Heterocyclic Syntheses. Part XXVIII.† *ortho*-Dialkylamino-benzenesulphonyl Azides, -benzoyl Azides, and -benzoyldiazomethanes

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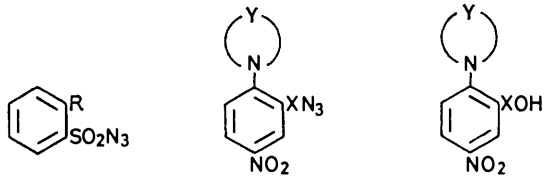
A series of the title compounds incorporating *ortho*-dimethylamino, diethylamino, dipropylamino, pyrrolidin-1-yl, piperidino, morpholino, 4-methylpiperazin-1-yl, perhydroazepin-1-yl, perhydroazocin-1-yl, and perhydroazonin-1-yl groups were prepared. Thermal decomposition of the sulphonyl azides in solution in chlorobenzene or dimethyl sulphoxide resulted in attack on the *ortho*-nitrogen atom to give mesoionic spirobenzothiadiazoles or (by ring-opening or dealkylation) 3-substituted benzothiadiazoles. The pyrrolidinyl system was unique in giving a variety of products derived by Curtius rearrangement or otherwise from an intermediate sulphonylnitrene. Thermolysis in the presence of a catalytic amount of base hydrochloride, or an excess of piperidine or of copper, gave a dihydrobenzothiadiazine by attack on an *N*-methylene group. Photolysis of the sulphonyl azides in solution in dimethyl sulphoxide gave the benzothiadiazines, but by a mechanism different from that of the thermal reaction which did not involve oxidation by dimethyl sulphoxide. The carbonyl azides spontaneously decomposed to give conventional products of a Curtius rearrangement, and one diazo-ketone gave a mesoionic system analogous to those derived from the sulphonyl azides. Unusual properties are associated with some of the intermediates prepared, and are accounted for by a neighbouring group effect. Mechanisms are proposed for the observed reaction pathways.

ARENESULPHONYL AZIDES have been observed to undergo thermal cyclisation involving an *ortho*-phenyl, -methyl, -phenoxy- (attack at the *ortho'*-position) or -phenylthio- (attack on S) substituent.[1] A similar intramolecular substitution has recently been observed in the photolysis of ferrocenesulphonyl azide.[2] The only reported example of cyclisation without prior rearrangement of an aroyl azide is the photolysis of *o*-vinylbenzoyl azide.[3] Only very low yields of products were obtained, but their nature is best explained by invoking an intermediate aziridine. We now report[4] the first examples of cyclisations of sulphonyl azides involving an *ortho*-dialkylamino-group [*e.g.* (1; R = NR'_2)] and our attempts to effect similar closures of carbonyl azides and diazo-ketones.

Preparation of the Azides.—Preparation of the sulphonyl azides (2) required care because of the powerful anchimeric effect of the *ortho*-amino-group. For instance, although the sulphonic acids (4) and carboxylic acids (5) are readily prepared by condensation of 2-chloro-5-nitrobenzene-sulphonic or -carboxylic acids with the appropriate base, the acids (4) in particular are very acid-sensitive and are desulphonated rapidly even at room temperature in dilute aqueous hydrochloric acid. Conversion into the sulphonyl chloride (and hence azide) derivatives is feasible but unreliable with phosphorus pentachloride in dry pyridine. The carboxylic acids (5) are not so labile, requiring hot mineral acid for decarboxylation. We have previously observed[5] that *NN*-disubstituted *o*-nitroanilines [in protonated form (6)] lose or suffer rearrangement of their nitro-group, though this reaction is much slower than the above reactions. We rationalise this general effect as shown in Scheme 1. The role of the dialkylamino-group is borne out by the fact that the *para*-analogues (8) are attacked only very slowly under similar conditions in the case of the acids (8; X = SO_2 or CO) and not all in the case of the nitro-compounds. Furthermore, the *N*-oxide of the sulphonic acid (4d) is inert to mineral acid.



(1) R = Ph, Me, or SPh (2) X = SO_2 (3) X = CO (4) X = SO_2 (5) X = CO (6) X = NO

a; Y = Me_2
b; Y = Et_2
c; Y = Pr_2
d; Y = $[CH_2]_4$
e; Y = $[CH_2]_5$
f; Y = $[CH_2]_2{\cdot}O{\cdot}[CH_2]_2$
g; Y = $[CH_2]_2{\cdot}NMe{\cdot}[CH_2]_2$
h; Y = $[CH_2]_6$
i; Y = $[CH_2]_7$
j; Y = $[CH_2]_8$

The appropriate sulphonyl azides were conveniently prepared by treatment of the 2-chloro-5-nitro-acid azide (9) with 2 mol. equiv. of base in dry benzene. Use of ethanol or other polar solvents caused displacement of the azido-group as well as the halogen by the base. This method was, however, inapplicable to the preparation of the carbonyl azides, since the carbonyl azide group is much more reactive towards the base than the chlorine atom in (10). However, the acid chlorides of the acids (5) were readily obtained by treatment of the acids with pure thionyl chloride and a trace of dimethylformamide in dry benzene at ambient temperature. Conversion into the azide directly or by way of the hydrazide gave reasonable yields but the products underwent spontaneous decomposition and had to be used quickly.

Decomposition of the Sulphonyl Azides.—The thermolysis of the sulphonyl azides (2) gave surprisingly different results as the nature of the substituents Y was varied. However, all products could be rationalised in terms of

† Part XXVII, R. Fielden, O. Meth-Cohn, and H. Suschitzky, *J.C.S. Perkin I*, 1973, 705.

[1] R. A. Abramovitch, C. I. Azogu, and I. T. McMaster, *J. Amer. Chem. Soc.*, 1969, **91**, 1219.

[2] R. A. Abramovitch, C. I. Azogu, and R. G. Sutherland, *Chem. Comm.*, 1969, 1439.

[2] 'Nitrenes,' ed. W. Lwowski, Interscience, New York, 1970, p. 234.

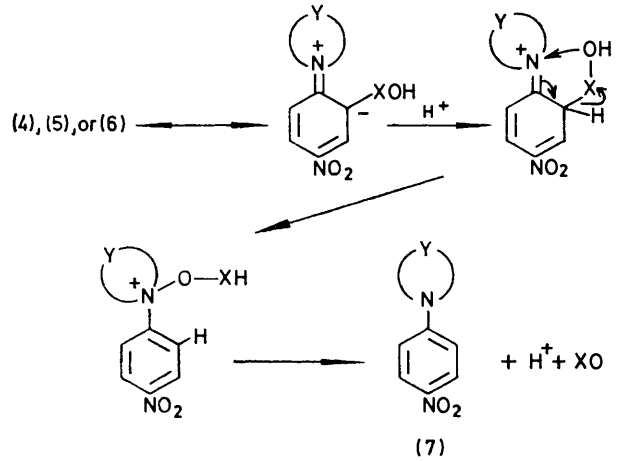
[4] J. Martin, O. Meth-Cohn, and H. Suschitzky, *Chem. Comm.*, 1971, 1319.

