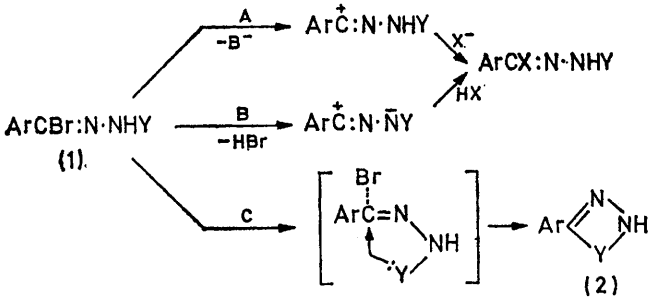
Synthesis and Solvolysis of a New Group of Reactive Halides, the Imidazolin-2-ylidenehydrazonyl Chlorides; a Route to 6,7-Dihydro-3-aryl-5*H*-imidazolo[2,1-*c*]-*s*-triazoles [1]

By **F. L. Scott,* J. K. O'Halloran, J. O'Driscoll,** and **A. F. Hegarty,** Chemistry Department, University College, Cork, Ireland

Reaction of 1-aryl-1,4,4-trichloro-2,3-diazabutadienes (5) with ethylenediamine forms the new *N*-(imidazolin-2-ylidene)benzohydrazonyl chlorides (6), which cyclise rapidly and in high (90%) yields to the new 6,7-dihydro-3-aryl-5*H*-imidazolo[2,1-*c*]-*s*-triazoles (8). The trichlorides (5) with *NN'*-dimethylethylenediamine yielded not only the corresponding *N*-(1,3-dimethylimidazolin-2-ylidene)-substituted benzohydrazonyl chlorides (14) but also the new *NN'*-(1,6-dichloro-2,5-dimethyl-2,5-diazahexane-1,6-diylidene)bis(benzohydrazonyl chlorides) (15). Hydrolysis of the hydrazonyl chlorides (14) yields the substituted *N'*-(1,3-dimethylimidazolidin-2-ylidene)-benzohydrazides (16), accompanied by varying quantities of the corresponding 3,6-diaryl-1,2,4,5-tetrazines (17), whereas the tetrachlorides (15) gave the *NN'*-bis-(5-aryl-1,3,4-oxadiazol-2-yl)-*NN'*-dimethylethylenediamines (26) under more vigorous conditions. The hydrazonyl chlorides (14) formed the corresponding *N*-phenylbenzamide *N'*-(1,3-dimethylimidazolidin-2-ylidene)hydrazones (24) with aniline; the tetrachlorides (15) yielded 3-anilino-5-aryl-4-phenyl-1,2,4-triazoles (25).

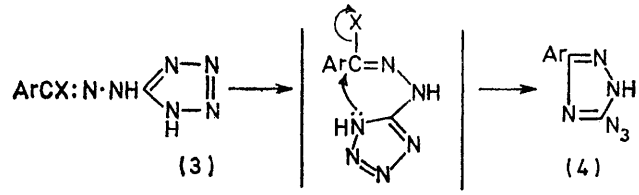
Bromine reacts with aldehydic hydrazones to give, depending upon the conditions, products of methine attack,[2] *i.e.* hydrazonyl bromides (1), or of cyclization (2).[3] In many cases the hydrazonyl bromides are intermediates in the formation of the cyclic materials.

We have been exploring the mechanisms of the formation of hydrazonyl halides [2] and their possible (or demonstrated [4]) role in the formation of compounds (2). With the bromides (1), the bromine atom may be replaced by a variety of mechanisms [5] (see Scheme 1), *i.e.* azocarbonium ion formation (path A), 1,3-dipolar ion formation (B), or anchimeric cyclization (C).



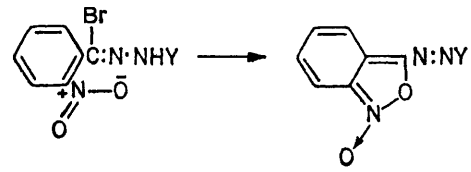
Scheme 1

In the cyclizations we have looked for instances in which the group Y played a truly anchimeric role. When Y was a tetrazolyl ring [as in (3)], the products of solvolysis were the triazolyl azides (4), confirming the involvement of the tetrazole ring (Scheme 2). However, the kinetics of solvolysis (with $\rho = -1{\cdot}8$ for Ar with X = Br and ρ (X = Cl) $= -0{\cdot}85$) clearly indicated that whatever the precise electronic effects the tetrazole ring had on the ionization of the C–X bond, its role was product- rather than rate-determining in the anchimeric sense.



Scheme 2

Another instance is the involvement of an *ortho*-nitro-function in hydrazonyl halide reactions.[6] Here again,



despite the kinetic acceleration afforded by the presence of the *ortho*-nitro-group (an acceleration displayed also, but to a lesser extent, by such *ortho*-substituents as F, Br, and Cl), we concluded that the rate-enhancement was not due to nucleophilic attack but rather involved a field effect by the substituents stabilizing the incipient carbonium ion.

We were interested in achieving the anchimeric role for Y in the hydrazonyl halide system that has been well-established [7] in other halides. To that end we wanted substrates wherein Y would have powerful nucleophilic character. The role of imidazole moieties as both inter- [8a] and intra- [8b] molecular catalysts (or nucleophiles) is well known, and thus we wished to

[1] This paper is considered to be Part VI of the series Polyhalogenodiazabutadienes: Part V, J. K. O'Halloran and F. L. Scott, preceding paper. Some of the results have been noted in preliminary form, J. K. O'Halloran and F. L. Scott, *Tetrahedron Letters*, 1970, 4083.

[2] A. F. Hegarty and F. L. Scott, *J. Chem. Soc.* (*B*), 1966, 672.

[3] R. N. Butler and F. L. Scott, *Chem. and Ind.*, 1970, 1216.

[4] R. N. Butler, P. O'Sullivan, and F. L. Scott, *J. Chem. Soc.* (*C*), 1971, 2265.

[5] A. F. Hegarty, M. P. Cashman, and F. L. Scott, *J.C.S. Perkin II*, 1972, 44.

[6] A. F. Hegarty, M. P. Cashman, and F. L. Scott, *J. Chem. Soc.* (*B*), 1971, 1879.

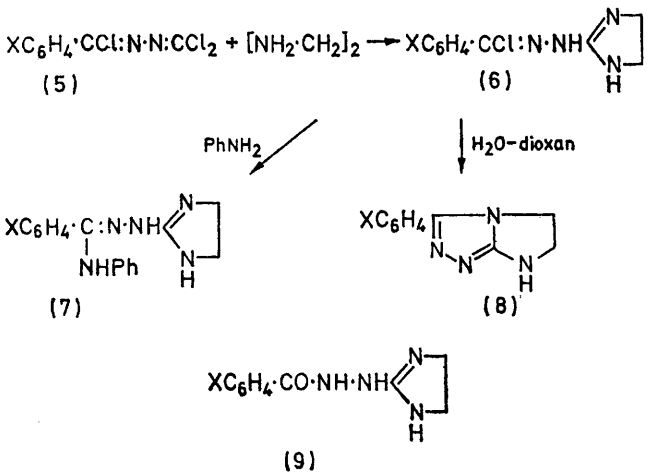
[7] F. L. Scott, E. J. Flynn, and D. F. Fenton, *J. Chem. Soc.* (*C*), 1971, 277 and references therein.

