OBITUARY NOTICE.

BEVAN LEAN.

1865—1947

BEVAN LEAN received his early education at Ackworth School, near Pontefract, and at Bootham School, York. He proceeded in 1887 to Owens College, Manchester, to study chemistry, where his exceptional ability was soon recognised. He held the Dalton Scholarship for research in 1891 and the Berkeley Fellowship in 1893, and was appointed to the staff of the Chemistry Department as Assistant Lecturer and Demonstrator in 1894. As a student he was resident at Dalton Hall, and was Tutor in Chemistry there from 1889 to 1894.

During these years at Manchester Lean was actively engaged in research, and was author or part author of six papers in the *Transactions* of the Chemical Society, published in the years 1892—1900. The first of these, with W. A. Bone, was on the " Behaviour of Ethylene on Explosion with less than its own Volume of Oxygen ", but the remainder showed that his chief interest lay in the realm of synthetical organic chemistry and dealt with butanetetracarboxylic acids, their homologues, and derived compounds. He took the external London Degrees of B.Sc. (1889) and D.Sc. (1894).

In 1897 Lean forsook an assured academic future to devote his life to school teaching. After four years as science master at Ackworth, he was appointed Headmaster of the Friends' school at Sidcot, Somerset, a position which he held for twenty-eight years. While there, he published with W. H. Perkin, Junr., in 1909 " An Introduction to Chemistry and Physics ". Lean was himself a lifelong member of the Society of Friends, and was deeply religious. Under his influence the school developed greatly, and the discipline of his scientific training and his whole-hearted devotion to the welfare of the school and the individual scholars combined to make him a headmaster of outstanding ability who won the respect and affection of many generations of Sidcot scholars. He leaves a widow and two sons. The elder, Oscar B. Lean, is in medical practice, and the younger, Owen B. Lean, is an entomologist with Imperial Chemical Industries Ltd.

W. BAKER.

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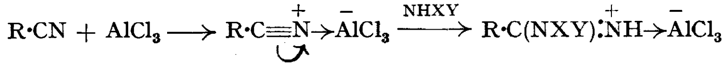
209. *Amidines. Part VII. Preparation of Amidines from Cyanides, Aluminium Chloride, and Ammonia or Amines.*

By P. OXLEY, M. W. PARTRIDGE, and W. F. SHORT.

Amidines and *N*-substituted amidines can be prepared from cyanides, aluminium chloride, and ammonia or an amine. The method gives good yields of *NN*-dialkylamidines, which are obtained in poor yield by the ammonium sulphonate method.

THE preparation of amidines from cyanides and ammonium or substituted ammonium sulphonates was described in Part I (Oxley and Short, *J.*, 1946, 147), in which the production of *NN*-disubstituted amidines was illustrated by a single example, namely *NN*-diphenylbenzamidine, obtained in 29% yield from phenyl cyanide and diphenylammonium benzenesulphonate. Application of the method to *p*-cyanophenyl methyl sulphone and piperidinium benzenesulphonate afforded NN-*pentamethylene*-p-*methylsulphonylbenzamidine* (27%), but our initial attempts to bring about a similar reaction with diethylammonium benzenesulphonate were unsuccessful. On raising the reaction temperature to 280°, however, *N*-ethyl-*p*-methylsulphonylbenzamidine was obtained in 0·8% yield, rising progressively to 4·5% at 325° The same amidine was obtained from the cyanide and triethylammonium benzenesulphonate at 305° (0·2%), ethylammonium benzenesulphonate at 280° (41%), or ethylammonium chloride at 250°. (We find that it is essential to use the ammonium salt of a sulphonic acid or ammonium thiocyanate in order to obtain reasonable yields of unsubstituted amidines, but mono- and dialkylammonium chlorides may give good yields of substituted amidines.) Ammonium benzenesulphonate (81%) was obtained when diethylammonium benzenesulphonate and phenyl cyanide were heated at 350° and little cyanide was recovered. Similarly, piperidinium benzenesulphonate and phenyl or benzyl cyanide at 300° gave ammonium benzenesulphonate and benzamidinium or phenylacetamidinium benzenesulphonate. These dealkylations recall the progressive dealkylation of trialkylammonium chlorides on heating (Hofmann, *Proc. Roy. Soc.*, 1860, **10**, 595; Fileti and Piccini, *Ber.*, 1879, **12**, 1508) and Werner's observation (*J.*, 1914, **105**, 2769) that whereas ammonium methyl sulphate rearranges to methylammonium hydrogen sulphate and undergoes some demethylation above 240°, ammonium ethyl sulphate is completely decomposed on heating into ammonium hydrogen sulphate and ethylene. We ultimately found that a 7% yield of *NN*-diethyl-*p*-methylsulphonylbenzamidine could be obtained from the cyanide and diethylammonium benzenesulphonate at 224° and was identical with a specimen prepared by the Pinner method. *NN*-Diethylbenzamidine was prepared by the Pinner method and its *toluene*-p-*sulphonate* was almost completely decomposed at 215—250° into phenyl cyanide and diethylammonium toluene-*p*-sulphonate. These observations indicate that the sulphonate method is unlikely to be generally suitable for the preparation of *NN*-dialkylamidines.

