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o-Nitroaniline Derivatives - 13[1]
Reactions of *N*-(*o*-Nitroaryl)sarcosine Esters with Bases[2]

Pamela A. Collins, Michael D. McFarlane, Raymond K. Mackie, and David M. Smith*

Department of Chemistry, University of St. Andrews
Purdie Building, St. Andrews, Fife, KY16 9ST, Scotland

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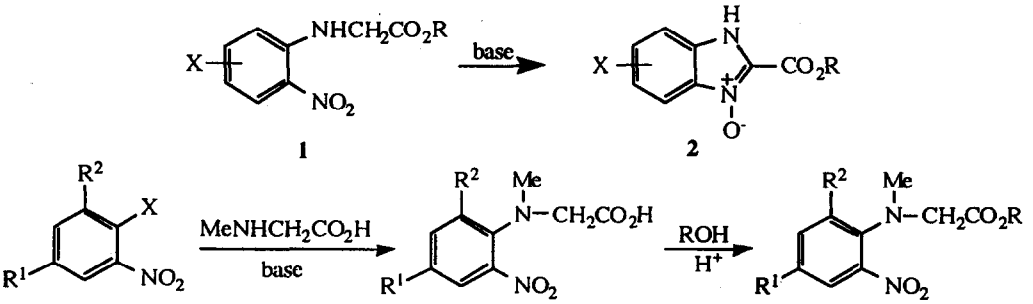
For Professor Charles Rees, a good friend for many years, in honour of his sixty-fifth birthday.

Abstract: The title reactions give 1-hydroxy-4-methylquinoxaline-2,3-diones (**4**) together with a variety of mono- and bi-cyclic by-products. All of these may result from a common intermediate, *viz.* a 1-hydroxy-4-methyl-3,4-dihydro-1*H*-2,1,4-benzoxadiazine-3-carboxylate ester (**18**).

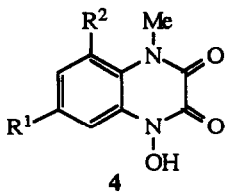
Although it is well known[3,4] that *N*-(*o*-nitrophenyl)glycine esters (e.g.**1**) are readily cyclised in basic media to esters of 1*H*-benzimidazole-2-carboxylic acid 3-oxide (e.g. **2**), we have shown in Part 12[1] that *N*-(2,4-dinitrophenyl)sarcosine ethyl ester (**3a**) reacts with bases to give quite different types of product, *viz.* 1-hydroxy-4-methyl-7-nitroquinoxaline-2,3-dione (**4a**) and, according to the base used, one or other of the azoxybenzene derivatives **5a** and **6a.** We now report on experiments intended to define the scope of these unusual reactions, and to shed some light on possible mechanisms.



Scheme 1

[**a-h**: see next page]

One limitation is the availability of *N*-(*o*-nitroaryl)sarcosine esters themselves. In general, they are most reliably prepared from an *o*-halogenonitroarene and sarcosine in presence of a base, followed by esterification (Scheme 1); direct reaction of the halogenonitroarene with a sarcosine ester frequently leads, in part, to further reaction of the required product **3**, and gives a mixture which is not easily separated. The precise reaction conditions under which each of the esters **3a** - **3h** is best obtained depend critically on the ring substituents (R^1 and R^2), and the methods described in the Experimental are the best we have discovered to date. Two *N*-(*o*-nitropyridyl)sarcosine esters, **7a** and **7b**, are obtained similarly.



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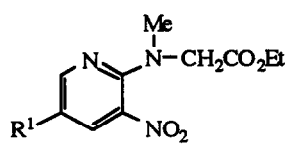

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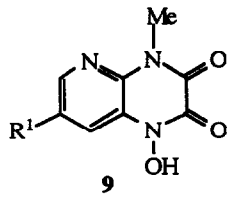

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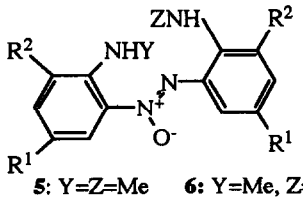
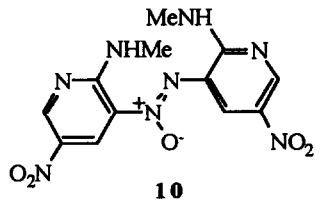


5: Y=Z=Me **6**: Y=Me, Z=H

17: Y=Z=H



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a: R^1=NO_2, R^2=H **b**: R^1=R^2=H **c**: R^1=CF_3, R^2=H **d**: R^1=F, R^2=H
e: R^1=H, R^2=NO_2 **f**: R^1=CF_3, R^2=NO_2 **g**: R^1=CF_3, R^2=Cl **h**: R^1=NO_2, R^2=CF_3.

The reactions of the dinitrophenylsarcosine ethyl ester **3a** with sodium ethoxide, potassium carbonate, and 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU) give the quinoxalinedione **4a** and the monomethyl-azoxybenzene **6a** in varying proportions (Table 1), with the weaker bases apparently favouring the former product. The reaction of the corresponding methyl ester **8a** with sodium methoxide gives similar results. On the other hand, reaction of **3a** with triethylamine gives at best only a trace of **4a**, the main product being the *dimethylated* azoxybenzene **5a**.

The reactions of the mononitrophenylsarcosine ester **3b**, and its pyridyl analogue **7b**, follow along similar lines: the former with sodium ethoxide gives the quinoxalinedione **4b** (44%),while the latter with either sodium ethoxide or potassium carbonate gives 1-hydroxy-4-methylpyrido[2,3-*b*]pyrazine-2,3-dione, **9b** (35 and 18% respectively). In none of these reactions is an azoxy compound isolated, although a coloured spot of the correct R_f is detectable on t.l.c. In the corresponding reactions of the dinitropyridylsarcosine ester **7a**, which give **9a** in 29 and 24% yield respectively, the dimethylated azoxypyridine **10** has been isolated in one instance (yield *ca.* 2%).

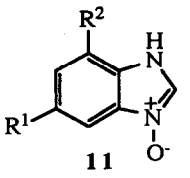
Ester	Base (mol)	Solvent	Temp./°C	Time/h	Yields/% **4a**	**5a**	**6a**
3a	NaOEt (1)	EtOH/DMF	room	3	19	-	32
3a	NaOEt (1)	EtOH	room	1	14	-	20
3a	K_2CO_3 (1)	EtOH/DMF	room	4	35	-	4
3a	DBU (1)	EtOH/DMF	room	1	23	-	trace
3a	DBU (1)	DMSO	room	3	33	-	trace
3a	Et_3N (1)	EtOH	reflux	4	1	7	-
3a	Et_3N (2)	EtOH	reflux	4	-	16	-
8a	NaOMe (1)	MeOH/DMF	room	3	21	-	19

Table 1. Products of the reactions of esters **3a** and **8a** with bases

In all of the above reactions, the isolated products together account, at best, for only half of the starting material **3** or **7** or **8**, and it is evident from t.l.c. and n.m.r. that both the acidic and non-acidic fractions of the

crude product contain several components. In exploring further the scope of the reaction, we have sought to identify these by-products, in the hope that these may help to clarify the reaction mechanism.