[8] (*a*) T. C. Bruice and S. Benkovic, 'Bio-organic Mechanisms,' Benjamin, New York, vol. 1, 1966, p. 125; (*b*) W. P. Jencks, 'Catalysis in Chemistry and Enzymology,' McGraw-Hill, New York, 1969, p. 67; (*c*) T. C. Bruice, *J. Amer. Chem. Soc.*, 1959, **81**, 5444.

prepare hydrazonyl halides containing such an imidazole unit. This paper describes the preparative work and the solvolytic behaviour of these compounds.

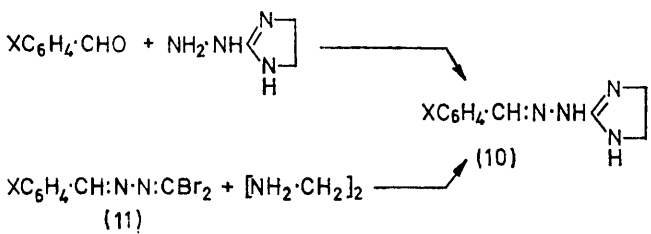
RESULTS AND DISCUSSION

Reaction of the diazabutadienes [1,9] (5) with 2 mol. equiv. of ethylenediamine in benzene led to the replacement of both terminal chlorine atoms to give the *N*-(imidazolin-2-ylidene)hydrazonyl chlorides (6) in good yields. The structure of these new hydrazonyl halides (6) is consistent both with their spectral and analytical data and also with the ready formation of the amidrazones (7) on treatment with aniline in benzene (see Scheme 3).



SCHEME 3

We attempted to synthesize the hydrazonyl chlorides (6) by the direct halogenation of the hydrazones (10). Such a reaction works smoothly with other heterocyclic hydrazones such as the 5-tetrazolyl-,[3] 1,2,4-triazolyl-,[10a] and 1,3,4-oxadiazolyl-compounds.[10b] The hydrazones (10) were themselves prepared by either (*a*) condensation



SCHEME 4

of the appropriate aldehyde with imidazolin-2-ylhydrazine hydroiodide [11] or (*b*) reaction of the 1,1-dibromodiazabutadiene (11) with ethylenediamine (see Scheme 4). The products formed by both methods were identical. Bromination (in glacial acetic acid) of two of the hydrazones (10; X = *p*-Br or *p*-Cl) did not yield the corresponding hydrazonyl bromides, but gave instead hydrazone perbromides (12) of the type Hy,HBr_3 (Hy = hydrazone). Support for this formulation is the fact that amperometric iodometric titration reveals the presence of 2 equiv. of oxidizing bromine in the molecules. The perbromides (12) could be reconverted into the starting hydrazones (10) under mild conditions (distribution between ether and aqueous base).

Similar perbromides have been isolated previously in the bromination of 2,3-diazabuta-1,3-dienes,[12] and related *N*-bromo-compounds of the type $HyBr^+Br^-$ have been obtained in the bromination of 2-pyridyl-[13] and 1,3,4-oxadiazolyl-hydrazones.[10b] The synthesis of compounds (6) that we have described (see Scheme 3) circumvents direct halogenation, which was not feasible.

The hydrazonyl halides (6) were solvolysed readily, cyclizing in dioxan–water (4 : 1) to the corresponding 6,7-dihydro-3-aryl-5*H*-imidazolo[2,1-*c*]-*s*-triazoles (8) (isolated as hydrochloride hydrates) in good yields.

Although a number of imidazolo-*s*-triazoles have previously been reported [14] this synthesis is the first for the fused imidazolo[2,1-*c*]-*s*-triazole system.

An alternative possible formulation of the hydrolysis product is the hydrazide (9) [which would have the same analysis as a hydrate of (8)]. Moreover a sharp absorption at 1760 (± 3) cm^{-1} in the i.r. spectra of all the solvolysis products could possibly be due to carbonyl stretching. The formation of the hydrazide (9) could arise either by solvolysis of the hydrazonyl chloride (6) or possibly by attack of water on the cyclized product (8).

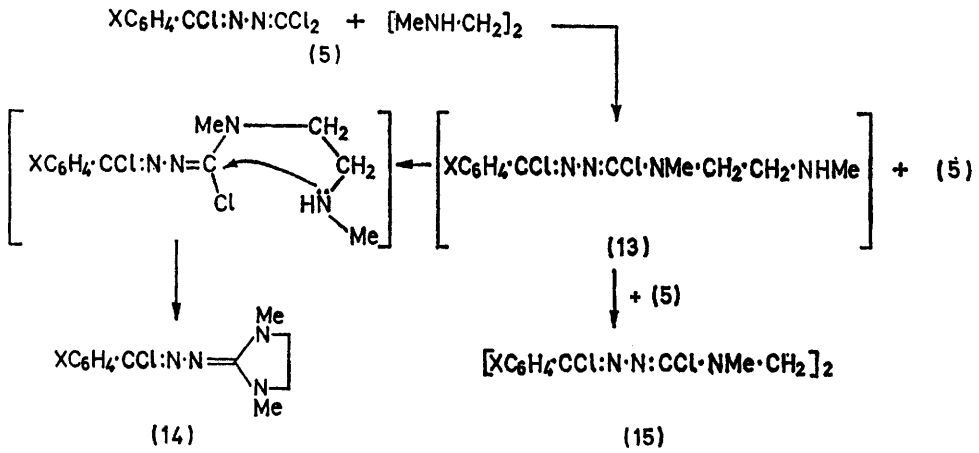
The hydrazides (9) were therefore synthesized by an alternative method (condensation of 2-hydrazinoimidazoline with appropriate aroyl chlorides), and then converted into their hydrochlorides. These hydrochlorides were distinctly different (m.p., spectra, *etc.*) from the materials obtained by solvolysis of the hydrazonyl chlorides (6). The former show no absorption at 1760 cm^{-1}, but have the strong absorption at 1700 (± 5) cm^{-1}, typical of hydrazides.[15] The i.r. spectra of the hydrochloride hydrates of (8) also show a sharp peak at 3570 cm^{-1}, due to O–H stretching, which is not present in the hydrazide hydrochlorides [(9),HCl].

When the hydrazonyl chlorides (6) were solvolysed in dioxan–water (4 : 1) in the presence of base (sodium carbonate), the free imidazolo[2,1-*c*]-*s*-triazoles (8) were isolated directly in high yield. On stirring the hydrochlorides of the free bases in water for 5 min, the hydrochloride hydrates $[(8),HCl,H_2O]$ were obtained quantitatively. These were identical with those obtained by direct solvolysis of compounds (6) in neutral or mildly acidic solution.

