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THE REACTION OF INDOLES WITH DIBORANE[1]

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Abstract—Reaction of excess diborane with N-unsubstituted indoles is postulated to yield a stable N_{ind}-boron adduct. Further reaction of this adduct depends on the conditions employed. If the excess hydride is quenched with acetone in the *absence* of a proton source, no net reaction occurs and starting indole is recovered. Effective reduction of indoles to indolines under nonacidic conditions occurs, however, if the initial nitrogen-boron adduct is treated with sodium methoxide-methanol. Indole, and mono-, di-, and aromatic ring substituted derivatives containing an N_{ind}-H are reduced in good yield; N-methylindoles are not reduced. When methanol-O-d is used as a proton source, specific incorporation of one carbon-bound deuterium atom at C_3 of the indoline occurs. Reduction of 2,3-dimethylindole yields a 47:53 mixture of *cis*- and *trans*-2,3-dimethylindoline while reduction of tetrahydrocarbazoles gives only the corresponding *cis*-hexahydrocarbazoles. A mechanism consistent with these data is proposed. Indole is excluded as an intermediate in the diborane reduction of oxindole to indoline.

ALTHOUGH the selective diborane reduction of various functional groups in molecules containing an indole ring is known,[3] there is evidence that the indole nucleus can react with diborane. For example, diborane reduction of an amide group during the synthesis[4] of dehydrobufotenine resulted, to a small extent, in concomitant reduction of the indole ring to an indoline moiety. Furthermore, treatment of the parent substrate, indole, with diborane is reported to yield variable amounts of indoline,[3] and 2-ethoxyindoles are reduced to indoles by diborane.[3b] It is also known that enamines react readily with diborane to yield *cis* addition products derived from attack of boron on the β-C atom of the enamine system.[5]

In view of the importance of diborane reactions as a general synthetic method[6] a detailed study of the reaction of diborane with various indoles was undertaken. The results of this study, described below, show that diborane can serve as a selective reducing agent for functional groups in the presence of an indole ring and that indoles can be reduced to indolines with diborane under non-acidic reaction conditions.*

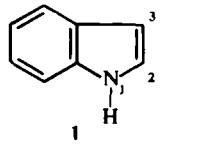
RESULTS

Initial reaction of indoles and various derivatives of indole containing an N—H group (Table 1) at room temperature with excess diborane in tetrahydrofuran (BH_3·THF complex, prepared by an external generation, see Experimental for details) resulted in rapid evolution of one equivalent of hydrogen gas. Depending on the subsequent conditions employed, further reaction of this initial mixture could be controlled to give either recovered starting indole (*i.e.*, no net reduction) or reduction to indoline.

If the excess hydride in this initial solution was *quenched*, either by treatment with excess acetone (preferred method) or by slow inverse addition to a large excess of

* Optimum conditions for both chemical and catalytic reductions of indoles to indolines involve strong acid, thus precluding the presence of acid sensitive groups[7]

methanol, the starting indole substrate was recovered unchanged. Thus it should be possible to suppress the previously observed side reaction of indole ring reduction during diborane reduction of other functional groups by quenching the reaction mixture with acetone before normal hydrolytic workup. Using this procedure, 5-hydroxy-2-methyl-3-acetylindole (**15a**) was reduced to the 3-ethylindole derivative **16a** in 82% yield,[8] and 3-acetylindole (**15b**) gave 3-ethylindole (**16b**). If, however, the acetone quenching step was omitted during the reduction of 3-acetylindole (**15b**) variable amounts of the corresponding indoline were obtained.[9]



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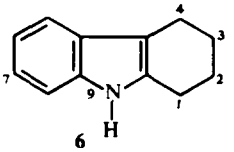

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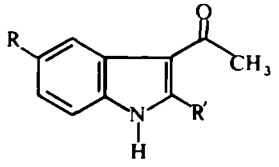
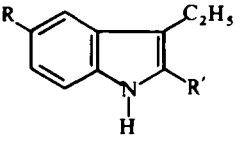


15 a: R = OH, R′ = CH_3
b: R = R′ = H



16 a: R = OH, R′ = CH_3
b: R = R′ = H

When the initial reaction mixture was treated with water or methanol under neutral, acidic, or basic conditions, reduction to indoline was observed. After considerable experimentation, optimum yields of indoline were achieved by slow addition of a sodium methoxide-methanol solution to the initial mixture at room temperature. When the evolution of hydrogen gas ceased, the resulting solution was heated briefly at reflux with excess acetone, and then the indoline was isolated by acid extraction. Table 1 summarizes the substrates examined and the results obtained.

