Stereoselective Nucleophilic Additions to 9,10-Anthraquinone. Comparison of Grignard and Sulphur Ylide Additions

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Analysis of long-range ^{1}H n.m.r. shielding effects has provided insight into the conformational behaviour of the products of single and double addition of dimethylsulphonium methylide to 9,10-anthraquinone. This information is consistent with a double addition reaction in which stereospecificity arises, at least in part, from a directing effect exerted by oxiran oxygen on the entering ylide.
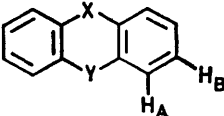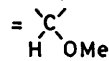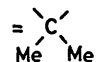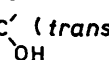
IT has been known for some time that Grignard reagents undergo *trans* double addition to 9,10-anthraquinone [1] with stereoselectivity increasing from methyl to ethyl Grignard reagent,[2] the first addition being faster than the second. The observed stereochemistry, which is not a result of equilibration on work-up,[2b] is consistent with steric arguments in which the new alkyl group occupies a pseudo-axial position in the intermediate mono-addition compound. (The same conformational preference is exhibited by substituted methylene dihydroanthracenes.[3]) This explanation appears inadequate for the analogous stereospecific addition of dimethylsulphonium methylide to 9,10-anthraquinone,[4] since the effective steric bulk (with respect to carbonyl) of both oxygen and methylene in the oxiran ring of the mono-addition product (3) is substantially lower than that of simple alkyl substituents. We therefore suggest that stereospecificity in this reaction arises, at least in part, *via* a directing effect on the entering ylide by the oxiran oxygen atom which causes a kinetic preference for the observed addition.[5,6] In this light, it is of interest to determine the preferred conformation in (3), since the absence of a strongly favoured conformation in (3) would not be compatible with stereoselectivity due solely to steric factors.

Many of the usual conformational probes are of little use in determining conformation in these molecules.[7] However, a qualitative evaluation of conformational preference in (3) is possible by consideration of the long-range shielding effects on H_A (Table) by the neighbouring oxiran ring. Such effects have been ascribed previously to shielding due to a ring current in oxirans,[8] but are also consistent with anisotropic shielding by the individual single bonds in the oxiran ring.[9] In the structurally similar spiro-ketone (5) (Table), Forsén and Norin report a shielding of H_A of 0.5 p.p.m. due to the cyclopropane ring by comparison with model compound (6).[10] These authors assumed that (5) is planar and though bond-angle considerations suggest that planarity may be more likely for (5) than for (6), this remains in question.

A comparison of chemical shifts (Table) for H_A in (3) and in model compound (7) demonstrates a shielding of 0.35 p.p.m. due to the oxiran ring, and not to differences in electronic and inductive effects between oxiran and hydroxy substituents.[11] A value of 0.40 p.p.m. for this shielding can be calculated *via* construction of a suitable

model by summing the shifts due to carbonyl and hydroxy substituents in anthrone (8) and the *trans*-diol (9), respectively, as compared to 9,10-dihydroanthracene. The magnitude of this shielding can be expected to vary

^{1}H N.m.r. shifts and structures of compounds referred to in the text

Compound	H_A shift (p.p.m.)	Apparent H_A shielding by 3-membered ring
(8); X = CO, Y = CH$_2$	7.41	ref. 10
(3); X = CO, Y = (oxiran)	7.61	0.35
(7); X = CO, Y = CH(OMe)	7.96	
(6); X = CO, Y = C(Me)(Me)	7.42	ref. 10
(5); X = CO, Y = (cyclopropane)	6.91	0.50 (ref. 10)
; X = Y = CH$_2$	ca. 7.2	*
(4); X = Y = (oxiran) (*trans*)	7.38	0.42
(9); X = Y = C(Me)(OH) (*trans*)	7.80	

* 'Aldrich Library of NMR Spectra,' eds. C. J. Pouchert and J. R. Campbell, vol. 4, p. 33a.

