Transformations on 2,3,4,5-Tetrahydrobenzo[*b*][1,4]-dioxocin Leading to Substituted *ortho*-Nitroaryl Azides, Benzofuroxans, Benzofurazans and Related Compounds

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Nitration of the acetamido-nitrobenzodioxocins **10**, prepared from the corresponding amino derivatives **9**, led to the acetamido-dinitrobenzodioxocins **11**, hydrolysis of which furnished the corresponding amines **13**. Preparation of the dinitroazides **18** and acetamido-nitroazides **21** as precursors to substituted dioxocino-annelated benzofuroxans is described. Thermolysis of the dinitro-azido derivatives **18a,c,e** and/or direct nitration of the unsubstituted benzofuroxans **1a**, **2a** afforded the isomeric nitrobenzofuroxans **1b**, **2b,c**. Thermolysis of the acetamido-nitroazides **21** gave the acetamidobenzofuroxans **1d**, **2d,e**. All benzofuroxans were deoxygenated to the corresponding benzofurazans **3b,d**, **4b-e**. Some aspects of electrophilic and nucleophilic aromatic substitution are discussed.

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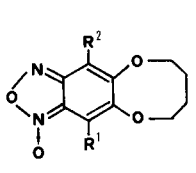
The importance of arylazides [1] furoxans and furazans [2] is manifested in the plethora of publications concerning the synthesis and study of these compounds. Our interest has been focused recently on 1,2-alkylenedioxy-annelated derivatives, as we have reported [3] on the preparation of the benzofuroxans **1a**, **2a** and the benzofurazans **3a**, **4a**. In this paper, we extend our work to further include the nitro- and acetamido-substituted derivatives **1b,d**, **2b-e**, **3b,d** and **4b-e**. This type of compounds, particularly the nitrobenzofuroxans, possess interesting



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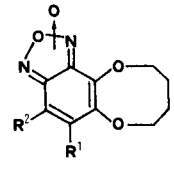

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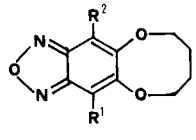

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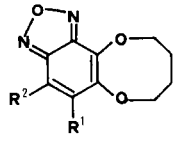


4

	R^1	R^2
a	H	H
b	H	NO_2
c	NO_2	H
d	H	NHAc
e	NHAc	H

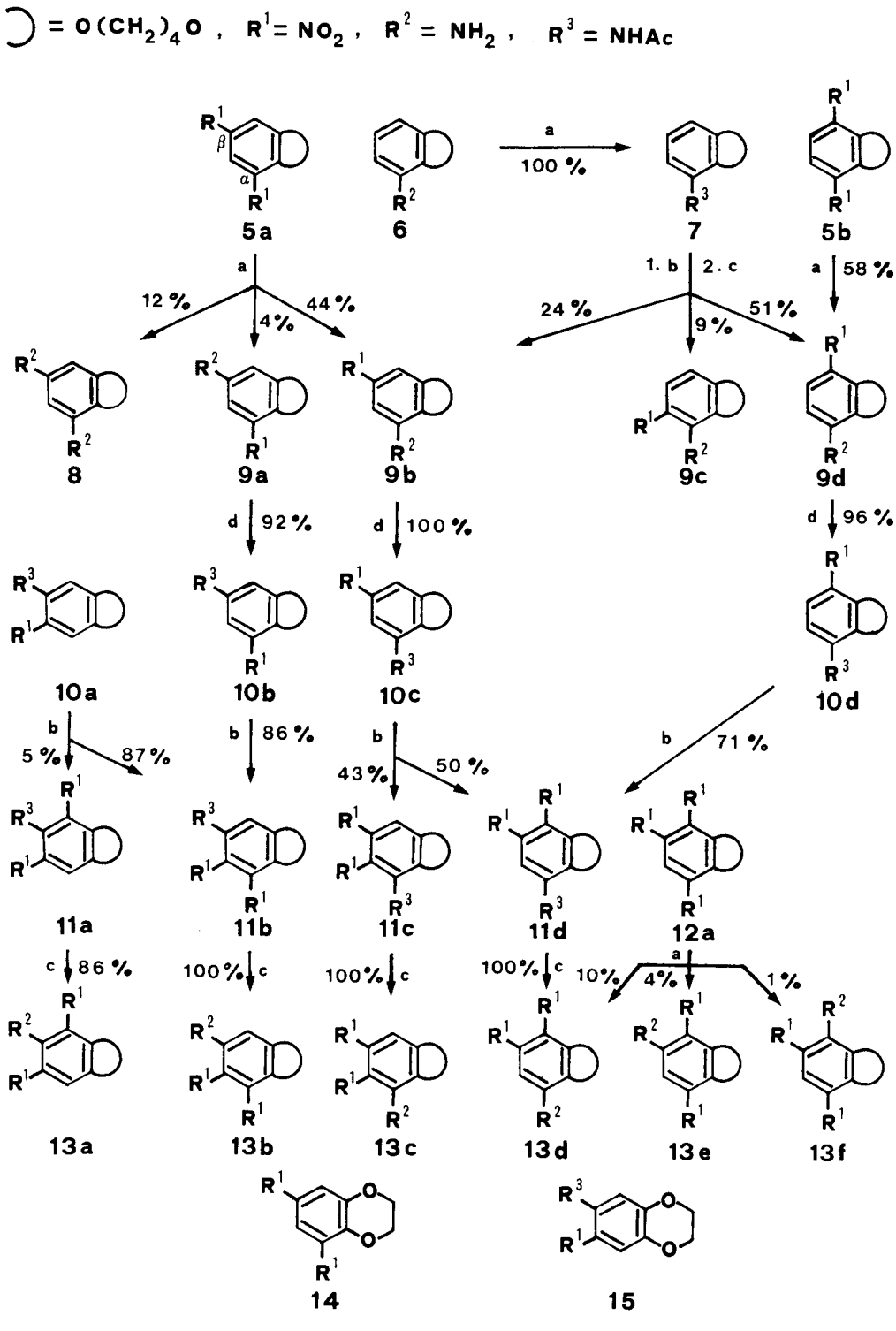
antileukemic and immunosuppressive properties [4]. Moreover, the Boulton-Katritzky rearrangement [5] concerning the nitrobenzofuroxans can be studied as a function of the heterocyclic ring-size [6a], while the acetamido derivatives provide a handle, after hydrolysis, for functionalization of the amino group with a great variety of pharmacologically interesting substrates. We note that the use of the eight-membered heterocycle (benzodioxocin) as the starting compound in this work is coincidental, as the transformations described herein can be applicable to the five- [7], six-, seven-, nine- and ten-membered heterocycles as well [6a].

Our initial efforts were directed towards preparation of the *ortho*-nitro amines **13** so that subsequent oxidation with hypochlorite ion [3,8,9] would furnish some of the desired furoxans. The synthetic transformations leading to the amino derivatives **13** are straightforward as shown in Scheme 1. A few points, however, merit mention. Preferential reduction of the nitro substituent at Ar-1 (Ar-α) position, instead of the Ar-3 (Ar-β), in **5a** has also been reported by Heertjes for the homologous dinitrobenzodioxin **14** under similar conditions [10a]. It is interesting that of the two possible isomeric acetamido-dinitrobenzodioxocins, nitration of **10b** afforded the more hindered isomer **11b** as the sole reaction product. In contrast, nitration of **10c** (where the acetamido and nitro groups are interchanged relative to **10b**) furnished both isomers **11c** and **11d** with slight predominance of the latter. For comparison, nitration of the dinitro derivative **5a** [6b] afforded the trinitro products **12a** (67%) and **12b** (see Scheme 2 for structure) (20%). With respect to nitration of the isomeric **10a** and **10d**, it was observed that substitution occurs *meta* to the acetamido (bulkier) group. An analogous result was reported by Heertjes during nitration of **15** (a homologue of **10a**) [10b]. It seems that in these types of polysubstituted homologous systems, further nitration depends heavily on the benzene ring substituents and not as much on the heterocyclic side ring [6b].

We have already commented on orientation during nitration of **7** ($R^3 = NO_2$) [6b]. It seems that in this case as well, the assertion that Ar-α substituted 1,2-alkylenedioxybenzenes, such as **7**, do not give 1,4-products of the type **9d** [11] is not applicable to the eight-membered heterocycles, since nitration of **7** afforded **9d**; in fact, as the major reaction product.

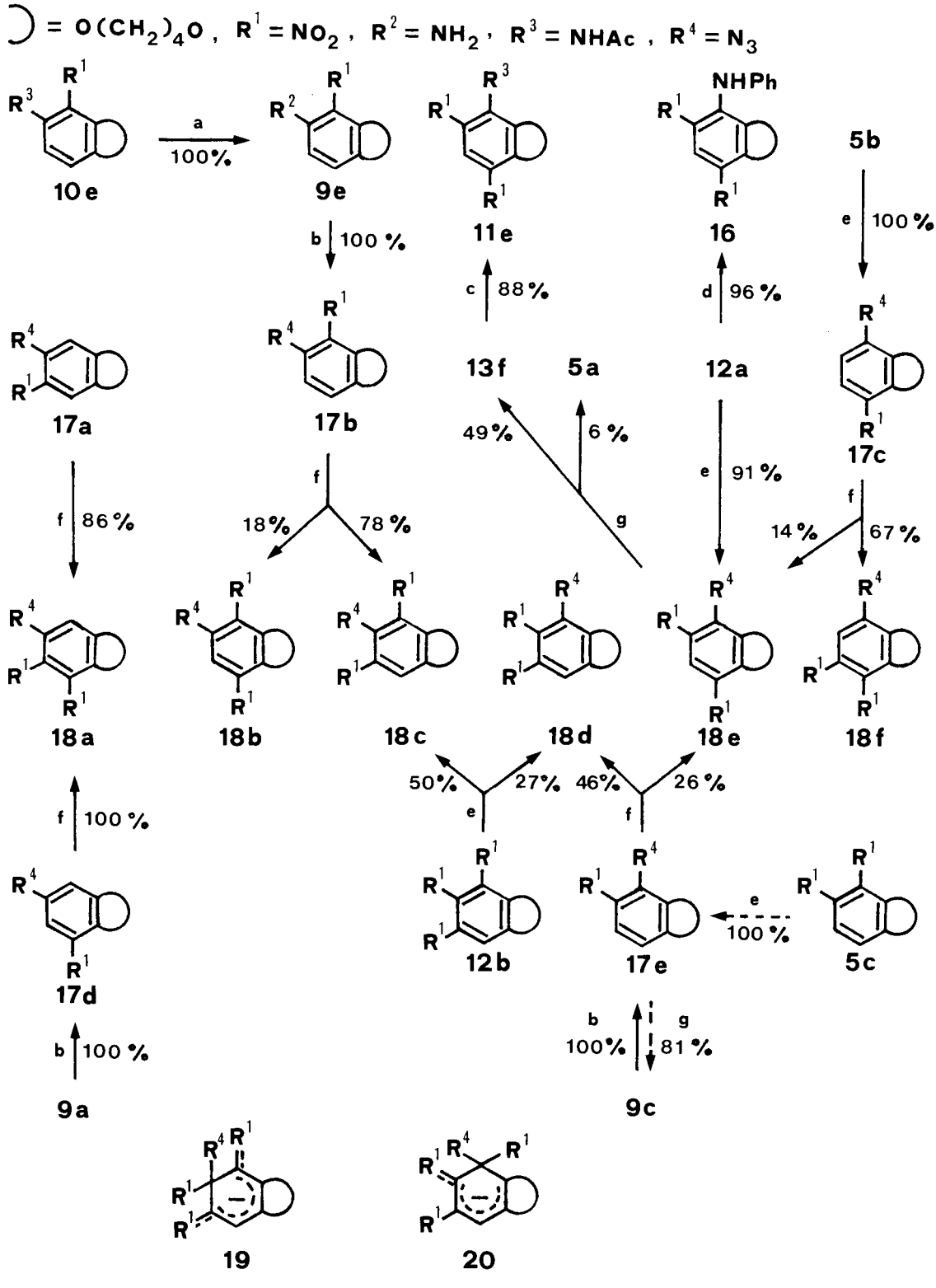
Attempts to prepare the desired nitrobenzofuroxans by treatment of the dinitro amines **13** with hypochlorite ion resulted in very poor yields of the furoxans, or in decom-

Scheme 1



Reagents. a: $SnCl_2 \cdot 2H_2O$, HCl ; b: HNO_3, HOAc ; c: HCl, EtOH ; d: Ac_2O, $NaOAc \cdot 3H_2O$.

Scheme 2



Reagents. a: H_3O^+; b: 1. HNO_2, 2. NaN_3; c: Ac_2O; d: $C_6H_5NH_2$; e: NaN_3, DMSO; f: HNO_3, HOAc; g: $NaBH_4$, EtOH.

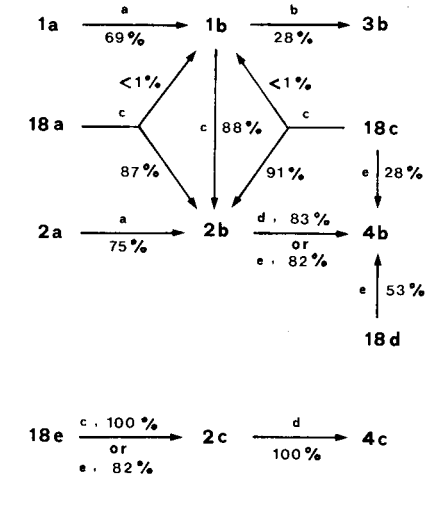
position products, or in nucleophilic substitution of one of the nitro groups by chloride ion [6c].

Next, we turned our attention to *ortho*-nitroarylazide thermolysis [2,12], since we [3] and others [7] have found this method to be superior to oxidation by hypochlorite ion. The appropriate azides **18** were obtained according to the steps depicted in Scheme 2. Preparation of all (six) isomers (some of which *via* more than one route) in combination with spectroscopic evidence, renders the structural assignments unequivocal. It is noteworthy that the positional selectivity in **17a**, **17c** and **17d** is analogous to that in **10a**, **10d** and **10b**, respectively, and that of the two vacant positions, the incoming electrophile (NO_2^+) occupies the position next to the nitro group either exclusively in **10b,d** and **17a,d** or predominantly in **10a** and **17c**.

