Pergamon

Tetrahedron Letters 40 (1999) 3681–3684

TETRAHEDRON
LETTERS

Syntheses and Diels-Alder Reactions of Cyclopentadienes Fused to Bicyclo[2.2.2]octenones

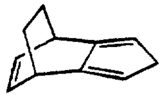
V. K. Singh,[a*] S. Prathap,[a] V. V. Kane,[b] C. C. Stessman,[c] and R. B. Bates[c]

[a]Department of Chemistry, Indian Institute of Technology, Powai, Bombay 400076, India
[b]Department of Chemistry, Ohio State University, Columbus, OH 43210, USA
[c]Department of Chemistry, University of Arizona, Tucson, AZ 85721, USA

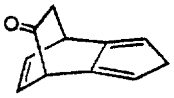
Received 11 February 1999; revised 16 March 1999; accepted 17 March 1999

Abstract: Syntheses of trienones 2 and 3 and their Diels-Alder reactions with dimethyl acetylenedicarboxylate and benzoquinone are described. The ketone and methyl groups in trienones 2 and 3 appear to be repulsive factors controlling π facial selectivity in their Diels-Alder reactions. Large amounts of exo adducts are formed in the benzoquinone reactions.

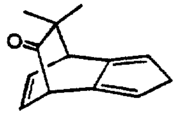
In studies of cycloadditions of facially differentiated cyclopentadienes and cyclohexadienes fused to bicyclic frameworks, many different factors have been used to explain the facial selectivities.[1] Triene **1** prefers to capture acetylenic dienophiles from the top face, but *N*-methyltriazolinedione from the bottom face.[1abj] We now report syntheses of trienones **2** and **3** and the facial selectivities of these keto and methyl derivatives of **1** in Diels-Alder reactions with dimethyl acetylenedicarboxylate (DMAD) and *p*-benzoquinone.



1



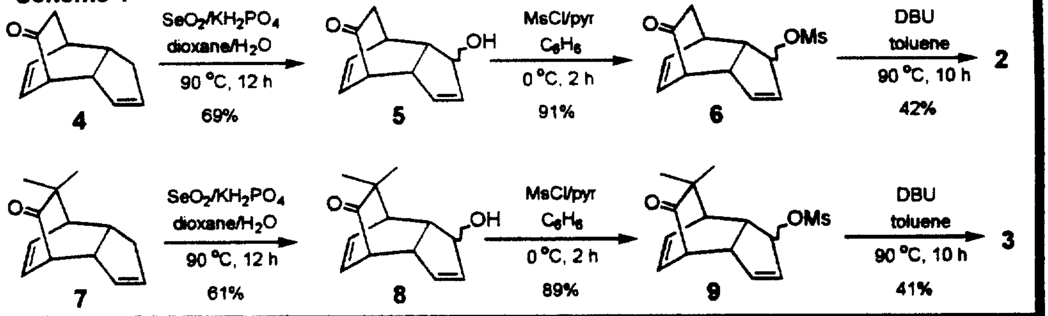
2



3

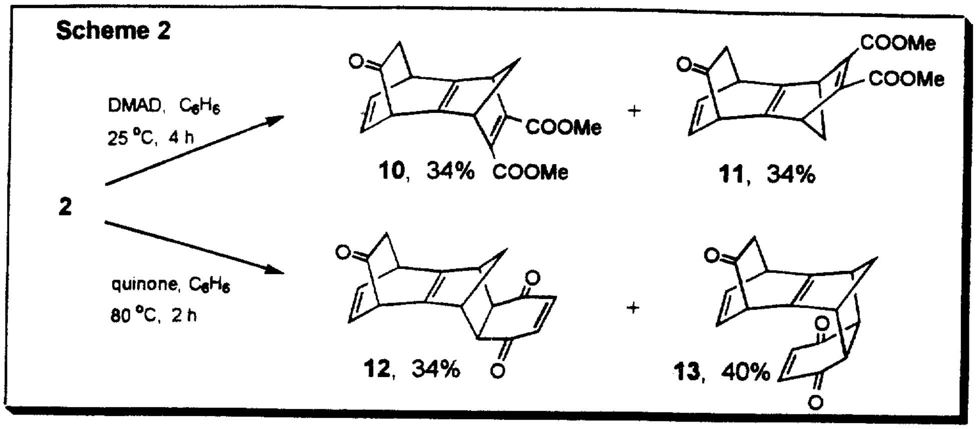
Trienone **2**[2] was synthesized as shown in Scheme 1 from dienone **4**[3] by SeO_2 oxidation to **5**, mesylation to **6**, and DBU-induced elimination. Trienone **3**[4] was prepared similarly from dienone **7**[3] via **8** and **9**.

