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# New strategy to the synthesis of (N → B) phenyl[N-alkyliminodiacetate-O,O′,N]-boranes: The crystal structure of (N → B) phenyl[N-benzyliminodiacetate-O,O′,N]-borane, (N → B)phenyl[N-(4-methyl)benzyliminodiacetate-O,O′,N]borane and (N → B) phenyl[N-phenacyliminodiacetate-O,O′,N]borane

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ABSTRACT

A new, mild and friendly method for the synthesis of (N → B) phenyl[N-alkyliminodiacetate-O,O′,N]boranes **2**–**7** is reported. All compounds were identified by $^{1}H$, $^{11}B$, $^{13}C$ NMR and their high resolution mass spectra (HRMS) are reported. The structure of the compounds **2**, **4** and **5** were established by single crystal X-ray. Compounds **2** and **4** crystallized with two independent molecules **2A**, **2B** and **4A**, **4B**, respectively in the asymmetric unit. These molecular structures established the bicyclic structure showing a N → B bond length of 1.666 (2) Å for **2A**, 1.675 (2) Å for **2B**, 1.675 (3) Å for **4A**, 1.663 (3) Å for **4B** and 1.679 (2) Å for **5**, as well as different torsion angles of the junction, 28.70 (2)° (C11–B1–N6–C17) for **2A**, 21.50 (2)° (C11a–B1a–N6a–C17a) for **2B**, 25.76 (0.26)° (C11–B1–N6–C17) for **4A**, 21.96 (0.28)° (C11a–B1a–N6a–C17a) for **4B** and −29.22 (0.20)° (C5–N1–B1–C13) for **5**.



## 1. Introduction

Since the past four decades boron heterocycles derived from amino acids have shown a potential use for biological studies, mainly phenyl derivatives exhibit cytotoxic activity [1–5] and have application in boron neutron capture therapy (BNCT) for the treatment of brain tumors [6,7] and melanomas [8]. The chemistry of boron iminodiacetic derivatives has been little studied [9–11], which could be precursors of the new ligands potentially useful for biological studies [12,13]. We have been interested in the synthesis, characterization, structural analysis and reactivity of boron heterocycles derived from hydroxyaminoacids, iminodiacetic acids and N-substitutedimino- and aminodiacetic acids [9–11,14–21]. We have reported that (N → B) phenyl[iminodiacetate-O,O′,N]borane **1** has a rigid bicyclic structure due to strong intramolecular N → B coordination bond, as well as hydrolytically stable [14] and also its N-alkylation with lithium 2,6-dimethylpiperidide and lithium 2,2,6,6-tetramethylpiperidide as bulky bases and alkyl halides under nitrogen atmosphere, the yields were between 39% and 33% [10,11]. Our current interest in the reactivity of (N → B) phenyl[iminodiacetate-O,O′,N]borane **1** to find a new methods to obtain its N-alkyl derivatives prompted us to extend these investigations to prepare them under friendly reaction conditions and improve the yield. Thus, this article describes the synthesis of (N → B) phenyl[N-alkyliminodiacetate-O,O′,N]boranes **2**–**7**, by the reaction of boron heterocycle **1** with potassium bicarbonate, $KHCO_3$, which is a soft base and alkyl halides under reflux of a mixture of acetonitrile/benzene (80/20) or acetonitrile (Fig. 1). This new method does not need anhydride conditions as we used previously [10,11]. All compounds were identified by $^{1}H$, $^{13}C$ and $^{11}B$ NMR; their spectra are according with those data previously reported by us [10,11]. While, their high resolution mass spectra (HRMS) are reported. The structure of compounds **2**, **4** and **5** were further established by a single crystal X-ray diffraction study.

## 2. Results and discussion

(N → B) phenyl[iminodiacetate-O,O′,N]borane **1** is characterized to have a rigid bicyclic structure due to a strong intramolecular nitrogen-boro coordination, and to be highly hydrolytically stable [14]. These characteristics, and the fact that NH group has acid property, led us to study its reactivity under different conditions to obtain its N-alkylboron heterocycles [9–11], which have been hydrolyzed to the corresponding N-substituted iminodiacetic acids [10,11], as interesting biological ligands [13]. However, the N-alkylboron heterocycles have been obtained with low yields, probably caused in the purification of the compounds for the use of lithium 2,6-dimethylpiperidide and lithium 2,2,6,6-tetramethylpiperidide as bases. We attempt to investigate if the use of a soft base as $KHCO_3$ could react with the NH group of (N → B)

