Synthesis of substituted 2$\lambda^4\delta^2$-[1,2,3]thiadiazolo[3,4-*c*]benzimidazoles and 2$\lambda^4\delta^2$-[1,2,3,5]thiatriazolo[3,4-*c*]benzimidazoles

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Abstract

Electrophilic substitution reactions in [1,2,3]thiadiazolo[3,4-*c*]benzimidazoles and [1,2,3,5]thiatriazolo[3,4-*c*]benzimidazoles and the cyclisation reactions of 5(6)-substituted *N*-aminobenzimidazol-2-ylmethanols were investigated. Bromo-, dibromo-, nitro-, dinitro-, and methoxy-substituted [1,2,3]thiadiazolo[3,4-*c*]benzimidazole and [1,2,3,5]thiatriazolo[3,4-*c*]benzimidazole derivatives were synthesized.

Keywords: [1,2,3]Thiadiazolo[3,4-*c*]benzimidazole, [1,2,3,5]thiatriazolo[3,4-*c*]benzimidazole, electrophilic substitution, cyclisation

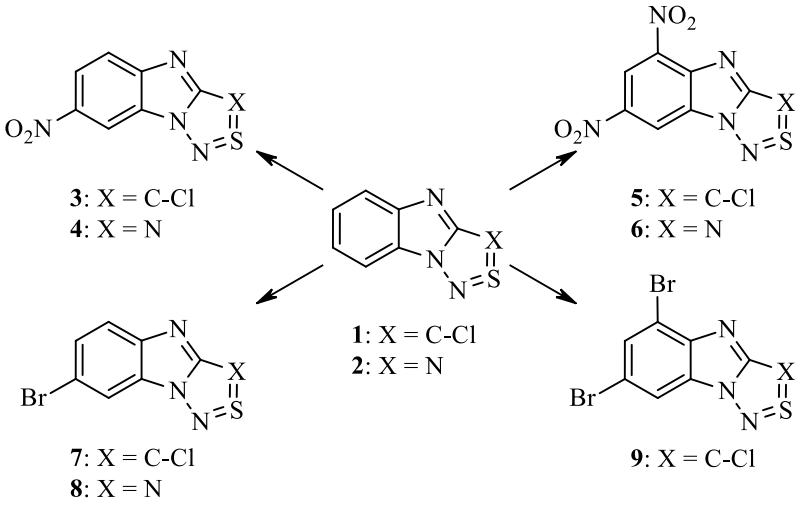
Introduction

1,2,3-Thiadiazoles are of substantial interest in medicinal chemistry for treatment of thromboses,[1] as antibacterials,[2-4] platelet-activating factors,[5] in agricultural chemistry as plant growth activators, and inducers of systemic acquired resistance (SAR) in plants.[6,7] 1,2,3-Thiadiazoles are also valuable as synthetic intermediates for substituted acetylenes,[8-10] thioamides,[11] 5-aryloxy(thio)-1,2,3-thiadiazoles[12] and other heterocyclic systems.[13] We have reported previously the synthesis of the first representatives of a fused heterocyclic system containing the 1,2,3-thiadiazole moiety – [1,2,3]thiadiazolo[3,4-*c*]benzimidazole.[14] The aim of this study is to investigate the synthesis and reactivity of 3-chloro[1,2,3]thiadiazolo[3,4-*c*]benzimidazole (**1**) and its aza-analog, [1,2,3,5]thiatriazolo[3,4-*c*]benzimidazole[15] (**2**), with substituents on the benzene ring.

Results and Discussion

It is known that compound **1** is unstable in basic medium and nucleophilic substitution often leads to decomposition of the thiadiazole ring.[14] To determine the properties of compounds **1** and **2,** and to investigate possibilities for the introduction of substituents into the benzene ring, electrophilic substitution reactions of 3-chloro[1,2,3]thiadiazolo[3,4-*c*]benzimidazole (**1**) and its [1,2,3,5]thiatriazole analog (**2**) have been studied.

We have found that nitration of compounds **1** and **2** (Scheme 1) at -4 °C in a mixture of fuming nitric acid and sulfuric acid afforded mononitro derivatives **3** and **4** in 42 and 48% yields, respectively (Method **A**).



Scheme 1

However, 3-chloro-7-nitro[1,2,3]thiadiazolo[3,4-*c*]benzimidazole (**3**) was obtained in better yield (83%) when the reaction was performed at 70-80 °C in a mixture of fuming nitric acid and trifluoroacetic acid (Method **B**). The nitration of **1** and **2** performed in a mixture of fuming nitric acid and sulfuric acid at 60-70 °C gave the 5,7-dinitro derivatives **5** and **6** as the sole products of the reaction in 71 and 67% yields, respectively.

