1,2,3-Benzotriazines [1]

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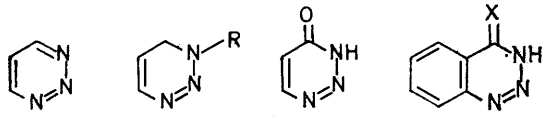
Although many 3,4-dihydro-4-oxo and -imido-derivatives of 1,2,3-benzotriazine are known, 1,2,3-benzotriazine itself was previously unknown, only very few of its aromatic derivatives had been reported, and no general methods for their synthesis had been described.

1,2,3-Benzotriazine, some simple 4-alkyl and aryl derivatives, and a pyrido[1,2,3]triazine are now described, together with four general syntheses of the ring system. These involve (i) oxidation of the hydrazones of *o*-azidophenyl ketones and thermal cyclisation of the resulting *o*-azidophenyldiazoalkanes, (ii) oxidative cyclisation of the hydrazones of *o*-aminophenyl ketones, (iii) oxidation of 1- and 2-aminoindazoles, and (iv) oxidation of *N*-aminoquinazolin-2-ones. Methods (iii) and (iv) involve heterocyclic ring expansions, the latter with loss of carbon monoxide.

1,2,3-Benzotriazines are susceptible to nucleophilic addition to the 3,4-bond, and the high reactivity of benzotriazine in this reaction explains the failure of earlier attempts to synthesise it.

Preparation of the azido-hydrazones required for method (i) from azido-ketones in the standard way led to an unusual but useful synthesis of indazoles.

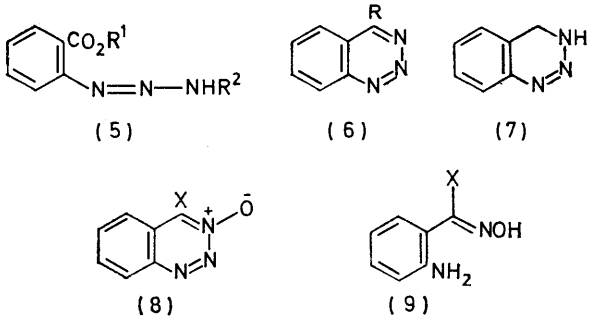
MONOCYCLIC, aromatic 1,2,3-triazines (1) are rare in comparison with their 1,2,4- and 1,3,5-isomers.[2] Until recently triphenyl-1,2,3-triazine, formed by rearrangement of triphenylcyclopropenyl azide,[3] was the only example reported, but several others [4] have now been prepared by this method. No monocyclic dihydro-1,2,3-triazine (2) or 1,2,3-triazinone (3) derivatives have been reported.



(1) (2) (3) (4)

X = O, S, or NR

Benzo-analogues of system (3) are well known as benzotriazine-ones, -thiones, or -imines (4).[2] Synthetic entry into these systems is achieved by diazotisation of anthranilamides, or by cyclisation of *o*-triazenobenzoate esters (5).[5] Benzotriazinone readily acts as a masked diazonium compound, and gives *N*-substituted derivatives although it is tautomeric with 4-hydroxybenzotriazine (6; R = OH). Unambiguous aromatic 1,2,3-benzotriazines (6) are much less well documented. *S*-Alkylation and acylation of the thione (4; X = S) gave such derivatives. The only other examples reported are the azide (6; R = N_3) [6] obtained from the hydrazine (6; R = $NH{\cdot}NH_2$) and the 4-*p*-methoxyphenyl derivative (6; R = *p*-$MeO{\cdot}C_6H_4$).[7] The latter was tentatively identified as the product of diazotisation of 2-amino-α-(*p*-methoxyphenyl)benzylideneamine.



(5) (6) (7) (8) (9)

[1] Preliminary communications, S. Bradbury, M. Keating, C. W. Rees, and R. C. Storr, *Chem. Comm.*, 1971, 827; D. J. C. Adams, S. Bradbury, D. C. Horwell, M. Keating, C. W. Rees, and R. C. Storr, *ibid.*, p. 828.

[2] J. P. Horwitz in 'Heterocyclic Compounds,' vol. 7, ed. R. C. Elderfield, Wiley, New York, 1961.

[3] E. A. Chandross and G. Smolinsky, *Tetrahedron Letters*, 1960, No. 13, 19.

[4] G. L. Closs and A. M. Harrison, *J. Org. Chem.*, 1972, **37**, 1051; H. Nuenhoeffer, H.-D. Vötter, and H. Ohl, *Chem. Ber.*, 1972, **105**, 3695.

[5] R. J. LeBlanc and K. Vaughan, *Canad. J. Chem.*, 1972, **50**, 2544.

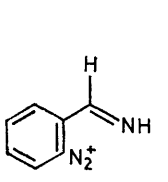
[6] B. Stanovnik and M. Tišler, *J. Heterocyclic Chem.*, 1971, **8**, 785.

[7] A. J. Nunn and K. Schofield, *J. Chem. Soc.*, 1953, 716.

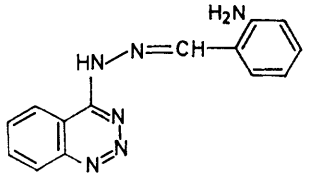
Dihydrobenzotriazines (7) and benzotriazine $N(3)$-oxides (8) have been reported from the diazotisation of *o*-aminobenzylamines and *o*-amino-oximes (9).[2]

Diazotisation of *o*-aminobenzylideneamines has not been generally explored as a route to benzotriazines presumably because of the instability of the imines. Indeed the only example, mentioned above, involves a particularly well stabilised imine. Two other routes have received attention, however. Attempts to reduce 1,2,3-benzotriazine $N(3)$-oxides (8; X = Me or NH_2) with zinc and acetic acid,[8] ammonium sulphide,[8] tin(II) chloride,[9,10] or hydrogen over Raney nickel [10] in methanol have all been reported to give indazoles. In our hands, the *N*-oxides (8; X = Me or Ph) were recovered in good yield from attempted deoxygenation with diazomethane and diphenyldiazomethane [11] and also *via* *O*-alkylation with dimethyl sulphate.[12] The *N*-oxides were consumed in thermal and photochemical reactions with triethyl phosphite and in thermal reactions with phosphorus trichloride and hexamethylphosphorous triamide. Only intractable gums in which no trace of benzotriazines (see later) was detected were obtained however. Observation of this marked resistance to deoxygenation has been corroborated by Lund,[13] who has been unable to deoxygenate 1,2,3-benzotriazine $N(3)$-oxides either chemically or electrochemically.

Unsubstituted heterocycles have frequently been obtained by oxidation of their hydrazino-derivatives, and two attempts to convert 4-hydrazino-1,2,3-benzotriazine into the parent system (6; R = H) have been reported. Stanovnik and Tišler failed to identify any products from oxidation with oxygen and ethanolic sodium hydroxide in the presence of a platinum catalyst.[6] Parnell oxidised the methanesulphonate salt of the hydrazinobenzotriazine with boiling aqueous copper(II) sulphate to obtain low yields of benzaldehyde and salicylonitrile.[10] In the presence of copper(I) chloride, oxidation gave *o*-chlorobenzaldehyde and *o*-chlorobenzonitrile. These products can be rationalised in terms of the ready ring opening of the conjugate acid of unsubstituted benzotriazine to give the imino-diazonium species (10).



(10)

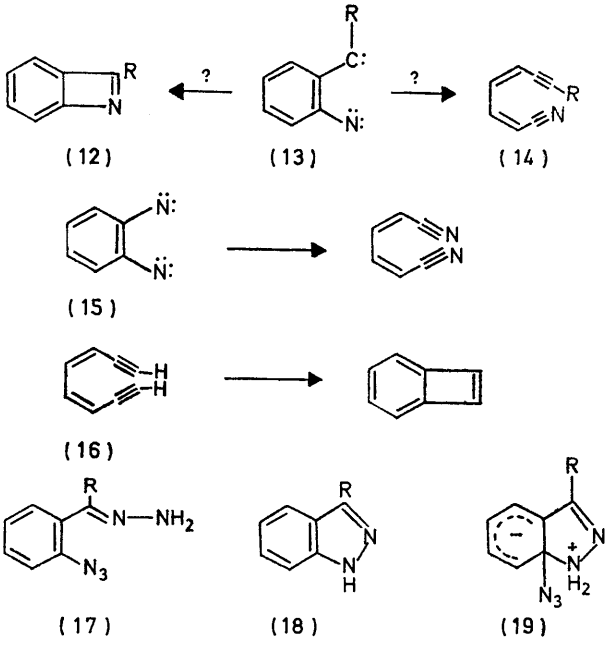


(11)

In our hands, oxidation with manganese dioxide or silver oxide in a variety of solvents gave benzonitrile and the *o*-aminobenzylidene derivative of 4-hydrazinobenzotriazine (11) as the only recognisable products. Formation of the latter is best rationalised by nucleophilic addition of unchanged hydrazine to the 3,4-bond of 1,2,3-benzotriazine formed in the oxidation, followed by ring opening and loss of nitrogen (*cf.* Scheme 3).

Subsequent synthesis of 1,2,3-benzotriazine (see below) and the demonstration of its high reactivity towards nucleophiles strongly supports this proposal. Significantly, in aqueous acidic solution 1,2,3-benzotriazine gave only *o*-aminobenzaldehyde, thus casting doubt on the formation of the triazine in Parnell's oxidations.

