Influence of the Substituents on the Structure and Properties of Benzoxaboroles

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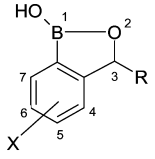
Benzoxaboroles possessing aryl substituents in the oxaborole ring were synthesized, and their structures were determined by single-crystal X-ray diffraction. Structures in the solid state are centrosymmetric dimers with two intermolecular hydrogen bonds. These compounds were investigated using a combination of the spectroscopic and the computational approach, comparing their properties with the unsubstituted compound. Investigated compounds were characterized by ^{1}H, ^{13}C, and ^{11}B NMR spectroscopy in solution. Assignment of ^{1}H and ^{13}C signals was made on the basis of HSQC and HMBC spectra. The molecular structure of 1,3-dihydro-1-hydroxy-3-phenyl-2,1-benzoxaborole was calculated by the density functional (B3LYP) method with the extended 6-311++G(d,p) basis set. The calculated geometrical parameters were compared with experimental X-ray data, and the differences between experimental and calculated values were found to be of the order of experiment standard deviation, confirming a good description by this level of theory. The harmonic frequencies, potential energy distribution (PED), and IR intensities of this compound and its deuterated analogue were calculated with the B3LYP method. The assignment of the experimental spectra was made on the basis of the calculated PED. The consequence of dimer formation is the splitting of the vibrational modes into symmetric and antisymmetric vibrations. The structure modification resulting from the hydrogen bonded dimers formation is presented.

Introduction

Boronic acids, $RB(OH)_2$, are objects of increasing interest because of their new applications in organic synthesis, catalysis, supramolecular chemistry, biology, and medicine.[1] Following the research on molecular recognition, phenylboronic acids have also recently been employed as promising building blocks in crystal engineering to achieve predictably organized crystal materials.[2] Supramolecular assemblies of various types have been generated in this manner.[3–5] The reversibility of their interactions with diols is widely exploited in the construction of molecular receptors[6] and makes them ideal candidates for the design of self-assembled molecular structures.[7,8]

Benzoxaboroles **I** are internal hemiesters of phenylboronic acids. They reveal a very high chemical stability of both



I

oxaborole ring and boron−carbon bond toward hydrolysis compared with corresponding boronic acids.[9] Only recently has great attention been paid to a new application of these compounds in medicine. 5-Fluoro-1,3-dihydro-1-hydroxy-2,1-benzoxaborole, AN2690, is a broad-spectrum antifungal drug that easily transits through the nail plate.[10,11] After the discovery of its antifungal properties,[12–14] systematic investigations of biological activity of substituted benzoxaboroles were carried out.[15,16] Recently, 5-chloro-substituted benzoxaborole, AN2718, is being developed for topical treatment of tinea pedis.[15] Benzoxaborole with cyanophenoxy substituents in five-position reveals anti-inflammatory activity against psoriasis, a common skin disease characterized by chronic inflammation. On the basis of structure−activity relationship studies, it was found to be the most active compound and is currently in clinical trials.[15,17,18] Determination of the structure of the complexes with leucyl-tRNA synthetase was the basis for the rational design of antifungal benzoxaboroles.[19] Benzoxaboroxoles were also tested for the treatment of periodontal disease.[20]

Although the possibility of ester formation by benzoxaboroles with monohydroxy compounds was reported as early as 1982 by Wulff,[21] their surprisingly high activity toward polyols was only recently reported. Formation of the cyclic esters by boronic acids with diols is the basis of boronic acids' action as sugar molecular receptors.[6] In that case, cyclic esters are formed by both hydroxy groups in the boronic group. Similar cyclic esters can be formed by the anionic form of the benzoxaboroles in neutral or slightly alkaline media.[22,23]

Another important application of benzoxaboroles is their use in Suzuki coupling to yield ortho-substituted benzyl alcohols.[24] Substituted benzoxaborole was used, for example, in the total synthesis of vancomycin.[25]

Only a few crystal structures of benzoxaboroles are known to date.[26] Similarly to phenylboronic acids, the basic structural motive is a dimer with two intermolecular hydrogen bonds. Importantly,

