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DIAMINE-DIALDEHYDE CONDENSATIONS

THE SYNTHESIS OF AN ANNELATED DIAZA[12]ANNULENE

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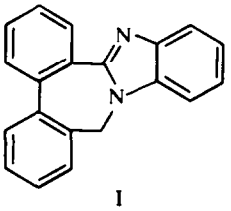
Abstract—The condensation of 1,8-diaminonaphthalene and naphthalene-1,8-dialdehyde has been shown to afford 14*H*-[4,5]benzoisoquino [2.1-*a*]perimidine as a major product, whereas the condensation of 2,2'-diaminobiphenyl and biphenyl-2,2'-dialdehyde gave the bis-Schiff base, 2 : 3, 4 : 5, 8 : 9, 10 : 11-tetrabenzo-1,6-diaza[12]annulene in quantitative yield. Various other aromatic diamines and dialdehydes were also condensed and it was concluded that the bis-Schiff base product could only be obtained when the macrocyclic ring was 12-membered or possibly larger. When the ring size of the potential bis-Schiff base was less than this, hydride shift products were obtained.

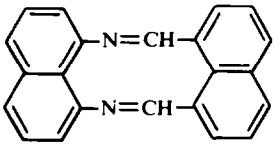
HETEROCYCLES containing a monocyclic, conjugated ten π-periphery are of considerable interest and recently the 9-membered oxonin[1] and azonin[2, 3] ring systems have been synthesized. To date no aza[10]annulenes have been reported.

The condensation of aromatic diamines and dialdehydes have so far proven futile as a route to annelated diaza[10]annulenes. Thus the reaction of biphenyl-2,2'-dialdehyde and *o*-phenylenediamine led to the formation of the bicyclic hydride-shift product, 15H-dibenzo[*c*,*e*]benzimidazo[1·2-*a*]azepine (I),[4] while the alternative condensation of 2,2'-diaminobiphenyl and *o*-phthalaldehyde led to the annelated analogues of diimino-β-isoindigo and related partially cyclized compounds.[5]

The condensation of 1,8-diaminonaphthalene (II) and naphthalene-1,8-dialdehyde (III) has now been investigated in an attempt to isolate the annelated diaza[10]-annulene (IV).



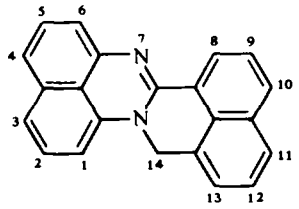
I



IV

Condensation of 1,8-*diaminonaphthalene and naphthalene*-1,8-*dialdehyde*

An earlier attempt to condense the dialdehyde (III) with various 1,2-diamines including (II) was reported to have failed.[6] However we have found that III does react with II to give a variety of red-coloured products. The major component was a "linear" polymer, but of the low molecular weight products, 14*H*-[4·5]benzoisoquino [2·1-*a*]perimidine (V) predominated.

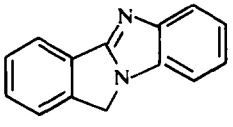


V

The product (V) was separated from the mixture by thick layer chromatography on silica gel, and the structure followed from the spectral data. In particular the empirical formula has been confirmed by accurate mass measurement, while the PMR spectrum exhibited a 2H singlet at 5·14 τ due to the methylene protons, thus eliminating structure IV for this product. Furthermore, the PMR spectrum remained unaltered in the presence of D_2O, and the IR spectrum confirmed the absence of any N—H group in the molecule. Presumably the formation of V in this reaction involves an intermolecular hydride shift analogous to that involved in the preparation of I.[4] Mass spectroscopy confirmed that several other minor products isolated from this reaction were not IV but their structures could not be elucidated.

Other diamine-dialdehyde condensations

The failure of the three aforementioned diamine-dialdehyde condensations to yield any annelated diaza[10]annulenes led us to speculate that the ring size of the potential diazaannulene might be a significant factor in determining the course of the reaction. Since the condensation of *o*-phthalaldehyde and *o*-phenylenediamine has been shown[7–9] to furnish the polycyclic "hydride shift"[4] product (VI) instead of a bis-Schiff base, it seemed of interest to investigate various other diamine-dialdehyde condensations to assess the effect of the distance between the reacting substituents on the nature of the reaction.

