis. Applications of these benzoboroxoles have been demonstrated in Pd-catalyzed cross-coupling reactions and the protocol has been extended for the synthesis of a chiral benzoboroxole. Exceptionally short synthesis of a potent antifungal agent AN2690 and several of its analogs has also been realized.

1. Introduction

Aryl boronic acids and boronates are highly useful synthetic intermediates especially for the transition metal catalyzed cross-coupling with aryl and vinyl halides.[1] One such class of cyclic boronic acids are the benzoboroxoles (**1**–**5**, Fig. 1).[2] They have been utilized in wide variety of applications in medicinal and materials chemistry. For example, some of these cyclic boronic acids exhibit excellent antifungal activity[3] and recently, a fluoro-substituted benzoboroxole, AN2690 (**3**, Fig. 1) has been identified for clinical trials for onychomycosis (an infection of toes and finger nails).[4] Some of the benzoboroxoles (e.g., **1**) have also been found to selectively complex with naturally occurring oligosaccharides to effect direct glycosidation of the sugars[5] and they are also used for the selective recognition of cell-surface glycoconjugates.[6] The other applications of these molecules include their use as cross-coupling synthons in organic chemistry,[7] steroid conjugates for molecular imprinting,[8] dyes,[9] biosensors of α-hydroxycarboxylic acids,[10] and biocides for plastic biodegradation (e.g., **2**, Fig. 1).[11]

2. Results and discussion

The existing literature methodologies for the synthesis of these boroles are somewhat limited, and often are not amenable for large scale and analog synthesis.[12] The impressive biological profile as well as our long standing interest in developing novel protocols for the synthesis of boronated molecules,[13] has prompted us to develop a practical procedure for the synthesis of the title compounds. Our preliminary work on the synthesis of benzoboroxoles involved dilithiation of *o*-bromobenzyl alcohol followed by the treatment with trimethylborate.[13b] We extended the protocol with the purpose of developing an inexpensive and practical procedure for the large scale synthesis of benzoboroxoles. We employed NaH for the initial deprotonation of hydroxyl group followed by treatment with ^{n}BuLi to effect debromination. The dianion thus generated was treated with triisopropylborate yielding the intermediate boronate. Acidic hydrolysis of the boronate ester with 10% sulfuric acid followed by column chromatography produced the required benzoboroxole **7a** (entry 1, Table 1). The synthesis of the remaining benzoboroxoles was initiated by the reaction of 2-bromobenzaldehyde with a variety of Grignards such as vinyl, allyl, phenyl, and decyl magnesium bromides to furnish the requisite *o*-bromobenzyl alcohols **6b**–**e** in good yields. Gratifyingly, under the reaction conditions,

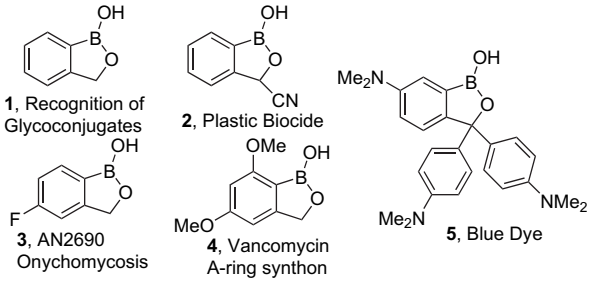

Figure 1. Important benzoboroxoles.

Keywords: Benzoboroxoles; Boronic acids; Boronate esters; C–C bond formation; Suzuki–Miyaura cross-coupling; Onychomycosis.
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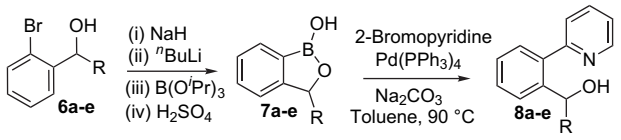
Table 1. Preparation and Suzuki cross-coupling of benzoboroxoles