significantly with conformational preference. For example, in conformation (3a) *deshielding* by the neighbouring oxygen atom should be observed.[12] In contrast, conformation (3b) should show measurable shielding of H_A and the planar conformation (3c) should
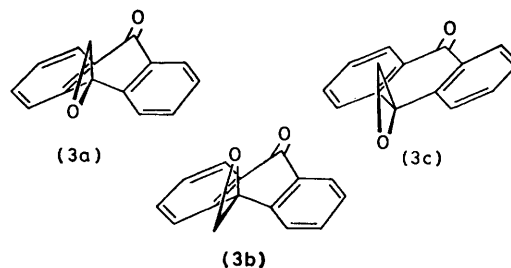

(3a)

(3c)

(3b)

exhibit maximum shielding of H_A. The possible conformations of (3) are (*i*) a mixture of (3a) and (3b) with equal contributions from each conformer; (*ii*) a mixture of (3a) and (3b) with one predominant conformer; or (*iii*) the single conformer (3c) representing an energy minimum. Since there are a number of reported shieldings [12] (of nearby protons by oxiran rings) which exceed our value, and since these are in systems in which the proton is less favourably located (*i.e.* at substantially greater distance from the oxiran ring plane), we conclude that (3c) does not represent an energy minimum. To distinguish possibilities (*i*) and (*ii*) it is useful to examine shieldings in the bisepoxide (4), dispiro[oxiran-2,9'-(10'H)-anthracene-10',2''-oxiran]. The double addition product (4) is the first reported 9,10-dihydroanthracene with small spirocyclic rings at both 9- and 10-positions. The 9,10-dihydroanthracenes generally exhibit boat-like conformations in solution with a boat-to-boat interconversion which is too fast for n.m.r. time-scale study (though past studies did not include temperatures below -60 °C).[7] Bond-angle considerations suggest that a planar conformation may be more favourable for (4) than for other dihydroanthracenes. A consideration of oxiran-shielding effects, however, supports the predominance of two identical boat-like conformers. Comparison of H_A shifts (Table) in (4) and model compound (9) allows calculation of a shielding of 0.42 p.p.m., a value which, again, appears to be too low to support a planar conformation.

The similarity between this value and that found for (3) suggests that (3) is a mixture of approximately equal populations of (3a) and (3b). The ylide attack apparently occurs preferentially on conformer (3b), with product stereochemistry determined by the previously suggested directing effect of oxygen.

One additional feature of the ^{1}H n.m.r. spectrum of (4) is worthy of comment. Protons H_A and H_B are coincident in shift when either deuteriochloroform or carbon disulphide are used as solvents at 60 MHz; and even at 270 MHz. However, in hexadeuterioacetone solvent, the 270-MHz spectrum exhibits a narrow multiplet for H_A and H_B (centre lines separated by 3 Hz). As the temperature is lowered the H_A and H_B resonances separate further until at -90 °C the centre lines of the multiplet are 18 Hz apart. The oxiran methylene protons, however, give rise to a sharp singlet throughout this temperature range, and it is therefore clear that the molecule remains fluxional on the n.m.r. time-scale even at -90 °C.

EXPERIMENTAL

All the ^{1}H n.m.r. spectra were run in deuteriochloroform with SiMe$_4$ as internal reference, except when otherwise indicated. The H_A shifts for (3) and (7) were extracted directly from the observed spectra, while the shift in (9) is from a proton-decoupled spectrum. Varian A-60 and Perkin-Elmer R-12 spectrometers were used for 60 MHz spectra. High-field (270 MHz) spectra for (3), (4), and (9) were run at the Southern New England High Field NMR Facility (Yale University).

10-Methoxyanthrone (7) was prepared by the procedure of Meyer.[13] *trans*-9,10-Dihydro-9,10-dihydroxy-9,10-dimethylanthracene (9) was prepared by the procedure of Beckett and Lingard.[2c]

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