Tetrahedron Letters,Vol.27,No.13,pp 1461-1464,1986 0040-4039/86 $3.00 + .00
Printed in Great Britain

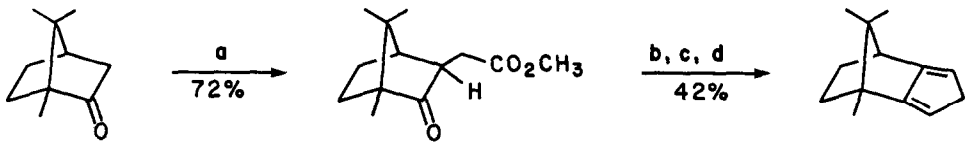
PRACTICAL SYNTHESIS OF TWO ANNELATED OPTICALLY ACTIVE CYCLOPENTADIENES FROM THE CHIRAL POOL AND THEIR TRANSITION METAL COMPLEXES

Ronald L. Halterman and K. Peter C. Vollhardt*
Department of Chemistry, University of California,
and the Materials and Molecular Research Division,
Lawrence Berkeley Laboratory, Berkeley, California 94720

Abstract: Starting from camphor or tartaric acid the two optically active annelated cyclopentadienes **3** and **5** are readily synthesized and complexed to transition metals.

The synthesis of optically active auxiliaries in the enantioselective construction of organic molecules has seen intensive recent activity.[1] In this connection, optically active cyclopentadienes could be valuable building blocks around which to assemble chiral synthons by Diels-Alder/retro-Diels-Alder cycloaddition strategies.[2] Perhaps more importantly, as ligands to transition metals, they should control the stereochemical outcome of a variety of catalytic[3] or stoichiometric[4] transformations in which new stereocenters are made. While such potential or actual ligands to transition metals are known, they have involved mainly cyclopentadienes with one chiral substituent.[5] We report the efficient and straightforward synthesis of the two annelated systems **3**[6] and **5** from the chiral pool (camphor or tartaric acid). These compounds appear attractive because the enforced rigidity of the chiral backbone may allow for better stereoselection in reactions involving the diene unit directly or, after complexation, in transition metal-mediated transformations.

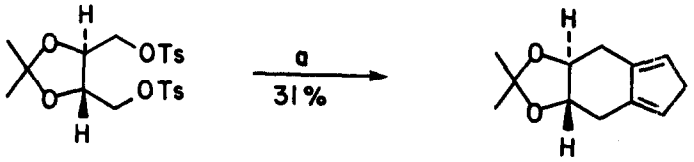
Scheme I[a]



1 2 3

[a](a) $[(CH_3)_2CH]_2NLi$, HMPA, THF, $BrCH_2CO_2CH_3$, -78°C to 23°C, 1h; (b) $LiCH_2P(OCH_3)_2$ (2 equiv.), diglyme, -78°C, 2h, Δ, 18h; (c) $LiAlH_4$, ether, 23°C, 30 min; (d) p-TsOH, C_6H_6, 23°C, 12h.

Scheme II[a]



4 5

[a](a) NaH, cyclopentadiene, THF, 23°C, 8h, Δ, 2h.

Schemes I and II depict our respective synthetic approaches to the target systems.[7] Several features are noteworthy: a) alkylation of **1** furnishes the kinetic product **2**, equilibrated by base with its diastereomer (stereochemistry established by NOE experiments), b) formation of the cyclopentenone did not require protection of the (evidently hindered) carbonyl function[8], c) reduction of the resulting product gave the allylic alcohol[9] which could be dehydrated to the (apparently) thermodynamic diene **3**, d) the ditosylate **4**[10] was cyclopentannulated directly to **5** without the generation of the possible spiroproduct,[11] e) both ligands can be complexed to transition metals. Thus, treatment with $Co_2(CO)_8$ gave (~50%) a 3:1 mixture (endo : exo) of (**3** - H)-$Co(CO)_2$,[7] but, because of C_2-symmetry, only one isomer of (**5** - H)-$Co(CO)_2$.[7] The potential of these complexes in cobalt-mediated enantioselective cyclizations[12] is being explored. Similarly, titanation[5l] of **3** gave mainly only one diastereomeric titanocene dichloride with C_2 symmetry (95:5, minor isomer unsymmetrial), tentatively assigned the bis-endo configuration.[7] The pure major isomer functions as a catalyst precursor for the enantioselective hydrogenation of 1-ethylstyrene with the best optical yields yet observed[5e,f,j] ($CH_3CH_2CH_2CH_2Li$, -20°C, 5h, 100%, 34% optical yield, catalyst precursor recovered by treatment with HCl), boding well for future synthetic applications.