TABLE 1. REACTION OF INDOLES WITH DIBORANE UNDER REDUCING CONDITIONS

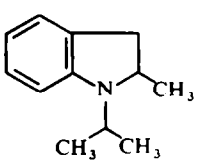
Substrate	Product	% Yield[a]
Indole (**1**)	Indoline (**9**)	44
3-Methylindole (**2**)	3-Methylindoline (**10**)	66
2-Methylindole (**3**)	2-Methylindoline (**11**)[b]	50
2,3-Dimethylindole (**4**)	2,3-Dimethylindoline (**12**)[c]	93
1,2,3-Trimethylindole (**5**)	[d]	67
Tetrahydrocarbazole (**6**)	*cis*-Hexahydrocarbazole (**13**)	98
7-Methoxytetrahydrocarbazole (**7**)	*cis*-7-Methoxyhexahydrocarbazole (**14**)	85
9-Methyltetrahydrocarbazole (**8**)	[d]	65

[a] Corrected for recovered starting material
[b] A small amount of N-isopropyl-2-methylindoline (**17**) (7%) was also isolated
[c] The ratio of *cis*/*trans* isomers was 47:53
[d] Recovered starting material

Examination of the data in Table 1 reveals several aspects of the net reduction process. With respect to substitution on the indole nucleus, indole, and mono-, di-, and aromatic ring substituted derivatives are reduced while N-methylindole substrates are not. In one case, N-isopropyl-2-methylindoline (**17**) was isolated as a by-product in the reduction of 2-methylindole (**3**). Most probably, **17** arises from reaction of 2-methylindoline (**11**) and acetone during work-up followed by reduction of the resulting imine derivative by some residual methoxyborohydride species. When the acetone step was omitted, **11** was the only product isolated.

Reduction of 2,3-dimethylindole (**4**) gives a 47:53 mixture of *cis*- and *trans*-2,3-dimethylindoline (**12**). These products were isolated by preparative VPC and identified by conversion to known derivatives.[10] (Experimental). Thus a simple *cis* addition, protonolysis mechanism is excluded.[5] Reduction of the tetrahydrocarbazole substrates **6** and **7** furnished selectively the *cis*-hexahydrocarbazole derivatives **13** and **14**. It should be noted that the same general stereochemical results are observed in acid catalyzed reductions of indoles; *e.g.*, 2,3-dimethylindole yields a mixture[7b, 10] of *cis*- and *trans*-products **12** while tetrahydrocarbazoles are reduced predominately[11] or exclusively[12] to the *cis*-fused products.

When the initial reaction mixtures derived from indole (**1**) and tetrahydrocarbazole (**6**) were treated with sodium methoxide-methanol-O-d, followed by acetone, and then hydrochloric acid extraction, the C_3-(indole numbering) monodeuterated indolines **18** and **19**, ca 70–85% incorporation, were formed. The extent and position of deuterium incorporation in the product indolines (**18** and **19**) were ascertained by NMR analysis of the N–D species **18b** and **19b** and of the N-acetyl derivatives **18c** and **19c**. In each case, the C_2- and C_3-protons are well resolved and clearly identified (Experimental). No evidence for deuterium incorporation at C_2 was observed. When methanol was used as a proton source, and either acetone-d_6 or deuterium chloride/deuterium oxide was substituted in the normal workup procedure, no carbon-bound deuterium was found in the resulting indoline.



