Preparation of Ring-fused Pyridazines by Reduction of 3,3'-Dinitro-4,4'-bipyridyl and 3,3'-Dinitro-4,4'-biquinolyl

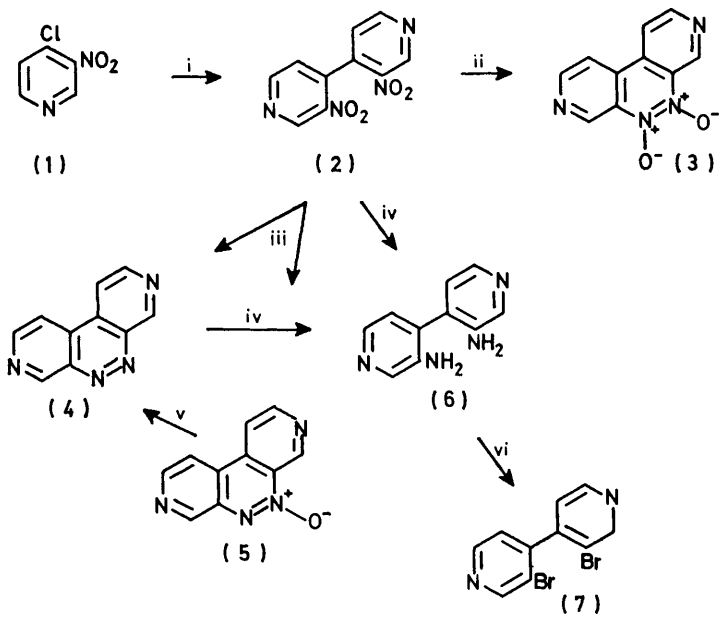
By **Santhi Kanoktanaporn** and **J. A. Hugh MacBride,*** Chemistry Division, Department of Physical Sciences, The Polytechnic, Chester Road, Sunderland SR1 3SD

Ullmann coupling of 4-chloro-3-nitropyridine and of 4-chloro-3-nitroquinoline in amide solvents gives the dinitrobipyridyl (2) and -biquinolyl (9), which on reductive ring closure give dipyrido- and diquinolino-pyridazines and their mono- and di-*N*-oxides; further reduction easily opens the pyridazine rings giving the diamines (6) and (12). The pyridazine ring can be reformed by oxidation of the diamine (12) with perdisulphuric acid. Hydrazine with sodium hydroxide converts the dinitro-biquinolyl (but not the bipyridyl) into an *N*-hydroxypyrrole (11), probably by nucleophilic displacement of a nitro-group, and further reduction gives the diquinolinopyrrole (14).

We needed 2,7,9,10-tetra-azaphenanthrene (4) and its dibenzo-derivative (15) in a study of the thermal extrusion [1,2] of nitrogen from the 9,10-diazaphenanthrene (benzo[*c*]cinnoline) ring system and we here report our investigation into the preparation of these new heterocyclic systems by Ullmann condensation of 4-chloro-3-nitropyridine (1) and 4-chloro-3-nitroquinoline (8), and reduction of the resulting dinitro-biaryls (2) and (9). The corresponding preparation of 4,5,9,10-tetra-azaphenanthrenes from 2-chloro-3-nitropyridines has been reported [3] but we are not aware of another example of the use of the Ullmann biaryl synthesis with *ortho*-halogenonitro-derivatives of pyridine or quinoline (in the heterocyclic ring).

Reaction between copper and 4-chloro-3-nitropyridine [4] in dimethylformamide at 100 °C gave a dark brown crystalline 1 : 1-complex of 3,3'-dinitro-4,4'-bipyridyl with cuprous chloride. The i.r. frequencies assigned to the nitro-groups in the complex (1 533 and 1 351 cm^{-1}) are close to those in the free ligand (1 528 and 1 350 cm^{-1}) showing that the nitro-groups are not involved in bonding to the metal. The somewhat intractable, presumably polymeric, complex was decomposed (without isolation in the normal procedure) by concentrated aqueous ammonia leaving the dinitrobipyridyl (2) which darkens quickly in light and begins to decompose at *ca.* 130 °C.

The dinitrobipyridyl (2) was treated with a series of reducing agents and the results are shown in Scheme 1. The pyridazine ring of the tetra-azaphenanthrene system (4) is more easily cleaved by reduction than that of benzo[*c*]cinnoline, which can be obtained [5] by reduction of its *N*-oxide with zinc and acetic acid, whereas the tetra-azaphenanthrene (4) and its *N*-oxide (5) each give

