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NEW ROUTES TO CONDENSED POLYNUCLEAR COMPOUNDS—VII

SYNTHESIS OF PHENANTHRIDINES THROUGH A NOVEL CYCLISATION REACTION OF HALOANILS

S. V. KESSAR,[1,*] R. GOPAL and M. SINGH[1,†]
Department of Chemistry, Panjab University, Chandigarh, India

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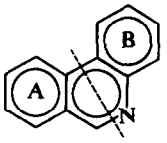
Abstract—A convenient phenanthridine synthesis based on reaction of haloanils with potassium amide in liquid ammonia has been developed. Experimental evidence supports the postulated mechanism implicating a benzyne intermediate in the cyclisation step and a prior addition of amide ions across the azomethine linkage.

Phenanthridine nucleus characterises a variety of alkaloids and synthetic compounds of importance.[2] Perhaps the simplest way of building this ring system is through the fusion of readily accessible synthons A and B. However, in this approach only the linking on the azomethine side can be effected efficiently. For the subsequent joining of the aromatic rings, in anils, no altogether satisfactory procedure‡ seems to be known. The present work explores the use of benzyne as a reactive intermediate for this purpose.



Normally, aryl groups show little proclivity to attack benzyne§ in the desired fashion, but appendage to a negatively charged oxygen confers sufficient nucleophilicity on *ortho* and *para* C atoms as is evidenced by such reactions of phenoxides.[5] On this basis, a general phenanthridine synthesis through an intramolecular benzyne reaction (5 → 6) seemed feasible, provided the potential anionic site inbuilt in the system, i.e. the N atom, could be successfully exploited to furnish the requisite ring activation. It may be pointed out that although the ambident reactivity of aza analogues of phenoxides does not seem to have been used for synthetic purposes, the electron density calculations do indicate even greater negative charge on the ring.[6,¶]

To test this idea, the chloroamine 4 was prepared by sodium borohydride reduction of the Schiff base from *o*-chlorobenzaldehyde and aniline. Its treatment with excess potassium amide in liquid ammonia gave 5,6-dihydrophenanthridine (8) in near quantitative yield. Cyclisation proceeded as well in presence of a variety of substituents on either of the anil rings. For aromatisation of the obtained 5,6-dihydrophenanthridines (8 → 9), two new procedures have been found to be very useful. Simple stirring with MnO_2 in chloroform affords phenanthridines quantitatively. Conversion to N-chloro derivatives followed by dehydrohalogenation with base also proceeds smoothly and can be advantageous for compounds having other easily oxidisable groups.

The above sequence to phenanthridines entails two steps, reduction of the anil and dehydrogenation of the cyclised product, which could be avoided if direct conversion of 3 to 9 was possible. With anils, however, cyclisations envisaging union of two rings through a 'reactive intermediate' are not expected to succeed because of the unfavourable geometry. The equilibrium lies entirely in favour of the *trans* isomer. Also, the interconversion is too slow, as adjudged from kinetic data on thermal relaxation of photoisomerised anil solutions,[7] to allow the *cis* configuration being acquired during the life time of a reactive intermediate. This problem is inherent[8] in all '*trans* cyclisations' and has been overcome in photoreaction of *o*-iodostilbenes

*To whom all communication should be addressed.

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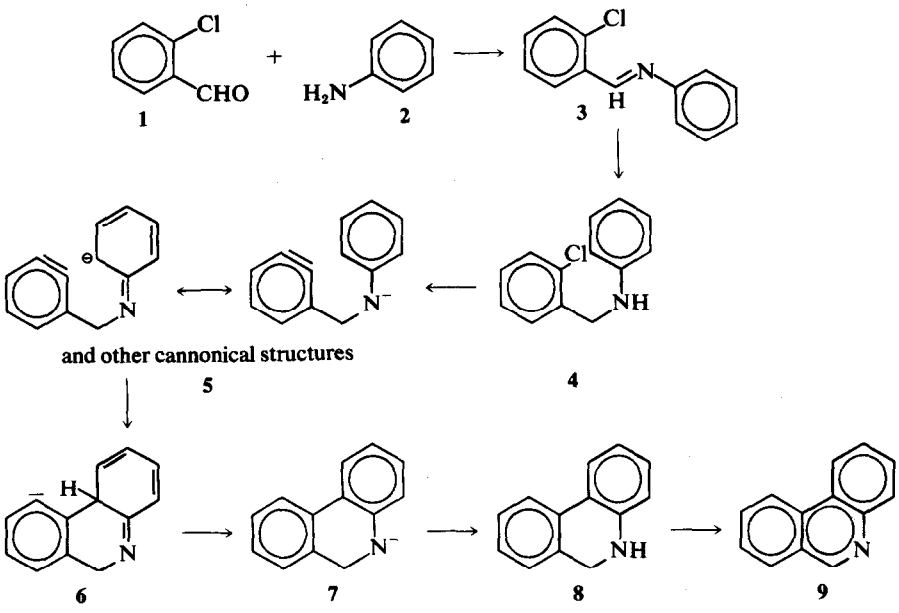
‡Both photocyclisations and Pschorr type reactions do not proceed as well with anils, or their derivatives as with stilbenes.[3]

§Many reactions involving benzyne can be carried in benzene as a solvent.[4]

¶Many factors besides the magnitude of its negative charge may determine the relative nucleophilic reactivity of a site, but some correlation between the two can be expected.

