

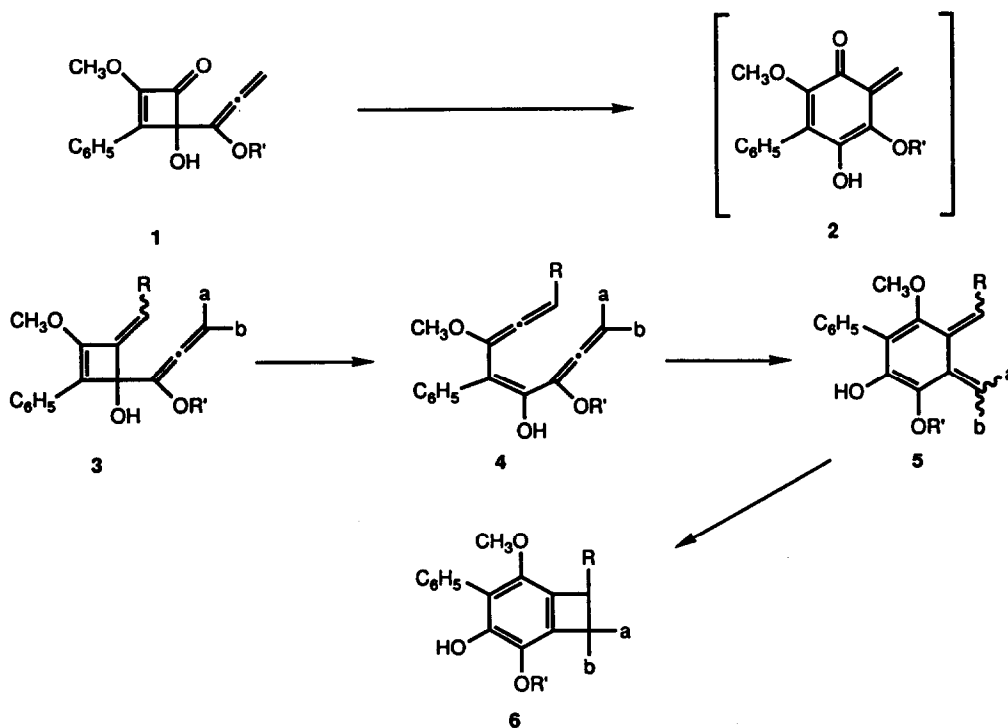
Synthesis of *o*-Quinodimethanes and Benzocyclobutenes from Dimethyl Squarate

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Abstract: Selected 3-alkylidene (and benzylidene)-4-allylcyclobutenes were shown to undergo an unusual thermal ring expansion to *o*-quinodimethanes and thus to benzocyclobutenes upon electrocyclic ring closure. The mechanism of this rearrangement is envisaged to involve ring opening of the starting cyclobutenes to the corresponding octa-1,2,4,6,7-pentaenes which lead to the quinodimethanes upon ring closure.

Reported here is a potentially general route to highly substituted *o*-quinodimethanes and thus to the corresponding benzocyclobutenes starting with readily available dimethyl squarate.¹ The transformation is