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phenyl[iminodiacetate-O,O′,N]borane **1** and carry out a substitution nucleophilic reaction with benzyl bromide **a**, 3-methylbenzyl bromide **b**, 4-methylbenzyl bromide **c**, phenacyl bromide **d**, 2-bromo-4′-chloroacetophenone **e** and 2-bromo-4′-phenylacetophenone **f**, under reflux of acetonitrile/benzene (80/20) or acetonitrile to obtain (N → B) phenyl[N-alkyliminodiacetate-O,O′,N]boranes **2**–**7**, (Fig. 1). Effectively, the yields are between 40% and 80%. $^{1}$H, $^{13}$C and $^{11}$B NMR and their high resolution mass spectra (HRMS) data of the compounds **2**–**7** are giving in the experimental part. Their $^{1}$H NMR spectra clearly show the AB coupling patterns for the diastereotopic $CH_2COO$ protons, which indicates the presence of the intramolecular N → B coordination bond. The $\delta(^{11}B)$ values confirm the tetrahedral environment of the boron nucleus, since they lie in the range reported previously for analogous boron heterocycles [9–11,13–16,19]. All compounds exhibit the expected $^{13}$C NMR spectra. Suitable crystals of **2**, **4** and **5** were obtained for X-ray analysis and an ORTEP view and crystallographic numbering of **2**, **4** and **5** are giving in Figs. 2–4, respectively. Selected bond distance and torsion angles are listed in Tables 1–3. In general the bond distances are within the values characteristic of analogous compounds [17,19]. Compounds **2** and **4** crystallized with two independent molecules **2A**, **2B** and **4A**, **4B**, respectively and **5** exhibits only one. The conformations of the two five member ring in all molecules are different and not planar, as indicated by the torsion angles values (Tables 1–3). This can be due in part to the following intermolecular interactions: $O_{9A}\cdots H_{5A}$ 2.288,