[5] R. Fielden, O. Meth-Cohn, and H. Suschitzky, *J.C.S. Perkin I*, 1973, 696.

initial formation of the mesoionic benzothiadiazole (11), the fate of which depended upon the nature of Y and the reaction conditions. The ylide was only isolable from the dimethylamino-azide (2a) or in those cases where Y was part of a six-membered ring (e, f, and g). The mesoionic structure was clearly demonstrated by spectral evidence. In particular the ^{1}H n.m.r. spectra showed the $^+NCH_2$ signals at low field and, in the case of the cyclic systems, revealed that the *N*-methylene protons were non-equivalent, demonstrating the rigidity of the system due to the presence of the quaternary nitrogen atom.

These novel mesoionic systems underwent further rearrangements as outlined below but were surprisingly stable in concentrated sulphuric or hot acetic acid. The action of hot base gave a complex mixture of products but with hot 4N-hydrochloric acid, the piperidino-compound (11e) gave the ring-opened 3-(5-chloropentyl)-thiadiazole (12) in good yield.

Thermolysis of the diethylamino- and dipropylamino-azides (2b and c, respectively) gave the monoalkylthiadiazole dioxides (13) and (14), respectively, in good yield. These products are reasonably explained by a Cope-type elimination of an alkyl group from the appropriate mesoionic system (11), a route not available to the methyl analogue and sterically unfavourable in the case of the six-membered ring systems. This mechanism of elimination was confirmed in the following ways: (*a*) the eliminated olefin was trapped by bromine; (*b*) the mesoionic system can be intercepted (see later); and (*c*) the thermolysis of azides with rings of more than six members (2h, i, and j) gave in each case the corresponding ring-opened thiadiazole dioxide (15)—(17) containing a terminal

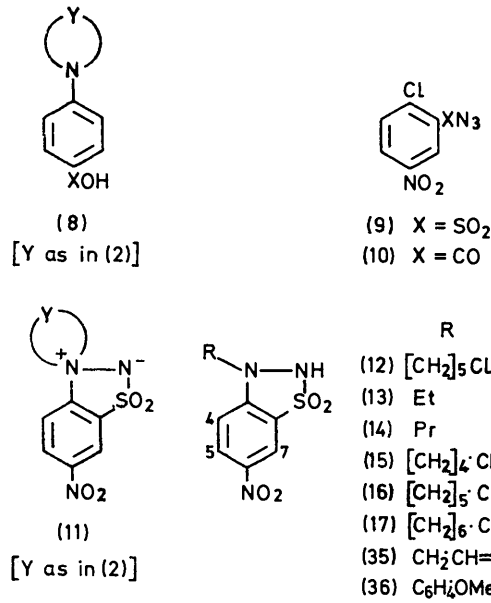


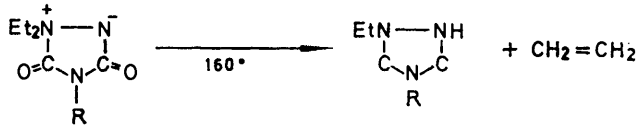
(7)

SCHEME 1

olefin group, again best rationalised by a Cope-type β-elimination. This type of elimination has also been observed by Lwowski [6] in the thermal decomposition of the mesoionic bicarbamimides [(18) ⟶ (19)].

The thermolysis of the pyrrolidinyl azide (2d) was unique in the series. It gave products which underlined the intermediacy of a nitrene and suggested that the mesoionic system (11c), if first formed, is in equilibrium with the corresponding nitrene. The course of the



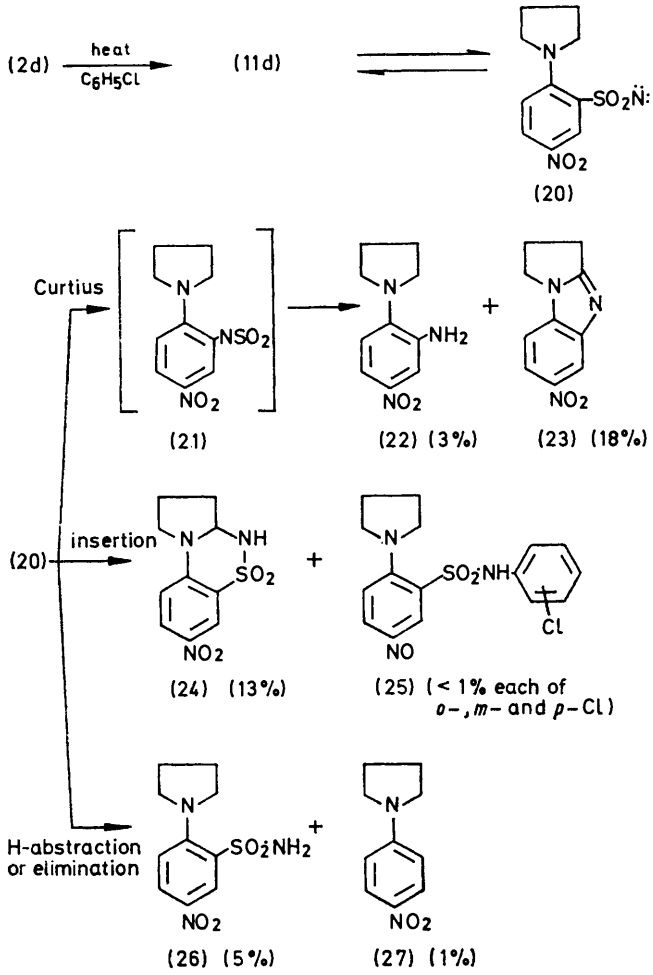


(18) (19)

thermolysis is outlined in Scheme 2. The yield of products from a Curtius rearrangement [(21) ⟶ (22) ⟶] (21%) is surprisingly high in view of its rare occurrence in the decomposition of sulphonyl azides,[7] suggesting again the anchimeric involvement of the amino-substituent. The attempted synthesis of the intermediate sulphonylamine (21) and its subsequent decomposition to yield the fused benzimidazole (23) [8] will be dealt with fully elsewhere. The intramolecular and intermolecular insertion products [(24) and (25), respectively] have precedents [9] and their formation suggests involvement of a singlet nitrene. Small amounts of the three isomeric chlorophenyl derivatives (25) were isolated, indicating the indiscriminate nature of the reactive intermediate. The intramolecular insertion product, a thiadiazine dioxide (24), is a rare example of cyclisation of an azide to give a six-membered ring system. This heterocycle was unambiguously synthesised in good yield by oxidation of the readily prepared sulphonamide (26) with persulphate. The formation of the sulphonamide (26), by analogy with other known cases,[9] suggests a triplet nitrene intermediate, and the loss of the sulphonyl group finds precedent in the work of Breslow.[10]

[6] W. Lwowski, R. A. de Mauriac, R. A. Murray, and L. Lunow, *Tetrahedron Letters*, 1971, 425.
[7] R. A. Abramovitch and W. D. Holcomb, *Chem. Comm.*, 1969, 1298.
[8] J. Martin, O. Meth-Cohn, and H. Suschitzky, *Tetrahedron Letters*, 1973, 4495.
[9] Ref. 3. ch. 8.
[10] D. S. Breslow, M. F. Sloan, N. R. Newburg, and W. B. Renfro, *J. Amer. Chem. Soc.*, 1969, **91**, 2273.