The few cyanides which are known to combine directly with ammonia or amines to yield amidines contain polar groups which stimulate the additive capacity of the cyano-group (Part I, *loc. cit.*), and it seemed probable that the reactivity of cyanides could be stimulated, as is the case with carbonyl compounds, by combination with a catalyst having strong kationoid properties. A number of alkyl cyanide–aluminium chloride complexes have been described (Genvresse, *Bull. Soc. chim.*, 1888, **49**, 341; Perrier, *Compt. rend.*, 1895, **120**, 1424; *Bull. Soc. chim.*, 1895, **13**, 1031), and it seemed likely that catalysts of the Friedel–Crafts type might enhance the dipole condition of the molecule and with it its reactivity :



$$\mathrm{R{\cdot}CN + AlCl_3 \longrightarrow R{\cdot}C{\equiv}\overset{+}{N}{\rightarrow}\overset{-}{A}lCl_3 \xrightarrow{NHXY} R{\cdot}C(NXY){:}\overset{+}{N}H{\rightarrow}\overset{-}{A}lCl_3}$$

On the other hand, aluminium chloride and similar kationoid compounds readily yield ammines with ammonia and amines, so that the efficiency of the catalyst would be reduced by the presence of the competitive anionoid centre in the base and would also depend upon the solubility of the respective complexes in the reaction mixture. Thus, *p*-cyanophenyl methyl sulphone and aluminium chloride yielded an insoluble brown complex which gave only traces of amidine (Fuller reaction; *Nature*, 1944, **154**, 773) when heated with ammonia in various solvents, but *p*-methylsulphonylbenzamidine was obtained in 54% yield when the cyanide and aluminium chloride were heated with excess of molten urea, which acts as a source of ammonia and as a solvent. A number of amidines have been prepared by heating a cyanide and aluminium chloride with a base, and the scope of the method is illustrated by the examples in the Table. It will be noted that the method affords good yields of *NN*-dialkylamidines and is therefore a useful supplement to the ammonium sulphonate method.

Amidine (*a*).	Yield, %.
Benzamidine (*b*)	57
o-Nitrobenzamidine (*c*)	13
p-Nitrobenzamidine (*c*)	60
p-Methylsulphonylbenzamidine (*c*)	54
β-Naphthamidine (*c*)	3·8
N-Phenylacetamidine (*d*)	50·5
*N-cyclo*Hexyldiethylacetamidine	28
N-Benzylbenzamidine	63
N-o-Nitrophenylbenzamidine	15
N-2-*Pyridylbenzamidine*	62
N-*Benzylanisamidine*	82·5
N-cyclo*Hexylanisamidine*	94
N-Phenyl-2 : 4-dichlorobenzamidine	74
N-2-*Pyridyl*-p-*methylsulphonylbenzamidine*	73·5
N-cyclo*Hexylphenylacetamidine*	90
*N-cyclo*Hexyl-1-amidino-*n*-heptane	98
1 : 3-*Bis*-(N-*phenyl*-4-*amidinophenoxy*)-*propane*	69
NN-Pentamethylenebenzamidine	37
N-Phenyl-*N*-methylbenzamidine	*ca.* 100
NN-Diethyl-*p*-methylsulphonylbenzamidine	*ca.* 100
NN-*Pentamethylene*-p-*methylsulphonylbenzamidine*	98
NN-*Diphenylpicolinamidine*	76

(*a*) The product was isolated as base, hydrochloride, picrate, or benzenesulphonate (see experimental section) : the yields recorded refer to the pure compound first isolated and are based on the cyanide employed.
(*b*) Gaseous ammonia used.
(*c*) Urea (16 mols.) employed as source of ammonia.
(*d*) *NN'*-Diphenylacetamidine (3·9%) was also formed.

We have made a cursory examination of the use of other catalysts for the production of amidines since it might be desirable to avoid the use of aluminium chloride in certain cases. Several catalysts used in reactions of the Friedel–Crafts type, such as ferric chloride, zinc, chloride, and stannic chloride, have been found to promote the formation of amidines, and other compounds exhibiting kationoid activity were also effective (see Table below). Boron trifluoride failed to promote the union of benzyl cyanide and *cyclo*hexylamine at 140°; this may be due to the stability of monoamminoboron trifluoride.

Catalyst.	Amidine.	Yield, %.
Ferric chloride	*p*-Nitrobenzamidine (*a*)	30
Zinc chloride	Phenylacetamidine (*a*)	33
	p-Nitrobenzamidine (*a*)	38
	N-Phenylbenzamidine	31
	N-*cyclo*Hexylphenylacetamidine	6
Stannic chloride	*p*-Nitrobenzamidine (*a*)	56
Triphenyltin chloride	*p*-Methylsulphonylbenzamidine	74
Triphenylaluminium	*NN*-Pentamethylene-*p*-methylsulphonylbenzamidine	32
Aluminium *iso*propoxide	*p*-Methylsulphonylbenzamidine	Trace
Triphenyl borate	Benzamidine	60
	NN-Pentamethylene-*p*-methylsulphonylbenzamidine	3·5
	p-Methylsulphonylbenzamidine (*b*)	60

(*a*) Urea used as source of ammonia. (*b*) Tribenzyl borate was ineffective.

EXPERIMENTAL.

Cyanides and Substituted Ammonium Benzenesulphonates.

Benzamidine.—Phenyl cyanide (10 g.) and piperidinium benzenesulphonate (25 g.; 1·06 mols.) were heated at 300° for 14 hours and afforded benzamidinium benzenesulphonate, m. p. and mixed m. p. 175—175·5° (5 g., 18·5%), and ammonium benzenesulphonate, m. p. and mixed m. p. 283—285° (6·2 g., 36·5%).

Phenylacetamidine.—Benzyl cyanide (10 g.) and piperidinium benzenesulphonate (12·5 g.; 1 mol.) similarly gave phenylacetamidinium benzenesulphonate, m. p. and mixed m. p. 186—186·5° (2·4 g., 16%), and ammonium benzenesulphonate, m. p. and mixed m. p. 283—285° (2·7 g., 30%), after 14 hours at 300°.