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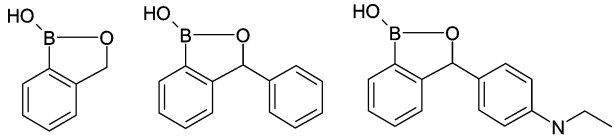
TABLE 1: Selected Crystal Data and Structure Refinement for Compounds 1−3

compound	1	2	3
empirical formula	$2C_7H_7BO_2$	$C_{13}H_{11}BO_2$	$C_{15}H_{16}NBO_2$
space group	$P2_1$	$C2/c$	$P\bar{1}$
unit cell dimensions			
a [Å]	4.536(1)	16.663(1)	6.897(1)
b [Å]	24.292(4)	6.247(1)	9.838(1)
c [Å]	6.144(1)	21.040(2)	10.578(1)
α [°]			68.399(6)
β [°]	102.73(1)	104.712(7)	78.575(6)
γ [°]			78.580(6)
volume V [Å^3]	660.5(2)	2118.3(3)	647.90(8)
Z [molecules/cell]	4	8	2
final R indices ($I > 2\sigma$)	$R = 0.0423$	$R = 0.0324$	$R = 0.0350$
	$wR^2 = 0.0881$	$wR^2 = 0.0876$	$wR^2 = 0.0969$

only one hydroxy group at the boron atom is present, and hence there is no possibility of lateral hydrogen bond formation to form infinite 2D or 3D networks, as observed in the case of phenylboronic acids.[27] The boron center is always trigonal, but unlike in phenylboronic acids, the BOO fragment is coplanar with the phenyl fragment. Substitution at phenyl ring and/or on methylene carbon of oxaborole fragment can influence the molecular interactions both by steric and electronic effects, so more complicated patterns are also observed.[28–30] Recently, the influence of amino substituent on the intermolecular hydrogen bond was investigated using a combination of the spectroscopic and the computational approach.[31]

The aim of the present work is the comparison of the parent compound, unsubstituted benzoxaborole (**1**), of which the crystal structure was redetermined, with the newly synthesized compounds (**2**, **3**) with different substituents in the oxaborole ring.



1 **2** **3**

Experimental Section

X-ray Crystallography. The crystals of **1** were obtained from an acidic aqueous-methanol solution. The crystals of **2** were obtained by recrystallization from acetonitrile and of **3** crystallized from the reaction mixture dissolved in hexane. The X-ray measurement of **1**, **2**, and **3** was performed at 100(2) K on a KUMA CCD k axis diffractometer with graphite-monochromated Mo Kα radiation (0.71073 Å). The crystal was positioned at 62.25 mm from the KM4CCD camera; 750 frames were measured at 0.5° intervals on a counting time of 20 s, 748 frames were measured at 0.8° intervals on a counting time of 10 s, and 4000 frames were measured at 0.3° intervals on a counting time of 20 s, respectively for **1**−**3**. Data reduction and analysis were carried out with the KUMA diffraction programs. The data were corrected for Lorentz and polarization effects, but no absorption correction was applied. Data reduction and analysis were carried out with the Kuma diffraction (Wrocław, Poland) programs.[32] The structure was solved by direct methods[33] and refined by using SHELXL.[34] The refinement was based on F^2 for all reflections except for those with negative F^2. The weighted R factor, wR, and all goodness-of-fit S values are based on F^2. The nonhydrogen atoms were refined anisotropically. The hydrogen atoms were located from a difference map and were refined isotropically. The atomic scattering factors were taken from the international tables.[35] Selected crystal structure and structural refinement are specified in Table 1. (See the Supporting Information for more details.) Selected bond lengths, bond angles, and torsion angles are given in Table 2. Crystallographic data for the structure have been deposited with the Cambridge Crystallographic Data Centre as supplementary publication no. CCDC 744739 (**1**), 744740 (**2**), and 744741 (**3**). Copies of the data can be obtained on application to CCDC, 12 Union Road, Cambridge CB2 1.EZ, U.K. (e-mail: deposit@ccdc.cam.ac.uk).

Nuclear Magnetic Resonance Measurements. The ^{1}H NMR, ^{13}C NMR, and 2D spectra were recorded on Varian INOVA 500 spectrometer operating at frequency 500 and 125.1 MHz at ambient temperature. The ^{11}B spectra were recorded on Varian UnityPlus 200 spectrometer at frequency 64 MHz.