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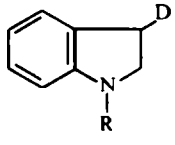
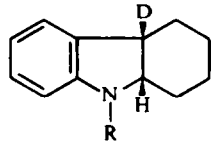
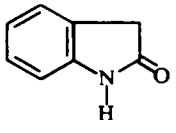


18a: R = H
b: R = D
c. R = Ac



19a: R = H
b: R = D
c: R = Ac



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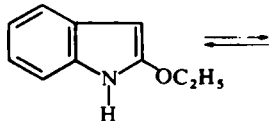
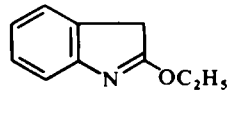


21a

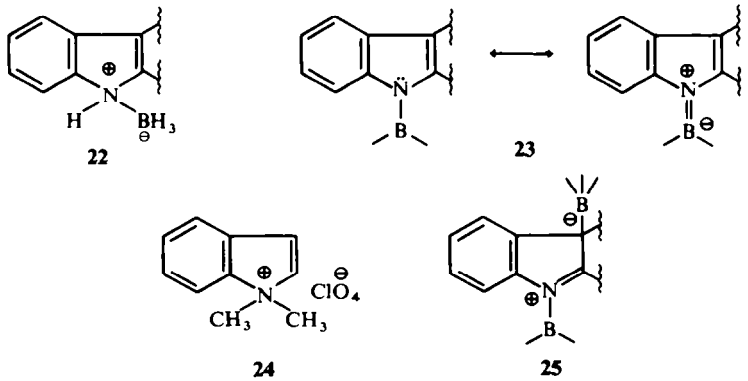


21b

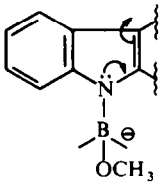
It has been reported that oxindole derivatives containing an N–H group (*e.g.*, **20**) are reduced to the corresponding indoline with diborane[3] while N-substituted oxindoles yield both indoles and indolines under similar conditions.[3b] Since it has now been shown that indoles can be reduced with diborane, the possible intermediacy of indole in the reduction of oxindole (**20**) to indoline (**9**) was considered. This possibility was excluded, however, on the basis of two experimental observations: (1) qualitatively the rate of diborane reduction of oxindole (**2**) to indoline (**9**) was much faster than the corresponding reduction of indole (**1**) to **9**; little or no indole was observed by TLC analysis of the crude reaction products; and (2) when the oxindole reduction mixture was worked up with deuterated solvent, no carbon-bound deuterium was found in the indoline product. In contrast, however, the reported reduction[3b] of 2-ethoxyindole (**21**, a mixture of the tautomers **21a**:**21b** in solution[13]) was confirmed when limited amounts of diborane were used; when excess diborane was employed, considerable indoline was formed.

DISCUSSION

The reaction of indoles with diborane can be divided into two distinct stages. In the first stage, formation of the amine-borane complex **22**, followed by facile loss of one equivalent of hydrogen to give the nitrogen-boron adduct **23** is postulated. Although simple amine-boron complexes are normally stable at room temperature,[14] regeneration of the aromatic π-system of the indole nucleus provides the driving force for the loss of hydrogen from **22**. In a similar fashion, the N,N-dimethylindole salt **24** undergoes rapid, room temperature cleavage with lithium chloride to give N-methylindole and methyl chloride.[15] Further reaction of adduct **23**, such as electrophilic addition at C_3 to give **25**, should be inhibited by resonance delocalization of the indole nitrogen atom lone pair of electrons to boron (see **23**). Support for this hypothesis was obtained by comparing the ultraviolet spectrum of the starting indole with that of the initial reaction mixture from diborane and the indole. Using indole (**1**) and tetrahydrocarbazole (**6**) as substrates, no significant changes in the absorption maxima were observed in either system. Thus a major perturbation in the chromophore, such as the formation of **25**, has not occurred. Since formation of adduct **23** does not involve a reduction, decomposition of the excess hydride in the absence of a proton source, followed by aqueous workup, results in regeneration of the starting indole as observed.



In the second stage, net reduction of adduct **23** to indoline upon treatment with a methoxide-methanol solution is postulated to involve sequentially a nucleophile, a proton source, and some hydride species. As an initiating step, methoxide adds to the boron atom of adduct **23** to give intermediate **26**. In contrast to adduct **23**, the N atom lone pair of electrons in **26** is now available to assist electrophilic addition at C_3. Thus, in the presence of methanol, intermediate **26** undergoes C_3 protonation to give the iminium species **27**. In the final step, **27** is reduced by some residual hydride species (diborane or a methoxyborohydride) to furnish, after hydrolysis, the observed indoline. In accord with this sequence, substitution of methanol-O-d as a proton source results in specific incorporation of one D atom at C_3. Furthermore, reduction of the iminium intermediate **27** is consistent with the observed stereochemical course of the reaction. Reduction of the iminium intermediate derived from 2,3-dimethylindole (**4**) is expected to furnish a mixture of *cis*- and *trans*-products **12**[7b, 10] while, due to torsional effects,[16] the analogous iminium species from tetrahydrocarbazole should give the *cis*-fused products.[12]