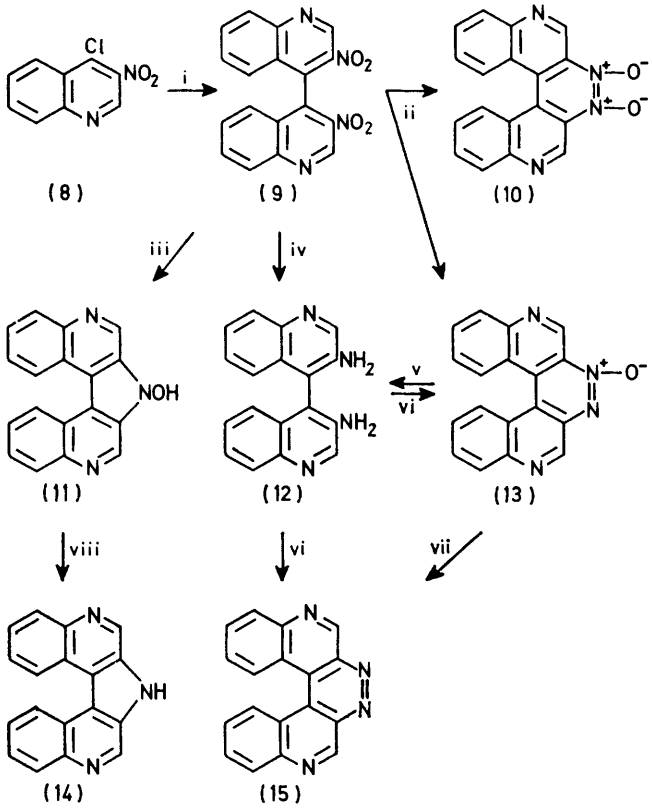


Scheme 1 *Reagents:* i, Cu–DMF at 100 °C; ii, As_2O_3–NaOH; iii, Na_2S–water at 20 °C; iv, Zn–AcOH (*etc.*); v, $Fe(H_2)$ at 250 °C; vi, HNO_2 at 5 °C, then Cu_2Br_2

[1] J. A. H. MacBride, *J.C.S. Chem. Comm.*, 1972, 1219.
[2] J. A. H. MacBride, *J.C.S. Chem. Comm.*, 1974, 359; S. Kanoktanaporn and J. A. H. MacBride, *Tetrahedron Letters*, 1977, 1817.
[3] A. Etienne and G. Izoret, F.P. 1,369,401 (1964) (*Chem. Abs.*, 1965, 570h); J. L. Murray and J. J. Porter, *J. Amer. Chem. Soc.*, 1965, **87**, 1628; J. W. Barton and R.. B. Walker, *Tetrahedron Letters*, 1975, 569.
[4] S. Kruger and F. G. Mann, *J. Chem. Soc.*, 1955, 2755.
[5] G. M. Badger, J. H. Seidler, and B. Thompson, *J. Chem. Soc.*, 1951, 3207.

the diamine (6) with this reagent. The most convenient preparation of pure 2,7,9,10-tetra-azaphenanthrene (4) is reduction of the dinitrobipyridyl (2) with aqueous sodium sulphide followed by deoxygenation of the minor amount (*ca.* 25%, by i.r.) of the *N*-oxide (5) in the resulting mixture by heating it to 250 °C with iron powder. The material supplied as ' iron powder reduced by hydrogen ' is most effective but a little of the diamine (6) is produced, presumably from hydrogen in the iron. Deoxygenation of the *N*-oxide (5) with boiling phosphorus trichloride was very slow; the proportion of *N*-oxide in the mixture was only slightly diminished after 6 h (by i.r.). The pure *N*-oxide (5), not isolable from the mixture with (4), was obtained (probably by spontaneous oxidation of the bishydroxylamino-derivative) when the dinitrobipyridyl (2) was reduced with 4 molecular equivalents of hydrogen.

The diamine (6) gave the dibromobipyridyl (7) upon diazotisation and addition of cuprous bromide; several

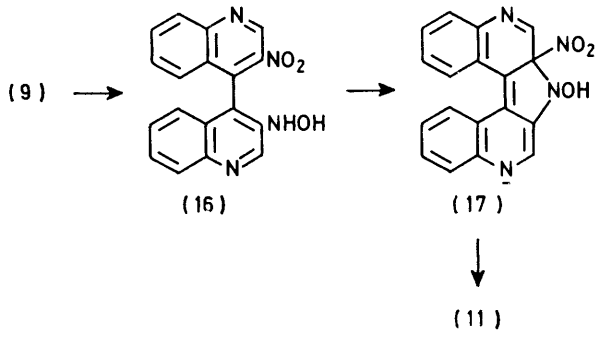


SCHEME 2 *Reagents:* i, Cu–HMPA at 100 °C; ii, H_2–Pt in dioxan at 20 °C; iii, N_2H_4–NaOH in dioxan at 100 °C; or Na_2S and H_2O in dioxan at 100 °C; iv, H_2–Pt in AcOH at 20 °C; v, Fe(H_2) at 260 °C; vi, $K_2S_2O_8$–H_2SO_4 in H_2O–$CHCl_3$ at 60 °C; vii, Fe(H_2) at 200 °C; viii, Fe(H_2) at 300 °C; or Zn–HOAc at 75 °C

minor products were observed but not isolated in this experiment.

With minor modification our procedure for Ullmann condensation worked well with 2-chloro-3-nitropyridine giving 3,3′-dinitro-2,2′-bipyridyl, which is light-stable and gives 4,5,9,10-tetra-azaphenanthrene [3] with aqueous sodium sulphide; a second deoxygenation step is unnecessary since only minor amounts of impurity, removable by recrystallisation, are formed.