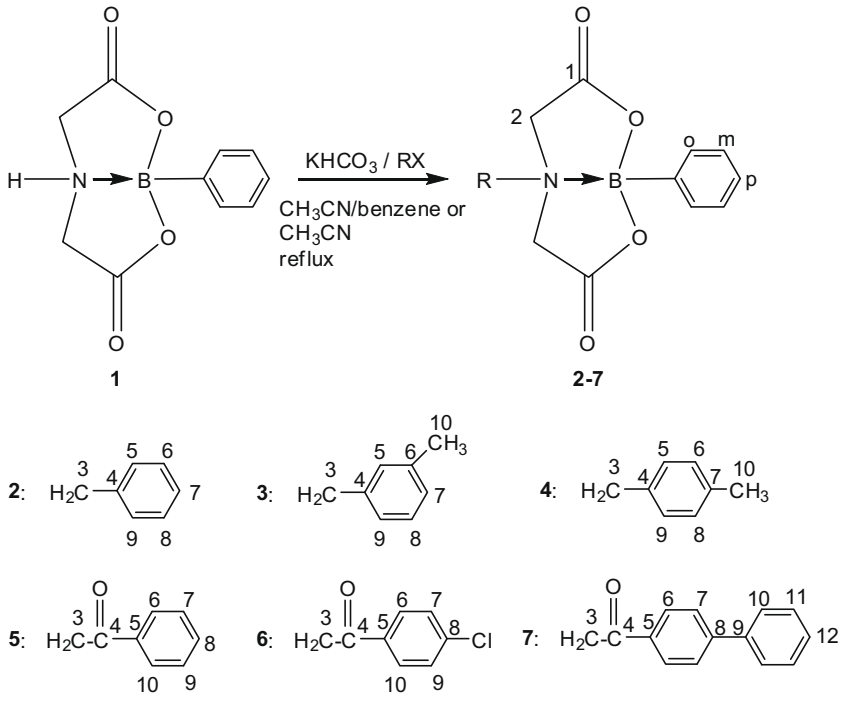


**Fig. 1.** Synthesis of boron heterocycles **2**–**7**.

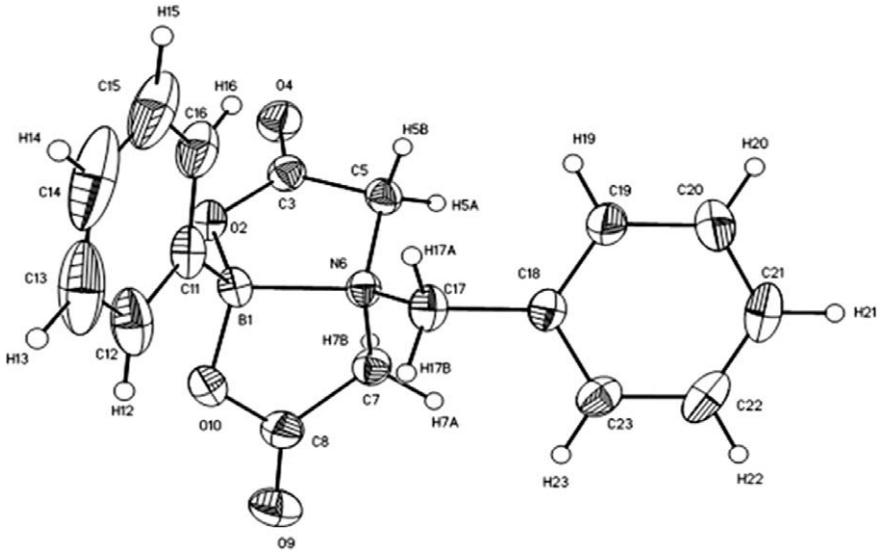


**Fig. 2.** Molecular structure of $C_{17}H_{16}BNO_4$ and crystallographic numbering scheme of molecule **2A**.

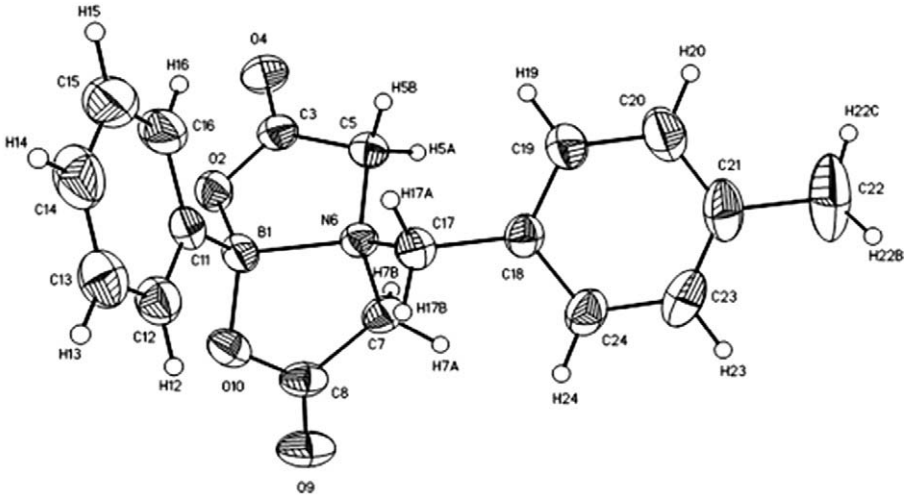


**Fig. 3.** Molecular structure of $C_{18}H_{18}BNO_4$ and crystallographic numbering scheme of molecule **4A**.

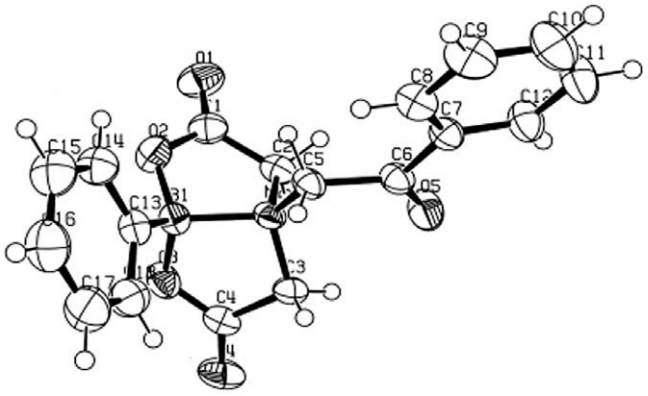


**Fig. 4.** Molecular structure of $C_{18}H_{16}BNO_5$ and crystallographic numbering scheme of molecule **5**.

$O_9\ldots H_{5A2}$ 2.522 and $O_{10}\ldots H_{16A}$ 2.544 Å for **2**, $O_4\ldots H_{5A1}$ 2.371, $O_{4A}\ldots H_{17D}$ 2.377, $O_9\ldots H_{17B}$ 2.450 and $O_{9A}\ldots H_{7B}$ 2.458 Å for **4** and $O_2\ldots H_{14}$ 2.5646, $O_5\ldots H_{3B}$ 2.4824, $O_5\ldots H_{2B}$ 2.5818 and $O_5\ldots H_{12}$ 2.4867 Å for **5**, which are significantly shorter than the sum of the van der Waals radii of oxygen and hydrogen (2.70 Å) [22]. On the another hand, the Ph–B and N–R groups are bent away from the N → B bond, as indicated by the bond angle values $C_{11}$–$B_1$–$N_6$ of 117.11 (13)° and $C_{17}$–$N_6$–$B_1$ of 112.90 (12)° for **2A**, $C_{11a}$–$B_{1a}$–$N_{6a}$ of 115.42 (15)° and $C_{17a}$–$N_{6a}$–$B_{1a}$ of 112.51 (13)° for **2B**, $C_{11}$–$B_1$–$N_6$ of 115.89 (19)° and $C_{17}$–$N_6$–$B_1$ of 114.29 (16)° for **4A**, $C_{11a}$–$B_{1a}$–$N_{6a}$ of 115.9 (2)° and $C_{17a}$–$N_{6a}$–$B_{1a}$ of 115.42 (17)° for **4B**, $C_{13}$–$B_1$–$N_1$ of 117.58 (14)° and $C_5$–$N_1$–$B_1$ of 113.39 (12)° for **5**. The molecular structures of the compounds **2**, **4** and **5** establish the bicyclic structures showing a N → B of bond length of 1.666 (2) Å for **2A**, 1.675 (2) Å for **2B**, 1.675 (3) Å for **4A**, 1.663 (3) Å for **4B** and 1.679 (2) Å for **5**, the values being comparable to the N → B bond length in analogous compounds [17,19].