Several new and general routes to simple 1,2,3-benzotriazines have arisen from our attempts to obtain benzazetes (12). Our first approach involved the attempted



(12) (13) (14)

(15)

(16)

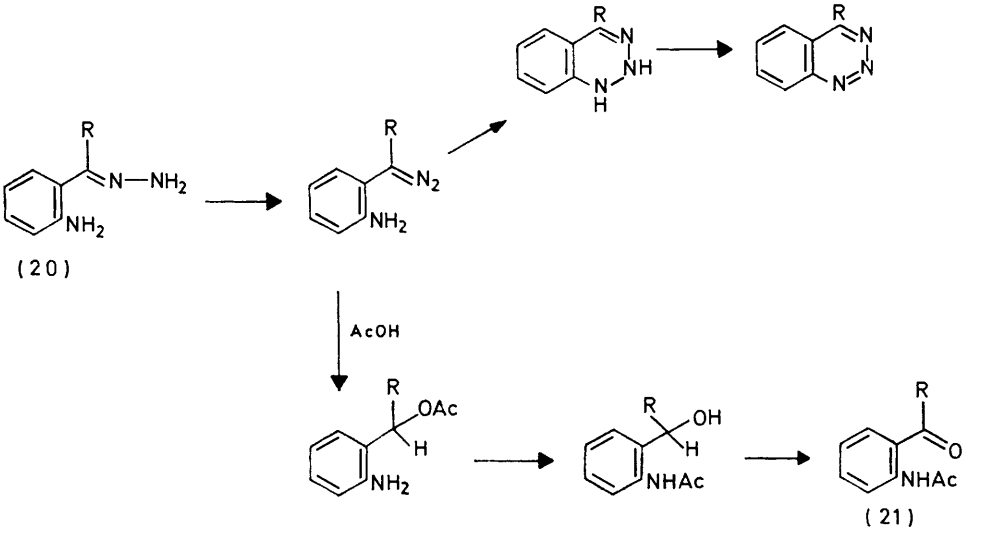
(17) (18) (19)

generation of *o*-carbeno-nitrenes (13). These could in principle collapse directly to benzazetes or ring open, by analogy with the corresponding dinitrenes (15),[14] to give cyano-acetylenes (14). The observation [15] that the diacetylene (16) spontaneously ring closed to give benzocyclobutene also raised the possibility that the cyanoacetylenes could be induced to ring close to benzazetes. The fundamental difference between species with the *o*-dinitrene stoicheiometry which collapse to stable dicyanobutadienes and species with the *o*-dicarbene stoicheiometry which give anti-aromatic benzocyclobutenes made the intermediate carbeno-nitrene species particularly intriguing.

The obvious precursors to *o*-carbeno-nitrenes (13) are the corresponding *o*-azido-diazo-compounds. The azidohydrazones (17; R = H or Me) were obtained from *o*-aminobenzaldehyde and *o*-aminoacetophenone *via* the

[8] J. Meisenheimer, O. Senn, and P. Zimmermann, *Ber.*, 1927, **60**, 1736.
[9] F. C. Cooper, *J. Chem. Soc.*, 1958, 4212.
[10] E. W. Parnell, *J. Chem. Soc.*, 1961, 4930.
[11] E. E. Schweizer, G. J. O'Neill, and J. N. Wemple, *J. Org. Chem.*, 1964, **29**, 1744.
[12] E. Ochiai, 'Aromatic Amine Oxides,' Elsevier, New York, 1967, p. 178.
[13] H. Lund, University of Aarhus, Denmark, personal communication.
[14] J. H. Hall and E. Patterson, *J. Amer. Chem. Soc.*, 1967, **89**, 5856; K. Nakagawa and H. Onoue, *Chem. Comm.*, 1965, 396; *Tetrahedron Letters*, 1965, 1433.
[15] G. H. Mitchell and F. Sondheimer, *J. Amer. Chem. Soc.*, 1969, **91**, 7520.

azido-carbonyl compounds when the latter were treated with hydrazine at room temperature with iodine catalysis. The more vigorous conditions required in the absence of iodine, *i.e.* refluxing in ethanol containing acetic acid, gave the indazoles (18) in high yield. Indeed such conditions provide a mild, general route to 3-alkyl- and aryl-indazoles which poses interesting mechanistic problems. The reaction does not involve intramolecular nucleophilic aromatic substitution *via* the intermediate (19) since even



2-azido-3-benzoylnaphthalene readily formed 3-phenylbenz[*f*]indazole, and with monosubstituted hydrazines (*e.g.* $MeNH{\cdot}NH_2$) 1-substituted indazoles were not formed. Cyclisation to 3-phenylindazole was unavoidable under the conditions necessary for the reaction of the less reactive carbonyl group of *o*-azidobenzophenone with hydrazine.

Oxidation of the azido-hydrazone (17; R = Me) with mercury(II) oxide gave a diazo-azide which was sufficiently stable to be isolated, with careful handling. Heating in refluxing benzene gave 4-methyl-1,2,3-benzotriazine (6; R = Me) in high yield; decomposition in refluxing bis-(2-methoxyethyl) ether was more extensive and gave mainly intractable material together with a small amount of cyano-acetylene (14; R = Me). The diazo-azide from (17; R = H) was too unstable to be isolated and decomposed to give an intractable mixture of products as rapidly as it was formed.

In view of the difficulty in obtaining the azido-diazo-compounds, oxidation of the much more readily available amino-hydrazones (20) was considered. Oxidative removal of hydrogen and loss of nitrogen would lead to the benzazete stoicheiometry. However on oxidation with lead tetra-acetate, the amino-hydrazones (20; R = Me, Ph, or *p*-$MeO{\cdot}C_6H_4$) and 2-amino-3-benzoylnaphthalene hydrazone again gave the 4-substituted benzotriazines together with the corresponding *o*-acetamidoketone (21). The former presumably arose from cyclisation of the amino-diazo-compound followed by oxidation of the dihydrotriazine. The amide (21) was not derived from the benzotriazine but its formation can be rationalised, as shown, by attack of acetic acid on the diazo-amine to give amino-acetate followed by *O*-to-*N*-acetyl transfer. That the amide can be the major product in these oxidations (Table 1) detracts from this as a general route to benzotriazines. The 4-*p*-methoxyphenylbenzotriazine obtained from this reaction was identical with that reported by Nunn and Schofield,[7] confirming their structural assignment. Significantly no benzotriazine was obtained from *o*-aminobenzaldehyde hydrazone.

TABLE 1

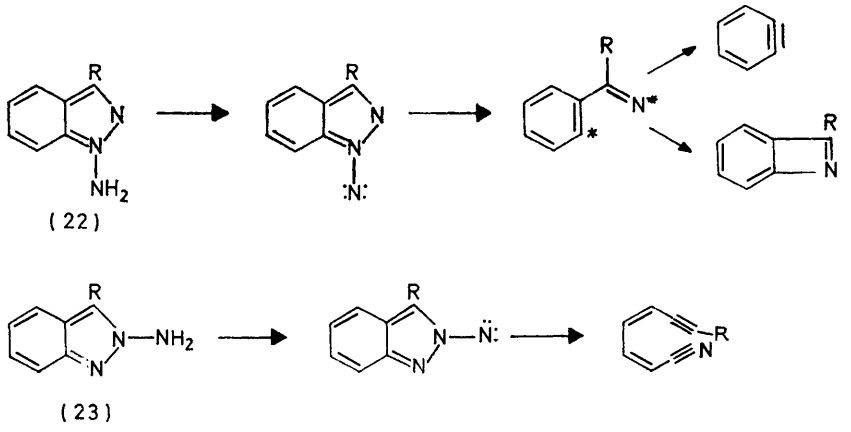
Oxidation of amino-hydrazones with lead tetra-acetate

	Products (%)	
Hydrazone of	Benzotriazine	Acetamido-ketone
2-Aminoacetophenone	47	10
2-Aminobenzophenone	50	29
2-Amino-4′-methoxybenzophenone	26	73
2-Amino-5-chlorobenzophenone	50	
2-Amino-3-benzoylnaphthalene	5	
2-Aminobenzaldehyde	0	

Oxidation of 1- and 2-aminoindazoles (22) and (23) provided the third and most efficient general route to benzotriazines. Again the initial hope was that, by analogy with the corresponding benzotriazole derivatives,[16] the nitrenes produced by oxidation would undergo fragmentation as shown in Scheme 1, the 1-nitrenes giving benzazetes or benzyne directly and the 2-nitrenes giving cyano-acetylene. The *N*-aminoindazoles were obtained by amination with hydroxylamine-*O*-sulphonic acid in alkaline solution, although with 3-methoxyindazole the action of chloramine in ether on the sodium salt was preferable. Distinction between the 1- and 2-amino-isomers was made on the basis of u.v. spectral comparison with the unsubstituted indazole and with the known 1- and 2-alkylindazoles. The assignment was confirmed for the indazoles (22 and 23; R = H or Me) by independent synthesis of the 2-amino-isomers by

[16] C. D. Campbell and C. W. Rees, *J. Chem. Soc.* (*C*), 1969, 742.

thermolysis of the *o*-azido-hydrazones (17; R = H or Me) (Scheme 2). In general the 1-aminoindazoles were mised by careful drying of solvent, addition of calcium oxide to the oxidation mixture, and slow addition of the



SCHEME 1

less polar than the 2-amino-isomers in chromatographic systems. The proportions of the isomers varied and the yields are summarised in Table 2.