The 4-trifluoromethyl-substituted ester **3c** with potassium carbonate gives, as expected, the quinoxalinedione **4c** (31%), but the by-products do not include an azoxy-compound: the acidic fraction also contains the 1-*unsubstituted* benzimidazole 3-oxide **11c**, identified by spectroscopic comparison with an authentic sample[5], and a fraction with *m/z* 214 which is probably a mixture of 6- and 7-trifluoromethylquinoxalin-2-ones **12c** and **13c** (*cf.* below). The non-acidic fraction contains, as well as unreacted starting material, *N*-methyl-2-nitroso-4-(trifluoromethyl)aniline, **14c**. The reaction of ester **3c** with triethylamine is very slow (only 2% yield of **4c** after 7h) and has not been explored further.



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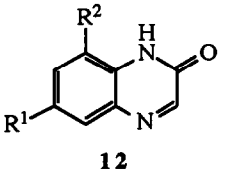

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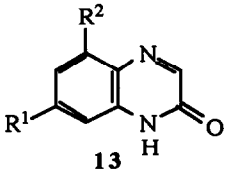

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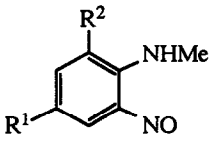

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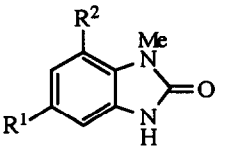

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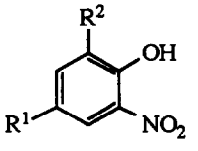

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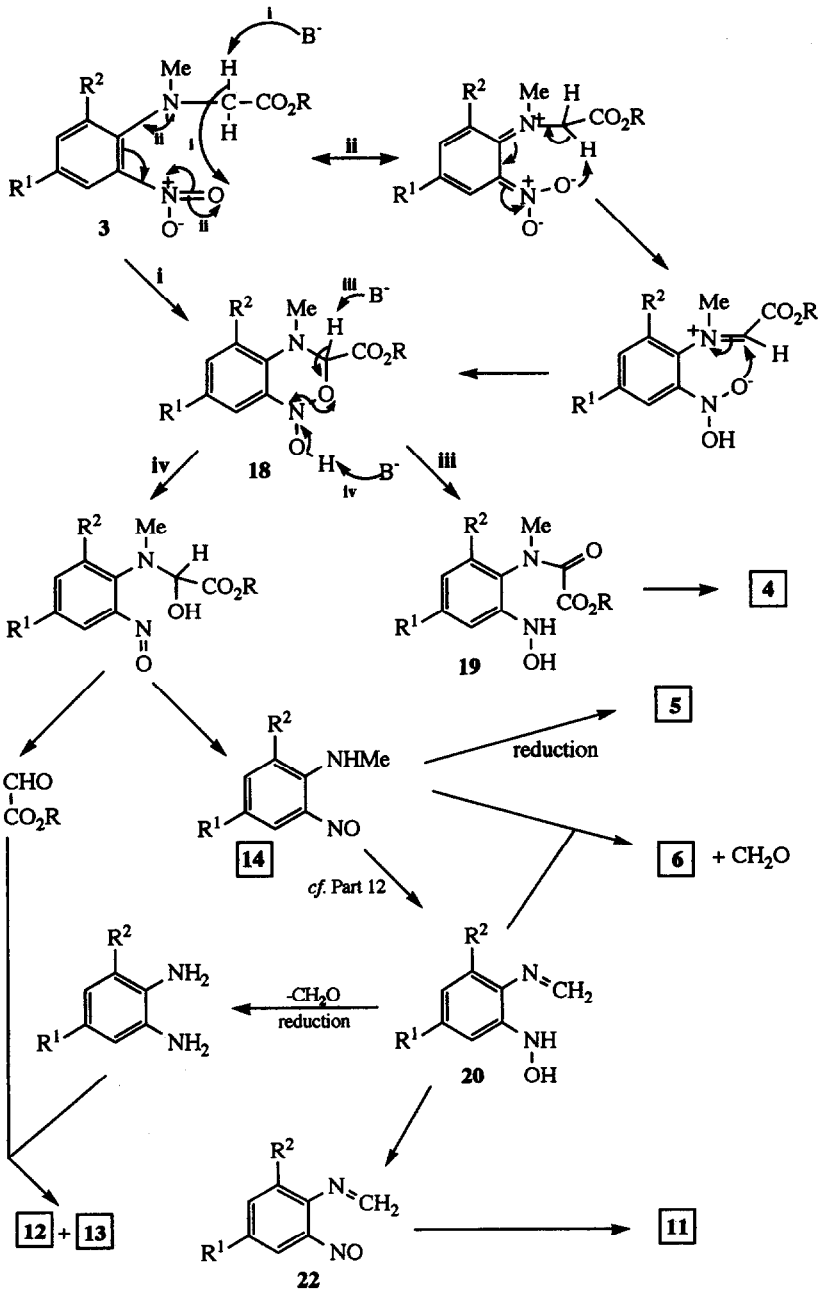
In contrast, the reaction of the 4-fluoro-substituted ester **3d** with potassium carbonate gives only a trace of the quinoxalinedione **4d**, the main acidic product being the known[3] 5-fluoro-1*H*-benzimidazole 3-oxide **11d** (10%); also identified were 6- and 7-fluoroquinoxalin-2-ones, **12d** and **13d**. The 2,6-dinitrophenylsarcosine ester **3e** gives the quinoxalinedione **4e** in 19% yield, together with 8-nitroquinoxalin-2-one, **12e**; the non-acidic fraction contains a product, the n.m.r. spectrum of which is consistent with its formulation as 1-methyl-7-nitrobenzimidazol-2-one, **15e**.

None of the four 2,4,6-trisubstituted esters, **3f**, **3g**, **8g**, and **3h**, gives a quinoxalinedione in satisfactory yield. In the reaction of **3f** with triethylamine, the dione **4f** was contaminated by 2,6-dinitro-4-trifluoromethylphenol, **16f**. Esters **3g** and **8g** with barium hydroxide give the benzimidazolone **15g** and the unmethylated azoxybenzene **17g**; compound **8g** with potassium carbonate, however, gives the quinoxalin-2-one isomers **12g** and **13g** as the only identifiable products. Ester **3h** appears to be highly reactive, and consequently is difficult to obtain pure; as prepared, it is contaminated both by 2,4-dinitro-6-trifluoromethylphenol, **16h**, and the quinoxalinedione **4h**. Products obtained from the subsequent reactions of this impure ester may therefore be suspect, and are not reported here.

