Synthesis of tricyclic compounds with a four-coordinate boron atom from 2-aminobenzazoles and nitriles

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The reactions of 2-aminobenzazoles with nitriles in the presence of organoboranes result in the formation of novel tricyclic chelate boron compounds with *N*-(benzazol-2-yl)amidines as ligands. *N*-(Benzothiazol-2-yl)-*p*-chlorobenzamidine was prepared from 2-aminobenzothiazole and *p*-chlorobenzonitrile *via* the corresponding chelate.

Key words: 2-aminobenzimidazole, 2-amino-1-methylbenzimidazole, 2-aminobenzothiazole, boron chelates, borylation, *N*-(benzothiazol-2-yl)-*p*-chlorobenzamidine.

The borylation of α-amino-*N*-heterocycles increases substantially the synthetic potential of these reagents.[1,2] In particular, it has been shown that dialkylboryl derivatives of 2-aminothiazole, 5-amino-1,2,4-triazole, and 5-aminotetrazole can add to nonactivated nitriles to give chelate boron complexes in which the corresponding heterylamidines in the deprotonated form serve as ligands.[3–5] In the present work, the reaction of 2-aminobenzazoles and nitriles with the application of the borylation methodology is considered.

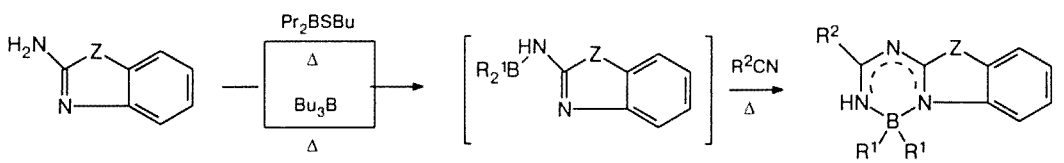
It is established that heating of 2-aminobenzimidazoles (**1**, **2**) or 2-aminobenzothiazole (**3**) with butylthiodipropylborane in excess acetonitrile results in high yields of cyclic compounds of four-coordinate boron (**5a—c**), *i.e.*, chelate complexes in which deprotonated *N*-(benzimidazol-2-yl)- or *N*-(benzothiazol-2-yl)amidines are the ligands (Scheme 1). Trialkylboranes can also be used as borylating agents. For example, the reaction of **3** with Bu_3B in the presence of an excess of the corresponding nitrile gives chelates (**5d,e**).

The process presented in Scheme 1 includes, evidently, the formation of dialkylboryl derivatives of aminobenzazoles of the type of **4** and their addition to the C≡N bond of nitriles (*cf.* the data on the reactions of amidines with nitriles in the presence of organoboranes[6]). The specific feature of the transformations described is that the borylated azoles are obtained *in situ*, and the ligand is formed directly in the synthesis of the chelate.

The structure of tricyclic compounds **5a—e** is confirmed by the spectral data. Their mass spectra are typical of dialkylboron chelates[7]: peaks of the ions $[M]^+$ are almost absent, and the peaks of $[M-R^1]^+$ are the most abundant. The ^{11}B NMR spectra of complexes **5a—e** exhibit the high-field signals (−4.9 to 1.6 ppm), which is characteristic of four-coordinate boron compounds. The intense absorption in the region of 1520—1590 cm^{-1} in the IR spectra of solutions of compounds **5a—e** in $CHCl_3$ indicates the existence of a delocalized π-electron system in the boron-containing ring.

