

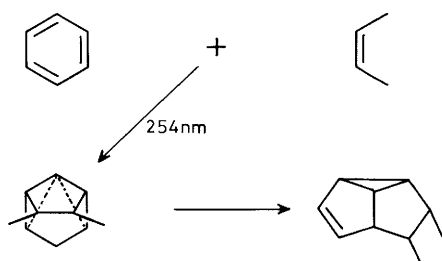
## Selective Formation of Linear and Angular Triquinane Carbon Skeleta by Directed Intramolecular Photocycloaddition of 5-Phenylpent-1-ene

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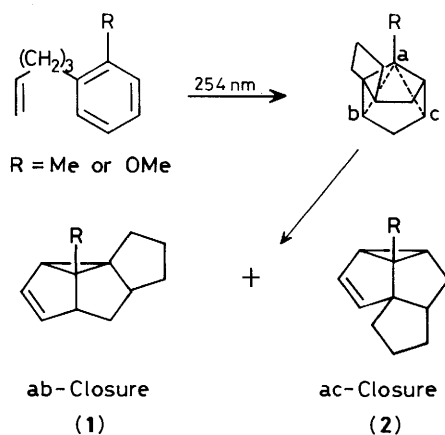
*trans* 1-Chloro- and 2-chloro-5-phenylpent-1-enes undergo selective intramolecular photocycloaddition of the ethene to the 1,3-positions of the phenyl ring, and the cyclopropane ring formation in the adduct is controlled by the chlorine substituent to give specific access to either the angular or linear triquinane carbon skeleton respectively.

The considerable synthetic potential of the *meta* photocycloaddition of ethenes to the benzene ring (Scheme 1) has been convincingly demonstrated for both the inter- and intramolecular processes by Wender and co-workers.<sup>1</sup> The remaining major problem of using this photoprocess as a



Scheme 1.

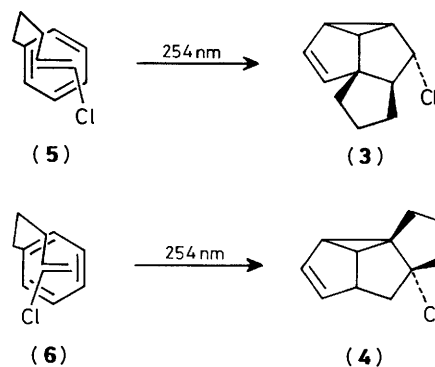
synthetic procedure lies in the fact that the formation of the cyclopropane ring in the adduct occurs in two directions in the reaction intermediate and, dependent on the points of attack of the ethene onto a substituted benzene ring, this can lead to positional isomers of the adduct.<sup>2</sup> This aspect of the reaction is particularly detrimental to the use of the intramolecular cycloaddition of 5-phenylpent-1-ene derivatives as the key step towards the synthesis of triquinane natural products.<sup>1</sup> In this application the photoaddition is directed to the 1,3-positions of the phenyl ring by an *ortho* methyl or methoxy substituent and the two modes of ring closure then yield both precursors (1) and (2) of the linear and angular triquinane skeleta respectively (Scheme 2).<sup>3</sup> In some cases these photoisomers can be photochemically and/or thermally interconverted by an ethenylcyclopropane-cyclopentene rearrangement<sup>4</sup> but decomposition is



Scheme 2.

also generally experienced during this process and there can be no assurance that the photostationary state or the thermal equilibrium will favour the required isomer. The acceptability of the intramolecular process as a synthetic procedure would obviously be considerably improved if the cyclopropane ring closure could be directed to give either the linear or angular triquinane skeleton as required.