We were interested in how alkylation of the imidazolyl

[9] F. L. Scott, J. Donovan, and J. K. O'Halloran, *Tetrahedron Letters*, 1970, 4079.
[10] (*a*) F. L. Scott and T. A. F. O'Mahony, *Tetrahedron Letters*, 1970, 1841; (*b*) F. L. Scott, T. M. Lambe, and R. N. Butler, *Tetrahedron Letters*, 1971, 1729.
[11] S. R. Aspinall and E. J. Bianco, *J. Amer. Chem. Soc.*, 1951, **73**, 602.
[12] F. L. Scott and P. A. Cashell, *J. Chem. Soc.* (*C*), 1970, 2674.
[13] M. S. Gibson, *Tetrahedron*, 1963, **19**, 1587.
[14] O. W. Webster, U.S.P., 3,093,653/1963 (*Chem. Abs.*, 1963, 59, 11507*e*); H. W. Heine, A. B. Smith, tert., and J. D. Bower, *J. Org. Chem.*, 1968, **33**, 1097.
[15] L. J. Bellamy, 'The Infra-Red Spectra of Complex Molecules,' Wiley, New York, 2nd edn., 1958, p. 162.

nitrogen centres would affect the cyclization of compounds (6). Accordingly we treated the trichlorides (5) with *NN'*-dimethylethylenediamine in benzene. In addition to the expected dimethylhydrazonyl bromides (14), varying amounts of the new tetrachlorides (15) were also obtained (see Scheme 5).



SCHEME 5

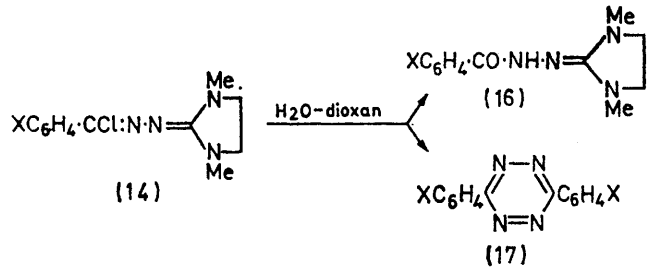
We have established in earlier work [16] that secondary amines react with the trichlorides (5) to yield substituted hydrazonyl halides of type (13). These can then undergo intramolecular nucleophilic attack to yield the hydrazonyl halides (14). Alternatively, further reaction of the products (13) with the geminal dihalide (5) by an intermolecularly competitive process leads to the dimers (15). A similar competition between inter- and intra-molecular processes has been described in the reactions between *NN'*-dimethylethylenediamine and phosgene.[17]

The formation of compounds (15) was unexpected inasmuch as rates of intramolecular attack by an amino-group on an acyl function can be several orders of magnitude greater than the corresponding intermolecular process.[18] Over the limited range of substituents (X = *p*-NO_2, *m*-NO_2, *m*-Cl, *p*-Cl, and *p*-Br), the intramolecular process was predominant (64—86% yield), while the corresponding yields from the intermolecular reactions were 19—8%.

Possibly, (*a*) an increase in electrophilicity of the trichlorides (5) as X is changed from *p*-Br to *p*-NO_2 favours intermolecular attack, or (*b*) if azocarbonium ions (as ion-pairs) were involved in the displacement of Cl^- from (15) as they are with such compounds in ionizing media,[16] then *p*-NO_2 would destabilize them more than *p*-Br and this might influence the level of intra-/inter- attack, or finally (*c*) steric factors might also facilitate the intermolecular process as the reaction site would be less hindered than in the intramolecular cyclization.

Other factors can influence the balance between the two processes. The yields of the dimers (15) were increased by using more concentrated solutions of compounds (5) (consistent with the bimolecular reaction involved) and by the introduction of a base (triethylamine) to prevent inhibition of the nucleophilic addition process by HCl.

On hydrolysis of the dimethylated hydrazonyl chlorides (14), the major products isolated were the hydrochlorides of the corresponding hydrazides (16). No cyclic material corresponding to the triazole (8) was formed. However, most unexpectedly, varying amounts of the 3,6-diaryl-1,2,4,5-tetrazines (17) were isolated in each case (see Scheme 6). The tetrazines were confirmed by unambiguous synthesis by Stolle's method.[19] The purple-coloured tetrazines could be readily isolated chromatographically, and were detectable even when present in very small quantities. When the solution was diluted substantially (to *ca.* 10^{-4}M), tetrazine formation was suppressed completely, the hydrazides (16) being the sole products. Addition of acid also almost completely suppressed tetrazine formation, whereas in either neutral or basic solution the yields of tetrazines were similar.



SCHEME 6

A possible mechanism for tetrazine formation is outlined in Scheme 7. We regard the key intermediate in this scheme as the carbonium ion (18). (Kinetic data

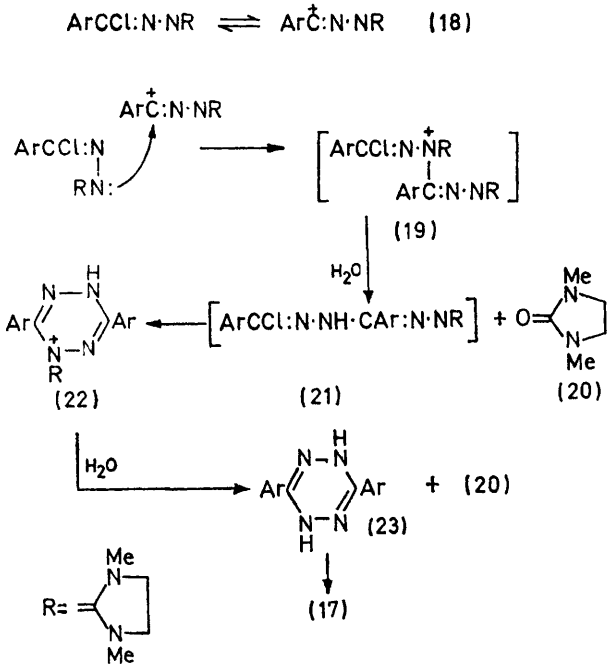
[16] (*a*) F. L. Scott, J. A. Cronin, and J. Dovovan, *Tetrahedron Letters*, 1969, 4615; (*b*) J. Donovan, J. Cronin, F. L. Scott, and A. F. Hegarty, *J.C.S. Perkin II*, 1972, 1050.

[17] W. R. Boon, *J. Chem. Soc.*, 1947, 307.

[18] Ref. 8*b*, ch. 1.