**Table 1**
Bond distances selected (Å) and torsion angles (°) for $C_{17}H_{16}BNO_4$ (**2**).

| Molecule **2A** | | Molecule **2B** | |
|---|---|---|---|
| *Bond distances (Å)* | | | |
| O2–B1 | 1.486 (2) | O2a–B1a | 1.484 (2) |
| O10–B1 | 1.460 (2) | O10a–B1a | 1.467 (2) |
| N6–B1 | 1.666 (2) | N6a–B1a | 1.675 (2) |
| O2–C3 | 1.332 (2) | O2a–C3a | 1.322 (3) |
| O10–C8 | 1.326 (2) | O10a–C8a | 1.329 (2) |
| O4–C3 | 1.201 (2) | O4a–C3a | 1.201 (2) |
| O9–C8 | 1.202 (2) | O9a–C8a | 1.203 (2) |
| C3–C5 | 1.510(2) | C3a–C5a | 1.508 (3) |
| C7–C8 | 1.506 (2) | C7a–C8a | 1.494 (3) |
| N6–C5 | 1.486 (2) | N6a–C5a | 1.484 (2) |
| N6–C7 | 1.494 (2) | N6a–C7a | 1.582 (3) |
| B1–C11 | 1.587 (3) | B1a–C11a | 1.587 (3) |
| N6–C17 | 1.511 (3) | N6a–Cl7a | 1.516 (3) |
| *Torsion angles (°)* | | | |
| N6–B1–O2–C3 | −15.75(0.17) | N6a–B1a–O2a–C3a | −12.17 (0.20) |
| C5–C3–O2–B1 | −0.61 (0.20) | C5a–C3a–O2a–B1a | −2.00 (0.23) |
| O2–C3–C5–N6 | 19.08 (0.18) | O2a–C3a–C5a–N6a | 17.43 (0.21) |
| C3–C5–N6–B1 | −27.09 (0.16) | C3a–C5a–N6a–B1a | −23.20 (0.18) |
| O2–B1–N6–C5 | 26.02 (0.15) | O2a–B1a–N6a–C5a | 21.42 (0.21) |
| N6–B1–O10–C8 | −15.15 (0.19) | N6a–B1a–O10a–C8a | −16.11 (0.19) |
| C7–C8–O10–B1 | −1.14 (0.22) | C7a–C8a–O10a–B1a | 8.16 (0.22) |
| N6–C7–C8–O10 | 19.15 (0.20) | N6a–C7a–C8a–O10a | 4.95 (0.21) |
| C8–C7–N6–B1 | −25.98 (0.16) | C8a–C7a–N6a–B1a | −13.63 (0.17) |
| O10–B1–N6–C7 | 24.97 (0.15) | O10a–B1a–N6a–C7a | 17.45 (0.16) |
| C11–B1–N6–C17 | 28.72 (0.20) | C11a–B1a–N6a–C17a | 21.45(0.21) |

**Table 2**
Bond distances selected (Å) and torsion angles (°) for $C_{18}H_{18}BN0_4$ (**4**).

| Molecule **4A** | | Molecule **4B** | |
|---|---|---|---|
| *Bond distances (Å)* | | | |
| O2–B1 | 1.489 (3) | O2a–B1 | 1.466 (3) |
| O10–B1 | 1.454 (3) | O10a–B1a | 1.482 (3) |
| N6–B1 | 1.675 (3) | N6a–B1a | 1.663 (3) |
| O2–C3 | 1.319 (3) | O2a–C4a | 1.311 (3) |
| C3–C5 | 1.508 (3) | C4a–C5a | 1.488 (4) |
| N6–C5 | 1.484 (3) | N6a–C5a | 1.495 (3) |
| N6–C7 | 1.498 (3) | N6a–C7a | 1.484 (3) |
| C7–C8 | 1.503 (3) | C7a–C8a | 1.506 (4) |
| O10–C8 | 1.320 (3) | O10a–C8a | 1.315 (3) |
| O4–C3 | 1.202 (2) | O4a–C4a | 1.205 (3) |
| O9–C8 | 1.196 (3) | O9b–C8b | 1.206 (3) |
| *Torsion angles (°)* | | | |
| N6–B1–O2–C3 | −20.70 (0.23) | N6a–B1a–O2a–C4a | −18.81 (0.26) |
| C5–C3–O2–B1 | 9.01 (0.26) | B1a–O2a–C4a–C5a | 9.91 (0.30) |
| O2–C3–C5–N6 | 9.17 (0.25) | O2a–C4a–C5a–N6a | 5.11 (0.29) |
| C3–C5–N6–B1 | −20.56 (0.21) | C4a–C5a–N6a–B1a | −15.32 (0.23) |
| O2–B1–N6–C5 | 24.28 (0.20) | O2a–B1a–N6a–C5a | 19.87 (0.22) |
| N6–B1–O10–C8 | −17.32 (0.24) | N6a–B1a–O10a–C8a | −10.87 (0.25) |
| C7–C8–O10–B1 | 5.86 (0.28) | C7a–C8a–O10a–B1a | −6.30 (0.29) |
| N6–C7–C8–O10 | 10.18 (0.26) | N6a–C7a–C8a–O10a | 22.48 (0.26) |
| C8–C7–N6–B1 | −18.91 (0.21) | C8a–C7a–N6a–B1a | −26.91 (0.23) |
| O10–B1–N6–C7 | 21.50 (0.20) | O10a–B1a–N6a–C7a | 22.81 (0.21) |
| C11–B1–N6–C17 | 25.76 (0.26) | C11a–B1a–N6a–C17a | 21.96 (0.28) |
| C12–C11–B1–N6 | −98.92 (0.27) | C12a–C11a–B1a–N6a | −79.95 (0.30) |