Entry	R	Benzoboroxole		Aminoalcohol	
		7	% Yield	**8**	% Yield
1	H	**7a**	84	**8a**	91
2	Vinyl	**7b**	79	**8b**	95
3	Allyl	**7c**	74	**8c**	90
4	Phenyl	**7d**	73	**8d**	89
5	*n*-Decyl	**7e**	41	**8e**	91

the remaining *o*-bromobenzyl alcohols **6b–e** also yielded the requisite benzoboroxoles **7b–e** in good yields (Table 1). In order to avoid column chromatography, the organic layer was treated with 6 N NaOH to effect the formation of water soluble boron 'ate' complex. Washing with pentane removed any organic byproducts, followed by acidification of the aqueous layer to pH 1 and extraction with ethyl acetate afforded essentially pure products. All the products were characterized based on ^{1}H, ^{13}C, ^{11}B NMR, and mass-spectrometric analysis. X-ray analysis of vinylbenzoboroxole **7b** ascertained the crystalline structure of benzoboroxole as a dimer with two intermolecular hydrogen bonds (Fig. 2). In order to demonstrate the applicability of these compounds, we performed the Suzuki–Miyaura cross-coupling[1] of the boroles **7a–e** with 2-bromopyridine. Thus, the reaction of **7a–e** with 2-bromopyridine, in the presence of $Pd(PPh_3)_4$ and Na_2CO_3 afforded the 2-pyridinyl benzyl alcohols **8a–e** in high yields (89–95%) (Table 1).

With an aim to expand the scope of the current protocol, chiral benzoboroxole (*S*)-**7c** was synthesized starting from *o*-bromobenzaldehyde **10** as depicted in Scheme 1. The enantioselective allylboration of aldehyde **10** with (−)-*B*-allyldiisopinocampheylborane **11**[14] furnished the homoallylic alchohol (*S*)-**6c** in 94% ee. Sequential addition of NaH, ^{n}BuLi, and $B(O^{i}Pr)_3$ to (*S*)-**6c** followed by hydrolysis provided the chiral benzoboroxole (*S*)-**7c** in high yield (Scheme 1).

We have also applied the methodology for synthesis of 5-fluorobenzoboroxole (AN2690) **3.** This molecule has recently

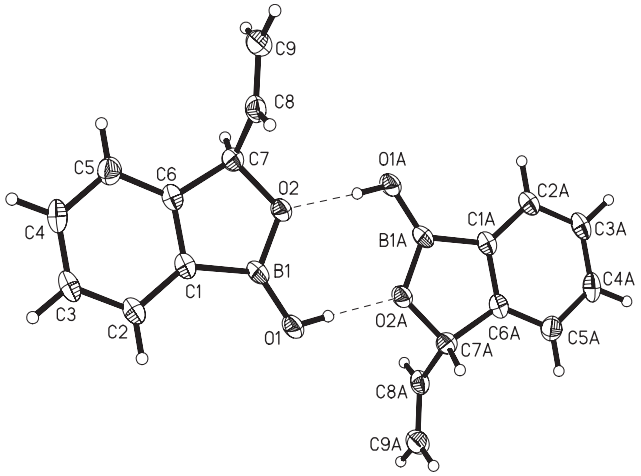
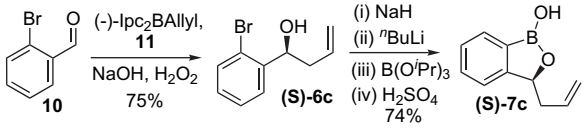
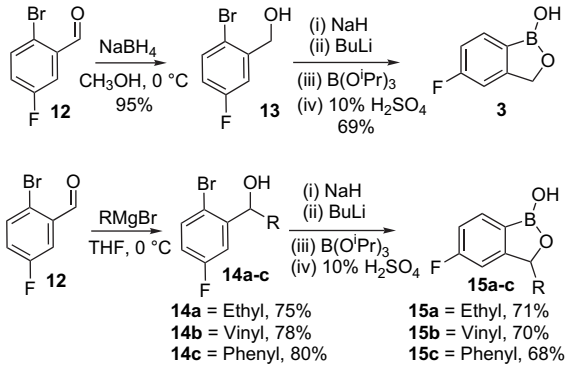


Figure 2. X-ray crystal structure of **7b**.



