Stereoselective Reductions and Alcohol Deoxygenation by a Phosphine in the 5,10-Dihydrodibenzo[*b*,*e*]phosphorin Series

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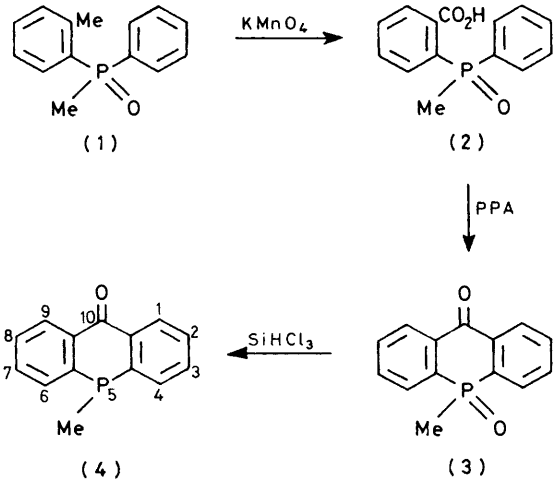
The stereospecific reductions of the 5-methyldibenzo[*b*,*e*]phosphorin-10(5*H*)-one (4) by $NaH_2Al(OC_2H_4OMe)_2$ and $LiHAl(OBu^t)_3$ give the pseudoaxial and pseudoequatorial alcohols (14) and (13), respectively. Alcohol (13), but not (14), undergoes ready oxygen transfer from carbon to phosphorus. $LiAlH_4$ deoxygenates the pseudoequatorial alcohol 5-methyl-5,10-dihydrodibenzo[*b*,*e*]phosphorin-10-ol 5-oxide (6), but not the corresponding pseudoaxial alcohol (7), to the phosphine oxide (8). Neither the isomeric alcohols (6) and (7) nor their acetate esters (17) and (18) equilibrate or isomerize under electron impact at 200 °C.

RECENTLY, we have described the synthesis and selective phosphine oxide reduction of 5-methyl- and 5-phenyldibenzo[*b*,*e*]phosphorin-10(5*H*)-one 5-oxide,[1] as shown in Scheme 1. It has been found that (3) and its *P*-phenyl



SCHEME 1

analogue may react regio- and stereo-specifically under steric approach control. The PMe group has also been planned as a sensitive n.m.r. probe for conformational analysis of the new compounds. In solution the *P*-substituents in these derivatives appear to be pseudoaxial in a relatively rigid boat conformation of the central ring.[1b]

It is generally accepted that the central rings in 9,10-dihydroanthracenes [2] and their heterocyclic analogues [3] adopt the boat conformation. We have shown that, in solution, the conformation, reactivity, and spectroscopy of 5,10-dihydrodibenzo[*b*,*e*]phosphorin derivatives are markedly affected by the marked preference of the PMe and P=O groups to occupy the pseudoaxial and pseudoequatorial positions, respectively. Accordingly, the ^1H n.m.r. signal of the MeP group is significantly influenced by both the condensed aromatic rings and the pseudoaxial C-10 substituent. A prominent example of this phenomenon is the high field PMe ^1H chemical shift of (5), δ 1.09, obtained as a single stereoisomer from (3) and phenylmagnesium bromide.[1b] The configuration shown for (5) is the only one possible in which effective shielding of the PMe by the diamagnetic phenyl ring current can occur. The stereochemical course of this and the following reactions is mainly controlled by *peri*-equatorial interactions;[4] axial–axial interactions are of secondary importance. Generally, pseudoaxial C-10 substituents exhibit higher-field resonances [1b,3,4] and larger P–H [1b,4] and H–H [3] coupling constants than their pseudoequatorial counterparts in the ^1H n.m.r. spectra. One opposite report [5] may be erroneous.[1b]

The stereochemistry of complex metal-hydride reduction of (3) illustrates the steric approach control imposed by the *peri*-hydrogens.[1b] Thus, preferential pseudoaxial attack by $LiAlH_4$ or $NaH_2Al(OC_2H_4OMe)_2$ on (3) gives (6) and (7) in the ratio 4 : 1 or 3 : 1, respectively.[1b]

The stereospecific synthesis of the pseudoequatorial alcohol (6), by reduction of (3) with $LiHAl(OBu^t)_3$ in tetrahydrofuran (THF), involves exclusive pseudoaxial attack by the hydride. Moreover, $LiAlH_4$ stereoselectively reduces (6) to the phosphine oxide (8), while (7), if present, remains intact and can easily be separated from (8) by extraction of the latter with chloroform.

