Tetrahedron Letters,Vol.27,No.46,pp 5595-5598,1986 0040-4039/86 $3.00 + .00
Printed in Great Britain Pergamon Journals Ltd.

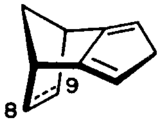
EFFICIENT PREPARATION OF HOMOCHIRAL BICYCLO-ANNULATED CYCLOPENTADIENES VIA THE SKATTEBØL REARRANGEMENT. AVOIDANCE OF LIMITATIONS DUE TO ANGLE STRAIN[1]

Mark L. McLaughlin, Jeffrey A. McKinney, and Leo A. Paquette*

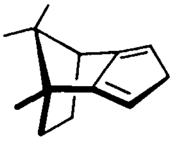
Evans Chemical Laboratories, The Ohio State University, Columbus, Ohio 43210

Abstract: (1R)-(-)-Nopol and (1R)-(+)-camphor have both been efficiently transformed in four steps into optically pure annulated cyclopentadienes.

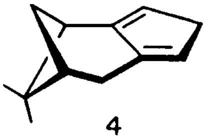
Isodicyclopentadiene (1) and its dehydro derivative 2 possess unique properties that have already serviced several synthetic objectives.[2] This effort has taken particular advantage of their predilection for below-plane Diels-Alder reaction[3] and for above-plane [6+4] cycloaddition.[4] More recently, an appreciation of the π-face selectivity of their cyclopentadiene ring coordination to transition metals has begun to emerge.[1,5,6] In this context, the enantiomerically pure hydrocarbons 3 and 4 hold special interest because they offer attractive possibilities for elaborating optically active building blocks through cycloaddition and for controlling the stereochemical course of many reactions when complexed to Fe, Ti, Zr, and other metals.



1, no $\Delta^{8,9}$
2, $\Delta^{8,9}$

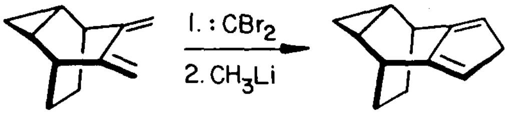


3

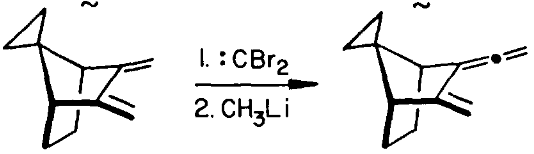


4

Experience has shown that although expedient cyclopentadiene annulation of 5[7] and related systems[8] can be efficiently realized by means of the Skattebøl procedure,[9] only allene formation, viz. 7 → 8, is seen when the ring system is further strained.[10] We attribute this entirely general[11] rerouting away from cyclopentadiene formation to an inability of the torsionally constrained empty carbene p orbital (see 9) to interact with



5 6



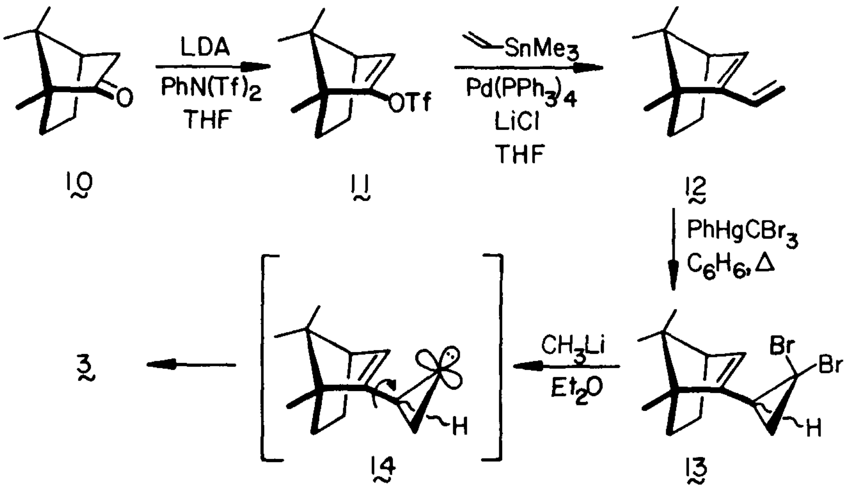
7 8

9

the flanking double bond.[12]