Scheme 1. Preparation of chiral benzoboroxole (*S*)-**7c**.

been identified as a lead molecule for the treatment of onychomycosis. Reduction of the commercially available 5-fluoro-2-bromobenzaldehyde **12** with $NaBH_4$, and the one-pot reaction with NaH, ^{n}BuLi, and $B(O^{i}Pr)_3$, followed by acid treatment provided **3** in 65% overall yield. We were further able to prepare three analogs of AN2690 via the reaction of aldehyde **12** with the appropriate Grignard reagent to afford the substituted fluorinated benzyl alcohols **14a–c** that underwent cyclization under the aforementioned conditions to furnish fluorinated benzoboroxoles **15a–c** (Scheme 2).



Scheme 2. Preparation of fluoro-benzoboroxoles.

3. Conclusions

In conclusion, we have developed a convenient procedure for the synthesis of benzoboroxoles starting from *o*-bromobenzyl alcohols in a single pot transformation. The product benzoboroxoles were utilized for cross-coupling under Suzuki–Miyaura conditions with 2-bromopyridine yielding the pyridinyl benzyl alcohols in high yields. The reaction protocol is highly tunable and it has been extended to prepare an optically pure benzoboroxole. We also synthesized AN2690 (a potential agent for topical treatment of onychomycosis) as well as several of its analogs. The present protocol is highly scalable and we were able to obtain multigram quantities of all the boroles with utmost ease. These compounds are highly stable and efforts are underway toward the commercialization of these molecules. Owing to the importance of benzoboroxoles in organic, bio-organic, materials, and medicinal chemistry, we believe the present methodology would find wide range of applications.

4. Experimental

4.1. Preparation of benzoboroxole, 7a

To a cooled (0 °C) suspension of sodium hydride (1.5 g, 50% solution, 63.6 mmol) in 10.0 mL diethyl ether was added a solution of 2-bromobenzyl alcohol **6a** (10.0 g, 53.0 mmol) in

diethyl ether (60.0 mL) and stirred for 1 h. The reaction was cooled to −78 °C and *n*-butyl lithium (25.4 mL, 2.4 M solution, 63.6 mmol) was added dropwise and stirred for 1 h. Triisopropylborate (14.6 mL, 63.6 mmol) was added to the mixture at −78 °C and stirred for 6 h while gradually warming to room temperature. The reaction mixture was acidified to pH 1 using 2 M H_2SO_4 and worked up with ether (3×100 mL) and water. The organic layer was separated and dried (Na_2SO_4), and concentrated in vacuo. Purification using silica gel column chromatography (4:1 hexanes–ethyl acetate) yielded the desired compound **7a** (84% yield). Mp: 96–98 °C, ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.70–7.83 (m, 1H), 7.4–7.54 (m, 3H), 6.15 (br s, 1H), 5.19 (s, 2H); ^{13}C NMR (125 MHz, $CDCl_3$): δ 153.6, 131.5, 131.3, 130.9, 127.5, 121.3, 71.8; ^{11}B NMR (160 MHz, DMSO): δ 33 (s).

4.2. Preparation of 1-(2-(pyridin-2-yl)phenyl) methanol, 8a

To a stirred solution of $Pd(PPh_3)_4$ (30.0 mg) and 2-bromopyridine (0.16 mL, 1 mmol) in toluene (3.0 mL) were added benzoboroxole **7a** (67.0 mg, 0.5 mmol) and Na_2CO_3 (0.3 mL, 20% w/v), and stirred for 4 h at 90 °C. After the completion of the reaction (TLC), the reaction mixture was cooled to room temperature and worked up with water and ether. The combined organic layers were dried (Na_2SO_4), concentrated, and purified by column chromatography (silica gel, 3:2 hexanes–ethyl acetate) to obtain 84 mg (91%) of **8a**. ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.54 (1H, d, J=4.93 Hz), 7.74 (1H, dt, J=1.82 and 7.76 Hz), 7.52 (1H, dt, J=1.03 and 7.96 Hz), 7.31–7.45 (m, 4H), 7.22 (1H, ddd, J=1.12, 4.95, and 7.55 Hz), 6.29 (1H, br s), 4.38 (2H, s); ^{13}C NMR (125 MHz, $CDCl_3$): δ 159.0, 148.0, 140.4, 139.7, 137.4, 131.0, 130.0, 129.0, 128.0, 123.8, 122.1, 64.6.