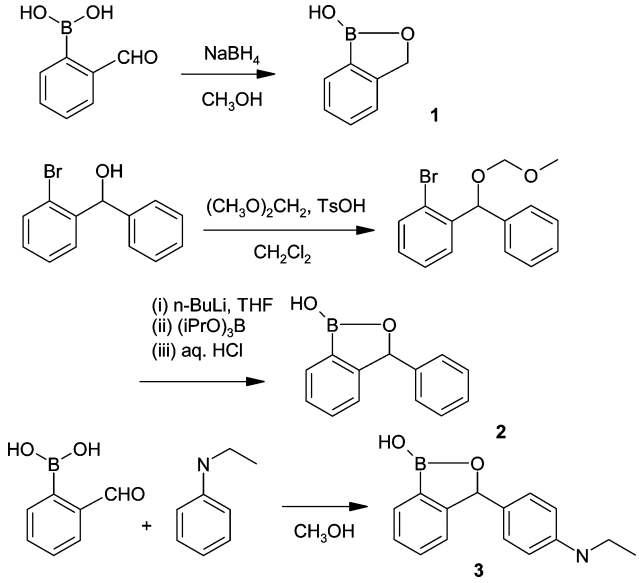
Infrared Measurements. Infrared absorption spectra were recorded on a computer interfaced Perkin-Elmer 2000 FT-IR system with a wavenumber resolution of 1 cm^{-1}. The spectra were obtained for samples dispersed in KBr pellets.

TABLE 2: Selected Bond Lengths (angstroms), Bond Angles (degrees), and Torsion Angles (degrees) for Compounds 1−3[a]

	1		2	3
compound/parameter	A	B		
B(1)−O(12)	1.351(5)	1.347(5)	1.3452(14)	1.3466(15)
B(1)−O(11)	1.401(5)	1.405(5)	1.3936(13)	1.3842(15)
B(1)−C(1)	1.550(6)	1.560(6)	1.5488(15)	1.5538(17)
O(11)−C(7)	1.455(4)	1.453(4)	1.4501(12)	1.4694(13)
O(12)−H(12)	0.89(5)	0.84(4)	0.881(16)	0.905(19)
C(1)−C(6)	1.398(5)	1.398(5)	1.3970(14)	1.3986(16)
C(1)−C(2)	1.406(4)	1.399(5)	1.3977(14)	1.3977(16)
O(12)−B(1)−O(11)	121.9(4)	122.3(4)	121.90(9)	122.44(10)
O(12)−B(1)−C(1)	130.1(3)	129.9(4)	129.97(9)	129.37(11)
O(11)−B(1)−C(1)	108.0(3)	107.8(3)	108.10(9)	108.19(10)
B(1)−O(11)−C(7)	111.0(3)	110.3(3)	111.19(8)	111.30(9)
C(2)−C(1)−B(1)	105.0(3)	105.7(3)	105.21(9)	105.09(10)
C(6)−C(1)−B(1)	136.2(3)	135.4(3)	135.21(10)	135.25(11)
O(11)−C(7)−C(2)	104.7(3)	106.0(3)	104.60(8)	103.91(9)
O(11)−B(1)−O(12)−C(7)	179.7(3)	179.2(3)	179.21(9)	177.67(10)
C(1)−B(1)−O(11)−C(7)	0.7(4)	0.1(4)	0.92(11)	2.20(12)
C(1)−C(2)−C(7)−O(11)	1.6(4)	−0.7(4)	0.30(10)	3.90(12)

[a] **A** and **B** denote two independent molecules of **1**.

SCHEME 1: Synthesis of the Investigated Compounds



Computational Details

Density function theory (DFT)[36] with the hybrid functionals (B3LYP)[37,38] and basis set 6-311++G(d,p) was applied to calculate vibrational frequencies and their IR intensities. Normal coordinate analysis method was used to obtain the potential energy distribution (PED).[39] Calculations were made using the Gaussian03 program.[40]

The comparison between the experimental structures of **2** and **3** and the calculated at B3LYP/6-311++G(d,p) level was performed (Table S3 in the Supporting Information). The differences between experimental and theoretical values are of the order of experiment standard deviations.

Results and Discussion

Synthesis. Compounds **1**−**3** were synthesized according to Scheme 1. Unsubstituted compound **1** was obtained by the reduction of 2-formylphenylboronic acid and spontaneous dehydration of the formed benzylic compound. Phenyl-substituted compound (**2**) was synthesized according to the literature method with small modifications.[24] Compound **3** was obtained as an unexpected product of the reaction of 2-formylphenylboronic acid with *N*-ethylaniline. The full description of the syntheses and characterization of the products are given in the Supporting Information.