The same procedure for Ullmann condensation of 4-chloro-3-nitroquinoline failed in dimethylformamide or



N-methylpyrrolidone, but in hexamethylphosphoramide gave the light-stable dinitrobiquinolyl (9) in 55% yield. The results of reduction experiments with this compound are shown in Scheme 2. Sodium sulphide did not give the expected pyridazine (15); instead the *N*-hydroxypyrrole (11) was isolated in low yield; the same product was obtained, in much better yield, when the dinitrobiquinolyl (9) was treated with hydrazine and sodium hydroxide. No simple product was observed when the dinitrobipyridyl (2) was treated with this reagent. Further reduction of the hydroxypyrrole (11) gave the pyrrole (14).

We postulate that the pyrrole system of (11) is formed by reduction of the dinitrobiquinolyl (9) to the hydroxylamino-derivative (16) followed by nucleophilic displacement of the second nitro-group *via* an intermediate anion such as (17).

Hydrogenation of the dinitrobiquinolyl (9) over platinum in dioxan solution gave the required pyridazine system as a mixture of the sparingly soluble *N*-oxide (13) and di-*N*-oxide (10), which precipitate and stop the reaction. Pyrroles were not detected under these conditions, perhaps because both nitro-groups are reduced, in a transoid conformation on the catalyst surface, before desorption. Deoxygenation of the *N*-oxide (13) was achieved with iron powder at 200 °C; at 260 °C only the diamine (12) was obtained, while phosphorus trichloride degraded the molecule to uncharacterised water-soluble materials. The pyridazine ring of (13) is, therefore, even more easily cleaved than that of its pyridine analogue (5); distortion by interaction between the benzene rings of (13) is presumably the reason.

Disappointingly, we were unable to find hydrogenation conditions which gave satisfactory reproducible yields of the mixture of *N*-oxides (10) and (13) (*ca.* 50% in the best experiment). Deoxygenation of the oxide mixture was also unpredictable. An alternative route to the tetra-azadibenzophenanthrene (15) by oxidation of the diamine (12), efficiently produced by hydrogenation of the dinitro-compound (9) over palladium–carbon in acetic acid was, therefore, studied. Peracetic acid,

lead tetra-acetate, mercuric acetate, and sodium hypochlorite failed, but perdisulphuric acid gave the required compound (15) in 30% yield (40% allowing for unchanged diamine) using a two-phase solvent system. Attempts to obtain a higher conversion of the diamine led to further oxidation of the tetra-azadibenzophenanthrene (15) and the *N*-oxide (13) was obtained.

The structures of the bipyridyls and biquinolyls and their ring-fused pyridazine derivatives all follow in a straightforward way from their spectrometric properties, together with the inter-relationships shown in Schemes 1 and 2. The remote possibility of migration of oxygen to pyridine or quinoline ring-nitrogen during reduction of the dinitro-compounds (2) or (9) can be excluded in the case of the *N*-oxide (5) since pyridine *N*-oxides are readily deoxygenated by phosphorus trichloride,[6] in contrast to the behaviour of this compound. The position of the oxygen function in the *N*-hydroxypyrrole (11) is shown by comparing its solid-state i.r. spectrum with that of its reduction product (14) when the very broad OH absorption [7] ($\nu_{max.}$ *ca.* 2 460 cm^{-1}) is replaced by a characteristic multiplet NH band ($\nu_{max.}$ 2 800—3 400 cm^{-1}). N.m.r. and solution i.r. spectra could not be obtained for the *N*-oxides or the hydroxypyrrole (11) owing to their very low solubility in neutral solvents and instability to trifluoroacetic acid.

EXPERIMENTAL

I.r. and u.v. spectra were measured with Unicam SP 1000 or SP 1200 and SP 1800 instruments respectively, and mass-spectra with various instruments at medium resolution. Melting points were determined with a Reichert hot-stage microscope. T.l.c. was on silica (Kieselgel 60 F 254 pre-spread for analyses and nominal 1-mm films of Kieselgel 60 PF for preparations) using u.v. detection and mixtures of chloroform and ethanol (usually 10 : 1 v : v) for development. Solutions were dried over sodium sulphate and evaporated under water-pump vacuum using a Büchi apparatus. Stirring refers to continuous use of a magnetic stirrer. Ammonia refers to the saturated aqueous solution (*d* 0.88). Copper powder refers to B.D.H. ' copper bronze for organic syntheses ' as supplied, and iron powder refers to B.D.H. ' iron powder reduced by hydrogen '. *NN*-Dimethylformamide was stored over 4A molecular sieve before use.