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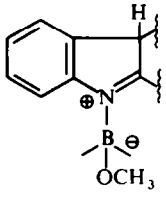

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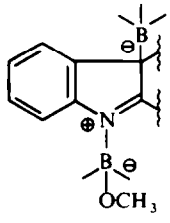

28

In analogy with the reaction of enamines and diborane, an alternative mechanism for the conversion of adduct **23** to indoline which involves electrophilic addition of boron to C_3 of intermediate **26** to give **28** must be considered. In this sequence, the deuterium incorporation results require that, after reduction of the iminium double bond of **28**, the C_3 carbon-boron bond must undergo protonolysis before addition of acetone. Although the protonolysis of the carbon-boron bond in methanol-base seems unlikely,[17] further evidence to support the absence of intermediates containing carbon-boron bonds was obtained by the following observation. Addition of anhydrous sodium methoxide to the initial reaction mixture derived from diborane and tetrahydrocarbazole, *e.g.*, **23** → **26**, followed by quenching with acetone and normal hydrolytic workup resulted in mainly recovered starting indole; no derivatives containing carbon-boron bonds and only a trace (6%) of hexahydrocarbazole were obtained. Thus intermediates such as **28** cannot play a significant role in the net reduction transformation.

The stability of N-methylindoles to reduction under these conditions indicates that they cannot undergo the initiating C_3 protonation step in methanol-methoxide. Since the basicity of simple indoles increases with N-substitution,[18] the net reduction of N-unsubstituted indoles suggests that formation of intermediate **26** results in a marked increase in basicity relative to the starting indole.

EXPERIMENTAL

NMR spectra were obtained on a Varian Associates Model A-60 spectrometer; UV spectra were measured on a Cary Model 14 spectrometer. M.ps were determined on a Mel-Temp apparatus and are uncorrected. TLC on silica gel G was employed routinely. Organic solns were dried over $MgSO_4$.

Starting materials. Compounds **1** (puriss, Aldrich). **3** (Matheson–Coleman). **2**, Matheson–Coleman), **4** (Aldrich). and **20** (Aldrich) were used as received without further purification. Compounds **6**,[19] **8**,[20] **7**,[21] **5**,[22] **15a**,[8] **15b**[23] and **21**[13] were prepared by the indicated procedures.

General reaction procedures

Diborane[24] in THF (*ca* 6 mmol) was added at room temp with stirring to a THF soln of the indole (*ca* 6 mmol) in a 3-necked flask equipped with magnetic stirring bar. septum cap. N_2 inlet. and gas measuring device. The mixture was stirred at room temp for 1–3 hr until gas evolution ceased; *ca* one equiv of H_2 was evolved. The mixture was then treated in one of the following ways:

A. *Reduction procedure.* A methanol/NaOMe soln (*ca* 0·5 M) was added slowly to the indole-diborane mixture over a period of 2 to 3 days until gas evolution ceased. The resulting mixture was added dropwise to acetone with stirring. the mixture was heated at reflux briefly. and then was concentrated *in vacuo*. 3N HCl was added and the resulting acidic soln extracted with ether. Evaporation of the ether phase furnished recovered indole and/or unidentified (decomp) products. The aqueous soln was made basic with NaOH pellets. cooled. and extracted with ether. Removal of the ether gave the crude reduction products which were purified by distillation or recrystallization. A typical procedure is described for the reduction of **6**.

Based on the suggestions of a referee. the indole-diborane reaction mixture was treated with a soln of $NaBH_4$, MeOH and NaOMe in an effort to make the reduction more convenient. Although no attempt was made to optimize conditions. the procedure did not alter significantly the net reduction yield (see procedures for **1** and **2**) but it did reduce the reaction time.

B. *Quenching procedure.* The indole-diborane mixture was added dropwise to acetone with stirring. the resulting mixture was heated at reflux briefly and then was concentrated *in vacuo*. The residue was dissolved in 3N HCl and worked up as described in procedure A. A typical procedure is described for the reaction of **6**.