Displacement of the nitro substituent at C-7 (aryl-α position) by a nucleophile is activated by the *ortho*- and *para*-nitro groups [13a]. Accordingly, **5c** and **12a** furnished **17e** and **18e**, respectively. Likewise, when **12a** was treated with aniline (a bulkier nucleophile), it afforded the dinitroazide **16**. Analogous results have been reported recently with the related 1-dialkylamino-2,4-dinitronaphthalenes [13b]. Similarly, substitution of the nitro group at C-7 or C-8 in **12b** by azide ion gave the respective products **18d** and **18c** in the ratio of 1:2. The higher yield of **18c** is rationalized in terms of a Meisenheimer intermediate complex **19** of greater stability compared to **20**, assuming operation of an S_NAr mechanism.

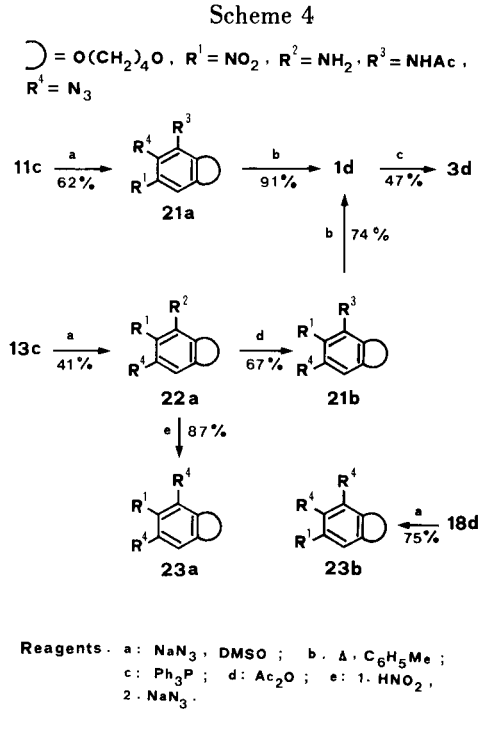
Thermolysis of the dinitroazides **18a** or **18c** afforded the nitrobenzofuroxan **2b**, an authentic sample of which was prepared by nitration of the unsubstituted benzofuroxan **2a** (Scheme 3). Interestingly, the isomeric nitrobenzofuroxan **1b** which should have resulted from thermolysis of the azides **18a** (totally) or **18c** (partially) was not obtained. However, when the time course of the thermolysis of **18a** or **18c** under milder conditions (refluxing in benzene instead of in toluene) to 81 and 80% conversions, respectively, was followed, **1b** was detected in trace quantities in both cases. Apparently, as soon as **1b** is formed it isomerizes to the thermodynamically more stable isomer **2b** *via* a Boulton-Katritzky rearrangement [5]. This was shown to be the case, as an authentic sample of **1b** (prepared by nitration of **1a**) underwent isomerization to **2b** within 0.5 hour in toluene under reflux [6a]. Further heating of **2b** for 4 hours did not cause its reversion to **1b**. Analogous results have been obtained with related homologous systems [6a]. The furoxan **2c** was also prepared similarly from the azide **18e**. The three isomeric furoxans were deoxygenated with triphenylphosphine to the corresponding nitrobenzofurazans **3b**, **4b,c**.

Scheme 3



The acetamidobenzofuroxan **1d** was prepared *via* thermolysis of the azides **21a** and **21b**. Deoxygenation furnished the furazan **3d** (Scheme 4). It is interesting that the azide ion displaced the nitro group at C-8 in the acetamido compound **11c**, whereas in the related amine **13c** the nitro group at C-9 was substituted instead. Differentiation between **21a** and **21b** was based on comparison of the ^1H nmr absorptions of the aromatic proton at the Ar-α position for these and related derivatives. Thus, for **21a**, **18c** and **23b**, δ 7.71, 7.91 and 7.37, while for **21b**, **18a**, **22a** and **23a**, δ 6.71, 6.92, 6.11 and 6.58. Furthermore, azide **22a** was converted to diazide **23a**. The diazide **23b** was made

Scheme 4

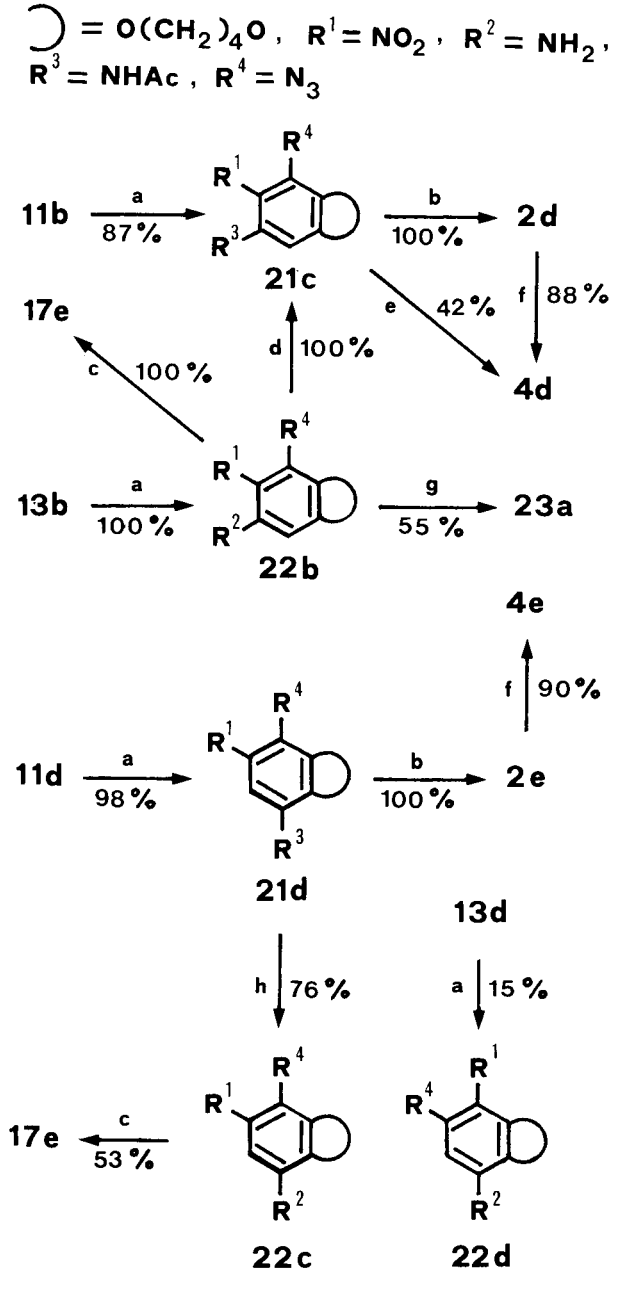


available by treatment of **18d** with the azide ion. Having both isomeric diazides, they can easily be distinguished by ^{1}H nmr (see above). Interestingly, here also the nitro group at C-8 is substituted as in the case of **11c**.

Preparation of the isomeric acetamidobenzofuroxan **2d** was accomplished *via* analogous routes depicted in Scheme 5. Azide ion displaced the nitro substituent at C-10 in both the acetamido derivative **11b** (to furnish the acetamidoazide **21c**) and the amino derivative **13b** (to yield the aminoazide **22b**). To ascertain this, **22b** was acetylated to **21c**, deaminated to **17e** and converted to the diazide **23a**.

The acetamidobenzofuroxan **2e** and furazan **4e** were prepared by similar reactions (Scheme 5, bottom). Displacement of the nitro group at C-10 (instead of at C-9) by the azide ion in **11d** was ascertained by hydrolysis of the acetamidoazide **21d** to the aminoazide **22c**, followed by deamination of the latter to the nitroazide **17e**. Furthermore, the isomeric **22d** was also prepared from **13d**, albeit in low yield, and compared to **22c**.

Scheme 5



EXPERIMENTAL

General.

Melting points (uncorrected) were determined on a Gallenkamp, or a Kofler hot-stage apparatus. The course of the reactions was followed by tlc, carried out on silica gel 60, F_{254} precoated plates (Merck). Column chromatography was performed on silica gel 60, 70-230 mesh (Merck), using a mixture of petroleum ether (bp 65-69°):ethyl acetate = 4:1 (v:v) to elute the column. The various fractions are listed in order of elution. The uv spectra (absolute ethanol) were obtained on a Shimadzu UV-210A instrument. The ir spectra (chloroform solution) were recorded on a Perkin-Elmer 297 or 1430 infrared spectrophotometer. The ^{1}H nmr spectra were taken on a Bruker AW 80 (80 MHz) instrument in deuteriochloroform solution containing 2% tetramethylsilane as the internal standard. The mass spectra (ms) were obtained at 70 eV on a Hitachi Perkin-Elmer RMU-6L single focusing mass spectrometer equipped with a direct inlet system. Evidence for the partial fragmentation patterns proposed stems from the metastable ions observed. Extractions were carried out with ethyl ether or dichloromethane and the solutions were dried over anhydrous sodium sulfate for *ca.* 15 hours. All the crude solids were recrystallized from boiling ethanol (95%). Nitric acid refers to the fuming reagent (d = 1.52). Acetic acid refers to the glacial reagent. Ether refers to ethyl ether. Exceptions are noted.

7-Acetamido-2,3,4,5-tetrahydrobenzo[*b*][1,4]dioxocin (**7**).

Into a stirred mixture of the amine **6** (544 mg, 3.04 mmoles) [3] and sodium acetate trihydrate (802 mg, 5.89 mmoles) was added acetic anhydride (2.50 ml, 2.71 g, 26.5 mmoles) according to the procedure in reference [14a]. The mixture was heated at *ca.* 40° for one hour, decomposed by the addition of water (4 ml) followed by heating at 70° for 0.5 hour, neutralized with sodium bicarbonate solution, extracted, dried and concentrated *in vacuo* to furnish 670 mg (100%) of **7**, mp 130-131° (50% aqueous acetic acid); ir (potassium bromide): ν max 3330 (m, NH), 1678 (m), 1658 (s, C=O), 1605 (m), 1588 (m), 1537 (s), 1472 (s), 1445 (s), 1278 (m), 1190 (m), 1084 (m), 1045 (m), 970 (m), 797 (m), 752 (w) cm^{-1}; ^{1}H nmr: δ 1.89 (m, 4H, 3,4-H), 2.15 (s, 3H, CH_3), 4.21 (t, J = 5 Hz, 2H, OCH_2), 4.35 (t, J = 5 Hz, 2H, OCH_2), 6.67 (dd, J = 8, 2 Hz, 1H, 10-H), 6.89 (dd, J = 8, 8 Hz, 1H, 9-H), 7.79 (br s, 1H, NH), 8.02 (dd, J = 8, 2 Hz, 1H, 8-H); ms: m/z (% relative intensity) 221 (M^+, 100), 179 (M^+ -CH_2=C=O, 46), 162 (7), 150 (13), 137 ($C_{10}H_{13}NO_2^+$ -C_3H_6, 42) [15], 136 (15), 125 ($C_{10}H_{13}NO_2^+$ -C_4H_6, 67), 124 (28), 109 (6), 108 (4), 107 (5), 96 (13), 95 (13), 80 (4), 79 (12), 67

(7), 66 (7), 55 ($C_4H_7^+$, 36), 52 (7), 43 ($C_2H_3O^+$, 40).

Anal. Calcd. for $C_{12}H_{15}NO_3$: C, 65.14; H, 6.83; N, 6.33. Found: C, 64.98; H, 6.64; N, 6.08.

7,9-Diamino-, 8-Amino-10-nitro-, 7-Amino-9-nitro-, 7-Amino-8-nitro-, 7-Amino-10-nitro-2,3,4,5-tetrahydrobenzo[*b*][1,4]dioxocins **8**, **9a**, **9b**, **9c**, **9d**.

A. Compounds **8**, **9a**, **9b** from the Reduction of **5a**.

Reduction of **5a** [3] was carried out according to the procedure in reference [14b] for the reduction of **14**. Into a stirred suspension of 7,9-dinitrobenzodioxocin **5a** (686 mg, 2.70 mmoles) in ethanol (5 ml) kept at 40°, was added a mixture of stannous chloride dihydrate (5.0 g, 22 mmoles) in ethanol (8 ml) and concentrated hydrochloric acid (5 ml). Heating continued at 50-60° for 7 hours and the mixture was decanted into ice-water and made basic with 10% sodium hydroxide. Extraction, drying and concentration furnished a red-brown residue. Column chromatography using chloroform to elute the column gave starting **5a** (45 mg, 93% conversion), **9b** (249 mg, 44% based on converted **5a**), followed by **9a** (22 mg, 4% based on converted **5a**). The elution solvent was changed to ethyl acetate to afford **8** (59 mg, 12% based on converted **5a**).

A different preparation with **5a** (1512 mg, 5.95 mmoles), ethanol (6.5 ml) and stannous chloride dihydrate (10.4 g, 46.1 mmoles), ethanol (10.4 ml), concentrated hydrochloric acid (10.4 ml), 50-60°, 8 hours, afforded on column chromatography (chloroform) starting **5a** (168 mg, 89% conversion), **9b** (684 mg, 58% based on converted **5a**) and **9a** (78 mg, 7% based on converted **5a**). The column was not eluted with ethyl acetate to obtain **8** (if any).

B. Compounds **9b**, **9c**, **9d** from the Nitration of **7**.

Into a stirred mixture of **7** (976 mg, 4.41 mmoles) in acetic acid (7 ml), was added dropwise nitric acid (0.35 ml) at 25° according to the procedure in reference [14a]. The mixture was stirred for one hour, decanted into ice-water, neutralized with 10% sodium carbonate, extracted, dried and concentrated to afford a yellow solid (1170 mg, 100%), inseparable by column chromatography. Hydrolysis with concentrated hydrochloric acid (4.0 ml) in refluxing 95% ethanol (10 ml), 2 hours, followed by column chromatography furnished **9c** (87 mg, 9%), **9b** (240 mg, 24%) and **9d** (508 mg, 51%). For a different preparation of **9c**, see below.

C. Compound **9d** from the Reduction of **5b**.

According to the above procedure (see reduction of **5a**), 7,10-dinitrobenzodioxocin **5b** (55 mg, 0.22 mmole) [3] in ethanol (1 ml) and stannous chloride dihydrate (400 mg, 1.77 mmoles) in ethanol (8 ml) and concentrated hydrochloric acid (5 ml), 50-60°, 7 hours, afforded 28 mg (58%) of crude **9d**.