[19] R. Stolle and A. Wiendel, *J. prakt. Chem.*, 1906, **74**, 1.

establish [20] that such species are formed in aqueous dioxan media.) Water or the substrate (14) then compete for this relatively stable carbonium ion. (The hydrazonyl chloride would be expected to be a reasonable nucleophile since the pK_a of its conjugate acid is *ca.* 4.[20]). The product from attack by the hydrazonyl chloride (14) is an acyl hydrazone (19). This deacylates to form the 1,3-dimethylimidazolidinone (20) and the hydrazonyl chloride (21), which in turn undergoes the same kind of



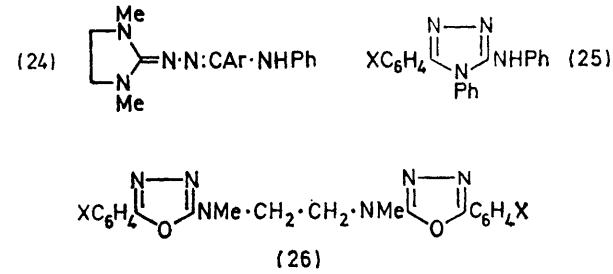
SCHEME 7

attack (except now intramolecularly) yielding first the acyltetrazine (22), then the dihydrotetrazine (23) and thence the fully oxidized tetrazine (17).

Consistent with this picture are the observations that (*a*) only in neutral or basic solution is sufficient unprotonated hydrazonyl chloride (14) available to act as a nucleophile; (*b*) with the least basic substrate (14) no nucleophilic attack (no tetrazine formation) is detected; (*c*) dilution [thereby decreasing the chance of such bimolecular processes as postulated in the formation of (19)] eliminates tetrazine formation completely.

An alternative mode of formation of the substituted tetrazines involving prior formation of the hydrazides (16) was ruled out when we found that in several control experiments the hydrazides (16) are relatively stable under conditions where the tetrazines (17) are formed in appreciable quantities from the hydrazonyl halides (14).

The hydrazides (16), which were isolated as hydrochloride salts, had similar i.r. and u.v. spectral characteristics to the unmethylated analogues (9). When an attempt was made to isolate the free bases (16), the products, even after extensive drying, analysed as hydrates. A representative compound (16; X = *m*-NO_2) was prepared unambiguously by a literature



technique,[21] and was identical with that prepared by the solvolysis of compound (14; X = *m*-NO_2). Both the hydrazonyl chlorides (14) and the tetrachlorides (15) undergo nucleophilic substitution by other reagents. For example, while (14) reacts normally in neat aniline solution to yield the amidrazone (24), compound (15) undergoes both amine exchange and halogen replacement to yield the triazole (25). In contrast with this when compounds (15) are hydrolysed in aqueous dioxan they form the linked bis-oxadiazoles (26).

EXPERIMENTAL

All compounds analysed satisfactorily, and the data are tabulated in Supplementary Publication No. SUP 20430 (9 pp., 1 microfiche).*

N-(Imidazolin-2-ylidene)-(m- and p-substituted)benzohydrazonyl Chlorides (6).—A typical procedure is described. To 1,1,4-trichloro-4-(*p*-chlorophenyl)-2,3-diazabuta-1,3-diene (5; X = *p*-Cl) (1·0 g, 3·7 mmol) in benzene (50 ml) was added ethylenediamine (0·5 ml, 7·4 mmol) in 10 ml of the same solvent. Immediate precipitation occurred. The resulting suspension was stirred for 2 h and then the insoluble material was filtered and dried. The solid was stirred in water (20 ml) for 5 min and again filtered off and dried. Two washings of this material with boiling anhydrous ether gave pure p-*chloro*-N-(*imidazolin*-2-*ylidene*)-*benzohydrazonyl chloride* (6; X = *p*-Cl), m.p. 200—202° (Found: C, 47·0; H, 3·9; Cl, 27·0; N, 22·0. $C_{10}H_{10}Cl_2N_4$ requires C, 46·7; H, 3·9; Cl, 27·5; N, 21·8%). On evaporation of the benzene filtrate, a further quantity of the hydrazonyl chloride was obtained (4%), m.p. 200—202°, after one extraction with boiling ether (anhydrous). The other hydrazonyl chlorides (6) were prepared similarly (see Table 1).

TABLE 1

N-(Imidazolin-2-ylidene)benzohydrazonyl chlorides (6)

Substituent X	M.p. (°C)	Yield (%)
p-Pr^i	188—190	60
p-Me	198—199	65
H	193—194	70
p-Cl	200—202	84
p-Br	198—200	82
p-NO_2	208—210	85
m-NO_2	180—181	74

N-Phenyl-(p-substituted)benzamide N-(Imidazolin-2-ylidene)hydrazones (7).—Typically aniline (1·0 ml, 10·7

* For details of Supplementary Publications, see Notice to Authors No. 7 in the index issue of *J. Chem. Soc.* (*A*), 1970.

[20] A. F. Hegarty, J. O'Driscoll, and F. L. Scott, unpublished data.

[21] S. Hunig and F. Muller, *Annalen*, 1962, **651**, 97.

mmol) was added to the *p*-chlorobenzohydrazonyl chloride (6; X = Cl) (0·77 g, 3 mmol) and the mixture was made into a slurry. Within 1 min an exothermic reaction took place and a solid material formed. The solid was extracted with boiling ether (× 3) and recrystallized (from chloroform–benzene) to yield the *amidrazone hydrochloride* (90%), m.p. 183° (Found: C, 54·6; H, 4·8; Cl, 20·15; N, 20·3. $C_{16}H_{17}Cl_2N_5$ requires C, 54·85; H, 4·85; Cl, 20·3; N, 20·0%). The ethereal extracts, on evaporation, yielded only aniline. Similarly were prepared: N-*phenylbenzamide* N-(*imidazolin-2-ylidene*)*hydrazone* (7; X = H) hydrochloride (85%), m.p. 170—172° (Found: C, 61·0; H, 5·7; Cl, 11·05; N, 22·2. $C_{16}H_{18}ClN_5$ requires C, 60·85; H, 5·7; Cl, 11·25; N, 22·2%); p-*nitro*-N-*phenylbenzamide* N-(*imidazolin-2-ylidene*)*hydrazone* (7; X = *p*-NO_2) hydrochloride (91%), m.p. 200—202° (Found: C, 53·55; H, 4·7; Cl, 9·95; N, 23·2; O, 8·55. $C_{16}H_{17}ClN_6O_2$ requires C, 53·25; H, 4·7; Cl, 9·85; N, 23·3; O, 8·85%). The free *base* (7; X = H), formed on neutralization of the hydrochloride, had m.p. 186—187° (Found: C, 69·0; H, 6·15; N, 24·85. $C_{16}H_{17}N_5$ requires C, 68·8; H, 6·1; N, 25·1%). Similarly were prepared p-*chloro*-N-*phenylbenzamide* N-(*imidazolin-2-ylidene*)*hydrazone* (89%), m.p. 209—210° (Found: C, 60·9; H, 5·0; Cl, 22·5; N, 11·5. $C_{16}H_{16}ClN_5$ requires C, 61·2; H, 5·1; Cl, 22·3; N, 11·3%) and p-*nitro*-N-*phenylbenzamide* N-(*imidazolin-2-ylidene*)*hydrazone* (92%), m.p. 222—224° (Found: C, 59·45; H, 4·85; N, 25·9; O, 9·8. $C_{16}H_{16}N_6O_2$ requires C, 59·25; H, 4·95; N, 25·9; O, 9·9%).