Acknowledgement. This work was supported by NIH-GM22479. R. L. H. was the recipient of a University of California Regents' Fellowship (1982-1984). K. P. C. V. is a Miller Research Professor in residence (1985-1986).

References and Notes

(1) Paquette, L. A. In "Asymmetric Synthesis"; Morrison, J. D. Ed.; Academic Press : New York, 1984; Vol.3, p. 455. Oppolzer, W. Angew. Chem., Int. Ed. Engl. **1984**, 23, 876. ApSimon, J. W.; Seguin, R. P. Tetrahedron **1979**, 35, 2797. Valentine, D., Jr.; Scott, J. W. Synthesis **1978**, 329.

(2) Wiersum, U. E. Aldrichim. Acta **1984**, 17, 31. Welzel, P. Nachr. Chem. Tech. Lab. **1983**, 31, 979. Desimoni, G.; Tacconi, G.; Barco, A.; Pollini, G. P. In "Natural Products Through Pericyclic Reactions"; Caserio, M., Ed.; American Chemical Society: Washington, D. C., 1983; p. 203. Brown, R. F. C. "Pyrolytic Methods in Organic Chemistry"; Academic Press : New York, 1980; p. 259. Ripoll, J. L.; Rouessac, A.; Rouessac, F. Tetrahedron **1978**, 34, 19.

(3) Kagan, H. B. In "Comprehensive Organometallic Chemistry"; Wilkinson, G.; Stone, F. G. A.; Abel, E. W., Eds.; Pergamon Press : New York, 1982; Vol. 8, p. 463.

(4) See, for example, Davies, S. G.; Warner, P. Tetrahedron Lett. **1985**, 26, 4815. Smith, D. E.; Gladysz, J. A. Organometallics **1985**, 4, 1480. Liebeskind, L. S.; Welker, M. E. Ibid. **1984**, 25, 4341, and the references therein.

(5) See, for example, (a) Cesarotti, E.; Chiesa, A.; Ciani, G. F.; Sironi, A.; Vefghi, R.; White, C. J. Chem. Soc., Dalton Trans. **1984**, 653. (b) Dormond, A.; El Bouadili, A.; Moise, C. Tetrahedron Lett. **1983**, 24, 3087. (c) Sato, F.; Iijima, S.; Sato, M. J. Chem. Soc., Chem. Commun. **1981**, 180. (d) Cesarotti, E.; Ciani, G.; Sironi, A. J. Organomet. Chem. **1981**, 216, 87. (e) Cesarotti, E.; Ugo, R.; Vitiello, R. J. Mol. Cat. **1981**, 12, 63. (f) Coutourier, S.; Tainturier, G.; Gautheron, B. J. Organomet. Chem. **1980**, 195, 291. (g) Cullen, W. R.; Einstein, F. W. B.; Huang, C.-H.; Willis, A. C.; Yeh, E.-S. J. Am. Chem. Soc. **1980**, 102, 988. (h) Fiaud, J. C.; Malleron, J. L. Tetrahedron Lett. **1980**, 21, 4437. (i) Tamao, K.; Hayashi, T.; Matsumoto, H.; Yamamoto, H.; Kumada, M. Ibid. **1979**, 2155. (j) Cesarotti, E.; Ugo, R.; Kagan, H. B. Angew. Chem., Int. Ed. Engl. **1979**, 18, 779. (k) Dormond, A.; Kolavudh, T.; Tirouflet, J. J. Organomet Chem. **1979**, 164, 317. (l) Cesarotti, E.; Kagan, H. B.; Goddard, R.; Krüger, C. Ibid. **1978**, 162, 297. (m) Leblanc, J. C.; Moise, C. Ibid. **1977**, 131, 35; **1976**, 120, 65. (n) Marquarding, D.; Burghard, H.; Ugi, I; Urban, R.; Klusacek, H. J. Chem. Res. S **1977**, 82. (o) Le Plouzennec, M.; Le Moigne, F.; Dabard, R. J. Organomet. Chem. **1976**, 111, C38. (p) See also, Sternbach, D. D.; Hobbs, S. H. Synth. Commun. **1984**, 14, 1305, and the references therein.

(6) Compound **3** has been prepared by a bis-Wittig reaction on campher quinone in low yield and with dubious optical purity, reported as $[\alpha]_D$-0.4° (hexane); Burgstahler, A. W.; Boger, D. L.; Naik, N. C. Tetrahedron **1976**, 32, 309.