Molecular models suggested that this structural inhibition should be entirely alleviated by positioning the cyclopropyl carbene *completely external* to the norbornene ring where conformational maneuverability is much less impeded. We therefore proceeded to evaluate the concept first with (1*R*)-(+)-camphor (**10**) (Scheme I). Its enol triflate was obtained by condensation of the lithium enolate with N-phenyltrifluoromethanesulfonimide (81%).[13] Smooth coupling (92%) subsequently occurred when **11** was heated with vinyltrimethylstannane in the presence of 5 mol % Pd(PPh$_3$)$_4$ and 4 equiv of lithium chloride in THF.[14] Heating **12**, $[\alpha]_D^{20}$ -159° (*c* 4.29, hexane) with 1 equiv of phenyl(tri-

Scheme I

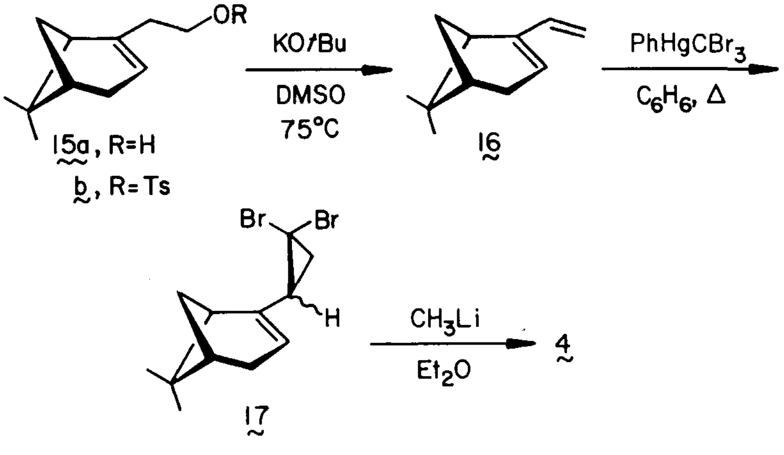


bromomethyl)mercury in refluxing benzene[15] resulted in regiospecific addition as in **13** (72%).[16] As expected, attack at the more heavily substituted internal double bond proved to be sterically precluded. When **13** was treated with 4 equiv of CH_3Li in ether at room temperature, **3**, $[\alpha]^{22}_{D}$ 4.6° (*c* 1.65, hexane), was isolated in 79% yield. The mechanistic implication is that carbene **14** does indeed find it possible to attain proper stereoelectronic alignment for electrocyclization.

A similar four-step sequence served to produce **4** (Scheme II). In this instance, (1*R*)-(-)-nopol (**15a**) was the starting material. Conversion to its tosylate, recrystallization of **15b** to optical purity ($[\alpha]^{25}_{D}$ -25.6° (*c* 1.0, C_2H_5OH)), and base-promoted elimination according to Cupas and Roach[17] afforded homochiral nopadiene (**16**, $[\alpha]^{24}_{D}$ 3.8° (*c* 8.4, hexane)).[18] Dibromocarbene, generated as before by the Seyferth method, added predominantly to the vinyl group of **16** to give a 4:1 mixture of diastereomeric dibromocyclopropanes **17** (94% after chromatography).[16] Following exposure of **17** to ethereal methyllithium at room temperature, the desired cyclopentadiene **4**, $[\alpha]^{24}_{D}$ -21.9° (*c* 1.8, C_2H_5OH), emerged (87% yield).

The ease of obtaining conjugated dienes such as **12** and **16**, the regioselectivity with which they undergo dibromocarbene addition, and the high efficiency with which cyclopentadiene annulation occurs from both diastereomeric adducts give the Skattebøl approach considerable practicality. In particular, the overall yields of **3** and **4** (42% and 40%,

Scheme II



respectively)[20] show that the earlier angle strain limitations have now been circumvented.

Currently, our intention is to explore the application of these substrates to asymmetric synthesis. The adjoining contribution[19] is illustrative of one facet of this program.

Acknowledgment. Financial support for this research was provided by the Public Health Service (Grant CA-12115).

References and Notes

(1) This paper represents our 36th contribution to the chemistry of isodicyclopentadienes. For part 35, consult Gallucci, J. C.; Gautheron, B.; Gugelchuk, M.; Meunier, P.; Paquette, L. A. *Organometallics*, submitted.

(2) For example: (a) [4]-peristylane: Paquette, L. A.; Fischer, J. W.; Browne, A. R.; Doecke, C. W. *J. Am. Chem. Soc.* **1985**, *107*, 686. (b) *syn*-sesquinorbornatriene: Paquette, L. A.; Künzer, H.; Green, K. E. *Ibid.* **1985**, *107*, 4788. (c) norbornyl-fused norbornyl cations: Paquette, L. A.; DeLucca, G.; Ohkata, K.; Gallucci, J. C. *Ibid.* **1985**, *107*, 1015.