The latter reaction provides a simple synthetic route to both (7) and (8). This stereoselective reduction of (6) may also be associated with hindrance to hydride approach to C-10 from the pseudoequatorial site of the intermediate pseudoaxial alkoxide (9). While pseudoequatorial attack on (3) by metal hydrides is relatively retarded, it is almost completely suppressed in the case of the alkoxide (9). In the stereoisomeric alkoxide (10), both intramolecular axial attack by the AlH_3 unit bonded to the pseudoequatorial oxygen atom, and pseudoaxial $LiAlH_4$ attack, are plausible. This deoxygenation reaction is reminiscent of the $LiAlH_4$ reduction of arylmethanols,[6] though the latter reaction is performed at elevated temperatures.

There is a remarkable deshielding of PMe in (7) (δ 1.94) by the pseudoaxial C-10 hydroxylic oxygen atom, as compared with δ_{Me} 1.49 of the isomer (6),

[1] (*a*) Y. Segall, I. Granoth, and A. Kalir, *J.C.S. Chem. Comm.*, 1974, 501; (*b*) Y. Segall, R. Alkabets, and I. Granoth, *J. Chem. Research*, 1977, (*S*) 310; (*M*) 3541.

[2] A. W. Brinkman, M. Gordon, R. G. Harvey, P. W. Rabideau, J. B. Stothers, and A. L. Ternay, jun., *J. Amer. Chem. Soc.*, 1970, **92**, 5912; R. G. Harvey and H. Cho, *ibid.*, 1975, **97**, 6790, 6799.

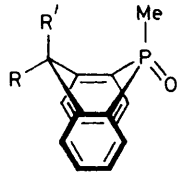
[3] A. L. Ternay, jun., and S. A. Evans, *J. Org. Chem.*, 1974, **39**, 2941 and references therein.

[4] (*a*) C. Jongsma, F. J. M. Freijee, and F. Bickelhaupt, *Tetrahedron Letters*, 1976, 481; (*b*) W. Winter, *Chem. Ber.*, 1976, **109**, 2405.

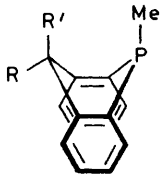
[5] K. C. Chen, S. E. Ealik, D. van der Helm, J. Barycki, and K. D. Berlin, *J. Org. Chem.*, 1977, **42**, 1170.

[6] A. W. H. Wardrop, G. L. Sainsbury, J. M. Harrison, and T. D. Inch, *J.C.S. Perkin I*, 1976, 1279.

further illustrating the pseudoaxial orientation of the PMe.



(5) R = OH, R′ = Ph
(6) R = OH, R′ = H
(7) R = H, R′ = OH
(8) R = R′ = H
(9) R = H, R′ = $OAlH_3^-$
(10) R = $OAlH_3^-$, R′ = H
(17) R = OAc, R′ = H
(18) R = H, R′ = OAc



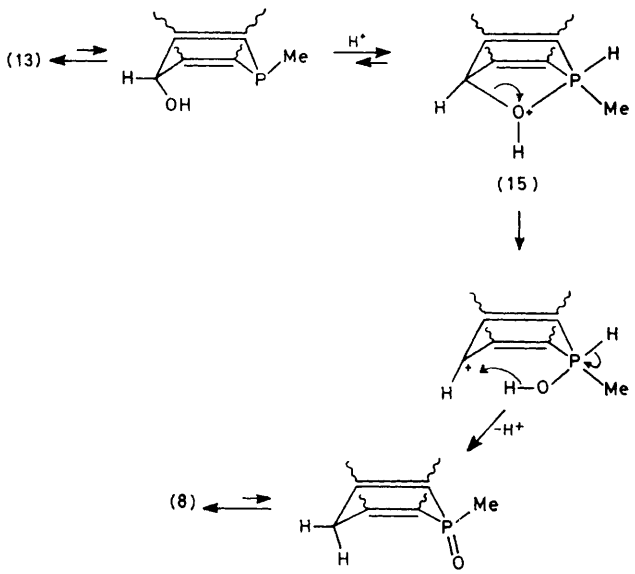
(11) R = O^-, R′ = H
(12) R = H, R′ = O^-
(13) R = OH, R′ = H
(14) R = H, R′ = OH