Reduction experiments

Tetrahedrocarbazole (**6**). Diborane in THF (7 ml. 0·85 M. 5·9 mmols) was added at room temp to a soln of **6** (1·0 g. 5·9 mmol) in THF (5 ml). The resulting mixture was stirred for 2 hr during which time a total of 130 ml H_2 gas (5·8 mmol) was collected. Methanolic NaOMe (0·57 M) was added a few drops at a time over a 2 day period until further addition gave no additional gas evolution. The resulting mixture was added dropwise to acetone with stirring. the soln was heated at reflux for *ca* 1 min and then was concentrated *in vacuo*. 3N HCl (40 ml) was added and the soln extracted with ether. Evaporation of the ether yielded 0·15 g (15%) of **6**. identified by mp and spectral data. The aqueous soln was made basic with NaOH pellets. cooled. and extracted with ether. Evaporation of the ether and crystallization from EtOH yielded 0·82 g (82%. 98% corrected) of **13**: mp 95–97° (lit.[11] mp 98–99°); NMR ($CDCl_3$ N—D*) δ 3·67 (m. 1. C-9a ("C_2")H) and 3·06 ppm (m. 1. C-4a ("C_3")H). The N-acetyl derivative **19c**, mp 95–97° (lit.[11] mp 98°). (prepared with Ac_2O) showed NMR ($CDCl_3$) δ 4·24 (m. 1. C-9a ("C_2")H). and 3·38 ppm (m. 1. C-4a ("C_3")H).

Indole (**1**) was reduced by procedure A to give 35% of neutral material which was a complex mixture containing some indole (TLC) and 44% of **9**; bp 96–97° (6·2 mm) (lit.[25] bp 70–75 at 2 mm); NMR (CCl_4. N—D*) δ 3·3 (m. 2. C-2 H) and 2·9 ppm (m. 2. C-3 H). The N-acetyl derivative **18c**. mp 101–103° (lit.[25] mp 105°) showed NMR ($CDCl_3$) δ 3·15 (m. 2. C-3 H). and 4·0 ppm (m. 2. C-2 H).[26]

In a second experiment. the indole-diborane mixture was treated over a 2 hr period with $NaBH_4$ (0·93 g. 25·5 mmol) and NaOMe (0·6 g. 11·0 mmol) in 20 ml MeOH instead of with NaOMe in MeOH over 2 or 3 days. Workup by procedure A yielded **9** (53%) and very crude starting material (44%).

3-*Methylindole* (**2**) was reduced by procedure A to give recovered (crude) starting material (67%) and **10** (22%) as an oil; picrate. mp 159–160° (lit.[7a] mp 154°).

* The indoline N-hydrogen was exchanged for deuterium by shaking the $CDCl_4$ or CCl_4 solution briefly with deuterium oxide.

In a second experiment the 3-methylindole-borane mixture was treated with $NaBH_4$ as described for indole. Workup by procedure A yielded **10** (13%) and very crude starting material (85%).

2-Methylindole (**3**) was reduced by procedure A to give a complex mixture of neutral material containing some starting material (TLC) and a basic fraction which was a mixture of **11** (50%) and **17** (7%). Isomer composition was determined by analytical VPC. column: 10% QF-1. 80/100 Chrom. W., $\frac{1}{8}$" × 5'. 110°. relative retention times: 2-methylindoline. 2·7 min. N-isopropyl-2-methylindoline. 4·8 min. The isomers were isolated by prep VPC. column: 20% QF-1. 45/50 chrom. W., $\frac{3}{4}$" × 5'. 115°. 2-Methylindoline (**11**): picrate. mp 158·5–159·5° (lit.[27] mp 157–158). N-isopropyl-2-methylindoline (**17**): NMR (CCl_4) δ 1·25 (d. 9, J = 6 Hz, overlapping Me's), 2·2–4·0 (m, 4, C-3 H's, C-2 H, N—<u>H</u>), and 6·2–7·0 ppm (m, 4, Ar-H); mass spectrum m/e 175 (molecular ion). In a second experiment, the acetone workup step was omitted in the reduction of **3** by procedure A. Concentration of the THF–MeOH soln. followed by treatment with HCl and normal workup yielded **11** (97%): no **17** was observed.

