Some Nitro Derivatives of 1,4-Benzodioxino[2,3-*b*]pyridine. Crystal and Molecular Structure of 2,7,8-Trinitro-1,4-benzodioxino[2,3-*b*]pyridine

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The electrophilic nitration of 1,4-benzodioxino[2,3-*b*]pyridine **1** with nitric acid in sulfuric acid has been studied. Some of the products of nitration including 7- and 8-nitro derivatives **2a** and **2b**, respectively, 7,9-, 7,8- and 6,8-dinitro derivatives **3a**, **3b** and **3c**, respectively, and 2,7,8-trinitro derivative **4** have been isolated and characterized. The structure of isomers have been assigned for derivatives **3b** and **4** while tentative structures have been proposed for the other products. The cyclopentadienyliron complex of **1** gives the same reaction products under similar conditions while for some other milder nitrating reagents no reaction was observed. 2,7,8-Trinitro-1,4-benzodioxino[2,3-*b*]pyridine **4** crystallizes in the monoclinic system, space group $P2_1/c$; the dihedral angle between the planes of outer rings was found to be 174.65(8) degrees. The planes of the nitro groups have been found to be rotated with respect to the appropriate pyridine and benzene ring planes by 11.13(11) degrees for the 2-nitro group and 47.56(9) and 29.80(9) degrees for the 7-nitro and 8-nitro groups, respectively.

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In the course of our study on the synthesis and reactivity of unsymmetrical 1,4-benzodioxins and related systems we have communicated recently some of the results on the electrophilic reactions of benzo[*b*]naphtho[2,3-*e*]-[1,4]dioxin [1] and 1,4-benzodioxin-2(3*H*)-one [2]. Another interesting system is the tricyclic 1,4-benzodioxino[2,3-*b*]pyridine **1** which was first reported by Butler [3]. He described the procedure for the synthesis of **1**, its [2,3-*c*] isomer and their *N*-oxides and claimed that such compounds can be used successfully in the treatment of senility and amnesia. The method of synthesis involved chlorination of 3-(2-methoxyphenoxy)pyridine 1-oxide with phosphorus oxychloride, separation of isomeric monochloro derivatives and cyclization of 2-chloro-3-(2-methoxyphenoxy)pyridine in anhydrous pyridine hydrochloride. Another synthesis presented recently by Lee and Denny gives **1** in the base catalyzed reaction of dichloropyridine with catechol in hexamethylphosphoramide [4]. An organometallic approach to this compound, which involves the reaction of (*o*-dichlorobenzene)-cyclopentadienyliron hexafluorophosphate and 2,3-dihydroxypyridine followed by a subsequent demetalation of the intermediate cyclopentadienyliron complex of **1** has been reported by Sutherland *et al.*[5].

Synthesis of two derivatives of **1** have also been described. Reaction of 2,3,4,5-tetrabromopyridine with potassium catecholate reported by Abele *et al.*, resulted in the formation of 2,3-dibromo-1,4-benzodioxino[2,3-*b*]-pyridine [6]. Another derivative, 1,2-dichloro-4-cyano-(1,4)-benzodioxino[2,3-*b*]pyridine has been prepared by Dainter *et al.* in the reaction of catechol with 2,3,5,6-tetrachloro-4-cyanopyridine [7].

Due to the biological activity of **1** and recent reports on the preparation of pharmacological agents based upon dibenzodioxin and related systems [8] we were interested in the examination of the reactivity of **1**. We have chosen nitration as a typical electrophilic reaction offering further possibilities in a synthesis of derivatives of **1** by transformation of nitro groups. It is expected that the selectivity of such a reaction may be poor since a number of structural isomers may be formed as has been observed in the case of a related system, benzo[*b*]naphtho[2,3-*e*]-[1,4]dioxin [1].