The mesoionic system (11) may be intercepted even when it is not isolable, in two ways. The azide (2e) was



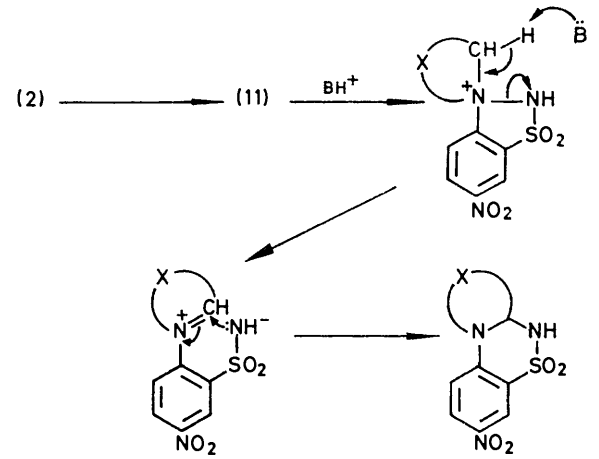
SCHEME 2

converted into the thiadiazine dioxide (28) by thermolysis in the presence of a trace of a secondary amine hydrochloride or a large excess of a secondary amine. The probable course of the reaction is outlined in Scheme 3. The rearrangement (11) ⟶ (28) proceeds equally well when applied to the mesoionic system (11e) itself, thus supporting its intermediacy. With the perhydroazepinyl azide, from which a mesoionic compound could not be isolated, a mixture of the thiadiazole (15) and the thiadiazine (29) was isolated, again suggesting a mesoionic intermediate.

Both the azide (2e) and the mesoionic benzothiadiazole (11e) decomposed smoothly in the presence of copper (widely used in azide work [11]) to yield the thiadiazine (28), in 48 and 73% yields, respectively. The analogous thiadiazine (29) was also produced, in 81% yield, from the perhydroazepino-azide (2h), together with a little of the thiadiazole (15). The morpholino-azide (2f) and the corresponding mesoionic compound (11f) surprisingly both gave mainly 2-morpholino-5-nitrobenzenesulphonamide [*cf.* (26)] under these conditions, together with a small amount of the thiadiazine (30). Heating compound (11f) at 150° under high vacuum, however, afforded some thiadiazine (30). It thus appears that the formation of a mesoionic benzothiadiazole–copper complex encourages N–N bond cleavage, and, in the case of the perhydroazepine derivative, inhibits the Cope elimination, leading to products from a nitrenoid intermediate.

The thermolyses were also conducted in dimethyl sulphoxide solution in attempts to trap a nitrene as a dimethylsulphoximide derivative.[12] Although no such product was isolated, the azides (2e, f, g, and h) decomposed at a lower temperature and gave cleaner products in higher yield, suggesting involvement of a sulphoximide intermediate. The use of dimethyl sulphoxide in the copper-catalysed decomposition of the piperidino-azide (2e) gave, in addition to the thiadiazine (28), the didehydro-analogue (31), which was shown not to come from the oxidation of (28) by the reagents. Again this raises the possibility of a sulphoximide intermediate, supported further by the following photolytic results.

Although the azides (2) were inert to u.v. irradiation in chlorobenzene even in the presence of a sensitiser (benzophenone), they rapidly underwent photolysis in dimethyl sulphoxide solution,[12] with colour change from yellow to crimson. Work-up, however, gave only a yellow product and in the case of the piperidino-azide (2e) (30%) this

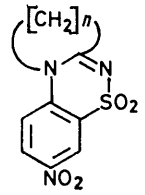


SCHEME 3

substance was identical with the copper–dimethyl sulphoxide thermolysis product (31). An analogous product (32) was isolated from photolysis of the perhydroazepinyl azide (2h) (42%). These results speak strongly for a sulphoximide intermediate (33) (Scheme 4), particularly since photolysis of such derivatives gives nitrenes. Significantly, both the mesoionic compound (11e) and the benzothiadiazine (27) were unaffected by irradiation in dimethyl sulphoxide, confirming the oxidation level of the product to be the result of an

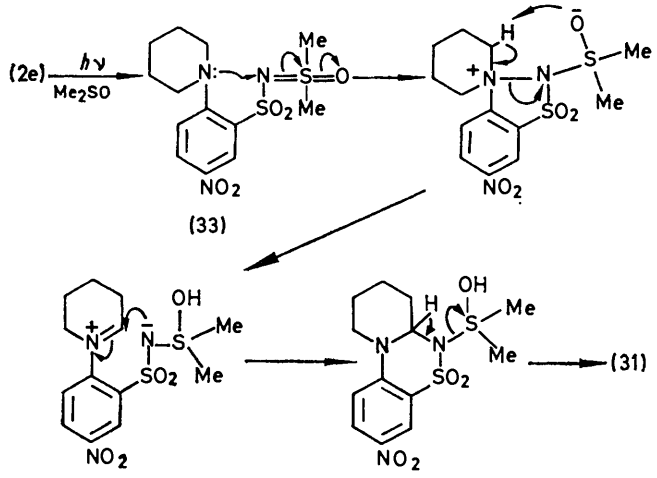
[11] Ref. 3, p. 284.
[12] L. Horner and A. Christmann, *Chem. Ber.*, 1963, **96**, 388.

elimination rather than an oxidation. The structure of the products (31) and (32) is evident both from their spectroscopic and analytical properties (see Experimental section) and from the fact that reduction with bis-(2-methoxyethoxy)aluminium hydride gave the dihydro-analogues (28) and (29), respectively.