Crystal Structures. The structure of the parent 1,3-dihydro-1-hydroxy-2,1-benzoxaborole (**1**) was published 10 years ago by Zhdankin et al.[41] The system crystallizes in $P\bar{1}$ triclinic space group where an asymmetric part of the unit cell consists of the two independent molecules. They form two kinds of planar centrosymmetric dimers, which are situated almost perpendicularly to each other. The angle between the best planes calculated for all atoms of the dimers is 73.7°.[41] In the present article, another polymorph of this compound is reported. Polymorph II crystallizes in monoclinic $P2_1$ space group and, similarly to the case of polymorph I, an asymmetric part of the unit cell is also formed by two molecules of benzoxaborole. In this case, however, two independent molecules form only one kind of dimer, which is also planar. (See Figure 1.) Despite this difference, the two-screw axis leads to almost perpendicular positioning of the neighboring dimers, and as in polymorph I,[41] the angle between the best planes calculated for all atoms of the dimers is 75.2°. The hydrogen bonds in the dimer are rather strong: the O(12A)−H(12A)···O(11B) and O(12B)−H(12B)···O(11A) distances are 1.88(5) and 1.91(4) Å, respectively (the

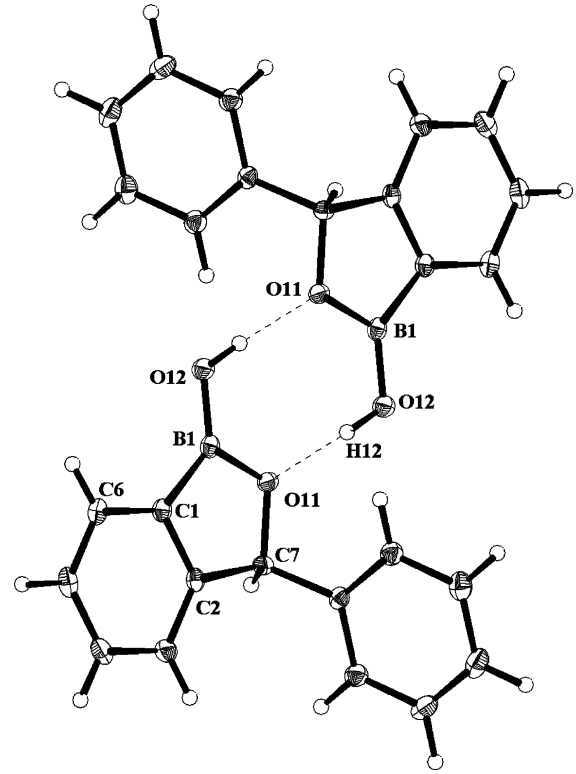


Figure 2. Dimeric interaction in **2**. The molecules are related by an inversion center (i: 1/2-*x*, 3/2-*y*, -*z*). The intermolecular hydrogen bonds are marked as dotted lines. The displacement parameters are drawn at 50% probability level.

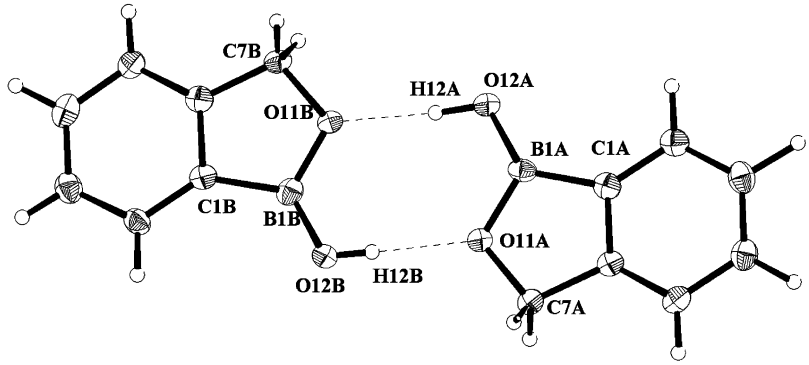


Figure 1. Dimeric interactions in 1,3-dihydro-1-hydroxy-2,1-benzoxaborole (polymorph II) (**1**). The intermolecular hydrogen bonds are marked as dotted lines. The displacement parameters are drawn at 50% probability level.