3,3'-Dinitro-4,4'-bipyridyl (2).—(*a*) *Normal procedure.* 4-Chloro-3-nitropyridine (43.7 g), *NN*-dimethylformamide (180 ml), and copper powder (42.0 g) were stirred in an oil-bath at 100 ± 2 °C for 15 h. The gelatinous product was cooled and diluted with water (*ca.* 1.5 l) and the precipitate was separated on a No. 3 sintered glass funnel and washed with water. The solid was triturated on the filter with ammonia (3 × 35 ml), washed with ice-cold ethanol (2 × 30 ml), and extracted with hot chloroform (5 × 60 ml). The chloroform extract was evaporated and the yellow crystalline residue (18.0 g) was recrystallised from ethanol (*ca.* 90 ml) to give pale yellow needles of the dinitrobipyridyl (14.8 g, 45%), m.p. 124—126 °C. Further recrystallisation gave an analytical sample, m.p. 127—128 °C [Found: C, 48.4; H, 2.7; N, 23.15%; *M* (m.s.), 246. $C_{10}H_6N_4O_4$ requires C, 48.8; H, 2.45; N, 22.8%; *M*, 246], $\nu_{max.}$ (KBr, strongest band) 1 528 cm^{-1} (NO_2); $\lambda_{max.}$ (MeOH) 245 nm (log ε 3.84) and 274infl. (3.69).

(*b*) *Isolation of cuprous chloride complex of* (2). 4-Chloro-3-nitropyridine (4.79 g), dimethylformamide (50 ml), and copper powder (4.12 g) were heated with stirring to 120 °C for 6 h; the temperature was raised briefly to 145 °C and the mixture was filtered using Hyflo; the filter was washed with hot dimethylformamide (3 × 4 ml). The combined filtrate deposited black crystals (3.69 g, 54%) which were washed with dimethylformamide and then acetone, and then dried *in vacuo* at 78 °C; they had m.p. *ca.* 220 °C (decomp.) (Found: C, 35.75; H, 2.75; N, 16.35. $C_{10}H_6N_4O_4$,CuCl requires C, 34.8; H, 2.8; N, 16.2%), $\nu_{max.}$ (KBr) 1 533 and 1 351 cm^{-1} (NO_2) (strongest bands).

(*c*) *Decomposition of the cuprous chloride complex of* (2). The complex (689 mg) was powdered and triturated with ammonia (7 ml) for 5 min. The residue (433 mg) was separated on a glass sinter, washed with water, dried *in vacuo*, and twice recrystallised from ethanol to give the dinitrobipyridyl (234 mg, 48%), m.p. 127—128 °C, identical (i.r. and t.l.c.) with the product of method (*a*).

2,7,9,10-Tetra-azaphenanthrene (4).—3,3'-Dinitro-4,4'-bipyridyl (14.7 g) was powdered and stirred at room temperature for 4 h with a solution of sodium sulphide nonahydrate (140 g) in water (600 ml). The precipitate (9.34 g) was washed successively with water, boiling aqueous ethanol (2 × 30 ml, 1 : 4 v : v) and ethanol, and dried *in vacuo* at 70 °C. This product (a mixture of 2,7,9,10-tetra-azaphenanthrene and its 9-oxide, *ca.* 3 : 1) was intimately mixed with iron powder (94 g) sealed in *vacuo* in a stainless-steel autoclave (or thick glass ampoule in smaller scale experiments) and heated to 250 °C for 14 h. The product was sublimed from the iron at 250 °C and *ca.* 10^{-3} Torr and re-extracted with boiling aqueous ethanol (1 : 4 v : v) to leave a primrose yellow residue (6.41 g, 59%) of the *tetra-azaphenanthrene* pure enough for the following preparation. An analytical sample, m.p. 343—344 °C (subl. decomp.), was obtained by recrystallisation from dioxan (Found: C, 66.0; H, 3.3%; *M*, 182. $C_{10}H_6N_4$ requires C, 66.0; H, 3.3%; *M*, 182), $\lambda_{max.}$ (dioxan) 237 nm (log ε 4.76), 261infl. (4.09), and 294.5 (4.17); $\nu_{max.}$ (KBr, strongest band) 1 400 cm^{-1}. Both aqueous ethanol washings contained small amounts of 3,3'-diamino-4,4'-bipyridyl.

The mixture of the tetra-azaphenanthrene and its *N*-oxide (21 mg) was boiled under reflux with phosphorus trichloride (1 ml) for 6 h and evaporated. The residue was dissolved in water and the product was precipitated with ammonia. Comparison of its i.r. spectrum with those of the two components showed that a considerable proportion of the *N*-oxide was still present.

3,3'-Diamino-4,4'-bipyridyl (6).—(*a*) 3,3'-Dinitro-4,4'-bipyridyl (935 mg) in acetic acid (15 ml) was injected through a rubber stopple into a stirred suspension of palladium–carbon (302 mg; 5% Pd) in acetic acid (25 ml) previously equilibrated with hydrogen at 23 °C. Hydrogen uptake (565 ml; 6.04 mol) stopped after 1.3 h. Excess of hydrogen was pumped off and replaced by air, the catalyst was filtered off using Hyflo, and the solution was evaporated to *ca.* 4 ml. The residue was diluted with water (20 ml) and cooled in ice while ammonia was added until the mixture was alkaline. The precipitate was recrystallised from

[6] For many examples see R. A. Abramovitch and E. M. Smith in ' The Chemistry of Heterocyclic Compounds: Pyridine and its Derivatives,' ed. R. A. Abramovitch, John Wiley, New York, Supp. Part 2, 1974, p. 69.

