

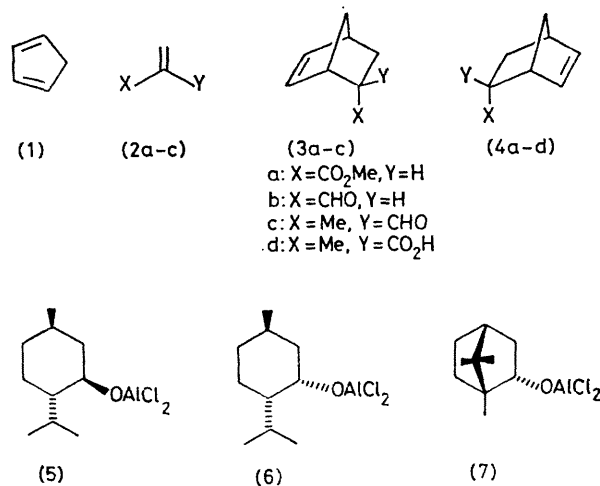
Asymmetric Diels–Alder Reaction Catalysed by Chiral Alkoxyaluminium Dichloride

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Summary Evidence is presented that considerable asymmetric induction can occur in Diels–Alder reactions catalysed by chiral alkoxyaluminium dichlorides.

ASYMMETRIC Diels–Alder reactions using chiral dienes or dienophiles have been extensively investigated.¹ As the catalytic activity of Lewis acids to enhance reaction rate, regioselectivity, and stereoselectivity is well documented,² it should be possible, in principle, to use an optically active Lewis acid as the chiral catalyst in this reaction; however, the only example reported so far is not promising [3.3% enantiomeric excess (e.e.) using menthyl ethyl ether–BF₃ complex as catalyst].³ We report here that chiral alkoxyaluminium dichlorides, prepared from optically active alcohols and ethylaluminium dichloride, are effective chiral catalysts. In a typical experiment, a solution of cyclopentadiene (**1**) (8.17 mmol), methacrolein (**2c**) (7.23 mmol), and menthoxyaluminium dichloride⁴ (**5**) (1.07 mmol) in toluene (10 ml) was stirred at –78 °C for 3 h. Water was added, and the mixture was extracted with pentane. G.l.c. of the extract showed that the product, obtained in quantitative yield, is composed of (**4c**)† and its 2-*exo*-methyl-2-*endo*-carbaldehyde isomer⁵ in a ratio of 98:2. Following column-chromatography the major adduct (**4c**)



(69% yield) was isolated as a colourless semi-solid, $[\alpha]_D^{20} +16.8^\circ$ (ethanol), corresponding to 72% e.e.‡ The optical purity of this sample was further confirmed by n.m.r. analyses using the chiral shift reagent Eu(hfc)₃.

† The structure of this compound was confirmed by direct comparison with the corresponding racemic sample prepared by the reported method, see ref. 5.

‡ A value of $[\alpha]_D^{20} +23.3^\circ$ (ethanol) was used for optically pure (**4c**) by chemical correlation with (**4d**), see ref. 7.

TABLE. Asymmetric Diels-Alder reactions of (1) with (2) in toluene

| Run | Dienophile | Catalyst | Catalyst/(2) ratio | Temp./°C | Major product | Isolated yield/% | $[\alpha]_D$ | Optical purity/% |
|-----|------------|----------|-----------------------|------------|------------------|---------------------|---------------------|---------------------|
| 1 | (2a) | (5) | 0.26 | -23 | (3a) | 65 | -8.2° ^a | 6 ^b |
| 2 | (2a) | (6) | 0.15 | -45 to -23 | (3a)+(4a) | 82 | ca. 0 | ca. 0 |
| 3 | (2a) | (7) | 0.16 | -45 to -23 | (4a) | 78 | +12.9° ^a | 9 ^b |
| 4 | (2b) | (5) | 0.11 | -78 | (3b)+(4b) | 40 | ca. 0 | ca. 0 |
| 5 | (2b) | (6) | 0.11 | -78 | (3b) | 73 | -3.0° ^c | 3 ^d |
| 6 | (2b) | (7) | 0.16 | -78 | (3b) | 55 | -22.9° ^c | 27 ^d |
| 7 | (2c) | (5) | 0.15 | -78 | (4c) | 69 | +16.8° ^c | 72 ^e |
| 8 | (2c) | (6) | 0.16 | -78 | (3c) | 72 | -15.3° ^c | 66 ^e |
| 9 | (2c) | (7) | 0.16 | -78 | (4c) | 84 | +5.9° ^c | 25 ^e |

^a In 95% EtOH. ^b $[\alpha]_D -141^\circ$ (95% EtOH) was used as the value for optically pure (3a). See ref. 7. ^c In EtOH. ^d $[\alpha]_D -83.3^\circ$ (EtOH) was used as the value for optically pure (3b) by chemical correlation with (3a). ^e See footnote †.

Other results are given in the Table. The degree of asymmetric induction is clearly greatly affected by the structure of the reactants as well as the catalysts.

We next examined the possibility of enantiomeric enrichment on a preparative scale. Thus, the crude product of run 7 (Table), obtained as described above, was subjected to silver oxide oxidation⁵ followed by iodolactone separation⁶ to give (4d) [71% yield from (1)] as a solid, $[\alpha]_D^{25} +48.5^\circ$

(95% ethanol), corresponding to 72% e.e.⁷ As recrystallization of this sample from hexane gave (4d) of low optical purity, the mother liquor was evaporated and distilled to give (4d) [45% yield from (1)] as a colourless solid, m.p. 38–40 °C, $[\alpha]_D^{25} +64.9^\circ$ (95% ethanol), corresponding to 96% e.e.

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