TABLE 2

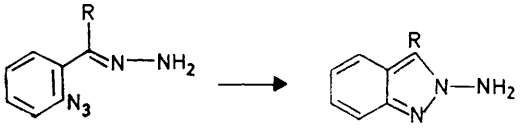
Amination of indazoles with hydroxylamine-*O*-sulphonic acid

Indazole	Products (%) 1-Amino	2-Amino
Indazole	50	33
3-Methylindazole	45	30
3-Phenylindazole	60	8
5-Nitroindazole	57	9
6-Nitroindazole	30	28
3-Methoxyindazole *	88	
3-Phenylbenz[*f*]indazole	84	
5-Methylpyrazolo[4,3-*b*]pyridine	42	40
Pyrazolo[3,4-*c*]pyridine	41	

* Amination with chloramine.

Oxidation of both 1- and 2-aminoindazoles with lead tetra-acetate in methylene chloride gave the benzotriazines in high yields (Table 3), except in the case of the 3-unsubstituted indazoles. With these the problem was shown to be the high reactivity of 4-unsubstituted 1,2,3-benzotriazines towards nucleophiles such as water, acetic acid formed in the oxidation, and unchanged *N*-amine (see Scheme 3). When these effects were minimised by careful drying of solvent, addition of calcium oxide to the oxidation mixture, and slow addition of the *N*-aminoindazole to lead tetra-acetate, the parent benzotriazine was isolable.

In the amination of 3-methoxyindazole with chloramine a trace of 4-methoxybenzotriazine was formed, suggesting that chloramine might be oxidising [17] the *N*-amino-derivative produced. This was found to be so;



SCHEME 2

when 1-amino-3-methoxyindazole was kept with ethereal chloramine at room temperature for 1 week 4-methoxybenzotriazine was formed in 80% yield.

Formation of the pyridotriazine (27) illustrates the versatility of this route to benzotriazine derivatives. Pyridotriazines were required as possible gas-phase precursors to didehydropyridines (see following paper) and the inaccessibility of the required *o*-amino-ketone derivatives precluded the use of the first two routes described above.

TABLE 3

Oxidation of *N*-aminoindazoles with lead tetra-acetate

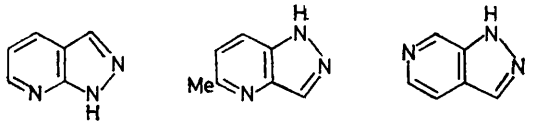
Indazole	Product	Yield (%)
1-Aminoindazole	1,2,3-Benzotriazine	19
2-Aminoindazole	1,2,3-Benzotriazine	16
1-Amino-3-methylindazole	4-Methyl-1,2,3-benzotriazine	85
2-Amino-3-methylindazole	4-Methyl-1,2-3-benzotriazine	80
1-Amino-3-phenylindazole	4-Phenyl-1,2,3-benzotriazine	97
2-Amino-3-phenylindazole	4-Phenyl-1,2,3-benzotriazine	90
1-Amino-3-*p*-methoxyphenylindazole	4-*p*-Methoxyphenyl-1,2,3-benzotriazine	50
1-Amino-3-methoxyindazole	4-Methoxy-1,2,3-benzotriazine	83
1-Amino-3-phenylbenz[*f*]indazole	4-Phenylnaphtho[2,3-*d*][1,2,3]triazine	57
1-Amino-5-methylpyrazolo[4,3-*b*]pyridine	6-Methylpyrido[3,2-*d*][1,2,3]triazine	65
2-Amino-5-methylpyrazolo[4,3-*b*]pyridine	6-Methylpyrido[3,2-*d*][1,2,3]triazine	62

Few simple pyrazolopyridines have been reported. Pyrazolo[3,4-*b*]pyridine (24) was prepared by reaction of 2-chloropyridine-3-carbonitrile with hydrazine, followed by deamination.[18] The pyrazolopyridines (25) [19] and (26) were prepared from the readily available 3-amino-

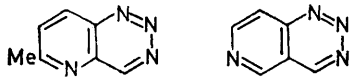
[17] C. W. Rees and A. A. Sale, *J.C.S. Perkin I*, 1973, 545.
[18] T. L. P. Hatt and J. D. R. Vass, *Chem. Comm.*, 1966, 293.
[19] H. E. Foster and J. Hurst, *J.C.S. Perkin I*, 1973, 2901.

2,6-dimethyl- and 3-amino-4-methyl-pyridine, respectively, by acetylation, *N*-nitrosation, and thermolysis of the *N*-nitroso-amide in benzene. Attempted amination of the pyrazolopyridine (24) with hydroxylamine-*O*-sulphonic acid in alkaline solution gave only water-soluble products, possibly resulting from amination at the pyridine rather than the pyrazole nitrogen atom. The pyrazole (25) gave both 1- and 2-aminopyrazolopyridines whereas compound (26) gave only one isomer, assumed to be the 1-amino-derivative. On oxidation both *N*-amino-compounds derived from (25) gave the pyridotriazine (27) in high yield. However the *N*-amine derived from (26) gave only intractable oils and none of the expected pyridotriazine (28). The reason for this is discussed later.

This amination–oxidation route to triazines has recently been extended successfully to the synthesis of the pyridazinotriazine system; lead tetra-acetate oxidation of 1-amino-3,4,7-triphenylpyrazolo[3,4-*d*]pyridazine gave 4,5,8-triphenylpyridazino[4,5-*d*]triazine (81%).[20]

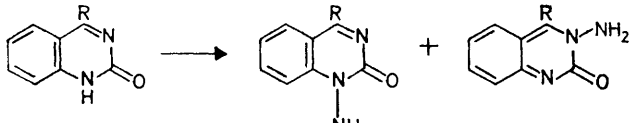


(24) (25) (26)



(27) (28)

The fourth route to benzotriazines, oxidation of *N*-aminoquinazolinones, was developed as a direct extension of the formation of pyridazines and 1,2,4-benzotriazines by oxidation of *N*-aminopyridones [21] and *N*-aminoquinoxalinones,[22] respectively. 4-Phenylquinazolin-2-one (29; R = Ph) gave two *N*-amino-derivatives [(30; R = Ph) and (31; R = Ph)] on amination with hydroxylamine-*O*-sulphonic acid. These isomers were separated

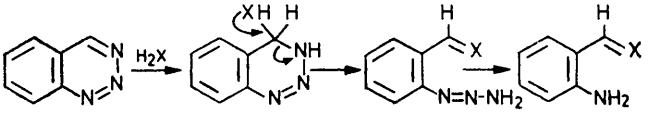


(29) (30) (31)

but their particular structures were not assigned; on oxidation both gave low yields of 4-phenyl-1,2,3-benzotriazine. 4-Methylquinazolin-2-one (29; R = Me) on amination gave only the 1-amino-derivative (30; R = Me) (85%), which on oxidation gave 4-methylbenzotriazine (23%). These reactions can be rationalised in terms of ring expansion of the *N*-nitrene to give a benzotriazepinone intermediate, followed by electrocyclic ring closure and extrusion of carbon monoxide (*cf.* ref. 21).

The benzotriazines (6) are colourless to pale yellow crystalline solids. Their structures are supported by analytical and spectral data and by their chemical properties. In particular their mass spectra show intense parent peaks and intense fragment peaks corresponding to losses of N_2 and RCN.

The 4-unsubstituted benzotriazines, and especially their conjugate acids, are susceptible to attack by nucleophiles in solution. Thus in dilute aqueous acid 1,2,3-benzotriazine gave *o*-aminobenzaldehyde and with phenylhydrazine the corresponding phenylhydrazone was formed, presumably as shown (Scheme 3). The analogous reaction of benzotriazine generated *in situ* with 4-hydrazinobenzotriazine and with 1- and 2-aminoindazole is referred to above.



H_2X=H_2O, $H_2N{\cdot}NH_2$, H_2NNHPh, 4-hydrazinobenzotriazine or 1- or 2-aminoindazole

SCHEME 3

The difficulty in isolating benzotriazine has already been mentioned; lead salts catalyse the addition of nucleophiles since, once isolated, the purified triazine is attacked only slowly by water in the absence of acid. Such nucleophilic attack is not unexpected; covalent hydration of similar heterocycles is well documented.[23] Surprisingly the pyridotriazine (27) is remarkably stable towards nucleophilic attack and can be isolated from oxidation of the aminopyrazolopyridine without difficulty. Although the pyridine nitrogen atom is not conjugated with C(4) it should slightly increase the electrophilicity of this centre and make (27) more rather than less reactive than benzotriazine. However this nitrogen atom may effect a ' through-space ' repulsive interaction on the approaching nucleophile. In agreement with this the pyridotriazine (28), which lacks this *peri*-interaction, could not be isolated from oxidation of the appropriate *N*-amino-compound.

As expected on both steric and electronic grounds, 4-substituted benzotriazines are less reactive towards attack at the imine function. However 4-phenylbenzotriazine gave *o*-aminobenzophenone and its hydrazone quantitatively with aqueous acid and hydrazine, respectively. 4-Methoxybenzotriazine shows imino-ether reactivity and is converted into 4-hydrazinobenzotriazine with hydrazine.

The aromatic stability of the system is underlined by our failure to observe cycloadditions with dienophiles such as acetylenedicarboxylic esters.

Further support for the structure of benzotriazines comes from the results of vapour-phase pyrolysis, which parallel the mass spectral breakdown. Above 450° complete fragmentation of the triazine ring occurs to give N_2, RCN, and benzyne, the last being isolated as its dimer biphenylene. Between 420 and 450° 4-arylbenzotriazines lose only N_2 to give benzazete-derived products.