Bromination reactions of compounds **1** and **2** were studied under different conditions (Table 1). The bromination reaction performed with bromine in acetic acid or in diluted sulfuric acid at 60 °C gave similar results: in both reactions, the 7-monobromo derivative **7** was formed in *ca*. 75% yield. The use of bromine in dioxane at room temperature afforded 7-bromo-3-chloro[1,2,3]thiadiazolo[3,4-*c*]benzimidazole (**7**) in 86% yield. 1,2,3,5-Thiatriazole **2** under the same bromination conditions gave the analogous 7-bromo derivative **8** in 69% yield. Reaction of compound **1** with bromine without solvent at room temperature led to a mixture of the monobromo derivative **7** and the 5,7-dibromo compound **9** in a ratio of 2:1 (according to the ^{1}H NMR spectra). All attempts to separate **7** from **9** using fractional crystallization or column

chromatography failed. The 5,7-dibromo derivative **9** was formed as the sole reaction product when compound **1** was refluxed in an excess of bromine for 16 h. Thus the method of choice for the synthesis of the monobromo derivatives appears to be the reaction of compounds **1** and **2** with bromine in dioxane at room temperature.

Table 1. Data of the bromination reactions of 3-chloro[1,2,3]thiadiazolo[3,4-*c*]benzimidazole (**1**) and [1,2,3,5]thiatriazolo[3,4-*c*]benzimidazole (**2**)

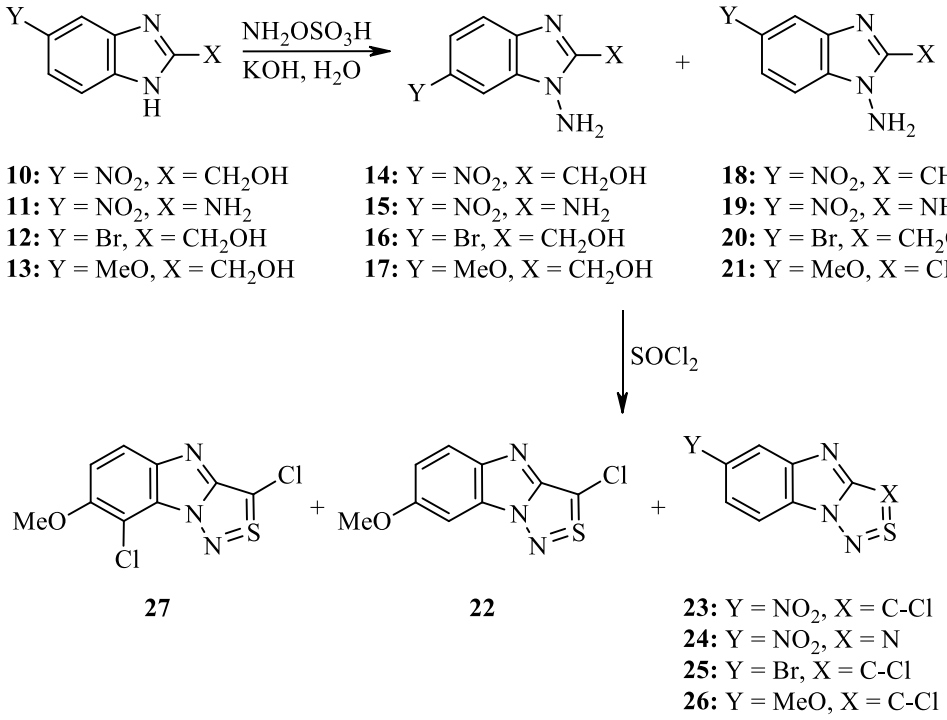
Initial compd.	Method (bromination conditions)	Reaction temperature (°C)	Reaction time (h)	Product yield (%)
1	Method **A** (Br_2/AcOH)	60	6	**7** (72)
1	Method **B** (Br_2/H_2SO_4, H_2O)	60	4	**7** (75)
1	Method **C** (Br_2/dioxane)	rt	4	**7** (86)
1	Method **D** (Br_2)	rt	10	**7** and **9**; 2/1
1	Method **D** (Br_2)	reflux	16	**9** (40)
2	Method **C** (Br_2/dioxane)	rt	16	**8** (69)

It should be noted that under mild conditions of nitration and bromination the electrophilic substitution took place only at position 7 of compounds **1** and **2**. The formation of other isomers was not observed. Compounds **1** and **2** did not undergo Friedel-Crafts acetylation because of the formation of practically insoluble complexes with aluminium chloride or tin tetrachloride.