Scheme 1



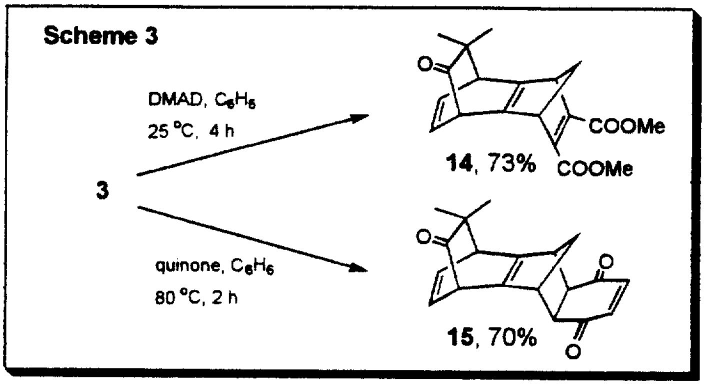
PII: S0040-4039(99)00624-3

As shown in Scheme 2, Diels-Alder reaction of trienone **2** with DMAD gave an inseparable 50:50 mixture of adducts **10** and **11**[5] arising from bottom and top face attack by the dienophile. Trienone **2** with quinone gave a 45:55 mixture of bottom-exo and bottom-endo adducts **12**[6] and **13**,[7] separated by silica gel chromatography.



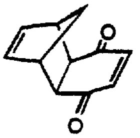
Scheme 2

As shown in Scheme 3, the corresponding Diels-Alder reactions of trienone **3** gave only bottom-face products: DMAD gave bottom adduct **14**,[8] and quinone gave bottom-exo adduct **15**.[9]

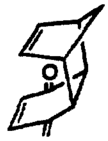


Scheme 3

The stereochemistry of adducts **12**-**15** was deduced from NMR data, including NOE spectra and comparisons with exo- (**16**) and endo-1,4,4a,8a-tetrahydro-1,4-methanonaphthalene-5,8-diones (**17**).[10] The assignments for adduct **12** were based on the similarity of its NMR spectrum to that of adduct **15**, whose stereochemistry was defined by an NOE study. The bottom-endo assignment for adduct **13** was based on the strong upfield shifts of all four vinyl hydrogens, expected only in this stereoisomer. Helpful in defining exo vs. endo were the chemical shifts of a) the bridgehead hydrogens α to the carbonyl groups: δ2.49 in exo model **16**, 3.17 in endo model **17**, 2.18 in **12** and 3.2 in **13**, and b) the vinyl hydrogens in the endione system: δ6.74 in exo model **16**, 6.52 in endo model **17**, 6.76 in **12** and 6.05 in **13**.



16



17

In accordance with findings for other systems,[1f,g,l] the ketone grouping in **2** has a *repulsive* effect on the facial selectivity compared with the methylene group in **1** since **2** gives equal amounts of bottom and top attack with DMAD whereas **1** gives almost entirely top attack with acetylenic dienophiles. **11** was the only product of top attack found in any of the four reactions. Steric hindrance from one of the methyl groups in **3** is presumably responsible for finding only bottom attack in the reaction of **3** with DMAD compared to equal amounts of top and bottom attack for **2** with DMAD. The finding of considerable amounts of exo Diels-Alder adducts **12** and **15** in the benzoquinone reactions is in keeping with earlier results with related cyclopentadienes.[1b,*]

*Dedicated to Prof. James B. Hendrickson on the occasion of his 70th birthday.