[20] T. L. Gilchrist, G. E. Gymer, and C. W. Rees, *J.C.S. Chem. Comm.*, 1973, 819.
[21] C. W. Rees and M. Yelland, *J.C.S. Perkin I*, 1972, 77.
[22] B. M. Adger, C. W. Rees, A. A. Sale, and R. C. Storr, *Chem. Comm.*, 1971, 695.
[23] A. Albert, *Angew. Chem. Internat. Edn.*, 1967, **6**, 919.

These novel aspects of benzotriazine chemistry and their implications are discussed in detail in the following papers.

EXPERIMENTAL

U.v. spectra are recorded for solutions in ethanol, i.r. spectra for Nujol mulls, and n.m.r. spectra for solutions in deuteriochloroform, unless otherwise stated.

Oxidation of 4-Hydrazino-1,2,3-benzotriazine.—(a) *With silver oxide.* Silver oxide (1 g) was added to a stirred suspension of 4-hydrazino-1,2,3-benzotriazine (161 mg) in absolute methanol (30 ml) at room temperature. After 90 min, silver residues were removed by filtration and thoroughly washed with anhydrous methanol. Evaporation of the combined filtrate and washings at 20° under reduced pressure gave an orange-yellow solid smelling of benzonitrile. Trituration of this solid with ether, followed by filtration, yielded *2-aminobenzaldehyde 1,2,3-benzotriazin-4-ylhydrazone* (11) (81 mg, 61%) as orange-yellow needles, m.p. 193·5—194·5° (decomp.) (from ethanol) (Found: C, 63·0; H, 4·5; N, 30·8. $C_{14}H_{12}N_6$ requires C, 63·6; H, 4·6; N, 31·8%), *m/e* 264 (M^+), $\nu_{max.}$ 3410 and 3300br (N–H) cm^{-1}, τ [$(CD_3)_2SO$] 1·8—3·5 (8H, m, aromtic) and 1·40 (1H, s, methine). The trituration filtrate was concentrated and the residue chromatographed on silica. Elution with benzene gave benzonitrile (4·5 mg, 4%) identical with an authentic specimen, and elution with ether gave more hydrazone (11) (12 mg, 9%; total 70%).

Analogous oxidations were carried out in the following solvents (time required for oxidation in parentheses) and gave the hydrazone (11) along with small yields of benzonitrile: dioxan (18 h), propan-2-ol (3 days), and benzene (4 days).

(b) *With activated manganese dioxide.* Similar oxidation with manganese dioxide in tetrahydrofuran for 17 h gave the same products.

2-Aminobenzaldehyde Hydrazone.—*o*-Nitrobenzaldehyde was reduced [24] to give *o*-aminobenzaldehyde, which was purified by rapid steam distillation to give pale yellow leaflets, m.p. 39—39·5°. *o*-Aminobenzaldehyde (2·4 g) in ether (15 ml) was added dropwise to hydrazine hydrate (25 ml) at 0° with agitation. A drop of acetic acid was added and the mixture was warmed to 45° to assist evaporation of the ether. After a further 0·5 h at this temperature, the mixture was poured into water (125 ml) and the product was extracted with methylene chloride (2 × 25 ml). The combined extracts were washed with water, dried (Na_2SO_4), and evaporated to give 2-aminobenzaldehyde hydrazone as pale yellow leaflets (1·6 g, 60%), m.p. 60—61° (from petroleum) (lit.,[25] 62°).

2-Aminoacetophenone Hydrazone.—A mixture of *o*-aminoacetophenone (4·0 g), hydrazine hydrate (7·5 g), and glacial acetic acid (1 ml) in ethanol (50 ml) was heated under reflux for 5 h, then poured into water (200 ml) and extracted with chloroform (2 × 50 ml). The extracts were washed with water, dried (Na_2SO_4), and evaporated to give a yellow oil. This was dissolved in the minimum amount of ethanol to leave *2-aminoacetophenone azine* (65 mg, 1%) as yellow leaflets, m.p. 161—162° (from ethanol) (Found: C, 72·0; H, 7·0; N, 20·8. $C_{16}H_{18}N_4$ requires C, 72·15; H, 6·8; N, 21·05%), *m/e* 266 (M^+), $\nu_{max.}$ 3350 (NH) cm^{-1}. The filtrate was evaporated to give *2-aminoacetophenone hydrazone* (4·1 g, 82%) as a straw-coloured oil (Found: C, 63·8; H, 7·2; N, 28·45. $C_8H_{11}N_3$ requires C, 64·4; H, 7·45; N, 28·15%), *m/e* 149 (M^+), $\nu_{max.}$ 3340, 3380, and 3290 (NH) cm^{-1}.

2-Aminobenzophenone Hydrazone.—Similar treatment of *o*-aminobenzophenone with hydrazine hydrate and acetic acid in refluxing ethanol for 8 h gave the *hydrazone* (68%) as needles, m.p. 140—141° (from ethanol) (Found: C, 73·4; H, 6·0; N, 19·45. $C_{13}H_{13}N_3$ requires C, 73·9; H, 6·2; N, 19·9%), *m/e* 211 (M^+), $\nu_{max.}$ 3450, 3360, and 3270 (N–H) cm^{-1}.

2-Amino-4'-methoxybenzophenone Hydrazone.—2-Amino-4'-methoxybenzophenone [7] with hydrazine hydrate and acetic acid in refluxing ethanol for 15 h gave the *hydrazone* as prisms, m.p. 126—127° (from ethanol) (Found: C, 69·8; H, 6·2; N, 17·3. $C_{14}H_{15}N_3O$ requires C, 69·7; H, 6·3; N, 17·4%), *m/e* 241 (M^+), $\nu_{max.}$ 3425 and 3350 (N–H) cm^{-1}.

2-Amino-3-benzoylnaphthalene Hydrazone.—2-Amino-3-benzoylnaphthalene [26] with hydrazine hydrate and acetic acid in refluxing ethanol for 24 h gave the *hydrazone* (92%), as needles, m.p. 137—138° (from ethanol) (Found: C, 77·6; H, 5·9; N, 15·6. $C_{17}H_{15}N_3$ requires C, 78·1; H, 5·7; N, 16·0%), *m/e* 261 (M^+), $\nu_{max.}$ 3400, 3300, and 3200 (N–H) cm^{-1}.

2-Amino-5-chlorobenzophenone Hydrazone.—2-Amino-5-chlorobenzophenone with hydrazine hydrate and acetic acid in refluxing ethanol for 14 h gave the *hydrazone* (83%) as pale yellow needles, m.p. 136—137° (from ethanol) (Found: C, 63·7; H, 4·9; N, 17·1. $C_{13}H_{12}ClN_3$ requires C, 63·7; H, 4·8; N, 17·1%), $\nu_{max.}$ 3400 and 3300 (N–H) cm^{-1}.

o-Azido-ketones.—All the azido-ketones were prepared as follows. Sodium nitrite (3·8 g, 55 mmol) in water (12 ml) was added slowly to a solution of the *o*-amino-ketone (50 mmol) in N-hydrochloric acid (20 ml) at 0°. After 0·5 h, the diazonium salt solution was filtered and sodium azide (6·5 g, 0·1 mol) in water (50 ml) was added dropwise with rapid stirring to the filtrate at 0°. The resulting *o*-azido-ketones were filtered off. *o*-Aminoacetophenone gave *o*-azidoacetophenone (94%), m.p. 23° (from petroleum) (lit.,[8] 22—22·5°). *o*-Aminobenzophenone gave *o*-azidobenzophenone (96%), m.p. 36—37° (from petroleum) (lit.,[27] 36—38°). *o*-Aminobenzaldehyde gave *o*-azidobenzaldehyde (50%), m.p. 36—37° (from petroleum) (lit.,[28] 37·5°). 2-Amino-4'-methoxybenzophenone gave *2-azido-4'-methoxybenzophenone* (91%), m.p. 71° (from ethanol) (Found: C, 66·4; H, 4·4; N, 16·6. $C_{14}H_{11}N_3O_2$ requires C, 66·1; H, 4·2; N, 16·6%); $\nu_{max.}$ 2130 (N_3) and 1650 (C=O) cm^{-1}, *m/e* 253 (M^+).

Conversion of o-Azido-ketones into Indazoles.—A mixture of the azido-ketone (30 mmol), hydrazine hydrate (25 ml), and acetic acid (2 ml) was heated under reflux in ethanol (125 ml) for 18 h. The cooled mixture was poured into water and extracted with methylene chloride (3 × 200 ml). (In some cases the indazole crystallised from the cooled mixture or was precipitated on pouring into water.) The methylene chloride extracts were washed thoroughly with water, and dried (Na_2SO_4). Evaporation gave the indazole. *o*-Azidoacetophenone gave 3-methylindazole (90%), needles from ether–petroleum, m.p. and mixed m.p. 112—113° (lit.,[29] 113°). *o*-Azidobenzophenone gave 3-phenylindazole (91%), needles from ether–petroleum, m.p. and mixed m.p. 107—108° (lit.,[30] 107—108°). *o*-Azidobenzaldehyde gave

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[26] W. C. Lothrop and P. A. Goodwin, *J. Amer. Chem. Soc.*, 1943, **65**, 363.
[27] P. A. S. Smith, B. B. Brown, R. K. Putney, and R. F. Reinisch, *J. Amer. Chem. Soc.*, 1953, **75**, 6335.
[28] E. Bamberger and E. Demuth, *Ber.*, 1901, **34**, 2292.
[29] K. von Auwers and M. Düesberg, *Ber.*, 1920, **53**, 1179.
[30] K. von Auwers and K. Hüttenes, *Ber.*, 1922, **55**, 1112.

indazole (87%), needles from ether–petroleum, m.p. 142—144°, mixed m.p. 143—145° (lit.,[31] 146·5°). 2-Azido-3-benzoylnaphthalene gave 3-*phenylbenz*[f]*indazole* (75%) pale yellow needles, m.p. 195—196° (from ethanol) (Found: C, 83·6; H, 5·1; N, 11·4. $C_{17}H_{12}N_2$ requires C, 83·6; H, 4·9; N, 11·5%), *m/e* 244 (M^+), $\nu_{max.}$ 3275br (NH) 1630, 1620, 1280, 1100, 1075, 870, 740, 700, and 680 cm^{-1}.