Substituted Benzaldehyde N-(*Imidazolin-2-ylidene*)*hydrazones* (10).—A typical procedure is described. A solution of *p*-chlorobenzaldehyde (13·75 g, 0·098 mol) in ethanol (20 ml) was added to a solution of imidazolin-2-ylhydrazine hydroiodide (prepared by the method of Aspinall and Bianco [11]) in ethanol (100 ml) to which had been added sodium hydroxide (1N, 20 ml). The resulting solution was heated at 80° for 10 min and then cooled in ice and agitated. The precipitate was filtered, dried and recrystallized (from 95% ethanol) to give p-*chlorobenzaldehyde* N-(*imidazolin-2-ylidene*)*hydrazone* (10; X = *p*-Cl) (50%), m.p. 208—210° (Found: C, 53·5; H, 4·8; Cl, 15·95; N, 25·7. $C_{10}H_{11}ClN_4$ requires C, 53·9; H, 4·9; Cl, 15·95; N, 25·2%). When the ethanolic filtrate was concentrated. a further quantity of the hydrazone was obtained (total yield, 86%). The following N-(*imidazolin-2-ylidene*)*hydrazones* were prepared: *benzaldehyde* (85%), m.p. 196—197° (Found: C, 64·0; H, 6·4; N, 29·7. $C_{10}H_{12}N_4$ requires C, 63·8; H, 6·4; N, 29·8%); p-*bromobenzaldehyde* (89%), m.p. 212—213° (Found: C, 44·65; H, 4·2; Br, 29·95; N, 21·0. $C_{10}H_{12}BrN_4$ requires C, 44·9; H, 4·1; Br, 30·0; N, 21·0%); and p-*nitrobenzaldehyde* (90%), m.p. 219—220° (Found: C, 51·2; H, 4·6; N, 30·5; O, 13·6. $C_{10}H_{11}N_5O_2$ requires C, 51·5; H, 4·7; N, 30·0; O, 13·7%).

Bromination of the p-*Chlorobenzaldehyde Hydrazone* (10; X = *p*-Cl).—Bromine (0·912 ml, 17·9 mmol) in glacial acetic acid (20 ml) was added dropwise to a suspension of the hydrazine (10; X = *p*-Cl) (2 g, 8·96 mmol) in glacial acetic acid (80 ml) which was magnetically stirred. A suspension persisted after addition of all the bromine and was stirred for 1 h. The insoluble material was filtered and dried to give the *hydrazone perbromide* (12; X = *p*-Cl) (60%), m.p. 163—164° (from acetic acid) (Found: C, 26·3; H, 2·55; Br, 50·95; Cl, 7·8; N, 12·3. $C_{10}H_{12}Br_3ClN_4$ requires C, 25·9; H, 2·6; Br, 51·75; Cl, 7·65; N, 12·1%). The perbromide (12; X = *p*-Br) of the *p*-bromo-compound (10; X = *p*-Br) was similarly prepared in 65% yield, m.p. 165—167° (from acetic acid) (Found: C, 24·0; H, 2·30; Br, 62·45; N, 11·2. $C_{10}H_{12}Br_4N_4$ requires C, 23·6; H, 2·35; Br, 63·0; N, 11·0%).

The perbromides were titrated for active bromine iodometrically. The perbromide (0·21 mmol) was added to 0·1N-methanolic potassium iodide (1N in acetic acid). The liberated iodine [22] was titrated against aqueous thiosulphate amperometrically. The end-point was detected as zero diffusion current between two platinum electrodes (with a potential difference of *ca.* 10 mV). *N*-Bromoacetamide, *N*-bromosuccinimide, and pyridinium perbromide were titrated first as standards. These standards and the perbromides yielded concordant results, indicative of one active bromine (*N*-Br or Br_2) per molecule: (one active bromine per molecule should give a reading of 1·0) *N*-bromoacetamide 0·994; *N*-bromosuccinimide 1·00; *p*-chloroperbromide (12; X = *p*-Cl) 0·987; and *p*-bromoperbromide (12; X = *p*-Br) 0·990.

The initial hydrazones could be regenerated as follows. The perbromide (12; X = *p*-Cl) (0·20 g, 0·43 mmol) was added to ether (100 ml) and water (100 ml) to which had been previously added sodium carbonate (0·5N, 20 ml). The mixture was shaken thoroughly and then the ethereal layer was run off, dried (Na_2SO_4), and evaporated to yield a material, which was established as the hydrazone (10; X = *p*-Cl) (95%) (mixed m.p., analysis, and i.r.).

Solvolysis of the Benzohydrazonyl Chlorides (6) *in Dioxan–Water* (4 : 1).—(a) *In unbuffered solution.* To the *p*-chlorohydrazonyl chloride (6; X = *p*-Cl) (0·26 g, 1 mmol) was added dioxan–water (4 : 1; 20 ml) and the resulting solution was stirred at room temperature for 10 h. The precipitate was filtered off, recrystallized [from acetone–water (99 : 1)], and dried *in vacuo* at 40° for 4 h over phosphorus pentoxide. Analysis indicated the presence of water of hydration (2 mol) but when it was further dried for 2 days at 100°, it corresponded to 3-(p-*chlorophenyl*)-6,7-5H-*imidazolo*[2,1-c]-s-*triazole hydrochloride monohydrate* [(8; X = *p*-Cl),HCl,H_2O] (50%), m.p. 245—247° (Found: C, 43·2; H, 4·3; Cl, 25·85; N, 20·6; O, 6·05. $C_{10}H_{12}Cl_2N_4O$ requires C, 43·6; H, 4·4; Cl, 25·8; N, 20·4; O, 5·8%). A large quantity of acetone was added to the aqueous mother liquor and this gave a further crop of the triazole hydrochloride hydrate (42%). The other *p*-substituted hydrazonyl chlorides (6) were solvolysed similarly to give the corresponding hydrochloride hydrates [(8),HCl,H_2O] (see Table 2). The i.r. spectra show absorptions at 3570 ± 3

TABLE 2

Hydrochloride hydrates of the 6,7-dihydro-3-aryl-5*H*-imidazolo[2,1-*c*]-*s*-triazoles (8)

Substituent X	M.p. (°C)	Yield (%)
p-Pr^i	230—232	88
p-Me	235—236	90
H	242—244	85
p-Cl	245—247	92
p-Br	230—232	95
p-NO_2	256—258	92

(O–H), 2800—2700 (at least 3 absorptions, NH_2^+ stretch), 1760ms, and 1675 cm^{-1} (C=N).