**Table 3**
Bond distances selected (Å) and torsion angles (°) for $C_{18}H_{16}BNO_5$ (**5**).

| | | | |
|---|---|---|---|
| *Bond distances (Å)* | | | |
| O2–B1 | 1.461 (2) | C1–C2 | 1.509 (3) |
| O3–B1 | 1.485 (2) | C3–C4 | 1.509 (2) |
| N1–B1 | 1.679 (2) | N1–C2 | 1.500 (2) |
| O2–C1 | 1.331 (2) | N1–C3 | 1.492 (2) |
| O3–C4 | 1.313 (2) | B1–C13 | 1.582 (2) |
| O1–C1 | 1.200 (2) | N1–C5 | 1.492 (2) |
| O4–C4 | 1.207 (2) | O5–C6 | 1.218 (2) |
| *Torsion angles (°)* | | | |
| B1–O2–C1–C2 | −3.09 (0.21) | B1–N1–C3–C4 | 24.94 (0.16) |
| O2–C1–C2–N1 | −14.41 (0.20) | C3–N1–B1–O3 | −26.94 (0.15) |
| B1–N1–C2–C1 | 22.61 (0.16) | C4–O3–B1–N1 | 20.27 (0.18) |
| C2–N1–B1–O2 | −23.81 (0.15) | C5–N1–B1–C13 | −29.22 (0.20) |
| C1–O2–B1–N1 | 17.04 (0.18) | C14–C13–B1–O2 | −15.04 (0.25) |
| B1–O3–C4–C3 | −5.63 (0.21) | C18–C13–B1–O3 | 34.17 (0.25) |
| N1–C3–C4–O3 | −14.22 (0.19) | C5–C6–C7–C8 | 8.57 (0.24) |

## 3. Conclusion

The new method for the synthesis of six (N → B) phenyl[N-alkyliminodiacetate-O,O′,N]boranes improved the yields, evade to use bases and avoid the use of anhydrous reaction conditions. Therefore, the identification of all compounds by NMR, their high resolution mass spectra (HRMS) data are reported, as well as the crystal structure of compounds **2**, **4** and **5** gives evidence of the N-alkylation of **1** and establish the bicyclic structures due to N → B coordination bond.

## 4. Experimental

### 4.1. General procedure and measurements

The reagents were purchased from Aldrich Co. (N → B) phenyl [iminodiacetate-O,O′,N]borane (**1**) was prepared as described previously [14]. $^1$H, $^{13}$C and $^{11}$B NMR spectra were recorded on a Jeol GLX-270, Jeol Eclipse-400 and Bruker Avance and 300-DPX spectrometers, DMSO-$d_6$ was used as solvent. The high resolution mass spectra (HRMS) were taken on Agilent Technologies, model LC/MSD-TOF spectrometer, coupled to HPLC 1100 with ESI as ionization source. Melting points were taken in open capillary tubes on a Gallenkamp MFB-595 apparatus and are uncorrected.

### 4.2. Preparation of compounds **2**–**7**

The procedure outlined below is general for the preparation of compounds **2**–**7**.

#### 4.2.1. Synthesis of (N → B) phenyl [N-benzyliminodiacetate-O,O′,N]borane (**2**)

A suspension of 0.80 g (3.65 mmol) of (N → B) phenyl[iminodiacetate-O,O′,N]borane **1**, 0.62 g (3.6 mmol) of benzyl bromide **a**, 0.62 g (3.65 mmol) and 1.11 g (10.95 mmol) of $KHCO_3$ in 100 ml of a mixture of acetonitrile/benzene (80/20) was placed into a 250 ml flask equipped with a magnetic stirrer and a Dean–Stark trap. The suspension was refluxed for 8 h. After being cooled to room temperature, the solution was filtered and $Na_2SO_4$ anhydrous was added to the solution, which was filtered and the solvent was evaporated under vacuum. The solid obtained was crystallized from dichloromethane/hexane to yield 0.68 g (61%) of compound **2** as a white crystals, mp 227 °C. $^1$H NMR $\delta$(DMSO-$d_6$, $J$ = Hz): $CH_2CO$ 4.40 ($H_A$, d, $J$ = 16.5), 3.90 ($H_B$, d, $J$ = 16.5), $CH_2N$ 3.80 (s), H aromatics 7.40–7.60 (m). $^{13}$C NMR: $C_1$169.10, $C_2$ 57.90, R group $C_3$ 60.80, $C_4$ 132.80, $C_{5,9}$ 128.90, $C_{6,8}$ 129.50, $C_7$ 127.60, B-Phenyl $C_o$ 131.60, $C_m$128.80, $C_p$130.60. $^{11}$B NMR: +12.50. HRMS: $C_{17}H_{17}BNO_4$ $[M^+ + 1]^+$ Calc. 310.1245, found 310.1249, error 1.2415.