2-Azido-4′-methoxybenzophenone gave 3-(*p*-methoxyphenyl)indazole as a viscous oil (93%). Chromatography on silica gel gave the solid indazole, m.p. 88—90° (lit.,[32] 110—111°); picrate, m.p. 148—150° (lit.,[32] 147—148°). Spectral data for the indazole were in accord with its structure.

2-*Azidoacetophenone Hydrazone*.—A mixture of *o*-azidoacetophenone (3·2 g) and hydrazine hydrate (2·8 g) in ethanol (50 ml) containing a crystal of iodine was set aside at room temperature. After 2 h, t.l.c. indicated complete disappearance of *o*-azidoacetophenone and the mixture was poured into water (200 ml) to give a yellow oil. This crystallised from ether petroleum at −20° to give the hydrazone (2·5 g, 70%), m.p. 47—48° (Found: C, 55·1; H, 5·2; N, 39·6. $C_8H_9N_5$ requires C, 54·8; H, 5·2; N, 40·0%), *m/e* 175 (M^+), $\nu_{max.}$ 3325, 3200 (N–H), and 2120 (N_3) cm^{-1}, τ ($CDCl_3$) 2·5—3·0 (4H, m, aromatic), 4·6br (2H, s, NH_2), and 7·9 (3H, s, Me).

2-*Azidobenzaldehyde Hydrazone*.—Similar treatment of *o*-azidobenzaldehyde with hydrazine hydrate at room temperature gave the *hydrazone* (75%), m.p. 72—73° (Found: C, 52·4; H, 4·1; N, 43·8. $C_7H_7N_5$ requires C, 52·2; H, 4·3; N, 43·5%), *m/e* 161 (M^+), $\nu_{max.}$ 3400, 3200 (N–H), and 2135 (N_3) cm^{-1}. *o*-Azidobenzophenone was recovered (85%) from similar treatment with hydrazine hydrate for 24 h. A complex mixture of minor products was indicated by t.l.c.

1-(2-*Azidophenyl*)-1-*diazoethane*.—A mixture of saturated ethanolic potassium hydroxide (1 ml), 2-azidoacetophenone hydrazone (875 mg), and yellow mercury(II) oxide (2·5 g) in petroleum was stirred in the dark for 2 h. The resulting bright red solution was filtered and the filtrate was concentrated carefully under reduced pressure to give the diazoazide as a red oil, which crystallised from petroleum at low temperature. The bright red prisms melted on warming to room temperature and the unstable compound was characterised by its i.r. spectrum only: $\nu_{max.}$ 2100 (N_3), 2050 (diazo), 1598, 1500, 1300, 1040, and 750 cm^{-1}.

Treatment of 2-azidobenzaldehyde hydrazone in an analogous manner appeared to give 2-azidophenyldiazomethane, which decomposed spontaneously on removal of the solvent.

Oxidation of Amino-hydrazones (20).—*General procedure*. Lead tetra-acetate (7 mmol) was added in portions over 15 min to a stirred solution of the amino-hydrazone (3 mmol) in dry methylene chloride (30 ml). After stirring for 1·5 h the lead salts were filtered off and washed with methylene chloride (10 ml). The combined filtrate and washings were evaporated on to silica gel for chromatography.

2-*Aminoacetophenone hydrazone*. Elution with 60% ether–petroleum gave *o*-acetamidoacetophenone (10%), m.p. 75—77° (from aqueous ethanol), mixed m.p. 75—77° (lit.,[33] 76—77°). 20% Ether–ethyl acetate eluted 4-*methyl*-1,2,3-*benzotriazine* (47%), prisms, m.p. 120—121° (from ethanol) (Found: C, 66·45; H, 5·05; N, 28·7. $C_8H_7N_3$ requires C, 66·2; H, 4·85; N, 28·95%), $\nu_{max.}$ 1608, 1570, 1250, 1208, 1141, 1018, 916, 825, 800, 762, and 711 cm^{-1}, $\lambda_{max.}$ 207 (log ε 3·58), 227 (4·0), and 275 nm (2·83); τ 1·45—2·2 (m, 4H, aromatic) and 6·95 (3H, s, CH_3); *m/e* 145 (M^+).

2-*Aminobenzophenone hydrazone*. Elution with 40% ether–petroleum gave *o*-acetamidobenzophenone (29%), m.p. 88—89° (from ethanol), mixed m.p. 88—89° (lit.,[34] 89°). 60% Ether–petroleum eluted 4-*phenyl*-1,2,3-*benzotriazine* (50%), needles, m.p. 159—160° (from ethanol) (Found: C, 75·5; H, 4·6; N, 20·25. $C_{13}H_9N_3$ requires C, 75·35; H, 4·4; N, 20·3%), $\nu_{max.}$ 1610, 1565, 1390, 1362, 930, 780, and 704 cm^{-1}; $\lambda_{max.}$ 206, 232 (log ε 4·1), and 293 nm (2·95), *m/e* 207 (M^+), 179, and 152.

2-*Amino*-4′-*methoxybenzophenone hydrazone*. Elution with 60% ether–petroleum gave 2-*acetamido*-4′-*methoxybenzophenone* (73%), prisms from aqueous ethanol, m.p. 120—121° (Found: C, 71·3; H, 5·6; N, 5·2. $C_{16}H_{15}NO_3$ requires C, 71·4; H, 5·6; N, 5·2%), $\nu_{max.}$ 3285 (NH), 1670 (C=O), and 1645 (C=O) cm^{-1}, τ 1·42 (1H, NH), 2·18—3·10 (8H, m, aromatic), 6·11 (3H, s, OCH_3), and 7·81 (3H, s, CH_3), *m/e* 269 (M^+). Elution with ether gave 4-(*p*-methoxyphenyl)-1,2,3-benzotriazine, yellow leaflets from ethanol, m.p. 141·5—142·5° (lit.,[7] 138—139°), identical with a specimen prepared by the method of Nunn and Schofield.[7]

2-*Amino*-5-*chlorobenzophenone hydrazone*. Elution with 50% ether–petroleum gave 6-*chloro*-4-*phenyl*-1,2,3-*benzotriazine* (50%), needles from ethanol, m.p. 126—127° (Found: C, 64·4; H, 3·4; N, 17·2. $C_{13}H_8N_3Cl$ requires C, 64·5; H, 3·3; N, 17·4%), $\nu_{max.}$ 1600, 1070, 940, 840, 800, 750, and 690 cm^{-1}, *m/e* 241 (M^+).

2-*Amino*-3-*benzoylnaphthalene hydrazone*. Elution with 50% ether–petroleum gave 4-*phenylnaphtho*[2,3-d][1,2,3]-*triazine* (5%), yellow needles from ethanol, m.p. 194—195° (Found: C, 79·0; H, 4·3; N, 16·1. $C_{17}H_{11}N_3$ requires C, 79·3; H, 4·3; N, 16·3%); $\nu_{max.}$ 1620, 1600, 1580, 1270, 1250, 940, 900, 760, and 700 cm^{-1}, *m/e* 257 (M^+). Further elution gave only black intractable tars.

2-*Aminobenzaldehyde hydrazone*. Oxidation gave only intractable tars.

Amination of Indazoles.—*General procedure*. All aminations were carried out by the method described in detail for 3-phenylindazole.

3-*Phenylindazole*. Ethanol was added to a stirred suspension of 3-phenylindazole (1·4 g, 7·5 mmol) in aqueous sodium hydroxide (1·65 g in 25 ml) at 50° until dissolution was complete. The mixture was then heated to 55° and hydroxylamine-*O*-sulphonic acid (2·25 g) was added in portions over 0·25 h with rapid stirring. Heating was discontinued and the mixture was stirred for a further 0·5 h. The solid which separated was filtered off and washed thoroughly with water. The filtrate was extracted with methylene chloride (2 × 25 ml) and the extracts were washed with water and dried (Na_2SO_4). The combined solid and methylene chloride extracts were adsorbed onto silica gel for chromatography. Elution with 40% ether–petroleum gave 1-*amino*-3-*phenylindazole* (22; R = Ph) (904 mg, 60%), needles from ether–petroleum, m.p. 112—113° (Found: C, 74·9; H, 5·3; N, 19·7. $C_{13}H_{11}N_3$ requires C, 74·6; H, 5·3; N, 20·1%), $\nu_{max.}$ 3330, 3200 (NH_2) 1638, 1570, 782, 740, and 700 cm^{-1}, $\lambda_{max.}$ 228 (log ε 4·15), 248 (4·10), 276 (4·15), and 312 nm (4·31), *m/e* 209 (M^+) [*anisylidene derivative*, m.p. 126—127° (from ethanol) (Found: C, 77·05; H, 5·3; N, 12·95. $C_{21}H_{17}N_3O$ requires C, 77·05; H, 5·25; N, 12·85%)]. Elution with ether gave 2-*amino*-3-*phenylindazole* (23; R = Ph) (120 mg,

[31] E. F. M. Stephenson, *Org. Synth.*, Coll. Vol. III, 1955, p. 475.
[32] K. von Auwers and P. Strödter, *Ber.*, 1926, **59**, 529.
[33] H. Gevekoht, *Ber.*, 1882, **15**, 2084.
[34] K. von Auwers, *Ber.*, 1896, **29**, 1255.