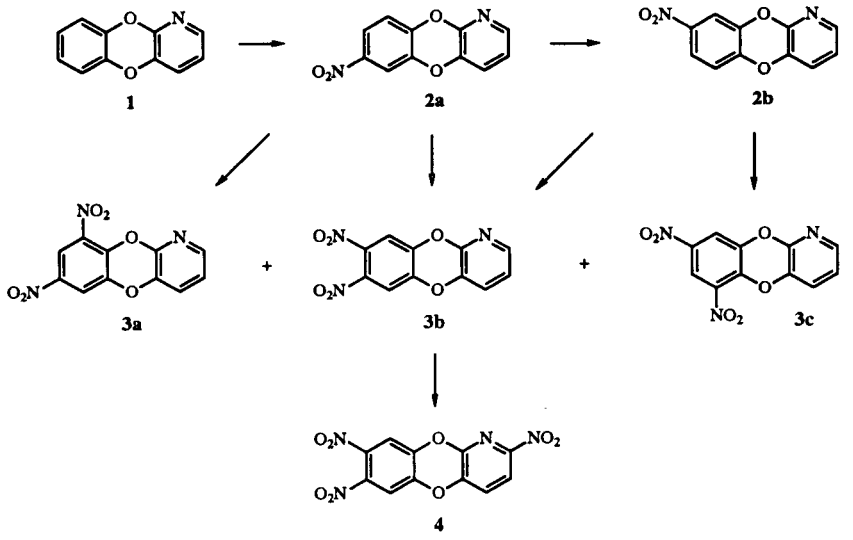
1,4-Benzodioxino[2,3-*b*]pyridine **1** was prepared using the method of Sutherland *et al.* [5]. Nitration of this compound using a mixture of nitric acid and sulfuric acid at 60° resulted in the formation of a number of nitrated derivatives of **1**. Both the temperature (ca. 100° was examined as well) and a ratio of heterocycle-nitric acid seem to have no significant influence on the outcome of the reaction. The only significant change was observed in the amount of unreacted heterocycle, which has been recovered from the reaction mixture even at a molar ratio 1:5. Judging by tlc results, the set of products remained unchanged in those attempts. Interestingly, similar results have been observed when a cyclopentadienyliron complex of **1** has been used in the reactions. It may be expected that in the presence of a strong oxidant such as nitric acid, the complex initially undergoes oxidative demetallation and heterocycle **1**, resulting from such a reaction is subsequently nitrated.

Some of the resultant nitro derivatives of **1** were isolated after repeated separations using plc and crystallization. The problems in the separation arise from the fact that solubility of nitro derivatives in solvent mixtures that enable a good separation on plates is poor. Therefore significant loss of compounds occurred during separation. We were able to isolate two mononitro derivatives, **2a** and

2b, three dinitro derivatives, **3a**, **3b** and **3c** and one trinitro derivative, **4**, (Scheme) in amounts which allowed for their characterization. The analytical data for these derivatives are presented in the Experimental. The structure of each derivative has been proposed based primarily on the analysis of the nmr spectra. The structure of the major product, trinitro derivative **4**, may be recognized as 2,7,8-trisubstituted since this is the only product showing both the presence of a nitro group in the pyridine ring and the presence of two nitro groups in neighboring positions of a benzene ring. Two protons of the pyridine ring are observed as doublets having a large coupling constant and appearing at slightly lower fields than the similar protons 3 and 4 of the parent heterocycle **1** [5]. Two protons of the benzene ring appear as singlets with only slightly different chemical shifts, therefore they must be protons 6 and 9. Carbon-13 nmr spectrum of **4** is consistent with this assignment. Results of the X-ray study presented later confirm this analysis. All the other isomeric derivatives **2-3** show the presence of one or two nitro groups in the molecule. The nmr spectra indicate clearly that these groups are located on the benzene rings since each of them have a splitting pattern and chemical shifts for pyridine protons that are similar to those of the parent heterocycle **1**. Among the disubstituted derivatives, the major isomer **3b** shows the pattern of benzene protons which is similar to the one found for trinitro derivative **4** and therefore the nitro groups should be located in positions 7 and 8. As for the remaining mononitro isomers **2a** and **2b**, as well as dinitro isomers **3a** and **3c**, with all the data obtained in this study we were unable to assign their structure unambiguously. The tentative structures that we have proposed here are based on the analysis of nmr spectra, although an independent confirmation of those structures is required. We are currently attempting to grow crystals suitable for the X-ray examination.

Results from the nitration of **1** may be justified on the basis of the known reactivity of related compounds such as dibenzodioxin and alkoxypyridines. The nitration of dibenzo[*b*,*e*][1,4]dioxin has led to the introduction of the nitro group into position 2 of the system, while further substitution results in the group entering the second benzene ring [9]. Halogenation [10], alkylation [11], chloromethylation [12] and acylations [13] of this compound give similar results. Electrophilic reactions involving alkoxypyridines have been extensively reviewed [14,15]. The kinetic studies of these reactions show that they are much slower than those for reactions involving benzenes, due to the lower electron density of the pyridine ring in comparison with the benzene ring. Reactivity of the pyridine ring can be lowered further upon protonation. Selectivity of the electrophilic reaction is determined by the strength of the pyridine base entering the reaction. In general, reactions of pyridines as free bases result in electrophilic substitution at position 3, while reactions of their conjugate acids result in a substitution occurring predominantly at position 2 [15].