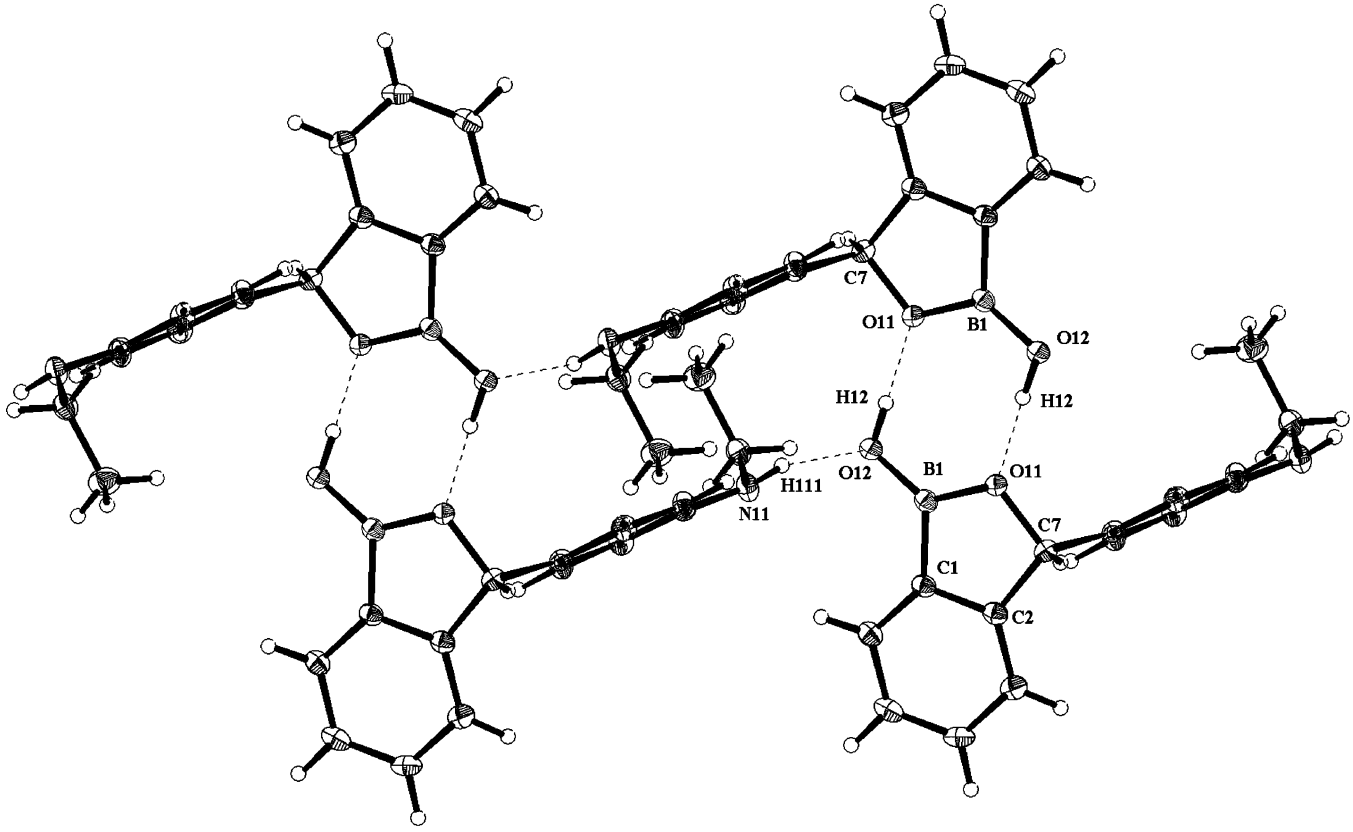


Figure 3. Dimeric interaction in **3**. The molecules are related by an inversion center (i: -*x*, 1-*y*, 1-*z*). The intermolecular hydrogen bonds are marked as dotted lines. The displacement parameters are drawn at 50% probability level.

O···O distances are 2.767(3) and 2.757(3) Å, respectively), which is comparable to the strength of the hydrogen bonds forming the dimers in polymorph I. (The O···O distances are in the range of 2.752 to 2.757 Å.) For polymorph I, it has been observed that the geometries of the benzoxaborole molecules differ significantly.[41,42] For instance, the endocyclic C−B or exocyclic BO(H) bond lengths differ by 0.046 or 0.021 Å, respectively. Such big discrepancies have been attributed to both the different environment of van der Waals interactions in the crystal lattice and the quality of the refinement.[42] Despite many attempts, we were unable to obtain a good quality crystal of polymorph I following the original procedure given in ref 41; therefore, it is difficult to argue with the latter factor. Importantly, in the case of polymorph II, the differences in geometries of two independent molecules are fairly small and statistically insignificant. (See Table 2.)