4.3. Preparation of 3-vinylbenzoboroxole, 7b

Procedure similar to that of **7a**. Mp: 74–76 °C, ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.76 (1H, d, J=7.28 Hz), 7.48 (1H, dd, J=6.92 and 7.38 Hz), 7.37 (1H, dd, J=7.22 and 7.30 Hz), 7.27 (1H, d, J=7.6 Hz), 6.39 (1H, br s), 5.88 (1H, ddd, J=7.41, 10.09, and 17.3 Hz), 5.62 (1H, d, J=7.35 Hz), 5.52 (1H, d, J=17.03 Hz), 5.29 (1H, d, J=10.17 Hz); ^{13}C NMR (125 MHz, $CDCl_3$): δ 155.2, 137.0, 131.5, 131.3, 130.6, 127.9, 121.9, 117.6, 83.3; ^{11}B NMR (160 MHz, DMSO): δ 33 (s); CI-MS: m/z 205 [100%, $(M-OH+2OCH_3)^+$], 159 $(M-H)^+$; HRMS-CI: 205.0381 (calculated), 205.0410 (observed).

4.4. Preparation of 1-(2-(pyridin-2-yl)phenyl) prop-2-en-1-ol, 8b

Procedure similar to that of **8a**. ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.60 (1H, d, J=4.96 Hz), 7.83 (1H, dt, J=1.84 and 7.77 Hz), 7.57 (1H, dt, J=1.01 and 7.94 Hz), 7.52 (1H, dd, J=1.66 and 7.57 Hz), 7.37–7.48 (3H, m), 7.30 (1H, ddd, J= 1.08, 4.95, and 7.56 Hz), 6.88 (1H, br s), 5.99 (1H, ddd, J=4.34, 10.60, and 17.22 Hz), 5.34 (1H, dt, J=1.88 and 17.23 Hz), 5.11 (2H, dt, J=1.88 and 10.63 Hz); ^{13}C NMR (125 MHz, $CDCl_3$): δ 159.6, 147.4, 141.9, 139.6, 138.5, 137.6, 130.7, 129.1, 129.0, 127.9, 124.1, 122.2, 114.5, 72.8.

4.5. Preparation of 3-allylbenzoboroxole, 7c

Procedure similar to that of **7a**. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.87–7.89 (1H, m), 7.74 (1H, d, J=7.3 Hz), 7.44–7.50 (1H, m), 7.35–7.37 (1H, m), 6.07 (1H, br s), 5.83–5.87 (1H, m), 5.28–5.48 (1H, m), 5.02–5.17 (2H, m), 2.70–2.78 (1H, m), 2.46–2.54 (1H, m); ^{13}C NMR (125 MHz, $CDCl_3$): δ 133.4, 133.1, 131.2, 131.0, 130.6, 127.4, 121.2, 118.1, 81.0, 40.6; ^{11}B NMR (160 MHz, DMSO): δ 32 (s); CI-MS: m/z 219 $(M-OH+2OCH_3)^+$, 173 [100%, $(M-H)^+$]; HRMS-CI: 219.0646 (calculated), 219.0563 (observed).