It was also necessary to find synthetic methods for the preparation of [1,2,3]thiadiazolo[3,4-*c*]benzimidazoles and [1,2,3,5]thiatriazolo[3,4-*c*]benzimidazoles carrying substituents at other positions of the benzene ring. For this purpose, [5(6)-nitrobenzimidazol-2-yl]methanol (**10**),[16] 5(6)-nitrobenzimidazol-2-ylamine (**11**),[17] [5(6)-bromobenzimidazol-2-yl]methanol (**12**),[18] and [5(6)-methoxybenzimidazol-2-yl]methanol (**13**)[19] were used as starting materials (Scheme 2). Amination of compounds **10**-**13** with hydroxylamine-*O*-sulfonic acid at 40-50 °C afforded mixtures of the corresponding 1*H*-benzimidazolamines **14**-**21**. The substituent in the benzene ring had no influence on the site of N-amination. According to the ^{1}H NMR spectra the ratio of isomers **14** and **18**, **15** and **19**, **16** and **20**, **17** and **21** was always close to 1:1. The mixtures of 1-amino derivatives (**14** and **18**, **15** and **19**, **16** and **20**, **17** and **21)** appeared to be inseparable, either by column chromatography or fractional crystallization. Therefore, expecting that the cyclic products will have more distinct difference in physical properties, the pairs of isomers **14**-**21** were used in the reaction with thionyl chloride without prior separation. Thus, the 1-amino derivatives **14** and **18** reacted with thionyl chloride to give a 1:1 mixture of 3-chloro-7-nitro[1,2,3]thiadiazolo[3,4-*c*]benzimidazole (**3**) and 3-chloro-6-nitro[1,2,3]thiadiazolo[3,4-*c*]-benzimidazole (**23**), which was fractionated by chromatography. Similarly, compounds **15** and **19** reacted with thionyl chloride to give a mixture of 7-nitro- and 6-nitro-[1,2,3,5]thiatriazolo-[3,4-*c*]benzimidazoles (**4** and **24**), but these were inseparable by column chromatography or fractional crystallisation.

The bromo derivatives **16** and **20** reacted with thionyl chloride, giving a mixture of 7-bromo-3-chloro- and 6-bromo-3-chloro[1,2,3]thiadiazolo[3,4-*c*]benzimidazoles (**7** and **25**) which were separated chromatographically. Analytical data of compounds **7** and **25** were in agreement with those in ref. 18. The yield of compound **7** was significantly improved (86 *vs* 25% in ref. 18) by direct bromination of thiadiazole **1**, but we were unable to obtain a better yield of compound **25**.

The methoxy derivatives **17** and **21** gave the corresponding 3-chloro-7-methoxy- and 3-chloro-6-methoxy[1,2,3]thiadiazolo[3,4-*c*]benzimidazoles (**22** and **26**) and, in an unexpected reaction, the product of benzene ring chlorination – 3,8-dichloro-7-methoxy[1,2,3]thiadiazolo-[3,4-*c*]benzimidazole **27**. The usual yields of compounds **22**, **26**, and **27** were low because of their significant instability under the reaction conditions and the slow reaction of compounds **17** and **21** with thionyl chloride.



Scheme 2

Experimental Section

General. Melting points were determined in open capillaries. IR spectra were recorded in KBr on a Perkin-Elmer spectrophotometer model FT-IR Spectrum BX II. NMR spectra were recorded on Varian Unity Inova (300 MHz for ^{1}H NMR and 75 MHz for ^{13}C NMR). HRMS spectra were obtained on a mass spectrometer Dual-ESI Q-TOF 6520 (Agilent Technologies). The purity of compounds was monitored by TLC using silica gel 60 F_{254} aluminium plates (Merck).

3-Chloro-7-nitro-2$\lambda^4\delta^2$-[1,2,3]thiadiazolo[3,4-*c*]benzimidazole (**3**) and **7-nitro-2$\lambda^4\delta^2$-[1,2,3,5]thiatriazolo[3,4-*c*]benzimidazole (4)**

Method A. A mixture of conc. H_2SO_4 (0.9 g, 9.2 mmol) and 100% HNO_3 (0.4 g, 6.3 mmol) was cooled to -4 °C. Compound **1** (0.02 g, 0.095 mmol) or compound **2** (0.025 g, 0.14 mmol) was added and the reaction mixture was kept at –4 °C for 0.5 h, then poured onto ice and extracted (EtOAc). The organic layer was washed with H_2O and evaporated to dryness under reduced pressure. The obtained solid was crystallized to give compound **3** as fine yellow orange crystals (0.01 g, 42%), mp 207-208 °C (EtOAc) or compound **4** as fine red brown crystals (0.015 g, 48%), mp 246-247 °C (EtOAc).