N-*Ethyl*-p-*methylsulphonylbenzamidine.*—(*a*) A mixture of *p*-methylsulphonylphenyl cyanide(9·05 g.) and ethylammonium benzenesulphonate (10·15 g.; 1 mol.) was heated at 275—280° for 80 minutes and the residue was recrystallised from hot water (100 c.c.), giving recovered cyanide (2 g.), m. p. and mixed m. p. 140—141°. The aqueous solution was extracted with chloroform and made alkaline with 5N-sodium hydroxide, and the amidine (4·6 g.; 41%) was collected in chloroform. This amidine was obtained as a gum, but N-*ethyl*-p-*methylsulphonylbenzamidinium picrate* had m. p. 155·5—156° (Found: N, 15·4. $C_{16}H_{17}O_9N_5S$ requires N, 15·4%). The *toluene*-p-*sulphonate* had m. p. 242° (Found: C, 51·2; H, 5·6; N, 7·2; S, 15·9. $C_{17}H_{22}O_5N_2S_2$ requires C, 51·25; H, 5·5; N, 7·0; S, 16·1%).

(*b*) A mixture of the cyanide (5 g.) and ethylammonium chloride (5 g.; 2·2 mols.) was heated at 250° for an hour and afforded 1·3 g. of recovered cyanide and 3·5 g. (56%) of crude amidine which gave 3·7 g. (34%) of pure toluene-*p*-sulphonate, m. p. and mixed m. p. 242°. After 3½ hours at 224° a mixture of the cyanide (5·43 g.) and ethylammonium chloride (9·8 g.; 4 mols.) afforded 27·6% of recovered cyanide and 43% of amidine, isolated as toluene-*p*-sulphonate. The following experiments with 5·43 g. of cyanide and 2·45 g. (1 mol.) of ethylammonium chloride illustrate the influence of experimental conditions on the yield of amidine.

Temp.	200—202°	224°	224°	224°	230°
Time, hrs.	1	2	4	14	1
Recovered cyanide, %	92	51·6	44·2	38·7	64·5
Yield of amidine, % *	2·85	15·9	26·7	32·3	17·9

* Isolated as toluene-*p*-sulphonate, m. p. 242°.

(*c*) *N*-Ethyl-*p*-methylsulphonylbenzamidine was also produced when the cyanide (5·5 g.) and diethylammonium benzenesulphonate (7 g.; 1 mol.) were heated at temperatures within the range 280—326°. The reaction mixture was worked up as described in (*a*), and the principal basic product was identified by the analysis and mixed m. p. of its toluene-*p*-sulphonate. Before purification this salt gave a faint Fuller reaction and therefore probably contained traces of *p*-methylsulphonylbenzamidinium toluene-*p*-sulphonate. The mother liquors may have contained *NN*-diethyl-*p*-methylsulphonylbenzamidinium toluene-*p*-sulphonate as a minor constituent. The results are summarised in the following table.

Temp.	280°	295°	310—312°	325—326°
Time, hrs.	2	½	½	½
Recovered cyanide, %	85	82	71	42
N-Ethyl-*p*-methylsulphonylbenzamidinium toluene-*p*-sulphonate (m. p. 242°), %	0·83	1·65	3·6	4·55

(*d*) Triethylammonium benzenesulphonate, prepared from its constituents and crystallised from *iso*propanol to constant m. p., formed hexagonal plates, m. p. 119° (Found: N, 5·5. Calc. for $C_{12}H_{21}O_3NS$: N, 5·4%). Norton and Westenhoff (*Amer. Chem. J.*, 1888, **10**, 133) record m. p. 120—121°. A mixture of this salt (12·95 g.; 1 mol.) and *p*-methylsulphonylphenyl cyanide (9·05 g.) was heated at 305—306° for 30 minutes. Gas evolution began at *ca.* 240° and continued throughout, the odour first resembling that of ethylamine but subsequently changing to that of a heterocyclic base. The product, which solidified on cooling, afforded 6·3 g. (70%) of recovered cyanide, m. p. 141—142°, and 0·55 g. of a crude base, from which only 0·04 g. (0·2%) of *N*-ethyl-*p*-methylsulphonylbenzamidinium toluene-*p*-sulphonate, m. p. and mixed m. p. 242°, was obtained.

N-*Methyl*-p-*nitrobenzamidine.*—A mixture of *p*-nitrophenyl cyanide (7·4 g.) and methylammonium chloride (3·9 g.; 1·2 mols.) became homogeneous after an hour's heating at 224° and after a further

3 hours at this temperature afforded 4·3 g. of recovered cyanide, m. p. 147°, and 0·7 g. (8%) of N-*methyl*-p-*nitrobenzamidine*, m. p. 137·5° (Found: N, 23·4. $C_8H_9O_2N_3$ requires N, 23·5%). The *picrate* crystallised from *iso*propanol in needles, m. p. 174·5° (Found: N, 20·6. $C_{14}H_{12}O_9N_6$ requires N, 20·6%).

NN-*Diethylbenzamidine*.—Benziminoethyl ether (10 g.; b. p. 106—108°/16 mm., Wheeler, Walden, and Metcalf, *Amer. Chem. J.*, 1898, **20**, 71), diethylammonium benzenesulphonate (15·5 g.; 1 mol.), and anhydrous ethanol (20 c.c.) were kept at 50° for 21 hours, then cooled and filtered to recover diethylammonium benzenesulphonate (6·5 g.). The filtrate was evaporated under diminished pressure and the residue was shaken with 2N-sodium hydroxide and chloroform. The dried chloroform solution was evaporated and the residue distilled. The first fraction, b. p. 65—85°/3 mm. (1 g.), smelled of phenyl cyanide, and the amidine, b. p. 85—90° (almost entirely at 88—89°/3 mm.) (6·1 g., 51·6%), then distilled leaving a residue (1·5 g.) of 2 : 4 : 6-triphenyl-1 : 3 : 5-triazine, m. p. 236° (Found: C, 81·5; H, 5·1; N, 13·6. Calc. for $C_{21}H_{15}N_3$: C, 81·55; H, 4·9; N, 13·6%). Robin (*Ann. Chim.*, 1921, **16**, 113) records m. p. 235°. NN-*Diethylbenzamidinium picrate* crystallised from methanol in plates, m. p. 161° (Found: N, 17·35. $C_{17}H_{19}O_7N_5$ requires N, 17·3%), and the *toluene*-p-*sulphonate* had m. p. 126° (Found: N, 8·1. $C_{18}H_{24}O_3N_2S$ requires N, 8·05%). When the imino-ether, benzenesulphonate, and ethanol were refluxed for 14 hours (internal temperature 90°), the yield of amidine was 5·1 g. (43%).

