

# High Asymmetric Induction in the Diels–Alder Reactions of 1-Benzoyl-1-phenylmethyloxycarbonylene

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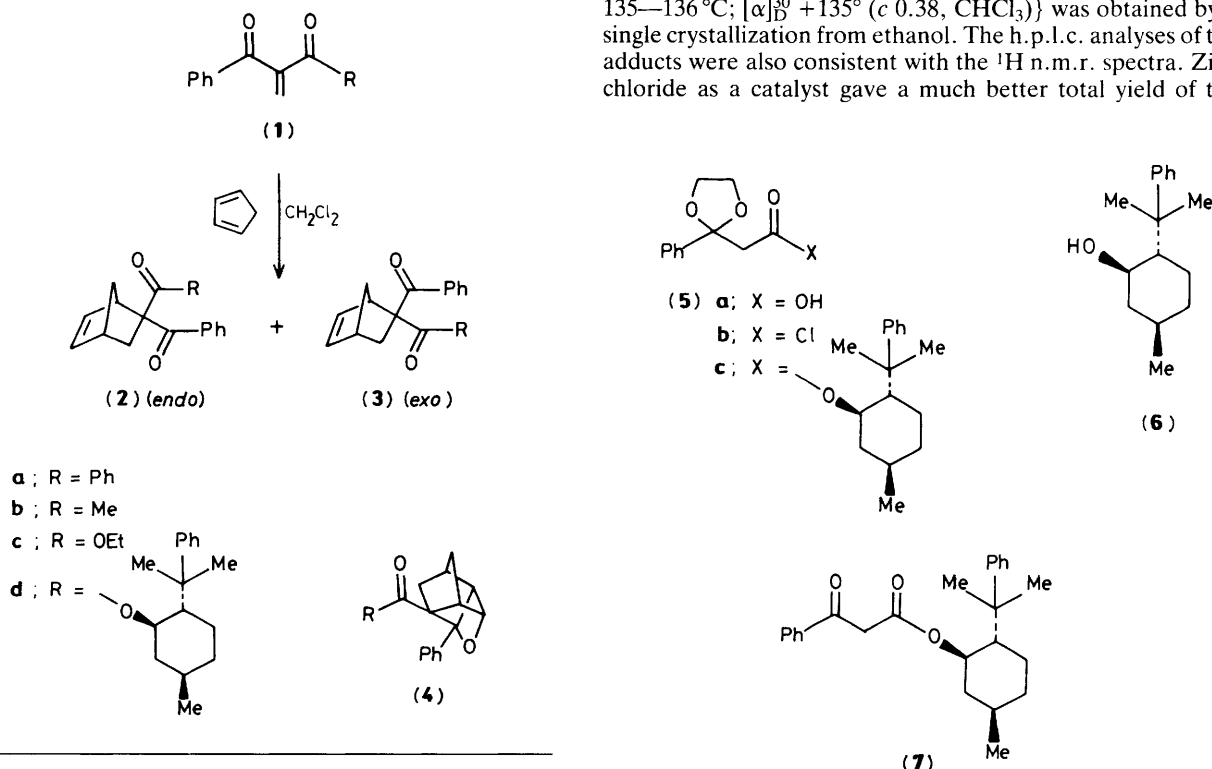
Lewis acid catalysed Diels–Alder reaction of 1-benzoyl-1-phenylmethyloxycarbonylene (**1d**) gave the *exo* adduct regio- and diastereo-selectively.

The Diels–Alder reaction is one of the most investigated areas<sup>1</sup> of asymmetric synthesis because of the spontaneous creation of many more than two chiral centres. Still lacking among the excellent studies reported so far is a study of a dienophile having two electron-withdrawing groups at the same olefinic carbon. We have already reported the isolation of various 1,1-dicarbonyl-ethenes (**1**), in which at least one of the carbonyl groups was included in a benzoyl group, *via* a thiomethylation–oxidation–elimination sequence.<sup>2</sup>

Compounds (**1**) were mixed with cyclopentadiene in dichloromethane for 5 h at ambient temperature. As with 1,1-dibenzoyl-ethene (**1a**),<sup>3</sup> 1-benzoyl-1-acetylene (**1b**)<sup>3</sup> and 1-benzoyl-1-ethoxycarbonyl-ethene (**1c**) gave *endo*-(**2**) and *exo*-(**3**) adducts (Table 1),† and these two isomers could not be separated by column, medium pressure, or preparative centrifugal chromatography. The structures of the products were determined by irradiation of the mixture at 300 nm through Pyrex;<sup>4</sup> oxetane (**4b**) and unreacted (**3b**), and oxetane (**4c**) and unreacted (**3c**), were obtained from the products of (**1b**) and (**1c**), respectively. Interestingly, the ratio of the products was reversed in the presence of Lewis acids in the case of 1-benzoyl-1-ethoxycarbonyl-ethene (**1c**). These results led us to examine the asymmetric Diels–Alder reaction of (**1d**)

having a phenylmethyloxycarbonyl group<sup>5</sup> as a chiral auxiliary in place of the ethyl group in (**1c**).