Compound **8** (viscous dark-red oil) had ir (neat): ν max 3430 (m, NH_2), 3350 (s, NH_2), 3220 (w, NH_2), 1610 (s), 1510 (m), 1503 (s), 1470 (m), 1367 (m), 1247 (m), 1219 (m), 1198 (s), 1089 (m), 1005 (m), 948 (m), 823 (m) cm^{-1}; ^1H nmr: δ 1.84 (m, 4H, 3,4-H), 3.56 (s, 4H, NH_2), 4.04 (t, J = 5 Hz, 2H, OCH_2), 4.36 (t, J = 5 Hz, 2H, OCH_2), 5.74 (s, 2H, aromatic); ms: m/z (% relative intensity) 194 (M^+, 62), 166 (7), 165 (7), 152 ($M^+ - C_3H_6$, 9) [15], 151 (7), 150 (10), 140 ($M^+ - C_4H_6$, 6) [15], 139 (24), 137 (16), 136 (18), 123 (32), 111 (67), 110 ($C_6H_6O_2^+$, 67), 94 (15), 82 (71), 55 ($C_4H_7^+$, 61), 54 (33), 53 (24), 52 (40), 42 (38), 41 (100), 39 (74).

Anal. Calcd. for $C_{10}H_{14}N_2O_2$: C, 61.84; H, 7.27; N, 14.42. Found: C, 61.62; H, 7.31; N, 14.32.

Compound **9a** (viscous red oil) had ir (neat): ν max 3465 (w, NH_2), 3370 (m, NH_2), 3230 (vw, NH_2), 1630 (m), 1530 (s), 1355 (m), 1333 (m), 1300 (m), 1224 (m), 1205 (m), 1148 (m), 1087 (m), 1027 (m), 936 (w), 774 (m) cm^{-1}; ^1H nmr: δ 1.91 (m, 4H, 3,4-H), 3.78 (s, 2H, NH_2), 4.24 (t, J = 5 Hz, 2H, OCH_2), 4.44 (t, J = 5 Hz, 2H, OCH_2), 6.45 (d, J = 2.5 Hz, 1H, 7-H), 6.66 (d, J = 2.5 Hz, 1H, 9-H); ms: m/z (% relative intensity) 224 (M^+, 100), 182 ($M^+ - C_3H_6$, 7), 181 (5), 178 (8), 170 ($M^+ - C_4H_6$, 50), 162 (14), 153 ($C_6H_6N_2O_4^+ - NH_3$, 35), 145 (18), 123 (21), 122 (19), 109 (13), 105 (14), 97 (20), 95 (33), 83 (20), 71 (23), 69 (30), 57 (45), 55 (80), 43 (45), 41 (55).

Anal. Calcd. for $C_{10}H_{12}N_2O_4$: C, 53.57; H, 5.39; N, 12.49. Found: C, 53.57; H, 5.41; N, 12.31.

Compound **9b** had mp 100-101° (red granules); ir (potassium bromide): ν max 3480 (m, NH_2), 3380 (m, NH_2), 3190 (vw, NH_2), 1617 (m), 1498 (s), 1488 (s), 1330 (s), 1220 (m), 1201 (m), 1119 (m), 1073 (m), 1040 (m), 949 (m), 869 (w), 742 (w) cm^{-1}; ^1H nmr: δ 1.93 (m, 4H, 3,4-H), 4.18 (br s, 2H, NH_2), 4.28 (t, J = 5 Hz, 2H, OCH_2), 4.54 (t, J = 5 Hz, 2H, OCH_2), 7.29 (s, 2H, aromatic H); partial ^1H nmr (acetone-d_6): δ 7.08 (d, J = 2.5 Hz, 1H, 8-H), 7.31 (d, J = 2.5 Hz, 1H, 10-H); ms: m/z (% relative intensity) 224 (M^+, 100), 207 (2), 195 (3), 182 (20), 181 (12), 178 (6), 170 ($M^+ - C_4H_6$, 32), 153 (6), 136 (17), 124 (9), 122 (12), 106 (10), 105 (9), 78 (26), 77 (13), 66 (17), 55 (84).

Anal. Calcd. for $C_{10}H_{12}N_2O_4$: C, 53.57; H, 5.39; N, 12.49. Found: C, 53.66; H, 5.28; N, 12.28.

Compound **9c** had mp 88-89° (yellow granules); ir (potassium bromide): ν max 3465 (w, NH_2), 3355 (w, NH_2), 1607 (m), 1586 (m), 1504 (m), 1457 (m), 1365 (m), 1242 (s), 1188 (s), 1079 (m), 967 (m), 820 (w), 771 (w) cm^{-1}; ^1H nmr: δ 1.94 (m, 4H, 3,4-H), 4.21 (t, J = 5 Hz, 2H, OCH_2), 4.59 (t, J = 5 Hz, 2H, OCH_2), 6.15 (s, 2H, NH_2), 6.21 (d, J = 9.5 Hz, 1H, 10-H), 7.76 (d, J = 9.5 Hz, 1H, 9-H); ms: m/z (% relative intensity) 224 (M^+, 56), 182 ($M^+ - C_3H_6$, 13), 181 (5), 170 ($M^+ - C_4H_6$, 8), 152 ($C_6H_6N_2O_4^+ - H_2O$, 18), 106 (13), 94 (12), 80 (10), 66 (11), 55 (100).

Anal. Calcd. for $C_{10}H_{12}N_2O_4$: C, 53.57; H, 5.39; N, 12.49. Found: C, 53.38; H, 5.18; N, 12.46.

Compound **9d** had mp 85-87° (yellow granules); ir (potassium bromide): ν max 3455 (m, NH_2), 3355 (m, NH_2), 1622 (s), 1587 (s), 1504 (s), 1487 (s), 1322 (s), 1308 (s), 1234 (m), 1205 (m), 1116 (m), 1093 (m), 1030 (m), 954 (m), 824 (w), 802 (w), 769 (w), 743 (w), 719 (w) cm^{-1}; ^1H nmr: δ 1.97 (m, 4H, 3,4-H), 4.40 (m, 6H, OCH_2 + NH_2), 6.35 (d, J = 9 Hz, 1H, 8-H), 7.58 (d, J = 9 Hz, 1H, 9-H); ms: m/z (% relative intensity) 224 (M^+, 94), 178 (7), 170 ($M^+ - C_4H_6$, 14), 169 (10), 152 ($C_6H_6N_2O_4^+ - H_2O$, 45), 145 (12), 135 (5), 130 (11), 125 (12), 124 ($C_6H_4N_2O_3^+ - CO$, 35), 122 (23), 96 (10), 80 (14), 79 (27), 66 (21), 55 (100).

Anal. Calcd. for $C_{10}H_{12}N_2O_4$: C, 53.57; H, 5.39; N, 12.49. Found: C, 53.77; H, 5.18; N, 12.36.

8-Amino-7-nitro-2,3,4,5-tetrahydrobenzo[*b*][1,4]dioxocin (**9e**).

8-Acetamido-7-nitrobenzodioxocin **10e** (125 mg, 0.469 mmole) [3] in ethanol (2 ml) and concentrated hydrochloric acid (2 ml) was heated at reflux for 0.5 hour. Work-up with water, neutralization with 10% sodium carbonate, extraction, drying and concentration furnished **9e** as a viscous dark-red oil (104 mg, 99%); ir (neat): ν max 3480 (w, NH_2), 3380 (m, NH_2), 3230 (vw, NH_2), 1628 (m), 1567 (m), 1520 (s), 1434 (w), 1360 (m), 1334 (m), 1252 (m), 1136 (m), 1087 (m), 1020 (m), 983 (m), 912 (w), 812 (w) cm^{-1}; ^1H nmr: δ 1.92 (m, 4H, 3,4-H), 4.21 (t, J = 5 Hz, 2H, OCH_2), 4.46 (m, 4H, OCH_2 + NH_2), 6.31 (d, J = 9 Hz, 1H, 9-H), 6.91 (d, J = 9 Hz, 1H, 10-H); ms: m/z (% relative intensity) 224 (M^+, 98), 198 (25),

178 (12), 170 (7), 155 (79), 153 (57), 144 (26), 122 (39), 107 (13), 95 (17), 88 (18), 80 (33), 55 (100).

Anal. Calcd. for $C_{10}H_{12}N_2O_4$: C, 53.57; H, 5.39; N, 12.49. Found: C, 53.66; H, 5.49; N, 12.44.

8-Acetamido-10-nitro-2,3,4,5-tetrahydrobenzo[*b*][1,4]dioxocin (**10b**).

According to the above procedure (see preparation of **7**), the amine **9a** (78 mg, 0.35 mmole), sodium acetate trihydrate (95 mg, 0.70 mmole) and acetic anhydride (0.50 ml, 0.54 g, 5.3 mmoles), 40-60°, one hour, furnished 86 mg (93%) of **10b**, mp 181-182° (pale-yellow needles); ir: ν max 3430 (w, NH), 1696 (m, C=O), 1586 (w), 1535 (s), 1491 (m), 1468 (w), 1363 (m), 1346 (m), 1319 (m), 1243 (w), 1138 (w), 1081 (w), 1035 (w), 998 (w) cm^{-1}; ^1H nmr: δ 1.95 (m, 4H, 3,4-H), 2.16 (s, 3H, CH_3), 4.41 (m, 4H, OCH_2), 7.34 (d, J = 3 Hz, 1H, 7-H), 7.47 (br s, 1H, NH), 7.53 (d, J = 3 Hz, 1H, 9-H); ms: m/z (% relative intensity) 266 (M^+, 24), 224 (M^+ -CH_2=C=O, 8), 212 (M^+ -C_4H_6, 2), 182 (4), 170 ($C_{10}H_{12}N_2O_4^+$ -C_4H_6 and $C_8H_8N_2O_5^+$ -CH_2=C=O, 22), 153 ($C_7H_6N_2O_4^+$ -CHO and $C_6H_6N_2O_4^+$ -NH_3, 8), 136 (4), 124 (4), 122 (7), 95 (7), 80 (5), 68 (16), 55 (48), 53 (12), 43 (100), 41 (33).

Anal. Calcd. for $C_{12}H_{14}N_2O_5$: C, 54.13; H, 5.30; N, 10.52. Found: C, 54.04; H, 5.30; N, 10.38.

7-Acetamido-9-nitro-2,3,4,5-tetrahydrobenzo[*b*][1,4]dioxocin (**10c**).

According to the above procedure (see preparation of **7**), the amine **9b** (1.35 g, 6.02 mmoles), sodium acetate trihydrate (1.60 g, 11.8 mmoles) and acetic anhydride (5.0 ml, 5.4 g, 53 mmoles), 40-50°, one hour, afforded 1.60 g (100%) of **10c**, mp 157-158° (pale-yellow needles); ir (potassium bromide): ν max 3340 (w, NH), 1680 (m, C=O), 1615 (m), 1520 (s), 1435 (m), 1337 (s), 1293 (m), 1250 (m), 1197 (m), 1086 (m), 956 (m), 891 (w), 750 (w) cm^{-1}; ^1H nmr: δ 1.96 (m, 4H, 3,4-H), 2.24 (s, 3H, CH_3), 4.26 (t, J = 5 Hz, 2H, OCH_2), 4.67 (t, J = 5 Hz, 2H, OCH_2), 7.62 (d, J = 2.5 Hz, 1H, 10-H), 7.84 (br s, 1H, NH), 9.00 (d, J = 2.5 Hz, 1H, 8-H); ms: m/z (% relative intensity) 266 (M^+, 32), 224 (M^+ -CH_2=C=O, 21), 207 (M^+ -CH_2=C=O + NH_3, 3), 182 ($C_{10}H_{12}N_2O_4^+$ -C_3H_6, 12), 181 (5), 178 ($C_{10}H_{12}N_2O_4^+$ -NO_2, 3), 170 ($C_{10}H_{12}N_2O_4^+$ -C_4H_6, 19), 153 ($C_7H_6N_2O_4^+$ -CHO and $C_6H_6N_2O_4^+$ -NH_3, 3), 136 (6), 124 (3), 122 (4), 119 (6), 66 (8), 65 (9), 55 (100), 43 (77).

Anal. Calcd. for $C_{12}H_{14}N_2O_5$: C, 54.13; H, 5.30; N, 10.52. Found: C, 54.05; H, 5.25; N, 10.59.

7-Acetamido-10-nitro-2,3,4,5-tetrahydrobenzo[*b*][1,4]dioxocin (**10d**).

According to the above procedure (see preparation of **7**), the amine **9d** (195 mg, 0.870 mmole), sodium acetate trihydrate (450 mg, 3.31 mmoles) and acetic anhydride (0.50 ml, 0.54 g, 5.3 mmoles), 40-50°, one hour, gave 230 mg (99%) of **10d**, mp 115-116° (pale-yellow crystals); ir (potassium bromide): ν max 3390 (m, NH), 1719 (m, C=O), 1702 (w), 1605 (m), 1580 (m), 1533 (s), 1495 (s), 1427 (m), 1376 (m), 1302 (s), 1289 (s), 1237 (m), 1212 (m), 1072 (m), 980 (m), 830 (w), 798 (w), 736 (w) cm^{-1}; ^1H nmr: δ 2.00 (m, 4H, 3,4-H), 2.24 (s, 3H, CH_3), 4.46 (m, 4H, OCH_2), 7.48 (d, J = 9.5 Hz, 1H, 9-H), 8.08 (br s, 1H, NH), 8.19 (d, J = 9.5 Hz, 1H, 8-H); ms: m/z (% relative intensity) 266 (M^+, 14), 224 (M^+ -CH_2=C=O, 7), 178 (3), 170 ($C_{10}H_{12}N_2O_4^+$ -C_4H_6, 9), 165 (7), 155 (4), 152 ($C_6H_6N_2O_4^+$ -H_2O, 12), 124 ($C_6H_4N_2O_3^+$ -CO, 9), 119 (12), 57 (10), 55 (79), 43 (100).

Anal. Calcd. for $C_{12}H_{14}N_2O_5$: C, 54.13; H, 5.30; N, 10.52. Found: C, 54.23; H, 5.34; N, 10.52.

8-Acetamido-7,9-dinitro-, 8-Acetamido-9,10-dinitro-2,3,4,5-tetrahydrobenzo[*b*][1,4]dioxocins **11a**, **11b**.