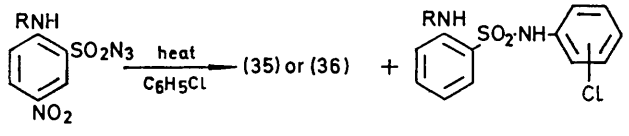
(31) $n = 4$
(32) $n = 5$

The decomposition of *ortho*-dialkylaminobenzene-sulphonyl azides thus appears in most cases to proceed by



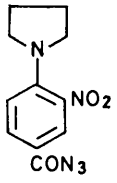
SCHEME 4

attack at the *ortho*-nitrogen atom. The two secondary amines (34a and b) were similarly found to give products [(35) and (36)] which could be explained in this way. The latter also gave a small amount of the mixture of insertion products (37b).



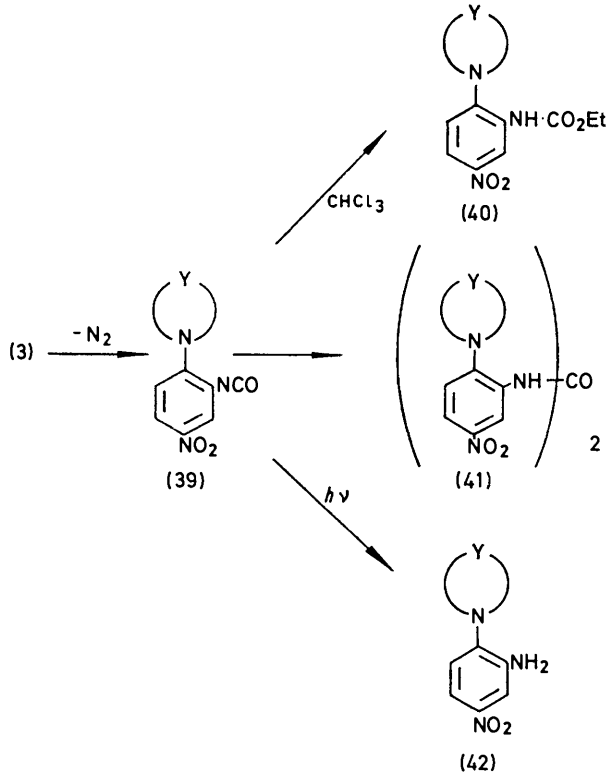
(34) (37)

a; R = $CH_2CH{=}CH_2$ b; R = *p*-C_6H_4OMe



(38)

Decomposition of the Carbonyl Azides.—The carbonyl azides (3) are very unstable, owing to the effect of the *ortho*-dialkylamino-substituent. Thus, whereas the azides (3) underwent spontaneous decomposition at ambient temperatures, the isomer (38) decomposed at 107° and was indefinitely stable at 20°. The decomposition of the *o*-dialkylaminobenzoyl azides (3) followed the classical Curtius pathway (Scheme 5) irrespective of the substituents, the rate of decomposition increasing as the size of the heterocycle was reduced. Under anhydrous conditions the isocyanate (39) could be isolated, and in chloroform (containing ethanol) the carbamate (40) was



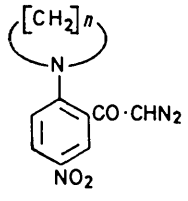
SCHEME 5

obtained. On exposure to air the azide was rapidly converted into the urea (41). Varying the temperature of decomposition or use of dimethyl sulphoxide as solvent or irradiation of the azide did not change the course of the reaction. Furthermore, photolysis of the isocyanate (39) gave only the amine (42) and no cyclised products [*e.g.* (23)] indicative of a nitrene intermediate. Such cyclisations have been observed in the photolysis of 2-isocyanatobiphenyl.[13]

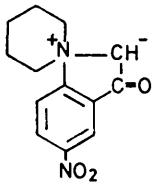
Preparation and Decomposition of the Benzoyldiazomethanes.—Although free acylnitrenes are not commonly involved in the decomposition of acyl azides, intermediacy of the analogous acylcarbenes (derived from α-diazo-ketones) is well founded. We prepared the diazoketones (43) and (44) from diazomethane in ether or benzene and the corresponding amino-nitrobenzoyl chlorides. These yellow compounds proved more stable

[13] J. S. Swenton, *Tetrahedron Letters*, 1967, 2855.

than the acyl azides but the piperidino-derivative (43) decomposed during preparation to precipitate a colourless product with a high frequency carbonyl band (1760 cm^{-1}) and no diazo-absorption in its i.r. spectrum. The product was indeed the ylide (45) analogous to the mesoionic sulphonyl azide decomposition products, showing non-equivalent, low-field $^{+}NCH_2$ n.m.r. signals (τ 5·82 and 6·35), indicative of the quaternised piperidine ring. The signal due to the ^{-}CH group appeared as a singlet at τ 2·90. Analytical and mass spectral data further confirmed the proposed structure. Decomposition of the more stable perhydroazepinyldiazo-ketone, however, gave complex mixtures of products.



(43) $n = 5$
(44) $n = 6$



(45)

EXPERIMENTAL

I.r. spectra were recorded on a Perkin-Elmer 257 instrument for Nujol mulls, n.m.r. spectra on a Varian A60A or HA-100 instrument for solutions in deuteriochloroform unless stated otherwise, and mass spectra on an A.E.I. MS12 or MS902S instrument. Light petroleum refers to the fraction of b.p. 60—80°.

5-Nitro-2-(pyrrolidin-1-yl)benzenesulphonic Acid (4d).—To sodium 2-chloro-5-nitrobenzenesulphonate (20·0 g) was added pyrrolidine (11 ml), and the mixture was heated for 3 h at 100°. Water (200 ml) was added and the mixture neutralised with concentrated hydrochloric acid. The precipitate was filtered off, washed, and dried (yield 20·8 g) and gave the *product* (4d) as pale yellow needles (16·8 g), m.p. 196° (from water) (Found: C, 43·9; H, 4·5; N, 10·3. $C_{10}H_{12}N_2O_5S$ requires C, 44·2; H, 4·45; N, 10·3%).

5-Nitro-2-piperidinobenzenesulphonic acid (4e) was obtained similarly (70%) as cream needles (from water), m.p. 192° (Found: C, 45·9; H, 4·9; N, 9·5. $C_{11}H_{14}N_2O_5S$ requires C, 46·2; H, 4·9; N, 9·8%).

Preparation of the N-Oxides of the 2-Amino-5-nitrobenzenesulphonic Acids.—The sulphonic acid (2·0 g) in formic acid (10 ml) was treated with hydrogen peroxide (5 ml; 30%) and the mixture heated at 100°. The solution became dark and a vigorous reaction occurred, giving an almost colourless solution. The mixture was cooled after 15 min to precipitate the *N*-oxide, which crystallised as white plates from water. *5-Nitro-2-(pyrrolidin-1-yl)benzenesulphonic acid N-oxide* (81%) had m.p. 180° (decomp.) (Found: C, 41·4; H, 4·2; N, 9·6. $C_{10}H_{12}N_2O_6S$ requires C, 41·7; H, 4·2; N, 9·7%). *5-Nitro-2-piperidinobenzenesulphonic acid N-oxide* (25%) had m.p. 238° (decomp.) (Found: C, 43·5; H, 4·6; N, 9·1. $C_{11}H_{14}N_2O_6S$ requires C, 43·7; H, 4·7; N, 9·3%).