#### 4.2.2. Synthesis of (N → B) phenyl[N-(3-methyl)benzyliminodiacetate-O,O′,N]borane (**3**)

Prepared from 1.0 g (4.56 mmol) of compound **1**, 0.84 (4.56 mmol) of 3-methylbenzyl bromide **b** and 1.39 g (13.7 mmol) of $KHCO_3$ in 120 ml of acetonitrile. The residue was crystallized from a mixture of dichloromethane/ether, 0.59 g (40%) of compound **4** were obtained as white solid, mp 251 °C $^1$H NMR $\delta$(DMSO-$d_6$, $J$ = Hz), $CH_2CO$ 4.05 ($H_A$, d, $J$ = 16.57), 3.45 ($H_B$, d, $J$ = 16.57), $CH_2N$ 3.55 (s), $CH_3$ 2.34 (s), H aromatics 7.0–7.24 (m), 7.40–7.62 (m). $^{13}$C NMR: $C_1$ 167.9, $C_2$ 57.8, R group $C_3$ 61.9, $C_4$ 141.1, $C_5$ 130.5, $C_6$ 132.6, $C_7$ 125.7, $C_8$ 128.5, $C_9$ 129.9, $C_{10}$ 21.6, B-Phenyl $C_o$ 135.7, $C_m$128.1, $C_p$130.9. $^{11}$B NMR: +11.38. HRMS: $C_{18}H_{19}BNO_4$ $[M^+ + 1]^+$ Calc. 324.1401, found 324.1400, error −0.5091.

#### 4.2.3. Synthesis of (N → B) phenyl[N-(4-methyl)benzyliminodiacetate-O,O′,N]borane (**4**)

Prepared from 1.0 g (4.56 mmol) of compound **1**, 0.62 (4.56 mmol) of 4-methylbenzylbromide **c** and 1.39 g (13.7 mmol) of $KHCO_3$ in 120 ml of acetonitrile. The residue was crystallized from a mixture of dichloromethane/ether, 1.10 g (75%) of compound **5** were obtained as white crystals, mp 187–189 °C. $^1$H NMR $\delta$(DMSO-$d_6$, $J$ = Hz), $CH_2CO$ 4.05 ($H_A$, d, $J$ = 16.5), 3.47 ($H_B$, d, $J$ = 16.5), $CH_2N$ 3.65 (s), $CH_3$ 2.36 (s), H aromatics 7.42–7.61 (m), 7.21($H_{5,9}$, d, $J$ = 7.9), 7.09 ($H_{6,8}$ d, $J$ = 7.9), $^{13}$C NMR: $C_1$ 167.5, $C_2$ 58.1, R group $C_3$ 60.9, $C_4$ 139.9, $C_{5,9}$ 129.1, $C_{6,8}$ 127.4, $C_7$ 128.8, $C_{10}$ 20.9, B-Phenyl $C_o$ 132.9, $C_m$ 127.6, $C_p$128.7. $^{11}$B NMR: +11.78. HRMS: $C_{18}H_{19}BNO_4$ $[M^+ + 1]^+$ Calc. 324.1401, found 324.1400, error −0.5091.

#### 4.2.4. Synthesis of N → B) phenyl [N-phenacyliminodiacetate-O,O′,N]borane (**5**)

Among of 1.0 g (4.56 mmol) of compound **1**, 0.9 g (4.56 mmol) of phenacyl bromide **d** and 1.39 g (13.7 mmol) of $KHCO_3$ in 100 ml of a mixture of acetonitrile/benzene (80/20). The residue was dissolved from a mixture of dichloromethane/acetonitrile and precipitate with ether to produce 1.04 g (67.5%) of compound **6** were obtained as white crystals. mp 254–255 °C. $^1$H NMR $\delta$(DMSO-$d_6$, $J$ = Hz): $CH_2CO$ 4.60 ($H_A$, d, $J$ = 17.38), 4.34 ($H_B$, d, $J$ = 17.38), $CH_2N$ 4.53 (s), H aromatics 7.40–7.60 (m), 7.54 ($H_{7,9}$, t, $J$ = 7.0), 7.63 ($H_8$, t, $J$ = 7.0). $^{13}$C NMR: $C_1$ 170.37, $C_2$ 61.31, R group $C_3$ 65.51, $C_4$ 193.10, $C_5$ 134.81, $C_{6,10}$ 129.38, $C_{7,9}$ 127.98, $C_8$ 134.65. B-Phenyl $C_o$ 133.13, $C_m$128.29, $C_p$129.66. $^{11}$B NMR: +11.61. HRMS: $C_{18}H_{17}BNO_5$ $[M^+ + 1]^+$ Calc. 338.1194, found 338.1188, error −1.8620.

#### 4.2.5. Synthesis of N → B) phenyl[N-(4-chloro) phenacyliminodiacetate-O,O′,N]borane (**6**)

Among of 1.0 g (4.56 mmol) of compound **1**, 1.06 g (4.56 mmol) of 2-bromo-4′-chloroacetophenone **e** and 1.39 g (13.7 mmol) of $KHCO_3$ in 100 ml of a mixture of acetonitrile/benzene (80/20). The residue was dissolved from a mixture of dichloromethane/acetonitrile and precipitate with ether to produce 1.19 g (73.5%) of compound **7** were obtained as white crystals, mp 226–227 °C. $^1$H NMR $\delta$(DMSO-$d_6$, $J$ = Hz): $CH_2CO$ 4.59 ($H_A$, d, $J$ = 17.4), 4.33 ($H_B$, d, $J$ = 17.4), $CH_2N$ 4.51 (s), H aromatics 7.39–7.46 (m), 7.56 ($H_{6,10}$, d, $J$ = 8.7), 7.54 ($H_{7,9}$, d, $J$ = 8.7). $^{13}$C NMR: $C_1$ 170.59, $C_2$ 61.57, R group $C_3$ 65.60, $C_4$ 192.60, $C_5$ 139.79, $C_{6,10}$ 130.17, $C_{7,9}$ 129.86, $C_8$ 133.88, B-Phenyl $C_o$133.88, $C_m$128.61, $C_p$129.98. $^{11}$B NMR: +12.38. HRMS: $C_{18}H_{16}BNO_5Cl$ $[M^+ + 1]^+$ Calc. 372.0804, found 372.0808, error 0.9210.