In the preliminary communication[2], we proposed a tentative mechanism to account for the formation of the quinoxalinediones **4**, and in Part 12[1] this mechanism was expanded to include a possible mechanistic route to the azoxybenzenes **5** and **6**. The key intermediate in this mechanism (Scheme 2) is a 1-hydroxy-4-methyl-3,4-dihydro-1*H*-2,1,4-benzoxadiazine-3-carboxylate ester **18**, which is envisaged as being formed from the ester **3** *either* (pathway **i**) by deprotonation followed by nucleophilic attack on the nitro-oxygen *or* (pathway **ii**) by intramolecular hydrogen transfer followed by nucleophilic attack on an iminium cation. Ring opening of **18** is then possible in several ways. Abstraction of the proton α to the ester group (pathway **iii**) gives an *o*-hydroxylamino-ester **19** which may then recyclise to the quinoxalinedione **4**. Abstraction of the hydroxyl proton (pathway **iv**) leads to an *o*-nitrosoaniline **14** and a glyoxylate ester; the former may then either be reduced to the


3
18
19
20
22
14
4
5
6
+ CH2O
reduction
cf. Part 12
-CH2O
reduction
12 + 13
11

Scheme 2

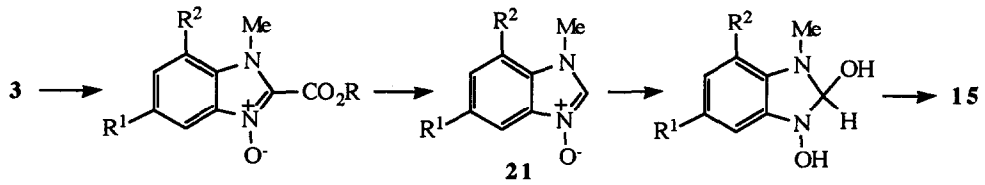
azoxybenzene **5** (with **19** as the possible reducing agent) or may undergo an internal redox reaction to give an *o*-hydroxylaminoanil **20**, and thence the azoxybenzene **6**.

The diverse by-products found in the reactions of the esters **3c-3h** serve to reinforce these mechanistic proposals. For the first time, a nitrosoaniline (*viz.***14c**) has been detected in these reactions, and the fact that a mixture of *two* quinoxalinones, **12** and **13**, are formed in some cases supports the idea that ethyl glyoxylate may indeed be an intermediate. The formation of quinoxalinones at all, however, also implies the presence of an *o*-phenylenediamine, and the most likely source of this appears to be the anil **20**.

[The **12:13** ratio in these reactions may not be the same as that obtained in separate experiments using pure diamines and pure ethyl glyoxylate; the isomer ratio in such reactions depends on the relative nucleophilicities of the two amino groups, and may therefore be sensitive to changes in the pH of the system[6]. The apparently exclusive formation of **12e** at the expense of **13e**, however, is to be expected from a diamine in which one amino group is obviously much more nucleophilic than the other.]

The most surprising by-product in any of these reactions is the unmethylated benzimidazole oxide **11**. A *1-methyl*benzimidazole 3-oxide (**21**) might indeed have been expected to have been the main product of all these cyclisations, by analogy with the reaction **1**→**2**, and the ease with which esters such as **2** are known to undergo hydrolysis and decarboxylation in basic media[3]. The *N*-methylbenzimidazolone **15** may represent the end-product of a mechanistic pathway (Scheme 3) which involves **21** as an intermediate, since the isomerisation of **15** to **21** in presence of water has been reported[7]. Labelling studies will be required to establish if C-2 of the *N*-oxide **11** is derived from the methylene or the *N*-methyl group of the ester **3**; in terms of Scheme 2, however, it may be worth noting that *o*-nitrosoanils **22** are expected to cyclise spontaneously to benzimidazole oxides[8], and such anils are conceivable as products of redox processes involving **14** or **20.**

These mechanistic aspects are continuing to receive our attention, and we shall report further on them in due course.



Scheme 3

EXPERIMENTAL

I.r. spectra were recorded for Nujol mulls. ^{1}H n.m.r. spectra were recorded at 80 or 300 MHz (Bruker WP80 or AM300), ^{19}F spectra at 75.3 MHz (WP80), and ^{13}C spectra at 75.5 MHz (AM300), in d_6-dimethyl sulphoxide unless otherwise indicated.

N-(2,4-Dinitrophenyl)sarcosine ethyl ester, **3a**,was prepared as described in Part 12[1]. The corresponding *methyl ester* **8a**, m.p. 109-110°C. (from methanol) was similarly obtained (yield, 70%) from 1-chloro-2,4-dinitrobenzene, methyl sarcosinate, and hydrogen chloride in methanol. (Found: C, 44.5; H, 4.1; N, 15.6. $C_{10}H_{11}N_3O_6$ requires C, 44.6; H, 4.1; N, 15.6%.)

N-(o-*Nitrophenyl)sarcosine Ethyl Ester* (**3b**).- Reaction of *o*-fluoronitrobenzene with sarcosine in presence of sodium hydrogen carbonate[9] gave *N*-(*o*-nitrophenyl)sarcosine, m.p. 88-92°C. (lit.[9], 75°C), in 81% yield. This acid (10.5 g) was esterified by dissolution in ethanol (150 ml) containing dry hydrogen chloride (3.5 g), and

boiling the solution for 5 h. Evaporation of the solvent and distillation (Kugelrohr) of the residue gave the *ester* (**3b**) (10.53g, 88%), b.p. 170°C./0.2mm. (Found: C, 55.2; H, 5.9; N, 11.8. $C_{11}H_{14}N_2O_4$ requires C,55.5; H, 5.9; N, 11.8%). $\nu_{max.}$ 1725 (C=O), 1560 and 1335 cm^{-1} (NO_2); δ_H 2.13 (3H, t, CH_2CH_3), 2.89 (3H, s, NCH_3), 3.99 (2H, s, NCH_2), 4.15 (2H, q, CH_2CH_3), 6.89-7.84 (4H, m, ArH); J_{ethyl} 7 Hz.

N-(*2-Nitro-4-trifluoromethylphenyl)sarcosine Ethyl Ester* (**3c**).-To a solution of 4-chloro-3-nitrobenzotrifluoride (1.13g, 5 mmol) in ethanol (25 ml) were added potassium carbonate (0.83g, 6 mmol) and sarcosine (0.53g, 6 mmol). The mixture was boiled for 5 h, then filtered and evaporated to dryness *in vacuo*. Ether (25 ml) was added, and the mixture extracted first with hydrochloric acid (5M) and then with sodium hydroxide (3M).The basic extract was acidified (conc. HCl), the product extracted with ether, and the ether dried (Na_2SO_4) and evaporated, giving the substituted *sarcosine* (1.05g, 76%), m.p. 120-121°C. (from toluene). (Found: C, 43.2; H, 3.0; N, 9.8. $C_{10}H_9F_3N_2O_4$ requires C, 43.2; H, 3.3; N, 10.1%). δ_H (d_6-acetone) 3.07 (3H, s, NCH_3), 4.27 (2H, s, CH_2), 7.42 (1H, d, H-6), 7.75 (1H, br s, NH), 7.90 (1H, dd, H-5), and 8.17 - 8.25 (1H, d, H-3); $J_{3,5}$ 2.0, $J_{5,6}$ 9.0 Hz.

Hydrogen chloride (4.0g, 0.11 mol) was bubbled into a solution of the foregoing substituted sarcosine (11.8g, 4.2 mmol) in ethanol (120 ml), and the solution then heated under reflux for 4.5 h. The crude *ester* (11.7g, 91%) was purified by chromatography on silica gel (CH_2Cl_2 eluant) and recrystallised from ethanol-water; it had m.p. 44-44.5°C. (Found: C, 47.3; H, 4.3; N, 9.2. $C_{12}H_{13}F_3N_2O_4$ requires C, 47.1; H, 4.3; N, 9.15%). δ_H (d_6-acetone) 1.25 (3H, t, CH_2CH_3), 3.07 (3H, s, NCH_3), 4.27 (2H, s, NCH_2), 4.32 (2H, q, CH_2CH_3), 7.45 (1H, d, H-6), 7.92 (1H, dd, H-5), and 8.23 (1H, d, H-3); J_{ethyl} 7.0, $J_{3,5}$ 2.0, $J_{5,6}$ 10 Hz; *m/z* 306 ($M^{+\cdot}$).