2-Chloro-5-nitrobenzenesulphonyl Chloride.—Sodium 2-chloro-5-nitrobenzenesulphonate (40·0 g) carefully mixed with phosphorus pentachloride (100·0 g) was heated on a boiling water-bath for 1·5 h giving a light brown oil, which was extracted several times with ether. The combined extracts were washed with water, dried ($MgSO_4$), treated with charcoal, and evaporated to give the sulphonyl chloride (33·0 g), m.p. 91° (from ether) (lit.,[14] 89—90°).

5-Nitro-2-(pyrrolidin-1-yl)benzenesulphonamide (26).—To 2-chloro-5-nitrobenzenesulphonyl chloride (5·0 g) in chloroform (100 ml) was added ammonium carbonate (10·0 g) and the solution was boiled for 6 h. The solvent was removed and water added to precipitate the crude 2-chloro-5-nitrobenzenesulphonamide, m.p. 185° (lit.,[15] 186°), as a white solid. This compound (2·0 g) in dry benzene was treated dropwise with stirring with pyrrolidine (1·4 ml), and after a further 1 h concentrated hydrochloric acid (3 drops) was added and the solution was filtered. Removal of the solvent gave a yellow solid which crystallised from ethanol as yellow *needles*, m.p. 210° (Found: C, 44·5; H, 4·8; N, 15·35. $C_{10}H_{13}N_3O_4S$ requires C, 44·3; H, 4·8; N, 15·5%).

5-Nitro-2-(pyrrolidin-1-yl)benzenesulphonyl Derivatives of o-, m- *and* p-*Chloroaniline.*—5-Nitro-2-(pyrrolidin-1-yl)-benzenesulphonyl chloride (0·5 g) in dry benzene (30 ml) was treated dropwise with a solution of *o-*, *m-*, or *p*-chloroaniline (0·44 g) in benzene (10 ml) and the mixture was stirred for 0·5 h. The precipitated hydrochloride was filtered off and the filtrate evaporated leaving a yellow solid. Crystallisation from benzene gave yellow needles [$\nu_{max.}$ 3200 cm^{-1} (NH)] of the *o-chloroanilide*, m.p. 192° (Found: C, 50·6; H, 4·1; N, 10·9. $C_{16}H_{16}ClN_3O_4S$ requires C, 50·3; H, 4·2; N, 11·0%), the *m-chloroanilide*, m.p. 168° (Found: C, 50·6; H, 4·4; N, 11·1%), or the *p-chloroanilide*, m.p. 187° (Found: C, 50·1; H, 4·0; N, 11·0%).

2,3,3a,4-Tetrahydro-7-nitro-1H-pyrrolo[2,1-c][1,2,4]benzothiadiazine 5,5-Dioxide (24).—A solution of potassium persulphate (2·5 g, 0·009 mol) in water (100 ml) was added dropwise with stirring to a suspension of 5-nitro-2-(pyrrolidin-1-yl)benzenesulphonamide (2·5 g, 0·009 mol) in water (100 ml) during 30 min at 100°. After a further 1·5 h at 100° the solution was cooled and the precipitate filtered off (0·8 g, 32%). Crystallisation from ethyl acetate gave yellow needles, m.p. 196° (Found: C, 44·5; H, 4·0; N, 15·7. $C_{10}H_{11}N_3O_4S$ requires C, 44·6; H, 4·1; N, 15·6%).

2-Chloro-5-nitrobenzenesulphonyl Azide.—To 2-chloro-5-nitrobenzenesulphonyl chloride (9·0 g) in ethanol (400 ml) was added dropwise with stirring an aqueous solution of sodium azide (2·4 g) in water (15 ml). A white precipitate was formed immediately and slowly redissolved. The mixture was left at room temperature for 1 h then poured into water (1·5 l) to give a white precipitate of *2-chloro-5-nitrobenzenesulphonyl azide* (8·5 g), which crystallised from ethanol as needles, m.p. 96° (Found: C, 27·2; H, 1·3; N, 21·6. $C_6H_3ClN_4O_4S$ requires C, 27·4; H, 1·2; N, 21·3%).

Preparation of the o-Aminobenzenesulphonyl Azides.—*General procedure.* To 2-chloro-5-nitrobenzenesulphonyl azide (0·1 mol) in dry benzene (150 ml) the appropriate base (0·21 mol) was added dropwise with stirring. After 12 h stirring a few drops of concentrated hydrochloric acid were added and the suspension was filtered and the filtrate evaporated to give the crude product. The yellow azides were purified by column chromatography on silica (benzene as eluant) and crystallised from ethanol (see Table 1).

Preparation of the 2-Amino-5-nitrobenzoyl Azides.—The 2-amino-5-nitrobenzoic acid [16] (5) (5·0 g) was added to a solution of pure thionyl chloride (4 ml) and dimethylformamide

[14] E. V. Zhakharov, V. I. Zetkin, M. Ya. Fishkis, and V. S. Nakh, *Zhur. org. Khim.*, 1965, **1**, 1866.
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[16] O. Meth-Cohn, H. Suschitzky, and M. E. Sutton, *J. Chem. Soc.* (*C*), 1968, 1722.

(4 drops) in dry benzene (200 ml) and the mixture was stirred overnight. The solvent and the excess of reagent were removed under reduced pressure, a further portion of dry benzene (150 ml) was added, and the mixture was evaporated to dryness. This procedure was repeated twice and the crude acid chloride [$\nu_{max.}$ 1750 cm^{-1} (CO)] was used directly.

Method 1. The benzoyl chloride in benzene was added dropwise to ice-cooled hydrazine hydrate (excess) with vigorous stirring. After 0·5 h the mixture was poured into water and the precipitated *hydrazide* filtered off and recrystallised from methanol (see Table 2). The hydrazide in the minimal quantity of hot glacial acetic acid was treated with an equal volume of aqueous hydrochloric acid (4M) and cooled in ice. To this stirred solution was added an equimolar amount of sodium nitrite in water, resulting in an immediate precipitate. After 0·5 h the solution was poured into water and the yellow *benzoyl azide* (2) was filtered off. Satisfactory analytical data were not obtained owing to the spontaneous decomposition of these products. The following decomposition temperatures were recorded: (3d), 62°; (3e), 65°; (3h), 67°. The i.r. spectra showed $\nu_{max.}$ 2160 (N_3) and 1690 cm^{-1} (CO). Also by this method was obtained *3-nitro-4-(pyrrolidin-1-yl)benzoyl azide* (38), m.p. 107° (decomp. 112°), as golden plates (from ethanol) (Found: C, 50·4; H, 4·2; N, 26·8. $C_{11}H_{11}N_5O_3$ requires C, 50·6; H, 4·25; N, 26·8%).