A. From the Nitration of **10a**.

According to the above procedure (see nitration of **7**), the acetamido compound **10a** (1.27 g, 4.77 mmoles), [3] in acetic acid (13 ml) was treated with nitric acid (8.0 ml) to yield, after decantation in ice-water, 1.30 g (87%) of **11b**. Continuous extraction of the mother liquor for 15 hours gave 82 mg (5%) of **11a**.

A different preparation using **10a** (1.00 g, 3.76 mmoles), acetic acid (10 ml) and nitric acid (5.0 ml) afforded 930 mg (80%) of **11b** and 133 mg (11%) of **11a**.

B. Compound **11b** from the Nitration of **10b**.

According to the above procedure (see nitration of **7**), compound **10b** (135 mg, 0.507 mmole), acetic acid (2 ml) and nitric acid (1.0 ml), 0.5 hour, furnished 136 mg (86%) of **11b**. The mother liquor was not extracted.

Compound **11a** had mp 217-218° (white needles); ir (potassium bromide): ν max 3245 (m, NH), 1670 (s, C=O), 1615 (w), 1576 (m), 1530 (s), 1493 (s), 1359 (m), 1346 (m), 1328 (m), 1297 (m), 1105 (w), 1087 (w), 1016 (m), 925 (w), 756 (w), 731 (w), 705 (w) cm^{-1}; ^1H nmr: δ 2.01 (m, 4H, 3,4-H), 2.16 (s, 3H, CH_3), 4.37 (t, J = 5 Hz, 2H, OCH_2), 4.62 (t, J = 5 Hz, 2H, OCH_2), 7.88 (s, 1H, aromatic H), 8.21 (br s, 1H, NH); ms: m/z (% relative intensity) 311 (M^+, 10), 269 (M^+ -CH_2=C=O, 100), 265 (M^+ -NO_2, 22), 223 (3), 215 ($C_{10}H_{11}N_3O_6^+$ -C_4H_6, 5), 197 ($C_6H_5N_3O_6^+$ -H_2O, 7), 169 ($C_6H_3N_3O_6^+$ -CO, 5), 167 (10), 137 (3), 135 (3), 123 (3), 122 (3), 95 (8), 69 (8), 57 (10), 55 (99), 43 (54).

Anal. Calcd. for $C_{12}H_{13}N_3O_7$: C, 46.31; H, 4.21; N, 13.50. Found: C, 46.12; H, 4.08; N, 13.39.

Compound **11b** had mp 193-195° (ethanol:acetone = 1:1, yellow granular plates); ir (potassium bromide): ν max 3380 (w, NH), 1703 (m, C=O), 1615 (w), 1551 (s), 1496 (s), 1418 (s), 1295 (s), 1217 (s), 1122 (m), 987 (m), 866 (w), 800 (w), 762 (w) cm^{-1}; ^1H nmr: δ 1.96 (m, 4H, 3,4-H), 2.28 (s, 3H, CH_3), 4.27 (t, J = 5 Hz, 2H, OCH_2), 4.66 (t, J = 5 Hz, 2H, OCH_2), 8.28 (s, 1H, aromatic H), 9.82 (br s, 1H, NH); ms: m/z (% relative intensity) 311 (M^+, 24), 269 (M^+ -CH_2=C=O, 46), 265 (M^+ -NO_2, 44), 215 ($C_{10}H_{11}N_3O_6^+$ -C_4H_6, 15), 211 ($C_{12}H_{13}N_2O_5^+$ -C_4H_6, 2), 198 ($C_6H_5N_3O_6^+$ -NH_3, 4), 177 (3), 122 (9), 95 (6), 93 (7), 68 (14), 55 (100), 43 (82).

Anal. Calcd. for $C_{12}H_{13}N_3O_7$: C, 46.31; H, 4.21; N, 13.50. Found: C, 46.43; H, 4.21; N, 13.58.

7-Acetamido-8,9-dinitro-, 7-Acetamido-9,10-dinitro-2,3,4,5-tetrahydrobenzo[*b*][1,4]dioxocins **11c**, **11d**.

A. From the Nitration of **10c**.

Using the above procedure (see nitration of **7**), compound **10c** (764 mg, 2.87 mmoles), acetic acid (8 ml) and nitric acid (5.1 ml) furnished a mixture, separated by column chromatography (ethyl acetate) to obtain 382 mg (43%) of **11c** followed by 444 mg (50%) of **11d**.

B. Compound **11d** from the Nitration of **10d**.

Using the above procedure (see nitration of **7**), compound **10d** (186 mg, 0.699 mmole), acetic acid (2 ml) and nitric acid (1.0 ml), 0.5 hour, afforded 154 mg (71%) of **11d**.

Compound **11c** had mp 186-187° (pale-yellow needles); ir (potassium bromide): ν max 3230 (m, NH), 1678 (s, C=O), 1546 (s),

1524 (s), 1480 (m), 1450 (m), 1341 (s), 1248 (m), 1100 (m), 990 (m), 879 (w), 801 (w), 769 (w) cm^{-1}; ^1H nmr: δ 2.00 (m, 4H, 3,4-H), 2.17 (s, 3H, CH_3), 4.36 (t, J = 5 Hz, 2H, OCH_2), 4.58 (t, J = 5 Hz, 2H, OCH_2), 7.01 (br s, 1H, NH), 7.68 (s, 1H, aromatic H); ms: m/z (% relative intensity) 311 (M^+, 3), 269 (54), 265 (M^+ -NO_2, 44), 223 ($C_{12}H_{13}N_2O_5^+$ -CH_2=C=O, 3), 215 ($C_{10}H_{11}N_3O_6^+$ -C_4H_6, 6), 210 ($C_{12}H_{13}N_2O_5^+$ -C_4H_7, 2), 197 ($C_6H_5N_3O_6^+$ -H_2O, 4), 105 (6), 77 (5), 69 (5), 57 (6), 55 (100), 43 (49).

Anal. Calcd. for $C_{12}H_{13}N_3O_7$: C, 46.31; H, 4.21; N, 13.50. Found: C, 46.41; H, 4.31; N, 13.54.

Compound **11d** had mp 210-211° (ethanol:chloroform = 1:1, off-white needles); ir (potassium bromide): ν max 3380 (m, NH), 1708 (s, C=O), 1605 (w), 1582 (m), 1533 (s), 1430 (s), 1381 (s), 1325 (s), 1229 (m), 1101 (s), 968 (m), 819 (w), 753 (w) cm^{-1}; ^1H nmr: δ 2.02 (m, 4H, 3,4-H), 2.26 (s, 3H, CH_3), 4.33 (t, J = 5 Hz, 2H, OCH_2), 4.75 (t, J = 5 Hz, 2H, OCH_2), 7.85 (br s, 1H, NH), 9.09 (s, 1H, aromatic H); ms: m/z (% relative intensity) 311 (M^+, 34), 269 (M^+ -CH_2=C=O, 30), 223 (4), 215 ($C_{10}H_{11}N_3O_6^+$ -C_4H_6, 9), 210 (4), 197 ($C_6H_5N_3O_6^+$ -H_2O, 6), 181 (8), 169 (6), 155 (5), 109 (5), 105 (8), 95 (8), 91 (8), 77 (15), 69 (15), 57 (22), 55 (100), 43 (96).

Anal. Calcd. for $C_{12}H_{13}N_3O_7$: C, 46.31; H, 4.21; N, 13.50. Found: C, 46.22; H, 4.15; N, 13.55.

7-Acetamido-8,10-dinitro-2,3,4,5-tetrahydrobenzo[*b*][1,4]dioxocin (**11e**).

Using the above procedure (see preparation of **7**), 162 mg (0.602 mmole) of the amine **13f** (see reduction of **18e** below), 350 mg (2.57 mmoles) of sodium acetate trihydrate and 0.62 g (6.1 mmoles) of acetic anhydride furnished, after 20 hours at 60-70°, a mixture which was separated by column chromatography (petroleum ether:ethyl acetate = 1:1) to give 97 mg (40% conversion) of starting material followed by 66 mg (88% based on converted **13f**) of **11e**, mp 158-159° (ethanol at 60°, white needles); ir: ν max 3410 (m, NH), 1721 (m, C=O), 1712 (m), 1600 (m), 1543 (s), 1536 (s), 1480 (m), 1426 (m), 1351 (s), 1080 (m), 1050 (w), 1020 (w), 995 (w), 938 (w) cm^{-1}; ^1H nmr: δ 2.02 (m, 4H, 3,4-H), 2.23 (s, 3H, CH_3), 4.50 (m, 4H, OCH_2), 7.99 (br s, 1H, NH), 8.18 (s, 1H, aromatic H); ms: m/z (% relative intensity) 311 (M^+, 18), 269 (M^+ -CH_2=C=O, 80), 265 (M^+ -NO_2, 20), 223 (2), 215 ($C_{10}H_{11}N_3O_6^+$ -C_4H_6, 4), 197 ($C_6H_5N_3O_6^+$ -H_2O, 13), 167 (3), 124 (2), 105 (7), 95 (5), 55 (100), 43 (52).

Anal. Calcd. for $C_{12}H_{13}N_3O_7$: C, 46.31; H, 4.21; N, 13.50. Found: C, 46.11; H, 4.08; N, 13.39.

8-Amino-7,9-dinitro-2,3,4,5-tetrahydrobenzo[*b*][1,4]dioxocin (**13a**).

Compound **11a** (112 mg, 0.360 mmole) in ethanol (5 ml) and concentrated hydrochloric acid (1.0 ml) was heated at reflux for 7 hours according to the above procedure (see preparation of **9e**) to yield 83 mg (86%) of **13a**, mp 151-152° (yellow needles); ir (potassium bromide): ν max 3470 (m, NH_2), 3360 (m, NH_2), 1625 (m), 1529 (m), 1514 (s), 1501 (s), 1495 (m), 1360 (m), 1340 (m), 1280 (s), 1268 (s), 1085 (m), 1001 (m), 935 (w), 915 (w), 749 (w) cm^{-1}; ^1H nmr: δ 1.98 (m, 4H, 3,4-H), 4.18 (t, J = 5 Hz, 2H, OCH_2), 4.78 (t, J = 5 Hz, 2H, OCH_2), 6.74 (br s, 2H, NH_2), 8.05 (s, 1H, aromatic H); ms: m/z (% relative intensity) 269 (M^+, 59), 239 (1), 223 (3), 215 (M^+ -C_4H_6, 5), 198 (2), 197 (M^+ -C_4H_6 -H_2O and $C_6H_5N_3O_6^+$ -H_2O, 6), 169 ($C_6H_3N_3O_5^+$ -CO, 4), 167 ($C_5H_3N_3O_4^+$ -H_2, 9), 139 (5), 123 (4), 121 (4), 109 (4), 105 (5), 95 (8), 93 (11), 77 (7), 69 (8), 65 (12), 55 (100).

Anal. Calcd. for $C_{10}H_{11}N_3O_6$: C, 44.62; H, 4.12; N, 15.61. Found: C, 44.48; H, 4.01; N, 15.66.

8-Amino-9,10-dinitro-2,3,4,5-tetrahydrobenzo[*b*][1,4]dioxocin (**13b**).

Compound **11b** (392 mg, 1.26 mmoles) in ethanol (8 ml) and concentrated hydrochloric acid (3.5 ml) was heated at reflux for 0.5 hour according to the above procedure (see preparation of **9e**) to give 339 mg (100%) of **13b**, mp 112-113° (orange needles); ir (potassium bromide): ν max 3490 (m, NH_2), 3370 (m, NH_2), 3185 (w, NH_2), 1629 (s), 1604 (w), 1538 (s), 1498 (s), 1396 (m), 1292 (s), 1277 (s), 1260 (s), 1230 (s), 1133 (m), 984 (m), 852 (m), 778 (m) cm^{-1}; ^1H nmr: δ 1.93 (m, 4H, 3,4-H), 4.19 (t, J = 5 Hz, 2H, OCH_2), 4.64 (t, J = 5 Hz, 2H, OCH_2), 6.06 (br s, 2H, NH_2), 6.35 (s, 1H, aromatic H); ms: m/z (% relative intensity) 269 (M^+, 29), 215 (M^+ -C_4H_6, 16), 198 ($C_6H_5N_3O_6^+$ -NH_3, 3), 177 (3), 168 ($C_6H_5N_3O_6^+$ -HONO, 3), 148 (4), 135 (7), 123 (6), 122 ($C_6H_4N_2O_4^+$ -NO_2 and 123-H, 15), 121 ($C_6H_4NO_2^+$ -H, 9), 111 (7), 95 (15), 94 (14), 93 ($C_6H_3NO_2^+$ -CO, 22), 77 (11), 76 (9), 68 (21), 65 (16), 55 (100).

Anal. Calcd. for $C_{10}H_{11}N_3O_6$: C, 44.62; H, 4.12; N, 15.61. Found: C, 44.64; H, 3.97; N, 15.43.

7-Amino-8,9-dinitro-2,3,4,5-tetrahydrobenzo[*b*][1,4]dioxocin (**13c**).

Compound **11c** (352 mg, 1.13 mmoles) in ethanol (20 ml) and 50% aqueous sulfuric acid (5 ml) was heated at reflux for 6 hours. Ethanol was removed by distillation *in vacuo* and the mixture was worked-up as above (see preparation of **9e**) to afford 303 mg (100%) of **13c**, mp 139-140° (orange leaflets); ir (potassium bromide): ν max 3480 (w, NH_2), 3375 (w, NH_2), 3340 (m, NH_2), 1616 (s), 1580 (m), 1538 (m), 1515 (m), 1445 (w), 1404 (m), 1372 (m), 1261 (s), 1248 (s), 1220 (s), 1200 (s), 1120 (m), 965 (w), 857 (w) cm^{-1}; ^1H nmr: δ 2.00 (m, 4H, 3,4-H), 4.35 (t, J = 5 Hz, 2H, OCH_2), 4.55 (t, J = 5 Hz, 2H, OCH_2), 6.28 (br s, 2H, NH_2), 6.61 (s, 1H, aromatic H); ms: m/z (% relative intensity) 269 (M^+, 22), 252 (M^+ -NH_3, 1), 239 (M^+ -CH_2O, 1), 227 (1), 215 (M^+ -C_4H_6, 3), 197 ($C_6H_5N_3O_6^+$ -H_2O, 2), 165 (7), 135 (6), 95 (3), 93 (3), 77 (8), 76 (9), 68 (6), 65 (18), 55 (100).