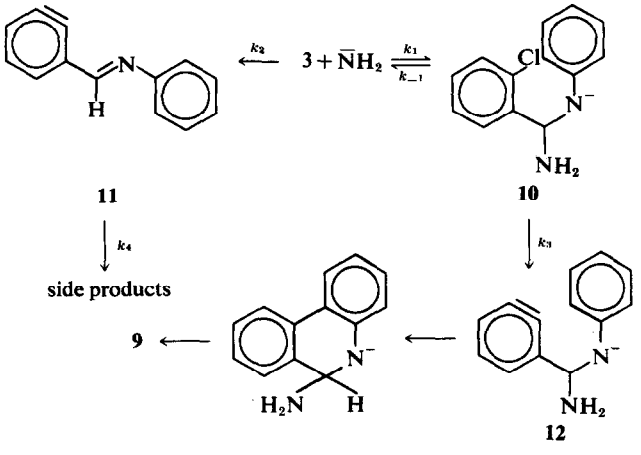


by building up the *cis* concentration in a radiation controlled pre-equilibrium.[9] A new type of solution, involving generation of a moiety sterically viable for cyclisation, seemed feasible in the present approach and was one of its fascinations. Cyclisation of the anil **3** could proceed through the amide ion adduct **10** with subsequent spontaneous expulsion of the addendum to afford the completely aromatic system, as shown. Addition of amide ions across azomethine linkage is well precedented,[10] only it needed to be sufficiently fast.[8]

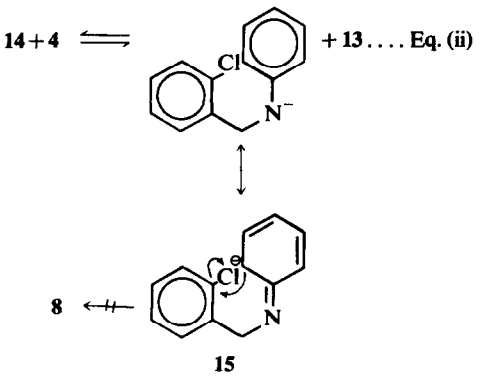
Experimentally, treatment of the anil **3** with excess amide ions in liquid ammonia was found to give phenanthridine (**9**) cleanly. In fact the yield (> 90%) was beyond all expectations for a complex multistep sequence. It was clear that hardly any undesirable benzyne (**11**) formation occurs, probably due to an extremely rapid adduct formation and a very favourable equilibrium position ($k_1 \gg k_2$ and k_{-1}).[8,*]

At this stage it was decided to find out if the reaction was really proceeding according to the rationale of its development. First, the possibility that the cyclisation step, common to the reaction of anils and the dihydro derivatives, entails direct displacement (**15** → **8**) was considered. If such be the case, then a base strong enough to generate the nitranion **15** but not the benzyne intermediate (**5**) should also be able to bring about the reaction.

*A slower rate of benzyne formation from **10** than from **3** could also be a factor though there is no apparent reason to expect it.



$$\underset{13}{Ph\text{-}CH_2\text{-}NH\text{-}Ph} + \bar{N}H_2 \rightarrow \underset{14}{Ph\text{-}CH_2\text{-}\bar{N}\text{-}Ph} + NH_3 \ldots\ldots \text{Eq. (i)}$$



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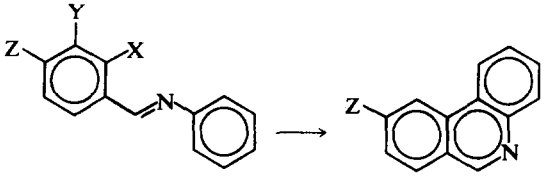
However, exposure of the chloroamine **4** to a six molar excess of the aromatic nitranion (**14**) generated from **13**, which meets the above requirement,*† lead to no cyclisation and the starting material was recovered unchanged. Direct substitution mechanism is, thus, considered untenable. This inference is reinforced by the observation that on treatment of N-(2-bromobenzylidene)-alinine (**16**) with amide ions in liquid ammonia the cyclisation proceeds normally, but it fails with the corresponding fluoro compound (**17**). Under these conditions, aryl fluorides form benzyne very slowly[12] while their nucleophilic substitutions are known to proceed at rates comparable with those of the other halides.[13]



16: X=Br; Y=Z=H
17: X=F; Y=Z=H
18: X=Z=H; Y=Cl
19: X=H; Y=Br; Z=OCH_3

9: Z=H
20: Z=OCH_3

Positive support for the intermediacy of benzyne came from successful cyclisation of N-(3-chlorobenzylidene)aniline (**18**) to phenanthridine (70%). The slightly lower yield, as compared to the ortho case, may be attributed to some 'wrong' benzyne formation. The corresponding 4-methoxy-3-bromoanil (**19**), in which this possibility is blocked, was found to cyclise quantitatively.

Having sufficient evidence to implicate a benzyne intermediate in the cyclisation, the possibility of the product (**8** or **9**) arising through a rearrangement of an initially formed azetidine‡ may be examined. A rearrangement of the type **21** → **22** has been observed[15] in reaction of 1-aryl-amino-3-alkanols and a suprafacial 1,3-sigmatropic shift entailing inversion was postulated. This, however, is not likely in the present case since the migrating centre can act only as a σ type group[16] and inversion is forbidden by its incorporation in a ring. If at all a concerted migration was to occur, it would entail the other (alkyl) centre and lead to an acridine. The same type of system is, by analogy to the carbocyclic case,[17]§ the expected product of a stepwise process. Thus, the reaction path **23** → **24** → **26** can be considered improbable.

In order to see how dependent the cyclisation was on strong anionic activation of the aromatic ring, N-methyl amine **28** was reacted with potassium amide in liquid ammonia. A complex mixture containing no product corresponding to cyclisation was obtained. Similarly, amide **29** also failed to furnish any 6(5H)-phenanthridinone, the *m*-amino compound **30** being the only isolable product of the reaction.‖ Formation of a nitranion from **28** is not possible, while in the case of the anion from **29** the negative charge is not fully operative for ring activation due to sharing with the carbonyl function. Thus, it is clear that intramolecular attack of the aromatic nucleus by benzyne does not proceed to any significant extent in absence of strong anionic activation.