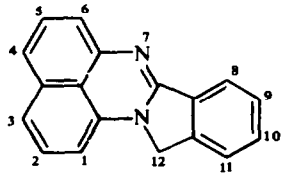


VI

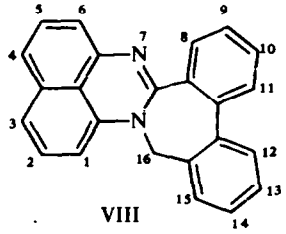
The condensations of II with *o*-phthalaldehyde and biphenyl-2,2′-dialdehyde and of III with *o*-phenylenediamine and 2,2′-diaminobiphenyl furnished the "hydride shift" products 12*H*-isoindolo[2·1-*a*]perimidine (VII), 16H-dibenzo[*c*,*e*]perimidino-[1·2-*a*]azepine (VIII), 7*H*-[4·5]benzobenzimidazo[2·1-*a*]isoquinoline (IX) and 7H-dibenzo[*d*·*f*]-4,5-benzisoquino[2·1-*a*]-1,3-diazepine (X) respectively.

The structures of these products followed from the spectral and analytical data.

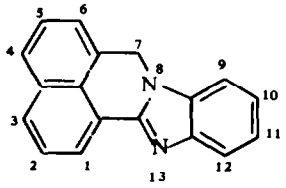
In marked contrast the condensation of biphenyl-2,2′-dialdehyde and 2,2′-diaminobiphenyl did proceed to give the bis-Schiff base, 2:3, 4:5, 8:9, 10:11-tetrabenzo-1,6-diaza[12]annulene (XI), in quantitative yield. The PMR spectrum of this product showed absorption only in the aromatic region while the IR spectrum displayed strong C=N absorption at 1625 cm^{-1}. The structure of XI was confirmed by reduction with sodium borohydride since this furnished the tetrahydro derivative (XII) in excellent yield.



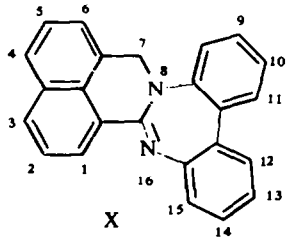
VII



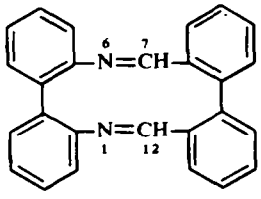
VIII



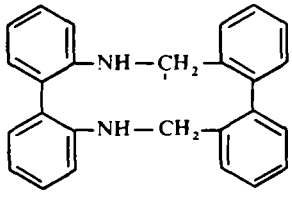
IX



X



XI



XII

The structure of the latter derivative was substantiated by the PMR spectrum which displayed a broad singlet at 5·79 τ (2 N—H protons which exchange with D_2O) and a sharp singlet at 6·21 τ (4H, methylene protons) as well as a complex multiplet due to the aromatic protons.

The N=CH protons of XI show a small but significant upfield shift in the PMR spectrum in comparison with similar protons in benzalaniline (τ 1·64) and dibenzo[*b*·*f*] [1,5]diazocine (τ 1·47).[10] This could be indicative of a weak paramagnetic ring current which would be expected if XI contained a delocalized 12π-system,[11, 12] but could also be due to special shielding effects arising from the geometry of these protons relative to the adjacent aromatic nuclei. The UV spectrum supported the latter explanation since it confirmed that there was no extended conjugated system in XI, and it must be concluded that this cyclic twelve-membered ring is not planar.

However it was apparent that the course of aromatic diamine-dialdehyde condensations is governed by the distance between the substituents and it appeared that a 12-membered ring is the minimum ring size necessary for the formation of a bis-Schiff base. When the ring size of the potential bis-Schiff base is less than twelve, only the hydride shift products are in fact observed.

EXPERIMENTAL

IR spectra were recorded on a Unicam model SP 200 G spectrometer and NMR spectra on a Perkin-Elmer R-10 spectrometer. Chemical shifts were measured on the τ-scale relative to TMS as internal standard

(τ = 10·0). Mass spectra were recorded on a MS-902 spectrometer. M.ps are uncorrected. All chromatograms were carried out on thick layer plates (100 × 20 × 0·1 cm) using silica gel (Merck $HF_{254+366}$) as adsorbent.