Method B. Compound **1**, (0.1 g, 0.47 mmol) was added to a mixture of CF_3CO_2H (3 mL) and 100% HNO_3 (0.46 g, 7.3 mmol) and stirred at 70-80 °C for 8 h. CF_3CO_2H was evaporated under reduced pressure. H_2O (4 mL) was added to the residue. The obtained solid was filtered off and crystallized to give compound **3** as fine yellow orange crystals (0.1g, 83%), mp 207-208 °C (EtOAc).

Compound 3. ^{1}H NMR (DMSO-d_6): δ 7.96 (d, 1H, J = 9 Hz, 5-H), 8.42 (dd, 1H, J = 2 and 9 Hz, 6-H), 9.13 (d, 1H, J = 2 Hz, 8-H). ^{13}C NMR (DMSO-d_6): 106.8, 121.1, 121.9, 136.2, 140.2, 141.7, 155.7, 158.4. IR (ν, cm^{-1}): 1521, 1350 (NO_2). Anal. Calcd. for $C_8H_3ClN_4O_2S$ (254.654): C, 37.73; H, 1.19; N, 22.00. Found: C, 37.91; H, 1.13; N, 22.26%. HRMS: Calcd for $C_8H_4ClN_4O_2S$: 254.9744. Found: 254.9736.

Compound 4. ^{1}H NMR (DMSO-d_6): δ 8.03 (d, 1H, J = 9 Hz, 8-H), 8.47 (dd, 1H, J = 2 and 9 Hz, 7-H), 9.23 (d, 1H, J = 2 Hz, 5-H). ^{13}C NMR (DMSO-d_6): δ 111.2, 120.4, 123.0, 123.8, 139.9, 158.2, 165.8. IR (ν, cm^{-1}): 1542, 1347 (NO_2). Anal. Calcd. for $C_7H_3N_5O_2S$ (221.197): C, 38.01; H, 1.37; N, 31.66. Found: C, 38.36; H, 1.4; N, 31.86%. HRMS: Calcd for $C_7H_4N_5O_2S$: 222.0086. Found: 222.0088.

3-Chloro-5,7-dinitro-2$\lambda^4\delta^2$-[1,2,3]thiadiazolo[3,4-*c*]benzimidazole (**5**) and **5,7-dinitro-2$\lambda^4\delta^2$-[1,2,3,5]thiatriazolo[3,4-*c*]benzimidazole** (**6**)

Compound **1** (0.12 g, 0.57 mmol) or compound **2** (0.12 g, 0.68 mmol) was dissolved in a mixture of conc. H_2SO_4 (4.5 g) and 100% HNO_3 (2.0 g) and stirred at 60-70 °C for 6 h, then cooled to rt and poured onto ice. The obtained precipitate was filtered off and crystallized to give the nitro-compounds **5** or **6**.

Compound 5. Fine yellow crystals (0.12 g, 71%), mp 245-246 °C (DMF). ^{1}H NMR (DMSO-d_6): δ 9.16 (d, J = 2 Hz, 6-H), 9.52 (d, J = 2 Hz 8-H). ^{13}C NMR (DMSO-d_6): 109.5, 112.8, 139.4, 140.2, 145.1, 146.6, 153.2, 159.4. IR (ν, cm^{-1}): 1529, 1318 (NO_2). Anal. Calcd. for $C_8H_2ClN_5O_4S$ (299.651): C, 32.07; H, 0.67; N, 23.37. Found: C, 32.27; H, 0.57; N, 23.26%. HRMS: Calcd for $C_8H_3ClN_5O_4S$: 299.9594. Found: 299.9589.

Compound 6. Fine red brown crystals (0.12 g, 67%) mp 254-226 °C (DMF). ^{1}H NMR (DMSO-d_6): δ 9.19 (d, 1H, J = 2.4 Hz, H-7), 9.66 (d, 1H, J = 2.4 Hz, H-5). ^{13}C NMR (DMSO-d_6): 108.3, 112.4, 137.7, 138.6, 139.6, 146.9, 149.5. IR (ν, cm^{-1}): 1540, 1329 (NO_2). Anal. Calcd. for

$C_7H_2N_6O_4S$: C, 31.59; H, 0.76; N, 31.57. Found: C, 31.36; H, 0.8; N, 31.46% HRMS: Calcd for $C_7H_3N_6O_4S$: 266.9937. Found: 266.9938.

7-Bromo-3-chloro[1,2,3]thiadiazolo[3,4-*c*]benzimidazole (7)

Method A. Compound **1** (0.08 g, 0.38 mmol) and bromine (0.06 g 0.38 mmol) in AcOH (3 mL) were heated at 60 °C for 6 h and then cooled. The precipitate that formed was filtered off, washed with H_2O, aqueous Na_2CO_3 and Na_2SO_3 solutions, and crystallized to give compound **7** (0.08 g, 72%).