The reduction of the phosphine ketone (4) by $LiHAl(OBu^t)_3$ is also stereoselective, essentially giving only the pseudoequatorial alkoxide (11), $\delta(C_6D_6)$ 1.38 [d, ^2J(HP) 3.0 Hz, PMe] and 6.05 (br, s, H-10). This reaction (heterogenous) is relatively slow (2 days) in benzene at ambient temperature, but it is completed within 5—10 min in THF. The corresponding alcohol (13) could not be isolated. Upon acidification of (11) in either benzene or THF, a rapid transfer of oxygen from carbon to phosphorus occurs, producing (8). The following observations suggest that this novel deoxygenation is intramolecular. The reaction yields only one product. The isomeric alcohol (14), obtained from (4) and $NaH_2Al(OC_2H_4OMe)_2$ in benzene, is far more stable than (13). No change in the ^1H n.m.r. spectrum of a CD_3OD or C_6D_6 solution of (14) was detected after 6 days at 20 °C or 20 h at reflux. Addition of excess of 30% H_2O_2 to a solution of (14) in benzene gives the phosphine oxide alcohol (7). This reaction, which proceeds with retention of configuration at phosphorus,[7] provides an alternative route to (7) and supports the structure assignment of the alcohols described in this report. Furthermore, when (13) is produced in the presence of a *ca.* equimolar quantity of the phosphine (4) [by acid quenching of the reaction of (4) with $LiHAl(OBu^t)_3$ in benzene after 1 day at room temperature], it is still transformed to (8), while (4) remains unchanged. Intermolecular deoxygenation of (13) might have involved the phosphine (4), when present, in this redox reaction. Scheme 2 shows a possible mechanism for an intramolecular deoxygenation of (13), including the phosphorane (15) as an intermediate. The suggested acid catalysis may explain the stability of the alkoxide precursor (11).

This appears to be the first report of a straightforward deoxygenation of an alcohol to a hydrocarbon by a phosphine. The related deoxygenation of epoxides is documented.[8] However, a recent report [9] describes the synthesis of thermally stable epoxyphosphines. Formal,[10] though mechanistically different,[10b,c] deoxygenations of alcohols by phosphines have been reported.

The exceptional pseudoequatorial attack by $NaH_2Al(OC_2H_4OMe)_2$ on (4) deserves comment. A geometrically feasible structure for pseudoequatorial attack at the carbonyl carbon atom may be formed upon complexation of this metal hydride with the phosphorus atom of the phosphine (4), but not with the phosphine oxide (3). The latter is predominantly attacked from the pseudoaxial face of the ketone.

In conclusion, the evidence presented in this and earlier related articles [1] suggests that the 5,10-dihydrodibenzo[*b*,*e*]phosphorin skeleton makes possible some relatively fast, selective, and sterically controlled reactions. These reactions, including esterification and solvolysis,[1b] are not exhibited by other, chemically related compounds. Consequently, (3), (4), and their relatives may be an attractive proving ground for known



SCHEME 2

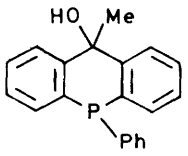
and new reactions of aromatic ketones, alcohols, phosphines, *etc.*

It has recently been reported [5,11] that in the crystalline state, (16) possesses a pseudoequatorial PPh group. Moreover, it has been suggested [5,11] that ' a complex equilibrium is quite conceivable in which butterfly conformers and invertomers could be interconvertible by a series of inversions on P and flipping of the butterfly structures.' Such a thermal equilibrium between −40 and +120 °C is highly unlikely.

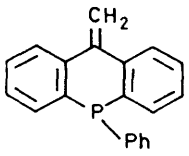
We now report that, under electron impact at 200 °C,

[7] D. B. Denney and J. W. Hanifin, jun., *Tetrahedron Letters*, 1963, 2178.
[8] M. J. Boskin and D. B. Denney, *Chem. and Ind.*, 1959, 330.
[9] C. Symmes, jun., and L. D. Quin, *Tetrahedron Letters*, 1976, 1853.
[10] (*a*) L. E. Overman and E. M. O'Connor, *J. Amer. Chem. Soc.*, 1976, **98**, 771; (*b*) M. Grayson and C. E. Farley, *Chem. Comm.*, 1967, 831; (*c*) J. E. Baldwin and D. P. Hesson, *J.C.S. Chem. Comm.*, 1976, 667.
[11] S. D. Venkataramu, G. D. Macdonell, W. R. Purdum, M. El-Deek, and K. D. Berlin, *Chem. Rev.*, 1977, **77**, 121.

no such equilibration, as described above,[5] is observed for either alcohols (6) and (7) or their acetate esters (17) and (18).[12] Accordingly, the mass spectra of (6) and (7) or (17) and (18) are distinctly different (see Experimental section). This is probably a consequence of some specific mass-spectral reactions of (6) or (7) or both, governed by the geometry of each isomer.[12] The apparent isomerization observed for (16), after many hours at 120 °C,[5] may be explained by thermal (or acid-catalysed) dehydration followed by nonspecific hydration of the intermediate olefin (19).[1b] A redox reaction, similar to that described above for (13), may also be involved when (16) is heated at 120 °C, leading to a >CHMe unit with ^3J(HH) 7 Hz,[1b] rather than the proposed ^{5} ^5J(PH) 7 Hz.