N-(*4-Fluoro-2-nitrophenyl)sarcosine Ethyl Ester* (**3d**).- A mixture of 1,4-difluoro-2-nitrobenzene (12.7g, 80 mmol), sarcosine (8.9g, 100 mmol), and potassium carbonate (13.8g, 100 mmol) in acetonitrile (HPLC grade; 250 ml) was heated under reflux for 22 h; the solution was then filtered, added to saturated sodium hydrogen carbonate solution, and extracted with dichloromethane.The aqueous layer was acidified and the crude substituted *sarcosine* (15.1g, 83%) recrystallised from methanol. It had m.p. 132°C. (Found: C, 47.4; H, 4.0; N, 12.3. $C_9H_9FN_2O_4$ requires C, 47.4; H, 4.0; N, 12.3%).δ_H (d_6-acetone) 3.00 (3H, s, CH_3), 4.10 (2H, s, CH_2), 7.50 (2H, dd*, H-5 and 6), 7.75 (1H, dt*, H-3), and 8.20 (1H, br s, OH).

Concentrated sulphuric acid (0.88g, 9 mmol) was added to a solution of the foregoing substituted sarcosine (3.0g, 13 mmol) in ethanol (50 ml), and the mixture heated under reflux for 2.75 h. The solvent was evaporated, dichloromethane was added to the residue, and this then extracted repeatedly with saturated sodium hydrogen carbonate solution until the extracts were colourless.The organic layer was dried (Na_2SO_4) and evaporated, giving the *ester* **3d** as an orange oil (3.20g, 96%), b.p. 168°C./1mm (Kugelrohr), which was adjudged pure by t.l.c. and n.m.r.: δ_H ($CDCl_3$) 1.28 (3H, t, CH_2CH_3), 3.02 (3H, s, NCH_3), 3.95 (2H, s, NCH_2), 4.27 (2H, q, CH_2CH_3), 7.35 (2H, dd*, H-3 and 6), and 7.65 (1H, dt*, H-5); δ_F -178.4; $J_{3,F}$ 8.1, $J_{5,F}$ 6.0, $J_{6,F}$ 5.0, $J_{3,5}$ 3.3, $J_{5,6}$ 9.0 Hz.†

N-(*2,6-Dinitrophenyl)sarcosine Ethyl Ester* (**3e**).- 1-Chloro-2,6-dinitrobenzene (4.37g, 22 mmol), ethyl sarcosinate hydrochloride (4.61g, 30 mmol) and potassium carbonate (8.29g, 60 mmol) were heated together in acetonitrile (HPLC grade; 100 ml) for 1.3 h at 70-90°C. Additional portions of the hydrochloride (2.15g) and of the base (4.15g) were added, the mixture heated for a further 1.3 h, then filtered, and the solvent evaporated. The residue solidified when treated with a little cold ether; the solid was filtered off and washed with cold ethanol, and the washings on concentration yielded a second crop. The *ester* **3e** (4.31g, 69%) had m.p. 77°C. (from ethanol). (Found: C, 46.7; H, 4.4; N, 14.9. $C_{11}H_{13}N_3O_6$ requires C, 46.7; H, 4.6; N, 14.8%). δ_H (d_6-acetone) 1.25 (3H, t, CH_2CH_3), 2.92 (3H, s, NCH_3), 3.80 (2H, s, NCH_2), 4.15 (2H, q, CH_2CH_3), 7.60 (1H, t, H-4), and

* Not first-order spectrum. † Coupling constants were determined by computer simulation.

8.10 (2H, d, H-3 and 5); J_{ethyl} 7.0, $J_{3,4} = J_{4,5}$ 8.0 Hz.

N-*(2,6-Dinitro-4-trifluoromethylphenyl)sarcosine Ethyl Ester* (**3f**).- Sodium hydrogen carbonate (4.62g, 55 mmol) and ethyl sarcosinate hydrochloride (3.69g, 24 mmol), both vacuum-dried, were added to 4-fluoro-3,5-dinitrobenzotrifluoride (5.08g, 20 mmol) in dry tetrahydrofuran (100 ml), and the mixture was heated under reflux for 0.5 h, then filtered and the solvent evaporated. Ethanol (15 ml) was added to the residue, and the whole poured on to crushed ice, giving a solid (6.68g) which was purified by repeated chromatography (silica gel; CH_2Cl_2 then petroleum eluant), giving the (slightly impure) ester **3f**, m.p. 41-43°C. δ_H ($CDCl_3$) 1.30 (3H, t, CH_2CH_3), 3.03 (3H, s, NCH_3), 3.85 (2H, s, NCH_2), 4.28 (2H, q, CH_2CH_3), and 8.27 (2H, s, H-3 and 5); J_{ethyl} 7.0 Hz. δ_C 14.1 (CH_2CH_3), 41.5(NCH_3), 56.6 (NCH_3), 61.6 (CH_2CH_3), 122.1 (q, *J* 272 Hz, CF_3), 124.9 (q, *J* 36 Hz, C-4), 126.3 (q, *J* 3 Hz, C-3 and 5), 141.6 (C-1), 146.9 (C-2 and 6), 168.2 (C=O).

N-*(6-Chloro-2-nitro-4-trifluoromethylphenyl)sarcosine Methyl Ester* (**8g**).- Barium hydroxide (3.15g, 10 mmol) was added to 3-chloro-4-fluoro-5-nitrobenzotrifluoride (4.87g, 20 mmol) and sarcosine (1.96g, 22 mmol) in tetrahydrofuran (45 ml), and the mixture stirred at room temperature. Two further portions of barium hydroxide (1.68g each) were added, after 6 h and after 14 h. Stirring was stopped after 18 h, the solid was removed by decantation, and the solvent evaporated. The residue, redissolved in dichloromethane, was extracted with saturated sodium hydrogen carbonate solution. This extract was acidified and re-extracted with dichloromethane, and the latter extract dried (Na_2SO_4) and evaporated, giving the substituted *sarcosine* (4.60g, 74%), m.p. 122-123°C. (from methanol). (Found: C, 38.7; H, 2.5; N, 9.0. $C_{10}H_8ClF_3N_2O_4$ requires C, 38.4: H, 2.6; N, 9.0%). δ_H ($CDCl_3$) 3.00 (3H, s, NCH_3), 3.97 (2H, s, NCH_2), and 8.00 (3H, br s, H-3, H-5, and OH).

The foregoing substituted sarcosine (8.6g, 28 mmol) was heated under reflux in methanol (200 ml) containing hydrogen chloride (3.0g) for 5 h. The solvent was evaporated, and the residue extracted with dichloromethane. The extract was washed with sodium hydrogen carbonate solution, then water, dried (Na_2SO_4), and evaporated,to give the *methyl ester* **8g** in almost quantitative yield. This was an oil, b.p. (Kugelrohr) 150°C./1mm, and was adjudged pure by t.l.c. and n.m.r.: δ_H ($CDCl_3$) 3.00 (3H, s, NCH_3), 3.82 (3H, s, OCH_3), 3.92 (2H, s, NCH_2), and 8.00 (2H, s, H-3 and 5).

