

THE STEREOCHEMISTRY OF THE ADDUCTS DERIVED FROM THE DIELS-ALDER ADDITION OF CYCLOBUTENES AND CYCLOPENTADIENONES: A CAVEAT ON SOME EXISTING PMR METHODS FOR THE ASSIGNMENT OF STEREOCHEMISTRY

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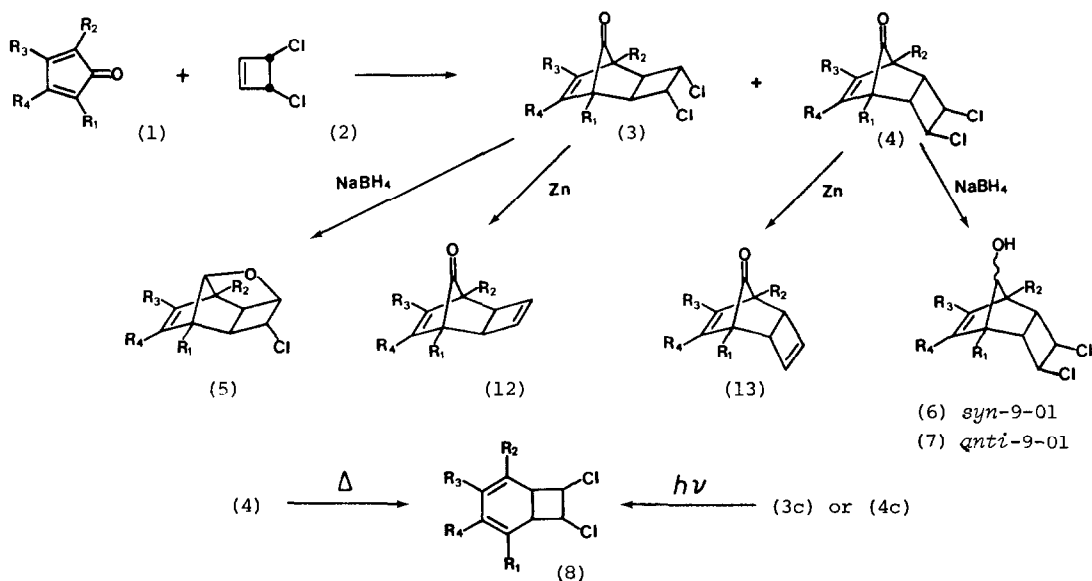
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
ABSTRACT. The stereochemistry of the adducts formed from the cycloaddition of tetracyclone, phencyclone and 2-methyl-3,4,5-triphenylcyclopenta-2,4-dienone with *cis*-3,4-dichlorocyclobutene (in one case with 3-chloro-4-methoxycyclobutene) has been evaluated in a rigorous fashion. This allows a firmly-based caveat to be issued regarding the p.m.r. probe for stereochemical evaluation of tetracyclone adducts recently proposed by Coxon and Battiste.¹

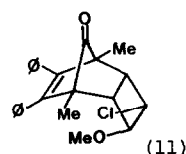
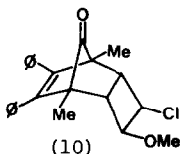
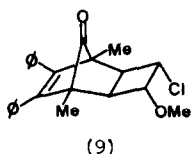
Heating tetracyclone (1a) with *cis*-3,4-dichlorocyclobutene (2) in chloroform solution at 60°C yields two 1:1 adducts. The main adduct, m.p. 218°C was confirmed as the *exo,anti*-isomer (3a) by conversion to the cyclic ether (5a), m.p. 169°C. This conversion, which was achieved by treatment of the bridged ketone (3a) with sodium borohydride in refluxing ethanol, has found general application in this series of compounds (see later). The second isomer m.p. 176°C, not originally reported by Nenitzescu², was assigned the *endo,anti*-structure (4a) for the following reasons: (a) dechlorination with zinc in ethanol yielded a cyclobutene (m.p. 154°C) different from that (m.p. 191°C) obtained by similar treatment of the *exo,anti*-isomer (3a); (b) reduction (NaBH₄) of the ketone function gave rise to two isomeric alcohols [*syn* (6a), m.p. 285°C, i.r. 3552, 3598 cm⁻¹ (in CCl₄ soln); *anti* (7a) m.p. 246.5°C, i.r. 3600 cm⁻¹ in CCl₄ soln] but no cyclic products; (c) Thermolysis yielded the decarbonylated product (8a) m.p. 178°C. The mild conditions (refluxing CHCl₃) required for this latter reaction suggested that decarbonylation was assisted by cyclobutyl edge participation.³ In contrast the *exo,anti* isomer (3a) was thermally stable even in refluxing toluene.