It was necessary to take into account that the chelate obtained from nonsubstituted 2-aminobenzimidazole can exist in the tautomeric form (**6**). In fact, the complexes that, according to the X-ray diffraction data,[4] have the structure **7** have been obtained previously from 5-amino-1,2,4-triazole. However, the tautomeric structure of the

Scheme 1



1—3 **4** **5a—e**

Z = NH (**1**), NMe (**2**), S (**3**)

R^1 = Pr, R^2 = Me, Z = NH (**5a**), NMe (**5b**), S (**5c**); Z = S, R^1 = Bu, R^2 = Me (**5d**), *p*-ClC_6H_4 (**5e**)

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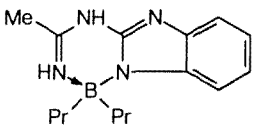
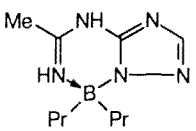
type **6** is impossible for compound **5b** synthesized from **2**. At the same time, the similarity of the IR and ^{1}H NMR spectra of **5b** and the chelate obtained from **1** indicates that the latter has the structure **5a**.



6



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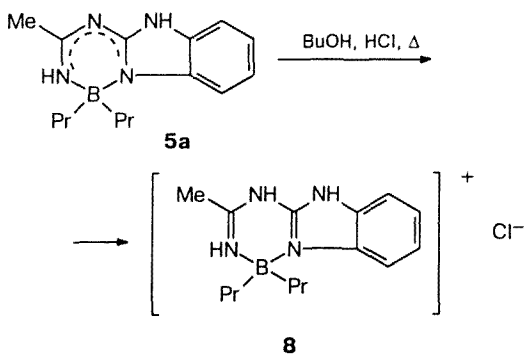
Compounds **5a—d** are colorless crystalline substances, and crystals of **5e** are bright-yellow. They are soluble in most of organic solvents. It is known that boron chelates with the delocalized π-electron system are distinguished by their high stability.[3] In fact, complexes **5** do not decompose upon long exposure in air, and some of them do not decompose even under the action of HCl in butanol. For example, heating of **5a** in a 6 *M* solution of HCl in BuOH results only in the formation of salt (**8**) in a yield of 95 % (Scheme 2).

Scheme 2



5a **8**

However, the action of a solution of HCl in BuOH on complex **5e** resulted in the formation of *N*-(benzothiazol-2-yl)-*p*-chlorobenzamidine hydrochloride (**9**), which was treated with $NaHCO_3$ to give a hitherto unknown amidine (**10**) in a yield of 85 % (Scheme 3).

The lowered stability of **5e** is probably caused by the weakening of the coordination interaction of the boron atom with the ligand, which evidently possesses a lower basicity than the corresponding acetamidines in **5a—d**.

Amidine **10** is moderately soluble in the majority of organic solvents. Its structure is confirmed by the spectral data. In the mass spectrum of **10**, the peak of $[M-H]^+$ is the most abundant (*cf.* the fragmentation of *N*-(1,2,4-triazol-5-yl)- and *N*-(tetrazol-5-yl)amidines[8,9]). The IR spectrum of a solution of **10** in $CHCl_3$ contains an intense absorption band in the region of 1630 cm^{-1} (νC=N), and the narrow band at 3490 cm^{-1} (NH free) and the broad band at 3140—3500 cm^{-1} (NH bound) correspond to the vibrations of the NH_2 group, which indicates the existence of an intramolecular hydrogen bond in the molecule of **10**.

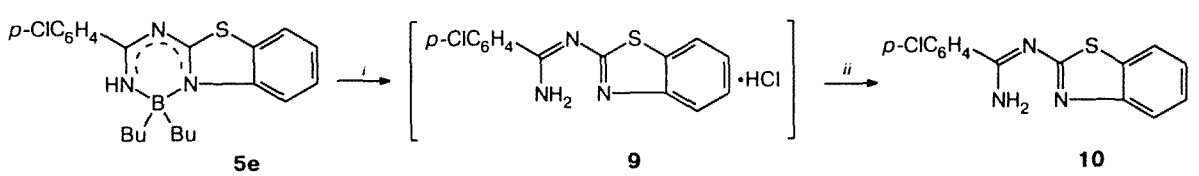
Experimental

All operations with the original organoboranes were performed in an atmosphere of dry argon. Mass spectra were recorded on a Varian MAT-311 instrument with direct inlet of samples into the ion source at 100—150 °C. IR spectra were recorded on a Perkin Elmer-577 instrument in $CHCl_3$. ^{1}H NMR spectra were recorded on a Bruker WM-250 instrument, and ^{11}B NMR spectra were recorded in $CHCl_3$ on a Bruker AM-300 instrument. Elemental analyses were performed in the Laboratory of Microanalysis (N. D. Zelinsky Institute of Organic Chemistry of the RAS).