2,3-Dimethylindole (**4**) was reduced by procedure A to give starting material (9%) and a 47:53 mixture of *cis* and *trans* **12** (84%). Isomer composition was determined by analytical VPC. column: 10% QF-1. 80/100 Chrom W., $\frac{1}{8}$" × 5'. 110°. relative retention times: *cis*-**12**. 2·1 min. *trans*-**12**. 2·5 min. The isomers were isolated prep VPC. column: 20% QF-1. 45/50 Chrom. W., $\frac{3}{4}$" × 6'. 115°; and identified by conversion to known derivatives: *cis*-**12** benzene-sulfonamide. mp 73–75° (lit.[10] mp 70–71°) and *trans*-**12** benzene-sulfonamide. mp 109·5–111·5° (lit.[10] mp 101–103°).

7-Methoxytetrahydrocarbazole (**7**) was reduced by procedure A to give starting material (crude. 6%) and **14** (80%) as an oil; picrate. mp 137–139° (lit.[28] mp 139–141°); NMR of **14** (CCl_4) δ 1·45 (broad m. 8). 2·91 (broad q, 1, J = 6·5 Hz, C-4a H), 3·49 (d, 1, J = 6 Hz, N—H), 3·55 (broad m, 1, C-9a H), 3·62 (s, 3, O—CH_3). 6·08 (d. 1. J = 2 Hz. C-8H). 6·13 (dd. 1. J = 7 and 2 Hz. C-6H). and 6·80 ppm (broad d. 1. J = 7. C-5H).

9-Methyltetrahydrocarbazole (**8**) was allowed to react under the conditions of procedure A except that an excess of methanolic KOH (0·57 M) was added over a 15 min period instead of methanolic NaOMe over 2 days; no acetone was used in the workup.* Extraction of the aqueous acid soln with ether yielded starting material (63%). Normal workup of the remaining aqueous phase yielded a residue (*ca* 8%) which contained at least 3 unidentified compounds (TLC).

1,2,3-Trimethylindole (**5**) was allowed to react under the conditions described for 9-methyltetrahydrocarbazole. Recovered starting material (67%) was isolated. The aqueous phase yielded a residue (2%) which contained a mixture of three unidentified compounds (TLC).

Reaction of tetrahydrocarbazole (**6**), *diborane and sodium methoxide.* Tetrahydrocarbazole (**6**) was allowed to react under the conditions of procedure A except that anhyd NaOMe was added slowly over 3 days instead of methanolic NaOMe. Normal workup yielded **6** (72%) and a small amount of *cis*-**13** (6%).

Deuterium incorporation

Tetrahydrocarbazole (**6**). Reduction by procedure A using NaOMe–MeOD yielded hexahydrocarbazole-4a-d (**19a**, 4a = "C_3"), 0·85 eq incorporation as judged by NMR analysis of (i) **19b**, ($CDCl_3$, N—D[25]) δ 3·67 (1H, C-9H), and 3·06 ppm (0·15H, C-4aH); the relative area of the 3·67 ppm signal to the aromatic protons was 1:4; and (ii) N-acetyl derivative **19c**, ($CDCl_3$) δ 4·24 (1H) and 3·38 ppm (0·15H); comparison of the 4·24 ppm signal to the N-acetyl methyl and to the aromatic region showed no incorporation had occurred at C-9a ("C_2").

Indole (**1**). Reduction by procedure A using NaOMe–MeOD yielded indole-3-d (**18a**). 0·7 eq incorporation, as judged by NMR analysis of the N-acetyl derivative **18c**, ($CDCl_3$) σ 4·0 (1H) and 3·15 ppm (0·3H). Comparison of the 4·0 ppm signal to the N-acetyl Me and to the aromatic protons showed no incorporation at C_2 had occurred.

UV spectral data. The reaction of indole and tetrahydrocarbazole was followed by measuring the UV spectra of aliquots of reaction taken (i) before addition of diborane; (ii) after diborane addition and H_2 evolution had ceased; and (iii) after slow addition of NaOMe–MeOH. THF was used as a reference blank for (i); diborane in THF for (ii); and diborane in THF to which NaOMe–MeOH had been added as in procedure A for (iii).