Anal. Calcd. for $C_{10}H_{11}N_3O_6$: C, 44.62; H, 4.12; N, 15.61. Found: C, 44.50; H, 3.99; N, 15.68.

7,9-Dinitro-, 7-Amino-9,10-dinitro-, 8-Amino-7,10-dinitro-, 7-Amino-8,10-dinitro-2,3,4,5-tetrahydrobenzo[*b*][1,4]dioxocins **5a**, **13d**, **13e**, **13f**.

A. Amine **13d** from the Hydrolysis of **11d**.

Compound **11d** (501 mg, 1.61 mmoles) was hydrolysed in ethanol (25 ml) and 30% aqueous sulfuric acid (5 ml) after it was heated at reflux for 1 hour as above (see preparation of **13c**) to yield 432 mg (100%) of the amine **13d**, mp 124-126° (orange needles); ir (potassium bromide): ν max 3465 (m, NH_2), 3375 (m, NH_2), 1615 (m), 1535 (s), 1518 (s), 1332 (s), 1245 (m), 1184 (m), 1132 (m), 964 (m), 900 (w), 817 (w) cm^{-1}; ^1H nmr: δ 2.00 (m, 4H, 3,4-H), 4.29 (s, 2H, NH_2), 4.35 (t, J = 5 Hz, 2H, OCH_2), 4.60 (t, J = 5 Hz, 2H, OCH_2), 7.15 (s, 1H, aromatic H); ms: m/z (% relative intensity) 269 (M^+, 82), 253 (3), 239 (M^+ -CH_2O, 4), 223 (M^+ -NO_2 and 253 -CH_2O, 4), 215 (M^+ -C_4H_6, 32), 197 (M^+ -72 and $C_6H_5N_3O_6^+$ -H_2O, 25), 177 (223 -NO_2, 9), 169 (197 -CO, 25), 155 (11), 135 (8), 123 (10), 111 (16), 109 (8), 105 (8), 97 (11), 95 (13), 93 (13), 83 (10), 81 (10), 77 (13), 69 (16), 65 (11), 57 (17), 55 (100).

Anal. Calcd. for $C_{10}H_{11}N_3O_6$: C, 44.62; H, 4.12; N, 15.61. Found: C, 44.69; H, 4.13; N, 15.48.

B. Compounds **5a**, **13f** from the Reduction of **18e**.

Reduction of 420 mg (1.42 mmoles) of azide **18e** (see below for preparation) was accomplished with 108 mg (2.85 mmoles) of sodium borohydride in 15 ml of refluxing ethanol (one hour). The solvent was removed *in vacuo* and water was added to the residue. Extraction, drying and concentration, followed by column chromatography (petroleum ether:ethyl acetate = 2:1), afforded 23 mg (6%) of **5a** (identified previously) [3] and 188 mg (49%) of the amine **13f**, mp 170-171° (yellow needles); ir: ν max 3510 (m, NH_2), 3390 (m, NH_2), 1615 (s), 1590 (s), 1523 (m), 1511 (m), 1449 (w), 1366 (m), 1336 (m), 1278 (s), 1252 (w), 1139 (w), 1075 (w), 1010 (w) cm^{-1}; ^1H nmr: δ 2.02 (m, 4H, 3,4-H), 4.39 (t, J = 5 Hz, 2H, OCH_2), 4.64 (t, J = 5 Hz, 2H, OCH_2), 6.78 (br s, 2H, NH_2), 8.61 (s, 1H, aromatic H); ms: m/z (% relative intensity) 269 (M^+, 19), 253 (1), 239 (1), 223 (1), 215 (M^+ -C_4H_6, 5), 198 (2), 197 (11), 177 (1), 167 (8), 152 (2), 122 (3), 121 (6), 105 (10), 95 (23), 94 (14), 93 (19), 77 (31), 65 (51), 55 (100), 53 (22), 41 (68).

Anal. Calcd. for $C_{10}H_{11}N_3O_6$: C, 44.62; H, 4.12; N, 15.61. Found: C, 44.48; H, 4.21; N, 15.44.

C. Amines **13d**, **13e**, **13f** from the Reduction of **12a**.

The trinitro derivative **12a** (1451 mg, 4.85 mmoles) [3] in ethanol (7 ml) was reduced as above (see reduction of **5a**) with stannous chloride dihydrate (7.0 g, 31 mmoles) in ethanol (7 ml) and concentrated hydrochloric acid (7.0 ml), 50-60°, 0.5 hour. Column chromatography (benzene) furnished starting material (155 mg, 89% conversion), **13e** (52 mg, 4% based on converted **12a**), **13d** (120 mg, 10% based on converted **12a**) and **13f** (14 mg, 1% based on converted **12a**). The amines **13d** and **13f** had identical ^1H nmr and ir spectra with those obtained from different procedures (see above). The amine **13e** was obtained in insufficient quantities for full characterization.

Compound **13e** had ^1H nmr: δ 1.98 (m, 4H, 3,4-H), 4.30 (t, J = 5 Hz, 2H, OCH_2), 4.46 (br s, 2H, NH_2), 4.58 (t, J = 5 Hz, 2H, OCH_2), 6.74 (s, 1H, aromatic H); ms: m/z (% relative intensity) 269 (M^+, 6), 215 (M^+ -C_4H_6, 3), 55 (100).

8-Azido-9,10-dinitro-2,3,4,5-tetrahydrobenzo[*b*][1,4]dioxocin (**18a**).

A. From 8-Amino-9-nitro-2,3,4,5-tetrahydrobenzo[*b*][1,4]dioxocin.

The title amine was converted to the corresponding azide **17a** in 100% yield as described previously [3], ir (carbon tetrachloride): ν max 2115 (s, N_3), 1613 (w), 1568 (m), 1528 (s), 1495 (s), 1344 (m), 1320 (s), 1304 (s), 1245 (s), 1175 (m), 1086 (m), 985 (s), 911 (m), 848 (w) cm^{-1}; ^1H nmr: δ 1.92 (m, 4H, 3,4-H), 4.23 (t, J = 5 Hz, 2H, OCH_2), 4.62 (t, J = 5 Hz, 2H, OCH_2), 6.81 (s, 1H, 7-H), 7.74 (s, 1H, 10-H).

Azide **17a** (458 mg, 1.83 mmoles) in acetic acid (0.5 ml) was treated with nitric acid (1.0 ml), 0.5 hour, as above (see nitration of **7**). The mixture was poured into ice-water to afford 464 mg (86%) of **18a** as a yellow solid.

B. From Amine **9a**.

Amine **9a** (44 mg, 0.20 mmole) in tetrahydrofuran (3 ml) was diazotized and the diazonium salt was subsequently treated *in situ* with sodium azide according to reference [3], to afford 49 mg (100%) of 8-azido-10-nitro-2,3,4,5-tetrahydrobenzo[*b*][1,4]dioxocin (**17d**); ir (carbon tetrachloride): ν max 2110 (s, N_3), 1618 (w), 1571 (w), 1535 (s), 1486 (s), 1363 (m), 1331 (m), 1284 (m), 1241 (s), 1088 (m), 1020 (m), 856 (w) cm^{-1}; ^1H nmr: δ 1.94 (m, 4H, 3,4-H), 4.39 (m, 4H, OCH_2), 6.79 (d, J = 2.5 Hz, 1H, 7-H), 6.98 (d, J = 2.5 Hz, 1H, 9-H).

Azide **17d** (49 mg, 0.20 mmole) in acetic acid (1 ml) was treated with nitric acid (0.4 ml), 0.5 hour, as above (see nitration of **7**) to furnish 57 mg (100%) of **18a**.

Compound **18a** had mp 79-81° dec (ethanol at 50°, yellow granules); ir (carbon tetrachloride): ν max 2120 (s, N_3), 1562 (s), 1555 (s), 1485 (s), 1391 (w), 1334 (m), 1300 (m), 1249 (m), 1090 (w), 1001 (w), 853 (vw) cm^{-1}; ^1H nmr: δ 2.00 (m, 4H, 3,4-H), 4.34 (t, J = 5 Hz, 2H, OCH_2), 4.64 (t, J = 5 Hz, 2H, OCH_2), 6.92 (s, 1H, aromatic H).

Anal. Calcd. for $C_{10}H_9N_5O_6$: C, 40.69; H, 3.07; N, 23.72. Found: C, 40.43; H, 2.99; N, 23.49.

8-Azido-7,10-dinitro-, 8-Azido-7,9-dinitro-, 7-Azido-8,9-dinitro-, 7-Azido-8,10-dinitro-, 7-Azido-9,10-dinitro-2,3,4,5-tetrahydrobenzo[*b*][1,4]dioxocins **18b**, **18c**, **18d**, **18e**, **18f**.

A. Azides **18b**, **18c** from Amine **9e**.

Diazotization of **9e** (77 mg, 0.34 mmole) in tetrahydrofuran (2 ml) followed by *in situ* reaction with excess sodium azide was carried out according to the procedure in reference [3] to yield 85 mg (100%) of 8-azido-7-nitro-2,3,4,5-tetrahydrobenzo[*b*][1,4]dioxocin (**17b**) as a pale yellow solid; ^1H nmr: δ 1.94 (m, 4H, 3,4-H), 4.39 (m, 4H, OCH_2), 6.78 (d, J = 9 Hz, 1H, 9-H), 7.08 (d, J = 9 Hz, 1H, 10-H).

The above azide **17b** (85 mg, 0.34 mmole) in acetic acid (0.5 ml) was treated with nitric acid (0.5 ml), 15 minutes, according to the procedure above (see nitration of **7**). The mixture was separated by column chromatography to afford 18 mg (18% overall) of **18b** and 79 mg (78% overall) of **18c**.

B. Azides of **18c**, **18d** from Trinitrobenzodioxocin **12b**.

A mixture of **12b** (504 mg, 1.68 mmoles) [3], sodium azide (116 mg, 1.78 mmoles) and dimethyl sulfoxide (7.7 ml) was stirred at 25° for 10 minutes and decanted into ice-water, according to the procedure in reference [3]. Extraction, drying and removal of ether *in vacuo* (without heating) furnished a yellow solid, separated by column chromatography to obtain 249 mg (50%) of **18c** followed by 132 mg (27%) of **18d**.

C. Azides **18d**, **18e** from Amine **9c** and Dinitro Derivative **5c**.

Diazotization of **9c** (78 mg, 0.35 mmole), 0°, 30 minutes, followed by the addition of excess sodium azide, 0°, 15 minutes [3], gave 87 mg (100%) of 7-azido-8-nitro-2,3,4,5-tetrahydrobenzo[*b*]-[1,4]dioxocin (**17e**) as a yellow solid; ir (carbon tetrachloride): ν max 2120 (s, N_3), 1642 (w), 1614 (w), 1581 (m), 1526 (s), 1478 (m), 1346 (m), 1316 (s), 1250 (m), 1082 (m), 1009 (m), 995 (m) cm^{-1}; ^1H nmr: δ 2.00 (m, 4H, 3,4-H), 4.32 (t, J = 5 Hz, 2H, OCH_2), 4.52 (t, J = 5 Hz, 2H, OCH_2), 6.74 (d, J = 9 Hz, 1H, 10-H), 7.56 (d, J = 9 Hz, 1H, 9-H).

Treatment of **5c** (241 mg, 0.948 mmole) [3] in dimethyl sulfoxide (4.3 ml) with sodium azide (428 mg, 6.58 mmoles) at 60-70° for 40 minutes according to the above procedure, also afforded azide **17e** (237 mg, 100%).

Reduction of **17e** (62 mg, 0.25 mmole), obtained from the dinitro derivative, with sodium borohydride (30 mg, 0.79 mmole) in refluxing ethanol (5 ml) for 10 minutes was carried out according to the procedure for the reduction of **18e** to obtain 45 mg (81%) of the amine **9c**.

The reaction of **17e** (87 mg, 0.35 mmole) in acetic acid (0.5 ml) with nitric acid (0.5 ml), 15 minutes, was carried out according to the procedure for the nitration of **7**. The mixture was separated by column chromatography to furnish 27 mg (26%) of **18e** fol-

lowed by 47 mg (46%) of **18d**.

D. Azide **18e** from Trinitrobenzodioxocin **12a**.

A mixture of **12a** (877 mg, 2.93 mmoles) [3], sodium azide (267 mg, 4.11 mmoles) and dimethyl sulfoxide (13.4 ml) was stirred at 25° for 30 minutes. Decantation into ice-water furnished 784 mg (91%) of **18e** as a pale-yellow solid.

E. Azides **18e**, **18f** from Dinitro Derivative **5b**.

A mixture of **5b** (475 mg, 1.87 mmoles) [3], sodium azide (854 mg, 13.1 mmoles) and dimethyl sulfoxide (8.0 ml) was thermostated at 50-60° for 4 hours. Work-up as above gave 466 mg (100%) of 7-azido-10-nitro-2,3,4,5-tetrahydrobenzo[*b*][1,4]dioxocin (**17c**) as a yellow solid; ir (carbon tetrachloride): ν max 2110 (s, N_3), 1595 (m), 1581 (m), 1530 (s), 1478 (s), 1372 (m), 1350 (s), 1328 (s), 1294 (s), 1254 (m), 1081 (w), 1029 (s), 927 (w) cm^{-1}; ^1H nmr: δ 2.00 (m, 4H, 3,4-H), 4.46 (m, 4H, OCH_2), 6.66 (d, J = 9 Hz, 1H, 8-H), 7.47 (d, J = 9 Hz, 1H, 9-H).

Azide **17c** (427 mg, 1.71 mmoles), in acetic acid (1 ml) was treated with nitric acid (1.0 ml) at 25°, 0.5 hour (according to the procedure for the nitration of **7**). Decantation into ice-water gave a yellow solid, separated by column chromatography (chloroform) to afford 336 mg (67%) of **18f**, followed by 72 mg (14%) of **18e**.

Compound **18b** had mp 114-116° dec (ethanol at 50°, pale-yellow needles); ir (carbon tetrachloride): ν max 2120 (s, N_3), 1619 (w), 1561 (w), 1548 (s), 1480 (m), 1372 (m), 1350 (m), 1287 (m), 1234 (w), 1088 (w), 1025 (w), 938 (w), 884 (vw), 849 (vw) cm^{-1}; ^1H nmr (carbon tetrachloride): δ 2.02 (m, 4H, 3,4-H), 4.52 (m, 4H, OCH_2), 7.15 (s, 1H, aromatic H); partial ^1H nmr (acetone-d_6): δ 7.64 (s, 1H, aromatic H).