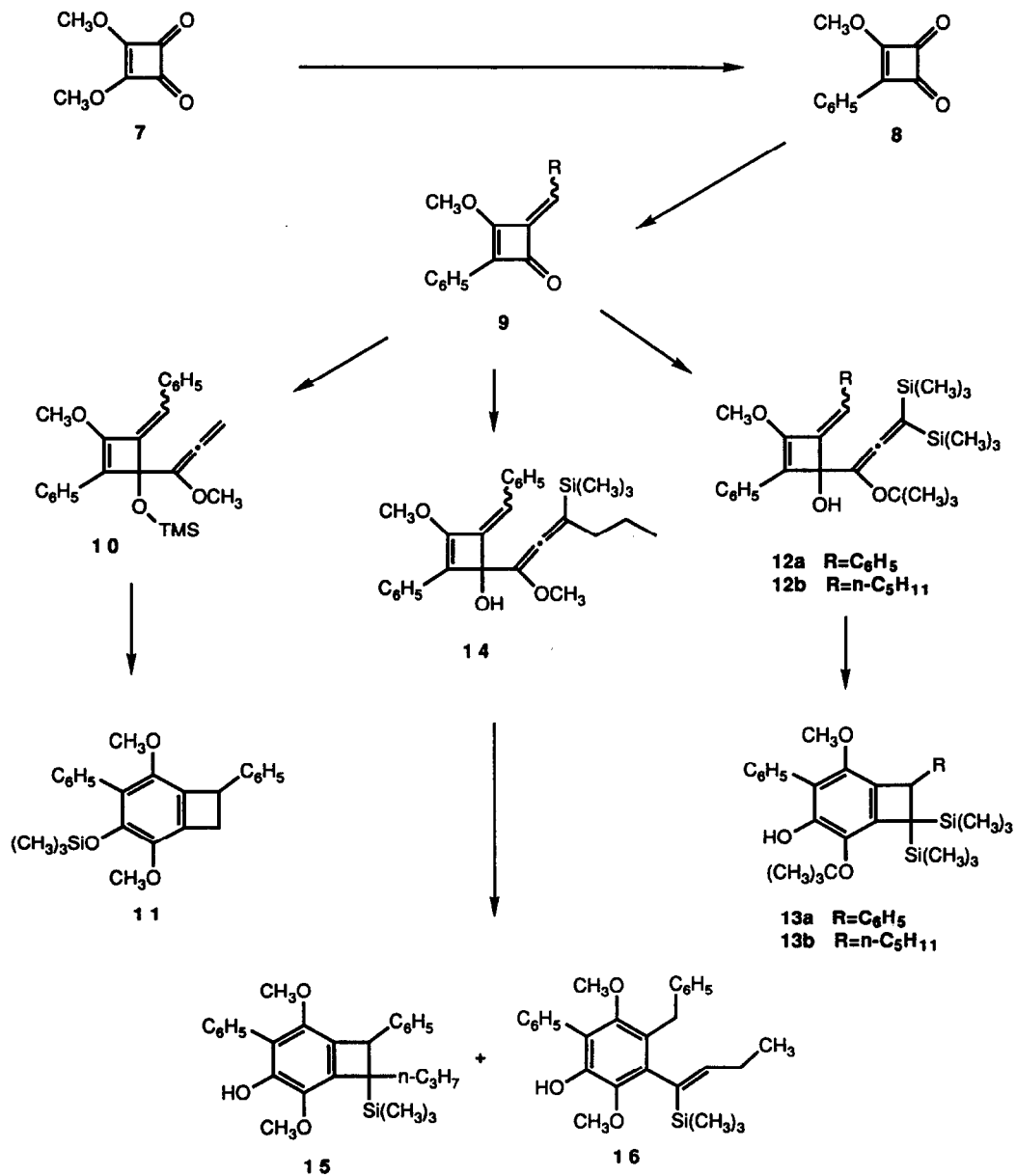
Scheme-1



based upon previously reported observations that 4-alkenyl-(or aryl- or alkynyl)cyclobutenones undergo facile ring expansions to quinones, hydroquinones and related compounds.² In this regard, a particularly

interesting analogy for the rearrangements outlined here is the observation that 4-allylcyclobutenones rings

Scheme-2



expand to the corresponding o-quinone methides, e.g., 1→2 (Scheme-1).^{2,3} Thus, as outlined here, 3-alkylidene(or benzylidene)-4-allenylcyclobutenes 3 were observed to undergo electrocyclic ring opening to the conjugated acyclic allenes 4 which then lead to the o-quinodimethanes 5 upon ring closure and ultimately to the benzocyclobutenes 6.