*4.2.6. Synthesis of N → B) phenyl[N-(4-phenyl)phenacylimino diacetate-O,O',N]borane (**7**)*

Among of 1.0 g (4.56 mmol) of compound **1**, 1.25 g (4.56 mmol) of 2-bromo-4'-phenylacetophenone **f** and 1.39 g (13.7 mmol) of $KHCO_3$ in 100 ml of a mixture of acetonitrile/benzene (80/20). The residue was dissolved from a mixture of dichloromethane/acetonitrile and precipitate with ether to produce 1.52 g (80.8%) of compound **7** were obtained as yellow crystals, mp 248–249 °C. $^1$H NMR $\delta$(DMSO-$d_6$, $J$ = Hz): $CH_2CO$ 4.62 ($H_A$, d, $J$ = 17.5), 4.36 ($H_B$, d, $J$ = 17.5), $CH_2N$ 4.56 (s), H aromatics 7.41–7.49 (m), 7.62 ($H_6$, d, $J$ = 7.2), 7.81 ($H_7$ d, $J$ = 7.2), 7.72 ($H_{10}$, d), 7.49 ($H_{11,12}$ 7.49 m) $^{13}$C NMR: $C_1$170.68, $C_2$ 61.67, R group $C_3$ 65.84, $C_4$ 192.94, $C_5$ 146.15, $C_6$ 127.76, $C_7$ 128.03, $C_8$ 139.29, $C_9$ 129.51, $C_{10}$ 127.85, $C_{11}$ 129.98, $C_{12}$ 133.91. B-Phenyl $C_o$133.46, $C_m$128.61, $C_p$129.51. $^{11}$B NMR: +12.92. HRMS: $C_{24}H_{21}BNO_5$ $[M^+ + 1]^+$ Calc. 414.1507, found 414.1509, error 0.4110.

*4.3. Crystal structure determination of compounds **2**, **4** and **5***

Diffraction data from compound **2** were collected on an Enraf-Nonius CCD diffractometer at 293 K. Compound **2** with two independent molecules, $C_{17}H_{16}BN\,O_4$ (MW 309.12) crystallized in the space group $P\,2_1/n$, monoclinic; from dichloromethane/hexane as white colourless block, size 0.3 × 0.2 × 0.1 mm$^3$ with $a$ = 10.934 (2), $b$ = 16.927 (4), $c$ = 17.100 (3) Å, $V$ = 3111.0 Å (1)$^3$, $\alpha$ = 90.00°, $\beta$ = 100.58 (10)°, $\gamma$ = 90.00°, $\rho$ = 1.320 mg/m$^3$, $Z$ = 8, $\mu$ = 0.093 mm$^{-1}$, $F$(0 0 0) = 1296. Data collection: a total of 12763 reflections were measured, 6988 were independent and of these 4544 were considered observed [$F_o > 4.0\sigma(F_o)$]. Solution and refinement: direct methods, all non hydrogen atoms were refined anisotropically, $R$ = 0.0499, $Rw$ = 0.1174, $w = 1/\sigma^2$, GOF = 1.017, largest residual electron density peak/hole in the final difference map: 0.185/−0.281 eÅ$^{-3}$.

Compound **4** with two independent molecules, $C_{18}H_{18}BNO_4$ (MW 323.14) crystallized in the space group $P\,2_1/c$, monoclinic; from dichloromethane/ether as white colourless block, size 0.3 × 0.2 × 0.1 mm$^3$ with $a$ = 11.2761 (4), $b$ = 20.2614 (11), $c$ = 15.2577 (6) Å, $V$ = 3485.9 (3) Å$^3$, $\alpha$ = 90.00°, $\beta$ = 89.953 (1)°, $\gamma$ = 90.00°, $\rho$ = 1.231 mg/m$^3$, $Z$ = 8, $\mu$ = 0.086 mm$^{-1}$, $F$(0 0 0) = 1360. Data collection: a total of 19902 reflections were measured, 7054 were independent and of these 3803 were considered observed [$F_o > 4.0\sigma(F_o)$]. Solution and refinement: direct methods, all non hydrogen atoms were refined anisotropically, $R$ = 0.0602, $Rw$ = 0.1432, $w = 1/\sigma^2$, GOF = 1.040, largest residual electron density peak/hole in the final difference map: 0.296/−0.342 eÅ$^{-3}$.

