distribution is uniform in the suspension. We are presently examining a number of association processes using various colloidal particles.

Acknowledgment. We are grateful to Professor G. Hall for his useful comments and H.K. thanks Associate Professor T. Okubo for his discussion.

Presumably Planar Derivatives of Tribenzo[*a*,*c*,*e*]cyclooctene: Synthesis of 10,11-Methano-1*H*-benzo[5,6]cycloocta[1,2,3,4-*def*]-fluorene-1,14-dione and 1,1,14,14-Tetramethyl-10,11-methano-1*H*-benzo[5,6]-cycloocta[1,2,3,4-*def*]fluorene[1]

Xue Long Hou

Shanghai Institute of Organic Chemistry
Academia Sinica, 345 Lingling Lu
Shanghai, China 200032

Henry N. C. Wong*[2]

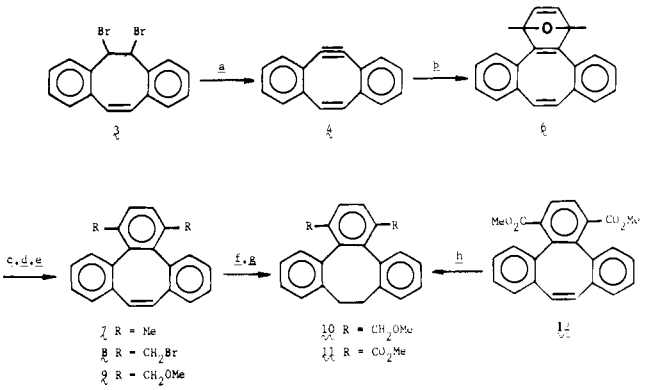
Department of Chemistry, The Chinese University of Hong Kong, Shatin, New Territories, Hong Kong

Received October 6, 1986

The intriguing properties exhibited by planar cyclooctatetraenes embedded in polycyclic frameworks have recently attracted considerable attention. Consequently, presumably coplanar derivatives of dibenzo[*a*,*c*]cyclooctene fused with carbocycles or heterocycles, i.e., cycloocta[*def*]biphenylene,[3] cycloocta[*def*]-fluorene,[4] and cycloocta[*def*]carbazole,[5] as well as tetraphenylene derivatives fused with cyclopentanoids[6] and furans[7] have been synthesized. Their properties have also been studied. On the other hand, no attention has been given to the synthesis of coplanar derivatives of tribenzo[*a*,*c*,*e*]cyclooctene. The reason of this might be attributed to the fact that substituted tribenzo[*a*,*c*,*e*]cyclooctenes are not readily available.

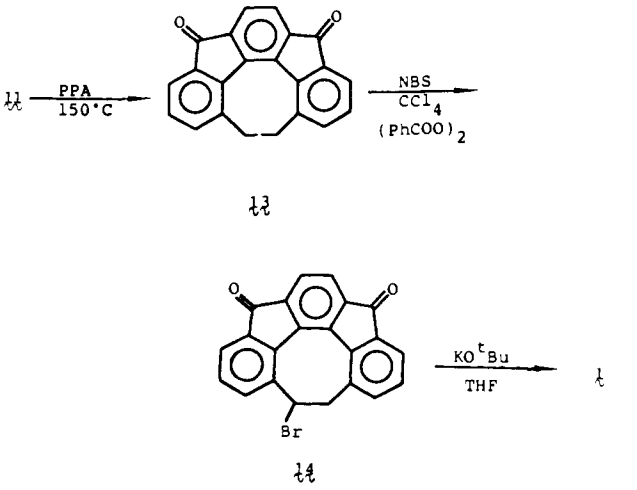
As part of a program aimed at the synthesis of novel coplanar derivatives of tribenzo[*a*,*c*,*e*]cyclooctene, we have recently prepared 1,4-disubstituted tribenzo[*a*,*c*,*e*]cyclooctenes.[8] Encouraged by these results, we set forth to apply appropriate Friedel-Crafts cyclization to these 1,4-disubstituted tribenzo[*a*,*c*,*e*]cyclooctenes in the hope of synthesizing hitherto unknown coplanar derivatives of tribenzo[*a*,*c*,*e*]cyclooctene. We report here the successful synthesis of 10,11-methano-1*H*-benzo[5,6]cycloocta[1,2,3,4-*def*]fluorene-1,14-dione (**1**) and 1,1,14,14-tetramethyl-10,11-methano-1*H*-benzo[5,6]cycloocta[1,2,3,4-def]fluorene (**2**).