The starting allenyl-substituted alkylidenecyclobutenes 10, 12a, b, 14 stem from dimethyl squarate 7 which was readily converted to 2-methoxy-3-phenylcyclobutenedione 8 by standard methods (Scheme-2).⁴ Wittig olifination of 8 with benzylidene triphenylphosphorane in anhydrous ethyl ether at ambient temperature gave 9a (60-85% isolated yield) as a 1.7:1 mixture of (E)- and (Z)-isomers. The stereochemistry of these isomers was readily assigned from their ¹H NMR spectra which showed the expected relatively greater deshielding of the vinyl proton absorption of the E-isomer (δ, 6.48) vs. the Z-isomer (δ, 6.38).⁵ Both isomers were observed to be stable, having an indefinite shelf life when stored at -20°C.

The (E)- and (Z)-alkylidenecyclobutenones 9b were prepared by the Peterson olefination using the lithium salt of trimethylhexylsilane. Addition of this reagent to 8 proceeded smoothly to give the diastereomeric alcohols in 59% isolated yield. Treatment of these with BF₃-etherate in CH₂Cl₂ at 0 °C then gave 9b as a mixture of (E)- and (Z)-isomers in 62% isolated yield. Unlike the benzylidene analogs (i.e., 9a), the alkylidenecyclobutenones 9b are very unstable and must be used immediately.⁶

The cyclobutenones 9a and 9b were converted directly to the corresponding isomeric mixtures of the cyclobutenes 10, 12a and 14 in 47-58% yield upon treatment with the respective lithioallene reagent.⁷

The two possible diastereomers of 10 were formed in a ratio of approximately 3:2 and independently subjected to thermolysis in refluxing p-xylene for 5-7.5 h. As expected, based upon the mechanism outlined in Scheme-1, they resulted in the benzocyclobutene 11, mp, 58-59.5 °C (49-82%), the structure of which was unambiguously established by a single crystal X-ray analysis. In a similar manner 12a and 12b gave the respective benzocyclobutenes 13a (49-64%) and 13b (35%), the structures of which are based upon characteristic spectral data.⁸

A variant of the rearrangement was observed for the thermolysis of the isomeric mixture of 14. Here, the benzocyclobutene 15 was isolated in 30% yield along with the phenol 16 in 5% yield. The former appears to be the primary precursor to the latter as evidenced by the fact it decreases in yield as 16 increases with prolonged thermolysis time. This is envisaged to involve an equilibrium between the benzocyclobutene 15 ring opened o-quinodimethane which then leads to the phenol 16 by a 1,5-hydrogen shift.

In conclusion, the ring expansion of 3-alkylidene-4-allenylcyclobutenones reported here provides a potentially general route to highly substituted benzocyclobutenenes. In this regard, the synthesis starts with dimethyl squarate which can be conveniently converted to a variety substituted cyclobutenediones and these in turn to the synthetically useful quinodimethane intermediates.