Compound **5**, $C_{18}H_{16}BNO_5$ (MW 337.13) crystallized in the space group $P\,2_1/c$, monoclinic; from dichloromethane/ether as white colourless block size 0.3 × 0.3 × 0.2 mm$^3$ with $a$ = 7.14030 (10), $b$ = 18.7329 (5), $c$ = 12.3949 (3) Å, $V$ = 1645.10 (6) Å$^3$, $\alpha$ = 90.00°, $\beta$ = 97.130 (1)°, $\gamma$ = 90.00°, $\rho$ = 1.361 mg/m$^3$, $Z$ = 4, $\mu$ = 0.099 mm$^{-1}$, $F$(0 0 0) = 704. Data collection: a total of 6705 reflections were measured, 3719 were independent and of these 2324 were considered observed [$F_o > 4.0\sigma(F_o)$]. Solution and refinement: direct methods, all non hydrogen atoms were refined anisotropically, $R$ = 0.0430, $Rw$ = 0.1497, $w = 1/\sigma^2$, GOF = 0.716, largest residual electron density peak/hole in the final difference map: 0.188/−0.168 eÅ$^{-3}$.

Data reduction and molecular graphics were performed by WINGX program set [23]. All calculations were carried out with SHELX-S-97 and SHELX-L-97 [24]. Atomic scattering factors were taken from the International Tables for X-ray crystallography [25].

## Supplementary data

CCDC 714540, 714541 and 714542 contains the supplementary crystallographic data for compounds **2**, **4** and **5**, respectively. These data can be obtained free of charge via http://www.ccdc.cam.ac.uk/conts/retrieving.html, or from the Cambridge Crystallographic Data Centre, 12 Union Road, Cambridge CB2 1EZ, UK; fax: (+44) 1223-336-033; or e-mail: deposit@ccdc.cam.ac.uk.

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## References

[1] G.J. Baum, J. Organomet. Chem. 22 (1970) 269.
[2] S.H. Tung, K.M. Chang, S.L. Tah, S.L. Liu, S.L. Chang, Chem. Abstr. 66 (1967) 37990m.
[3] R. Csuk, H. Hönig, H. Weidmann, H.K. Zimmerman, Arch. Pharm. 317 (1984) 336.
[4] M.C. Miller III, A. Sood, B.F. Spielvogel, I.H. Hall, Anticancer Res. 17 (1997) 3299.
[5] S. Karthikeyan, A. Sood, J. Tomas, B.F. Spielvogel, I.H. Hall, Amino Acids 8 (1995) 323.
[6] C.A. Perks, A.J. Mill, G. Constantine, K.G. Harrison, J.A. Gibson, Br. J. Radiol. 61 (1988) 1115.
[7] H. Nemoto, J. Cai, N. Asao, J. Med. Chem. 38 (1995) 1673.
[8] J.P. Pignol, J.C. Abbe, O. Lefebvre, A. Stampfler, G. Methlin, J.C.R. Sahel, Acad. Sci. III 317 (1994) 543.
[9] T. Mancilla, S.L. Gálvez, Main Group Met. Chem. 15 (1992) 9.
[10] T. Mancilla, Ma.L. Alarcón, L. Carrillo, Heteroatom Chem. 15 (1994) 455.
[11] T. Mancilla, L. Carrillo, Ma.P. Reducindo, Polyhedron 15 (1996) 3777.
[12] G. Shtacher, W. Taub, J. Med. Chem. 9 (1966) 197.
[13] T. Mancilla, L. Carrillo, L.S. Zamudio Rivera, C. Camacho Camacho, D. de Vos, R. Kiss, F. Darro, B. Mahieu, E.R.T. Tiekink, H. Rahier, M. Gielen, M. Kemmer, M. Biesemans, R. Willem, Appl. Organomet. Chem. 15 (2001) 593.
[14] T. Mancilla, R. Contreras, B. Wrackmeyer, J. Organomet. Chem. 307 (1986) 1.
[15] T. Mancilla, R. Contreras, J. Organomet. Chem. 321 (1987) 191.
[16] N. Farfán, T. Mancilla, D. Castillo, G. Uribe, L. Carrillo, P. Joseph-Nathan, R. Contreras, J. Organomet. Chem. 381 (1990) 1.
[17] T. Mancilla, H. Höpfl, G. Bravo, L. Carrillo, Main Group Met. Chem. 20 (1997) 31.
[18] H.I. Beltrán, L.S. Zamudio Rivera, T. Mancilla, R. Santillán, N. Farfán, J. Oganomet. Chem. 657 (2002) 194.
[19] T. Mancilla, L.S. Zamudio Rivera, H.I. Beltrán, R. Santillán, N. Farfán, Arkivoc Part (IV) (2005) 366.
[20] T. Mancilla, M.A. Calixto-Romo, L. Amaya-Delgado, Polyhedron 26 (2007) 1023.
[21] T. Mancilla Percino, M. López Martínez, J.L. León, NPC 3 (2008) 329.
[22] A. Bondi, J. Phys. Chem. 68 (1964) 441.
[23] L.J. Farrugia, Department of Chemistry, University of Glasgow, UK, 2000.
[24] G.M. Sheldrick, SHELX-97, Program for Crystal Structure Solution, University of Göttingen, Germany, 1993.
[25] D.T. Cromer, I.T. Waber, International Tables for X-ray crystallography, vol. 4, Kynoch Press, England, 1974.