Scheme



While the formation of 7- and 8-mononitro-**1** in the first step of the reaction might have been expected on the basis of studies presented above, the subsequent steps required examination of reports describing the reactivity of di- or polysubstituted dibenzodioxin derivatives. Nitration of 2,7- or 2,8-dinitrodibenzodioxins has been reported to result in the formation of 2,3,8-trinitrodibenzodioxin [9a]. Our results indicate that the major products of nitration of **1** are derivatives **3b** and subsequently **4** and it is in agreement with this report. The other results of nitration [9b], halogenation [10], alkylation [11] and acylation [13a,13d] indicate clearly that when a substituent is present in position 2 of a disubstituted dibenzodioxin derivative, the next

substitution in the same benzene ring of dibenzodioxin takes place at the neighboring position 3. When an acylamino group is present in position 1 of the system, the next substitution in either position 2 or 4 of the system has been reported [9b]. Some reactions of polysubstituted dibenzodioxins were also studied [9b,10,13a,16] and the results indicate that in general substitution in dibenzodioxins occurs first at positions 2 and 3 regardless of the electronic effect of substituents if dibenzodioxin is a starting compound.

Experimental results of nitration of **1** show that the benzene ring of the system is indeed more reactive than the pyridine ring. Introduction of one nitro group results in an isomeric mixture of two products, **2a** and **2b**. The benzene ring of these mononitro derivatives would still be more reactive than the pyridine ring, as subsequent nitration results in the formation of three dinitro derivatives **3a-c**. The 7,8-dinitro derivative **3b** is the major product among these three derivatives, and this is in agreement with quoted reports. The formation of the 6,8- and 7,9-dinitro derivatives can be explained on the basis of steric hindrance exerted by a first nitro group present in the molecule. As can be seen from the crystal structure of **4**, the nitro groups in positions 7 and 8 are not coplanar with the benzene ring (Figure 1). The nitro groups would normally be expected to be coplanar with the benzene ring due to the partial double bond character of C-N bonds. However, the proximity of these nitro groups to one another results in a steric hindrance and this may be a factor in the formation of **3a** and **3c**. This observation has no precedent in reports on the nitration of dibenzodioxin. Subsequent nitration of the protonated major dinitro derivative **3b** results in formation of the trinitro derivative **4** with a third nitro group entering a pyridine ring of **1**. While there are reports of the nitration of a disubstituted benzene ring of dibenzodioxin [14a,16], a nitro derivative of dibenzodioxin with three nitro groups in one benzene ring of dibenzodioxin has never been reported. Formation of **4** would complete the sequence since the presence of three nitro groups in the molecule would render it unreactive against further nitration.

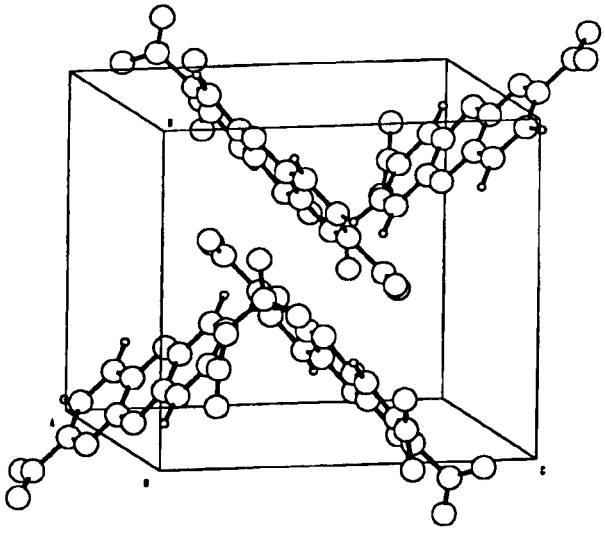


Figure 1. Crystal packing diagram for derivative **4**.

Our tlc analyses of the crude reaction product indicate that at least three other minor products have been formed during the reaction. While we are trying to isolate and identify these products, it is obvious that only 2,7,8-trinitro derivative **4** may be easily obtained in a direct nitration of **1**. Curiously, the other nitrating agents that we employed under mild conditions such as nitronium tetrafluoroborate or ammonium nitrate-trifluoroacetic anhydride did not give any isolable nitration products. Therefore, mono and dinitro derivatives of **1** should be approached using synthetic methods.

X-Ray Study of 2,7,8-Trinitro-1,4-benzodioxino[2,3-*b*]pyridine **4**.