Acknowledgements: We thank R.S.I.C., I.I.T. Bombay and T.I.F.R. Bombay for spectral facilities. S. P. is thankful to CSIR New Delhi for a senior fellowship. Financial support to V. K. S. from DST New Delhi is gratefully acknowledged.

REFERENCES AND NOTES

1 a) Paquette, L. A.; Carr, R. V. C., Charumilind, P., Blount, J. F. *J. Org. Chem.* **1980**, *45*, 4922-4926. b) Bohm, M. C.; Carr, R. V. C.; Gleiter, R, Paquette, L. A. *J. Am. Chem. Soc.* **1980**, *102*, 7218-7228. c) Watson, W. H.; *Stereochemistry and Reactivity of Systems Containing π Electrons*; Verlag Chemie International: Deerfield Beach, FL; **1983**, pp 41-73, 105-146. d) Avenati, M.; Vogel, P. *Helv. Chim. Acta* **1983**, *66*, 1279-1287. e) Brown, F. K., Houk, K. N. *J. Am. Chem. Soc.* **1985**, *107*, 1971-1978. f) Coxon, J. M.; O'Connell, M. J.; Steel, P. J. *J. Org. Chem.* **1987**, *52*, 4726-4732. g) Coxon, J. M.; Maclagan, R. G. A. R.; McDonald, D. Q., Steel, P. J. *J. Org. Chem.* **1991**, *56*, 2542-2549. h) Hickey, E. R.; Paquette, L. A. *Tetrahedron Lett.* **1994**, *35*, 2309-2312. i) Paquette, L. A.; Hickey, E. R. *Tetrahedron Lett.* **1994**, *35*, 2313-2316. j) Hickey, E. R.; Paquette, L. A. *J. Am. Chem. Soc.* **1995**, *117*, 163-176. k) Paquette, L. A.; Branan, B. M.; Rogers, R. D.; Bond, A. H.; Lange, H.; Gleiter, R. *J. Am. Chem. Soc.* **1995**, *117*, 5992-6001. l) Mehta, G.; Uma, R. *Tetrahedron Lett.* **1995**, *36*, 4873-4876.