N-*(6-Chloro-2-nitro-4-trifluoromethylphenyl)sarcosine Ethyl Ester* (**3g**).- Dried potassium carbonate (0.91g, 6.6 mmol) was added to a mixture of 3-chloro-4-fluoro-5-nitrobenzotrifluoride (0.38g, 3 mmol) and ethyl sarcosinate hydrochloride (0.51g, 3.3 mmol) in dry tetrahydrofuran (10 ml).The solution was stirred at room temperature, with exclusion of moisture, for 24 h; more ester (0.09g) and base (0.17g) were then added and stirring continued for a further 5 h. The solution was filtered, the solvent evaporated, and the residue redissolved in ether. The ether solution was washed (5M HCl; 3M NaOH; water), dried (Na_2SO_4), and evaporated, giving the *ester* **3g** (0.57g, 56%), b.p. (Kugelrohr) 150°C./1 mm; δ_H ($CDCl_3$) 1.30 (3H, t, CH_2CH_3), 2.98 (3H, s, NCH_3), 3.83 (2H, s, NCH_2), 4.22 (2H, q, CH_2CH_3), 7.80-7.85 (1H, m, H-5) and 7.85-7.90 (1H, m, H-3); J_{ethyl} 7.0 Hz, $J_{3,5}$ not measurable.

N-*(2,4-Dinitro-6-trifluoromethylphenyl)sarcosine Ethyl Ester* (**3h**).- Ethyl sarcosinate hydrochloride (6.91g, 45 mmol) and triethylamine (4.55g, 45 mmol) were stirred together in dry toluene (10 ml) for 0.5 h, then added to 2-chloro-3,5-dinitrobenzotrifluoride (4.1g, 15 mmol) in dry toluene (30 ml), and the mixture heated at 90-110°C. for 5 h. The solution was filtered, and the filtrate diluted with dichloromethane, washed with water, dried, and evaporated. Chromatography (silica gel; CH_2Cl_2 eluant) gave the (slightly impure) *ester* **3h** (1.10g, 21%), m.p.31-33°C., as the main product. δ_H (d_6-acetone) 1.25 (3H, t, CH_2CH_3), 3.05 (3H, s, NCH_3), 3.92 (2H, s, NCH_2), 4.20 (2H, q, CH_2CH_3), 8.87 (1H, d, H-5), and 9.02 (1H, d, H-3); $J_{3,5}$ 3.0 Hz.The first product eluted from the column appeared to be 2,4-dinitro-6-trifluoromethylphenol, **16h** [δ_H 2.38 s and 7.33 s (ratio 1:2)].

The water washings were carefully acidified (5M HCl) and extracted with dichloromethane, to give a solid, the mass spectrum of which contained the correct molecular ion for the quinoxalinedione **4h** ($M^{+\cdot}$ 305).

N-(*3-Nitro-2-pyridyl)sarcosine Ethyl Ester* (**7b**).- A mixture of sarcosine (4.45g, 50 mmol) and sodium hydrogen carbonate (18.5g) in water (100 ml) was added to a stirred solution of 2-chloro-3-nitropyridine (7.9g, 50 mmol) in ethanol (250 ml), and the mixture heated under reflux for 3 h, then concentrated to *ca.* 100 ml and extracted with ether. The remaining aqueous solution was acidified (HCl) and the product filtered off. N-(*3-Nitro-2-pyridyl)sarcosine* (8.56g, 81%) had m.p. 126-128°C. (from propan-2-ol - water). (Found: C, 45.5; H, 4.1; N, 19.9. $C_8H_9N_3O_4$ requires C, 45.5; H, 4.3; N, 19.9%). ν_{max}.2640, 2560br (O-H), 1690 (C=O), 1545 and 1340 cm^{-1} (NO_2); δ_H 2.88 (3H, s, CH_3), 4.29 (2H, s, CH_2), 6.86 (1H, dd, H-5), 8.19 (1H, dd, H-4), 8.34 (1H, dd, H-6); $J_{4,5}$ 8.0, $J_{4,6}$ 1.6, $J_{5,6}$ 4.6 Hz.

The foregoing acid (8.5g) was dissolved in ethanol (150 ml) containing dry hydrogen chloride (3.5g) and the solution heated under reflux for 4 h, then concentrated to *ca.* 50 ml and poured, with stirring, into ice-water (300 ml). The product was filtered off and recrystallised from ethanol-water **at 60°C.** (to avoid decomposition).The ester **7b** (7.38g, 77%) had m.p. 52°C. (Found: C, 50.2; H, 5.5; N, 17.6. $C_{10}H_{13}N_3O_4$ requires C, 50.2; H, 5.5; N, 17.6%). $\nu_{max.}$ 1740 (C=O), 1560 and 1345 cm^{-1} (NO_2). δ_H 1.19 (3H, t, CH_2CH_3), 2.89 (3H, s, NCH_3), 4.12 (2H, q, CH_2CH_3), 4.35 (2H, s, NCH_2), 6.87 (1H, dd, H-5), 8.21 (1H, dd, H-4), 8.31 (1H, dd, H-6); J_{ethyl} 7.0, $J_{4,5}$ 8.0, $J_{4,6}$ 1.7, $J_{5,6}$ 4.6 Hz.

N-(*3,5-Dinitro-2-pyridyl)sarcosine Ethyl Ester* (**7a**).- Ethyl sarcosinate hydrochloride (3.76g, 24.5 mmol) was added at room temperature to a stirred solution of 2-chloro-3,5-dinitropyridine (5.0g, 24.5 mmol) and triethylamine (4.95g, 49 mmol) in ethanol (120 ml). After 0.5 h the product was filtered off and the filtrate concentrated to *ca.* 30 ml to give a second crop. The total yield of *ester* **7a**, m.p. 77 - 80°C. (from ethanol-water), was 5.35g (77%). (Found: C, 42.3; H, 4.1; N, 19.7. $C_{10}H_{12}N_4O_6$ requires C, 42.3; H, 4.3; N, 19.7%). $\nu_{max.}$ 1715 (C=O), 1520 and 1325 cm^{-1} (NO_2). δ_H 1.21 (3H, t, CH_2CH_3), 3.00 (3H, s, NCH_3), 4.15 (2H, q, CH_2CH_3), 4.55 (2H, s, NCH_2), 8.89 and 9.09 (2x 1H, 2d, H-4 and H-6); J_{ethyl} 7.0, $J_{4,6}$ 2.0 Hz.

Reactions of the esters with bases

Reactions of **3a**. Those with sodium ethoxide, potassium carbonate, and triethylamine (Table 1) are described in Part 12[1].

With DBU. (a) DBU (1.08g, 7.1mmol) was added dropwise to a stirred solution of ester **3a** (2.0g, 7.1 mmol) in ethanol (50 ml) and dimethylformamide (30 ml), and the mixture stirred at room temperature for 3 h. The solvent was evaporated *in vacuo*, the residue partitioned between water and dichloromethane, and the aqueous layer acidified (HCl) to give the quinoxalinedione **4a** (0.39g, 23%), as described in Part 12. The organic layer, dried (Na_2SO_4) and evaporated, gave a dark oil which (by t.l.c.) was a complex mixture; a spot with the correct R_f for the azoxybenzene **5a** was observed. (b) The above reaction, in dimethyl sulphoxide (10 ml) as solvent, gave after 1 h the quinoxalinedione **4a** in 33% yield, and again only a trace of the azoxybenzene **5a**.