4.6. Preparation of 1-(2-(pyridin-2-yl)phenyl) but-3-en-1-ol, 8c

Procedure similar to that of **8a**. ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.61–8.63 (1H, m), 7.84 (1H, dt, J=1.81 and 7.74 Hz), 7.54–7.58 (2H, m), 7.36–7.44 (3H, m), 7.32 (1H, ddd, J=1.12, 4.94, and 7.57 Hz), 6.31 (1H, br s), 5.71–5.83 (m, 1H), 4.95–5.03 (m, 2H), 4.59–4.63 (1H, dd, J=6.22 and 8.24 Hz), 2.60–2.68 (m, 1H), 2.46–2.52 (m, 1H); ^{13}C NMR (125 MHz, $CDCl_3$): δ 159.8, 147.9, 142.2, 139.6, 137.6, 135.6, 130.8, 129.1, 127.7, 127.6, 124.2, 122.2, 116.6, 71.7, 39.3.

4.7. Preparation of 3-phenylbenzoboroxole, 7d

Procedure similar to that of **6a**. Mp: 142–144 °C, ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.42 (1H, dd, J=7.40 and 7.50 Hz), 7.24–7.37 (7H, m), 7.16 (1H, d, J=7.66 Hz), 6.18 (1H, br s), 5.42 (1H, s); ^{13}C NMR (125 MHz, $CDCl_3$): δ 156.8, 140.1, 131.6, 131.4, 130.4, 128.8, 128.4, 137.6, 126.0, 122.3, 83.8; ^{11}B NMR (160 MHz, DMSO): δ 33 (s); ESIMS: m/z 233.1 [100%, $(M+Na)^+$]; HRMS-ESI: 233.0260 (calculated), 233.0737 (observed).

4.8. Preparation of phenyl 1-(2-(pyridin-2-yl)phenyl) methanol 8d

Procedure similar to that of **8a**. ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.50–8.60 (m, 1H), 7.15–7.76 (m, 12H), 5.60 (s, 1H), 1.57 (br s, 1H); ^{13}C NMR (125 MHz, $CDCl_3$): δ 159.7, 147.6, 143.8, 142.8, 139.7, 137.5, 130.7, 130.0, 129.0, 128.6, 127.8, 126.8, 126.4, 124.1, 122.1, 74.2.

4.9. Preparation of 3-decylbenzoboroxole, 7e

Procedure similar to that of **6a**. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.75 (1H, d, J=7.24 Hz), 7.46 (1H, dd, J=7.38 and 7.47 Hz), 7.35 (1H, dd, J=7.22 and 7.34 Hz), 7.29 (1H, d, J=7.76 Hz), 6.46 (1H, br s), 5.28 (1H, dd, J=3.75 and 7.57 Hz), 1.93–2.02 (m, 2H), 1.25–1.78 (m, 12H), 0.75–0.97 (m, 7H); ^{13}C NMR (125 MHz, $CDCl_3$): δ 131.5, 131.1, 130.9, 130.6, 127.2, 120.9, 82.1, 41.4, 36.4, 31.9, 29.6, 29.5, 29.3, 26.2, 24.8, 22.6, 14.1; ^{11}B NMR (160 MHz, DMSO): δ 31 (s); ESIMS: m/z 297 [100%, $(M+Na)^+$]; HRMS-ESI: 297.1959 (calculated), 297.1991 (observed).

4.10. Preparation of 1-(2-(pyridin-2-yl)phenyl)-1-undecanol, 8e

Procedure similar to that of **8a**. ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.62–8.64 (1H, m), 7.84 (1H, dt, J=1.82 and 7.73 Hz), 7.53–7.57 (2H, m), 7.42–7.44 (2H, m), 7.35–7.38 (1H, m), 7.31 (1H,

ddd, J=1.07, 4.97, and 7.55 Hz), 4.50 (1H, dd, J=6.43 and 7.89 Hz), 1.80–1.87 (m, 1H), 1.61–1.68 (m, 1H), 1.10–1.44 (m, 16H), 0.86 (3H, t, J=7.15 Hz); ^{13}C NMR (125 MHz, $CDCl_3$): δ 131.5, 131.1, 130.9, 130.6, 127.2, 120.9, 82.1, 41.4, 36.4, 31.9, 29.6, 29.5, 29.3, 26.2, 24.8, 22.6, 14.1.