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References

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6. The instability of the alkylidenecyclobutenones **9b** appears to be due to their facility to react with oxygen in an ene reaction at the alkylidene site. Similar instability was observed for 4-butyl-3-methoxy-3-benzylidenecyclobutenone. Here isomerization (proton shift) to 4-benzyl-3-methoxy-2-butylidenecyclobutenones and subsequent ene reaction is assumed.
7. Excellent reviews of allene chemistry are the following: Moreau, in S. Patai, Ed. *The Chemistry of Ketenes, Allenes and Related Compounds*, Wiley, New York 1980, 363; Schuster, H. E.; Coppola, G. M. *Allenenes In Organic Synthesis*, Wiley, New York, 1984. For a specific reference to 1-lithio-1-methoxyallene see: Hoff, S.; Brandsma, L.; Arens, J. F. *Recueil* 1968, 87, 916; Weiberth, F. J.; Hall, S. S. *J. Org. Chem.* 1985, 50, 5308.
8. Characteristic spectral data for the benzocyclobutenes are: **11** ^1H NMR (500 MHz, acetone- d_6) δ 7.33-7.30 (m, 6H), 7.24-7.22 (m, 4H), 4.86 (dd, $J=2.2$, 6 Hz, 1H), 3.96 (dd, $J=6$, 13.6 Hz, 1H), 3.90 (s, 3H), 3.42 (s, 3H), 3.17 (dd, $J=2.2$, 13.6 Hz, 1H), -0.10 (s, 9H); ^{13}C NMR 146.5, 145.2, 143.3, 141.3, 136.8, 131.9, 129.3, 127.9, 127.5, 127.3, 127.0, 126.9, 124.6, 123.7, 57.6, 57.2, 48.4, 41.0, 0.2; IR (CDCl₃) 2962, 1602, 1493; MS (EI) m/e calc'd for C₂₅H₂₉O₃Si: 405.1886, found 405.1838; **13a** ^1H NMR 7.48-7.42 (m, 4H), 7.36-7.22 (m, 6H), 5.21 (s, 1H), 4.70 (s, 1H), 3.44 (s, 3H), 1.50 (s, 9H), 0.29 (s, 9H), -0.16 (s, 9H); ^{13}C NMR 147.4, 146.7, 142.5, 141.0, 134.0, 133.5, 131.2, 129.8, 128.6, 127.9, 127.3, 126.9, 119.3, 115.9, 80.6, 57.8, 52.2, 44.8, 29.9, 1.7, 0.5; IR (CDCl₃) 3535, 1603, 1578; MS (CI) m/e calc'd for C₃₁H₄₃O₃Si₂: 519.2750, found 519.2751 **13b** ^1H NMR 7.46, (d, $J=7.5$ Hz, 3H), 7.21-7.09 (m, 3H), 5.06 (s, 1H), 3.16 (dd, $J=6.3$, 7.5 Hz, 1H), 3.29 (s, 3H), 2.03-1.97 (m, 3H), 1.62-1.60 (m, 1H), 1.40 (s, 9H), 1.40-1.32 (m, 6H), 0.92 (t, $J=7.0$ Hz, 3H), 0.32 (s, 9H), 0.27 (s, 9H); ^{13}C NMR 147.4, 146.9, 141.7, 134.4, 130.8, 128.5, 128.4, 127.2, 118.8, 80.7, 60.6, 47.8, 40.6, 32.4, 32.1, 29.9, 29.3, 22.8, 14.2, 1.8, 0.3; IR (CDCl₃) 3539, 1610; MS (CI) m/e calc'd for C₃₀H₄₉O₃Si₂: 513.3220, found 513.3184; **15** (2.3:1 diastereomeric mixture, A and B) ^1H NMR 7.47-7.44 (m, 4H, A+B), 7.37-7.24 (m, 6H, A+B), 5.46 (s, 1H, A), 5.38 (s, 1H, B), 4.74 (s, 1H, B), 4.60 (s, 1H, A), 3.85 (s, 3H, B), 3.82 (s, 3H, A), 3.52 (s, 3H, B), 3.51 (s, 3H, A), 2.23 (dt, $J=13.2$, 4.0 Hz, 1H, A), 1.92 (dt, $J=13.2$, 4.0 Hz, 1H, A), 1.75-1.62 (m, 6H, A+B), 1.06 (t, $J=7.3$ Hz, 3H, A), 0.47 (t, $J=7.3$ Hz, 3H, B), 0.17 (s, 9H, B), 0.24 (s, 9H, A); ^{13}C NMR 148.5, 147.9, 146.3, 141.6, 141.0, 140.9, 140.7, 136.7, 136.5, 134.0, 133.9, 130.9, 129.2, 129.1, 128.3, 128.2, 128.1, 127.9, 127.2, 127.1, 126.8, 126.5, 117.2, 117.0, 116.8, 61.3, 61.2, 57.8, 57.4, 56.5, 52.9, 50.6, 48.3, 41.0, 34.7, 20.6, 19.9, 15.0, 14.9, -1.0, -2.1; IR (CDCl₃) 3535, 1602, 1494; MS (CI) m/e calc'd for C₂₈H₃₅O₃Si: 447.2355, found 447.2315.

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