(16)



(19)

A detailed study of the mass-spectral fragmentations of (6), (7), (17), and (18) is planned. CH_2CO or CH_2CO_2 is lost from the molecular ion of the pseudoequatorial acetate (17), but not from that of its isomer (18). This may imply that a specific hydrogen rearrangement occurs in (17), possibly hydrogen transfer to the phosphinoyl group,[11,12] following ring flipping. Such a reaction is not feasible for (18). Further detailed studies of this and related reactions may confirm such possibilities.

EXPERIMENTAL

M.p.s were obtained with a Thomas–Hoover capillary apparatus. Unless otherwise noted, n.m.r. spectra were run in $CDCl_3$ with $SiMe_4$ as internal standard, on JEOL C-60 HL and Varian XL 100 spectrometers. Mass spectra were obtained at 70 eV and 200 °C source temperature, using the direct insertion probe of a Hitachi–Perkin-Elmer RMU 6 instrument. Only peaks with intensities greater than 20% of the base peak are given. All solvents were conventionally dried, except for extraction. Compounds (3)—(5) were prepared as described before.[1]

cis-5-*Methyl*-5,10-*dihydrodibenzo*[b,e]*phosphorin*-10-*ol* 5-*Oxide* (6).—Lithium hydridotri-t-butoxyaluminate (2.3 g), the ketone (3) (1.0 g), and THF (50 ml) were stirred for 30 min at ambient temperature. The mixture was then carefully decomposed with 5% hydrochloric acid (50 ml), followed by water (150 ml). Filtration and recrystallization from ethanol gave the *alcohol* (6) (0.9 g, 90%), m.p. 224 °C; δ 1.49 [3 H, d, J(HP) 13.5 Hz, PMe], 5.38 [1 H, d, J(HP) 3.0 Hz, H-10], and 7.15—8.10 (8 H, m, aromatic); *m/e* 244 (M^+, 6%), 242 ($M - H_2$, 31), 227 ($M - H_2$ — Me, 100), and 152 ($C_{12}H_8^+$, 24) (Found: C, 68.6; H, 5.4; P, 12.6. $C_{14}H_{13}O_2P$ requires C, 68.8; H, 5.3; P, 12.7%).

trans-5-*Methyl*-5,10-*Dihydrodibenzo*[b,e]*phosphorin*-10-*ol* 5-*Oxide* (7) *and* 5-*Methyl*-5,10-*dihydrodibenzo*[b,e]*phosphorin* 5-*Oxide* (8).—*Method* (*a*). Lithium aluminium hydride (2 g), the ketone (3) (2 g), and THF (100 ml) were stirred under dry N_2 at ambient temperature for 80 h, then carefully decomposed with 5% hydrochloric acid (50 ml). The organic layer and a chloroform extract gave a mixture of (7) and (8) after evaporation. Trituration of this mixture with chloroform (10 ml) left the sparingly soluble, crystalline *alcohol* (7) (0.33 g, 16%), m.p. 260 °C (from ethanol); δ 1.94 [3 H, d, J(HP) 14.0 Hz, PMe], 5.62 [1 H, d, J(HP) 0.5 Hz, H-10], 7.30—7.60 (6 H, m, aromatic), and 7.80—8.23 (2 H, m, H-4, -6); *m/e* 244 (M^+, 96%), 243 (M — H, 100), 228 ($M - H$ — Me, 32), 227 ($M - H_2$ — Me, 62), 215 (M — CHO, 64), 183 ($C_{12}H_8P^+$, 25), 165 ($C_{13}H_9^+$, 64), and 152 ($C_{12}H_8^+$, 32) (Found: C, 68.5; H, 5.3; P, 12.8. $C_{14}H_{13}O_2P$ requires C, 68.8; H, 5.3; P. 12.7%).