NN-Diethylbenzamidinium toluene-*p*-sulphonate began to decompose with evolution of phenyl cyanide at 215—220°, and after ½ hour at 250° the residue afforded diethylammonium toluene-*p*-sulphonate, m. p. and mixed m. p. 103°, after being washed with ether and crystallised from *iso*propanol–ether (Found: N, 5·7. Calc. for $C_{11}H_{19}O_3NS$: N, 5·7%). Norton and Otten (*Amer. Chem. J.*, 1888, **10**, 140) record m. p. 88°.

Considerable pressure was developed when phenyl cyanide (8·5 g.) and diethylammonium benzenesulphonate (19 g.; 1 mol.) were heated in a sealed tube for 22 hours at 345—350°. The resulting mixture of brown oil and colourless plates was triturated with chloroform and gave ammonium benzenesulphonate, m. p. and mixed m. p. 283—285° (11·6 g., 81%). The oil isolated from the chloroform solution distilled over a very wide range and afforded neither fractions of constant boiling point nor crystalline picrates.

NN-*Diethyl*-p-*methylsulphonylbenzamidine*.—(*a*) A solution of *p*-methylsulphonylphenyl cyanide (9·05 g.) in ethanol (2·5 g.; 1·1 mols.) and chloroform (60 c.c.) was treated with a current of hydrogen chloride until 2·3 g. (1·3 mols.) had been absorbed. The imino-ether hydrochloride (8·4 g.), m. p. 220—225° (decomp.), was collected after being kept for 60 hours at room temperature (cf. Fuller, Tonkin, and Walker, *J.*, 1945, 636; Andrewes, King, and Walker, *Proc. Roy. Soc.*, 1946, *B*, **133**, 46). The imino-ether (5·6 g., 49%), obtained as a viscous gum by shaking the hydrochloride with 5N-sodium hydroxide and chloroform, was heated with diethylammonium benzenesulphonate (6 g.; 1·05 mols.) for 1¼ hours at 140°. Alcohol was evolved, and trituration of the crystalline product with chloroform afforded an almost insoluble solid (0·35 g.) which separated from pyridine in colourless needles, m. p. >360°, and was probably 2 : 4 : 6-*tris*-p-*methylsulphonylphenyl*-1 : 3 : 5-*triazine* (Found: N, 8·0. $C_{24}H_{21}O_6N_3S_3$ requires N, 7·7%). Concentration of the chloroform solution afforded recovered cyanide (1·3 g., m. p. and mixed m. p. 141°) and then the crude amidine (2 g., 32%) which gave a picrate, m. p. 184·5°, identical with that obtained from *NN*-diethyl-*p*-methylsulphonylbenzamidine prepared by the aluminium chloride method (below).

(*b*) The cyanide (4·5 g.) and diethylammonium benzenesulphonate (23·1 g.; 4 mols.), heated at 224° for 14½ hours, afforded 3·5 g. of recovered cyanide and the crude amidine (0·5 g., 8%) which afforded the pure picrate, m. p. and mixed m. p. 184·5° (0·83 g., 7%). Almost the same yields were obtained when diethylammonium chloride (11 g.; 4 mols.) was used in place of the benzenesulphonate and the mixture heated at 224° for 2¼ hours.

(*c*) The preparation of this amidine by the aluminium chloride method is described below.

NN-*Pentamethylene*-p-*methylsulphonylbenzamidine*.—*p*-Methylsulphonylphenyl cyanide (4·5 g.) and piperidinium benzenesulphonate (24·3 g.; 4 mols.) were heated at 230° for 4 hours and gave 2·4 g. of recovered cyanide and 1·8 g. (27%) of *NN*-pentamethylene-*p*-methylsulphonylbenzamidine, m. p. 97°. The amidine afforded a toluene-*p*-sulphonate, m. p. 230—231°, and there was no depression in m. p. on admixture of the amidine and its salt with preparations made by the aluminium chloride method (see below).

*Preparation of Amidines from Cyanides, Bases, and Kationoid Reagents.**

Except where otherwise indicated, the cyanide and the base were employed in the proportion of one mol. of base per cyano-group, and one mol. of aluminium chloride (reckoned as $AlCl_3$) or of zinc chloride was added to the mixture. The experimental conditions used varied considerably and did not appear to be critical. The yields recorded are not necessarily the highest obtainable since a systematic examination of the effect of conditions on the yield of amidine was made in only a few cases. The reaction product, consisting of a complex of the amidine with the catalyst, was carefully decomposed with water and, when the amidine hydrochloride was sparingly soluble in water, it separated on cooling from the hot, filtered solution. Usually, however, the amidine was liberated from the solution by excess of aqueous sodium hydroxide, collected in chloroform, and then isolated as base, picrate, or hydrochloride. The methods employed follow closely those described in previous parts of this series, to which reference is made for earlier descriptions of many of the amidines (Part I, Oxley and Short, *J.*, 1946, 147; Part II, Oxley, Robson, Partridge, and Short, *ibid.*, p. 763; Part III, Oxley and Short, this vol., p. 382; Part IV, Partridge and Short, *ibid.*, p. 390; Part V, Hullin, Miller, and Short, *ibid.*, p. 394).