Regarding the mechanism of the reaction with

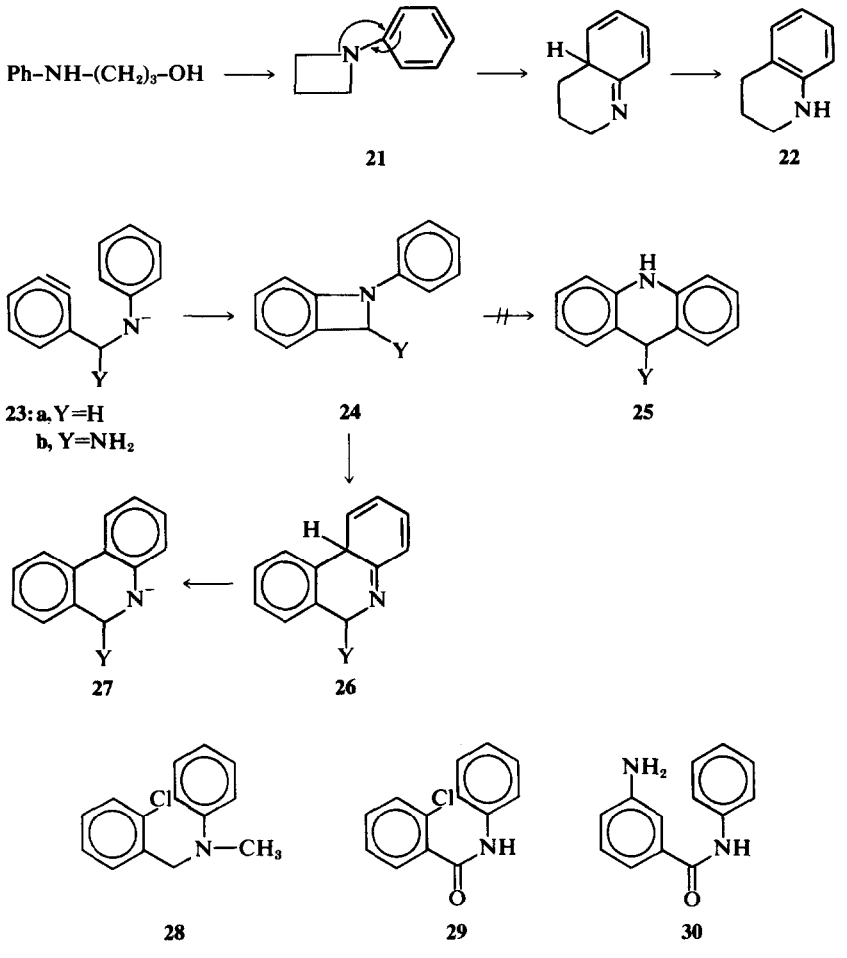
*It is known that anilide ions do not generate dehydrobenzene in liquid ammonia.[11]

†Due to similar pK_a values of benzylaniline (**13**) and its *o*-chloro analogue **4**, the equilibrium represented by equation (ii) could be expected to get established.

‡Intramolecular reactions of benzyne with carbanions are known to lead to four membered ring structures.[14]

§Ring fission to a benzyl radical should be preferred over that to a phenyl radical. This reaction proceeds only at high temperature.

‖The *meta* orientation observed in the amination is perhaps a consequence of the blocking of the attack at *ortho* position due to a field interation, in the transition state, between the two proximate negative charges; *cf* orientation effect of carboxylate ion.[17a]



anils, the postulated adduct **10** has the requisite activation to undergo cyclisation like **4**. For the amide ion addition step itself, the following evidence has been adduced to show: (a) such a process can occur under the reaction conditions, (b) its rate is sufficiently fast and (c) the equilibrium lies in favour of the adduct* anion.

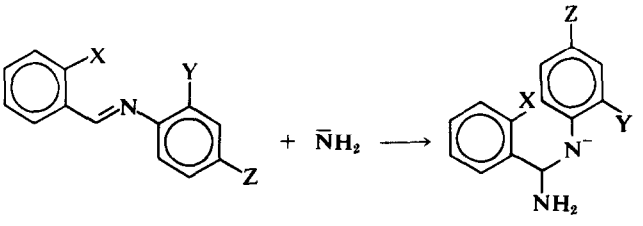
Model anil **31a**, excess sodamide, dioxan (as reference lock) and liquid ammonia were brought together in an NMR tube, at liquid nitrogen temperature, and sealed under vacuum. The tube was allowed to warm up to −40° and immediately placed in a 100 Mc NMR spectrometer probe maintained at this temperature. Scanning was repeated at 5 min intervals and the disappearance of the azomethine proton signal† at δ 4·96 was used as a measure of the progress of the amide ion addition. By the time the first spectrum could be recorded, a substantial portion of the anil had already reacted and its concentration was negligible after 20 min. As the intensity of the δ 4·96 signal diminished, new peaks started appearing in the δ 1·8–3·2 area (Fig 1). On the basis of the NMR spectra reported[18] for anilide anions, these peaks can be assigned to protons of the ring attached to the negatively charged N atom in the adduct **12**.

When the chloroanil **31b** was treated with potassium amide in liquid ammonia, the rate of halide loss was found to be extremely slow. Evidently, the reactant had been rapidly converted into a species in which benzyne formation was suppressed—an effect expected in the adduct **32b** due to the presence of the negative charge adjacent to the ring carrying the halogen atom.[19] Good yield of 2-chlorophenanthridine obtained in cyclisation of anil **31c** also seems to be a consequence of this protective anion formation.

Condensation of *p*-carbethoxyaniline with *o*-chlorobenzaldehyde was found to afford a stable adduct[20] (**33**). Reaction of this material with potassium amide in liquid ammonia gave the

*For a successful cyclisation these conditions have to be met.[8]

†This was determined from an independent spectrum of the anil **31a** in liquid ammonia.