[7] L. J. Bellamy, ' The Infrared Spectra of Complex Molecules,' Chapman and Hall, London, 1975, 3rd edn., p. 119 *et seq.*

aqueous ethanol (*ca.* 20 ml, 1 : 4 v : v) to give short off-white needles of *the diamine* (485 mg, 69%), m.p. 276—277 °C (subl.) (Found: C, 64.6; H, 4.45; N, 29.7%; *M*, 186. $C_{10}H_{10}N_4$ requires C, 64.5; H, 5.35; N, 30.0%; *M*, 186), $\nu_{max.}$ (KBr, strongest band) 1 640 cm^{-1} (NH_2); $\lambda_{max.}$ (MeOH) 235infl. (log ε, 5.23) and 318 nm (4.85).

(*b*) In a similar experiment the dinitrobipyridyl (252 mg) in ethanol (35 ml) containing sodium hydroxide (2 drops; 2.5M) was hydrogenated over an excess of Raney nickel * and gave the diaminobipyridyl (155 mg, 81%) identical (i.r. and t.l.c.) with that obtained by method (*a*) but containing minor persistent impurities.

(*c*) Zinc dust (373 mg) was added to the dinitrobipyridyl (78 mg) in acetic acid (2 ml). After the initial vigorous reaction the mixture was heated to *ca.* 70 °C for 5 min, set aside for 0.5 h, diluted with acetic acid (2 ml), filtered, and evaporated. The residue was dissolved in water (2 ml) and made alkaline with ammonia to give a precipitate (39 mg, 68%) of the diamine, identical (i.r. and t.l.c.) with that obtained by method (*a*).

(*d*) The diamine was obtained in similar yield when a mixture of the tetra-azaphenanthrene (4) and its oxide (5) was treated with zinc and acetic acid, under the conditions of experiment (*c*).

3,3′-*Dibromo*-4,4′-*bipyridyl* (7).—3,3′-Diamino-4,4′-bipyridyl (600 mg) in aqueous sulphuric acid (10 ml; 1M) was stirred in ice and sodium nitrite (446 mg) in water (2.5 ml) was added dropwise during 5 min. The mixture was poured into a solution of cuprous bromide (3.14 g) in hydrobromic acid (3 ml, 60%), stirred for 1¼ h at room temperature, and warmed to *ca.* 80 °C for 1 h. The brown precipitate was washed successively with dilute sulphuric acid and water, triturated with ammonia (6 ml), and extracted with warm chloroform; the residue was triturated again with ammonia and re-extracted with chloroform: most of the solid dissolved. The extract was washed with water, dried, and evaporated. The crystalline residue (630 mg) was dissolved in hot ethanol (3 ml) and the solution was filtered through Hyflo. The brown solid (38 mg) which separated initially was set aside and with time the solution deposited light brown prisms (136 mg) of the *dibromobipyridyl*, m.p. 117.5—119 °C, unchanged by further recrystallisation [Found: C, 38.4; H, 1.9; N, 9.25%; *M*, 312. $C_{10}H_6Br_2N_2$ requires C, 38.25; H, 1.9; N, 8.9%; *M* ($^{79}Br_2$), 312], $\nu_{max.}$ (KBr, strongest band) 1 400 cm^{-1} (pyridine ring); $\lambda_{max.}$ (EtOH) 272 nm (log ε 3.70). A second crop (194 mg; total yield 33%) of the dibromobipyridyl of comparable purity was obtained by evaporation of the mother-liquor; t.l.c. examination of the crude product revealed the presence of significant amounts of six other substances.

2,7,9,10-*Tetra-azaphenanthrene* 9,10-*Dioxide* (3).—3,3′-Dinitro-4,4′-bipyridyl (54 mg) in warm ethanol (1.5 ml) was added dropwise during 5 min to a stirred, boiling solution of arsenious oxide (412 mg) and sodium hydroxide (217 mg) in water (3 ml). The mixture was boiled in an open vessel for a further 5 min, refluxed for 1 h, and allowed to cool. The precipitate (33 mg) was washed with water and recrystallised from acetic acid to give the *dioxide* (17.5 mg, 38%) which decomposed below 300 °C without melting or sublimation (Found: C, 55.8; H, 3.2%; *M*, 214. $C_{10}H_6N_4O_2$ requires C, 56.1; H, 2.8%; *M*, 214), $\nu_{max.}$ (KBr, strongest band) 1 402 cm^{-1} (*cis*-ON=NO).