The chloroform extract (above), yielded the P-*oxide* (8) (1.3 g, 67%) after recrystallization from benzene–petrol; m.p. 170 °C; δ 1.68 [3 H, d, J(HP) 13.0 Hz, PMe], 4.12 [2 H, d, J(HP) 3.0 Hz, H-10], 7.32—7.56 (6 H, m, aromatic), and 8.02—8.22 (2 H, m, H-4,-6); *m/e* 228 (M^+, 100%), 227 (M — H, 69), 213 (M — Me, 69), 183 ($C_{12}H_8P^+$, 25), 166 ($C_{13}H_{10}^+$, 50), 165 ($C_{13}H_9^+$, 89), 152 ($C_{12}H_8^+$, 22), 105 (33), 97 (45), and 96 (28) (Found: C, 73.5; H, 5.3; P, 13.7. $C_{14}H_{13}OP$ requires C, 73.7; H, 5.7; P, 13.6%).

Method (*b*). The phosphine (14) (100 mg), benzene (30 ml), and 30% H_2O_2 (300 mg) were stirred at room temperature for 3 h and set aside overnight. The crystalline product (7) was filtered off (100 mg, 94%); m.p. and mixed m.p. 260 °C, and ^{1}H n.m.r. data identical with those for (7).

The phosphine (4) (200 mg), THF (20 ml), and $LiHAl(OBu^t)_3$ (350 mg) were stirred for 20 min at room temperature, then the mixture was decomposed with 10% hydrochloric acid (5 ml). The ^{1}H n.m.r. spectrum of the crude product was identical with that of (8). Recrystallization of the crude product (benzene–light petroleum) gave (8) (182 mg, 90%), m.p. and mixed m.p. 170 °C.

5-*Methyl*-5,10-*dihydrodibenzo*[b,e]*phosphorin*-10-*ol* (14).—The phosphine (4) (2 g), benzene (100 ml), and a 70% solution of $NaH_2Al(OC_2H_4OMe)_2$ in benzene (4 ml) were stirred under dry N_2 for 20 min, then the mixture was carefully decomposed by dropwise addition of 5% hydrochloric acid (30 ml), with cooling and stirring. The organic layer was dried ($MgSO_4$) and evaporated, and the product was recrystallized from CF_3CH_2OH (1.7 g, 83%), m.p. 106 °C; δ 1.75 [3 H, d, J(HP) 2.5 Hz, PMe], 5.34 (1 H, br, s, H-10), and 7.20—7.75 (8 H, m, aromatic), *m/e* 228 (M^+, 100%), 213 (M — Me, 91), 166 (M — MePO, 63), and 165 (M — MePHO, 98) (Found: C, 74.0; H, 5.9; P, 13.4. $C_{14}H_{13}OP$ requires C, 73.7; H, 5.7; P, 13.6%).

cis-10-*Acetoxy*-5-*methyl*-5,10-*dihydrodibenzo*[b,e]*phosphorin* 5-*Oxide* (17).—This *ester* and the following were prepared in 80—86% yield from the corresponding alcohols and acetic anhydride in pyridine, by the standard procedure;[1b] m.p. 129 °C (ethyl acetate–petroleum 1 : 9); δ 1.75 [3 H, d, J(HP) 13.0 Hz, PMe], 2.36 (3 H, s, MeCO), 6.77 [1 H, d, J(HP) 3.0 Hz, H-10], and 7.35—8.35 (8 H, m, aromatic), *m/e* 286 (M^+, 4%), 244 ($M - CH_2CO$, 30), 243 (M — Ac, 61), 228 ($M - CH_2CO_2$, 37), 213 ($M - CH_2CO_2$ — Me, 28), 167 (25), 166 ($[C_{13}H_{10}]^+$, 28), 165 ($[C_{13}H_9]^+$, 68), 149 (100), and 91 (24) (Found: C, 67.0; H, 5.2; P, 10.7. $C_{16}H_{15}O_3P$ requires C, 67.1; H, 5.3; P, 10.8%).

trans-10-*Acetoxy*-5-*methyl*-5,10-*dihydrodibenzo*[b,e]*phosphorin* 5-*Oxide* (18).—The *ester* had m.p. 187—189 °C (ethyl acetate–petroleum), δ 1.96 (3 H, s, MeCO), 1.99 [3 H, d, J(HP) 14.0 Hz, MeP], 6.82 [1 H, d, J(HP) 1.0 Hz, H-10], 7.40—7.60 (6 H, m, aromatic), and 7.90—8.25 (2 H,

[12] M. M. Green, *Topics Stereochem.*, 1976, **9**, 35.

m, H-4,-6), *m/e* 286 (M^+, 0.5%), 243 (M — Ac, 38), 167 (21), 165 ($[C_{13}H_9]^+$, 43), 149 (100), and 91 (41) (Found: C, 67.0; H, 5.3; P, 10.6. $C_{16}H_{15}O_3P$ requires 67.1; H, 5.3; P, 10.8%).

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