Benzamidine.—(*a*) A mixture of phenyl cyanide (2·1 g.) and aluminium chloride (5·3 g.; 2 mols.) was heated at 100° for 30 minutes in an atmosphere of dry ammonia, and the amidine was isolated as picrate, m. p. and mixed m. p. 239—240°. Yield, 3·95 g.

(*b*) Phenyl cyanide (2·06 g.), ammonium benzenesulphonate (3·5 g.; 1 mol.), and triphenyl borate

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* See also B.P. Applns. 22748 and 22749 (4.9.1945).

(5·8 g.; 1 mol.) gave a 60% yield of benzamidinium benzenesulphonate, m. p. and mixed m. p. 175—175·5°, when heated at 160° in a stream of dry ammonia for 5 hours.

o-*Nitrobenzamidine.*—*o*-Nitrophenyl cyanide (5·6 g.), aluminium chloride (5 g.), and urea (36 g.; 16 mols.) were heated at 180° for 2 hours with vigorous stirring. The amidine was isolated as picrate, m. p. 228—229° (Found: N, 21·4. Calc. for $C_{13}H_{10}O_9N_6$: N, 21·3%). Yield, 1·9 g. The m. p. of *o*-nitrobenzamidinium picrate is recorded in Part I as 232—233° (decomp.).

p-*Nitrobenzamidine.*—(*a*) This amidine was prepared from *p*-nitrophenyl cyanide (1·5 g.), aluminium chloride, and urea in the proportions used in the previous example, and was isolated either as base, m. p. 216° (decomp.), or as picrate, m. p. 239—240° (Part I). After 15 minutes at 180° the yield was 26% and rose to 60% after 30 minutes. When only 8 mols. of urea were employed, the reaction mixtures solidified after 20 minutes and the yield of *p*-nitrobenzamidine was only 4%.

(*b*) A mixture of *p*-nitrophenyl cyanide (1·5 g.), urea (9·6 g.; 16 mols.), and zinc chloride (1·4 g.) afforded a homogeneous mixture after being stirred at 180° for 15 minutes, and after another 15 minutes at this temperature the yield of amidine, m. p. 212°, was 38%.

(*c*) A 9·1% yield of amidine was obtained when the cyanide (3 g.) and zinc chloride (2·8 g.) were heated at 180° for 15 minutes in a stream of ammonia. After 15 minutes at 135—140° the yield was 1·5%.

(*d*) When *p*-nitrophenyl cyanide (1·5 g.), urea (9·6 g.; 16 mols.), and anhydrous ferric chloride (1·6 g.) were heated to 120°, an exothermic reaction raised the temperature to 180°, and the cooled reaction mixture then afforded a 30% yield of the amidine.

(*e*) The cyanide (1·5 g.), urea (2·4 g.; 4 mols.), and stannic chloride (2·6 g.) afforded a 56% yield of amidine, isolated as picrate, m. p. 230—232°, after 30 minutes at 180°. Recrystallisation from methanol raised the m. p. of the picrate to 238—239°.

p-*Methylsulphonylbenzamidine.*—(*a*) A mixture of *p*-methylsulphonylphenyl cyanide (9 g.), aluminium chloride (6·7 g.), and urea (48 g.; 16 mols.) was heated at 180° for 30 minutes. The amidine was isolated as the picrate, m. p. and mixed m. p. 263—264° (Part IV). Yield, 11·5 g.

p-Methylsulphonylphenyl cyanide (4·5 g.) and aluminium chloride (3·3 g.; 1 mol.) afforded a brown complex when heated in benzene (250 c.c.). This solid, which softened at 95—105° and decomposed at 120—125° with gas evolution, gave a trace of amidine (Fuller reaction) when heated in a stream of ammonia in various solvents. A similar result was obtained when zinc chloride, ferric chloride, or stannic chloride was substituted for aluminium chloride. Only traces of amidine were formed when the cyanide and aluminium *iso*propoxide were heated in ammonia at 100° or 110°, 99% of the cyanide being recovered.

(*b*) A mixture of *p*-methylsulphonylphenyl cyanide (1·81 g.) and triphenyltin chloride (3·85 g.; 1 mol.; Kozeschkov, Nadj, and Alexandrov, *Ber.*, 1934, **67**, 1348) was heated for 24 hours at 100° in a stream of ammonia, and the amidine was isolated as p-*methylsulphonylbenzamidinium toluene*-p-*sulphonate*, m. p. 292—293° (Found: N, 7·6. $C_{15}H_{18}O_5N_2S_2$ requires N, 7·6%). The yield was 2·75 g. (74%).

(*c*) A 40% yield of the toluene-*p*-sulphonate was similarly prepared from the product obtained by heating the cyanide (3·62 g.) and triphenyl borate (5·8 g.; 1 mol.) in a stream of ammonia for 17 hours at 100°. No amidine was obtained when tribenzyl borate (1 mol.) was used in place of triphenyl borate.

β-Naphthamidine.—A mixture of *β*-naphthyl cyanide (1·5 g.), urea (9·6 g.; 16 mols.), and aluminium chloride (1·3 g.) evolved ammonia when heated but was not completely homogeneous after 1 hour at 180°. The product afforded *β*-naphthamidinium picrate (0·15 g.), m. p. 248°, and recrystallisation from methanol gave the pure product, m. p. and mixed m. p. 252° (Part I).

Phenylacetamidine.—Phenylacetamidinium picrate (1·18 g.), m. p. and mixed m. p. 227—228° (decomp.), was prepared from the homogeneous melt obtained by heating benzyl cyanide (1·2 g.), urea (9·6 g.; 16 mols.), and zinc chloride (1·4 g.) at 180° for an hour. The same m. p. is recorded in Part IV.