Method 2. 5-Nitro-2-(pyrrolidin-1-yl)benzoyl chloride (1·6 g) in dry acetone (20 ml) was treated dropwise with stirring at −70° with a supersaturated solution of activated sodium azide (0·6 g) in water (1 ml). After 0·5 h the solution was poured into water to give the 5-nitro-2-(pyrrolidin-1-yl)benzoyl azide (1·1 g).

Decomposition of the Sulphonyl Azides.—(A) *General procedure.* The azide in the solvent (dry chlorobenzene or freshly distilled dimethyl sulphoxide to give a *ca.* 5—10% solution) was heated under reflux until complete decomposition had occurred (generally *ca.* 2 h), the amount of starting azide present being monitored by t.l.c. In most cases, the decompositions were performed both with and without a nitrogen atmosphere, but no appreciable variance in products was observed. The work-up varied with each azide as follows:

(a) *With the dimethylamino-* (2a), *piperidino-* (2c), *morpholino-* (2f), *and 4-methylpiperazin-1-yl* (2g) *azides.* The solution was cooled and (with chlorobenzene) the precipitate product filtered off. Removal of the remaining solvent *in vacuo* gave a little more product, which was purified by crystallisation from water or ethanol to give the *mesoionic spirobenzothiadiazoles* (11) as shown in Table 3.

(b) *With the diethylamino-* (2b), *dipropylamino-* (2c), *allylamino-* (34a), p-*methoxyanilino-* (34b), *perhydroazepin-1-yl* (2h), *perhydroazocin-1-yl* (2i), *and perhydroxazonin-1-yl* (2j) *azides.* The solvent was removed under vacuum to yield a dark oil. Chromatography on silica gel [benzene, chloroform, or methanol–benzene (1 : 6) as eluant] gave the appropriate benzothiadiazole [(13)—(17), (35), or (36); see Table 4].

(c) *With the pyrrolidin-1-yl azide* (2d). The solvent was removed under vacuum and the dark red oil remaining (derived from 2·0 g of the azide) was separated by chromatography on alumina. Elution with light petroleum–ether (4 : 1) gave first *N*-(4-nitrophenyl)pyrrolidine (27) as a bright yellow solid (0·01 g, 1%), m.p. 107° (lit.,[17] 106°), followed by *N*-(2-amino-4-nitrophenyl)pyrrolidine (22) (0·04 g, 3%) as crimson crystals, m.p. 77° (lit.,[18] 79—80°). Elution with diethyl ether gave 2,3-dihydro-6-nitro-1*H*-pyrrolo[1,2-*a*]-benzimidazole (23) (0·4 g, 18%), m.p. 207° (lit.,[18] 209°). Elution with chloroform gave a mixture (0·1 g) of the three isomeric sulphonamides (25) together with traces of unidentified material. These were separated by thick-layer chromatography on silica gel (2 mm) with benzene–chloroform (1 : 1) and the products were compared with authentic samples (see above) (m.p., mixed m.p., and i.r. spectrum). Elution finally with ethanol gave a dark yellow oil (0·45 g) which was separated on thick-layer plates of silica gel (2 mm) by three elutions with ethanol to give two major components: first 5-nitro-2-(pyrrolidin-1-yl)benzenesulphonamide (0·09 g, 5%), identical with that described above, and then 2,3,3a,4-tetrahydro-7-nitro-1*H*-pyrrolo[2,1-*c*][1,2,4]benzothiadiazine 5,5-dioxide (24) (0·24 g, 13%), m.p. 196°, identical with the sample described above.

TABLE 1

Properties of the 2-amino-5-nitro-sulphonyl azides (2) and (34)

Compound	Yield (%)	M.p. (decomp. p.) (°C)	Found (%) C	H	N	Formula	Required (%) C	H	N
(2a)	*ca.* 100	87 (91)	35·3	3·3	25·7	$C_8H_9N_5O_4S$	35·4	3·4	25·8
(2b)	83	75 (85)	39·9	4·3	23·3	$C_{10}H_{13}N_5O_4S$	40·1	4·4	23·4
(2c)	80	70 (101)	44·1	5·3	21·3	$C_{12}H_{17}N_5O_4S$	44·0	5·2	21·4
(2d)	90	104 (104)	40·1	3·7	28·1	$C_{10}H_{11}N_5O_4S$	40·4	3·7	28·3
(2e)	95	117 (117)	42·4	4·3	22·5	$C_{10}H_{11}N_5O_4S$	42·4	4·2	22·6
(2f)	90	116 (116)	38·6	3·6	22·5	$C_{10}H_{11}N_5O_5S$	38·3	3·5	22·4
(2g)	*ca.* 100	119 (119)	40·5	4·3	25·9	$C_{11}H_{14}N_6O_4S$	40·5	4·3	25·8
(2h)	83	88 (95)	44·5	4·5	21·8	$C_{12}H_{15}N_5O_4S$	44·3	4·7	21·5
(2i)	77	106 (106)	45·8	5·0	20·5	$C_{13}H_{17}N_5O_4S$	46·0	5·1	20·6
(2j)	70	92 (97)	47·3	5·6	19·7	$C_{14}H_{19}N_5O_4S$	47·6	5·4	19·8
(34a)	56	93 (113)	38·3	3·1	24·6	$C_9H_9N_5O_4S$	38·2	3·2	24·7
(34b)	50 *	112 (118)	44·6	3·2	20·2	$C_{13}H_{11}N_5O_5S$	44·7	3·2	20·05

* The reaction mixture was heated for 200 h at 80° after addition of the amine.

TABLE 2

Properties of the 2-NR_2-5-nitrobenzoyl hydrazides

R_2	M.p. (°C)	Found (%) C	H	N	Formula	Required (%) C	H	N
$[CH_2]_4$	220	53·2	5·7	22·0	$C_{11}H_{14}N_4O_3$	52·8	5·6	22·4
$[CH_2]_5$	310	54·0	6·2	20·4	$C_{12}H_{16}N_4O_3$	54·5	6·1	21·2
$[CH_2]_6$	264	56·3	6·4	19·9	$C_{13}H_{18}N_4O_3$	56·1	6·5	20·1

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[18] M. D. Nair and R. Adams, *J. Amer. Chem. Soc.*, 1961, **83**, 3518.