31: a; X=Y=Z=H
b; X=Z=H, Y=Cl
c; X=Z=Cl, Y=H

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phenanthridine* (**34**; 75%) along with *p*-carbethoxyaniline. Thus, it has been possible to simulate the path proposed for reaction of haloanils (**3** → **9**)– the anion from **33** is analogous to the amide ion adduct and a molecule of *p*-carbethoxyaniline, instead of ammonia, gets expelled subsequent to cyclisation.

Lastly, one other aspect of the mechanism of this cyclisation has been investigated. In the intermediate **35**, the starred proton can be transferred intramolecularly to the anionic site (path a) or a gain from and loss to the surroundings can occur (path b). When the labelled anil **36**, from 2,4,6-trideutereoaniline and *o*-chlorobenzaldehyde, was subjected to the reaction conditions, the mass spectrum of the isolated phenanthridine (M^+ at *m/e* 181) revealed the presence of only two deuterium atoms in the molecule. Since only one deuterium atom was lost and further exposure (1 hr) of the product led to no change, it is clear that amide ions in liquid ammonia as such do not cause general proton exchange. To exclude the remote possibility that in the product deuterium is still present at C-10 but has been specifically exchanged from one of the other two positions, location of the residual deuteriums was undertaken by NMR spectroscopy.

The 100 Mc NMR spectra of phenanthridine† and the isolated labelled product (**37**) are shown in Fig 2. In the latter, the signal corresponding to H-4 is completely missing showing retention of deuterium at this site. The signal from H-2 falls in a highly overlapped region and no conclusion regarding this site can be drawn. Interestingly, there is a drastic simplification of the pattern in the δ 8·5 region (H-1, H-10) which may, at first sight, suggest absence of hydrogen at position 10 thus indicating intramolecular deuterium transfer. However, the integral ratio of the signal in this

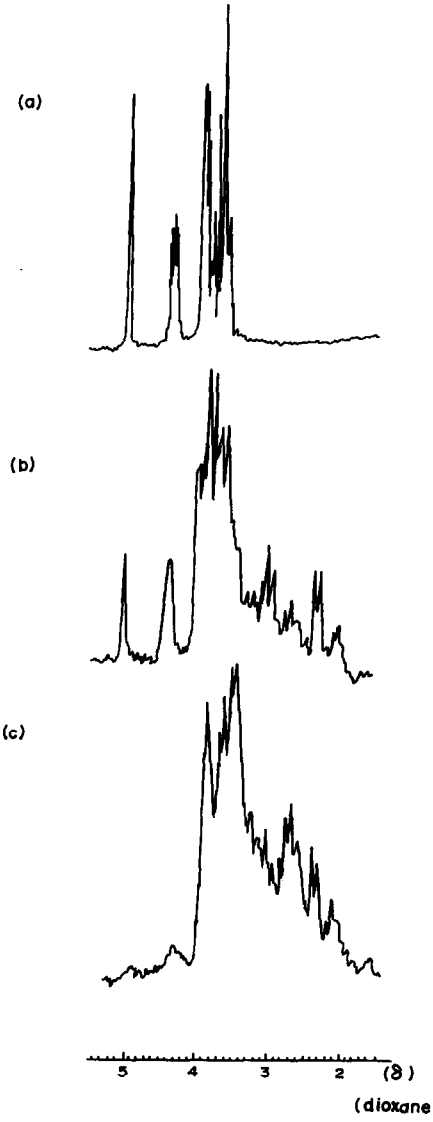

Fig 1. (a) NMR spectrum of benzylideaniline (**31a**) in liquid ammonia at −40°. (b, c) NMR spectrum of benzylideneaniline (**31a**) and sodamide in liquid ammonia at −40°, scanning started at (b) 0 minute and (c) 20 min.

*The ester group in the formed phenanthridine apparently gets converted to an amide under the reaction conditions.

†60 Mc NMR of phenanthridine, along with assignment of various peaks, is known. Due to some overlapping of peaks of interest at this field strength, NMR spectra were recorded at 100 Mc in the present work.[21]