[*N*-(Benzimidazol-2-yl)acetamidinato]dipropylboron (5a). A mixture of 2-aminobenzimidazole **1** (0.266 g), Pr_2BSBu (0.372 g), and MeCN (5 mL) were boiled for 1.5 h. The solvent was distilled off, and the residue was washed with hexane, dried, and recrystallized from benzene. Compound **5a** (0.373 g, 69 %) was obtained, m.p. 206—208 °C. Found (%): C, 66.40; H, 8.66; B, 4.30; N, 20.40. $C_{15}H_{23}BN_4$. Calculated (%): C, 66.62; H, 8.58; B, 4.07; N, 20.73. MS, *m/z*: 227 $[M-Pr]^+$. IR, ν/cm^{-1}: 3410 (NH); 1630, 1590, 1555, 1525 (C=C, C=N). ^{11}B NMR, δ: −1.8. ^{1}H NMR ($CDCl_3$), δ: 7.58—7.18 (m, 4 H arom.); 5.64 (s, NH); 2.40 (s, Me); 1.33—0.35 (m, 2 Pr).

[*N*-(1-Methylbenzimidazol-2-yl)acetamidinato]dipropylboron (5b) was obtained similarly to **5a** from 2-amino-1-methylbenzimidazole **2** (0.294 g), Pr_2BSBu (0.372 g), and MeCN (5 mL). Yield of **5b** was 0.454 g (80 %), m.p. 136—137 °C (from MeCN). Found (%): C, 68.01; H, 9.05; B, 4.04; N, 20.20. $C_{16}H_{25}BN_4$. Calculated (%): C, 67.55; H, 8.86; B, 3.87; N, 19.71. MS, *m/z*: 241 $[M-Pr]^+$. IR, ν/cm^{-1}: 3410 (NH); 1625, 1575, 1520, 1480 (C=C, C=N). ^{11}B NMR, δ: −4.9. ^{1}H NMR ($CDCl_3$), δ: 7.52—7.14 (m, 4 H arom.); 5.50 (s, NH); 3.65 (s, NMe); 2.20 (s, CMe); 1.28—0.28 (m, 2 Pr).

Scheme 3



5e **9** **10**

Reagents and conditions: *i*. BuOH, HCl, Δ; *ii*. $NaHCO_3$.

[*N*-(Benzothiazol-2-yl)acetamidinato]dipropylboron (5c) was obtained similarly to **5a** from 2-aminobenzothiazole **3** (0.3 g), Pr_2BSBu (0.372 g), and MeCN (5 mL). Yield of **5c** was 0.492 g (84 %), m.p. 145—148 °C (from MeCN). Found (%): C, 62.71; H, 7.47; B, 3.57; N, 14.74; S, 11.41. $C_{15}H_{22}BN_3S$. Calculated (%): C, 62.68; H, 7.72; B, 3.88; N, 14.63; S, 11.13. MS, *m/z*: 244 $[M-Pr]^+$. IR, ν/cm^{-1}: 3400 (NH); 1580, 1495, 1445 (C=C, C=N). ^{11}B NMR, δ: 1.3. ^1H NMR ($CDCl_3$), δ: 7.79—7.22 (m, 4 H arom.); 5.80 (s, NH); 2.18 (s, Me); 1.34—0.25 (m, 2 Pr).