N-*Phenyl- and* NN′-*Diphenyl-acetamidine.*—Powdered aluminium chloride (66·6 g.) was added in portions during ¾ hour to methyl cyanide (20·5 g.) and aniline (46·5 g.) so that the temperature remained at 90—100°, and the mixture was kept at 100° for an hour. The mixture of bases (58·7 g.), isolated from the product in the usual way, afforded crystals (3·9%) of *NN′*-diphenylacetamidine, m. p. 131—132°, on recrystallisation from aqueous methanol. A second recrystallisation from aqueous methanol afforded the pure amidine, m. p. 133·5—134° (cf. Part III). The original mother liquor was made acid to brilliant-yellow with ethanolic picric acid and the crude picrate was recrystallised from methanol giving *N*-phenylacetamidinium picrate, m. p. 194—195° (Found: N, 19·3. Calc. for $C_{14}H_{13}O_7N_5$: N, 19·3%), higher than the values previously recorded (Part III). Yield, 91·6 g.

N-cyclo*Hexyl-αα-diethylacetamidine.**—When powdered aluminium chloride (10·6 g.) was added in one portion to 1-ethylbutyl cyanide (7·7 g.; Ziegler and Ohlinger, *Annalen*, 1932, **495**, 110) and *cyclo*hexylamine (9·6 g.; 1·2 mols.), the temperature rose to about 200°. When the temperature had fallen to 100°, the product was mixed with ice (100 g.) and the solid was collected and washed with a little ether. Recrystallisation of the solid (12 g.) from 0·5N-hydrochloric acid (125 c.c.) afforded 5·1 g. of N-cyclo*hexyl-αα-diethylacetamidinium chloride*, m. p. 240—242° (Found: N, 12·3. $C_{12}H_{25}N_2Cl$ requires N, 12·0%).

N-*Benzylbenzamidine.*—Aluminium chloride (13·3 g.) was added with stirring during 30 minutes to phenyl cyanide (10·3 g.) and benzylamine (10·7 g.) so that the temperature remained below 120°. After 20 minutes' heating at 180°, the amidine was isolated, collected in chloroform, and converted in aqueous solution into the hydrochloride, m. p. and mixed m. p. 227—229° (Part V). The yield of hydrochloride was 10·6 g., and 8·6 g. of *N*-benzylbenzamidinium picrate, m. p. 162—164°, were obtained from the mother liquor and sodium picrate solution. Recrystallisation from ethanol raised the m. p. of the picrate to 169—170° (Part V).

N-o-*Nitrophenylbenzamidine.*—*o*-Nitroaniline (13·8 g.) was dissolved in phenyl cyanide (10·3 g.) at 50°, finely powdered aluminium chloride (13·4 g.) was then added, and the mixture was stirred at 140°

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* Preparation by Mr. J. Miller.

for 20 minutes. The amidine was liberated, collected in chloroform, dissolved in an equivalent of 5N-hydrochloric acid, and mixed with aqueous sodium picrate. Recrystallisation of the precipitate from aqueous cellosolve afforded N-o-*nitrophenylbenzamidinium picrate*, m. p. 208—209° (Found : N, 17·9. $C_{19}H_{14}O_9N_6$ requires N, 17·9%). Yield, 6·92 g.

N-2-*Pyridylbenzamidine*.—When aluminium chloride (6·7 g.) was added to a mixture of phenyl cyanide (5·15 g.) and 2-aminopyridine (4·7 g.) the temperature rose to 160° and the reaction was completed by heating at 200° for 15 minutes. Crystallisation of the crude amidine from light petroleum afforded N-2-*pyridylbenzamidine*, m. p. 99—99·5° (Found : N, 21·3. $C_{12}H_{11}N_3$ requires N, 21·3%). Yield, 6·1 g. The *picrate* crystallised from methanol in plates, m. p. 209° (Found : N, 19·9. $C_{18}H_{14}O_7N_6$ requires N, 19·7%), and the *toluene*-p-*sulphonate* had m. p. 171·5° (Found : N, 11·6. $C_{19}H_{19}O_3N_3S$ requires N, 11·4%).

N-*Phenylbenzamidine*.—A mixture of phenyl cyanide (5·2 g.), aniline (4·7 g.), and zinc chloride (6·8 g.) was heated at 110—115° for 30 minutes, and the temperature was then quickly raised to 210° to give a homogeneous melt, which was then cooled immediately. The crude amidine afforded 0·54 g. of *N*-phenylbenzamidine, m. p. and mixed m. p. 116° (Part I), on crystallisation from ethanol, and a second crop (2·5 g.), m. p. 112°, gave pure amidine (2·45 g.) when purified through the toluene-*p*-sulphonate.

N-*Benzylanisamidine*.—The temperature rose to about 200° when aluminium chloride (13·4 g.) was added to *p*-methoxyphenyl cyanide (13·3 g.) and benzylamine (11 g.). The product was crystallised from water giving N-*benzylanisamidinium chloride*, m. p. 225° (Found : N, 10·1. $C_{15}H_{17}ON_2Cl$ requires N, 10·1%). Yield, 22·8 g. N-*Benzylanisamidine* crystallised from light petroleum (b. p. 80—100°) in prisms, m. p. 89° (Found : N, 11·5. $C_{15}H_{16}ON_2$ requires N, 11·7%).

N-cyclo*Hexylanisamidine*.—*p*-Methoxyphenyl cyanide (6·65 g.), *cyclo*hexylamine (6·0 g.), and aluminium chloride (7 g.), brought into reaction as described in the previous example, afforded N-cyclo*hexylanisamidinium chloride* (12·6 g.), m. p. 275—276° (decomp.) (Found : N, 10·4. $C_{14}H_{21}ON_2Cl$ requires N, 10·4%). N-cyclo*Hexylanisamidine*, purified by sublimation in a vacuum, had m. p. 100° (Found : N, 12·3. $C_{14}H_{20}ON_2$ requires N, 12·1%), and the *picrate* crystallised from ethanol in needles, m. p. 141° (Found : N, 15·3. $C_{20}H_{23}O_8N_5$ requires N, 15·2%).