Method B. compound **1** (0.03 g, 0.14 mmol) and bromine (0.02g, 0.38 mmol) in H_2SO_4 (0.6 mL) and H_2O (0.8 mL) were heated at 60 °C for 6 h and then cooled. The obtained precipitate was filtered off, washed with H_2O, aqueous Na_2CO_3 and Na_2SO_3 solutions and crystallized to give compound **7** (0.03 g, 75%).

Method C. Solutions of compound **1** (0.2 g, 0.95 mmol) in dioxane (5 mL) and bromine (0.15 g, 0.95 mmol) in dioxane (3 mL) were combined and stirred at rt for 4 h. The precipitate was filtered off, washed with H_2O, aqueous Na_2CO_3 and Na_2SO_3 solutions and crystallized to give compound **7** (0.24 g, 86%).

Method D. A mixture of bromine (3 mL) and compound **1** (0.04 g, 0.19 mmol) was kept at rt for 10 h and evaporated under reduced pressure. The solid residue was washed with H_2O, aqueous Na_2CO_3 and Na_2SO_3 solutions to give a mixture of compounds **7** and **9** (2:1).

Compound **7**: fine orange brown crystals mp 193-194 °C (MeOH). ^{1}H NMR (DMSO-d_6): δ 7.71 (dd, 1H, J = 2 and 9 Hz, 6-H), 7.81 (dd, 1H, J = 0.3 Hz, and 9 Hz, 5-H), 8.47 (dd, 1H, J = 1 Hz and 2 Hz, 8-H). ^{13}C NMR (DMSO-d_6): δ 112.8, 116.2, 123.0, 126.6, 129.4, 131.7, 151.7, 152.5. IR (ν, cm^{-1}): 3042, 3030 (CH). Anal. Calcd. for $C_8H_3BrClN_3S$ (288.552): C, 33.30; H, 1.05; N, 14.56. Found: C, 33.56; H, 1.15; N, 14.63%. HRMS: Calcd for $C_8H_4BrClN_3S$: 287.8998. Found: 287.9001.

7-Bromo-2$\lambda^4\delta^2$-[1,2,3,5]thiatriazolo[3,4-*c*]benzimidazole (8). Compound **2** (0.04 g) was treated with bromine according to the method **C** used for compound **7** for 16 h to give compound **8** as fine red brown crystals (0.04 g, 69%), mp 145-146 °C (MeOH). ^{1}H NMR (DMSO-d_6): 7.79 (dd, 1H, J = 2 Hz, J = 9 Hz, 7-H), 7.89 (dd, 1H, J = 1 and Hz, 8-H), 8.42 (dd, 1H, J = 1 and 2 Hz, 5-H). ^{13}C NMR (DMSO-d_6): δ 113.0, 117.4, 122.9, 126.4, 132.05, 154.55, 163.4. IR (ν, cm^{-1}): 3045, 3038 (CH). Anal. Calcd. for $C_7H_3BrN_4S$ (255.096): C, 32.96; H, 1.19; N, 21.96. Found: C, 33.11; H, 1.29; N, 21.68%. HRMS: Calcd for $C_7H_4BrN_4S$: 254.9340. Found: 254.9346.

5,7-Dibromo-3-chloro-2$\lambda^4\delta^2$-[1,2,3]thiadiazolo[3,4-*c*]benzimidazole (9). A mixture of compound **1** (0.2 g, 0.95mmol) and bromine (3 mL) was refluxed for 16 h. An excess of bromine was evaporated at reduced pressure, the precipitate was filtered off, washed with H_2O, aqueous Na_2CO_3 and Na_2SO_3 solutions and crystallized from DMF to give compound **9** as fine orange brown crystals (0.07 g, 40%), mp 235-237 °C. ^{1}H NMR (DMSO-d_6): δ 8.05 (d, 1H, J = 2 Hz, ArH), 8.54 (d, 1H, J = 2 Hz, ArH). ^{13}C NMR (DMSO-d_6): 117.2, 122.5, 124.4, 135.0, 137.1, 138.2, 155.3, 166.0. IR (ν, cm^{-1}): 3051, 3034 (CH). Anal. Calcd. for $C_8H_2Br_2ClN_3S$ (367.448):

C, 26.15; H, 0.55; N, 11.44. Found: C, 26.20; H, 0.53; N, 11.65%. HRMS: Calcd for $C_8H_3Br_2ClN_3S$: 367.8083. Found: 367.8076.