X-ray crystallographic studies of **4** and the cyclopentadienyliron complex of **1** were completed in our department [17]. Atomic positional and thermal parameters for derivative **4** are listed in Table 1 while the bond lengths and angles for selected atoms are listed in Table 2 [18]. The least-square plane data and the dihedral angles between those planes are listed in Table 3.

Table 1

Atomic Parameters x,y,z and B_{iso} for $[C_6H_2(NO_2)_2O_2C_5H_2N(NO_2)]$ **4**

	x	y	z	B_{iso}
O5	0.80059(13)	0.67697(15)	0.93927(14)	4.16(7)
O10	0.94927(13)	0.86760(14)	1.05857(15)	4.14(7)
O21	0.70567(21)	1.11928(20)	1.30259(18)	6.56(11)
O22	0.51990(20)	1.07505(21)	1.24926(22)	8.11(13)
O31	1.36062(15)	0.75172(20)	0.94336(17)	5.59(9)
O32	1.34532(16)	0.54339(21)	0.91632(18)	6.26(10)
O41	1.21752(19)	0.52049(19)	0.69419(18)	6.24(10)
O42	1.10748(19)	0.36975(18)	0.77121(16)	5.97(10)
N1	0.78627(16)	0.95533(18)	1.14272(16)	3.62(8)
N2	0.62888(23)	1.05708(23)	1.24490(21)	5.36(12)
N3	1.30289(18)	0.65247(24)	0.92432(17)	4.35(11)
N4	1.14606(20)	0.48102(21)	0.76759(18)	4.37(10)
C2	0.66844(21)	0.95464(23)	1.16008(21)	4.07(11)
C3	0.58734(22)	0.8683 (3)	1.10909(25)	4.95(13)
C4	0.63246(21)	0.77248(25)	1.03321(23)	4.69(13)
C4A	0.75383(19)	0.77131(21)	1.01397(20)	3.51(10)
C5A	0.92380(19)	0.67493(20)	0.93231(19)	3.30(9)
C6	0.97419(20)	0.57868(21)	0.86255(19)	3.48(10)
C7	1.09772(21)	0.57546(21)	0.85413(19)	3.45(10)
C8	1.17054(19)	0.66395(21)	0.91758(19)	3.42(10)
C9	1.12013(19)	0.76065(22)	0.98633(20)	3.54(10)
C9A	0.99662(20)	0.76690(21)	0.99146(19)	3.29(9)
C10A	0.82626(19)	0.86464(21)	1.07145(19)	3.38(10)

B_{iso} is the Mean of the Principal Axes of the Thermal Ellipsoid. e.s.ds. refer to the last digit printed.

Table 2

Bond Lengths and Angles for the Non-Hydrogen Atoms of **4**.

1	2	3	1-2	1-2-3
N1	C2	C3	1.328(3)	125.64(22)
C10a	N1	C2	1.302(3)	116.09(20)
C2	C3	C4	1.368(4)	117.08(20)
C3	C4	C4a	1.391(4)	118.30(22)
C4	C4a	C10a	1.371(3)	118.80(21)
C4a	C10a	N1	1.387(3)	124.08(20)
O5	C4a	C4	1.379(3)	119.29(20)
O5	C4a	C10a		121.90(19)
O5	C5a	C9a		121.97(20)
C5a	O5	C4a	1.373(3)	116.08(16)
C6	C5a	O5	1.378(3)	117.77(18)
C6	C5a	C9a		120.26(20)
C7	C6	C5a	1.378(3)	118.57(19)
C8	C7	C6	1.386(3)	121.03(20)
C9	C8	C7	1.375(3)	120.32(20)
C9a	C9	C8	1.376(3)	118.74(20)
C9a	O10	C10a		115.76(17)
C5a	C9a	C9	1.388(3)	120.99(20)
O10	C9a	C5a	1.381(3)	121.98(20)
O10	C10a	C4a	1.378(3)	122.00(20)
O10	C10a	N1		113.91(19)
O10	C9a	C9		117.04(19)
N2	C2	C3		120.69(22)
N2	C2	N1	1.479(3)	113.66(22)
O21	N2	C2	1.223(4)	118.55(22)
O22	N2	C2	1.226(3)	116.47(24)
O21	N2	O22		124.95(23)
N3	C8	C7	1.473(3)	122.45(20)
O31	N3	C8	1.216(3)	117.43(21)
O32	N3	C8	1.217(3)	117.23(22)
O31	N3	O32		125.25(21)
N3	C8	C9		117.00(20)
N4	C7	C8	1.469(3)	122.34(20)
O41	N4	C7	1.218(3)	117.90(21)
O42	N4	C7	1.219(3)	117.29(21)
O41	N4	O42		124.73(20)
N4	C7	C6		116.45(20)