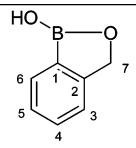
Both benzoxaborole derivatives **2** and **3** crystallize as centrosymmetric planar dimers with one molecule in the asymmetric part of the unit cell. The strength of the interactions in dimers is comparable to that of the parent system (**1**), albeit the O···O distances are slightly smaller (2.737 and 2.712 Å, respectively, for **2** and **3**). The structure of **3** is additionally stabilized by a hydrogen bond between amino group and oxygen of hydroxy group (Figure 3), with the O···HN distance equal to 2.142 Å (O···N distance 3.001 Å). In both cases, the substituting phenyl ring is twisted in respect to oxaborole moiety by 65.9 and 83.2° for **2** and **3**, respectively.

The phenyl ring is known as a weakly interacting substituent,[43] and its impact on molecular geometry is usually small. Indeed, in the case of **2**, the geometry of the benzoxaborole fragment is similar to that of **1** (Figure 2). However, small modification of the phenyl ring by substitution in para position by ethylamino substituent noticeably influences the geometry of the oxaborole ring. For instance, O(11)−C(7) bond length increases to 1.469(1) Å in **3** from 1.450(1) Å in **2** or 1.453(4)−1.455(4) Å in **1**. Also, B(1)−O(11) shortens to 1.384(2) Å in **3** as compared with 1.401(5)−1.405(5) Å in **1**. This is solely an intramolecular effect because the ethylamino group is involved in an intermolecular hydrogen bond with O(12) (Figure 3), but despite this, the B(1)−O(12) bond is not perturbed appreciably. (The B−O distance is 1.347(2) versus 1.347(5)−1.351(5) Å, respectively, for **3** and **1**.) This strongly supports a view that an oxaborole fragment is highly sensitive to the structural modifications arising from substitution.[42]

Nuclear Magnetic Resonance Spectroscopy. The assignment of all of the signals in ^{1}H and ^{13}C spectra of **1**, **2**, and **3** was made on the basis of ^{1}H−^{1}H COSY (correlated spectroscopy), HSQC (heteronuclear single quantum coherence), and HMBC (heteronuclear multiple bond correlation) spectra of the solutions in deuterated acetone. The ^{13}C NMR spectra of all of the investigated boronic acids displayed the characteristic lack of the signal of carbon atom adjacent to boron atom.[1] The B−OH proton signals were observed as singlets at 8.04 (**1**), 8.25 (**2**), and 8.07 ppm (**3**), respectively. The deshielding effect of B−OH group[44] results in the 6-H (β to the B−OH) signal being the most shifted and similar for all compounds (7.74 for **1**, 7.78 for **2**, and 7.75 ppm for **3**). Substitution at the benzoxaborole ring in **2** and **3** results in shifting of the corresponding proton signals (7-H) from 5.01 ppm for **1** to 6.18 (**2**) and 6.06 (**3**). The most deshielded carbon signals correspond to C-2 and appear at 155.35 for **1**, 158.48 for **2**, and 159.10 for **3**, showing no correlation in HSQC spectra. All of the observed ^{1}H and ^{13}C signals of **1**, **2**, and **3** as well as correlations are given in Tables 3−5.

Infrared Spectroscopy. The harmonic frequencies, PED, and IR intensities of the compound **2** were calculated with the

TABLE 3: ^{1}H and ^{13}C NMR Signals and ^{1}H,^{13}C Correlations of Compound 1[a]

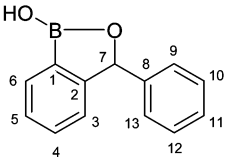


1

Atom C	δ (ppm)	Atom H	δ (ppm)	Multipl., $J_{H,H}$ (Hz)	^{1}H, ^{1}H COSY	^{1}H,^{13}C HSQC	^{1}H,^{13}C HMBC
C-1	no signal	BOH	8.04	s	-	-	-
C-2	155.35	-	-	-	-	-	-
C-3	122.16	3-H	7.41-7.40	m	4-H	+	C-5, C-7*
C-4	131.52	4-H	7.49-7.46	m	3-H	+	C-5
C-5	127.78	5-H	7.34-7.31	m	6-H, 4-H	+	C-3, C-7*
C-6	131.27	6-H	7.74	d, 7.5	5-H	+	C-4
C-7	71.34	7-H	5.01	s	6-H, 3-H, 5-H*	+	C-2, C-3*, C-4*, C-5*

[a] * indicates signals of low intensity.