Reaction of **8a** *with sodium methoxide.* This followed the same procedure as previously described[1] for the reaction of **3a** with sodium ethoxide.The results are shown in Table 1.

Reaction of **3b** *with sodium ethoxide.* Sodium ethoxide (21 mmol; from sodium, 0.48g, in ethanol, 25 ml) was added to a stirred solution of the ester **3b** (5.0g, 20 mmol) in ethanol (25 ml) at 0-5°C. Stirring was continued for 15 h, and the solvent then evaporated *in vacuo*. The residue was partitioned between water and dichloromethane; acidification (HCl) of the aqueous layer gave 1-hydroxy-4-methylquinoxaline-2,3-dione (**4b**), (1.79g, 44%), m.p. 255°C.(dec.) (from acetic acid; lit.[10], 253°C.), spectroscopically identical with an authentic sample. T.l.c. of the organic layer indicated a complex mixture, including unreacted starting material.

Reactions of **7b**. (a) *With sodium ethoxide.* This was carried out by a similar procedure, using the ester **7b** (2.5g, 10 mmol) in ethanol (30 ml), sodium ethoxide (sodium, 0.25g, 11 mmol) in ethanol (15 ml), and a reaction time of 2 h. (b) *With potassium carbonate.* The ester **7b** (3.0g, 12.5 mmol) and potassium carbonate (1.74g, 12.5 mmol) were stirred together in ethanol (60 ml) at room temperature for 15 h; the precipitate was filtered off and dissolved in water.

The water-soluble fraction in each case gave on acidification *1-hydroxy-4-methylpyrido[2,3-b]pyrazine-2,3-dione* (**9b**) (35 and 18% respectively), m.p. 242-244°C. (dec.) (from DMF-ethanol). (Found: C, 49.85; H, 3.5; N, 21.8. $C_8H_7N_3O_3$ requires C, 49.75; H, 3.65; N, 21.75%). $\nu_{max.}$ 3200 (O-H), 1675 cm^{-1} (C=O); δ_H 3.56 (3H, s, CH_3), 7.31 (1H, dd, H-7), 7.85 (1H, dd, H-8), and 8.24 (1H, dd, H-6). $J_{6,7}$ 5.0, $J_{6,8}$ 1.6, $J_{7,8}$ 8.0 Hz. δ_C: see Table 2. In neither (a) nor (b) did the organic layer give an identifiable product.

Compd.	Chemical shift (δ)									
	C-2	C-3	C-4a	C-5	C-6	C-7	C-8	C-8a	Me	CF_3
4a	155.2	150.1	130.8	115.8	119.2	142.7	107.8	127.9	30.6	-
4b	154.0	150.2	125.3	114.9	124.2	123.8	112.8	127.3	39.9	-
4c	155.1	150.2	128.5	115.8	120.7	124.0	109.4	127.9	30.2	124.0
4d	154.5	150.3	122.0	116.6	110.5	158.5	99.9	128.6	30.2	-
4e	156.2	149.8	119.7	139.2	120.2	123.6	116.8	130.1	34.5	-
4f	156.1	149.7	123.1	138.9	117.0	123.4	112.3	131.3	34.2	122.8
9a	155.8	149.8	140.1	N	137.9	141.6	114.4	124.4	29.2	-
9b	155.7	149.9	137.2	N	142.3	120.3	119.3	124.0	28.4	-

J(C-F) (Hz):	**4c:**			**4d:**			**4f:**		
	C-6	3		C-5	9		C-6	4	
	C-7	33		C-6	23		C-7	34	
	C-8	4		C-7	240		C-8	3	
	CF_3	272		C-8	29		CF_3	272	
				C-8a	11				

Table 2. ^{13}C N.m.r. spectra of 1-hydroxy-4-methylquinoxaline-2,3-diones (**4**) and their 5-aza analogues (**9**)

Reactions of **7a**. (a) *With sodium ethoxide.* The ester (1.5g, 5.3 mmol) in ethanol (85 ml) and sodium ethoxide (5.7 mmol) in ethanol (85 ml), initially at 0°C. and then at room temperature for 3 h, gave the pyridopyrazinedione **9a** (0.36g, 29%) as the only identifiable product. (b) *With potassium carbonate.* The carbonate (0.49g, 3.6 mmol) was added in portions to a stirred suspension of the ester (1.0g, 3.5 mmol) in ethanol (50 ml) and the mixture stirred at room temperature for 6 h, filtered, the filtrate treated with charcoal and evaporated to dryness, and the residue extracted with water. The extract and the original precipitate were combined and acidified, giving the dione **9a** (0.20g, 24%).

1-Hydroxy-4-methyl-7-nitropyrido[2,3-b]pyrazine-2,3-dione (**9a**) had m.p. 285°C. (dec.) (from DMF-water). (Found: C, 40.6; H, 2.6; N, 23.65. $C_8H_6N_4O_5$ requires C, 40.35; H, 2.5; N, 23.5%). $\nu_{max.}$ 3400 br (O-H), 1710 and 1685 cm^{-1}(C=O). δ_H 3.63 (3H, s, CH_3), 8.34 (1H, d, H-8), 9.08 (1H, d, H-6), and 12.25 (1H, br s, OH); $J_{6,8.}$ 1.6 Hz. δ_C: see Table 2.

The water-insoluble material was extracted with ethanol, the extract treated with charcoal and evaporated, and the red solid recrystallised from ethanol to give *2,2'-bis(methylamino)-5,5'-dinitro-3,3'-azoxypyridine* (**10**) (10mg, *ca.*2%), m.p. 272-274°C. δ_H 3.04 (3H, d, NHCH_3'), 3.09 (3H, d, NHCH_3), 8.22 (1H, br d, N*H*CH_3'), 8.78 (1H, br d, N*H*CH_3), 9.02 (1H, d, H-6), 9.06 (1H, d, H-6'), 9.19 (1H, d, H-4), and 9.46 (1H, d, H-4')‡; $J_{4,6}$ 2.5 and $J_{4',6'}$ 2.6 Hz.

Reaction of **3c** *with potassium carbonate.* The ester (2.14g, 7mmol) and potassium carbonate (0.97g, 7 mmol) were stirred together in ethanol (50 ml) for 4.5 h, and worked up in the manner described above. The non-

‡ Assignments based on decoupling experiments.

acidic fraction, a green oil, had an R_f value similar to that of **3c**. Its ^1H n.m.r. spectrum, however, showed no ester protons; δ 3.10 (3H, d, CH_3), 7.35 (1H, d, H-6), 7.88 (1H, dd, H-5), 8.97-9.10 (1H, m, H-3), and 10.75 (1H, br s, NH); $J_{5,6}$ 9, $J_{3,5}$ 2, $J_{NH,Me}$ 5 Hz; *m/z* 204.0523. ($C_8H_7F_3N_2O$ requires $M^{+\cdot}$ 204.0510). This product is therefore considered to be *N-methyl-2-nitroso-4-(trifluoromethyl)aniline*, **14c**.