The bond lengths and bond angles in the pyridine ring of **4**, while compared to those found in the cyclopentadienyliron complex of **1**, are in the same range (Figure 2). The difference is observed for the angle N1-C2-C3 [125.64(20) and 123.5(7) degrees and for **4** and cyclopentadienyliron-**1**, respectively]. The bond lengths between N1 and C10a and C4 and C4a are also shorter than those found typically in pyridines [19] [1.302(3) Å vs. 1.338 A and 1.371(3) Å vs. 1.394 Å, respectively]. The bond lengths and angles in the benzene ring were compared with those in dibenzodioxin [20] and it was found that both the bond angles and the bond lengths are comparable.

Compound **4** was found to have a dihedral angle between the planes of the outer benzene and pyridine

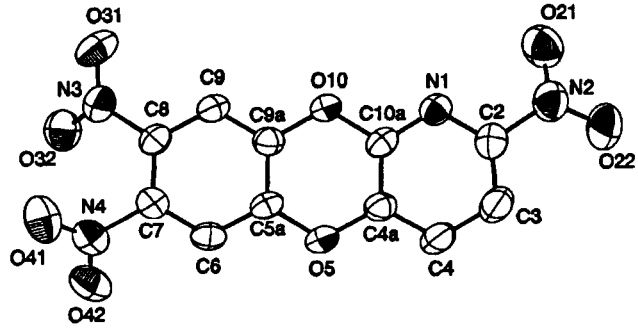


Figure 2. View of molecule **4** showing atom-labelling scheme.

Table 3

Distances(Å) to the Least-Squares Planes for $[C_6H_2(NO_2)_2O_2C_5H_2N(NO_2)]$ **4**

Plane No. 1

Equation of the plane: 1.271(11)X - 6.218(8)Y + 8.569(7)Z = 4.853(15)

Distances (Å) to the plane from the atoms in the plane.

N1	-.0016(23)	C2	.002(3)
C3	-.001(3)	C4	.001(3)
C4a	-.002(3)	C10a	.002(3)

Chi squared for this plane 2.460

Distances (Å) to the plane from the atoms out of the plane.

O5	.004(3)	O10	.030(3)
O21	.247(4)	O22	-.172(4)
N2	.041(4)		

Plane No. 2

Equation of the plane: 1.185(7)X - 6.231(5)Y + 8.573(4)Z = 4.786(9)

Distances (Å) to the plane from the atoms in the plane.

O5	-.0024(20)	O10	.0088(21)
N1	-.0096(22)	C2	.004(3)
C3	.009(3)	C4	.009(3)
C4a	-.0052(24)	C1Oa	-.0081(23)

Chi squared for this plane 74.658

Distances (Å) to the plane from the atoms out of the plane.

O21	.244(3)	O22	-.158(4)
N2	.046(3)	C5a	.097(3)
C9a	.117(3)		

Plane No. 3

Equation of the plane: 0.249(10)X - 6.146(8)Y + 8.749(6)Z = 4.226(15)

Distances (Å) to the plane from the atoms in the plane.

C5a	.011(3)	C6	.005(3)
C7	-.018(3)	C8	.011(3)
C9	.006(3)	C9a	-.018(3)

Chi squared for this plane 131.801

Table 3 (Continued)

Distances (Å) to the plane from the atoms out of the plane.

O5	.029(3)	O10	-.062(3)
O22	.224(8)	O31	-.255(4)
O41	-1.050(4)	O42	.523(4)
N3	.174(4)	N4	-.183(4)

Plane No. 4

Equation of the plane: 0.322(6)X - 5.994(5)Y + 8.864(4)Z = 4.510(9)

Distances (Å) to the plane from the atoms in the plane.

O5	.0154(20)	O10	-.0219(21)
C5a	.0056(23)	C6	-.020(3)
C7	-.035(3)	C8	.020(3)
C9	.034(3)	C9a	.0021(24)

Chi squared for this plane 651.870

Distances (Å) to the plane from the atoms out of the plane.

O31	-.216(3)	O32	.788(3)
O41	-1.085(3)	O42	.466(3)
N3	.191(3)	N4	-.221(3)
C4a	.097(3)	C10a	.070(3)

Plane No. 5

Equation of the plane: -0.846(14)X - 1.348(14)Y + 10.8499(20)Z = 8.067(22)

Distances (Å) to the plane from the atoms in the plane.