Anal. Calcd. for $C_{10}H_9N_5O_6$: C, 40.69; H, 3.07; N, 23.72. Found: C, 40.38; H, 3.19; N, 23.61.

Compound **18c** had mp 100-101° (ethanol at 50°, yellow needles or granules); ir: ν max 2145 (m, N_3), 1610 (w), 1561 (m), 1552 (s), 1528 (m), 1484 (m), 1339 (m), 1303 (s), 1256 (m), 1157 (w), 1088 (w), 1003 (m) cm^{-1}; ^1H nmr: δ 1.98 (m, 4H, 3,4-H), 4.35 (t, J = 5 Hz, 2H, OCH_2), 4.64 (t, J = 5 Hz, 2H, OCH_2), 7.91 (s, 1H, aromatic H).

Anal. Calcd. for $C_{10}H_9N_5O_6$: C, 40.69; H, 3.07; N, 23.72. Found: C, 40.39; H, 3.13; N, 23.48.

Compound **18d** had mp 95-97° dec (ethanol at 50°, yellow needles or granules); ir (carbon tetrachloride): ν max 2140 (s, N_3), 2120 (s, N_3), 1560 (s), 1545 (s), 1478 (m), 1356 (s), 1341 (s), 1187 (w), 1087 (m), 1004 (m), 921 (w), 879 (w) cm^{-1}; ^1H nmr: δ 2.02 (m, 4H, 3,4-H), 4.39 (t, J = 5 Hz, 2H, OCH_2), 4.61 (t, J = 5 Hz, 2H, OCH_2), 7.61 (s, 1H, aromatic H).

Anal. Calcd. for $C_{10}H_9N_5O_6$: C, 40.69; H, 3.07; N, 23.72. Found: C, 40.41; H, 2.99; N, 23.42.

Compound **18e** had mp 90-92° dec (ethanol:acetone = 4:1 at 50°, yellow rhombohedral granules); ir (carbon tetrachloride): ν max 2125 (s, N_3), 1592 (s), 1536 (s), 1450 (m), 1347 (s), 1325 (s), 1294 (m), 1225 (w), 1149 (w), 1037 (m), 939 (w), 902 (w) cm^{-1}; ^1H nmr: δ 2.09 (m, 4H, 3,4-H), 4.45 (t, J = 5 Hz, 2H, OCH_2), 4.63 (t, J = 5 Hz, 2H, OCH_2), 8.15 (s, 1H, aromatic H).

Anal. Calcd. for $C_{10}H_9N_5O_6$: C, 40.69; H, 3.07; N, 23.72. Found: C, 40.38; H, 3.12; N, 23.99.

Compound **18f** had mp 110-111° (off-white needles, photosensitive); ir (carbon tetrachloride): ν max 2120 (s, N_3), 1560 (s), 1554 (s), 1546 (s), 1482 (m), 1432 (m), 1357 (s), 1343 (s), 1230 (w), 1086 (w), 1033 (m), 940 (w), 896 (w) cm^{-1}; ^1H nmr: δ 2.03 (m, 4H, 3,4-H), 4.38 (t, J = 5 Hz, 2H, OCH_2), 4.63 (t, J = 5 Hz, 2H, OCH_2), 7.52 (s, 1H, aromatic H).

Anal. Calcd. for $C_{10}H_9N_5O_6$: C, 40.69; H, 3.07; N, 23.72. Found: C, 40.48; H, 2.91; N, 23.85.

7-Phenylamino-8,10-dinitro-2,3,4,5-tetrahydrobenzo[*b*][1,4]dioxocin (**16**).

A mixture of the trinitro derivative **12a** (63 mg, 0.21 mmole) [3], aniline (105 mg, 1.13 mmoles) and tetrahydrofuran (5 ml) was thermostated at 60-70° for one hour. Removal of the solvent *in vacuo* followed by column chromatography (chloroform) afforded 70 mg (96%) of **16**, mp 113-114° (closed tube) (ethanol:acetone = 2:1, yellow needles); ir (carbon tetrachloride): ν max 3320 (w, NH), 1608 (m), 1597 (m), 1577 (s), 1499 (s), 1414 (w), 1339 (s), 1271 (m), 1092 (m), 940 (w) cm^{-1}; ^1H nmr: δ 1.43-2.18 with maxima at 1.69, 1.76, 1.81, 1.87, 1.94, 2.02 (m, 4H, 3,4-H), 3.76 (t, J = 5 Hz, 2H, OCH_2), 4.59 (t, J = 5 Hz, 2H, OCH_2), 6.72-7.49 with maxima at 6.86, 6.99, 7.09, 7.33 (m, 5H, Ph), 8.62 (s, 1H, 9-H), 9.17 (br s, 1H, NH); ms: m/z (% relative intensity) 345 (M^+, 8), 291 (1), 290 (4), 244 (2), 243 (2), 225 (3), 199 (4), 198 (5), 197 (4), 196 (6), 183 (7), 182 (8), 171 (16), 170 (13), 169 (16), 155 (11), 154 (20), 153 (10), 141 (20), 140 (22), 139 (12), 128 (19), 119 (12), 114 (15), 104 (18), 103 (20), 96 (13), 93 (14), 91 (14), 77 (65), 58 (18), 55 (100), 51 (31), 43 (85).

Anal. Calcd. for $C_{16}H_{15}N_5O_6$: C, 55.65; H, 4.38; N, 12.17. Found: C, 55.88; H, 4.51; N, 12.19.

4-Nitro-[1,4]dioxocino[2,3-*f*]-6,7,8,9-tetrahydro-2,1,3-benzoxadiazole 1-Oxide (**1b**).

To a suspension of furoxan **1a** (121 mg, 0.545 mmole) and acetic acid (1 ml) was added a solution of nitric acid (0.30 ml) and acetic acid (1 ml) according to the procedure for the nitration of **7**. Work-up afforded 100 mg (69%) of **1b**, mp rearranges to isomer **2b** on heating (ethanol at 50°, yellow needles); uv: λ max (ϵ) 394 (8500), 344 (8000), 332 (8000), 224 (28500) nm; ir: ν max 1631 (s), 1596 (s), 1535 (s), 1358 (m), 1318 (s), 1259 (w), 1188 (w), 1151 (w), 1077 (w), 1041 (w), 993 (s), 926 (w), 859 (w) cm^{-1}; ^1H nmr: δ 2.04 (m, 4H, 7,8-H), 4.37 (t, J = 5 Hz, 2H, OCH_2), 4.72 (t, J = 5 Hz, 2H, OCH_2), 7.12 (s, 1H, pseudoaromatic H); ms: m/z (% relative intensity) 267 (M^+, 1), 251 (0.5), 77 (7), 55 (23), 30 (100).

Anal. Calcd. for $C_{10}H_9N_3O_6$: C, 44.95; H, 3.40; N, 15.73. Found: C, 44.65; H, 3.34; N, 15.99.

4-Nitro-[1,4]dioxocino[2,3-*f*]-6,7,8,9-tetrahydro-2,1,3-benzoxadiazole (**3b**).

A mixture of **1b** (105 mg, 0.393 mmole), triphenylphosphine (155 mg, 0.591 mmole) and dichloromethane (5 ml) was stirred at 25° for 2 hours. Removal of the solvent *in vacuo*, without heating, gave a dark-red solid, suspected to be a 1:1 complex of **1b**:triphenylphosphine as shown by ^1H nmr. This was extracted several times with petroleum ether, dried and concentrated *in vacuo* (without heating) to obtain a red oil. Column chromatography (benzene) afforded 28 mg (28%) of **3b**, mp 94-95° (pale-yellow leaflets); uv: λ max (ϵ) 351 sh (2500), 304 (5500), 209 (11500) nm; ir (carbon tetrachloride): ν max 1640 (w), 1543 (s), 1498 (w), 1369 (w), 1329 (s), 1311 (m), 1219 (w), 1204 (m), 1078 (w), 1000 (s), 928 (w), 887 (w) cm^{-1}; ^1H nmr: δ 2.05 (m, 4H, 7,8-H), 4.40 (t, J = 5 Hz, 2H, OCH_2), 4.72 (t, J = 5 Hz, 2H, OCH_2), 7.55 (s, 1H, pseudoaromatic H).

Anal. Calcd. for $C_{10}H_9N_3O_5$: C, 47.82; H, 3.61; N, 16.73. Found: C, 47.68; H, 3.58; N, 16.38.

An attempt to nitrate furazan **3a** gave back starting material.

11-Nitro-[1,4]dioxocino[2,3-*e*]-5,6,7,8-tetrahydro-2,1,3-benzoxadiazole 1-Oxide (**2b**).

A. From Benzofuroxan **2a**.

To a suspension of furoxan **2a** (250 mg, 1.13 mmoles) in acetic acid (2 ml) was added a solution of nitric acid (0.5 ml) in acetic acid (2 ml) according to the procedure for the nitration of **7**. After stirring for 0.5 hour, the mixture was decanted in ice-water to furnish 225 mg (75%) of **2b**.

B. From Nitrobenzofuroxan **1b**.

A solution of **1b** (33 mg, 0.12 mmole) in toluene (10 ml) was heated at reflux for 0.5 hour. Removal of the solvent *in vacuo* afforded an orange solid, purified further by column chromatography to give 29 mg (88%) of **2b**. Further refluxing of **2b** in toluene for 4 hours did not cause any change.

C. From Azide **18a**.

Azide **18a** (67 mg, 0.23 mmole) was completely converted to **2b** (53 mg, 87%), after refluxing in toluene (3 ml) for 0.5 hour.

A solution of azide **18a** (106 mg, 0.36 mmole) in benzene (10 ml) was heated at reflux and the time course of the reaction was followed over a period of 6 hours; tlc (benzene) of all the samples withdrawn indicated (in order of decreasing R_f values) starting **18c**, and furoxans **1b** (trace) and **2b** (major). Removal of benzene followed by column chromatography (benzene) furnished 20 mg (81% conversion) of **18a** and 66 mg (85% based on converted **18a**) of **2b**.

D. From Azide **18c**.

Azide **18c** (74 mg, 0.25 mmole) was completely converted to **2b** (61 mg, 91%), after refluxing in toluene (3 ml) for 0.5 hour. The time course of the thermolysis of azide **18c** (98 mg, 0.33 mmole) in benzene (10 ml) was followed over a period of 23 hours according to the above procedure; tlc (benzene) of the samples withdrawn indicated identical results to those of the thermolysis of **18a** above. Column chromatography (benzene) afforded 20 mg (80% conversion) of starting **18c** and 66 mg (93% based on converted **18c**) of **2b**.

Compound **2b** had mp 177-179° (acetone:ethanol = 2:1, orange-red needles); uv: λ max (ε) 443 (9000), 333 sh (1500), 299 (3500), 223 (20000) nm; ir: ν max 1632 (s), 1586 (s), 1543 (s), 1529 (s), 1502 (m), 1430 (m), 1327 (s), 1309 (s), 1137 (w), 1093 (w), 997 (s), 984 (m), 897 (w) cm^{-1}; ^1H nmr: δ 2.04 (m, 4H, 6,7-H), 4.36 (t, J = 5 Hz, 2H, OCH_2), 4.83 (t, J = 5 Hz, 2H, OCH_2), 8.16 (s, 1H, pseudoaromatic H).

Anal. Calcd. for $C_{10}H_9N_3O_6$: C, 44.95; H, 3.40; N, 15.73. Found: C, 44.69; H, 3.40; N, 15.46.

11-Nitro-[1,4]dioxocino[2,3-*e*]-5,6,7,8-tetrahydro-2,1,3-benzoxadiazole (**4b**) [16].

A. From Nitrobenzofuroxan **2b**.

A mixture of **2b** (250 mg, 0.936 mmole) and triphenylphosphine (337 mg, 1.28 mmoles) in toluene (5 ml) was heated at reflux for 2 hours. Evaporation of the solvent *in vacuo* followed by column chromatography gave 194 mg (83%) of the furazan **4b**.

Deoxygenation of **2b** (26 mg, 0.097 mmole) was also carried out in ethylene glycol (3 ml) after heating at 140-150° for one hour. The mixture was decanted into ice-water, extracted, dried and concentrated to obtain 20 mg (82%) of **4b**.

B. From Azide **18c**.

A mixture of **18c** (256 mg, 0.867 mmole) in ethylene glycol (5 ml) was heated at 110-120° for 5 hours followed by work-up as described above. Column chromatography afforded 62 mg (28%) of furazan **4b** and 44 mg (19%) of furoxan **2b**.

C. From Azide **18d**.

A mixture of **18d** (42 mg, 0.14 mmole) in ethylene glycol (3 ml) was thermostated at 140-150° for 3 hours and worked-up as described above. Decantation into ice-water furnished 19 mg (53%) of **4b**.

Compound **4b** had mp 125-126° (pale-yellow needles, leaflets or granules); uv: λ max (ε) 391 (10000), 280 (6000), 212 (19000) nm; ir: ν max 1633 (w), 1531 (s), 1446 (m), 1331 (s), 1300 (s), 1152 (m), 1111 (m), 1041 (w), 1006 (s), 932 (w), 904 (w), 893 (w) cm^{-1}; ^1H nmr: δ 2.07 (m, 4H, 6,7-H), 4.41 (t, J = 5 Hz, 2H, OCH_2), 4.91 (t, J = 5 Hz, 2H, OCH_2), 8.30 (s, 1H, pseudoaromatic H).

Anal. Calcd. for $C_{10}H_9N_3O_5$: C, 47.82; H, 3.61; N, 16.73. Found: C, 47.81; H, 4.00; N, 16.63.

10-Nitro-[1,4]dioxocino[2,3-*e*]-5,6,7,8-tetrahydro-2,1,3-benzoxadiazole 1-Oxide (**2c**) [16].

Azide **18e** (225 mg, 0.762 mmole) was converted to **2c** (203 mg, 100%) after refluxing in toluene (5 ml) for one hour.