The acidic fraction gave *1-hydroxy-4-methyl-7-trifluoromethylquinoxaline-2,3-dione*, **4c** (0.56g, 31%), m.p. 218-219°C. (from water). (Found: C, 44.4; H, 3.1; N, 10.4. $C_{10}H_7F_3N_2O_3 + 0.5H_2O$ requires C, 44.6; H, 3.0; N, 10.4%). $\nu_{max.}$ 3250br (O-H), 1700 and 1680br cm^{-1}(C=O); δ_H 3.60 (3H, s, CH_3), 7.60–7.70 (1H, m, H–5 and 6), 7.75 (1H, s, H-8), and 12.0 (1H, br s, OH); δ_C, see Table 2; *m/z* 260 ($M^{+\cdot}$), 244, 242, 232, 225, 215, 187 (100%), etc.

The aqueous mother-liquor was evaporated and partitioned between dichloromethane and water, and the organic layer extracted first with 5M hydrochloric acid and then with 3M sodium hydroxide. The latter extract on careful acidification (HCl) gave a solid (0.10g) which was clearly a mixture, and showed *m/z* 216 (38%) and 214 (100%).The latter peak is considered to be due to 6- (**12c**) and/or 7-trifluoromethylquinoxalin-2-one (**13c**), especially since the (complicated) ^1H n.m.r. spectrum contained resonances at δ>8 which are characteristic of such compounds (see below). The peak at *m/z* 216 may be due to 1-methyl-5-trifluoromethylbenzimidazol-2-one (**15c**), although this assignment is currently unsupported by other evidence. The water-soluble material from the original partition gave on acidification a solid product consisting mainly of the quinoxalinedione **4c**, but subtraction of the ^1H and ^{13}C n.m.r. and mass spectra of **4c** from those of the mixture gave spectra which corresponded exactly with those of *5-trifluoromethyl-1H-benzimidazole 3-oxide*, **11c** ($M^{+\cdot}$ 202)[5].

Reactions of **3d** *with potassium carbonate.* The ester (2.28g, 9 mmol) and potassium carbonate (1.38g, 10 mmol) in ethanol (30 ml) were stirred for 4.5 h, then filtered. The solid (mainly inorganic) was extracted with acetone, and the extract on evaporation gave a thin oily film of the quinoxalinedione **4d**, identified by its mass spectrum ($M^{+\cdot}$, 210) and n.m.r. δ_H 3.60 (3H, s. CH_3), 7.13 (1H, dt, H-6), 7.32 (1H, dd, H-8),7.47 (1H, dd, H-5), and 12.0 (1H, br s, OH); $J_{5,6}$=$J_{6,F}$ =$J_{8,F}$ 8, $J_{6,8}$ 2, $J_{5,F}$ 4 Hz; δ_C, see Table 2. The ethanolic filtrate was evaporated and the residue partitioned between dichloromethane and water, as above. The organic layer, on evaporation, gave a mixture of 6- and 7-fluoroquinoxalin-2-ones, **12d** and **13d**. For the main product **12d**, δ_H 7.36 (1H, dd, H-8),7.45 (1H, dt, H-7), 7.59 (1H, dd, H-5), and 8.21 (1H, s, H-3); $J_{7,8}$=$J_{5,F}$=$J_{7,F}$ 8, $J_{5,7}$ 2, $J_{8,F}$ 5 Hz. For the minor isomer **13d**, δ_H 7.06 (1H, dd, H-8), 7.14 (1H,m, H-6), 7.84 (1H, dd, H-5), and 8.11 (1H, s, H-3); $J_{5,6}$=$J_{6,F}$=$J_{8,F}$ 9, $J_{6,8}$ 3, $J_{5,F}$ 6 Hz. δ_C (both isomers): see Table 3.

The aqueous layer on acidification gave a mixture (0.21g; at least three compounds), the main component of which was 5-fluoro-1*H*-benzimidazole 3-oxide, **11d**, identical spectroscopically (^1H and ^{13}C n.m.r.) with an authentic sample[3]. Also detected (^{13}C n.m.r.) were the quinoxalinedione **4d** and the quinoxalinone **12d**.

Reaction of **3e** *with potassium carbonate.* The carbonate (0.69g, 5 mmol) was added in portions during 1 h to the ester (1.42g, 5 mmol) in ethanol (50 ml), and the mixture stirred for a further 3.5 h, then filtered.The solid was dissolved in water and the solution acidified (5M HCl) and chilled for 48 h. The product was filtered off and washed with a little acetone, giving *1-hydroxy-4-methyl-5-nitroquinoxaline-2,3-dione*, **4e**, as its *hemihydrochloride* (0.23g, 19%), m.p. 160°C. (from water). (Found: C, 42.3; H, 2.95; N, 16.5. $C_9H_7N_3O_5 + 0.5HCl$ requires C, 42.3; H, 3.0; N, 16.45%).$\nu_{max.}$ 3200-3600br (O-H),1690 and 1665 cm^{-1} (C=O); δ_H 3.25 (3H, s, CH_3), 7.45 (1H, t, H-7), 7.70 (1H, dd, H-8), and 7.84 (1H, dd, H-6); $J_{6,7}$= $J_{7,8}$ 8, $J_{6,8}$ 2 Hz. δ_C: see Table 2.

The ethanol solution was evaporated and partitioned as before. No product was obtained from the aqueous layer on acidification. The organic layer, after extraction with 5M hydrochloric acid and then with 3M sodium hydroxide, contained only the starting material **3e**. The basic extract on acidification gave a solid identified (i.r., n.m.r., m.s.) as *1-methyl-7-nitrobenzimidazol-2-one*, **15e**. $\nu_{max.}$ 1700 cm^{-1} (C=O); δ_H 3.4 br (CH_3 + water), 7.37 (1H, t, H-5), 7.62 (1H, dd, H-4), 7.82 (1H, dd, H-6), and 11.80 (1H, br s, NH); $J_{4,5}$=$J_{5,6}$ 8, $J_{4,6}$ 2Hz. δ_C: see Table 4. *m/z* 193 ($M^{+\cdot}$). The aqueous filtrate, on extraction with dichloromethane, gave one main

product which was identified spectroscopically as *8-nitroquinoxalin-2-one*, **12e** ($M^{+\cdot}$ 191). δ_H 7.63 (1H, t, H-6), 8.35 (1H, dd, H-5), 8.50-8.55 (2H, s+dd,H-2 and 7), and 11.75 (1H, br s, NH); $J_{5,6}$=$J_{6,7}$ 8, $J_{5,7}$ 2 Hz.

Reaction of **3f** *with triethylamine.* A solution of the ester (1.75g, 5 mmol) and triethylamine 1.01g, 10 mmol) in toluene (25 ml) was stirred at room temperature for 6.5 h. The solvent was evaporated *in vacuo* and the residue partitioned as before. The aqueous layer was acidified, extracted with dichloromethane, then saturated with sodium chloride and re-extracted with ethyl acetate.The extracts were dried (Na_2SO_4) and evaporated; the n.m.r. and mass spectra of the residue identified it as the quinoxalinedione **4f.** δ_H 3.30 (3H, s, CH_3), 8.08 (1H, d, H-8), and 8.28 (1H, d, H-6); $J_{6,8}$ 2 Hz; δ_C, see Table 2; *m/z* 305 ($M^{+\cdot}$). The dichloromethane layer from the original partitioning was extracted with 5M hydrochloric acid. The extract was saturated with sodium chloride and re-extracted with ethyl acetate. Evaporation of this (dried) extract gave a film which appeared to be mainly 2,6-dinitro-4-trifluoromethylphenol, **16f:** δ_H(d_6-acetone) 8.70 (s); *m/z* 252.