[*N*-(Benzothiazol-2-yl)acetamidinato]dibutylboron (5d) was obtained similarly to **5a** from 2-aminobenzothiazole **3** (0.37 g), Bu_3B (0.45 g), and MeCN (5 mL). Yield of **5d** was 0.46 g (73 %), m.p. 153—154 °C (from MeCN). Found (%): C, 64.77; H, 8.34; B, 3.42; S, 10.09. $C_{17}H_{26}BN_3S$. Calculated (%): C, 64.72; H, 8.31; B, 3.49; N, 13.33; S, 10.14. MS, *m/z*: 258 $[M-Bu]^+$. IR, ν/cm^{-1}: 3400 (NH); 1570, 1500 (C=C, C=N). ^{11}B NMR, δ: 1.68. ^1H NMR [$(CD_3)_2SO$], δ: 8.38 (s, NH); 7.78—7.22 (m, 4 H arom.); 2.08 (s, Me); 1.18—0.19 (m, 2 Bu).

[*N*-(Benzothiazol-2-yl)-*p*-chlorobenzamidinato]dibutylboron (5e). A mixture of 2-aminobenzothiazole **3** (0.3 g), Bu_3B (0.387 g), *p*-chlorobenzonitrile (0.79 g), and benzene (5 mL) was boiled for 3.5 h. Excess nitrile and the solvent were distilled off, and the residue was recrystallized from hexane. Yield of **5e** was 0.46 g (73 %), m.p. 120—121 °C. Found (%): C, 64.43; H, 6.74; B, 2.83; Cl, 8.41; S, 7.61. $C_{22}H_{27}BClN_3S$. Calculated (%): C, 64.21; H, 6.62; B, 2.68; Cl, 8.50; N, 10.22; S, 7.78. MS, *m/z*: 354 $[M-Bu]^+$. IR, ν/cm^{-1}: 3400 (NH); 1550, 1490 (C=C, C=N). ^{11}B NMR, δ: 1.68. ^1H NMR [$(CD_3)_2SO$], δ: 8.62 (s, NH); 8.16 and 7.59 (both d, C_6H_4); 7.88 (d); 7.69 (d); 7.45 (t); 7.30 (t, 4 H arom.); 1.28—0.38 (m, 2 Bu).

[*N*-(Benzimidazol-2-yl)acetamidinato]dipropylboron hydrochloride (8). Chelate **5a** (0.54 g) was boiled in a 6 *M* solution (5 mL) of HCl in Bu^nOH for 1.5 h. The solvent was distilled off, and the residue was washed with hexane and recrystallized from acetonitrile. Hydrochloride **8** was obtained (0.52 g, 95 %), m.p. 224—226 °C. Found (%): C, 57.79; H, 7.64; B, 3.57; Cl, 11.41. $C_{15}H_{24}BClN_4$. Calculated (%): C, 58.78; H, 7.89; B, 3.60; Cl, 11.42. MS, *m/z*: 227 $[M-Pr-HCl]^+$. IR, ν/cm^{-1}: 3395 (NH). ^{11}B NMR (THF), δ: 1.4.

***N*-(Benzothiazol-2-yl)-*p*-chlorobenzamidine (10)**. A mixture of **5e** (0.4 g), toluene (5 mL), and a 6 *M* solution of HCl in butanol (1 mL) was boiled for 3 h. The precipitate was filtered off, washed with benzene, and treated with a saturated solution of $NaHCO_3$ (5 mL). After stirring for 1.5 h, the precipitate was filtered off, washed with water, and dried *in vacuo* over P_2O_5. Compound **10** was obtained (0.25 g, 85 %) with m.p. 181—183 °C. Found (%): C, 58.14; H, 3.62; Cl, 12.40. $C_{14}H_{10}ClN_3S$. Calculated (%): C, 58.53; H, 3.50; Cl, 12.18; N, 14.64; S, 11.14. MS, *m/z*: 286 $[M-H]^+$. IR, ν/cm^{-1}: 3490 (NH); 1630 (C=N). ^1H NMR [$(CD_3)_2SO$], δ: 10.19 and 9.23 (both br.s, 2 NH); 8.12 and 7.61 (both d, C_6H_4); 7.89—7.28 (m, 4 H arom.).

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