(B) *Decomposition in the presence of a base or base hydrochloride.* 5-Nitro-2-(piperidin-1-yl)benzenesulphonyl azide (1·4 g) was heated as in (A) in chlorobenzene in the presence of piperidine hydrochloride (0·1 g). After work-up as in (A) (b) chromatography gave the *thiadiazine dioxide* (28) (1·25 g, 98%) as yellow crystals (from benzene), m.p. 194° (see Table 5). The same product (80%) was obtained when the azide (0·6 g) was refluxed in piperidine (10 ml) for 1 h and the product was worked up in the above manner.

with a high-pressure u.v. lamp (Pyrex filter) under nitrogen, decomposition being complete after 18 h. Removal of the solvent at 28° and 0·5 mmHg gave a dark red oil which, on elution through silica gel with chloroform, afforded a yellow solid. (*a*) The piperidinyl azide (2e) gave 1,2,3,4-tetrahydro-8-nitropyrido[2,1-*c*][1,2,4]benzothiadiazine 6,6-dioxide (31) (30%), m.p. 272°, as yellow crystals (from methanol) (Found: C, 46·4; H, 4·0; N, 14·0. Calc. for $C_{11}H_{11}N_3O_4S$: C, 47·0; H, 4·0; N, 14·9%) (lit.,[19] m.p. 268°),

TABLE 3

Properties of the mesoionic benzothiadiazoles (11) derived by thermolysis of the azides (2) in chlorobenzene

Cpd.	Yield (%)	M.p. (°C)	Found (%) C	H	N	Formula	Required (%) C	H	N	τ [$(CD_3)_2SO$] Aromatic H	Aliphatic H
(11a)	65 [a]	188	38·9	3·8	17·2	$C_8H_9N_3O_4S$	39·5	3·7	17·3	1·40 (s)	6·24 (s)
(11e)	70 [b] (90 *)	225	46·8	4·7	14·8	$C_{11}H_{13}N_3O_4S$	46·6	4·6	14·8	1·42 (s)	5·78br (t, NCH_α), 6·55br (d, NCH_β), 7·2—8·0 (m, $[CH_2]_3$)
(11f)	85 [a]	224	42·1	4·1	14·7	$C_{10}H_{11}N_3O_5S$	42·1	3·9	14·7	1·42 (s)	5·4—6·1 (m, NCH_α), 6·55br (d, NCH_β), 5·4—6·1 (OCH_3)
(11g)	60 [b]	216	44·6	4·9	18·8	$C_{11}H_{14}N_4O_4S$	44·3	4·7	18·8	1·42 (s)	5·3—6·0 (m, NCH_α), 6·55br (d, NCH_β), 6·8—7·1 (m, CH_2NCH_2) 7·60 (s, Me)

* In dimethyl sulphoxide instead of chlorobenzene.

[a] Recrystallised from water. [b] Recrystallised from ethanol.

TABLE 4

Properties of the benzothiadiazoles (12)—(17), (35), and (36)

Cpd.	Yield (%)	M.p. (°C)	Found (%) C	H	N	Formula	Required (%) C	H	N	τ Values: Aromatic H H-7	H-5	H-4	Olefinic H H_A	H_B	H_B	Aliphatic H NCH_3	Others	NH
(12)	42 [a]	98	41·2	4·4	13·1	$C_{11}H_{14}ClN_3O_4S$	41·3	4·4	13·1									
(13)	58 [b]	107	39·3	4·7	17·1	$C_8H_9N_3O_4S$	39·5	4·7	17·3									
(14)	65 [b]	109	41·9	4·2	16·2	$C_9H_{11}N_3O_4S$	42·0	4·3	16·3									
(15)	76 [a]	66	47·9	5·1	13·6	$C_{12}H_{15}N_3O_4S$	48·5	5·1	14·1	1·61 (d)	1·68 (dd)	2·95 (d)	4·55 (m)	4·70 (m)	5·25 (m)	6·40 (t)	7·68—8·75 (m)	3·10br (s)
(16)	74 [a]	72	49·9	5·4	13·3	$C_{13}H_{17}N_3O_4S$	50·2	5·5	13·5	1·63 (d)	1·68 (dd)	2·95 (d)	4·55 (m)	4·80 (m)	5·20 (m)	6·40 (t)	7·68—8·82 (m)	2·98br (s)
(17)	90 [a]	42	51·5	5·8	13·0	$C_{14}H_{19}N_3O_4S$	51·7	5·9	12·9	1·60 (d)	1·66 (dd)	2·95 (d)	4·58 (m)	4·85 (m)	5·25 (m)	6·45 (t)	7·68—8·80 (m)	3·28 br(s)
(35) *	38 [b]	155	42·1	3·3	16·1	$C_9H_9N_3O_4S$	42·35	3·6	16·5	2·39 (d)	2·18 (dd)	3·22	4·60 (m)	4·70 (m)	5·20 (m)	5·12 (m)		
(36)	19 [c]	218	48·8	3·5	13·3	$C_{13}H_{11}N_3O_5S$	48·6	3·4	13·1									

[a] Benzene used as eluant. [b] Chloroform used as eluant. [c] Methanol–Benzene (1:6) used as eluant.

* N.m.r. in $CDCl_3$–$(CD_3)_2SO$.

TABLE 5

Properties of the benzothiadiazines derived by copper-catalysed decomposition of the azides (2)

Compound	Yield (%)	M.p. (°C)	Found (%) C	H	N	Formula	Required (%) C	H	N	ν_{NH}/cm^{-1}
(28)	48 *	194	46·9	4·7	15·0	$C_{11}H_{13}N_3O_4S$	46·6	4·6	14·8	3240
(29)	81 †	180	48·3	4·9	13·8	$C_{12}H_{15}N_3O_4S$	48·5	5·1	14·1	3240
(30)	8 ‡	188	41·9	3·7	14·4	$C_{10}H_{11}N_3O_5S$	42·1	3·9	14·7	3240

* When dimethyl sulphoxide solution (instead of chlorobenzene) was used this product (53%) was isolated together with a little (31) (4%). † Together with a trace of the benzothiadiazole (15). ‡ Together with 5-nitro-2-morpholinobenzenesulphonamide (80%).

(C) *Decomposition in the presence of copper.* The azide (2·0 g) was refluxed in chlorobenzene in the presence of freshly precipitated copper (1·0 g per mol of azide), the decomposition requiring about 1·5 h. The copper was filtered off and the solvent removed from the filtrate to give a yellow oil. Chromatography on silica gel [benzene–chloroform (1 : 1) as eluant] gave the *thiadiazine dioxides* recorded in Table 5. Similar treatment of the mesoionic benzothiadiazoles (11e and f) gave the thiadiazines (28) (73%) and (30) (6%), the latter together with 2-morpholino-5-nitrobenzenesulphonamide (79%).

(D) *Photolytic decomposition.* The azide (1·6 g) in freshly distilled dimethyl sulphoxide (70 ml) was irradiated

[19] R. Cameroni, M. T. Bernalsei, and V. Ferioli, *Farmaco ed. Sci.*, 1972, **27**, 574.