1-Benzoyl-1-phenylmethyloxycarbonyl-ethene (**1d**) was synthesized from ethyl 3-oxo-3-phenylpropanoate *via* 8 steps in 61% total yield. Thus acetalization followed by saponification of ethyl 3-oxo-3-phenylpropanoate gave the acid (**5a**).<sup>6</sup> The acid chloride (**5b**), obtained by the treatment of (**5a**) with oxalyl chloride, was treated with phenylmethanol (**6**)<sup>5</sup> derived from (+)-pulegone to yield chiral ester (**5c**). Deacetalization was achieved by treatment of (**5c**) with 10% HCl–MeOH (1:6) at ambient temperature. The resulting dione (**7**) was converted into (**1d**) [viscous oil;  $\delta$  5.84 and 6.05 (each s, olefinic H)] by the method<sup>2</sup> previously developed in our laboratory. The Diels–Alder reactions of (**1d**) with cyclopentadiene were carried out under various conditions (Table 1). No diastereoisomeric excess was observed in the adducts in the absence of Lewis acid; *i.e.* a pair of doublets ( $\delta$  0.64 and 0.73) indicating methyl groups and a pair of double triplets ( $\delta$  4.80 and 4.84) indicating protons attached to a carbon bearing ester oxygen were observed at almost same intensities in the <sup>1</sup>H n.m.r. spectrum of diastereoisomeric mixtures of the *endo* adduct (**2d**). However a high diastereoisomeric excess (>95%) was achieved in the presence of Lewis acids; only one doublet ( $\delta$  0.49) and one double triplet ( $\delta$  4.66) due to the groups described above were observed in the <sup>1</sup>H n.m.r. spectrum in the *exo* product (**3d**), from which pure (**3d**) {m.p. 135–136 °C;  $[\alpha]_D^{30} +135^\circ$  (c 0.38, CHCl<sub>3</sub>)} was obtained by a single crystallization from ethanol. The h.p.l.c. analyses of the adducts were also consistent with the <sup>1</sup>H n.m.r. spectra. Zinc chloride as a catalyst gave a much better total yield of the



† *endo* and *exo* are defined by the relationship of the benzoyl group and the bicyclo[2.2.1]heptene.

Scheme 1

**Table 1.** Reactions of 1,1-dicarbonyl ethenes (**1**) with cyclopentadiene.

R	Reaction conditions			Total yield (%)	Product ratio <sup>b</sup> (2):(3)
	Catalyst	T/°C	t/h		
Ph	None	A.t. <sup>a</sup>	5	70	
Me	None	A.t.	5	80	32:68
OEt	None	A.t.	5	67	79:21
OEt	BF <sub>3</sub> ·OEt <sub>2</sub> <sup>c</sup>	0	7	30	25:75
OEt	BF <sub>3</sub> ·OEt <sub>2</sub>	-40	7	54	17:83
OEt	BF <sub>3</sub> ·OEt <sub>2</sub>	-78	7	50	9:91
OEt	ZnCl <sub>2</sub> <sup>d</sup>	A.t.	7	47	12:88
					(9:91)
OEt	ZnCl <sub>2</sub>	-40	7	75	5:95
					(6:94)
OEt	ZnCl <sub>2</sub>	-78	7	73	4:96
					(5:95)
PMO <sup>e</sup>	None	A.t.	6	91	82:18
PMO	BF <sub>3</sub> ·OEt <sub>2</sub> <sup>c</sup>	-40	7	57	13:87
PMO	BF <sub>3</sub> ·OEt <sub>2</sub>	-78	7	49	8:92
PMO	ZnCl <sub>2</sub> <sup>d</sup>	A.t.	6	46	14:86
PMO	ZnCl <sub>2</sub>	-40	7	91	10:90
					(11:89)
PMO	ZnCl <sub>2</sub>	-78	7	88	4:96
					(5:95)

<sup>a</sup> A.t. = ambient temperature. <sup>b</sup> Ratios were determined by <sup>1</sup>H n.m.r. (olefinic protons) or h.p.l.c. <sup>c</sup> 1 equiv. BF<sub>3</sub>·OEt<sub>2</sub> was used with respect to (**1**). <sup>d</sup> 1.5 equiv. ZnCl<sub>2</sub> was used with respect to (**1**). <sup>e</sup> PMO = phenylmenthyloxy.

adduct than BF<sub>3</sub>·OEt<sub>2</sub>. Very similar regio- and diastereoselectivities, but lower total yields, were achieved using diethylaluminium chloride at -40 and -78 °C. The configuration of the quaternary carbon of (**3d**) should be *R*, assuming that the reaction proceeded *via* the 'π-stacking' intermediate.<sup>7</sup>

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