N-*Phenyl*-2 : 4-*dichlorobenzamidine*.—Powdered aluminium chloride (6·7 g.) was added during 10 minutes to a solution of 2 : 4-dichlorophenyl cyanide (8·6 g.) in aniline (4·7 g.) prepared at 50°. The temperature rose to *ca.* 130° during the addition and the reaction was completed by heating at 140° for an hour. The crude amidine (12·7 g.) was converted into N-*phenyl*-2 : 4-*dichlorobenzamidinium chloride* (11·1 g.), m. p. 147—149° (Found : N, 9·0. $C_{13}H_{11}N_2Cl_3$ requires N, 9·3%). Addition of sodium picrate to the mother liquors afforded the *picrate* (2·4 g.), m. p. 148—149° (Found : N, 13·9. $C_{19}H_{13}O_7N_5Cl_2$ requires N, 14·15%).

N-2-*Pyridyl*-p-*methylsulphonylbenzamidine*.—Aluminium chloride (4·5 g. ; 0·7 mol.) was added with cooling to *p*-methylsulphonylphenyl cyanide (9·05 g.) and 2-aminopyridine (4·7 g.), and the mixture was then heated at 180° for 30 minutes. N-2-*Pyridyl*-p-*methylsulphonylbenzamidine* (10·1 g.) crystallised from methanol in colourless plates, m. p. 170·5° (Found : N, 15·5. $C_{13}H_{13}O_2N_3S$ requires N, 15·3%). The base afforded a *monopicrate*, m. p. 208—208·5° (Found : N, 16·4. $C_{19}H_{16}O_9N_6S$ requires N, 16·7%). Less than 0·1% of this amidine was produced when the cyanide and 2-aminopyridine benzenesulphonate (4 mols.) were heated at 224° for 5 hours.

N-cyclo*Hexylphenylacetamidine* —(*a*) The addition of aluminium chloride (13·4 g.) to benzyl cyanide (11·7 g.) and *cyclo*hexylamine (9·9 g.) was regulated so that the temperature of the mixture did not exceed 140°, and the cold reaction product was decomposed by cold water (100 c.c.). The crude hydrochloride (22·7 g., m. p. 299—300° decomp.) was collected after cooling, and recrystallisation from water afforded N-cyclo*hexylphenylacetamidinium chloride*, m. p. 301—302° (decomp.) (Found : N, 11·0. $C_{14}H_{21}N_2Cl$ requires N, 11·1%). N-cyclo*Hexylphenylacetamidine* crystallised from light petroleum (b. p. 100—120°) in needles, m. p. 122·5° (Found : N, 12·95. $C_{14}H_{20}N_2$ requires N, 13·0%). The *picrate* had m. p. 103—105° (Found : N, 15·9. $C_{20}H_{33}O_7N_5$ requires N, 15·7%). The effect of variations in the proportion of reactants and in the reaction conditions on the yield of amidine is shown in the table below. Each experiment was performed with 11·7 g. of benzyl cyanide, and variations in the reaction time were due to the necessity of controlling the temperature in some experiments by regulating the rate of addition of aluminium chloride and in others by heating the reaction mixture.

Benzylamine (mols.)	1	1	1	1	1	1	3	1	0·33
Aluminium chloride (mols.)	1	0·5	0·25	0·1	0·5	0·5	0·5	0·7	0·5
Temp.	140°	140°	140°	140°	80°	80° *	80°	15°	80°
Time, mins.	20	20	35	35	60	150	60	60	60
Yield of amidine, %	90	88	50	33	66	31	86	7·5	78 †

* Benzene (50 c.c.) was used as solvent. † Calculated on the amine.

(*b*) The temperature rose to *ca.* 60° when anhydrous zinc chloride (13·7 g.) was added to benzyl cyanide (11·7 g.) and *cyclo*hexylamine (9·9 g.), and after 2 hours at 200° *N*-*cyclo*hexylphenylacetamidine (1·2 g. or 6%), m. p. and mixed m. p. 122·5°, was isolated from the reaction product. After 30 minutes at 100° the yield of amidine was 5%.

N-cyclo*Hexyl*-1-*amidino*-n-*heptane*.—An exothermic reaction occurred when aluminium chloride (2·7 g.) was added to *n*-heptyl cyanide (2·5 g.) and *cyclo*hexylamine (2 g.), and the temperature rose to *ca.* 200°. The reaction mixture, which was allowed to cool immediately, afforded N-cyclo*hexyl*-1-*amidino*-n-*heptane hydrochloride* (5·1 g.), m. p. 200° (Found: N, 10·65. $C_{14}H_{29}N_2Cl$ requires N, 10·75%). The *picrate* had m. p. 102° (Found : N, 15·6. $C_{20}H_{31}O_7N_5$ requires N, 15·45%).

1 : 3-*Bis*-(N-*phenyl*-4-*amidinophenoxy*)*propane*.—Powdered aluminium chloride (2·67 g. ; 1 mol.) was added during 10 minutes with stirring to a mixture of 1 : 3-bis-(4-cyanophenoxy)propane (5·6 g.) and aniline (3·7 g. ; 2 mols.) previously heated to 140°, and, after 20 minutes at this temperature, the mixture was cooled and decomposed with hot aqueous alcohol. The crude amidine (6·4 g.) was

liberated and converted into 1 : 3-*bis*-(N-*phenyl*-4-*amidinophenoxy*)*propane benzenesulphonate*, m. p. 219—220° (Found : N, 7·3. $C_{41}H_{40}O_8N_4S_2$ requires N, 7·2%). The *amidine* had m. p. 206—207° (Found : N, 12·1. $C_{29}H_{28}O_2N_4$ requires N, 12·1%), and the *hydrochloride*, m. p. 287—288° (decomp.) (Found : N, 10·5. $C_{29}H_{30}O_2N_4Cl_2$ requires N, 10·4%).