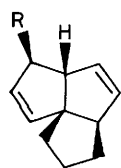
In this communication we describe a method, based on our observations of the features influencing the photoadditions of *trans*-1,2-dichloroethene to the benzene ring,<sup>5</sup> for gaining control over the photoisomer formation of 5-phenylpent-1-enes. The approach taken was that, following attack of the alkene entity onto the 1,3-positions of the phenyl ring, a chlorine substituent on the 1- or 2-position of the bichromophore may influence the cyclopropane ring formation and, as shown in Scheme 3, lead preferentially to the angular and linear



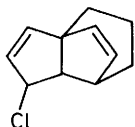
Scheme 3.

triquinane carbon skeleta (3) and (4) respectively. The preliminary studies have been concerned with the 1- and 2-chloro-5-phenylpent-1-enes (5) and (6) respectively in which there is no substituent on the phenyl group to influence the regiochemistry of the addition. The parent 5-phenylpent-1-ene yields an adduct derived from attack of the alkene onto the 2,6-positions of the arene and approximately equal amounts of isomers (1) and (2) (R=H) resulting from the two modes of cyclopropane ring formation following addition at the 1,3-positions of the phenyl ring.<sup>3</sup> The preference for the former mode of reaction (4.8:2.25 respective ratio) is understandable in terms of polarised reaction intermediates<sup>2</sup> and was not expected to be markedly perturbed by chlorine substitution on the alkene.

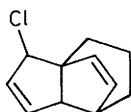
The *cis* and *trans* isomers of 1-chloro-5-phenylpent-1-ene showed considerably different reactivities on 254 nm irradiation of 1% (w/v) solutions in cyclohexane. Thus while the *cis*→*trans* isomerisation was essentially the sole process in the former case, the *trans* isomer (5) gave three photoisomers in a chemical yield of 70% and a ratio of 4.3:1:1 [order of increasing retention time



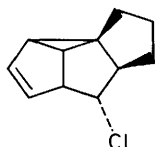
(7) R = Cl  
(8) R = OH



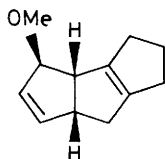
(9)



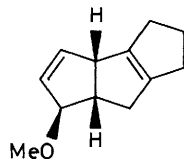
(10)



(11)



(12)



(13)

on non-polar gas chromatography (g.c.). The major isomer was isolated by preparative g.c. and from spectral analysis was shown to have the angular triquinane structure (7):\* [ $\delta_{\text{H}}$ (220 MHz;  $\text{CDCl}_3$ , standard  $\text{Me}_4\text{Si}$ ), 1.49–1.88 (6 H, m,  $\text{CH}_2$ ), 2.80 (1 H, m, 8-H), 3.18 (1 H, m, 5-H), 4.64 (1 H, m, 4-H,  $J_{4,5}$  3.6 Hz), 5.53 (1 H, m, 6-H,  $J_{5,6}$  4.9,  $J_{6,8}$  2.4 Hz), 5.64 (1 H, m, 7-H,  $J_{5,7}$  2.2,  $J_{6,7}$  5.5,  $J_{7,8}$  4.2 Hz), 5.69 (1 H, dd, 3-H,  $J_{3,4}$  2.2 Hz), and 5.87 (1 H, d, 2-H,  $J_{2,3}$  5.4 Hz)]. This product is accounted for by a 1,3-chlorine shift in the first-formed intramolecular *meta* cycloadduct (3).<sup>6</sup> Attempts to isolate (3) by other methods always gave the rearranged isomer and indeed extraction of the irradiated solution with aqueous silver nitrate which led to the efficient recovery of the alcohol (8), proved to be the best method of product isolation. It is, therefore, deduced that under the conditions of its formation the primary adduct is very labile and readily undergoes the chlorine shift.