8%), needles from ether–petroleum, m.p. 80·5—81·5° (Found: C, 74·4; H, 5·5; N, 20·0%), $\nu_{max.}$ 3350, 3180 (NH_2) 1620, 742, and 682 cm^{-1}, $\lambda_{max.}$ 234 (log ε 4·21), 260 (3·90), and 313 nm (4·42), *m/e* 209 (M^+).

3-*Methylindazole*. Chromatography was performed on alumina. Elution with methylene chloride gave 1-*amino*-3-*methylindazole* (22; R = Me) (45%), needles from ether–petroleum, m.p. 116—117° (Found: C, 65·35; H, 6·2; N, 28·75. $C_8H_9N_3$ requires C, 65·3; H, 6·15; N, 28·55%), $\nu_{max.}$ 3310 and 3280 (NH_2) cm^{-1}, $\lambda_{max.}$ 220 (log ε 4·03), 258 (3·37), and 300 nm (3·66), τ 2·4—3·2 (4H, m, aromatic), 4·7 (2H, s, NH_2), and 7·6 (3H, s, CH_3), *m/e* 147 (M^+) [*anisylidene derivative*, m.p. 102—103° (needles from ethanol) (Found: C, 72·4; H, 5·85; N, 15·8. $C_{16}H_{15}N_3O$ requires C, 72·45; H, 5·7; N, 15·85%)]. Elution with 15% ethyl acetate–methylene chloride gave 2-*amino*-3-*methylindazole* (23; R = Me) (30%), plates from ether–petroleum, m.p. 154° (Found: C, 65·1; H, 6·2; N, 28·4. $C_8H_9N_3$ requires C, 65·3; H, 6·15; N, 28·55%), $\nu_{max.}$ 3300 and 3160 (NH_2) cm^{-1}, $\lambda_{max.}$ 220 (log ε 4·0), 278 (3·4), and 300 nm (3·5), τ 2·2—3·15 (4H m, aromatic), 4·35 (2H, s, NH_2), and 7·45 (3H, s, CH_3), *m/e* 147 (M^+) [*anisylidene derivative*, m.p. 115—116° (needles from ethanol) (Found: C, 72·3; H, 5·75; N, 15·7. $C_{16}H_{15}N_3O$ requires C, 72·45; H, 5·7; N, 15·85%)].

2-Amino-3-methylindazole was also obtained (80%) when 2-azidoacetophenone hydrazone was heated under reflux for 12 h in toluene. The amino-compound crystallised from the cooled solution.

Indazole. Elution with 10% ethyl acetate–methylene chloride gave 1-aminoindazole (22; R = H) (49%), granules from benzene–petroleum, m.p. 104—108°, containing a minor impurity which could not be removed by successive recrystallisations; $\nu_{max.}$ 3330, 3200 (NH_2), 1650, 1620, 1075, and 735 cm^{-1}, $\lambda_{max.}$ 217, 253 (log ε 3·72), 280sh, 290 (3·72), and 292 nm (3·71), τ 1·95 (1H, s), 2·05—3·15 (4H, m, aromatic), and 4·59 (2H, s, NH_2), *m/e* 133 (M^+) [*anisylidene derivative*, m.p. 80—81° (from ethanol) (Found: C, 71·2; H, 5·2. $C_{15}H_{13}N_3O$ requires C, 71·7; H, 5·2%)]. Elution with 80% ethyl acetate–methylene chloride gave 2-aminoindazole (23; R = H) as pink plates from benzene–petroleum, m.p. 97—99° (lit.,[35] 96—97°) (Found: C, 62·8; H, 5·3; N, 31·7. Calc. for $C_7H_7N_3$: C, 63·1; H, 5·3; N, 31·6%), $\nu_{max.}$ 3240, 3160 (NH_2), 1665, 1625, 1220, 795, 755, and 740 cm^{-1}, $\lambda_{max.}$ 217 and 276 nm (log ε 3·90), τ 2·25 (1H, s), 2·25—3·25 (4H, m, aromatic) and 4·0 (2H, s, NH_2), *m/e* 133 (M^+) [*anisylidene derivative*, m.p. 120—121° (from ethanol) (Found: C, 71·3; H, 5·3; N, 16·3. $C_{15}H_{13}N_3O$ requires C, 71·7; H, 5·2; N, 16·7%)].

3-p-*Methoxyphenylindazole*. The solid which separated from the amination mixture was recrystallised from methanol to give 1-*amino*-3-p-*methoxyphenylindazole* (88%) as needles, m.p. 170—172° (Found: C, 70·5; H, 5·65; N, 17·6. $C_{14}H_{13}N_3$ requires C, 70·3; H, 5·5; N, 17·6%), $\nu_{max.}$ 3300, 3130 (NH_2), 1630, 780, and 755 cm^{-1}, $\lambda_{max.}$ 227 (log ε 3·90), 256 (3·87), and 310 nm (3·71), τ 2·00—3·05 (8H, m, aromatic), 5·09br (2H, s, NH_2), and 6·12 (3H, s, OCH_3), *m/e* 239 (M^+).

5-*Nitroindazole*. Preparative t.l.c. on silica gel gave, on elution with chloroform, 1-*amino*-5-*nitroindazole* (R_F 0·50) (57%), pale yellow needles from benzene, m.p. 203—204° (Found: C, 47·0; H, 3·7; N, 31·5. $C_7H_6N_4O_2$ requires C, 47·2; H, 3·4; N, 31·5%), $\nu_{max.}$ 3350, 3200 (NH_2), 1660, 1620, 1600, 1540, 1400, 1360, 1075, and 800 cm^{-1}, $\lambda_{max.}$ 219 (log ε 4·29) and 280 nm (3·95), *m/e* 178 (M^+), and 2-*amino*-5-*nitroindazole* (R_F 0·45) (9%), pale yellow needles from benzene, m.p. 179—180° (Found: C, 47·2; H, 3·4; N, 31·6%), $\nu_{max.}$ 3390, 3250 (NH_2), 1630, 1510, 1400, 1080, and 760 cm^{-1}, $\lambda_{max.}$ 225 (log ε 4·36) and 290 nm (4·20), *m/e* 178 (M^+).

6-*Nitroindazole*. Preparative t.l.c. on silica gel gave, on elution with chloroform, 1-*amino*-6-*nitroindazole* (R_F 0·45) (30%), pale yellow needles from benzene, m.p. 155—156° (Found: C, 47·4; H, 3·4; N, 31·5%), $\nu_{max.}$ 3450, 3300 (NH_2), 1660, 1620, 1530, 1390, 1350, 860, 840, and 715 cm^{-1}, $\lambda_{max.}$ 224 (log ε 4·29) and 304 nm (3·98), *m/e* 178 (M^+), and 2-*amino*-6-*nitroindazole* (R_F 0·40) (28%), pale yellow needles from benzene, m.p. 167—168° (Found: C, 47·5; H, 3·5; N, 31·6%), $\nu_{max.}$ 3450, 3310 (NH_2), 1650, 1530, 1380, 1340, 1000, 980, 820, and 715 cm^{-1}, $\lambda_{max.}$ 228 (log ε 4·33) and 308 nm (4·16), *m/e* 178 (M^+).

3-*Phenylbenz*[f]*indazole*. The solid which separated from the amination mixture was recrystallised from ethanol to give 1-*amino*-3-*phenylbenz*[f]*indazole*, bright yellow needles, m.p. 186—187° (Found: C, 78·5; H, 5·2; N, 16·4. $C_{17}H_{13}N_3$ requires C, 78·7; H, 5·1; N, 16·2%), $\nu_{max.}$ 3450, 3300 (NH_2), 1640, 1500, 1220, 1190, 1100, 1070, 870, 740, 700, and 670 cm^{-1}, *m/e* 259 (M^+).

Pyrazolo[3,4-b]*pyridine* (24). Attempted amination gave only water-soluble products. No *N*-amino-compounds were isolated.

5-*Methylpyrazolo*[4,3-b]*pyridine* (25). Preparative t.l.c. on silica gel gave, on elution with ethyl acetate, 1-*amino*-5-*methylpyrazolo*[4,3-b]*pyridine* (R_F 0·40) (42%), pale yellow needles from benzene, m.p. 110—111° (Found: C, 56·8; H, 5·5; N, 37·6. $C_7H_8N_4$ requires C, 56·7; H, 5·4; N, 37·8%), $\nu_{max.}$ 3400, 3250 (NH_2), 1645, 1380, 1140, 1060, 800, and 680 cm^{-1}, $\lambda_{max.}$ 290 (log ε 3·70), 300 (3·65), and 305 nm (3·40), *m/e* 148 (M^+), and 2-*amino*-5-*methylpyrazolo*[4,3-b]*pyridine* (R_F 0·35) (40%), pale yellow needles from benzene, m.p. 135—136° (Found: C, 56·5; H, 5·4; N, 37·6%), $\nu_{max.}$ 3400, 3300 (NH_2), 1640, 1420, 1360, 1240, 1170, 1005, 800, and 660 cm^{-1}, $\lambda_{max.}$ 303 (log ε 3·76), 318 (3·70), and 320 nm (3·50), *m/e* 148 (M^+).