Similar techniques were used to establish the *exo,anti*-stereochemistry for the major adducts and *endo,anti*-stereochemistry for the minor adducts formed in the reaction of *cis*-dichlorocyclobutene (2) with phencyclone (1b) and with 2-methyl-3,4,5-triphenylcyclopentadienone (1c). The structures assigned to adducts (3c) and (4c) was further supported by the fact that u.v. irradiation (254 nm) of both adducts afforded the same diene (8c).

The reaction of *cis*-3,4-dimethoxycyclobutene with 2,5-dimethyl-3,4-diphenylcyclopentadienone (1d) was also investigated but rapid ring-opening of the cyclobutene in refluxing chloroform solution precluded significant adduct formation. However the reaction of *cis*-3-chloro-4-methoxycyclobutene⁴ with the dienone (1d) yielded three adducts. The major adduct m.p. 170°C was again shown to be the *exo,anti*-isomer (9) by cyclic ether formation, the second most abundant isomer m.p. 134°C to have the *endo,anti*-structure (10) and a third isomer, sometimes obtained, tentatively assigned the *exo,syn*-stereochemistry (11) on spectral grounds.



(a) $R_1=R_2=R_3=R_4=\text{Ph}$, (b) $R_1=R_2=\text{Ph}$; $R_3/R_4=$ , (c) $R_1=R_3=R_4=\text{Ph}$; $R_2=\text{Me}$



CAVEAT ON SOME EXISTING P.M.R. METHODS OF STEREOCHEMICAL ASSIGNMENT

Coxon and Battiste have recently proposed a p.m.r. probe for evaluating the stereochemistry of adducts in the tetracyclone series.¹ These are classified on the basis of distinctive phenyl proton resonances: the *exo*-series consisting of a low field singlet (stilbene-type phenyls) and upfield multiplets (bridgehead phenyls), whereas *endo*-adducts display multiplet resonances only. The present study, where the stereochemistry of the above-mentioned adducts have been rigorously assigned, clearly shows the deficiency of their method. For example, inspection of the p.m.r. spectra of the isomeric tetracyclone adducts *exo* (3a), *endo* (4a), in Fig. 1 shows that the aromatic resonance in each case is comprised of a low field singlet and upfield multiplets, a feature assigned by Coxon and Battiste to *exo*-isomers only. What is more distressing is that dechlorination of these adducts yields the corresponding *exo*- and *endo*- pair of cyclobutenes, (12a) and (13a) respectively, where the resonances are essentially indistinguishable (Fig. 2) but now both display multiplet resonances "typical" of *endo*-isomers in the Coxon-Battiste analysis. Thus the claim by these authors to "provide a useful empirical rule to assist in the assignment of stereochemistry" must be questioned. In addition these authors propose that the conformation of the phenyl rings comprising the

stilbene moiety of the tetracyclone *exo*-adducts is such that they must be substantially in the plane of the π bond. If this suggestion is correct, it should allow extension into the phenacyclone series of adducts, since the phenanthrene moiety serves as an excellent model for planar *cis*-stilbene. Inspection of the spectra (Fig. 3) for the phenacyclone adducts, *exo*- (3b) and *endo*- (4b) shows the absence of any siglet resonance. This finding confirms that the method has severe limitations and draws into question the basis upon which the multiplicities are justified.

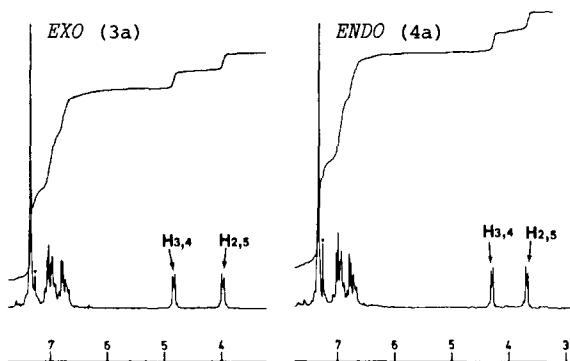


FIG. 1 $^1\text{H-n.m.r.}$ spectra of isomers (3a) and (4a)

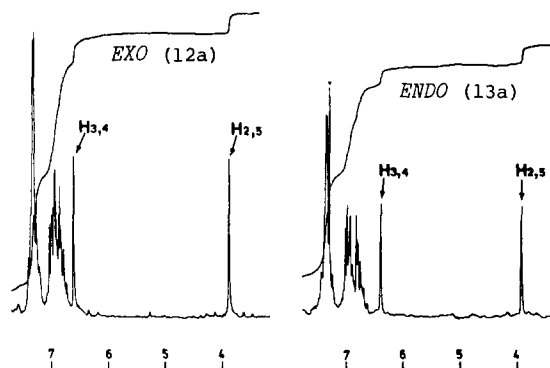


FIG. 2 $^1\text{H-n.m.r.}$ spectra of isomers (12a) and (13a)