NN-*Pentamethylenebenzamidine*.—Aluminium chloride (13·4 g.) was added during 20 minutes with cooling in ice-water to phenyl cyanide (10·3 g.) and piperidine (8·5 g.), and the mixture was subsequently heated on the steam-bath for 1½ hours. *NN*-Pentamethylenebenzamidine (6·9 g.), b. p. 98°/0·5 mm., was isolated from the product and converted into the picrate, m. p. and mixed m. p. 173—174° (Part IV).

N-*Phenyl*-N-*methylbenzamidine*.—Aluminium chloride (6·7 g.) was slowly added to phenyl cyanide (5·15 g.) and methylaniline (5·35 g.), and, after 20 minutes at 160°, *N*-phenyl-*N*-methylbenzamidine (10·5 g.) was isolated; it crystallised from light petroleum (b. p. 60—80°) in needles, m. p. 85·5° (Found : N, 13·3. Calc. for $C_{14}H_{14}N_2$: N, 13·3%). The picrate had m. p. 187° (Found : N, 15·9. Calc. for $C_{20}H_{17}O_7N_5$: N, 15·9%). The m. p.s of the amidine and its picrate are recorded in Part V as 85° and 186—188° respectively.

NN-*Diethyl*-p-*methylsulphonylbenzamidine*.—A mixture prepared by slowly adding aluminium chloride (7 g.) to *p*-methylsulphonylphenyl cyanide (9·05 g.) and diethylamine (7·3 g.; 2 mols.) was heated on the steam-bath for 1½ hours, and afforded the crude amidine (12·8 g.) as a gum. NN-*Diethyl*-p-*methylsulphonylbenzamidinium picrate* had m. p. 184·5° (Found : N, 14·7. $C_{18}H_{21}O_9N_5S$ requires N, 14·5%), and the *toluene*-p-*sulphonate* had m. p. 162° (Found : N, 6·6. $C_{19}H_{26}O_5N_2S_2$ requires N, 6·6%).

NN-*Pentamethylene*-p-*methylsulphonylbenzamidine*.—(*a*) A mixture of *p*-methylsulphonylphenyl cyanide (9·05 g.), piperidine (8·5 g.; 2 mols.), and aluminium chloride (7 g.), prepared and heated as in the last example, afforded NN-*pentamethylene*-p-*methylsulphonylbenzamidine* (13·1 g.), m. p. 97° (Found : N, 10·4. $C_{13}H_{18}O_2N_2S$ requires N, 10·5%). The *picrate* was first obtained from methanol in slender needles, m. p. 199—199·5° (Found : N, 14·2. $C_{19}H_{21}O_9N_5S$ requires N, 14·5%), but a second form crystallising from the same solvent in cubic crystals, m. p. 188·5°, was subsequently obtained. The lower-melting form was converted into the needle form, m. p. 199·5°, at its m. p., and either could be obtained by inoculating a methanolic solution with a crystal of the desired form. The *toluene*-p-*sulphonate* crystallised from alcohol in prisms, m. p. 230—231° (Found : N, 6·5. $C_{20}H_{26}O_5N_2S_2$ requires N, 6·4%).

The following experiments, performed on a 0·025 g.-mol. scale using equimolecular proportions of the reactants, illustrate the influence of solvents on the yield of amidine. The yields are in terms of the picrate, m. p. 199·5°.

Solvent.	Nitrobenzene.	Chloroform.	Carbon tetrachloride.	Benzene.	
Vol., c.c.	20	25	25	25	25
Temp.	95°	65°	80°	85°	85°
Time, hrs.	1	2	2	2	6
Yield, %	25	15·2	25·0	56·5	60·5

(*b*) Triphenylaluminium, prepared from aluminium turnings (1 g., 2·7 atoms) and diphenylmercury (5 g.; 1 mol.) (cf. Hilpert and Gruttner, *Ber.*, 1912, **45**, 2828), was mixed with *p*-methylsulphonylphenyl cyanide (2·5 g.) and piperidine (1·2 g., 1 mol.). The temperature rose spontaneously to 125° and was maintained by heating for another 10 minutes. The crude amidine (1·7 g.) was isolated, and afforded the pure picrate (2·2 g., 32%), m. p. 199·5°.

(*c*) A solution of *p*-methylsulphonylphenyl cyanide (3·62 g.), piperidine (1·7 g.; 1 mol.), and triphenyl borate (5·8 g.; 1 mol.) in benzene (10 c.c.) was boiled for 2 hours (internal temp. 85°) and diluted with chloroform, and the amidine was extracted with dilute sulphuric acid. The yield of picrate, m. p. 199·5°, was 3·5%.

(*d*) The preparation of this amidine by the benzenesulphonate method is described above.

NN-*Diphenylpicolinamidine*.—2-Cyanopyridine (5·2 g.) and diphenylamine (8·5 g.) were warmed until a homogeneous mixture was obtained, and powdered aluminium chloride (6·7 g.) was then added with stirring, the temperature rising to 85°. The mixture was heated at 140° for 30 minutes and the amidine was then liberated and collected in chloroform. The crude amidine (10·4 g.; m. p. 116—118°) was crystallised several times from light petroleum and afforded NN-*diphenylpicolinamidine*, m. p. 129—130° (Found : N, 15·2. $C_{18}H_{15}N_3$ requires N, 15·4%). The *picrate* crystallised from methano in prisms, m. p. 164·5—165·5° (Found : N, 16·5. $C_{24}H_{18}O_7N_6$ requires N, 16·7%).

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[*Received, November 27th,* 1946.]