O31	.005(3)	O32	.005(3)
N3	-.019(3)	C8	.004(3)

Chi squared for this plane 57.815

Distances (Å) to the plane from the atoms out of the plane.

O41	-2.266(4)

Plane No. 6

Equation of the plane: 8.039(10)X - 2.374(13)Y + 6.840(11)Z = 13.306(12)

Distances (Å) to the plane from the atoms in the plane.

O41	-.005(3)	O42	-.005(3)
N4	.0161(24)	C7	-.005(3)

Chi squared for this plane 52.251

Distances (Å) to the plane from the atoms out of the plane.

O32	2.487(3)

Plane No. 7

Equation of the plane: 0.692(17)X - 6.872(11)Y + 8.116(10)Z = 2.39(3)

Distances (Å) to the plane from the atoms in the plane.

O21	-.003(3)	O22	-.003(3)
N2	.009(3)	C2	-.002(3)

Chi squared for this plane 13.547

Table 3 (continued)

Dihedral Angle Between Planes A and B

A	B	Angle (deg)
1	2	0.45(7)
1	3	5.35(8)
1	4	5.24(7)
1	5	31.94(10)
1	6	42.74(10)
1	7	11.13(11)
2	3	4.92(6)
2	4	4.85(4)
2	5	31.85(8)
2	6	43.18(9)
2	7	10.70(10)
3	4	1.12(6)
3	5	29.80(9)
3	6	47.56(9)
3	7	7.23(10)
4	5	28.85(8)
4	6	46.91(8)
4	7	8.27(9)
5	6	51.87(11)
5	7	34.56(11)
6	7	53.81(12)

rings of 174.65(8) degrees. The molecule of **4** is bent more than heterocycle **1** in its cyclopentadienyliron complex since the angle of 177.4(3) degrees was found for the latter [18]. It is interesting that both **4** and the heterocycle ligand in the complex of **1** are slightly bent whereas unsubstituted dibenzodioxin is considered to be planar within experimental error [20]. Cordes and Fair reported that dibenzodioxin has a dihedral angle of 175.9(9) degrees [21] although their assessment and the structure has been disputed [20a]. Similarly, chlorinated dibenzodioxins were found to be essentially planar [22a-c] with only hexachloro (175.7 degrees, [22d]) and 2,8-dichlorodibenzodioxins (175.2 degrees, [22e]), being non-planar. Due to steric hindrance, the nitro groups located in positions 7 and 8 are not coplanar with the benzene ring. Their planes are found to be rotated with respect to the plane of the benzene ring by 47.56(9) and 29.80(9) degrees for 7-nitro and 8-nitro groups, respectively. Surprisingly, the nitro group in position 2 is also slightly rotated with respect to the plane of the pyridine ring by 11.13(11) degrees. The geometry of all nitro groups, *ie.* N-O and N-C bond lengths and the angles O-N-O and O-N-C are very similar with the exception of the 2-nitro group. The angle O-N-O for this group is the same for the other two nitro groups. The two other angles, O21-N2-C2 and O22-N2-C2 are found to be unsymmetrical, 118.55(22) and 116.47(24) degrees, respectively, as compared to pairs 117.43 (21) and 117.23 (22) for 8-nitro group and 117.90 (21) and 117.29(21) degrees for 7-nitro group, respectively. Also the angle N2-C2-N1 is significantly smaller for the 2-nitro group [113.66(22) degrees] than the analogous angles for 7-nitro and 8-nitro groups

[116.45(20) and 117.00(20) degrees, respectively].

The X-ray structure has unambiguously confirmed the presence of three nitro groups in positions 2,7 and 8 of **4** as it has been previously found from nmr data.

EXPERIMENTAL

Melting points are uncorrected. All the chemicals used were of reagent grade quality and were purified according to standard procedures. Heterocycle **1** and its cyclopentadienyliron complex were prepared following the procedure of Sutherland *et al.* [5]. The 250 MHz ^{1}H and 62.5 MHz ^{13}C nmr spectra were recorded on a Bruker AC250F spectrometer at the Atlantic Regional Magnetic Resonance Centre, Halifax. Acetone-d_6 solutions of compounds **2-4** were used; chemical shifts are reported in δ, ppm scale (internal TMS for proton, calculated from the solvent shift for carbon-13 nmr) where δ_{TMS} = 0 ppm, coupling constants are given in Hz. Mass spectra were recorded at the Institute for Marine Bioscience, NRC, Halifax (Mr. D. J. Embree) using electron impact ionization at 70 eV. Purity of compounds **2-4** have been confirmed by the elemental analysis results (courtesy of the University of Saskatchewan). Merck plates were used for tlc analysis (aluminum backed, 0.2 mm layer of Kieselgel 60 F_{254}, unactivated) and for plc separations (glass plates, 20 x 20 cm, 0.5 mm layer of Kieselgel 60 F_{254}, unactivated).