2,7,9,10-*Tetra-azaphenanthrene* 9-*Oxide* (5).—3,3′-Dinitro-4,4′-bipyridyl (410 mg) in acetic acid (5 ml) was injected through a rubber stopple into a stirred suspension of Adams' catalyst (21 mg) in acetic acid (25 ml) containing sodium acetate (2.5 g) previously equilibrated with hydrogen. After 1 h hydrogenation was stopped when hydrogen (172 ml, 4.2 mol) had been absorbed. The catalyst was separated on Hyflo and the red solution with green fluorescence was evaporated and became yellow. The solid residue was dissolved in water (15 ml), made alkaline with ammonia, and cooled in ice. The precipitate was dissolved in hot dimethylformamide and allowed to cool; the initial precipitate (74 mg) (consisting of the 9-oxide with a small proportion of the tetra-azaphenanthrene) was set aside and with time the solution deposited a second crop (140 mg, 43%) of the 9-*oxide*. Further recrystallisation from dioxan gave very pale orange plates which decomposed without melting near 270 °C (Found: C, 61.3; H, 2.95%; *M*, 198. $C_{10}H_6N_4O$ requires C, 60.7; H, 3.05%; *M*, 198), $\lambda_{max.}$ (dioxan) 242 nm (log ε 4.63) 258infl. (4.37), and 334 (4.13); $\nu_{max.}$ (KBr) 1 400 cm^{-1} (strongest band) and 700 (distinction from the tetra-azaphenanthrene whose spectrum is similar).

3,3′-*Dinitro*-2,2′-*bipyridyl*.— 2-Chloro-3-nitropyridine (50 g) *NN*-dimethylformamide (150 ml), and copper powder (50 g) were heated under the conditions described for the preparation of 3,3′-dinitro-4,4′-bipyridyl. Isolation in the same way, with the exception that the product was extracted with boiling dioxan (4 × 200 ml) and crystallised from dioxan, gave the bipyridyl (29.9 g, 77%), m.p. 210—211 °C; (lit.,[3] m.p. 206 °C).

4,5,9,10-*Tetra-azaphenanthrene*.— 3,3′-Dinitro-2,2′-bipyridyl (25 g) was powdered and stirred at room temperature for 4.5 h with a solution of sodium sulphide nonahydrate (225 g) in water (1 l). The solution was extracted with chloroform (3 × 500 ml). The chloroform extract was washed with water, dried, and evaporated to dryness; the bright yellow residue (18 g) was recrystallised from ethanol to give bright yellow needles of 4,5,9,10-tetra-azaphenanthrene (16.4 g, 89%), m.p. 225—230.5 °C (lit.,[3] m.p. 239—240 °C) (Found: C, 66.2; H, 3.5; N, 30.3. Calc. for $C_{10}H_6N_5$: C, 65.9; H, 3.3; N, 30.7%), $\lambda_{max.}$ (EtOH) 232 nm (log ε 4.52), 259 (4.43), 295.5infl. (3.78), 329 (3.49), and 344.5 (3.42).

3,3′-*Dinitro*-4,4′-*biquinolyl* (9).— 4-Chloro-3-nitroquinoline [9] (5.0 g), copper powder (5.0 g), and hexamethylphosphoramide (25 ml; pH *ca.* 10, see note below) were stirred in an oil-bath at 100 °C for 16 h. The solution was cooled, diluted with water (250 ml), and the precipitate was separated on a No. 3 sintered glass funnel and washed with water (20 ml). The solid was triturated on the filter with concentrated ammonia solution (3 × 30 ml), washed with water (20 ml) then with ethanol (15 ml). The residue was extracted with boiling chloroform (4 × 150 ml) and the extract was dried and evaporated. The pale yellow crude product (3.4 g) was recrystallised from acetic acid, giving the *biquinolyl* (2.3 g, 55%) as pale yellow needles, m.p. 295.5—296.5 °C (Found: C, 62.4%; *M*, 346. $C_{18}H_{10}N_4O_4$ requires C, 62.4%; *M*, 346), $\nu_{max.}$ (KBr, strongest bands) 1 340 and 1 530 cm^{-1} (NO_2); $\lambda_{max.}$ (dioxan) 260.5 (log ε 4.65) and 304 nm (4.20).

* Prepared by the method of Burgstahler.[8]

[8] L. F. Fieser and M. Fieser, 'Reagents for Organic Synthesis,' John Wiley, New York, 1967, p. 729.

[9] G. B. Bachman, D. E. Welton, G. L. Jenkins, and J. E. Christian, *J. Amer. Chem. Soc.*, 1947, **69**, 365.

Note. Hexamethylphosphoramide was used as supplied and tested with pH paper after dilution with an equal volume of water. Samples showing pH *ca.* 10 were satisfactory but when samples with pH <6 were used 3-nitroquinoline, m.p. 126—128° (lit.,[10] m.p. 126—128 °C) was the major product.