Condensation of 1,8-*diaminonaphthalene* (II) *and naphthalene*-1,8-*dialdehyde* (III). Naphthalene-1,8-dialdehyde hydrate (1·01 g, 5 mmole) was refluxed in benzene (100 ml) under a Dean–Stark separator for 20–30 min, and then a solution of 1,8-diaminonaphthalene (0·77 g, 5 mmole) in benzene was added and the reaction mixture refluxed overnight. The soln was then evaporated to dryness and the residue chromatographed using $CHCl_3$ as eluent. The major front moving band was separated, extracted and the residue recrystallized from EtOH to give V (0·1 g, 7%) as dark red needles, m.p. 278°; UV $\lambda_{max}^{CHCl_3}$ 247 mμ (log ε 4·56), 335 (4·44), 346 (4·45), 362 sh (4·35), 446 sh (3·40), 462 (3·47) and 490 (3·41); NMR ($CDCl_3$) τ 1·35 (1H, dd J 7. 1·5 Hz, aromatic proton), 2·00–3·06 (m, 10H, aromatic protons), 3·42–3·75 (m, 1H aromatic proton) and a singlet at 5·14 (2H, methylene protons); IR ν max ($CHCl_3$) 1630, 1600, 1575 cm^{-1} (C=N, C=C); mass spec *m/e* 306 (M^+, base peak), 307 (21%), 305 (90%), 304 (6·5%), 303 (7·5%), 153 (20%), 152 (28%), 151 (7%), 135 (11%). (Found: M, 306·1158. $C_{22}H_{14}N_2$ requires: M, 306·1157).

Diamine-dialdehyde condensations. The diamine (5 mmole) and the dialdehyde (5 mmole) were stirred and refluxed overnight in a neutral solvent (ca. 150 ml) and then evaporated to dryness. The product was purified either by recrystallization or by chromatography using 1:1 chloroform–light petroleum (b.p. 40–60°) as eluent. The hydrated form of (III) was dehydrated by refluxing in benzene under a Dean–Stark separator for 20–30 min, before being used in the condensation reaction.

The condensation of III and *o*-phenylenediamine (in benzene–MeOH) furnished IX as a pale yellow solid in quantitative yield. This product crystallized from MeOH as pale yellow needles, m.p. 225°; UV $\lambda_{max}^{90\%\ EtOH}$ 217 mμ (log ε 4·43), 239 (4·47), 315 sh (4·00), 328 (4·31), 344 (4·47), and 363 (4·42); NMR (CCl_4) τ 1·55 (dd, J 7, 1·5 Hz; 1H, aromatic proton), 2·15–2·86 (m, 9H, aromatic protons) and a singlet at 4·56 (2H, methylene protons); IR ν max ($CHCl_3$) 1620, 1605, 1590 cm^{-1} (C=N, C=C); mass spec *m/e* 256 (M^+ 99%), 257 (18%), 255 (base peak), 254 (5%), 128 (20%), 127 (13%), 126 (10%). (Found: C, 84·29; H, 4·94; N, 10·85. $C_{18}H_{12}N_2$ requires: C, 84·35; H, 4·72; N, 10·93; M, 256).

The condensation of III and 2,2′-diaminobiphenyl (in benzene) furnished a complex mixture. The main product (X) was separated by chromatography and crystallized from MeOH as pale yellow needles (335 mg. 20%), m.p. 168°; UV $\lambda_{max}^{90\%\ EtOH}$ 221 mμ (log ε 4·66), 245 (4·66), 321 sh (4·14), 335 (4·19 and 348 (4·15); NMR ($CDCl_3$) τ 1·35 (dd, J 7, 1·5 Hz; 1H, aromatic proton), 1·72–3·70 (m, 13H, aromatic proton) and a singlet at 5·15 (2H, methylene protons); IR ν max ($CHCl_3$), 1715, 1655, 1630, 1590 cm^{-1} (C=N, C=C); mass spec *m/e* 332 (M^+, base peak), 333 (30%), 331 (75%), 330 (12%), 329 (20%), 304 (5%), 169 (5%), 167 (11%), 166 (32%), 165 (26%), 164 (10%), 163 (7%), 152 (10%), 151 (9%), 140 (6%) and 139 (6%). (Found: C, 86·31; H, 5·06; N, 8·19. $C_{24}H_{16}N_2$ requires: C, 86·72; H, 4·85; N, 8·43%; M, 332).