Nitration of 1,4-Benzodioxino[2,3-*b*]pyridine **1**.

To a 10 ml solution of nitric acid in concentrated sulfuric acid (1:5), 0.37 g (2.0 mmoles) of **1** was added. The mixture was heated at 60° overnight. The solution was then poured into 200 ml of water, neutralized with sodium carbonate and then extracted with a 1:1 dichloromethane-nitromethane mixture. The extracts were combined, dried over sodium sulfate and evaporated. The products were isolated using several consecutive separations by plc (developed in hexanes/acetone 9:1, 7:1 and 5:1) and crystallized upon slow evaporation of the solvent.

Similar reaction results were observed using various amounts of nitric acid in the nitrating mixture and also using the cyclopentadienyliron complex of **1** as the starting material. In the course of all separations we have observed significant loss of products due to their poor solubility, thus we were not able to provide reliable quantitative results.

7-Nitro-1,4-Benzodioxino[2,3-*b*]pyridine **2a**.

The 7-nitro derivative was separated as yellow needles, mp 203-204°; ^{1}H nmr: δ 7.14 (d, 7.7, d, 4.9, 1H), 7.24 (d 9.0, 1H), 7.45 (d, 8.0, d, 1.4, 1H), 7.84 (d, 2.5, 1H), 7.91 (d, 4.8, d, 1.4, 1H), 7.94 (d, 8.9, d, 2.5, 1H); ^{13}C nmr: δ 113.2, 117.5, 121.4, 122.7, 125.4, 139.4 (quaternary), 141.1 (quaternary), 142.8 (quaternary), 143.3 (quaternary), 147.4 (quaternary), 148.9 (quaternary); ms: m/z 230 (M^+,100), 184, 149, 128, 101,

Anal. Calcd. for $C_{11}H_6O_4N_2$: C, 57.43; H, 2.63; N, 12.18. Found: C, 57.31; H, 2.49; N, 12.75.

8-Nitro-1,4-benzodioxino[2,3-*b*]pyridine **2b**.

The 8-nitro derivative separated as a yellow powder, mp 164-165°; ^{1}H nmr: δ 7.13 (d, 7.6, d, 4.9, 1H), 7.19 (d, 8.9, 1H), 7.43 (d, 7.6, d, 1.4, 1H), 7.79 (d 2.5, 1H), 7.91 (d, 4.9, d, 1.4, 1H), 7.94 (d, 8.9, d, 2.4, 1H); ^{13}C nmr: δ 112.5, 118.2, 121.2, 123.0, 125.3, 139.6 (quaternary), 141.1 (quaternary), 141.4 (quaternary), 142.3 (quaternary), 148.8 (quaternary); ms: m/z 230 (M^+), 177, 149, 128, 105.

Anal. Calcd. for $C_{11}H_6O_4N_2$: C, 57.43; H, 2.63; N, 12.18. Found: C, 57.15; H, 2.36; N, 12.57.

7,9-Dinitro-1,4-benzodioxino[2,3-*b*]pyridine **3a**.

The 7,9-dinitro derivative separated as a yellow-orange powder, mp 173-174°; ^{1}H nmr: δ 7.22 (d, 7.8, d 4.8, 1H), 7.57 (d, 7.8, d, 1.4, 1H), 7.99 (d, 4.8, d, 1.4, 1H), 8.13 (d, 2.6, 1H), 8.50 (d, 2.6, 1H); ^{13}C nmr: δ 116.5, 117.0, 123.3, 125.7, 139.1 (quaternary), 140.5 (quaternary), 141.4 (quaternary), 142.0 (quaternary), 142.2 (quaternary), 148.9, (quaternary); ms: m/z 275 (M^+), 183, 167, 149 (100), 129, 97.

Anal. Calcd. for $C_{11}H_5O_6N_3$: C, 48.04; H, 1.83; N, 15.28. Found: C, 48.45; H, 1.59; N, 15.08.

7,8-Dinitro-1,4-benzodioxino[2,3-*b*]pyridine **3b**.