(1-Amino-6-nitrobenzimidazol-2-yl)methanol (**14**) and **(1-amino-5-nitrobenzimidazol-2-yl)-methanol (18).** [5(6)Nitro-1*H*-benzimidazol-2-yl]methanol (**10**) (4.4 g, 23 mmol) and KOH (4.8 g) in water (40 mL) was treated with hydroxylamine-*O*-sulfonic acid (6.0 g, 53 mmol) in water (15 mL), neutralized with $NaHCO_3$ immediately before reaction. The reaction temperature was kept within 35-40 °C. After the exothermic reaction had ceased, the reaction mixture was heated to 40-50 °C for 0.5 h, then left overnight at rt. The obtained crystals were filtered off, washed with cold H_2O and recrystallized (EtOH) to give a mixture (1.6 g, 34%) of compounds **14** and **18** in 1:1 ratio. ^{1}H NMR (DMSO-d_6): δ 4.82 (2H, s, CH_2), 5.62 (1H, br. s, OH), 6.23 (2H, s, NH_2), 6.26 (2H, s, NH_2), 8.49 - 8.52 (2H, m, ArH), 7.6 - 8.3 (2H, m, ArH). ^{13}C NMR (DMSO-d_6): δ 55.3, 55.4, 106.9, 110.3, 115.2, 117.0, 117.8, 119.2, 135.2, 138.8, 140.3, 142.4, 142.6, 144.4, 158.8, 159.9. IR (ν, cm^{-1}): 3395, 3099, 3034, 1537, 1348 (OH, NH_2, NO_2). Anal. Calcd. for $C_8H_8N_4O_3$ (208.174): C 46.16; H 3.87; N 26.91. Found: C 46.07; H 3.81; 27.15%. HRMS: Calcd for $C_8H_9N_4O_3$: 209.06747. Found: 209.06746.

3-Chloro-7-nitro-2$\lambda^4\delta^2$-[1,2,3]thiadiazolo[3,4-*c*]benzimidazole (**3**) and **3-chloro-6-nitro-2$\lambda^4\delta^2$-[1,2,3]thiadiazolo[3,4-*c*]benzimidazole (23).** The mixture of compounds **14** and **18** (0.5 g, 2.4 mmol), obtained as above, was refluxed with $SOCl_2$ (5 mL) for 10 min. Excess of $SOCl_2$ was evaporated under reduced pressure, and the residue was treated with aqueous $NaHCO_3$. The resulting solid mixture (0.53 g, 86%) of **3** and **23** was filtered off and fractionated by chromatography. Compound **3** was identical with a sample synthesized by nitration of compound **1**.

Compound 23. Fine orange yellow crystals m. p. 227-228 °C (DMF), ^{1}H NMR (DMSO-d_6): δ 8.10 (dd, 1H, J = 2 and 9 Hz, 7-H), 8.43 (d, 1H, J = 9 Hz, 8-H), 8.65 (d, 1H, J = 2 Hz, 5-H). ^{13}C NMR (DMSO-d_6): 114.4, 117.9, 123.8, 136.6, 142.5, 146.9, 151.4, 157.9. IR (ν, cm^{-1}): 1535, 1353 (NO_2). Anal. Calcd. for $C_8H_3ClN_4O_2S$ (254.654): C, 37.73; H, 1.19; N, 22.00. Found: C 37.44; H 1.55; N 22.28%. HRMS: Calcd for $C_8H_4ClN_4O_2S$: 254.9744. Found: 254.9738.

5-Nitro-1*H*-benzimidazole-1,2-diamine (**15**) and **6-nitro-1*H*-benzimidazole-1,2-diamine (19).** A solution of 5(6)-nitro-1*H*-benzimidazol-2-amine (**11**) (7.12 g, 40 mmol) and KOH (5 g) in H_2O (50 mL) was treated with hydroxylamine-*O*-sulfonic acid (8 g) in H_2O (15 mL) neutralized with $NaHCO_3$ immediately before reaction. The reaction temperature was kept within 40-50 ºC. After the exothermic reaction had ceased, the mixture was heated to 40-50 °C for 3 h, then cooled to rt and left overnight. Crystals that separated were filtered off, washed with cold H_2O and recrystallized (EtOH) to give a 1:1 mixture (6.7 g, 87%) of compounds **15** and **19**. ^{1}H NMR (DMSO-d_6): δ 6.83 (4H, s, NH_2), 7.07 (4H, s, NH_2), 7.17 (1H, d, J = 9 Hz, ArH) 7.22 (1H, d, J = 9 Hz, ArH), 7.80-8.00 (4H, m, ArH). ^{13}C NMR (DMSO-d_6): δ 103.0, 106.6, 109,71, 113.7, 114.8, 117.7, 134.6, 138.6, 140.1, 140.3, 141.7, 147.2, 158.0, 159.4. IR (ν, cm^{-1}): 3109, 3120, 3085, 3031 (NH_2). Anal. Calcd. for $C_7H_7N_5O_2$ (193.163): C 43.53, H 3.65, N 36.26. Found: C 43.37, H 3.81, N 36.15%. HRMS: Calcd for $C_7H_8N_5O_2$: 194.0678. Found: 194.0682.