τ [$(CD_3)_2SO$] 1·40 (2H, m, aromatic), 2·05 (1H, d, *J* 8·0 Hz, aromatic), 5·90br (t, NCH_2), 7·10br (t, $=C-CH_2$), and 7·72—8·42 (m, $[CH_2]_2$). (*b*) The perhydroazepinyl azide (2h) gave *2,3,4,5-tetrahydro-9-nitro-1H-azepino*[2,1-c][1,2,4]*benzothiadiazine* 7,7-dioxide (32) (42%), m.p. 194°, as yellow needles (from benzene) (Found: C, 48·6; H, 4·2; N, 14·4. $C_{12}H_{13}N_3O_4S$ requires C, 48·8; H, 4·4; N, 14·2%), τ 5·6—5·85 (m, NCH_2), 6·75—7·05 (m, $=C-CH_2$), and 7·72—8·22 (m, $[CH_2]_3$).

Action of Acid on the Mesoionic Benzothiadiazole (11e).—Compound (11e) (1·0 g) was boiled gently in aqueous hydrochloric acid (4M) for 0·5 h, after which time an oil separated. Extraction of the cooled solution with chloroform (3 × 20 ml) gave an oil which was eluted through silica gel with benzene to give a yellow solid. Recrystallisation from benzene

gave 3-(5-*chloropentyl*)-1,2-*dihydro*-6-*nitro*-1,2,3-*benzothiadiazole* 1,1-*dioxide* (12) as yellow needles, m.p. 98° (see Table 4).

Decomposition of the Carbonyl Azides (3).—(a) *Under anhydrous conditions.* When 5-nitro-2-(pyrrolidin-1-yl)benzoyl azide was stored over phosphorus pentoxide in the dark overnight, it underwent quantitative conversion into N-(2-*isocyanato*-4-*nitrophenyl*)*pyrrolidine* (39; Y = $[CH_2]_4$), which crystallised from light petroleum (b.p. 80—100°) as orange plates, m.p. 118° (Found: C, 56·4; H, 4·9; N, 17·9. $C_{11}H_{11}N_3O_3$ requires C, 56·65; H, 4·8; N, 18·0%), $\nu_{max.}$ 2260 cm^{-1} (NCO).

(b) *In the open atmosphere.* When the azides (3) were left in the open, or heated in chlorobenzene at 70° for 1·5 h, an orange solid formed. Crystallisation from anisole gave, in each case, a urea derivative (41). The pyrrolidine (3d) gave NN′-*bis*-[5-*nitro*-2-(*pyrrolidin*-1-*yl*)*phenyl*]*urea*, m.p. 225° (Found: C, 57·0; H, 4·5; N, 18·0. $C_{21}H_{24}N_6O_5$ requires C, 57·3; H, 5·5; N, 19·1%). The piperidine (3e) gave NN′-*bis*-(5-*nitro*-2-*piperidinophenyl*)*urea*, m.p. 222° (Found: C, 58·45; H, 6·0; N, 17·5. $C_{23}H_{28}N_6O_5$ requires C, 59·0; H, 6·0; N, 17·9%). The perhydroazepine (3h) gave NN′-*bis*-[5-*nitro*-2-(*perhydroazepin*-1-*yl*)*phenyl*]*urea*, m.p. 231° (Found: C, 60·3; H, 6·6; N, 16·8. $C_{25}H_{42}N_6O_5$ requires C, 60·5; H, 6·5; N, 16·9%).

(c) *In chloroform* (*containing ethanol*). When 5-nitro-2-(pyrrolidin-1-yl)benzoyl azide (2·0 g) was heated under reflux in chloroform (30 ml) for 4 h, removal of the solvent gave *ethyl* N-[5-*nitro*-2-(*pyrrolidin*-1-*yl*)*phenyl*]*carbamate* (40) as a yellow solid which crystallised from light petroleum (b.p. 100—120°), m.p. 134° (Found: C, 55·9; H, 6·0; N, 14·8. $C_{13}H_{17}N_3O_4$ requires C, 55·9; H, 6·1; N, 15·0%). The same product was formed from the isocyanate (39) in warm ethanol.

The (b) and (c) yields were variable because of the instability of the azides.

Preparation and Decomposition of the Diazo-ketones (43) *and* (44).—A solution of the 5-nitro-2-aminobenzoyl chloride in dry benzene (100 ml) was added dropwise to an excess of diazomethane in benzene and the mixture was kept for 100 h at ambient temperature in the dark.

(*a*) From 5-nitro-2-(piperidin-1-yl)benzoyl chloride (7·0 g) a white precipitate (2·4 g) formed which was filtered off and recrystallised from n-propanol to give white needles, m.p. 180°, of 2,3-*dihydro*-5-*nitro*-3-*oxospiro*[*indole*-1,1-*piperidinium*]-2-*ide* (45), $\nu_{max.}$ 1760 cm^{-1} (CO), $[(CD_3)_2SO]$ 0·33 (1H, d, *J* 2·5 Hz), 1·96 (1H, dd, *J* 2·5 and 9·0 Hz), 2·37 (1H, d, *J* 9·0 Hz), 2·90 (s, ^-CH), 5·82br (t, NCH_A), 6·35br (t, NCH_B), and 7·8—8·8 (m, $[CH_2]_3$) (Found: C, 63·2; H, 5·5; N, 11·8%; M^+, 246. $C_{13}H_{14}N_2O_3$ requires C, 63·4; H, 5·7; N, 11·4%; *M*, 246). From the filtrate was obtained an orange oil which was purified by elution through a silica gel column with benzene followed by trituration to give 5-*nitro*-2-*piperidinobenzoyldiazomethane* (43) as a yellow solid, m.p. 78° (decomp. 88°), $\nu_{max.}$ 3120 (CH), 2120 (CHN_2), and 1640 cm^{-1} (CO), τ (CCl_4) 1·78 (1H, d, *J* 2·8 Hz), 1·97 (1H, dd, *J* 2·8 and 9·0 Hz), 3·03 (1H, d, *J* 9·0 Hz), 3·90 (s, CHN_2), 6·85br, NCH_2), and 8·27br ($[CH_2]_3$).

(b) From 5-nitro-2-(perhydroazepin-1-yl)benzoyl chloride (5·0 g) was obtained, by evaporation of the solvent, a yellow solid (2·9 g) which was eluted through a silica gel column with benzene (the compound rapidly darkened on the column) to give 5-*nitro*-2-(*perhydroazepin*-1-*yl*)*benzoyldiazomethane* (44) as an orange solid which crystallised from ethyl acetate as yellow needles, m.p. 143° (decomp.) (Found: C, 58·6; H, 5·6; N, 19·0. $C_{14}H_{16}N_4O_3$ requires C, 58·3; H, 5·6; N, 19·4%). Thermolysis in chlorobenzene gave a complex mixture of products.

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