5,7,8,10-*Tetra-azadibenzo*[c,g]*phenanthrene* 7-*Oxide* (13) and 5,7,8,10-*Tetra-azadibenzo*[c,g]*phenanthrene* 7,8-*Dioxide* (10).—3,3′-Dinitro-4,4′-biquinolyl (546 mg) and Adam's catalyst (47 mg) were suspended in dioxan (30 ml). The mixture was hydrogenated at atmospheric pressure and room temperature until no more hydrogen was taken up (hydrogen used *ca.* 150 ml.) The precipitate was separated and extracted with boiling dioxan. The dioxan extract was evaporated to leave a yellow residue (255 mg) of a mixture of the mono-*N*-oxide and the di-*N*-oxide which was separated by p.t.l.c. on silica [$CHCl_3$–EtOH (10 : 1 v : v); eluted $CHCl_3$] giving the *mono*-N-*oxide* (R_F 0.89) after recrystallisation from dioxan, as yellow needles (101 mg, 22%), m.p. 273—273.5 °C (Found: C, 72.8; H, 3.1; N, 18.7%; *M*, 298, $C_{18}H_{10}N_4O$ requires C, 72.5; H, 3.3; N, 18.7%; *M*, 298), $\lambda_{max.}$ (dioxan) 236 nm (log ε 4.41), 301 (4.38), 410 (3.44), and 434 (3.36); $\nu_{max.}$ (KBr, strongest band) 760 cm^{-1}. The *di*-N-*oxide* (R_F 0.78) was recrystallised from dioxan as yellow-orange needles (43 mg, 9%), m.p. 253—255 °C (Found: C, 68.5; H, 2.8; N, 17.6%; *M*, 314. $C_{18}H_{10}N_4O_2$ requires C, 68.7; H, 3.1; N, 17.8%; *M*, 314), $\lambda_{max.}$ (dioxan) 251 nm (log ε 4.49), 312.5 (4.38), 337.5 (4.38), 356 (4.18), and 384 (3.89); $\nu_{max.}$ (KBr, strongest band) 755 cm^{-1}.

In seven experiments under apparently identical, or similar, conditions the yield of the mixture of mono- and di-oxides varied from 13 to 53%. Use of palladium–carbon, Raney nickel,[8] and ruthenium–carbon gave only traces, or none, of the required tetra-azadibenzophenanthrene derivatives, as did dry reaction [11] between the dinitrobiquinolyl and ferrous oxalate at 180 °C.

7-*Hydroxy*-5,7,9-*triazadibenzo*[c,g]*fluorene* (11).—(*a*) Hydrazine hydrate (20 ml; 60% w/w) was added slowly to a mixture of 3,3′-dinitro-4,4′-biquinolyl (680 mg), finely ground sodium hydroxide (2.0 g), and dioxan (30 ml). The solution was stirred and refluxed for 15 min, cooled, and filtered. The yellow-orange product (406 mg) was recrystallised from acetic acid (charcoal) to give the N-*hydroxy-derivative* (244 mg, 44%) as yellow-orange needles, m.p. 341—341.5 °C (Found: C, 75.9; N, 14.7. $C_{18}H_{11}N_3O$ requires C, 75.8; N, 14.7%), mass spectrum: *m/e* 285 (M^+, 24%) and 269 (M − 16, 100%); $\nu_{max.}$ (KBr) 2 460vbr and 755 cm^{-1} (strongest band). The compound gave a bright red solution with trifluoroacetic acid.

(*b*) 3,3′-Dinitro-4,4′-biquinolyl (293 mg) finely ground sodium sulphide nonahydrate (8.8 g) and dioxan (30 ml) were stirred and refluxed for 1 h. The solution was cooled and diluted with water (250 ml). The orange precipitate was separated after 24 h at room temperature, and recrystallised from acetic acid to give the *N*-hydroxy-derivative (24 mg, 10%) as yellow-orange needles, m.p. 341—341.5 °C, identical (i.r. and t.l.c.) with that prepared by method (*a*).

5,7,9-*Triazadibenzo*[c,g]*fluorene* (14).—(*a*) The *N*-hydroxy-derivative (32 mg) was mixed with iron powder (3.0 g), sealed *in vacuo* in a thick-walled glass ampoule, and heated to 300 °C for 18 h. The product was extracted with boiling acetone (5 × 20 ml). The acetone extract was evaporated and the yellow residue was sublimed at 210 °C and 10^{-4} Torr, to give the yellow *fluorene* (27 mg, 89%), m.p. >345 °C (Found: C, 79.9; H, 3.8; N, 15.2%; *M*, 269. $C_{18}H_{11}N_3$ requires C, 80.3; H, 4.0; N, 15.6%; *M*, 269), mass spectrum: *m/e* 269 (M^+, 100%); $\nu_{max.}$ (KBr) 2 800—3 400br,m (NH) and 750 cm^{-1} (strongest band).

(*b*) The *N*-hydroxy-derivative (38 mg), zinc dust (315 mg), and glacial acetic acid (5 ml) were stirred at 75 °C for 2 h. The solution was cooled, filtered, and neutralised with ammonia; the precipitate was separated and dried *in vacuo* to give the fluorene (24 mg, 67%), identical (i.r. and t.l.c.) with that prepared by method (*a*).