Indole in THF (i) UV maximum 224 (ε 11.600), 272 (ε 6000), 278 (ε 6000) and 288 nm (ε 5400).

Indoline in THF. UV maximum 248 (ε 10,000) and 303 nm (ε 3900).

* Under similar conditions, tetrahydrocarbazole, indole, 2-methylindole, 3-methylindole and 2,3-dimethylindole gave the corresponding indoline but in slightly lower yields than by procedure A.

Indole and diborane in THF (ii). UV maximum 222 (ε 16.000), 288 (ε 4400), 279 (ε 5000), 262 (ε 5800) and 272 nm (ε 5400).

Indole, diborane and sodium methoxide in THF-methanol (iii). UV maximum 224 (indole), 248 (indoline), and 303 nm (indoline; shoulders that could be caused by other indole peaks).

Tetrahydrocarbazole in THF (i). UV maximum 232 (ε 30.000), and 284 nm (ε 9700).

Hexahydrocarbazole in THF. UV maximum 247 (ε 10.600) and 298 nm (ε 4700).

Tetrahydrocarbazole and diborane in THF (ii). UV maximum 233 (ε 34.000) and 280 nm (ε 13.000).

Tetrahydrocarbazole, diborane and sodium methoxide in THF-methanol (iii). UV maximum 231 (tetrahydrocarbazole) 245 (*sh.* hexahydrocarbazole) and 295 nm (hexahydrocarbazole).

Quenching experiments

Tetrahydrocarbazole (**6**). Diborane in THF (1·05 M, 9·5 ml, 10 mmol) was added to a soln of **6** (1·71 g, 10 mmol) in THF (5 ml). After gas evolution had ceased the soln was heated at reflux for 1·5 hr, cooled, and then added to acetone (75 ml) with stirring. The mixture was then worked up as described above for the reduction of **6** to yield recovered **6** (1·32 g, 77%) and a small amount of **13** (0·15 g, 9%).

Indole (**1**). Following procedure B, indole yielded a complex mixture of neutral products (95%, one of which was indole by TLC) after acid treatment; no indoline was present in the acid soluble residue (5%, TLC analysis). No attempt was made to minimize the acid catalyzed decomposition of indole.

Reaction of 3-acetylindole with diborane. Diborane in THF (1·05 M, 30 ml, 28·5 mmol) was added at room temp to 3-acetylindole (1·0 g, 6·3 mmol) in THF (5 ml). The reaction was exothermic and foamed vigorously. The resulting soln was heated at reflux for 1 hr, cooled, and divided into two equal portions.

The first portion was quenched under procedure B conditions to yield **16b**, isolated as the picrate, mp 119–120° (lit.[3a] mp 120–121°) in 38% yield (based on starting indole).

The second portion was treated under conditions of procedure A using methanolic KOH and rapid (4 hr) addition to yield a complex mixture containing 3-ethylindole (TLC of neutral fraction) and 3-ethylindoline, isolated as the benzenesulfonamide, mp 93–96° (lit.[29] mp 97–97·5°).

Reduction of oxindole (**20**) *with diborane.** Diborane in THF (75 ml, 27·2 mmol) was added at 0° to oxindole (2·7 g, 20·3 mmole) in THF (30 ml) with gas evolution (0·82 eq) stirred at room temp for 2 hr and allowed to reflux for 1 hr. 10% aqHCl (150 ml) was added (gas evolution) and the THF was removed by distillation. Extraction of the resulting yellow mixture with ether and evaporation of the organic phase gave recovered oxindole (0·9 g). The aqueous layer was made basic with NaOH pellets and extracted with ether. Removal of the ether yielded indoline (1·0 g, 41%, 63% corrected for recovered oxindole). TLC of the crude mixture indicated that only trace amounts of indole could have been present.

In a similar experiment substitution of DCl/D_2O in the workup yielded indoline which contained no carbon-bound deuterium by NMR analysis.**

When a limited amount of diborane (1·88 mmol) and oxindole (7·5 mmol) were allowed to react, recovered oxindole was the major product, trace amounts of indole and indoline were observed by TLC.

Reduction of 2-ethoxyindole (**21**) was carried out exactly as described [3b] to yield **1** in 45% yield. When excess diborane was used, variable amounts of indoline were obtained.*

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** Under these acidic conditions indole yielded indoline-3-d (**18a**).

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