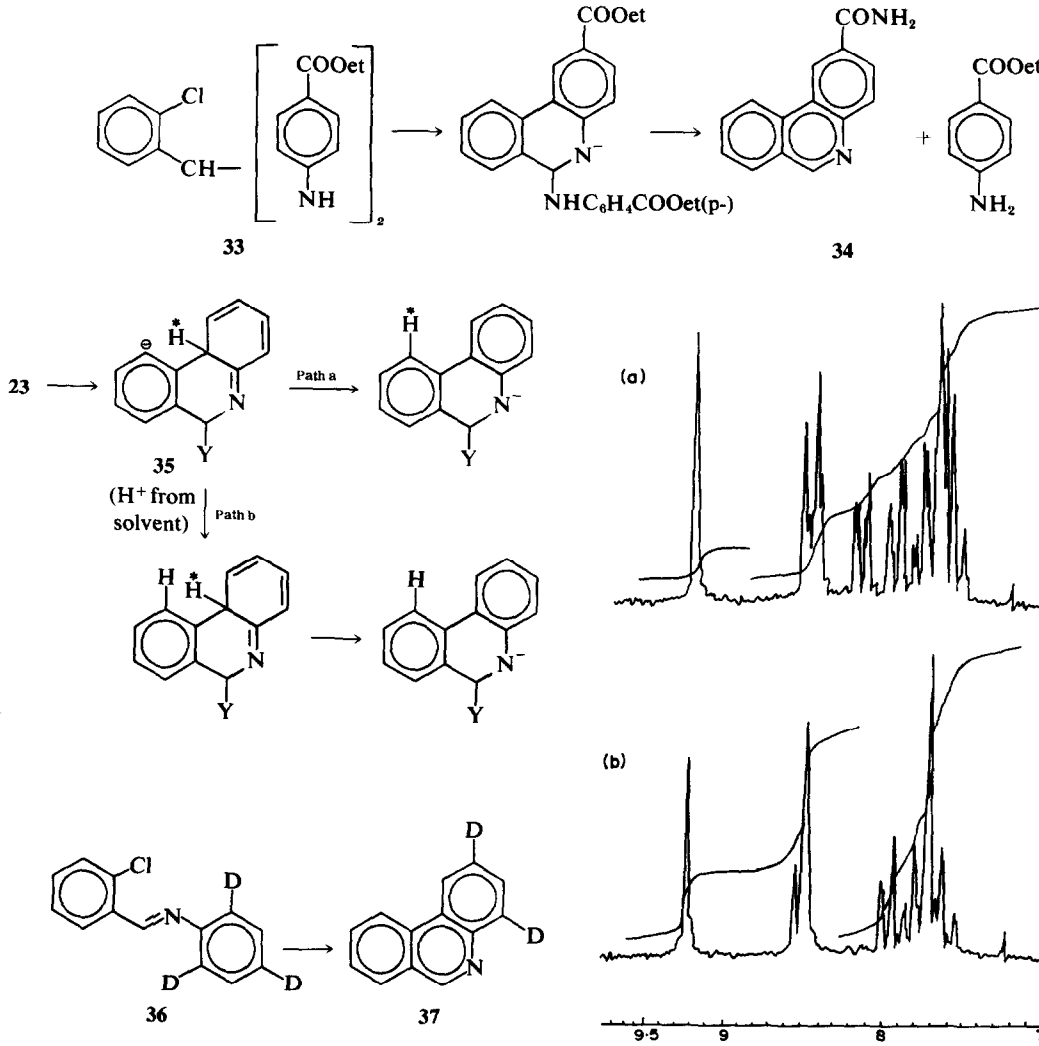

Fig 2. (a) NMR spectrum of phenanthridine (9). (b) NMR spectrum of 2,4-dideutereophenanthridine (37).

area to that of H-6 signal at δ 9·25 still remains 2:1. The simplification is clearly due to collapse of coupling between H-1 and H-2 as the latter gets replaced by deuterium. Only two peaks (integral ratio 1:3) are observed because of a fortuitous superimposition of the singlet from H-1 on the higher component of the doublet from H-10.

From the above experiments it is clear that the proton H* does not get transferred intramolecularly. This may be due to the fact that the orbital at C-10 in 35 is not ideally directed towards it. Availability of protons in liquid ammonia could be another factor and a different situation may obtain in an aprotic solvent.

EXPERIMENTAL

M.p.'s and b.p.'s are uncorrected. NMR spectra were recorded on a Varian HA-100. Mass spectra (70 e/V) were recorded on a MS-9 spectrometer.

o-Chloro-N-phenylbenzylamine (4). A soln of 3[22] (2·5 g, 11·6 mmole) in EtOH (15 ml) was treated at 0° with $NaBH_4$ (445 mg, 11·7 mmole) and then heated at 50° for 2 hr.[23] The mixture was decomposed with H_2O (100 ml) and extracted with ether. The ether extract was washed with H_2O and dried. The solvent was removed and the residual oil distilled under reduced pressure giving 4 (2·1 g, 83%); b.p. 155–60°/2 mm; (Lit.[24] b.p. 325–27°).

General method of cyclisation. To liquid NH_3 (300 ml) contained in a 500 ml 3-necked flask, fitted with a sealed mechanical stirrer and a KOH guard tube, small pieces of K metal were added till the blue colour persisted for about 10 min. Then, after putting in a small crystal of $Fe(NO_3)_3$ to catalyse the conversion of K metal to KNH_2, the calculated amount of K metal (6 moles, unless otherwise specified) was added. When the metal had reacted completely, as indicated by a colour change from blue to deep grey, the substrate was introduced quickly. The solids were added directly, whereas liquids were transferred to the flask with the aid of a minimum amount of

anhyd ether. As soon as the reactant came into contact with the basic medium the entire soln acquired a deep colour – usually orange brown.

After the chosen time (1/2 hr, unless otherwise specified), the reaction was quenched with excess NH_4Cl and NH_3 was allowed to evaporate. To the residue, H_2O (200 ml) was added and the organic material was taken up in ether (unless otherwise specified) and washed with H_2O. After drying over Na_2SO_4, the solvent was removed. Absence of halogen was checked at this stage by Beilstein's test. The crude residue was examined by TLC and m.p. determination. Pure materials were obtained by crystallisation from a suitable solvent. In cases where incomplete reaction was indicated by the presence of halogen, reaction was repeated giving longer time or using a larger molar ratio of metal amide to the substrate.

5,6-Dihydrophenanthridine (**8**). Reaction of **4** (0·5 g, 2·3 mmole) with KNH_2 (from 538 mg, 13·8 mmole, K metal), according to the general procedure described above, for 3 hr gave a solid (409 mg, 98%; m.p. 110–16°). TLC (light petroleum:ether, 2:1) showed two spots (major > 90%). It was crystallised from light petroleum to give pure **8**, m.p. 124–5°, undepressed on admixture with an authentic sample.[25]

Oxidation of 5,6-dihydrophenanthridine (**8**) *with manganese dioxide.* A soln of **8** (150 mg) in $CHCl_3$ (10 ml) was stirred with MnO_2 (1·5 g) for 3 hr at room temp. The mixture was filtered and the residue was washed with $CHCl_3$. Solvent was removed from the combined filtrate to get **9** (116 mg, 78%); m.p. 103–5°. TLC (light petroleum:ether, 2:1) showed a single spot corresponding to (**9**).