3,3′-*Diamino*-4,4′-*biquinolyl* (12).—(*a*) 3,3′-Dinitro-4,4′-biquinolyl (1.0 g) and palladium on charcoal (350 mg; 10% Pd) were suspended in glacial acetic acid (50 ml). The solution was hydrogenated at 30 °C, atmospheric pressure; hydrogenation was stopped when hydrogen (450 ml *ca.* 6.5 mol) had been absorbed. The catalyst was separated to leave a yellow-orange solution which was concentrated to *ca.* 8 ml, diluted with water (10 ml), and basified with ammonia. The precipitate was recrystallised from ethanol to give the *diaminobiquinolyl* (634 mg, 77%) as pale yellow needles, m.p. 302—304 °C (Found: C, 75.6; H, 4.6; N, 19.6%; *M*, 286. $C_{18}H_{14}N_4$ requires C, 75.5; H, 4.9; N, 19.6%; *M*, 286) $\lambda_{max.}$ (ethanol) 248 (log ε 4.27), 277 (3.59), and 362 nm (3.58); $\nu_{max.}$ (KBr, strongest band) 1 632 cm^{-1} (NH_2).

(*b*) 5,7,8,10-Tetra-azadibenzo[*c,g*]phenanthrene 7-oxide (22 mg) was mixed with iron powder (3.0 g), sealed *in vacuo* in a thick-walled glass ampoule, and heated to 260 °C for 18 h. The product was extracted with boiling chloroform (5 × 20 ml) and the extract was evaporated, to leave the light brown *diaminobiquinolyl* (21 mg, 99%), identical (i.r. and t.l.c.) with that prepared by method (*a*).

5,7,8,10-*Tetra-azadibenzo*[c,g]*phenanthrene* (15).—(*a*) *By reduction of the* N-*oxide* (13). 5,7,8,10-Tetra-azadibenzo[*c,g*]-phenanthrene 7-oxide (82 mg) was mixed with iron powder (4.0 g), sealed under atmospheric pressure (air) in a thick-walled glass ampoule, and heated to 200 °C for 9 h. The product was extracted with boiling chloroform (3 × 20 ml.) and the extract was evaporated to leave a brown residue (70 mg), which was recrystallised from dioxan to give the tetra-azadibenzophenanthrene (61 mg, 79%) as yellow cubes, m.p. 285—287 °C (Found: C, 76.3; H, 3.2; N, 19.5%; *M*, 282. $C_{18}H_{10}N_4$ requires C, 76.6; H, 3.5; N, 19.8%; *M*, 282), $\lambda_{max.}$ (dioxan) 233.5 nm (log ε 4.34), 279.5 (4.24), and 304 (4.28); $\nu_{max.}$ (KBr, strongest band) 765 cm^{-1}.

(*b*) *By oxidation of the diamine* (12). (i) 3,3′-Diamino-4,4′-biquinolyl (300 mg) in sulphuric acid (15 ml; 2M) was stirred with potassium perdisulphate (570 mg, 2 mol) and chloroform (20 ml) at 60 °C for 10 h. The chloroform was separated, washed with water, dried, and evaporated. The residue was recrystallised from dioxan and washed with ethanol to give the tetra-azadibenzo[*c,g*]phenanthrene (90 mg, 30%), identical (i.r. and t.l.c.) with that obtained by method (*a*), and, from the ethanol washings, the diamine (76 mg, 25%) was recovered.

(ii) 3,3′-Diamino-4,4′-biquinolyl (800 mg), potassium perdisulphate (1.1 g, 1.5 mol), sulphuric acid (20 ml; 2M), and chloroform (40 ml) were stirred at 60 °C and two further portions of potassium perdisulphate (2 × 382 mg, 2 × 0.5 mol) were added at 3 and 6 h from the start. The chloroform layer was taken out and replaced by a fresh one every

[10] F. C. Uhle and W. A. Jacobs, *J. Org. Chem.*, 1945, **10**, 76.
[11] H. C. Waterman and D. L. Vivian, *J. Org. Chem.*, 1949, **14**, 289.

hour for the first 6 h. After a total of 24 h the chloroform extracts were combined and worked up as before, to give the tetra-azadibenzophenanthrene (264 mg, 33%).

(iii) 5,7,8,10-Tetra-azadibenzo[*c*,*g*]phenanthrene 7-oxide (183 mg, 21%) was obtained as the major product, isolated as in experiment (*b*) (i), and only traces of the tetra-azadibenzo[*c*,*g*]phenanthrene were detected by t.l.c. when the diaminobiquinolyl (900 mg) was treated with potassium perdisulphate (2.9 g, 3.5 mol) in sulphuric acid (45 ml; 2M) and chloroform (60 ml) at 60 °C for 24 h.

(iv) The tetra-azadibenzo[*c*,*g*]phenanthrene was not detected by t.l.c. when the diamine was treated with hydrogen peroxide, mercuric acetate, or lead tetra-acetate each in acetic acid, or with aqueous sodium hypochlorite.

We thank Drs. D. J. Gilman and R. Hull, I.C.I. Pharmaceuticals Division, and Dr. M. Kilner, Durham University, for discussion and both institutions for mass spectra and analyses.

[7/1567 *Received*, 2*nd September*, 1977]