The minor photoisomers were assigned structures (9) and (10) by comparison of their spectral data with those of intramolecular adducts and their rearranged isomers of known structure:<sup>3,6</sup> these products are rationalised by respective 1,5- and 1,3-chlorine shifts in the primary photoproduct resulting from an addition at the 2,6-positions of the phenyl ring. Thus it is evident that as well as the alkenyl chlorine providing the hoped for direction of the cyclopropane ring formation giving the angular triquinane ring system exclusively [*i.e.* no linear triquinane (11) or rearranged isomers detected], it also has a marked influence on the regiochemistry of the intramolecular *meta* photocycloaddition of 5-phenylpent-1-ene and preferentially directs the reaction towards the 1,3-positions of the arene. This feature clearly outweighs the need for stabilisation of developing charge centres which promotes the addition at the 2,6-positions of the arene in other non-directed systems.<sup>3</sup>

Satisfyingly, both these features of the reaction of *trans* 1-chloro-5-phenylpent-1-ene also dominated the photochemistry of the 2-chloro isomer and hence the linear triquinane skeleton also becomes predictably accessible. For this latter isomer,

however, it was necessary to carry out the reaction in alcoholic solution since in solvents such as cyclohexane or acetonitrile multicomponent mixtures were obtained and HCl was evolved. In methanol solution for example, (6) gave three isomeric components in a chemical yield of 60% and a ratio of 1.5:1.0:7.5 (order of increasing retention time). The two minor products were deduced to have arisen from addition of the chloroalkene moiety to the 2,6-positions of the phenyl ring while the major component was separated by flash chromatography into two isomers (12) and (13) (ratio 4:1 respectively) of the linear triquinane skeleton: \* [(12)  $\delta_{\text{H}}$ (400 MHz,  $\text{CDCl}_3$ ,  $\text{Me}_4\text{Si}$  standard) 1.91 (1 H, split d, 7'-H), 2.06–2.25 (6 H, m,  $\text{CH}_2$ ), 2.39 (1 H, br m, 7-H,  $J_{7,7'}$  15.3 Hz), 3.00 (1 H, br m, 2-H), 3.33 (3 H, s, OMe), 3.87 (1 H, m, 6-H,  $J_{2,6}$  7.0,  $J_{6,7}$  9.3,  $J_{6,7'}$  2.5 Hz), 4.25 (1 H, m, 3-H), 5.74 (1 H, d of t, 4-H,  $J_{3,4} = J_{4,6} = 2.3$  Hz), and 5.97 (1 H, ddd, 5-H,  $J_{3,5}$  0.9,  $J_{4,5}$  5.7,  $J_{5,6}$  2.3 Hz); (13)  $\delta_{\text{H}}$  2.25–2.06 (7 H, m, 7'-H, and  $\text{CH}_2$ ), 2.57 (1 H, br m, 7-H), 3.16 (1 H, m, 6-H), 3.35 (3 H, s, OMe), 3.65 (1 H, br m, 2-H), 4.25 (1 H, m, 5-H,  $J_{5,6}$  3.7 Hz), 5.78 (1 H, d of t, 4-H,  $J_{4,5}$  2.1 Hz), and 6.07 (1 H, ddd, 3-H,  $J_{2,3}$  1.1,  $J_{3,4}$  5.7,  $J_{3,5}$  2.3 Hz)]. These products arise once more by selective (75%) intramolecular cycloaddition of the alkene entity to the 1,3-phenyl positions followed by specific chlorine directed formation of the cyclopropane ring as in Scheme 3. The photoadduct is, however, again labile and undergoes chlorine shifts followed by nucleophilic displacement: this must be the sequence of events as no photosolvolysis of the starting material was observed and reaction of the primary adduct with methanol is unlikely since the tertiary centre cannot attain planarity whereas the substitution of chlorine by methoxy at the allylic position would be facile. Similarly, methoxy substituted products of the angular triquinane skeleton are obtained directly from 254 nm irradiation of the 1-chloro bichromophore in methanol solution.

We have thus demonstrated that following intramolecular photocycloaddition of 5-phenylpent-1-ene the reaction can then be specifically controlled to produce the angular or linear triquinane skeleton as required. Further, the alkenyl chlorine has a substantial directing effect on the regiochemistry of the intramolecular ethene attack thus obviating the necessity for 2-substitution on the phenyl ring to promote the addition at the 1,3-positions.

### Acknowledgements

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\* All photoproducts reported gave satisfactory analytical data but chemical yields have not been optimised.