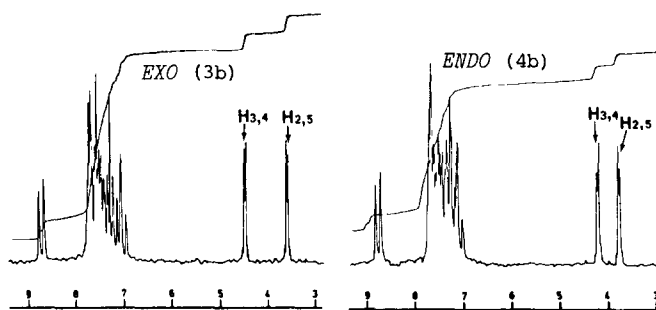


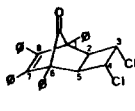
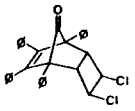
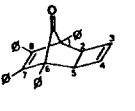
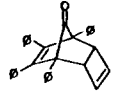
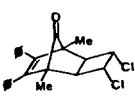
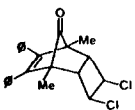
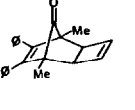
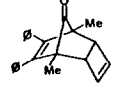
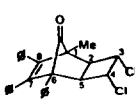
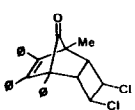
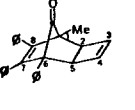
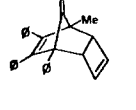
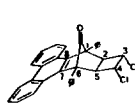
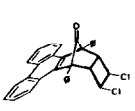
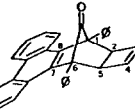
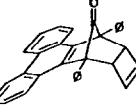
FIG. 3 $^1\text{H-n.m.r.}$ spectra of isomers (3b) and (4b)

▼ CHCl_3
All spectra were recorded at 80 MHz

The second p.m.r. method used for stereochemical assignments was reported by Haywood-Farmer and his co-workers.⁵ They found that the *endo*-proton resonances of norbornan-7-one suffer a larger upfield shift than those of the corresponding *exo*-protons upon solvent change from chloroform- d_1 to benzene- d_6 . This technique was used to confirm some stereochemical assignments in the Coxon-Battiste work. Applications of this method to the present adducts, summarised in Table 1, shows that there is an upfield shift of the relevant protons in every case (i.e. Δ_E and Δ_N positive), but the difference ($\Delta_N - \Delta_E$), which should be negative according to the Haywood-Farmer analysis is seldom so, i.e. the method predicts the wrong stereochemistry more often than the correct one (entries I, II, III, V are wrong; entries VI, VII, VIII are ambiguous and only entry IV is correct). Since there is NO significant improvement between entries I-IV which contain chlorine and entries V-VIII which have no chlorine, the poor results cannot be ascribed to preferential coordination of the solvent to the chlorine atoms.

These findings serve to highlight the deficiency of the solvent induced shift technique. The stereochemistry of the adducts derived from tetracyclone with endoxynaphthalene and from cyclohexene are in need of revision and will be discussed in a forthcoming article.

TABLE 1 Benzene induced shifts (Δ) observed in *exo*- and *endo*-isomers upon solvent change from CDCl_3 to C_6D_6 . Spectra recorded on a CFT-20 n.m.r. spectrometer operating at 80 MHz.

<i>exo</i> -adducts	Δ_E^a	<i>endo</i> -adducts	Δ_N^b	$\Delta_N - \Delta_E$	<i>exo</i> -compound	Δ_E^a	<i>endo</i> -compound	Δ_N^b	$\Delta_N - \Delta_E$
	0.11		0.32	+		0.22		0.29	+
	0.16		0.31	+		0.25		0.26	\pm
	H_2 0.17 H_5 0.12		H_2 0.35 ^c H_5 0.26 ^c	+		H_2 0.25 ^c H_5 0.23 ^c		0.24 ^c 0.32 ^c	\pm
	0.46		0.30	-		0.30		0.32	\pm

(a) $\Delta_E = \delta_{\text{CDCl}_3} - \delta_{\text{C}_6\text{D}_6}$ for protons $\text{H}_{2,5}$ in *exo*-adducts, (b) $\Delta_N = \delta_{\text{CDCl}_3} - \delta_{\text{C}_6\text{D}_6}$ for protons $\text{H}_{2,5}$ in *endo*-adducts.

(c) assignments may be interchanged

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