(b) *In basic solution.* To a solution of the *p*-nitrobenzo-

[22] R. E. Buckles, B. T. Simpson, and W. F. Edgell, *J. Org. Chem.*, 1958, **23**, 483.

hydrazonyl chloride (6; X = *p*-NO_2) (0·27 g, 1 mmol) in dioxan–water (4 : 1; 50 ml) was added sodium carbonate (0·5N, 20 ml). Immediate precipitation occurred and the resulting suspension was cooled in ice and agitated for 3 h. The precipitate was filtered off and dried. The solid was boiled in benzene and again filtered off and dried to give 6,7-*dihydro*-3-(p-*nitrophenyl*)-5H-*imidazolo*[2,1-c]-s-*triazole* (8; X = *p*-NO_2) (65%), m.p. 242—243° (Found: C, 51·6; H, 3·9; N, 30·3; O, 13·95. $C_{10}H_9N_5O$ requires C, 51·9; H, 3·9; N, 30·3; O, 13·8%). When the mother liquor was evaporated at 70° to 20 ml and then cooled to 0° and agitated, it yielded a further quantity of the imidazolotriazole (8; X = *p*-NO_2) (20%) whose analysis, i.r., and m.p. were identical to the previously isolated material. The other substituted imidazolotriazoles (8) were prepared in a similar manner (see Table 3); common to all the imidazolotriazoles (8) are the absorptions at $\nu_{max.}$ 3300 (N–H) and 1645 cm^{-1} (C=N), and $\lambda_{max.}$ 260—270 nm ($\pi \longrightarrow \pi^*$).

TABLE 3

6,7-Dihydro-3-aryl-5*H*-imidazolo[2,1-*c*]-*s*-triazoles

Substituent X	M.p. (°C)	Yield (%)
p-Me	170—172	82
H	184—185	87
p-Cl	214—216	85
p-Br	229—230	88
p-NO_2	242—243	85

The hydrochlorides and hydrochloride hydrates were identical with those obtained in (a) above. Dry hydrogen chloride gas was bubbled into a solution of the imidazolotriazole (8; X = *p*-Cl) (0·22 g, 1 mmol) in methanol (20 ml) for 3 min. Ether (10 ml) was then added and the precipitate was filtered off and dried. The solid was boiled in benzene, filtered, and dried, to give the *hydrochloride* (60%), m.p. 266—270° (Found: C, 46·2; H, 3·9; Cl, 27·9; N, 21·9. $C_{10}H_{10}Cl_2N_4$ requires C, 46·7; H, 3·9; Cl, 27·5; N, 21·8%). The hydrochloride was dissolved in water (3 ml) over 5 min. Acetone was added until precipitation occurred. The precipitate was filtered off and dried to yield the *hydrochloride hydrate* of (8; X = *p*-Cl) (90%), m.p. 245—247° (Found: C, 43·8; H, 4·3; Cl, 25·5; N. 20·4; O, 6·0. $C_{10}H_{12}Cl_2N_4O$ requires C, 43·6; H, 4·4; Cl, 25·8; N, 20·4; O, 5·8%). The p-*bromo-hydrochloride* [(8; X = *p*-Br),HCl] was prepared similarly (65%), m.p, 264—266° (Found: C, 40·1; H, 3·4; Br, 26·2; Cl, 11·6; N, 18·7. $C_{10}H_{10}BrClN_4$ requires C, 39·8; H, 3·3; Br, 26·6; Cl, 11·8; N, 18·5%). The hydrochloride hydrate (92%), prepared as before, was identical (analysis and i.r.) with the material prepared previously from the hydrazonyl chloride (see Table 2).

N′-(*Imidazolin-2-ylidene*)-*benzohydrazides* (9).—To a solution of imidazolin-2-ylhydrazine hydroiodide [11] (1·0 g, 4·4 mmol) in ethanol (50 ml) was added *p*-chlorobenzoyl chloride (0·55 ml, 4·4 mmol) in ethanol (10 ml). The solution was heated at 50° for 15 min and to it was added sodium carbonate (0·5N, 20 ml). The precipitate was filtered and dried to yield p-*chloro*-N′-(*imidazolin*-2-*ylidene*)*benzohydrazine* (9; X = *p*-Cl) (60%), m.p. 246—248° (from 95% ethanol) (Found: C, 50·6; H, 4·7; Cl, 14·7; N, 23·4; O, 6·6. $C_{10}H_{11}ClN_4O$ requires C, 50·3; H, 4·6; Cl, 14·9; N, 23·5; O, 6·7%). When the mother liquor was evaporated to 10 ml, a further quantity of the hydrazide was obtained (total yield 80%). The other *p*-substituted benzohydrazides (9) were prepared similarly (see Table 4). The hydrochlorides were prepared as before

TABLE 4

N-(Imidazolin-2-ylidene)benzohydrazides (9)

Substituent X	M.p. (°C)	Yield (%)
H	227	78
Cl	246—248	70
Br	240—242	80
NO_2	260—261	88

in (b) except the precipitate from addition of ether, was not purified further. p-*Chloro*-N-(*imidazolin*-2-*ylidene*)*benzohydrazide hydrochloride* (70%) had m.p. 285—287° (Found: C, 37·25; H, 3·7; Br, 25·45; Cl, 11·3; N, 17·6; O, 4·9%. $C_{10}H_{12}BrClN_4O$ requires C, 37·55; H, 3·75; Br, 25·0; Cl, 11·1; N, 17·5; O, 5·1%).

m-*Chloro*-N-(1,3-*dimethylimidazolidin*-2-*ylidene*)*benzohydrazonyl Chloride* (14; X = *m*-Cl).—(*a*) The diazabutadiene (5; X = *m*-Cl) (1·0 g, 3·7 mmol) was dissolved in dry benzene (20 ml) at room temperature, and *NN*′-dimethylethylenediamine (0·79 ml, 7·4 mmol) in benzene (5 ml) was added over 5 min. The precipitate was filtered off; this was water soluble indicating it to be *NN*′-dimethylethylenediamine hydrochloride. The benzene filtrate was evaporated to dryness *in vacuo* at 30° to yield a red solid. The solid was stirred in methanol (20 ml) and the remaining material which failed to dissolve was mm′-*dichloro*-NN′-(1,6-*dichloro*-2,5-*dimethyl*-2,5-*diazahexane*-3,6-*diylidene*)*bis*-(*benzohydrazonyl chloride*) (15; X = *m*-Cl) (90 mg, 9%), m.p. 126° (from benzene). The methanolic solution on evaporation to dryness at 30° gave a gum which failed to yield further products on work-up. T.l.c., however, indicated the presence of 3,6-bis-(*m*-chlorophenyl)-1,4-dihydro-1,2,4,5-tetrazine (23; X = *m*-Cl) and *m*-chloro-N′-(1,3-dimethylimidazolidin-2-ylidene)benzohydrazide (16; X = *m*-Cl), which are the decomposition products of the hydrazonyl chloride (14).