7-Nitro-2$\lambda^4\delta^2$-[1,2,3,5]thiatriazolo[3,4-*c*]benzimidazole (**4**) and **6-nitro-2$\lambda^4\delta^2$-[1,2,3,5]thiatriazolo[3,4-*c*]benzimidazole (24).** The mixture (0.1 g, 0.52 mmol) of 5- and 6-nitro-1*H*-benzimidazole-1,2-diamines obtained as above was refluxed in $SOCl_2$ (10 mL) for 10 h. Excess $SOCl_2$ was evaporated *in vacuo*, and the residual crystalline solid was treated with Na_2CO_3 solution, extracted (EtOAc) and fractionated by column chromatography. The usual yield of the mixture of compounds **4** and **24** (1:1) obtained in this way was 0.03 g (30%). Compound **4**: ^{1}H NMR (DMSO-d_6): δ 8.02 (1H, d, J = 9Hz, 5-H), 8.47 (1H, dd, J= 2 and 9Hz, 6-H), 9.21 (1H, d, J = 2Hz, 8-H). ^{13}C NMR (DMSO-d_6): δ 111.3, 120.4, 123.0, 123.8, 140.0, 158.2, 165.8. Compound **24**: ^{1}H NMR (DMSO-d_6): δ 8.54 (1H, d, J = 9 Hz, 8-H), 8.10 (1H, dd, J = 2 and 9 Hz, 7-H), 8.74 (1H, d, J = 2 Hz, 5-H), ^{13}C NMR (DMSO-d_6): δ 114.9, 115.0, 116.2, 128.1, 146.5, 153.3, 164.6. IR (ν, cm^{-1}): 1552, 1545, 1351, 1329 (NO_2). Anal. Calcd. for $C_7H_3N_5O_2S$ (221.197): C 38.01, H 1.37, N 31.66. Found: C 38.24, H 1.13, N 31.74%. HRMS: Calcd for $C_7H_4N_5O_2S$: 222.0086. Found: 222.0081.

(1-Amino-6-bromo-1*H*-benzimidazol-2-yl)methanol (**16**) and **(1-amino-5-bromo-1*H*-benzimidazol-2-yl)methanol (20).** A solution of [5(6)-bromo-1*H*-benzimidazol-2-yl]methanol (**12**) (5.2 g, 22.7 mmol) and KOH (5 g) in H_2O (40 mL) was treated with hydroxylamine-*O*-sulfonic acid (6 g) in H_2O (15 mL) neutralized with $NaHCO_3$ immediately before reaction. The reaction temperature was kept below 40 °C. After the exothermic reaction had ceased, the reaction mixture was heated to 40-50 °C for 0.5 h and then cooled to rt. The obtained crystals were filtered off, washed with cold H_2O and crystallized from H_2O to give a 1:1 mixture (3.7 g, 67%) of compounds **16** and **20**. IR (ν, cm^{-1}): 3350, 3313, 3184, 3120 (NH_2). ^{1}H NMR (DMSO-d_6): δ 4.73 (4H, s, CH_2), 5.43 (1H, s, OH), 5.45 (1H, s, OH), 6.01 (2H, s, NH_2), 6.03 (2H, s, NH_2), 7.31 (1H, d, J = 9 Hz, ArH), 7.39 (1H, d, J = 9 Hz, ArH), 7.46 (1H, d, J = 9 Hz, ArH), 7.53 (1H, d, J = 9 Hz, ArH), 7.67 (1H, s, ArH), 7.73 (1H, s, ArH). ^{13}C NMR (DMSO-d_6): δ 55.8, 112.5, 113.5, 114.2, 115.0, 121.5, 122.0, 124.9, 125.4, 135.7, 137.8, 139.6, 141.9, 156.2, 156.5. IR (ν, cm^{-1}): 3350, 3313, 3184, 3120 (OH, NH_2). Anal. Calcd. for $C_8H_8BrN_3O$ (242.073): C 39.67, H 3.31, N 17.36. Found: C 39.88, H 3.52, N 17.46%. HRMS: Calcd for $C_8H_9BrN_3O$: 241.9929. Found: 241.9926.