TABLE 4: ^{1}H and ^{13}C NMR Signals and ^{1}H,^{13}C Correlations of Compound 2[a,b]

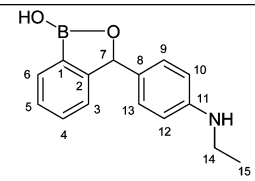


2

Atom C	δ (ppm)	Atom H	δ (ppm)	Multipl., J_{HH} (Hz)	^{1}H, ^{1}H COSY	^{1}H,^{13}C HSQC	^{1}H,^{13}C HMBC
C-1	no signal	BOH	8.26	s	-	-	-
C-2	158.48	-	-	-	-	-	-
C-3	123.22	3-H	7.20	m	7-H, 4-H	+	C-7, C-5
C-4	128.21	4-H	7.36-7.26[#]	m	[#]	+	C-7, C-4
C-5	131.87	5-H	7.43-7.41	m	3-H, 4-H	+	C-6, C-4
C-6	131.24	6-H	7.78	d, 7.3	5-H	+	C-5
C-7	83.61	7-H	6.18	s	3-H*	+	C-13, C-9
C-8	142.54	-	-	-	-	-	-
C-9 C-13	127.36	9-H 13-H	7.36-7.26[#]	m	[#]	+	C-7, C-10, C-12
C-10 C-12	129.40	10-H 12-H	7.36-7.26[#]	m	[#]	+	C-9, C-13, C-11
C-11	128.76	11-H	7.36-7.26[#]	m	[#]	+	C-10, C-12

[a] # indicates 5-H, 9-H, 10-H, 11-H, 12-H, and 13-H signals overlap, and it is not possible to make the assignment, [b] * indicates signals of low intensity.

TABLE 5: ^{1}H and ^{13}C NMR Signals and ^{1}H,^{13}C Correlations of Compound 3[a]



3

Atom C	δ (ppm)	Atom H	δ (ppm)	Multipl., J_{HH} (Hz)	^{1}H,^{1}H COSY	^{1}H,^{13}C HSQC	^{1}H,^{13}C HMBC
C-1	no signal	BOH	8.07	s	-	-	-
C-2	159.10	-	-	-	-	-	-
C-3	123.33	3-H	7.16-7.13	m	4-H	+	C-4, C-7
C-4	127.90	4-H	7.34-7.32	m	5-H	+	C-3, C-6
C-5	131.60	5-H	7.43-7.39	m	6-H	+	C-6, C-2
C-6	130.97	6-H	7.75	d, 7.0	5-H	+	C-5, C-2
C-7	84.04	7-H	6.03	s	3-H*	+	C-2, C-6*, C-3*
C-8	129.64	-	-	-	-	-	-
C-9 C-13	112.98	9-H 13-H	6.55	d, 8.6	10-H, 12-H	+	C-7, C-3*, C-10, C-12
C-10 C-12	128.78	10-H 12-H	6.97	d, 8.6	H-9, H-13	+	C-9, C-13, C-8
C-11	150.05	NH	4.83	s	14-H*	-	-
C-14	38.76	14-H	3.14-3.07	m	15-H NH*	+	C-15, C-11
C-15	14.96	15-H	1.19	t, 7.5	14-H	+	C-14

[a] * indicates signal of low intensity.

B3LYP method. Experimental and calculated IR frequencies of this compound as well as their assignment together with PED values calculated by normal coordinate analysis are presented in the Supporting Information (Table S2). For the calculated frequencies, the scaling factor of 0.9940 was applied,[45] which slightly improves the agreement between these series of values. Experimental and calculated IR spectrum of compound **2** as well as its deuterated analog is shown in Figure 4. The spectrum of the deuterated compound was measured to facilitate bands assignment. Appropriate calculations were also performed for samples deuterated at OH position. Definitions of symmetry coordinates are presented at the end of Table S2 in the Supporting Information, which describes the character of particular modes. In these assignments, no specification of vibrations of particular bonds is given, so, for example, the *r*(C−H) marks the stretching of the C−H bond, regardless of the numbers of atoms forming the particular C−H bonds.