2. **2:** An oil. IR (neat) 1736 cm^{-1}. ^{1}H NMR: δ6.70 (td, 7 and 1.5 Hz, 1H, γ-H of β,γ-enone), 6.45 (br t, 7 Hz, 1H, β-H of β,γ-enone), 6.09 (s, 1H, vinyl), 5.98 (s, 1H, vinyl), 4.15 (d, 6 Hz, 1H, α-CH), 3.86 (m, 1H, CH), 3.2 (m, 2H, allylic CH_2), 2.4 (dd, 18 and 3 Hz, 1H, α-CH_2), 2.2 (dd, 18 and 3 Hz, 1H, α-CH_2). ^{13}C NMR: δ207.1, 147.8, 142.5, 137.0, 129.5, 122.4, 118.7, 54.9, 44.4, 39.8 and 35.3. Mass (m/z): 158 (M$^+$).
3. Singh, V; Porinchu, M. *Tetrahedron* **1996**, *52*, 7087-7126.
4. **3:** An oil. IR (neat) 1729 cm^{-1}. ^{1}H NMR: δ6.62 (td, 7 and 2 Hz, 1H, γ-H of β,γ-enone), 6.33 (br t, 7 Hz, 1H, β-H of β,γ-enone), 5.96 (m, 2H, vinyls), 4.06 (br d, 6 Hz, 1H, α-CH), 3.40 (br d, 6 Hz, 1H, β-CH), 3.18 (m, 2H, CH_2),1.20 (s, 3H, CH_3), 0.90 (s, 3H, CH_3). ^{13}C NMR: δ213.3, 147.2, 142.5, 138.0, 129.0, 122.0, 121.0, 55.0, 47.8, 44.4, 27.5 and 25.5 (quaternary C not shown). Mass (m/z): 186 (M$^+$).
5. **10** and **11:** ^{1}H NMR: singlets for four methyl groups at δ3.79, 3.77, 3.76 and 3.74, and peaks for four vinyl hydrogens at δ6.63 (m, 1H, γ-H of β,γ-enone), 6.52 (m, 2H) and 6.32 (m, 1H). Mass (m/z): 300 (M$^+$).
6. **12**: Mp 120°C. IR (neat) 1725, 1675 cm^{-1}. ^{1}H NMR: δ6.76 (s, 2H, enedione), 6.58 (td, 6.5 and 1.5 Hz, 1H, γ-H of β,γ-enone), 6.38 (br t, 6.5 Hz, 1H, β-H of β,γ-enone), 4.20 (br d, 6 Hz, 1H, α-CH), 4.02 (m, 1H, β-CH), 3.44 (m, 1H, bicyclo[2.2.1] bridgehead H), 3.40 (m, 1H, bicyclo[2.2.1] bridgehead H), 2.18 (m, 2H, dienone α-CH's), 2.04 (m, 2H, CH_2CO), 1.52 (dt, 9.0, 1.5 Hz, 1H, CH_2), 0.90 (dt, 9.0, 1.5 Hz, 1H, CH_2).
7. **13**: IR (neat) 1725, 1680 cm^{-1}. ^{1}H NMR: δ6.25 (m, 3H, vinyls), 5.85 (m, 1H, β-H of β,γ-enone), 4.0 (m, 3H, bicyclo[2.2.1] and [2.2.2] bridgehead H's), 3.8 (m, 1H, bicyclo[2.2.1] or [2.2.2] bridgehead H), 3.2 (m, 2H, dienone α-CH's), 2.1 (m, 2H, CH_2) 1.8 (m, 2H, CH_2CO). Mass (m/z): 266 (M$^+$).
8. **14:** An oil. IR (neat) 1720, 1610 cm^{-1}. ^{1}H NMR: δ6.46 (td, 7.0, 1.5 Hz, 1H, γ-H of β,γ-enone), 6.27 (m, 7.0, 1.5 Hz, 1H, β-H of β,γ-enone), 4.26 (br d, 6 Hz, 1H, α-CH), 3.95 (m, 1H, bicyclo[2.2.1] bridgehead CH), 3.79 (br d, 6 Hz, 1H, β-CH), 3.76 (s, 6H, OCH_3's), 2.53 (dt, 8, 2 Hz, 1H, CH_2), 2.32 (dt, 8, 2 Hz, 1H, CH_2), 1.16 (s, 3H, CH_3), 1.12 (s, 3H, CH_3). ^{13}C NMR: δ207.7, 165.2, 165.1, 161.8, 152.8, 152.7, 152.4, 138.0, 128.5, 71.1, 57.5, 55.1, 54.4, 2 x 52.0, 51.4, 43.1, 28.4, 28.3. Mass (m/z): 328 (M$^+$).
9. **15:** Mp 144°C. IR (KBr) 1723, 1670 cm^{-1}. ^{1}H NMR: δ6.75 (s, 2H, enedione), 6.51 (td, 5.9 and 1.5 Hz, 1H, γ-H of β,γ-enone), 6.33 (td, 5.9 and 1.5 Hz, 1H, β-H of β,γ-enone), 4.18 (br d, 5.5 Hz, 1H, α-CH in bicyclo[2.2.2] system), 3.69 (br d, 5.5 Hz, 1H, β-CH in bicyclo[2.2.2] system), 3.40 (br s, 1H, bicyclo[2.2.1] bridgehead H closer to Me's), 3.37 (br s, 1H, bicyclo[2.2.1] bridgehead H farther from Me's), 2.22 (s, 2H, dienone α-CH's), 1.57 (dt, 9.7, 2.0 Hz, 1H, CH_2 H closer to Me's), 1.41 (dt, 9.7, 2.0 Hz, 1H, CH_2 H farther from Me's), 1.13 (s, 3H, CH_3 closer to CH_2), 1.11 (s, 3H, CH_3 farther from CH_2). ^{13}C NMR: δ207.4, 198.7, 153.2, 143.5, 141.8, 137.3, 128.1, 56.5, 52.3, 50.6, 50.4, 47.6, 47.4, 45.0, 42.7, 28.5, and 28.2. Satisfactory elemental analysis.
10. Yates, P.; Switlak, K. *Can. J. Chem.* **1990**, *68*, 1894-1900.