Reaction of 5,6-dihydrophenanthridine (**8**) *with N-chloro succinimide and base.* To a stirred soln of **8** (150 mg, 0·83 mmole) in CH_2Cl_2 (30 ml) N-chlorosuccinimide (222 mg, 1·66 mmole) in CH_2Cl_2 (15 ml) was added dropwise in 1 hr, maintaining the temp below −5°.[26] The mixture was stirred further at room temp for 15 min. It was then washed with cold H_2O and dried ($CaCl_2$). The solvent was removed and the crude solid was shaken with NaOEt (from 39 mg Na) in EtOH (10 ml) for 1/2 hr. The mixture was diluted with H_2O, filtered and washed well with H_2O to give **9** (136 mg, 90%; m.p. 103–5°). TLC (light petroleum:ether, 2:1) showed a single spot corresponding to **9**.

Phenanthridine (**9**). Reaction of **3** (0·5 g, 2·32 mmole) with KNH_2 (from 543 mg, 13·92 mmole, K metal), according to the general procedure, gave a solid (408 mg, 98%; m.p. 102–4°). TLC (light petroleum:ether, 2:1) showed two spots (major > 90%). The solid was crystallised from aq EtOH to give pure **9**, m.p. 104–5°, undepressed on admixture with an authentic sample;[26] NMR ($CDCl_3$) δ 9·23 (s,1,H-6), δ 8·5 (m,2,H-1,H-10), δ 8·20 (s,1,H-4), δ 8·05–7·52 (m,5,H-2,3,7,8,9).

Reaction of o-chloro-N-phenylbenzylamine (**4**) *with potassium salt of N-benzylaniline* (**13**). To KNH_2 (from 538 mg, 13·8 mmole, K metal) in liquid NH_3, prepared according to the general procedure, **13** (2·95 g, 16·1 mmole) in ether (5 ml) was added. The mixture was stirred for 15 min to ensure complete salt formation. Then, an ethereal soln (5 ml) of **4** (500 mg, 2·3 mmole) was added to the stirred mixture. After 3 hr further stirring, excess NH_4Cl (5 g) was added and NH_3 allowed to evaporate. To the residue H_2O (200 ml) was added and the resulting suspension extracted with ether. The ether extract was washed with H_2O and dried. Solvent was removed to get an oil which on comparative TLC (light petroleum:ether, 2:1) did not show any spot corresponding to **8** but showed spots corresponding to the starting amines only. The oil also gave a positive Beilsteins test for halogen.

N-(2-Bromobenzylidene)-aniline (**16**). A mixture of *o*-bromobenzaldehyde (2 g, 10·81 mmole) and aniline (1 g, 10·81 mmole) was heated in a test tube on an oil bath at 110°. Water started to condense on the sides of the test tube which was wiped with a cotton plug. When the water formation stopped, the residue was distilled under reduced pressure to get **16** (1·97 g, 70%, b.p. 160°/1 mm). (Found: N, 5·30. $C_{13}H_{10}Br$ requires: N, 5·38%).

Phenanthridine (**9**) *from N-(2-bromobenzylidene)-aniline* (**16**). Reaction of **16** (0·5 g, 1·92 mmole) with KNH_2 (from 0·45 g, 11·53 mmole, K metal) gave a solid (325 mg, m.p. 93–100°) TLC (light petroleum:ether, 2:1) of the solid showed 3 spots (major > 90%). No halogen was observed in Beilstein's test. Crystallisation of the solid from aq EtOH afforded pure **9**, m.p. 105°.

N(2-Fluorobenzylidene)-aniline (**17**). The anil **17** (4·25 g, 98%; b.p. 135° at 1 mm) was prepared from *o*-fluorobenzaldehyde (3 g, 24·2 mmole) and aniline (2·25 g, 24·2 mmole) according to the procedure described above for the preparation of the **16**. (Found: N, 6·92. $C_{13}H_{10}FN$ requires: N, 7·03%).

Reaction of N-(2-fluorobenzylidene)-aniline (**17**) *with potassium amide.*

A. The anil **17** (0·5 g, 2·51 mmole) was treated with KNH_2 (from 589 mg, 15·1 mmole, K metal, according to the general procedure for 1/2 hr. No brown or orange colour appeared and the mixture remained grey throughout the course of the reaction. The usual work up gave an oil (470 mg), TLC (light petroleum:ether, 2:1) of which showed no spot corresponding to **9**.

B. Reaction of **17** (0·5 g, 2·51 mmole) with KNH_2 (from 975 mg, 25 mmole, K metal) for 3 hr gave an oil (460 mg). Comparative TLC (light petroleum:ether, 2:1) again showed little phenanthridine (2–3%) formation and Beilstein's test remained positive.

Phenanthridine (**9**) *from N-(3-chlorobenzylidene)-aniline* (**18**). Reaction of **18**[27] (1 g, 4·6 mmole) with KNH_2 (1·09 g, 27·8 mmole, K metal) gave a solid (806 mg, m.p. 88–95°). TLC (light petroleum:ether, 2:1) showed four spots (major ~ 75%). The solid was crystallised from aq EtOH to give **9**; m.p. 99–103°, undepressed on admixture with an authentic sample.

9-Methoxyphenanthridine (**20**). Reaction of **19**[28] (1 g, 3·45 mmole) with KNH_2 (from 807 mg, 20·69 mmole, K metal), afforded a solid (0·7 g, 97%; 80–83°) which on TLC (light petroleum:ether, 1:1) showed two spots (major ~ 90%). It was crystallised from light petroleum to give **20**, m.p. 85–6°. A hydrochloride was prepared in ether and purified by crystallisation from EtOH; m.p. 241–2°; (Lit.[29] m.p. 236–8°). (Found: N, 6·46. $C_{14}H_{11}NO$ requires: N, 6·69%).

o-Chloro-N-methyl-N-phenylbenzylamine (**28**). A solution of *o*-chlorobenzylchloride (5 g, 31·06 mmole) and N-methylaniline (6·65 g, 62·15 mmole) in ether (100 ml) was kept overnight at room temp and then refluxed for 6 hr.[30] The solid hydrochloride was filtered off and washed with ether. The filtrate was washed with H_2O, dried and the solvent removed. The residue was distilled under vacuum. After an initial fraction at 70–80°/1 mm, **28** distilled over as a colourless liquid (5·39 g, 75%); b.p. 165–70°/1 mm. (Found: N, 6·35. $C_{14}H_{14}ClN$ requires: N, 6·1%).