(*b*) The same method was used as for (*a*) except that the trichloride (5) was added dropwise to the diamine over 2 min at 10°. The mixture was filtered and evaporated as before at 30°. The required chloride (14; X = *m*-Cl) was then leached out of the resulting solid with pentane, yielding 952 mg (92%), m.p. 80°. This chloride appeared to be free from contamination by the tetrachloride since (*a*) the m.p. was sharp and (*b*) no residue was obtained on dissolution in methanol.

TABLE 5

The tetrachlorides (15)

Substituent X	M.p. (°C)	Yield (%)	*M* [a]
p-NO_2	264	19·4 [b,c]	
m-NO_2	200	18·4 [b,c]	
m-Cl	126	9·0 [b]	548 (555)
p-Cl	205	8·1 [b]	570 (555)
p-Br	215	8·4 [b]	619 (644)

[a] Molecular weights were determined in benzene solution with a Perkin-Elmer model 115 apparatus; required values in parentheses. [b] Procedure A. [c] The dimeric material precipitated from solution with the amine hydrochloride, which was separated by dissolution in water. The tetrachloride was insoluble for recrystallization from a wide range of solvents.

The same procedures (*a*) and/or (*b*) were used to obtain the other substituted benzohydrazonyl chlorides (14) and the corresponding tetrachlorides (15) (see Tables 5 and 6).

In several cases, method (*a*) also gave considerable yields of the chlorides (14).

The yield of the tetrachloride (15) could be increased as follows. The trichloride (5; X = *m*-Cl) (3·0 g, 11 mmol) was dissolved in dry benzene (10 ml), and triethylamine (5·32 ml, 39 mmol) and *NN'*-dimethylethylenediamine (3·95 ml, 39 mmol) in benzene (10 ml) were added over 30 min. The resulting mixture was filtered and the filtrate reduced to *ca.* 5 ml *in vacuo*. Methanol (20 ml) was added to precipitate (15; X = *m*-Cl) (1·24 g, 36%).

TABLE 6

N-(1,3-Dimethylimidazolidin-2-ylidene)benzhydrazonyl chlorides (14)

Substituent X	M.p. (°C)	Yield (%)
p-NO_2	175	64 [a,b]
m-NO_2	145	65 [a]
m-Cl	80	92 [c]
p-Cl	95	94 [c]
p-Br	90	86 [c]

[a] Procedure A. [b] From dry ether. [c] Procedure B.

TABLE 7

The hydrazide (16) hydrochlorides

Substituent X	Yield (%)	M.p. (°C)
p-NO_2	85 [a]	235
m-NO_2	78	230
m-Cl	75	205
p-Cl	62	217
p-Br	54	195

[a] A further quantity (3·6%) of the free hydrazide was obtained on chromatography (it was eluted in the benzene fraction).

Hydrolysis of Hydrazonyl Chlorides (14).—(a) *In unbuffered solution.* Typically, the hydrazonyl chloride (14; X = *m*-Cl) (0·568 g, 2 mmol) was dissolved in dioxan (8 ml) and water was added (2 ml). The solution was evaporated. Addition of ethanol and ether precipitated the hydrochloride of m-*chloro*-N'-(1,3-*dimethylimidazolidin*-2-*ylidene*)-*benzohydrazide* (16; X = *m*-Cl) together with a quantity of gum. The gum was chromatographed [alumina (Grade II) column; methanol and then benzene]. The methanol extracts yielded 3,6-*bis*-(m-*chlorophenyl*)-1,2,4,5-*tetrazine* (17; X = *m*-Cl). The other hydrazonyl chlorides (14) were hydrolysed similarly (see Tables 7 and 8).

TABLE 8

The tetrazines (17)

Substituent X	Yield (%) [a]	M.p. (°C)
p-NO_2	0	
m-NO_2	5·1	215
m-Cl	11	215
p-Cl	26	315
p-Br	28	337

[a] On hydrolysis of (14).

(b) *In acidic solution.* The hydrazonyl chloride (0·56 g, 2 mmol) was dissolved in dioxan (8 ml) and hydrochloric acid (2 ml) of such strength that the final pH of the solution of 1·0 was added.

Isolation of the products as described before yielded the hydrochloride of the hydrazide (16; X = *m*-Cl) (0·45 g, 71%) together with 3,6-bis-(*m*-chlorophenyl)tetrazine (17; X = *m*-Cl) (0·014 g, 9%).

(c) *In basic solution.* The hydrazonyl chloride (0·56 g, 2 mmol) was dissolved in 8 ml dioxan and sodium carbonate solution (2 ml) of such concentration that the final pH was 9 was added. The solution was acidified to pH 3 after 5 min and the products isolated as before, yielding the hydrazide hydrochloride (0·38 g, 59%) and the tetrazine (17; X = *m*-Cl) (0·035 g, 23%).

The Free Hydrazides (16).—The hydrazone hydrochloride [(16; X = *m*-NO_2),HCl] (0·50 g) was dissolved in ethanol (10 ml) and 10% aqueous sodium carbonate solution was added to bring the indicated pH of the solution to 9 (the solution changes from colourless to orange). Addition of water precipitated a compound, m.p. 205°, which analysed even after extensive drying, as the monohydrate of the hydrazide (Found: C, 48·6; H, 6·1; N, 24·1. $C_{12}H_{17}N_5O_4$ requires C, 48·7; H, 5·75; N, 23·8%). The hydrate can be reconverted into the hydrochloride by dissolution in ethanol and addition of hydrochloric acid; the *picrate* of the hydrazone (16; X = *m*-NO_2) had m.p. 142° (from ethanol) (Found: C, 42·9; H, 3·9; N, 22·0. $C_{18}H_{18}N_8O_{10}$ requires C, 42·5; H, 3·75; N, 22·0%).

N'-(1,3-*Dimethylimidazolidin*-2-*ylidene*)-m-*nitrobenzohydrazide* (16; X = *m*-NO_2).—To *NN'*-dimethylethylenediamine (4·4 g, 0·05 mol) in ethanol (75 ml) and water (8 ml) was added carbon disulphide (4·0 g) over 0·5 h. Concentrated hydrochloric acid (0·75 ml) was then added and the solution was heated under reflux for 6 h. On cooling 1,3-dimethylimidazolidine-2-thione precipitated (4·1 g, 71%), m.p. 110—112° (lit.,[21] 110—112°). The thione (4·0 g) was added to *m*-nitrobenzohydrazide (5·7 g) in ethanol in the presence of dimethyl sulphate (3·9 g) to give the hydrazide (16; X = *m*-NO_2) (6·7 g, 73%), m.p. 205—206° (from 95% ethanol). This compound was identical (spectra and mixed m.p.) with that obtained before and also analysed as a monohydrate.

Attempted Conversion of Hydrazides (16) *into Tetrazines* (17).—(a) *In acid.* The hydrazide hydrochloride (16; X = *m*-NO_2) (0·40 g) was dissolved in dioxan–water (4 : 1 v/v). Concentrated hydrochloric acid (0·1 ml) was added and the solution was stirred at room temperature overnight. On evaporation, the starting hydrochloride was recovered unchanged (0·35 g). Moreover the colour of the solution did not change, indicating the absence of the tetrazine.