(7) All new compounds gave satisfactory analytical and/or spectral data. Selected data: **3**: colorless oil; IR (neat) 2957, 1442, 1383, 1156, 893, 759 cm^{-1}; ^1H NMR (250 MHz, $CDCl_3$) δ

5.66 (br s, 1H), 5.60 (s, 1H), 3.14 (d, J = 23.0, 1H), 3.02 (d, J = 23.0, 1H), 2.47 (d, J = 3.5, 1H), 1.99 (dddd, J = 11.2, 11.0, 3.8, 3.5, 1H), 1.77 (ddd, J = 11.0, 10.5, 2.6, 1H), 1.36 (ddd, J = 11.2, 9.6, 2.6, 1H), 1.27 (ddd, J = 10.5, 9.6, 3.8, 1H), 1.11 (s, 3H), 0.94 (s, 3H), 0.67 (s, 3H); ^{13}C NMR (63.1 MHz, $CDCl_3$) δ 159.4, 154.5, 114.9, 113.5, 54.3, 49.1, 48.3, 44.3, 34.6, 26.9, 20.6, 18.2, 11.9; $[\alpha]_D$ = +5.8° (c = 0.376, hexane, 26°C). **5**: colorless crystals, mp 44.0 - 44.5°C; IR (neat) 2987, 2933, 2857, 1615, 1448, 1380, 1234, 1139, 1078, 857 cm^{-1}; MS m/e (relative intensity) 192 (M^+, 34), 117 (100), 105 (68); ^1H NMR (250 MHz, $CDCl_3$) δ 6.32 (br s, 2H), 3.77 (m, 2H), 2.75 - 2.90 (m, 4H), 2.40 - 2.55 (m, 2H), 1.48 (s, 6H); ^{13}C NMR (63.1 MHz, $CDCl_3$) δ 133.6, 132.3, 110.2, 78.3, 43.0, 30.1, 27.1; $[\alpha]_D$ = 113.1° (c = 0.275, 95% ethanol, 26°C). (**5** - H)-$Co(CO)_2$: red crystals, mp 72 - 73°C; IR (neat) 2024, 1960 cm^{-1}; ^1H NMR (300 MHz, C_6D_6) δ 4.43 (dd, J = 2.6, 2.5, 1H), 4.31 (m, 2H), 4.08 (ddd, J = 10.5, 9.2, 5.1, 1H), 3.32 (ddd, J = 10.3, 9.2, 7.0, 1H), 2.65 (dd, J = 14.6, 5.1, 1H), 2.54 (m, 2H), 2.11 (dd, J = 14.6, 10.5, 1H), 1.42 (s, 3H), 1.40 (s, 3H); ^{13}C NMR (75.5 MHz, C_6D_6, off-reson decoup) δ 206.0 (br s), 110.9 (s,), 101.2 (s), 99.3 (s), 83.2 (d), 82.1 (d), 81.4 (d), 78.5 (d), 77.6 (d), 28.7 (t), 28.1 (t), 27.3 (q), 27.2 (q); $[\alpha]_D$ = 70° (c = 0.00095, 95% ethanol, 26°C). (**3** - H)$_2$-$TiCl_2$: red crystals, mp 178 - 179°C; ^1H NMR (250 HHz, $CDCl_3$) δ 6.47 (d, J = 2.7, 4H), 5.92 (dd, J = 2.7, 2.7, 2H), 2.75 (d, J = 4.1, 2H), 1.4 - 2.0 (m, 8H), 1.23 (s, 6H), 0.92 (s, 6H), 0.27 (s, 6H); ^{13}C NMR (50.8 MHz, $CDCl_3$) δ 158.5, 152.2, 122.1, 113.5, 113.0, 70.0, 54.2, 51.5, 32.2, 25.4, 21.0, 19.9, 12.8.

(8) Clark, R. D.; Kozar, L. G.; Heathcock, C. H. Synth. Commun. **1975**, 5, 1.

(9) Brown, H. C.; Hess, H. M. J. Org. Chem. **1969**, 34, 2206.

(10) Townsend, J. M.; Blount, J. F.; Sun, R. C.; Zawoiski, S.; Valentine, D., Jr. J. Org. Chem. **1980**, 45, 2995.

(11) Hallam, B. F.; Pauson, P. L. J. Chem. Soc. **1958**, 646. Antczak, K.; Kingston, J. F.; Fallis, A. G. Can. J. Chem. **1984**, 62, 2451.

(12) Vollhardt, K. P. C. Angew. Chem., Int. Ed. Engl. **1984**, 23, 539.

(Received in USA 14 January 1986)