Pyrazolo[3,4-c]*pyridine* (26). Extraction of the amination mixture with chloroform gave a pale yellow solid. T.l.c. indicated that this was a single compound and recrystallisation from ethyl acetate gave a pure *N*-amino-compound assumed to be 1-*aminopyrazolo*[3,4-c]*pyridine* from the close similarity of its u.v. spectrum to that of pyrazolo[3,4-*c*]pyridine. It formed yellow needles, m.p. 126—127° (Found: C, 53·9; H, 4·6; N, 42·0. $C_6H_6N_4$ requires C, 53·7; H, 4·5; N, 41·8%), $\nu_{max.}$ 3350, 3250 (NH_2), 1680, 1670, 1620, 1580, 1340, 1305, 1260, 1040, 860, 805, and 760 cm^{-1}, $\lambda_{max.}$ 287 (log ε 3·62), 295 (3·45), and 305 nm (3·58), *m/e* 134 (M^+).

3-*Methoxyindazole*. Sodium hydride (50% dispersion in oil; 956 mg, 19·9 mmol) was added slowly, in portions, to a solution of 3-methoxyindazole (2·95 g, 19·9 mmol) in dry ether (40 ml). When effervescence had ceased the mixture was heated gently for 10 min to complete salt formation. After cooling, a solution of chloramine (22 mmol) in ether (156 ml) was added and the mixture was stirred overnight and then filtered. The inorganic salts were washed thoroughly with ether and the combined filtrate and washings were evaporated. The residue was sublimed and recrystallised from cyclohexane to give, in two crops, 1-*amino*-3-*methoxyindazole* (22; R = OMe) (2·87 g, 88%), m.p. 107·5—108·5° (Found: C, 59·1; H, 5·8; N, 25·5. $C_8H_9N_3O$ requires C, 58·9; H, 5·6; N, 25·7%), $\nu_{max.}$ 3300, 3190 (NH_2), 1642, 1621, 1587, 1541, 1502, 1417, 1360, 1210, 1157, 1140, 995, 920, 778, and 737 cm^{-1}, $\lambda_{max.}$ 226 (log ε 3·96), 252sh

[35] K. Sakai and J.-P. Anselme, *J. Org. Chem.*, 1972, **37**, 2351.

(3·24), and 307 nm (3·60), τ 2·3—3·1 (4H, m, aromatic), 5·15 (2H, s, NH_2), and 5·94 (3H, s, OCH_3), *m/e* 163 (M^+) [*anisylidene derivative*, m.p. 87·5—89° (from ethanol) (Found: C, 68·3; H, 5·5; N, 15·2. $C_{16}H_{15}N_3O_2$ requires C, 68·3; H, 5·4; N, 14·9%)]. The recrystallisation mother liquors were concentrated and subjected to preparative t.l.c. on silica gel. This gave more 1-amino-3-methoxyindazole (5·4%) and a trace of 4-methoxy-1,2,3-benzotriazine. A control experiment in which 1-amino-3-methoxyindazole was kept in ether with an excess of chloramine showed that 4-methoxybenzotriazine was formed (80%) with slow deposition of ammonium chloride over 7 days.

The assumption that the single *N*-amino-compound formed from 3-methoxyindazole is the 1-amino-isomer is in accord with the observation that 3-methoxyindazole is acetylated and alkylated only at the 1-position.

Oxidation of N-*Aminoindazoles.—General procedure.* Lead tetra-acetate (2·2 mmol) was added to a rapidly stirred solution of the *N*-aminoindazole (2 mmol) in dry methylene chloride at room temperature. After 1 h, lead salts were removed by filtration and the residue was washed with methylene chloride. The combined filtrate and washings were evaporated and the triazine was isolated from the residue by chromatography on silica gel or by crystallisation. In some cases, especially for sensitive triazines, the oxidation was carried out in the presence of an excess of freshly activated calcium oxide to remove acetic acid, and unchanged lead tetra-acetate was destroyed prior to filtration by the addition of 1 or 2 drops of glycerol.

1- *and* 2-*Amino*-3-*methylindazole.* The isomers were oxidised separately. Elution with 20% ether–ethyl acetate gave 4-methyl-1,2,3-benzotriazine, m.p. and mixed m.p. 120—121° (85 and 80%, respectively).

1- *and* 2-*Amino*-3-*phenylindazole.* The isomers were oxidised separately. Elution with 60% ether–petroleum gave 4-phenyl-1,2,3-benzotriazine, m.p. and mixed m.p. 156—157° (97 and 90%, respectively).

1-*Amino*-3-p-*methoxyphenylindazole.* Oxidation was carried out in the presence of calcium oxide, after which glycerol was added. 4-*p*-Methoxyphenylbenzo-1,2,3-triazine (50%), m.p. and mixed m.p. 138—139°, was obtained, without chromatography, by recrystallisation from ethanol.

1-*Amino*-3-*methoxyindazole.* Oxidation was carried out in the presence of calcium oxide, after which glycerol was added. Elution with 30% ether–petroleum gave 4-*methoxy*-1,2,3-*benzotriazine* (83%), m.p. 105·5—106·5° (from cyclohexane) (Found: C, 59·75; H, 4·4; N, 26·0. $C_8H_7N_3O$ requires C, 59·6; H, 4·4; N, 26·1%), $\nu_{max.}$ 1617, 1579, 1537, 1497, 1453, 1251, 1233, 1186, 1118, 1000, 976, 918, 786, 733, and 678 cm^{-1}, $\lambda_{max.}$ 232 (log ε 4·08) and 275 nm (3·75), τ 1·50—2·15 (4H, m, aromatic) and 5·63 (3H, s, OCH_3), *m/e* 161 (M^+), 133 ($M - N_2$), 103, 90, and 76.

1-*Amino*-3-*phenylbenz*[f]*indazole.* 4-Phenylnaphtho-[2,3-*d*][1,2,3]triazine (57%), m.p. and mixed m.p. 194—195°, was obtained, without chromatography, by crystallisation from ethanol.

1- *and* 2-*Amino*-4- *and* 5-*nitroindazole.* The four isomers were oxidised separately in the presence of calcium oxide but in no case was any benzotriazine isolated.

1- *and* 2-*Amino*-5-*methylpyrazolo*[4,3-b]*pyridine.* The isomers were oxidised separately in the presence of calcium oxide. Elution with ethyl acetate gave 6-methylpyrido-[3,2-*d*][1,2,3]*triazine* (27) (65 and 62%, respectively), as yellow needles from ethyl acetate–ether, m.p. 146—147° (Found: C, 57·6; H, 4·3; N, 37·9. $C_7H_6N_4$ requires C, 57·5; H, 4·2; N, 38·3%), $\nu_{max.}$ 1620, 1565, 1380, 1155, 960, 870, and 670 cm^{-1}, $\lambda_{max.}$ 218 (log ε 4·24), 290 (3·67), and 300 nm (3·63), τ 0·45 (1H, s, 4-H), 1·47 (1H, d, 8-H), 2·17 (1H, d, 7-H), and 7·16 (3H, s, 6-CH_3), *m/e* 146 (M^+), 118, and 91.

1-*Aminopyrazolo*[3,4-c]*pyridine.* Vigorous nitrogen evolution occurred during this oxidation, which gave only dark brown intractable oils.

1- *and* 2-*Aminoindazole.* Oxidation of 1- and of 2-aminoindazole as described above was complex and gave, amongst other products, indazole, *o*-acetamidobenzaldehyde, and *o*-aminobenzaldehyde (see also ref. 35). Also formed from 1-aminoindazole was 2-*amino*-N-(*indazol*-1-*yl*)*benzylideneamine*, pale yellow crystals, m.p. 141—142°, from ether–petroleum (Found: C, 70·8; H, 5·0; N, 23·1. $C_{14}H_{12}N_4$ requires C, 71·2; H, 5·1; N, 23·7%), identical with that obtained as follows. *o*-Aminobenzaldehyde (220 mg) and 1-aminoindazole (250 mg) were heated to 60° in ethanol (20 ml) containing acetic acid (1 drop). The resulting solution was evaporated to dryness and the residue recrystallised from ether–petroleum.

Also formed from 2-aminoindazole was 2-*amino*-N-(*indazol*-2-*yl*)*benzylideneamine*, yellow needles, m.p. 166—167° (from ethanol) (Found: C, 70·9; H, 5·0; N, 23·8. $C_{14}H_{12}N_4$ requires C, 71·2; H, 5·1; N, 23·7%), identical with a specimen prepared from *o*-aminobenzaldehyde and 2-aminoindazole as described above.

The following procedure however gave 1,2,3-benzotriazine. A mixture of lead tetra-acetate (1·85 g, 4·2 mmol), calcium oxide (*ca.* 6 g), and dry methylene chloride was stirred in a vessel sealed with a serum cap. A solution of 1-aminoindazole (532 mg, 4 mmol) in methylene chloride (10 ml) was injected in 1 ml portions over 5—10 min. The mixture was stirred for a further 5 min, quickly filtered, and evaporated to *small bulk*. Dry ether was added and the mixture was concentrated. The resulting precipitate (*ca.* 250 mg) was filtered off and sublimed at 90—95° and 0·1 Torr to give a yellow powder. This was crystallised from dry ether to give 1,2,3-*benzotriazine* (99 mg, 19%) as pale yellow needles, m.p. 119—120° (Found: C, 64·0; H, 3·9; N, 32·3. $C_7H_5N_3$ requires C, 64·1; H, 3·8; N, 32·05%), $\nu_{max.}$ (KBr) 1473, 1383, 877, 800, and 750 cm^{-1}, τ [$(CD_3)_2SO$] 0·15 (1H, d) and 1·45—1·86 (4H, m), *m/e* 131 (M^+), 103, and 76.