The condensation of II and *o*-phthalaldehyde (in MeOH) gave VII in quantitative yield. This product crystallized from MeOH as brown needles, m.p. 190°; UV $\lambda_{max}^{90\%\ EtOH}$ 214 mμ (log ε 4·61), 235 (4·67), 257 (4·45), 335 (4·22), 348 (4·32), 406 (3·12), 430 (3·19), 456 (3·11) and 492 sh (2·73); NMR (CCl_4) τ 2·00–2·18 (m, 1H, aromatic proton), 2·6–3·15 (m, 8H, aromatic protons), 3·95–4·18 (m, 1H, aromatic proton) and a singlet at 5·76 (2H, methylene protons); IR ν max ($CHCl_3$) 1635, 1620 and 1595 cm^{-1} (C=N, C=C); mass spec *m/e* 256 (M^+, base peak), 257 (19%), 255 (55%), 128 (16%), 127 (15%) and 126 (15%). (Found: C, 83·88; H, 4·73; N, 10·60. $C_{18}H_{12}N_2$ requires: C, 84·35; H, 4·72; N, 10·93%; M, 256).

The condensation of II and biphenyl-2,2′-dialdehyde in benzene yielded a complex mixture. The major product (VIII) was purified by chromatography. Crystallization from MeOH gave VIII as orange needles (738 mg, 44%), m.p. 216°; UV $\lambda_{max}^{90\%\ EtOH}$ 215 mμ (log ε 4·70), 237 (5·47), 339 (4·22), 350 (4·25) and 422 (3·28); NMR ($CHCl_3$) τ 1·75–2·00 (m, 1H, aromatic proton), 2·26–3·25 (m, 12H, aromatic protons), 3·36–3·52 (m, 1H, aromatic proton) and a double doublet centred at 5·28 and 5·70 (J 15 Hz, total 2H, methylene protons); IR ν max ($CHCl_3$) 1630, 1585 cm^{-1} (C=N, C=C); mass spec *m/e* 332 (M^+, base peak), 333 (26%), 331 (16%), 330 (7%), 329 (7%), 166 (18%), 165 (19%) and 164 (6%). (Found: C, 86·38; H, 4·97; N, 8·48. $C_{24}H_{16}N_2$ requires: C, 86·72; H, 4·85; N, 8·43%; M, 332).

The condensation of 2,2′-diaminobiphenyl and biphenyl-2,2′-dialdehyde in MeOH furnished XI as colourless crystals (quantitative yield), m.p. 326°; UV $\lambda_{max}^{90\%\ EtOH}$ 235 mμ (log ε 4·62) and 300 (3·94); NMR (CF_3COOH) displayed a complex multiplet between 1·80 and 2·85 τ; IR ν max (nujol) 1625, 1595 cm^{-1}; mass spec *m/e* 358 (M^+, base peak), 359 (28%), 360 (6%), 357 (30%), 356 (7%), 330 (7%), 192 (9·5%), 191 (12%), 190 (10%), 181 (33%), 180 (10%), 179 (12%), 178 (16%), 177 (5%), 165 (16%), 164 (6%), 163 (10%), 161 (5%), 152 (7%) and 151 (5%). (Found: C, 86·91; H, 4·99; N, 7·89. $C_{26}H_{18}N_2$ requires: C, 87·12; H, 5·06; N, 7·82%; M, 358).

Sodium borohydride reduction of XI. Sodium borohydride (100 mg) was added to a suspension of XI (100 mg) in MeOH (50 ml) and the reaction mixture was stirred and refluxed for 3 hr. The soln was then evaporated to dryness under vacuum, diluted with water and extracted with $CHCl_3$. Concentration of the $CHCl_3$ soln gave XII (82 mg, 80%) as a brownish solid. After crystallization from MeOH XII was obtained as colourless needles m.p. 158°, which turned brownish on storing; UV $\lambda_{max}^{90\%\ EtOH}$ 217 mμ (log ε 4·65), 230 (4·54) and 290 sh (4·00); NMR ($CHCl_3$) τ 2·45–3·45 (16H, aromatic protons), 5·79 (s, exchanged with D_2O, 2 N—H protons), 6·21 (4H, methylene protons); IR ν max ($CHCl_3$) 3270 cm^{-1} (N—H); mass spec *m/e* 362 (M^+, 25%), 363 (6·5%), 361 (7%), 195 (5%), 185 (13%), 184 (base peak), 183 (19%), 181 (5%), 180 (8%), 179 (38%), 178 (20%), 168 (17%), 167 (23%), 166 (7%) and 165 (9%). (Found: C, 86·06; H, 6·10; N, 7·68. $C_{26}H_{22}N_2$ requires: C, 86·16; H, 6·12; N, 7·73%; M, 362).

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