(3) (a) Paquette, L. A. In "Stereochemistry and Reactivity of Pi Systems"; Watson, W. H.; Ed., Verlag Chemie International: Deerfield Beach, FL, 1982. (b) Gleiter, R.; Paquette, L. A. *Accounts Chem. Res.* **1983**, *16*, 328.

(4) Paquette, L. A.; Hathaway, S. J.; Schirch, P. F. T. *J. Org. Chem.* **1985**, *50*, 4199 and relevant references cited therein.

(5) (a) Hsu, L.-Y.; Hathaway, S. J.; Paquette, L. A. *Tetrahedron Lett.* **1984**, 259. (b) Paquette, L. A.; Hathaway, S. J.; Schirch, P. F. T.; Gallucci, J. C. *Organometallics* **1986**, *5*, 500. (c) Paquette, L. A.; Schirch, P. F. T.; Hathaway, S. J.; Hsu, L.-Y.; Gallucci, J. C. *Ibid.* **1986**, *5*, 490 and earlier references cited therein.

(6) Halterman, R. L.; Vollhardt, K. P. C. *Tetrahedron Lett.* **1986**, 1461.

(7) Charumilind, P.; Paquette, L. A. *J. Am. Chem. Soc.* **1984**, *106*, 8225.

(8) Butler, D. N.; Gupta, I. *Can. J. Chem.* **1978**, *56*, 80.

(9) Skattebøl, L. *Tetrahedron* **1967**, *23*, 1107.

(10) Paquette, L. A.; Green, K. E.; Gleiter, R.; Schäfer, W.; Gallucci, J. C. *J. Am. Chem. Soc.* **1984**, *106*, 8232.

(11) Reinarz, R. B.; Fonken, G. J. *Tetrahedron Lett.* **1973**, 4591.

(12) (a) Holm, K. H.; Skattebøl, L. *Acta Chem. Scand.* **1985**, *39B*, 549. (b) Brun, R.; Grace, D. S. B.; Holm, K. H.; Skattebøl, L. *Ibid.* **1986**, *40B*, 21. (c) Baird, M. S.; Jeffries, I. *Tetrahedron Lett.* **1986**, 2493.

(13) McMurry, J. E.; Scott, W. J. *Tetrahedron Lett.* **1983**, 979.

(14) Scott, W. J.; Stille, J. K. *J. Am. Chem. Soc.* **1986** *108*, 3033.

(15) (a) Seyferth, D.; Burlitch, J. M. *J. Organometal. Chem.* **1965**, *4*, 127. (b) Seyferth, D.; Lambert, R. L., Jr. *Ibid.* **1969**, *16*, 21.

(16) Two diastereomeric dibromocyclopropanes are possible in each example studied. All available evidence denotes that both are transformed efficiently to the cyclopentadiene.

(17) Cupas, C. A.; Roach, W. S. *J. Org. Chem.* **1969**, *34*, 742.

(18) Nopol tosylate exhibiting $[\alpha]_D^{20}$ -29.7° (*c* 1.0, C_2H_5OH) has previously been reported to give nopadiene of *ca* 100% ee with $[\alpha]_D^{20}$ 1.3° (*c* 1.5, $CHCl_3$): Samuel, O.; Couffignal, R.; Lauer, M.; Zhang, S. Y.; Kagan, H. B. *Nouv. J. Chim.* **1981**, 15.

(19) Paquette, L. A.; McKinney, J. A.; McLaughlin, M. L.; Rheingold, A. L. accompanying paper.

(20) **3**: ^1H NMR (300 MHz, $CDCl_3$) δ 5.69 (br s, 1H), 5.63 (s, 1H), 3.18 (d, *J* = 22.9 Hz, 1H), 3.06 (d, *J* = 22.9 Hz, 1H), 2.51 (d, *J* = 4.3 Hz, 1H), 2.07-1.93 (m, 1H), 1.86-1.77 (m, 1H), 1.44-1.20 (m, 2H), 1.15 (s, 3H), 0.98 (s, 3H), 0.71 (s, 3H). **4**: ^1H NMR (300 MHz, $CDCl_3$) δ 5.99 (s, 1H), 5.77 (s, 1H), 2.99 (s, 2H), 2.70 (m, 2H), 2.60 (m, 1H), 2.11 (m, 1H), 1.60 (s, 1H), 1.33 (s, 3H), 1.24 (m, 1H), 0.72 (s, 3H).

(Received in USA 15 July 1986)