Thermolysis of azide **18e** (784 mg, 2.66 mmoles) in ethylene glycol (5 ml) at 100-110° for 15 minutes also afforded 585 mg (82%) of **2c**, mp 123-124° (yellow needles); uv: λ max (ε) 392 (5000), 333 sh (5000), 318 (5500), 307 sh (5000), 267 sh (4500), 223 (20500) nm; ir: ν max 1621 (s), 1548 (s), 1494 (s), 1451 (w), 1375 (m), 1318 (m), 1278 (w), 1189 (w), 1109 (m), 1096 (m), 1074 (m), 1064 (m), 1020 (w), 935 (w) cm^{-1}; ^1H nmr: δ 2.08 (m, 4H, 6,7-H), 4.45 (t, J = 5 Hz, 2H, OCH_2), 4.76 (t, J = 5 Hz, 2H, OCH_2), 7.36 (s, 1H, pseudoaromatic H).

Anal. Calcd. for $C_{10}H_9N_3O_6$: C, 44.95; H, 3.40; N, 15.73. Found: C, 45.06; H, 3.38; N, 15.83.

10-Nitro-[1,4]dioxocino[2,3-*e*]-5,6,7,8-tetrahydro-2,1,3-benzoxadiazole (**4c**) [16].

A mixture of furoxan **2c** (203 mg, 0.760 mmole) and triphenylphosphine (210 mg, 0.801 mmole) in toluene (5 ml) was heated at reflux for 0.5 hour. Removal of the solvent *in vacuo* followed by column chromatography afforded 190 mg (100%) of **4c**, mp 100-101° (pale-yellow leaflets); uv: λ max (ε) 351 (3000), 292 sh (2000), 263 (5000), 216 (20000) nm; ir (carbon tetrachloride): ν max 1627 (w), 1547 (s), 1470 (m), 1365 (m), 1338 (w), 1311 (m), 1177 (m), 1095 (m), 1012 (s), 934 (w), 893 (w) cm^{-1}; ^1H nmr: δ 2.04 (m, 4H, 6,7-H), 4.44 (t, J = 5 Hz, 2H, OCH_2), 4.77 (t, J = 5 Hz, 2H, OCH_2), 7.68 (s, 1H, pseudoaromatic H).

Anal. Calcd. for $C_{10}H_9N_3O_5$: C, 47.82; H, 3.61; N, 16.73. Found: C, 47.91; H, 3.81; N, 16.88.

7-Acetamido-8-azido-9-nitro-2,3,4,5-tetrahydrobenzo[*b*][1,4]dioxocin (**21a**).

A mixture of **11c** (102 mg, 0.328 mmole) and sodium azide (46 mg, 0.71 mmole) in dimethyl sulfoxide (6 ml) was stirred at 25° for 24 hours and decanted into ice-water to obtain 62 mg (62%) of **21a**, mp dec to furoxan **1d** (ethanol at 50°, pale-yellow needles); ir: ν max 3410 (w, NH), 2130 (s, N_3), 1703 (m, C=O), 1692 (m), 1629 (w), 1589 (w), 1527 (s), 1493 (m), 1469 (m), 1451 (s), 1332 (s), 1242 (w), 1102 (m), 1047 (w), 992 (w), 972 (w) cm^{-1}; ^1H nmr: δ 1.95 (m, 4H, 3,4-H), 2.24 (s, 3H, CH_3), 4.23 (t, J = 5 Hz,

2H, OCH_2), 4.61 (t, J = 5 Hz, 2H, OCH_2), 6.80 (br s, 1H, NH), 7.71 (s, 1H, aromatic H).

Anal. Calcd. for $C_{12}H_{13}N_5O_5$: C, 46.91; H, 4.26; N, 22.79. Found: C, 46.64; H, 4.31; N, 22.48.

7-Acetamido-9-azido-8-nitro-2,3,4,5-tetrahydrobenzo[*b*][1,4]dioxocin (**21b**).

A mixture of the amine **13c** (100 mg, 0.371 mmole) and sodium azide (149 mg, 2.29 mmoles) in dimethyl sulfoxide (3 ml) was thermostated at 60-70° for 3 hours and worked-up as described above (see azidation of **12b**). Column chromatography (petroleum ether:ethyl acetate = 1:1) afforded 35 mg (41% based on converted **13c**) of 7-amino-9-azido-8-nitro-2,3,4,5-tetrahydrobenzo[*b*]-[1,4]dioxocin (**22a**) as an orange solid, followed by starting amine **13c** (14 mg, 86% conversion). Compound **22a** had ir (carbon tetrachloride): ν max 3505 (w, NH_2), 3390 (w, NH_2), 2110 (s, N_3), 1597 (s), 1586 (s), 1514 (s), 1339 (m), 1279 (m), 1250 (m), 1222 (m), 1120 (w), 1082 (w), 977 (w) cm^{-1}; ^1H nmr: δ 1.94 (m, 4H, 3,4-H), 4.19 (t, J = 5 Hz, 2H, OCH_2), 4.60 (t, J = 5 Hz, 2H, OCH_2), 5.99 (br s, 2H, NH_2), 6.11 (s, 1H, aromatic H).

A mixture of **22a** (54 mg, 0.20 mmole) in tetrahydrofuran (1 ml) was treated with sodium acetate trihydrate (109 mg, 0.801 mmole) and acetic anhydride (250 mg, 2.45 mmoles) at 25° for 0.5 hour, according to the procedure described for the preparation of **7**. Column chromatography (chloroform:ethyl acetate = 2:1) furnished 42 mg (67%) of **21b**, mp dec to furoxan **1d** (ethanol at 60°, pale-yellow needles); ir: ν max 3415 (w, NH), 2115 (s, N_3), 1707 (m, C=O), 1578 (m), 1534 (s), 1339 (m), 1243 (m), 1103 (w), 1080 (w), 977 (w) cm^{-1}; ^1H nmr: δ 1.95 (m, 4H, 3,4-H), 2.14 (s, 3H, CH_3), 4.25 (t, J = 5 Hz, 2H, OCH_2), 4.48 (t, J = 5 Hz, 2H, OCH_2), 6.71 (s, 1H, aromatic H), 6.99 (br s, 1H, NH).

Anal. Calcd. for $C_{12}H_{13}N_5O_5$: C, 46.91; H, 4.26; N, 22.79. Found: C, 47.11; H, 4.38; N, 22.96.

7,9-Diazido-8-nitro-2,3,4,5-tetrahydrobenzo[*b*][1,4]dioxocin (**23a**).

Diazotization of **22a** (23 mg, 0.087 mmole) in tetrahydrofuran (2 ml), 0°, 30 minutes, was carried out according to the procedure described for diazotization of **9e** except that concentrated sulfuric acid was used instead of hydrochloric acid to generate nitrous acid. Addition of sodium azide in water, 0°, 30 minutes, followed by work-up and column chromatography gave 22 mg (87%) of diazide **23a**, mp 104-106° (ethanol at 50°, pale-yellow needles); ir (carbon tetrachloride): ν max 2140 (s, N_3), 2110 (s, N_3), 1604 (w), 1543 (m), 1479 (m), 1357 (m), 1344 (w), 1269 (m), 1185 (w), 1083 (w), 1008 (w) cm^{-1}; ^1H nmr: δ 1.98 (m, 4H, 3,4-H), 4.29 (t, J = 5 Hz, 2H, OCH_2), 4.49 (t, J = 5 Hz, 2H, OCH_2), 6.58 (s, 1H, aromatic H); ms: m/z (% relative intensity) 291 (M^+, 8), 235 (1), 219 (1), 206 (2), 193 (2), 190 (1), 175 (2), 164 (1), 163 (2), 152 (2), 147 (4), 133 (5), 123 (2), 105 (12), 89 (4), 77 (10), 55 (100).

Anal. Calcd. for $C_{10}H_9N_7O_4$: C, 41.24; H, 3.11; N, 33.67. Found: C, 41.11; H, 2.89; N, 33.48.

7,8-Diazido-9-nitro-2,3,4,5-tetrahydrobenzo[*b*][1,4]dioxocin (**23b**).

Azide **18d** (58 mg, 0.20 mmole) in dimethyl sulfoxide (2.5 ml) was treated with sodium azide (78 mg, 1.2 mmoles), 25°, 30 minutes, according to the procedure for azidation of **12b**. Column chromatography gave 43 mg (75%) of **23b**, mp 78-80° (ethanol at 50°, pale-yellow needles); ir (carbon tetrachloride): ν max 2130 (s, N_3), 2115 (s, N_3), 1528 (w), 1474 (m), 1454 (m), 1437 (m), 1344 (m), 1231 (m), 1186 (w), 1087 (w), 1080 (w), 1013 (m) cm^{-1}; ^1H nmr: δ 1.99 (m, 4H, 2,3-H), 4.29 (t, J = 5 Hz, 2H, OCH_2), 4.58 (t, J = 5 Hz, 2H, OCH_2), 7.37 (s, 1H, aromatic H); ms: m/z (% relative intensity) 291 (M^+, 3), 263 (1), 235 (4), 193 (1), 190 (1), 175 (2), 147 (2), 139 (2), 135 (2), 133 (2), 123 (1), 117 (3), 105 (6), 89 (9), 78 (10), 77 (19), 55 (100).

Anal. Calcd. for $C_{10}H_9N_7O_4$: C, 41.24; H, 3.11; N, 33.67. Found: C, 41.16; H, 2.99; N, 33.84.

4-Acetamido-[1,4]dioxocino[2,3-*f*]-6,7,8,9-tetrahydro-2,1,3-benzoxadiazole 1-Oxide (**1d**).

A. From **21a**.

Thermolysis of **21a** (56 mg, 0.18 mmole) in refluxing toluene (3 ml) for 4 hours, followed by column chromatography (chloroform:ethyl acetate = 3:1) furnished 40 mg (91%) of **1d**.

B. From **21b**.

Thermolysis of **21b** (9.0 mg, 0.029 mmole) in refluxing toluene (2 ml) for 7 hours, followed by column chromatography (chloroform:ethyl acetate 2:1) afforded 6.1 mg (75%) of **1d**, mp 185-186° dec (pale-yellow needles); uv: λ max (ϵ) 377 (6500), 343 (6000), 328 (5500), 313 sh (3500), 227 (24000), 210 sh (16000) nm; ir: ν max 3420 (w, NH), 1710 (m, C=O), 1631 (s), 1590 (s), 1494 (s), 1369 (w), 1333 (s), 1299 (m), 1239 (w), 1187 (w), 1145 (w), 1080 (m), 1042 (w), 1000 (m) cm^{-1}; ^1H nmr: δ 1.96 (m, 4H, 7,8-H), 2.23 (s, 3H, CH_3), 4.38 (m, 4H, OCH_2), 6.79 (s, 1H, pseudoaromatic H), 7.25 (br s, 1H, NH).

Anal. Calcd. for $C_{12}H_{13}N_3O_5$: C, 51.61; H, 4.69; N, 15.05. Found: C, 51.61; H, 4.49; N, 14.78.

4-Acetamido-[1,4]dioxocino[2,3-*f*]-6,7,8,9-tetrahydro-2,1,3-benzoxadiazole (**3d**).

A mixture of furoxan **1d** (91 mg, 0.33 mmole) and triphenylphosphine (120 mg, 0.458 mmole) in toluene (5 ml) was heated at reflux for 2 hours. Column chromatography (chloroform:ethyl acetate = 2:1) furnished 40 mg (47%) of furazan **3d**, mp 202-203° (white needles); uv: λ max (ϵ) 335 (5000), 297 (9000), 239 sh (7500), 215 (27000) nm; ir: ν max 3420 (w, NH), 1702 (m, C=O), 1630 (w), 1550 (w), 1478 (m), 1468 (m), 1438 (m), 1368 (w), 1335 (s), 1239 (w), 1117 (w), 1078 (w), 1039 (w), 998 (m) cm^{-1}; ^1H nmr: δ 1.98 (m, 4H, 7,8-H), 2.26 (s, 3H, CH_3), 4.42 (m, 4H, OCH_2), 7.19 (s, 1H, pseudoaromatic H), 7.50 (br s, 1H, NH).

Anal. Calcd. for $C_{12}H_{13}N_3O_4$: C, 54.75; H, 4.98; N, 15.96. Found: C, 54.61; H, 5.03; N, 15.89.

8-Acetamido-10-azido-9-nitro-2,3,4,5-tetrahydrobenzo[*b*][1,4]dioxocin (**21c**).

A. From **11b**.

A mixture of **11b** (464 mg, 1.49 mmoles) and sodium azide (237 mg, 3.65 mmoles) in dimethyl sulfoxide (7 ml) was stirred at 25° for 4 hours and decanted into ice-water to give 398 mg (87%) of **21c**.

B. From **13b**.

A mixture of the amine **13b** (170 mg, 0.631 mmole) and sodium azide (246 mg, 3.78 mmoles) in dimethyl sulfoxide (3 ml) was thermostated at 60-70° for 3.5 hours. Work-up gave 167 mg (100%) of 8-amino-10-azido-9-nitro-2,3,4,5-tetrahydrobenzo-[*b*][1,4]dioxocin (**22b**) as a dark-red oil; ir (carbon tetrachloride): ν max 3500 (w, NH_2), 3400 (w, NH_2), 2115 (s, N_3), 1614 (s), 1546 (m), 1513 (s), 1477 (m), 1327 (m), 1288 (s), 1264 (m), 1236 (m), 1224 (m), 1123 (m), 1082 (w), 1005 (m), 987 (m) cm^{-1}; ^1H nmr: δ 1.94 (m, 4H, 3,4-H), 4.16 (t, J = 5 Hz, 2H, OCH_2), 4.54 (t, J = 5 Hz, 2H,

OCH_2), 5.03 (br s, 2H, NH_2), 6.08 (s, 1H, aromatic H).

The azido amine **22b** (69 mg, 0.26 mmole) in tetrahydrofuran (3 ml) was diazotized as described above (see preparation of **23a**), 0°, 0.5 hour, followed by heating of the mixture at 50-60° for 0.5 hour. Work-up with water, extraction, drying and concentration afforded 65 mg (100%) of azide **17e** having identical ir and ^{1}H nmr spectra with those of a previous sample.

The azido amine **22b** (75 mg, 0.28 mmole) in tetrahydrofuran (5 ml) was diazotized according to the procedure described above (see preparation of **23a**) to afford 45 mg (55%) of diazide **23a** having identical ir and ^{1}H nmr spectra with those of a sample obtained previously.

The azido amine **22b** (64 mg, 0.24 mmole) was acetylated with acetic anhydride (200 mg, 1.96 mmoles) in the presence of sodium acetate trihydrate (63 mg, 0.46 mmole), 40-50°, one hour, to obtain 74 mg (100%) of the acetamido azide **21c** having identical ir and ^{1}H nmr spectra with those of a sample obtained above.