4.11. Preparation of (*S*)-1-(*o*-bromophenyl) but-3-en-1-ol, (*S*)-6c

Aldehyde **10** (6.9 g, 18.4 mmol) was added to a stirred solution of Ipc_2BAll, **11** (44.0 mL of 0.5 M solution in Et_2O–pentane) at −78 °C and maintained at that temperature for 2 h. The reaction was followed by ^{11}B NMR spectroscopy (δ 56). Upon completion, the mixture was oxidized with 7.4 mL of 3.0 M sodium hydroxide and 7.4 mL of 30% hydrogen peroxide. The reaction was stirred for 4 h at room temperature and extracted with Et_2O. The crude product was purified by column chromatography (silica gel, hexanes–ethyl acetate (7:3)) to obtain 5.8 g (75%) of alcohol (*S*)-**6c**. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.56 (1H, dd, J=1.6 and 7.6 Hz), 7.52 (1H, dd, J=1.2 and 8.0 Hz), 7.34 (1H, dt, J=0.8 and 7.2 Hz), 7.13 (1H, dt, J=2.0 and 7.6 Hz), 5.88 (1H, dddd, J=6.4, 7.6, 10.0, and 16.8 Hz), 5.20 (1H, d, J=17.2 Hz), 5.18 (1H, d, J=10.0 Hz), 5.11 (1H, dt, J=3.6 and 7.6 Hz), 2.67–2.61 (1H, m), 2.36 (1H, dt, J=8.0 and 14.0 Hz), 2.22 (1H, d, J=3.6 Hz); ^{13}C NMR (125 MHz, $CDCl_3$): δ 142.7, 134.3, 132.7, 128.9, 127.7, 127.4, 121.9, 118.8, 72.0, 42.4. The chiral alcohol was derivatized as its monophthalate ester for chiral HPLC analysis. To a solution of the alcohol **6c** (0.23 g, 1 mmol) in 2 mL CH_2Cl_2 were added phthalic anhydride (0.22 g, 1.5 mmol) and triethyl amine (0.34 mL, 2.5 mmol) and stirred at room temperature overnight. Upon completion (TLC), the reaction mixture was acidified with 1 M HCl and worked up with dichloromethane and water. The combined organic layers were dried ($MgSO_4$), concentrated in vacuo, and purified by silica gel column chromatography (hexanes–ethyl acetate (2:3)) to obtain 320 mg (93% yield) of the monophthalate ester. ^{1}H NMR (500 MHz, $CDCl_3$): δ 11.4 (br s, 1H), 7.12–7.92 (m, 8H), 6.46 (dd, J=5.5 and 8.0 Hz, 1H), 5.84–5.92 (m, 1H), 5.10–5.17 (m, 2H), 2.70–2.81 (m, 2H). The optical purity of the phthalate ester was found to be 94% as established by chiral HPLC analysis (Shimadzu LC-10ADVP HPLC fitted with Chiralpak AD-H column, hexanes–isopropanol (96:4), flow rate: 0.5 mL/min, λ=254 nm, retention times: 25.6, 27.6).

4.12. Preparation of (*S*)-3-allylbenzoboroxole, (*S*)-7c

Procedure similar to that of **7a**. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.74–7.80 (m, 1H), 7.27–7.52 (m, 3H), 6.07 (br s, 1H), 5.83–5.87 (m, 1H), 5.28–5.48 (m, 1H), 5.02–5.17 (m, 2H), 2.70–2.78 (m, 1H), 2.46–2.54 (m, 1H); ^{13}C NMR (125 MHz, $CDCl_3$): δ 133.4, 133.1, 131.2, 131.0, 130.6, 127.4, 121.2, 118.1, 81.0, 40.6; ^{11}B NMR (160 MHz, DMSO): δ 32 (s); CI-MS: m/z 219 $(M-OH+2OCH_3)^+$, 173 [100%, $(M-H)^+$]; HRMS-CI: 219.0646 (calculated), 219.0563 (observed).