(1-Amino-6-methoxy-1*H*-benzimidazol-2-yl)methanol (**17**) and **(1-amino-5-methoxy-1*H*-benzimidazol-2-yl)methanol (21).** [5(6)-Methoxy-1*H*-benzimidazol-2-yl]methanol (**13**) (5 g, 28 mmol) was treated with a neutralized solution of hydroxylamine-*O*-sulfonic acid as described above for compound **12**. The obtained solid was crystallized from H_2O to give a 1:1 mixture (3.7 g, 65%) of compounds **17** and **21**. ^{1}H NMR (DMSO-d_6): δ 3.78 (3H, s, OCH_3), 3.81 (3H, s, OCH_3), 4.68 (4H, d, J = 6 Hz, CH_2), 5.36 (2H, t, J = 6 Hz, OH), 5,91 (4H, s, NH_2), 6.6-7.54 (6H, m, ArH). ^{13}C NMR (DMSO-d_6): δ 52.6, 55.2, 55.2, 57.7, 93.1, 101.4, 110.2, 110.9, 111.6, 119.5, 130,4, 134.0, 136.5, 140.4, 153.5, 154.4, 155.3, 155.8. IR (ν, cm^{-1}): 3358, 3322, 3191, 3131 (OH, NH_2). Anal. Calcd. for $C_9H_{11}N_3O_2$ (193.203): C 55.74, H 5.74, N 21.75. Found: C 55.82, H 5.64, N 21.86%. HRMS: Calcd for $C_9H_{12}N_3O_2$: 194.0930. Found: 194.0927.

3-Chloro-7-methoxy-2$\lambda^4\delta^2$-[1,2,3]thiadiazolo[3,4-*c*]benzimidazole (22), 3-chloro-6-methoxy-2$\lambda^4\delta^2$-[1,2,3]thiadiazolo[3,4-*c*]benzimidazole (26) and 3,8-dichloro-7-methoxy-2$\lambda^4\delta^2$-[1,2,3]-

thiadiazolo[3,4-*c*]benzimidazole (27). The mixture of compounds **17** and **21** (0.2 g, 1.04 mmol) was refluxed with $SOCl_2$ (5 mL) for 0.5 h, and then evaporated under reduced pressure. The residue was treated with aqueous $NaHCO_3$ solution and fractionated by column chromatography [R_f (toluene/EtOAc, 2:1) for compounds **26**, **22** and **27** are 0.2, 0.26 and 0.35, respectively].

Compound 22. Fine orange crystals 0.04 g (16□), dec. >147 °C. ^{1}H NMR ($CDCl_3$): δ 3.93 (3H, s, OCH_3), 7.26 (1H, dd, J = 2 and 9Hz, 6-H), 7.44 (1H, d, J = 2Hz, 8-H), 7.81 (1H, d, J = 9Hz, 5-H). ^{13}C NMR ($CDCl_3$): δ 56.2, 93.4, 121.2, 122.4, 125.3, 128.8, 150.0, 150.2, 155.3. IR (ν, cm^{-1}): 1265 (C-O). Anal. Calcd. for $C_9H_6ClN_3OS$ (239.682): C 45.10, H 2.52, N 17.53. Found: C 45.35, H 2.64, N 17.59%. HRMS: Calcd for $C_9H_7ClN_3OS$: 239.9998. Found: 240.0003.

Compound 26. Fine orange crystals 0.02 g (8□), dec. >180 °C, ^{1}H NMR ($CDCl_3$): δ 3.95 (3H, s, OCH_3), 6.97 (1H, dd, J = 2 and 9 Hz, 7-H), 7.24 (1H, d, J = 2 Hz, 5-H), 8.00 (1H, d, J = 9 Hz, 8-H). ^{13}C NMR ($CDCl_3$): δ 55.9, 100.6, 113.7, 113.8, 123.4, 124.2, 151.1, 156.4, 161.1. IR (ν, cm^{-1}): 1257 (C-O). Anal. Calcd. for $C_9H_6ClN_3OS$ (239.682): C 45.10, H 2.52, N 17.53. Found: C 45.21, H 2.49, N 17.68%. HRMS: Calcd for $C_9H_7ClN_3OS$: 239.9998. Found: 240.0001.

Compound 27. fine orange crystals 0.04 g (14□), m. p. 195-197 °C. ^{1}H NMR ($CDCl_3$): δ 4.07 (3H, s, OCH_3), 7.08 (1H, d, J = 9 Hz, 7-H), 8.02 (1H, d, J = 9 Hz, 8-H). ^{13}C NMR ($CDCl_3$): δ 57.5, 107.9, 111.1, 111.7, 125.1, 125.3, 152.0, 152.9, 155.8. IR (ν, cm^{-1}): 1268 (C-O). Anal. Calcd. for $C_9H_5Cl_2N_3OS$ (274.127): C 39.43, H 1.84, N 15.33. Found: C 39.58, H 2.07, N 15.65%. HRMS: Calcd for $C_9H_6Cl_2N_3OS$: 273.9609. Found: 273.9603.

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