Reaction of o-*chloro*-N-*methyl*-N-*phenylbenzylamine* (**28**) *with potassium amide.* Reaction of **28** (0·5 g, 2·16 mmole) with KNH_2 (from 506 mg, 12·97 mmole, K metal) for 3 hr gave an oil. TLC (light petroleum:ether, 2:1) showed 5 spots none of which corresponded to 5-methyl-5,6-dihydrophenanthridine.[31]

Reaction of 2-*chlorobenzanilide* (**29**) *with potassium amide.* The anilide **29** (2 g, 8·64 mmole) was treated with KNH_2 (from 2·02 g, 51·8 mmole, K metal) for 3 hr. The mixture was extracted with EtOAc, washed with H_2O and the organic layer extracted with 1:1 HClaq. Acidic layer was washed with EtOAc and basified with 10% NaOHaq. On standing white needles appeared which were collected by filtration, washed with H_2O and dried (875 mg, 48%; m.p. 123–5°). Crystallisation from H_2O afforded pure **30**; m.p. 124–5°, undepressed on admixture with an authentic sample.[32] Identical R_f values were obtained on comparative TLC in several solvent systems.

Reaction of N-*benzylidene*-o-*chloroaniline* (**31b**) with potassium amide. The anil[33] **31b** (0·5 g, 2·32 mmole) was treated with KNH_2 (from 543 mg, 13·92 mmole, K metal) for 3 hr to get an oil which by comparative TLC (light petroleum:ether, 2:1) showed no spot corresponding to **9**. The material also gave a positive Beilstein's test.

2-*Chlorophenanthridine.* Reaction of **31c**[34] (0·5 g, 2 mmole) with KNH_2 (from 468 mg, 12 mmole K metal) gave a solid (420 mg, m.p. 142–7°). TLC (light petroleum:ether, 2:1) showed 3 spots (major ~ 85%). It was crystallised from EtOH to furnish pure 2-chlorophenanthridine (250 mg, 58%; m.p. 155–6°). (Found: N, 6·89. $C_{13}H_8ClN$ requires: N, 6·56%).

N,N′-(2-*Chlorobenzylidene*)-*bis*(p-*carbethoxyaniline*) (**33**). A soln of *o*-chlorobenzaldehyde (2·56 g, 1·82 mmole) and *p*-carbethoxyaniline (3 g, 1·82 mmole) in EtOH (50 ml) was refluxed for 2 hr. It was concentrated and cooled to furnish **33** (3·3 g, 80%), m.p. 95–6°. (Found: N, 6·48. $C_{25}H_{25}ClN_2O_4$ requires: N, 6·19%).

Phenanthridine-2-*carboxamide* (**34**). The amine **33** (0·5 g, 1·1 mmole) was treated with KNH_2 (from 407 mg, 10·43 mmole, K metal) for 2 hr. After the usual work up the mixture was extracted with ether and the insoluble solid removed by filtration. Ether extract was washed with H_2O dried. Removal of solvent afforded a gummy solid (280 mg). It was crystallised from light petroleum (residue 40 mg) to give *p*-carbethoxyaniline (100 mg); m.p. 88–9°, undepressed on admixture with an authentic sample.[35]

The ether insoluble portions were washed well with H_2O and dried (183 mg, 75%). Crystallisation from EtOH afforded pure **34**, m.p. 268–9°. (Found: N, 12·8. $C_{14}H_{10}N_2O$ requires: N, 12·61%).

N-(o-*Chlorobenzylidene*)-2,4,6-*trideuterioaniline* (**36**). A mixture of *o*-chlorobenzaldehyde (2·93 g, 20·83 mmole) and 2,4,6-trideuterioaniline (2 g, 20·83 mmole) was heated in a test tube at 110°. Water started to condense on the sides of the test tube and was wiped with a cotton plug. When the water formation stopped, the residue was distilled under vacuum to give the anil **36** (4·1 g, 90%), b.p. 140–4°/2–3 mm.

2,4-*Dideuteriophenanthridine* (**37**). Reaction of **36** (0·5 g, 2·29 mmole) with KNH_2 (from 524 mg, K metal), according to the general procedure, gave crude **37** (406 mg, 98%, m.p. 101–3°). TLC (light petroleum:ether, 2:1) showed two spots (major > 90%). Crystallisation from aq EtOH furnished pure **37** (250 mg), m.p. 105–6°, NMR ($CDCl_3$) δ9·25 (s,1,H-6), δ8·5 (d,2,J ~ 8 cps, H-1, H-10), δ8·05–7·54 (m,4,H-3,7,8,9); mass spectrum (70 e/V) *m/e* (rel intensity) 182(13), 181(100), 180(26), 179(50), 178(8), 154(5), 153(9), 152(8), 151(7), 90·5(8) M^{++}), 85(5), 83(9·5), 77(12·6), 76(8).

Treatment of 2,4-*dideuteriophenanthridine* (**37**) *with potassium amide.* The labelled product **37** (200 mg) was treated with KNH_2 (from 258 mg K metal) in liquid NH_3 (100 ml) for 1 hr and reisolated according to the general procedure. The crude solid (185 mg, m.p. 104–5°) showed only one spot on TLC (light petroleum:ether, 2:1); NMR superimposable on that of the starting material.