The force field of the dimer consists of 156 normal modes. The interpretation of the spectra requires, however, such a tedious procedure, because the formation of hydrogen bonds in dimers leads to remarkable structural changes in interacting molecules. Because of the performed calculations within

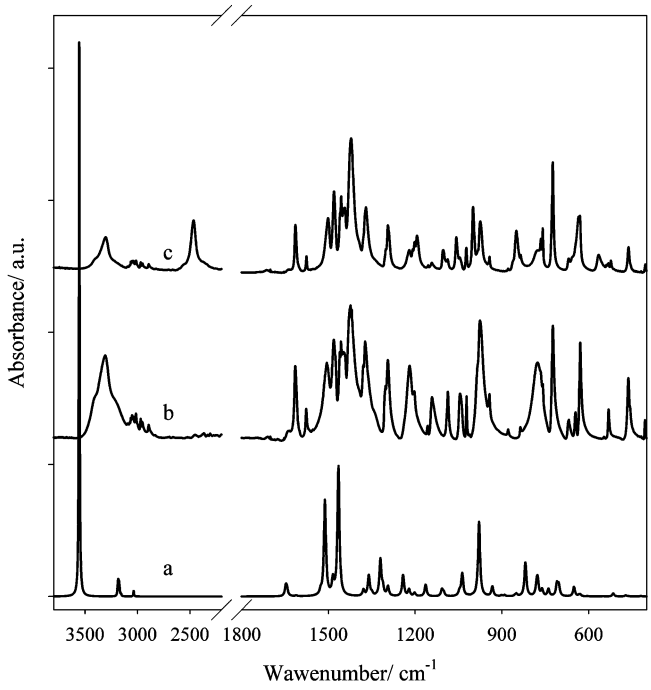


Figure 4. Experimental IR spectrum of solid **2** (b), its deuterated analog (c), and calculated spectrum (a).

TABLE 6: Force Constants in Internal Coordinates [N/m]

	monomer	dimer
rOH	827	699
rBO(H)	662	757
rBO	582	523
RCO	425	412
rCC(O)	427	436
rCC(B)	656	662
γOH	5.9	6.1
βBOH	52	149

approximation of internal coordinates, we are able to demonstrate those changes in force constants of the most important bonds in the formation of dimers. The results are presented in Table 6.

The formation of a cyclic dimer leads to weakening of the O−H bond force constant, from 827 to 699 N/m, which is typical for hydrogen bonding. The difference in the behavior of B−O bonds is interesting. The B−O(H) bond becomes stronger after formation of the hydrogen bond, whereas the B−O bond, participating in a five-member ring, becomes weaker. In the first case, the force constant increases from 662 to 757, whereas for the B−O bond, it decreases from 582 to 523 N/m. Simultaneously, the strength of the C−O bond being a member of a five-atom ring decreases, the force constant changes from 425 to 412 N/m. Additional increase in the bending frequencies is observed. The formation of dimers of hydrogen bonds leads to substantial reorganization of electron clouds in the five-member ring.

The consequence of the formation of dimers with the symmetry center is the splitting of the vibrational modes into symmetric and antisymmetric vibrations. In experimental IR, as a rule, only in-phase vibration is observed. Running the quantum chemical calculations, one can establish the effect of the splitting. For the νOH stretching vibrations, it is 30 cm^{-1}, which demonstrates rather weak interactions in the hydrogen bonds forming dimers.

A similar conclusion follows from the experimental value of ISR (isotopic spectral ratio) for the frequency of nondeuterated and deuterated samples, which is 1.34 in molecule **2**. For νBO and νB−O(H) frequencies, the splitting is 5 and 7 cm^{-1}, respectively.

Conclusions

The introduction of a phenyl substituent at the methylene group of oxaborole ring has a small influence on the structure. However, a small modification of the phenyl ring by the introduction of an ethylamine group results not only in the formation of N···H−O hydrogen bond, but also in a change of the angles between oxaborole and substituting phenyl rings as well as the change of the O−C and B−O distances.

The geometrical parameters calculated by the DFT method with the B3LYP/6-311++G(d,p) basis set are in good agreement with the experimental values. The obtained results confirm the good description of experimental spectra by this level of theory. Performing calculations in internal coordinates, we were able to discuss the effects of hydrogen bond formation on the force field of monomers taking part in interactions. The results demonstrate that it is necessary to describe the dimer as one unit in calculations. It was also possible to describe the mutual interactions in the complex by the band splitting parameters. Crystallographic data also show that in molecules **1** and **3**, the hydrogen bonds are of similar strength, as one can judge from the length of studied hydrogen bonds.

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Supporting Information Available: Description of the syntheses of the investigated compounds, full crystal structure, and structural refinement information, detailed description of all NMR signals assignments as well as copies of ^{1}H, ^{13}C, HH COSY, HMBC, and HSQC spectra for compounds **1**−**3**, and comparison of experimental and calculated molecular parameters of compound **2** and **3**. This material is available free of charge via the Internet at http://pubs.acs.org.

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