(b) *In unbuffered solution.* The hydrazide was treated as in (a) without the addition of acid; under these conditions also only the unchanged starting material was isolated.

(c) *In basic solution.* The hydrazide (16; X = *p*-Cl) (0·40 g) was dissolved in dioxan–water (4 : 1) (10 ml) to which sodium carbonate had been added to bring the indicated pH to 10. The solution was left overnight, and the solvent was evaporated. The remaining solid was worked-up to give both starting material (305 mg) and 3,6-bis-(*p*-chlorophenyl)tetrazine (17; X = *p*-Cl) (5 mg).

p-*Bromo*-N-*phenylbenzamide* N-(1,3-*Dimethylimidazolidin*-2-*ylidene*)*hydrazone* (24; Ar = *p*-C_6H_4).—The hydrazonyl chloride (14; X = *p*-Br) (1·0 g) was mixed at room temperature with aniline (0·56 ml) and then heated at 50° for 30 min. The solid obtained on cooling was recrystallized from ethanol to give the *amidrazone hydrochloride* (69%), m.p. 232° (Found: C, 50·7; H, 5·1; N, 16. $C_{18}H_2BrClN_5$ requires C, 51·2; H, 4·75; N, 16·7%). The *m*-nitro-derivative was similarly prepared (85%), m.p. 172—174° (from ethanol) (Found: C, 55·2; H, 5·4; N, 21·8. $C_{18}H_{21}ClN_6O_2$ requires C, 55·6; H, 5·3; N, 21·6%).

3,6-Bis(substituted phenyl)-1,2,4,5-tetrazines. p-*Chloro-compound* (17; X = *p*-Cl). *p*-Chlorobenzoyl chloride (4·8 g) was added dropwise to hydrazine sulphate (1·6 g) in ethanol. The resulting bis-(*p*-chlorobenzoyl)hydrazine (3·6 g, 93%) had m.p. 291° on recrystallization from ethanol (Found: C, 55·2; N, 3·6; N, 9·3. $C_{14}H_{10}Cl_2N_2O_2$ requires C, 54·6; H, 3·25; N, 9·1%). The bis-(*p*-chlorobenzoyl)-hydrazine (2·25 g) was thoroughly mixed with finely ground phosphorus pentachloride (3·0 g) and heated at 110° for 1 h, the apparatus being protected from moisture throughout. Extraction with ether gave 1,4-*dichloro*-1,4-*bis*-(p-*chlorophenyl*)-2,3-*diazabuta*-1,3-*diene* (0·25 g, 10%), m.p. 125° (Found: C, 48·8; H, 2·3; N, 8·2. $C_{14}H_8Cl_4N_2$ requires C, 48·6; H, 2·3; N, 8·1%). The other major product, remaining on ether extraction, was 2,5-*bis*-(p-*chlorophenyl*)-1,3,4-*oxadiazole*, m.p. 248° (Found: C, 57·9; H, 2·8; N, 9·6. $C_{14}H_8Cl_2N_2O$ requires: C, 57·85; H, 2·9; N, 9·8%). The 2,3-diazabuta-1,3-diene (0·20 g, 0·73 mmol) was dissolved in ethanol and hydrazine hydrate (0·073 g, 1·46 mmol) added. The mixture was worked-up as described [19] to give 3,6-bis-(*p*-chlorophenyl)-1,4-dihydro-tetrazine (23; Ar = *p*-ClC_6H_4) (0·12 g, 61%), m.p. 215° (lit.,[19] 215°). The dihydrotetrazine (0·05 g) was oxidized with silver nitrate [19] to 3,6-bis-(*p*-chlorophenyl)tetrazine. This material was identical with that obtained before in solvolysis.

An attempt was also made to prepare 3,6-bis-(*m*-nitrophenyl)tetrazine (17; X = *m*-NO_2) by this route. However, the reaction of *NN'*-bis-(*m*-nitrobenzoyl)hydrazine with phosphorus pentachloride failed to give appreciable quantities of the chloride. 1,4-Dichloro-1,4-bis-(*m*-nitrophenyl)-2,3-diazabuta-1,3-diene was therefore prepared by direct chlorination of 1,4-bis-(*m*-nitrophenyl)-2,3-diazabuta-1,3-diene in anhydrous acetic acid.[12] 3,6-*Bis*-(m-*nitrophenyl*)-1,4-*dihydro*-1,2,4,5-*tetrazine* thus prepared (61% yield) had m.p. 178° (Found: C, 51·5; H, 3·1; N, 24·9. $C_{14}H_{10}N_6O_4$ requires C, 51·5; H, 3·1; N, 25·6%). Oxidation with silver nitrate gave the tetrazine, m.p. 215° (see Table 8).

Reactions of the Tetrachlorides (15).—(a) *With aniline.* The tetrachloride (15; X = *m*-Cl) (0·20 g) was dissolved in aniline (1·0 ml) and heated at 60° for 10 min. On cooling this solidified to a white mass. This was washed with water to remove aniline hydrochloride and recrystallized from benzene to yield 3-*anilino*-5-(m-*chlorophenyl*)-4-*phenyl*-4H-1,2,4-*triazole* (0·19 g, 75%), m.p. 173° (Found: C, 69·7; H, 4·5; N, 16·6. $C_{20}H_{15}ClN_4$ requires C, 69·3; H, 4·1; N, 16·1%). The corresponding *p*-bromo-substituted tetrachloride (15; X = *p*-Br) was similarly treated to yield 5-anilino-3-(*p*-bromophenyl)-4-phenyl-4*H*-1,2,4-triazole (71%) (25; X = *p*-Br) which was shown by m.p. and mixed m.p. to be identical with an authentic sample.[23]

(b) *With water.* The tetrachloride (15; X = *m*-Cl) (0·20 g) was dissolved in dioxan–water (80 ml, 4 : 1) and heated at 70° for 6 h. On cooling, water was added and the solution was extracted with benzene. Evaporation yielded after several crystallizations from benzene, NN'-*bis*-[5-(m-*chlorophenyl*)-1,3,4-*oxadiazol*-2-*yl*]-NN'-*dimethylethylene-diamine* (26; X = *m*-Cl) (0·08 g, 52%), m.p. 190° (Found: C, 53·6; H, 4·4; N, 18·6. $C_{20}H_{18}Cl_2N_6O_2$ requires C, 54·1; H, 4·1; N, 18·9%). The corresponding *p*-bromo-compound (26; X = *p*-Br) was obtained similarly (44%), m.p. 205° (Found: C, 45·1; H, 3·6; N, 15·6. $C_{20}H_{18}Br_2N_6O_2$ requires C, 45·0; H, 3·4; N, 15·7%).

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[23] J. K. O'Halloran and F. L. Scott, *Chem. Comm.*, 1971, 426