REFERENCES

[1]S. V. Kessar, M. Singh, P. Jit, G. Singh and A. K. Lumb, *Tetrahedron Letters* 471 (1971).

[2a]R. S. Theobald and K. Schofield, *Chem. Rev.* **46**, 171 (1950); [b]J. Eisch and H. Gilman, *Ibid* **57**, 525 (1957); [c]Recent developments: *Advances in Heterocyclic Chemistry* (Edited by A. R. Katritzky) Vol. 13. Academic Press, New York (1971).

[3]F. B. Mallory, C. S. Wood and J. T. Gordon, *J. Am. Chem. Soc.* **86**, 3094 (1964); P. Hugelshofer, J. Kalvoda and K. Schaffner, *Helv. Chim. Acta* **43**, 1322 (1969).

[4]R. G. Miller and M. Stiles, *J. Am. Chem. Soc.* **85**, 1798 (1963).

[5]R. W. Hoffmann, *Dehydrobenzene and cycloalkynes* p. 126. Academic Press, New York (1969); D. H. Hey, J. A. Leonard and C. W. Rees, *J. Chem. Soc.* 5266 (1963).

[6]C. A. Coulson and A. Streitwieser, *Dictionary of Electron Calculations.* Pergamon Press, New York (1965).

[7]E. Fischer, and Y. Frei, *J. Chem. Phys.* **27**, 808 (1957); D. G. Abderson and G. Wettermarg, *J. Am. Chem. Soc.* **87**, 1433 (1965); G. Wettermark, J. Weinstien, J. Sousa and L. Dogliotti, *J. Phys. Chem.* **69**, 1584 (1965).

[8]For a general discussion of 'Trans Cyclisation' and kinetic conditions necessary for its success, see S. V. Kessar, M. Singh, R. Chander, D. Pal and U. K. Nadir, *Tetrahedron Letters* 467 (1971).

[9]S. M. Kupchan and H. C. Wormser, *J. Org. Chem.* **30**, 3792 (1965).

[10]H. H. Strain, *J. Am. Chem. Soc.* **50**, 2218 (1928).

[11]R. E. Wright and F. W. Bergstron, *J. Org. Chem.* **1**, 179 (1936).

[12]F. W. Bergstron, R. E. Wright, C. Chandler and W. A. Gilkey, *J. Org. Chem.* **1**, 170 (1936).

[13]R. T. Morrison and R. N. Boyd, *Organic Chemistry*, (2nd Edition) p. 841–2. Prentice Hall of India, New Delhi (1969).

[14]J. F. Bunnett and J. A. Skorcz, *J. Org. Chem.* **27**, 3836 (1962).

[15]V. N. Gogte, H. M. El-Namaky, M. A. Salama and B. D. Tilak, *Tetrahedron Letters* 3320 (1969).

[16]R. B. Woodward and R. Hoffmann, *The Conservation of Orbital Symmetry*, p. 118. Verlag Chemie, GmbH, Academic Press (1970).

[17]G. Quinkert, W. W. Wiersdorff, M. Finke, K. Opitz and F. G. Von der Haar, *Chem. Ber.* **101**, 2302 (1968).

[17a]E. R. Biehl, E. Nieh, H. M. Li and C. I. Hong, *J. Org. Chem.* **34**, 500 (1969).

[18]T. Birchall, and W. L. Jolly, *J. Am. Chem. Soc.* **88**, 5439 (1966); R. Waack, M. A. Doran, E. B. Baker and G. A. Olah, *Ibid.* **88**, 1272 (1966).

[19]J. F. Bunnett, *J. Chem. Ed.* **38**, 283 (1961); G. B. R. deGraaf, H. J. denHertog and W. Ch. Melger, *Tetrahedron Letters* 963 (1965).

[20]R. W. Layer, *Chem. Rev.* **63**, 489 (1963); E. W.

Nasiruddin and M. Latif, *Chem. Ind.* 51 (1969).
[21]R. H. Martin, N. Defay, F. Geerts-Evrard and D. Verhoogen-Bogaert, *Tetrahedron* Supp. **8**, 181 (1968) and refs therein.
[22]E. Bamberger and J. Muller, *Ann. Chem.* **313**, 116 (1902).
[23]Z. Horii, T. Sakai and T. Inoi, *J. Pharm. Soc. Japan* **75**, 1161 (1955); *Chem. Abstr.* **50**, 7756i (1956).
[24]I. Heilbron, *Dictionary of Organic Compounds* (4th Edition) p. 106. Eyre and Spottiswoode, London (1965).
[25]W. C. Wooten and R. L. McKee, *J. Am. Chem. Soc.* **71**, 2946 (1949).
[26]J. Kenner, W. H. Ritchie and F. S. Statham, *J. Chem. Soc.* 1169 (1937).
[27]A. Roe and J. A. Montgomery, *J. Am. Chem. Soc.* **75**, 910 (1953).
[28]R. G. Naik and T. S. Wheeler, *J. Chem. Soc.* 1780 (1938).
[29]T. R. Govindachari, B. R. Pai and V. N. Sundararajan, *Ibid.* 1715 (1958).
[30]N. Ueda, T. Tokuyama and T. Sakan, *Bull. Chem. Soc. Japan* 2012 (1966).
[31]P. Karrer, L. Szabo, H. J. V. Krishna and R. Schwyzer, *Helv. Chim. Acta* **33**, 294 (1950).
[32]Engler and Volkhausen, *Ber. dtsch. chem. Ges.* **8**, 35 (1875).
[33]O. Fisher and P. Neber, *Ibid.* **45**, 1094 (1912).
[34]A. Hantzsch and O. Schwab, *Ibid.* **34**, 832 (1901).
[35]I. Heilbron, *Dictionary of Organic Compounds* (4th Edition) p. 338. Eyre and Spottiswoode, London (1965).