Dimethoxycarbene: Stereospecificity in the Additions of a Nucleophilic Carbene to β-Deuteriostyrenes

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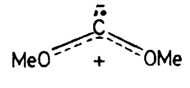
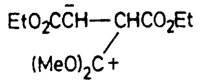
Summary Dimethoxycarbene added stereospecifically to *cis*- and *trans*-β-deuteriostyrene, affording the corresponding cyclopropanes.

Dimethoxycarbene (**1**) has been the subject of intense interest for more than a decade,[1–3] but only recently has it been shown to undergo typical[4] olefin addition reactions.[5] The carbene (**1**) is strongly nucleophilic, adding to diethyl fumarate, diethyl maleate, ethyl cinnamate, and styrene,[5] but not to cyclohexene, keten diethyl acetal, or ethyl acrylate.[2] Addition of (**1**) to either diethyl fumarate or diethyl maleate gave *trans*-1,2-diethoxycarbonyl-3,3-dimethoxycyclopropane.[5] However, it could not be determined whether this lack of stereospecificity was due to a two-step addition mechanism, proceeding *via* the zwitterion (**2**), or represented a mechanistically trivial isomerization [*via* (**2**)] of a thermally unstable, initially formed *cis*-adduct.[5] Notwithstanding the mechanistic uncertainty, zwitterions are frequently invoked as intermediates in these (and related) reactions of (**1**).[3,5,6]



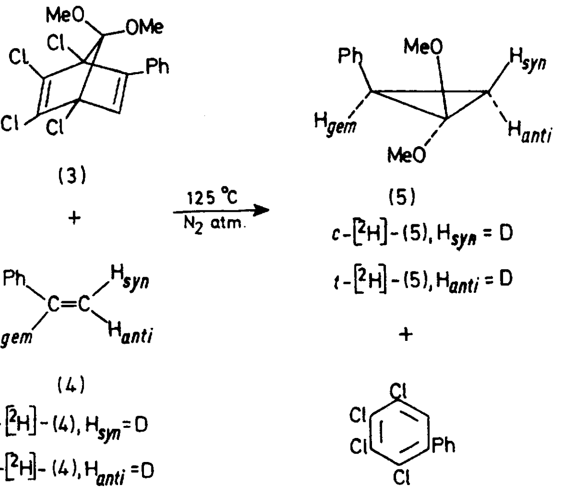
(1)



$\mathrm{EtO_2C\overset{-}{C}H{-}CHCO_2Et}$, with $\mathrm{(MeO)_2\overset{+}{C}}$ on the second CH

(2)

We now describe the first mechanistically unequivocal determination of reaction stereochemistry in a dialkoxycarbene–olefin cycloaddition. The dimethoxycarbene progenitor (**3**) was pyrolysed in styrene (**4**),[5] and in two mixtures of styrene and *cis*-β-deuteriostyrene, *c*-[^{2}H]-(**4**),† and *trans*-β-deuteriostyrene, *t*-[^{2}H]-(**4**), affording the expected cyclopropanes (**5**),[5] *c*-[^{2}H]-(**5**), and *t*-[^{2}H]-(**5**), which were purified by g.l.c. on an S.E.-30 column at 130 °C. The 220 MHz n.m.r. spectrum of non-deuteriated (**5**) was in agreement with a prior report,[5] and could be well reproduced by computer simulation: δ (CCl_4, Me_4Si) 1·168 (H_{syn}), 1·317 (H_{anti}), and 2·266 (H_{gem}); $J_{syn-anti}$ 5·8, $J_{syn-gem}$ 7·0, $J_{anti-gem}$ 10·2 Hz. From ternary mixtures of the styrenes, the corresponding ternary cyclopropane product mixtures were obtained. The compositions of the styrene mixtures† appear in the Table; those of the product mixtures were determined by integration of the appro-



c-[^{2}H]-(4), H_{syn} = D

t-[^{2}H]-(4), H_{anti} = D

c-[^{2}H]-(5), H_{syn} = D

t-[^{2}H]-(5), H_{anti} = D

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† *cis*-β-Deuteriostyrene was prepared by hydrogenation of PhC≡CD (see ref. 7) over 5% Pd–$BaSO_4$ in MeOH containing quinoline. The composition of the purified styrene mixture was determined by n.m.r. spectroscopy.

priate signals in their 220 MHz n.m.r. spectra. Results of the product analyses also appear in the Table; standard deviations averaged *ca.* 0·02.

Table. Relative compositions of substrates and products in additions of (**1**) to styrenes.

Styrene composition†[a] Mole fraction			1,1-Dimethoxy-2-phenylcyclopropane composition[b] Mole fraction		
Isomer	Expt. 1	Expt. 2[c]	Isomer	Expt. 1	Expt. 2
(**4**)	0·19	0·15	(5)	0·19	0·15
c-[^{2}H]-(**4**)	0·78	0·64	*c*-[^{2}H]-(5)	0·79	0·64
t-[^{2}H]-(**4**)	0·03	0·21	*t*-[^{2}H]-(5)	0·02	0·21

[a] Styrene recovered after the addition had an unaltered composition. [b] See text. [c] An aliquot portion of a second styrene mixture† was irradiated in pentane containing I_2 (1 mg), thus equilibrating *c*-[^{2}H]-(**4**) and *t*-[^{2}H]-(**4**). Recombination of this material with the parent mixture afforded the substrate for expt. 2.

Comparisons of the styrene and product compositions clearly show that the additions of (**1**) to β-deuteriostyrenes are stereospecific, within the sensitivity of the experiments (*ca.* 2%). Moreover, there is no observable isotope effect for carbene selectivity between [$^2H_0$]-(**4**) and [$^2H_1$]-(**4**). The stereochemical results are most compatible with concerted addition of (**1**) to styrene, in accord with typical singlet carbene behaviour,[8] and with the lack of theoretical prohibition of concerted nucleophilic carbene–olefin [1+2] cycloadditions.[9] The present results yield no cogent evidence for the intervention of a zwitterionic intermediate, *e.g.*, (**6**). There are two caveats, however. There is no

$$\overset{-}{\mathrm{PhCH}}\mathrm{{-}CH_2{-}}\overset{+}{\mathrm{C}}\mathrm{(OMe)_2}$$

(**6**)

spin-inversion barrier to rapid closure of a 1,3-dipole, so that a two-step singlet carbene addition is not as certain to occur non-stereospecifically as is a triplet carbene addition, which proceeds *via* a triplet 1,3-diradical. Also, the zwitterion (**2**) is more stabilized than (**6**). Its intermediacy in the reaction of (**1**) with maleate is therefore not precluded by our work, although it should be noted that the nucleophilic carbene, cycloheptatrienylidene, does add stereospecifically to maleonitrile and fumaronitrile.[10]

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