4.13. Preparation of 5-fluorobenzoboroxole, 3

Procedure similar to that of **7a**. Mp: 120–122 °C, ^{1}H NMR (500 MHz, DMSO): δ 9.22 (s, 1H), 7.74 (dd, J=8.2 and 6.2 Hz, 1H), 7.24 (dd, J=9.7 and 1.8 Hz, 1H), 7.15 (m, 1H), 4.95 (s, 2H); ^{13}C NMR (125 MHz, DMSO): δ 165.9, 164.0, 157.5 (d, J=8.8 Hz), 133.3 (d, J=9.2 Hz), 115.3 (d, J=24.9 Hz), 109.2 (d, J=22.0 Hz), 70.3 (d, J=3.2 Hz); ^{11}B NMR (160 MHz, DMSO): δ 32 (s); ESIMS: m/z 151 $(M-H)^+$.

4.14. Preparation of 5-fluoro-3-ethylbenzoboroxole, 15a

Procedure similar to that of **7a**. Mp: 70–72 °C, ^{1}H NMR (500 MHz, $CDCl_3$): δ 9.16 (s, 1H), 7.72 (dd, J=6.0 and 8.0 Hz, 1H), 7.25 (dd, J=2.0 and 9.5 Hz, 1H), 7.14–7.18 (m, 1H), 5.08 (dd, J=4.0 and 8.0 Hz, 1H), 1.96–2.01 (m, 1H), 1.49–1.55 (m, 1H), 0.84 (t, J=7.2 Hz, 3H); ^{13}C NMR (125 MHz, DMSO): δ 164.5, 164.5, 159.4 (d, J=8.2 Hz), 132.8 (d, J=9.1 Hz), 115.5 (d, J=22.0 Hz), 108.5 (d, J=21.9 Hz), 82.7 (d, J=3.2 Hz), 29.2, 9.0; ^{11}B NMR (160 MHz, DMSO): δ 32 (s); ESIMS: m/z 169 $(M-H)^+$.

4.15. Preparation of 5-fluoro-3-vinylbenzoboroxole, 15b

Procedure similar to that of **7a**. ^{1}H NMR (500 MHz, $CDCl_3$): δ 9.45 (br s, 1H), 7.75 (dd, J=6.0 and 8.0 Hz, 1H), 7.15–7.20 (m, 2H), 5.90 (ddd, J=6.0, 10.5, and 17.0 Hz, 1H), 5.57 (d, J=6.0 Hz, 1H), 5.43 (dt, J=1.5 and 17.0 Hz, 1H), 5.19 (dt, J=1.5 and 10.0 Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$): δ 166.0, 164.1, 159.2 (d, J=8.7 Hz), 138.4, 133.5 (d, J=9.2 Hz), 116.5, 115.7 (d, J=21.5 Hz), 109.6 (d, J=21.8 Hz), 81.2 (d, J=2.7 Hz); ^{11}B NMR (160 MHz, DMSO): δ 32 (s); ESIMS: m/z 167 $(M-H)^+$.

4.16. Preparation of 5-fluoro-3-phenylbenzoboroxole, 15c

Procedure similar to that of **7a**. Mp: 145–147 °C, ^{1}H NMR (500 MHz, $CDCl_3$): δ 9.54 (br s, 1H), 7.79 (dd, J=6.0 and 8.5 Hz, 1H), 7.27–7.37 (m, 5H), 7.16–7.20 (m, 1H), 6.97 (dd, J=1.5 and 9.0 Hz, 1H), 6.18 (s, 1H); ^{13}C NMR (125 MHz, $CDCl_3$): δ 166.0, 164.1, 160.5, 141.3, 133.6 (d, J=9.2 Hz), 129.3, 128.7, 126.8, 115.8 (d, J=21.5 Hz), 109.9 (d, J=21.8 Hz), 81.8 (d, J=3.2 Hz); ^{11}B NMR (160 MHz, DMSO): δ 33 (s); ESIMS: m/z 227 $(M-H)^+$.

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