Reaction of ester **3f** with 1 equivalent of triethylamine gave after 22 h small amounts of the quinoxalinedione **4f** and the phenol **16f** along with unreacted starting material.

Compd.	Chemical shift (δ)								
	C-2	C-3	C-4a	C-5	C-6	C-7	C-8	C-8a	CF_3
Parent	154.8	151.5	131.8*	130.6	123.1	128.7	115.6	132.0*	-
12d	154.8	153.2	132.5	118.9	157.9	114.0	117.3	128.9	
13d†	153.2			131.3	111.3		101.7		-
12e	153.8	152.5	129.9	135.9	122.6	127.2	133.3	127.4	-
12g	155.5	153.6	132.8*	125.1*	124.0	126.7*	120.7	133.0*	123.3
13g	154.4	154.9	134.0*	130.4	119.6	130.5	112.2	134.1*	122.8

* Provisional assignments. † minor component in mixture: some resonances obscured.

J(C-F) (Hz):	C-4a	C-5	C-6	C-7	C-8	CF_3
12d	12	24	240	22	9	-
13d		11	23		27	-
12g	-	3	34	3	-	272
13g	-	-	3	33	4	273

Table 3. ^{13}C N.m.r. spectra of quinoxalin-2-ones **12** and **13.**

Reactions of **3g** *and* **8g.** (a) **8g** *with triethylamine and potassium carbonate.* Reaction of the ester with triethylamine in boiling toluene being very slow (72 h for complete reaction), a mixture of the ester (2.48g, 8.7 mmol) and triethylamine (2.02g, 20 mmol) were heated under reflux; further portions of triethylamine (total, 6.06g) were added at intervals, and finally, after 48 h, potassium carbonate (2.76g, 20 mmol) was also added. After a total of 102 h under reflux, the solution was filtered, the solvent evaporated, and the residue partitioned as before. The aqueous layer on careful acidification (HCl) gave a solid which was filtered off and washed with a little acetone, giving *5-chloro-7-trifluoromethyl-* (**13g**) and, in small amount, *8-chloro-6-trifluoromethyl-quinoxalin-2-one* (**12g**) (0.21g, 11%), m.p. 180-184°C. $\nu_{max.}$ 3300br (N-H) and 1695br cm^{-1} (C=O). δ_H: see below; δ_C, see Table 3. The non-acidic layer gave only a complex mixture which was not further investigated.
(b) **3g** *with potassium carbonate.* This also gave only complex mixtures. (c) **3g** *with barium hydroxide.* The ester (2.04g, 6 mmol) and barium hydroxide (2.52g, 8 mmol) were stirred in tetrahydrofuran (30 ml) at room temperature for 24 h. The solution was decanted off and the solvent evaporated; the residue was treated with methanol and water, filtered, and the solid product extracted from ether solution, first with acid (HCl) and then with base (NaOH). The latter extract was filtered, giving *7-chloro-1-methyl-5-trifluoromethylbenzimidazol-2-one,* **15g** (0.18g, 18%), m.p. 280°C. $\nu_{max.}$ 3060 (N-H),1670br cm^{-1}(C=O); δ_H 3.60 (3H, s, CH_3), 7.00-7.08 (1H, m, H-4), and 7.10-7.20 (1H, m, H-6): δ_C, see Table 4; *m/z*, 250 ($M^{+\cdot}$). The ether solution on evaporation gave *2,2'-diamino-3,3'-dichloro-5,5'-bis(trifluoromethyl)azoxybenzene,* **17g** (0.11g, 4%), m.p. 171-175°C.

δ_H ($CDCl_3$) 5.22 and 6.50 (2x 2H, 2s, 2x NH_2), 7.72 and 7.82 (2x 1H, 2d, H-4 and 4'), 8.25-8.40 (1H, m, H-6), and 9.00 (1H, m, H-6'). *m/z* 432 ($M^{+\cdot}$).

Synthesis of **12g** *and* **13g**.- 3-Chloro-4-fluoro-5-nitrobenzotrifluoride (2.44g, 10 mmol) was stirred with ammonia solution (*d* 0.88; 10 ml) for 0.5 h, then poured on to ice and the product, *2-chloro-6-nitro-4-trifluoromethylaniline* (2.3g, 95%), m.p. 80-82°C., filtered off. (Found: *m/z*, 239.9914. $C_7H_4ClF_3N_2O_2$ requires $M^{+\cdot}$ 239.9913.) δ_H 7.00 (2H, br s, NH_2), 7.85 (1H, s, H-3), 8.50 (1H, s, H-5).

Palladium-charcoal (10%, 2.5g) was added to a solution of the nitro-amine (2.0g) in ethanol (100 ml) and cyclohexene (25 ml). The mixture was heated under reflux for 1.2 h, then filtered and the filtrate evaporated. The residue was washed with a little dichloromethane and hydrochloric acid, to give 1,2-diamino-3-chloro-5-(trifluoromethyl)benzene (0.75g, 43%), m.p. 201°C. (dec.). (Found: *m/z* 210.0173. $C_7H_6ClF_3N_2$ requires $M^{+\cdot}$ 210.0172.) δ_H 7.35 (4H, br s, 2x NH_2), 7.50 (2H, s, H-3 and 5). The diamine (0.55g, 2.3 mmol) in ice-cold ethanol (20 ml) was treated with ethyl glyoxylate[11] (0.35g, 3.4 mmol) and the mixture heated under reflux for 3 h, with triethylamine (0.35g, 3.5 mmol) being added after 0.5 h. The residue obtained by evaporation of the solvent was treated with dichloromethane and water, and filtered off; yield, 0.30g (53%). The product, m.p. 189-192°C., was mainly *8-chloro-6-trifluoromethylquinoxalin-2-one*, **12g** (i.e. the minor product of the previous reaction), with a lesser amount of the *5-chloro-7-trifluoromethyl isomer*, **13g** (Found: C, 43.1; H, 1.2; N, 11.0. $C_9H_4ClF_3N_2O$ requires C, 43.5; H, 1.6; N, 11.3%.) For **12g**, δ_H 8.20 (2H, br s, H-5 and 7), 8.50 (1H, s, H-3).For **13g**, δ_H 7.62 (1H, s, H-8), 7.78 (1H, s, H-6), and 8.40 (1H, s, H-3). δ_C for both isomers: see Table 3.

Compd.	Chemical shift (δ)								
	C-2	C-3a	C-4	C-5	C-6	C-7	C-7a	Me	CF_3
15e	154.6	124.4	116.7	113.6	120.7	133.3	131.3	30.0	-
15g	152.0	123.7	100.7	121.2	116.0	112.4	132.1	28.9	124.1

J (C-F) (Hz) for 15g: C-4, 4; C-5, 32; CF_3, 272.

Table 4. ^{13}C N.m.r. spectra of the benzimidazol-2-ones **15.**

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