Compound **21c** had mp dec to furoxan **2d** (ethanol:acetone = 3:1 at 50°, pale-yellow needles); ir: ν max 3410 (w, NH), 2120 (s, N_3), 1709 (m, C=O), 1604 (m), 1580 (m), 1535 (m), 1494 (s), 1420 (m), 1323 (m), 1303 (m), 1244 (m), 1119 (w), 1008 (m) cm^{-1}; ^{1}H nmr: δ 1.98 (m, 4H, 3,4-H), 2.13 (s, 3H, CH_3), 4.27 (t, J = 5 Hz, 2H, OCH_2), 4.51 (t, J = 5 Hz, 2H, OCH_2), 7.67 (s, 1H, aromatic H), 8.34 (br s, 1H, NH).

Anal. Calcd. for $C_{12}H_{13}N_5O_5$: C, 46.91; H, 4.26; N, 22.79. Found: C, 47.06; H, 4.18; N, 22.67.

11-Acetamido-[1,4]dioxocino[2,3-*e*]-5,6,7,8-tetrahydro-2,1,3-benzoxadiazole 1-Oxide (**2d**) [16].

Thermolysis of **21c** (119 mg, 0.387 mmole) in refluxing toluene (4 ml) for 2 hours furnished 108 mg (100%) of furoxan **2d**, mp 200-201° (yellow needles); uv: λ max (ϵ) 404 (6000), 326 (3500), 313 (4000), 242 (16000), 223 (19000), 211 sh (17000) nm; ir: ν max 3375 (w, NH), 1708 (m, C=O), 1638 (w), 1626 (s), 1531 (s), 1500 (m), 1454 (m), 1359 (m), 1321 (m), 1084 (w), 1023 (m), 870 (w) cm^{-1}; ^{1}H nmr: δ 1.98 (m, 4H, 6,7-H), 2.21 (s, 3H, CH_3), 4.37 (t, J = 5 Hz, 2H, OCH_2), 4.63 (t, J = 5 Hz, 2H, OCH_2), 7.78 (s, 1H, pseudoaromatic H), 8.62 (br s, 1H, NH).

Anal. Calcd. for $C_{12}H_{13}N_3O_5$: C, 51.61; H, 4.69; N, 15.05. Found: C, 51.48; H, 4.42; N, 14.93.

11-Acetamido-[1,4]dioxocino[2,3-*e*]-5,6,7,8-tetrahydro-2,1,3-benzoxadiazole (**4d**) [16].

A. From Azide **21c**.

A mixture of **21c** (130 mg, 0.423 mmole) in dimethyl sulfoxide (3 ml) was heated at 190-200° for 2 hours. Work-up as in azidation of **12b** followed by column chromatography furnished 47 mg (42%) of furazan **4d**.

B. From Furoxan **2d**.

A mixture of **2d** (108 mg, 0.387 mmole) and triphenylphosphine (169 mg, 0.644 mmole) in toluene (4 ml) was heated at reflux for 2 hours. Removal of the solvent *in vacuo* followed by column chromatography (benzene:ethyl acetate = 3:1) afforded 90 mg (88%) of **4d**, mp 207-209° (pale-yellow needles); uv: λ max (ϵ) 373 (4500), 305 sh (2000), 291 (3000), 281 sh (2500), 245 sh (13000), 221 (19000) nm; ir: ν max 3425 (m, NH), 1705 (s, C=O), 1631 (m), 1573 (w), 1551 (s), 1518 (s), 1476 (s), 1454 (s), 1320 (s), 1244 (m), 1132 (m), 1084 (m), 1062 (m), 1002 (s), 993 (s), 891 (w) cm^{-1}; ^{1}H nmr: δ 2.00 (m, 4H, 6,7-H), 2.27 (s, 3H, CH_3), 4.40 (t, J = 5 Hz, 2H, OCH_2), 4.63 (t, J = 5 Hz, 2H, OCH_2), 7.88 (br s, 1H, NH), 7.96 (s, 1H, pseudoaromatic H).

Anal. Calcd. for $C_{12}H_{13}N_3O_4$: C, 54.75; H, 4.98; N, 15.96. Found: C, 54.48; H, 4.71; N, 15.63.

7-Acetamido-10-azido-9-nitro-2,3,4,5-tetrahydrobenzo[*b*][1,4]dioxocin (**21d**).

A mixture of **11d** (102 mg, 0.328 mmole) and sodium azide (127 mg, 1.95 mmoles) in dimethyl sulfoxide (1.5 ml) was stirred at 25° for 7 hours and decanted into ice-water to afford 99 mg (98%) of azide **21d**, mp 174-175° (ethanol:acetone = 4:1 at 55°, pale-yellow needles); ir: ν max 3430 (w, NH), 2120 (s, N_3), 1697 (m, C=O), 1588 (w), 1530 (s), 1514 (m), 1433 (m), 1352 (m), 1308 (m), 1241 (w), 1160 (w), 1102 (m), 970 (w) cm^{-1}; ^{1}H nmr: δ 2.02 (m, 4H, 3,4-H), 2.20 (s, 3H, CH_3), 4.31 (t, J = 5 Hz, 2H, OCH_2), 4.62 (t, J = 5 Hz, 2H, OCH_2), 7.68 (br s, 1H, NH), 8.71 (s, 1H, aromatic H).

Anal. Calcd. for $C_{12}H_{13}N_5O_5$: C, 46.91; H, 4.26; N, 22.79. Found: C, 47.11; H, 4.31; N, 22.85.

The acetamidoazide **21d** (87 mg, 0.28 mmole) was hydrolyzed with concentrated hydrochloric acid (0.5 ml) in refluxing ethanol (5 ml) according to the procedure described for the preparation of **9e**. Purification by column chromatography (chloroform:ethyl acetate = 2:1) afforded 57 mg (76%) of an orange solid, identified as 7-amino-10-azido-9-nitro-2,3,4,5-tetrahydrobenzo[*b*][1,4]-dioxocin (**22c**); ir: ν max 3495 (w, NH_2), 3400 (w, NH_2), 2115 (s, N_3), 1617 (m), 1590 (m), 1578 (m), 1520 (s), 1485 (s), 1462 (m), 1341 (s), 1315 (s), 1283 (m), 1165 (m), 1130 (m), 1081 (m), 966 (m) cm^{-1}; ^{1}H nmr: δ 2.00 (m, 4H, 2,3-H), 4.00 (br s, 2H, NH_2), 4.32 (t, J = 5 Hz, 2H, OCH_2), 4.52 (t, J = 5 Hz, 2H, OCH_2), 7.01 (s, 1H, aromatic H).

The azido amine **22c** (40 mg, 0.15 mmole) in tetrahydrofuran (3 ml) was deaminated according to the procedure described for the azido amine **22b**. Purification by column chromatography afforded 20 mg (53%) of azide **17e** having identical ir and ^{1}H nmr spectra with those of the samples obtained above.

The isomeric 7-amino-9-azido-10-nitro-2,3,4,5-tetrahydrobenzo-[*b*][1,4]dioxocin (**22d**) was prepared in low yield from **13d** (151 mg, 0.561 mmole) and sodium azide (615 mg, 9.46 mmoles) in dimethyl sulfoxide (3 ml) after heating at 60-70° for 16 hours. Column chromatography (petroleum ether:ethyl acetate = 2:1) afforded 5 mg of an unidentified yellow oil, 18 mg (15% based on converted **13d**) of **22d** as an orange solid and 32 mg (79% conversion) of starting **13d**. Compound **22d** had ir (carbon tetrachloride): ν max 3500 (w, NH_2), 3405 (w, NH_2), 2115 (s, N_3), 1610 (m), 1530 (m), 1495 (m), 1437 (w), 1358 (w), 1267 (m), 989 (w) cm^{-1}; ^{1}H nmr: δ 1.93 (m, 4H, 3,4-H), 4.02-4.78 with maxima at 4.28, 4.36, 4.44 (m, 6H, OCH_2 + NH_2), 6.14 (s, 1H, aromatic H).

10-Acetamido-[1,4]dioxocino[2,3-*e*]-5,6,7,8-tetrahydro-2,1,3-benzoxadiazole 1-Oxide (**2e**) [16].

Thermolysis of **21d** (183 mg, 0.596 mmole) in refluxing toluene (20 ml) for 2 hours afforded 166 mg (100%) of furoxan **2e**, mp 171-172° (pale-yellow needles); uv: λ max (ϵ) 376 (6000), 348 (7000), 334 (6500), 317 sh (4500), 253 (29500), 208 (15000) nm; ir: ν max 3415 (w, NH), 1708 (m, C=O), 1628 (s), 1593 (w), 1553 (w), 1510 (m), 1494 (s), 1372 (w), 1311 (w), 1279 (w), 1241 (w), 1099 (m), 1051 (w), 1001 (w), 970 (w), 917 (w) cm^{-1}; ^{1}H nmr: δ 2.05 (m, 4H, 6,7-H), 2.23 (s, 3H, CH_3), 4.48 (t, J = 5 Hz, 2H, OCH_2), 4.67 (t, J = 5 Hz, 2H, OCH_2), 8.06 (br s, 2H, pseudoaromatic H + NH).

Anal. Calcd. for $C_{12}H_{13}N_3O_5$: C, 51.61; H, 4.69; N, 15.05.

Found: C, 51.61; H, 4.63; N, 15.00.

10-Acetamido-[1,4]dioxocino[2,3-*e*]-5,6,7,8-tetrahydro-2,1,3-benzoxadiazole (**4e**) [16].

A mixture of furoxan **2e** (60 mg, 0.21 mmole) and triphenylphosphine (79 mg, 0.30 mmole) in toluene (5 ml) was heated at reflux for 2 hours. Evaporation of the solvent *in vacuo* followed by column chromatography (chloroform:ethyl acetate = 2:1) furnished 51 mg (90%) of furazan **4e**, mp 196-197° (white needles); uv: λ max (ε) 351 sh (2500), 317 sh (7500), 306 (8500), 230 (22000) nm; ir: ν max 3415 (m, NH), 1705 (m, C=O), 1627 (w), 1559 (s), 1499 (s), 1491 (s), 1398 (m), 1332 (m), 1312 (m), 1238 (m), 1176 (w), 1118 (s), 1108 (s), 1000 (m), 971 (m), 878 (m) cm^{-1}; ^1H nmr: δ 2.04 (m, 4H, 6,7-H), 2.27 (s, 3H, CH_3), 4.50 (t, J = 5 Hz, 2H, OCH_2), 4.67 (t, J = 5 Hz, 2H, OCH_2), 8.12 (br s, 1H, NH), 8.49 (s, 1H, pseudoaromatic H).

Anal. Calcd. for $C_{12}H_{13}N_3O_4$: C, 54.75; H, 4.98; N, 15.96. Found: C, 54.73; H, 4.84; N, 15.83.

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REFERENCES AND NOTES

[1] E. V. F. Scriven and K. Turnbull, *Chem. Rev.*, **88**, 297 (1988).

[2a] A. Gasko and A. J. Boulton, *Adv. Heterocyclic Chem.*, **29**, 251 (1981); [b] R. M. Paton, in Comprehensive Heterocyclic Chemistry, Vol **6**, A. R. Katritzky, ed, Pergamon Press, New York, 1984, p 393; [c] P. B. Ghosh, B. Ternai and M. W. Whitehouse, *Med. Res. Rev.*, **1**, 159 (1981).

[3] I. M. Takakis and P. M. Hadjimihalakis, *J. Heterocyclic Chem.*, **27**, 177 (1990).

[4] P. B. Ghosh and M. W. Whitehouse, *J. Med. Chem.*, **11**, 305 (1968); M. W. Whitehouse and P. B. Ghosh, *Biochem. Pharmacol.*, **17**, 158 (1968); P. B. Ghosh, B. Ternai and M. W. Whitehouse, *J. Med. Chem.*, **15**, 255 (1972).

[5] A. J. Boulton, P. B. Ghosh and A. R. Katritzky, *Angew. Chem., Int. Ed. Engl.*, **3**, 693 (1964) and references therein.

[6a] I. M. Takakis, P. M. Hadjimihalakis and G. G. Tsantali, *Tetrahedron*, accepted; [b] I. M. Takakis and P. M. Hadjimihalakis, *J. Heterocyclic Chem.*, **28**, 625 (1991); [c] Unpublished observations in this laboratory.

[7] S. V. Eswaran and S. K. Sajadian, *J. Heterocyclic Chem.*, **25**, 803 (1988).

[8] F. B. Mallory, *Org. Synth.*, **37**, 1 (1957).

[9] P. M. Hadjimihalakis, *J. Heterocyclic Chem.*, **13**, 1327 (1976).

[10a] P. M. Heertjes, A. A. Knape and H. Talsma, *J. Chem. Soc.*, 1068 (1954); [b] P. M. Heertjes, A. A. Nijman-Knape, H. Talsma and N. J. Faasen, *J. Chem. Soc.*, 1313 (1955).

[11] V. K. Daukšas, G. V. Purvaneckas, E. B. Udrénaité, V. L. Gineityté and A. V. Barauskaité, *Heterocycles*, **15**, 1395 (1981).

[12] P. A. S. Smith and J. H. Boyer, *Org. Synth.*, **31**, 14 (1951); L. K. Dyall, *Aust. J. Chem.*, **39**, 89 (1986); R. Noto, R. Rainieri and C. Arnone, *J. Chem. Soc., Perkin Trans. 2*, 127 (1989).

[13a] J. R. Beck, *Tetrahedron*, **34**, 2057 (1978); [b] S. Sekigushi, T. Suzuki, Y. Hirosawa and H. Ishikura, *J. Org. Chem.*, **55**, 1829 (1990).

[14a] P. M. Heertjes and L. J. Revallier, *Rec. Trav. Chim. Pays-Bas*, **69**, 262 (1950); [b] P. M. Heertjes, A. A. Knape and H. Talsma, *J. Chem. Soc.*, 1868 (1954).

[15] P. Vouros and K. Biemann, *Org. Mass Spectrom.*, **3**, 1317 (1970).

[16] Since furoxans may exist in two equilibrating isomeric forms [2], for reasons of consistency, we have based naming of the furoxans **2** on the isomer in which the *N*-oxide oxygen is furthest away from the heterocyclic side ring. It is understood that the name thus derived may not always represent the most stable isomeric form.