Similar oxidation of 2-aminoindazole gave 1,2,3-benzotriazine (16%).

N-*Amino*-4-*phenylquinazolin*-2-*ones.*—Ethanol was added to a stirred suspension of 4-phenylquinazolin-2-one [36] (29; R = Ph) (2·2 g, 10 mmol) in aqueous sodium hydroxide (2·0 g, 50 mmol in 30 ml) maintained at 50°, until dissolution was complete. The temperature was raised to 60° and hydroxylamine-*O*-sulphonic acid (3·2 g) was added in portions over 0·5 h. The mixture was then allowed to cool and was filtered. The residue was washed and the filtrate extracted with methylene chloride. The combined washings and extracts were dried (Na_2SO_4) and evaporated to give a colourless gum. Trituration with ether gave a solid which crystallised from ethanol to give an N-*amino*-4-*phenylquinazolin*-2-*one* (540 mg, 25%) as needles, m.p. 150—153° (Found: C, 70·6; H, 4·7; N, 17·6. $C_{14}H_{11}N_3O$ requires C, 70·8; H, 4·7; N, 17·7%), $\nu_{max.}$ 3300, 3200 (NH_2), 1650, 1460, 1380, 1120, 980, 770, and 685 cm^{-1}, *m/e* 237 (M^+). The ether washings from the trituration were evaporated onto silica gel for chromatography. Elution with 40% ether–petroleum gave a second isomer of N-*amino*-4-*phenylquinazolin*-2-*one* (250 mg, 12%) as needles, m.p. 100—

[36] K. Schofield, *J. Chem. Soc.*, 1952, 1927.

102° (from ether–petroleum) (Found: C, 70·7; H, 4·5; N, 17·6%), $\nu_{max.}$ 3350, 3200 (NH_2), 1640 (C=O), 1460, 1360, 1100, 750, and 700 cm^{-1}, *m/e* 237 (M^+), 210, 209, 208, 195, 180, 152, 105, and 77.

N-*Amino*-4-*methylquinazolin*-2-*one*.—Similar amination of 4-methylquinazolin-2-one (29; R = Me) [37] gave a single N-*amino*-4-*methylquinazolin*-2-*one* (85%) as needles from ethanol, m.p. 176—177° (Found: C, 61·8; H, 5·2; N, 23·9. $C_9H_9N_3O$ requires C, 61·7; H, 5·1; N, 24·0%), $\nu_{max.}$ 3425, 3310 (NH_2), 1670 (C=O), 1620, 1600, 1580, 1520, 1440, 1280, 1260, 920, 770, 760, and 700 cm^{-1}, $\lambda_{max.}$ 254 (log ε 4·30) and 344 nm (4·02), τ 2·06—2·65 (4H, m, aromatic), 5·16br (2H, s, NH_2), and 7·34 (3H, s, CH_3).

Oxidation of N-*Aminoquinazolin*-2-*ones*.—N-*Amino*-4-*methylquinazolin*-2-*one*. The quinazolin-2-one (350 mg, 2·2 mmol) in dry methylene chloride (3 ml) was added dropwise to a stirred suspension of lead tetra-acetate (980 mg, 2·2 mmol) in dry methylene chloride. After 30 min the resulting mixture was filtered and the residue was washed with methylene chloride. The combined filtrate and washings were evaporated and the residue was chromatographed on silica gel. Elution with 75% ether–petroleum gave 4-methyl-1,2,3-benzotriazine (70 mg, 23%), m.p. and mixed m.p. 120—121°.

N-*Amino*-4-*phenylquinazolin*-2-*one*. The quinazolin-2-one (m.p. 150—153°) (474 mg, 2 mmol) was oxidised as described for the 4-methyl compound. Elution with 60% ether–petroleum gave 4-phenyl-1,2,3-benzotriazine (100 mg, 24%), m.p. and mixed m.p. 154—156°.

A similar oxidation of the second isomer of *N*-amino-4-phenylquinazolin-2-one (m.p. 100—102°) was carried out on a very small scale. T.l.c. showed the presence of 4-phenyl-1,2,3-benzotriazine.

Pyrazolo[3,4-b]*pyridine* (24).—Pyrazolo[3,4-*b*]pyridine, m.p. 98—100° (lit.,[18] 98—99°), was prepared in four stages from nicotinamide.[18]

5-*Methylpyrazolo*[4,3-b]*pyridine* (25).—5-Methylpyrazolo-[4,3-*b*]pyridine, m.p. 202—204° (lit.,[19] 203°), was prepared from 3-acetamido-2,6-dimethylpyridine.[19]

Pyrazolo[3,4-c]*pyridine* (26).—3-Acetamido-4-methylpyridine [38] was treated with nitrosyl chloride and acetic anhydride as described [19] for 3-acetamido-2,6-dimethylpyridine to give 1-*acetylpyrazolo*[3,4-c]*pyridine* (10%) as light-sensitive needles, m.p. 102—103° (from hexane), $\nu_{max.}$ 1705 (C=O), 1410, 1385, 1375, 1250, 930, and 820 cm^{-1}, *m/e* 161 (M^+). Hydrolysis with 15% hydrochloric acid gave *pyrazolo*[3,4-c]*pyridine* as needles (75%), m.p. 99—100° (from ethyl acetate) (Found: C, 60·5; H, 4·2; N, 35·3. $C_6H_5N_3$ requires C, 60·7; H, 4·3; N, 35·1%), $\nu_{max.}$ 3330 (NH), 1605, 1560, 1360, 1320, 1195, 1120, 1060, 830, and 820 cm^{-1}, $\lambda_{max.}$ 285 (log ε 3·60), 295 (3·50), and 303 nm (3·55), *m/e* 119 (M^+).

Reactions of 1,2,3-*Benzotriazines with Nucleophiles*.—1,2,3-*Benzotriazine*. (a) *Hydrolysis*. 1,2,3-Benzotriazine was kept overnight in tetrahydrofuran containing water (10%). T.l.c. indicated complete conversion into *o*-aminobenzaldehyde. Addition of dilute hydrochloric acid or copper sulphate caused very rapid hydrolysis.

(b) *Reaction with phenylhydrazine*. Phenylhydrazine (41 mg, 0·38 mmol) in dry methylene chloride (1 ml) was added to a solution of the triazine (50 mg, 0·38 mmol) in dry methylene chloride (5 ml), causing evolution of nitrogen. The solution was evaporated to dryness and the residue was recrystallised from ether–petroleum to give 2-*aminobenzaldehyde phenylhydrazone* (58 mg, 89%), m.p. 191—195°, mixed m.p. with a specimen prepared from *o*-aminobenzaldehyde and phenylhydrazine, 193—196°. The authentic specimen had m.p. 198—200° (Found: C, 74·0; H, 6·3; N, 19·9. $C_{13}H_{13}N_3$ requires C, 73·9; H, 6·2; N, 19·9%).

4-*Phenyl*-1,2,3-*benzotriazine*. (a) *Hydrolysis*. The triazine (100 mg) was heated under reflux for 10 min in 10% aqueous ethanol (10 ml) containing concentrated sulphuric acid (0·5 ml). After cooling the resulting solution was poured into water and extracted with methylene chloride. The methylene chloride layer was washed with water, dried (Na_2SO_4), and evaporated to give *o*-aminobenzophenone (91 mg, 100%).

(b) *Reaction with hydrazine*. The triazine (190 mg) was suspended in 95% aqueous ethanol (15 ml) and hydrazine hydrate (3·5 ml) was added. There was an immediate effervescence and complete dissolution. The solution was heated under reflux for 30 min and the hot solution was then poured into water (200 ml) and extracted with chloroform. The extracts were washed with water, dried, and evaporated to give 2-aminobenzophenone hydrazone (190 mg, 98%).

6-*Methylpyrido*[3,2-d]1,2,3-*triazine* (27). *Reaction with phenylhydrazine*. 6-Methylpyrido[3,2-*d*]1,2,3-triazine (146 mg, 1 mmol) was dissolved in dry methylene chloride (5 ml) and phenylhydrazine (108 mg, 1 mmol) in methylene chloride was added dropwise. Vigorous evolution of nitrogen occurred. The mixture was evaporated onto silica gel for chromatography. Elution with ethyl acetate gave 3-*amino*-6-*methylpyridine*-2-*carbaldehyde phenylhydrazone* (198 mg, 93%) as pale yellow needles (from chloroform–hexane), m.p. 79—80° (Found: C, 69·1; H, 6·2; N, 25·0. $C_{13}H_{14}N_4$ requires C, 69·0; H, 6·2; N, 24·8%), $\nu_{max.}$ 3400, 3300, 3200 (NH + NH_2), and 1600 (C=N) cm^{-1}, *m/e* 226 (M^+).

4-*Methoxy*-1,2,3-*benzotriazine*. *Reaction with hydrazine*. Hydrazine hydrate (0·5 ml) was added dropwise to a stirred solution of 4-methoxy-1,2,3-benzotriazine (161 mg, 1 mmol) in methanol (2 ml). After 15 min the resulting solid was filtered off, washed with a little methanol, and dried to give 4-hydrazino-1,2,3-benzotriazine (123 mg, 76%), m.p. 177—180° (decomp.). Recrystallisation from ethanol raised the m.p. to 183—184° (decomp.), mixed m.p. 183—184° (decomp.) [lit.,[10] 188° (decomp.)].

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