The 7,8-dinitro derivative separated as a yellow powder, mp 274°; ^{1}H nmr: δ 7.21 (d, 8.0, d, 4.8, 1H), 7.49 (d, 8.0, d, 1.4, 1H), 7.79 (s, 1H), 7.84 (s, 1H), 7.94 (d, 4.8, d, 1.4, 1H); ^{13}H nmr: δ 114.3, 114.9, 123.5, 126.0, 139.2 (quaternary), 139.4 (quaternary), 141.4 (quaternary), 142.9 (quaternary), 143.8 (quaternary), 146.7 (quarternary); ms: m/z 275 (M^+, 100), 229, 183, 149, 127, 75.

Anal. Calcd. for $C_{11}H_5O_6N_3$: C, 48.04; H, 1.83; N, 15.28. Found: C, 48.12; H, 1.62; N, 15.46.

6,8-Dinitro-1,4-benzodioxino[2,3-*b*]pyridine **3c**.

The 6,8-dinitro derivative separated as a yellow-orange powder, mp 192°; ^{1}H nmr: δ 7.22 (d, 7.8, d, 4.8, 1H), 7.57 (d, 7.8, d, 1.4, 1H), 7.99 (d, 4.8, d, 1.4, 1H), 8.23 (d, 2.4, 1H), 8.80 (d, 2.4, 1H); ^{13}C nmr: 113.2, 117.5, 120.0, 122.2, 139.3 (quaternary), 139.4 (quaternary), 140.1 (quaternary), 142.3 (quaternary), 142.4 (quaternary), 145.1 (quaternary); ms: m/z 275 (M^+, 100), 229, 183, 167, 149, 127, 100, 77.

Anal. Calcd. for $C_{11}H_5O_6N_3$: C, 48.04; H, 1.83; N, 15.28. Found: C, 47.86; H, 1.67; N, 15.03.

2,7,8-Trinitro-1,4-benzodioxino[2,3-*b*]pyridine **4**.

The 3,7,8-trinitro derivative separated as yellow-orange crystals, decomposition over 230°; ^{1}H nmr: δ 7.86 (d, 8.3, 1H), 7.91 (s, 1H), 7.96 (s, 1H), 8.16, (d 8.3, 1H); ^{13}C nmr: δ 113.6, 114.1, 117.8, 127.0, 138.7 (quaternary), 138.9 (quaternary), 141.7 (quaternary), 143.8 (quaternary), 144.5 (quaternary), 146.0 (quaternary), 148.9 (quaternary); ms: m/z 320 (M^+, 100), 274, 228, 182, 120, 99, 80.

Anal. Calcd. for $C_{11}H_4O_8N_4$: C, 41.28; H, 1.26; N, 17.51. Found: C, 41.14; H, 0.99; N, 17.91.

X-Ray Crystal Structure Determination.

Crystals were grown as yellow plates from an acetone-chloroform-hexane solution (298 K). A crystal with dimensions 0.33 x 0.38 x 0.80 mm was chosen for the study. The intensity data were collected on a Nonius diffractometer, which utilized graphite monochromator, using MoK_α radiation (λ = 0.70930 Å). The lattice parameters were obtained from the least-squares of 24 reflections with 36.00 < 2θ < 43.00 degrees: a = 11.1027(13), b = 10.2471(10), c = 10.9550(11) Å, V = 1245.62(23) Å^3. The crystal system is monoclinic; space group

is P $2_1/c$, Z = 4, d_x = 1.707 mg/m^3, F(000) = 648, μ = 0.14 mm^{-1}. Data were collected using omega scan mode (1700 reflections measured, 1611 unique, 2θ range 2.0-45°, the index range h = -11-11, k = 0-11, l = 0-11. The three standard reflections, which were measured every hour, indicate that both crystal and electronics were stable within 1%. A total of 1308 reflections [I>2.5σ(I)] were used in structure solution. Weights based on counting statistics were used; absorption corrections were made. The structure was solved using direct methods. All non-hydrogen atoms were located in E-map and they were refined anisotropically. The position of all hydrogen atoms were calculated (D_{C-H} = 1.08 Å) and given temperature factors based upon the carbon atom to which they were bonded. The final R indices were R = 3.60% and R_w = 4.20%. The data:parameter ratio was 6.3:1, the largest shift/σ was 0.001, the goodness of fit term was 2.70 and the largest peak and hole in the final difference map were -0.200 eÅ^{-3} and 0.140 eÅ^{-3} respectively. Neutral scattering factors and anomalous dispersion corrections were taken from the International Tables for X-ray Crystallography [23]. All crystallographic calculations were conducted with the PC version of the NRCVAX program package [24] which was locally implemented on IBM compatible 80486 computers.

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