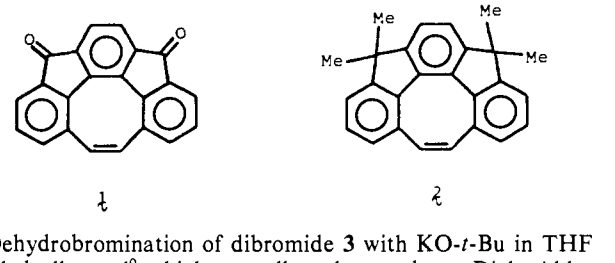
Scheme I[a]

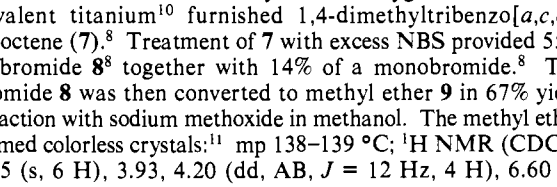


[a] (a) KO-*t*-Bu,THF; (b) 2,5-dimethylfuran; (c) $TiCl_4$, $LiAlH_4$, Et_3N, THF; (d) NBS, CCl_4; (e) NaOMe, MeOH; (f) H_2, 10% Pd-C, EtOAc; (g) $RuO_2 \cdot H_2O$, $NaIO_4$, CCl_4, CH_3CN, H_2O; (h) H_2, 10% Pd-C, EtOAc.

Scheme II





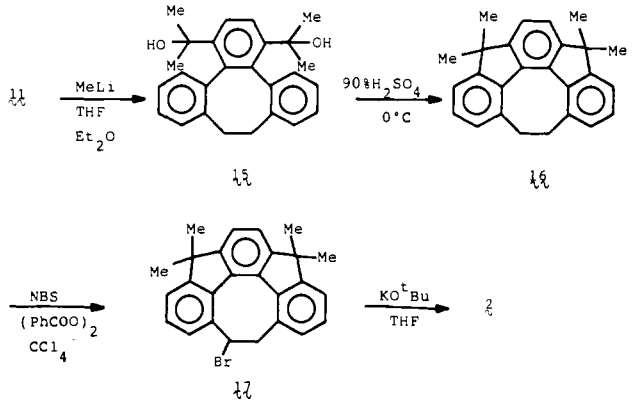


Dehydrobromination of dibromide **3** with KO-*t*-Bu in THF yielded alkyne **4**[9] which was allowed to undergo Diels-Alder cycloaddition with 2,5-dimethylfuran (**5**).[8] The adduct 1,4-endoxide **6** was isolated in 63% yield.[8] Deoxygenation of **6** with low-valent titanium[10] furnished 1,4-dimethyltribenzo[*a*,*c*,*e*]-cyclooctene (**7**).[8] Treatment of **7** with excess NBS provided 55% of dibromide **8**[8] together with 14% of a monobromide.[8] The dibromide **8** was then converted to methyl ether **9** in 67% yield by reaction with sodium methoxide in methanol. The methyl ether **9** formed colorless crystals:[11] mp 138-139 °C; ^1H NMR ($CDCl_3$) δ 3.05 (s, 6 H), 3.93, 4.20 (dd, AB, J = 12 Hz, 4 H), 6.60 (s,

(1) Arene Synthesis by Extrusion Reaction. 9. Part 8: Chan, C. W.; Wong, H. N. C. *J. Am. Chem. Soc.* **1985**, *107*, 4790.
(2) Also known as Nai Zheng Huang.
(3) Wilcox, C. F., Jr., Uetrecht, J. P.; Grohmann, K. G. *J. Am. Chem. Soc.* **1972**, *94*, 2532. Wilcox, C. F., Jr.; Uetrecht, J. P.; Grantham, G. D.; Grohmann, K. G. *J. Am. Chem. Soc.* **1975**, *97*, 1914. Wilcox, C. F., Jr.; Grantham, G. D. *Tetrahedron* **1975**, *31*, 2889. Obendorf, S. K.; Wilcox, C. F., Jr.; Grantham, G. D.; Hughes, R. E. *Tetrahedron* **1976**, *32*, 1327. Wilcox, C. F., Jr.; Farley, E. N. *J. Am. Chem. Soc.* **1983**, *105*, 7191. Wilcox, C. F., Jr.; Farley, E. N. *J. Am. Chem. Soc.* **1984**, *106*, 7195. Wilcox, C. F., Jr.; Farley, E. N. *J. Org. Chem.* **1985**, *50*, 351. Aihara, J.-i. *J. Am. Chem. Soc.* **1985**, *107*, 298.
(4) Willner, I.; Rabinovitz, M. *Tetrahedron Lett.* **1976**, 1223. Willner, I.; Rabinovitz, M. *J. Org. Chem.* **1980**, *45*, 1628. Willner, I.; Gutman, A. L.; Rabinovitz, M. *J. Am. Chem. Soc.* **1977**, *99*, 4167. Rabinovitz, M.; Willner, I.; Minsky, A. *Acc. Chem. Res.* **1983**, *16*, 298.
(5) Kulagowski, J. J.; Mitchell, G.; Moody, C. J.; Rees, C. W. *J. Chem. Soc., Chem. Commun.* **1985**, 652.
(6) Hellwinkel, D.; Reiff, G. *Angew. Chem., Int. Ed. Engl.* **1970**, *9*, 527. Hellwinkel, D.; Reiff, G.; Nykodym, V. *Justus Liebigs Ann. Chem.* **1977**, 1013.
(7) Erdtman, H.; Högberg, H.-E. *J. Chem. Soc., Chem. Commun.* **1968**, 773. Erdtman, H.; Högberg, H.-E. *Tetrahedron Lett.* **1970**, 3389. Högberg, H.-E. *Acta Chem. Scand.* **1972**, *26*, 309. Högberg, H.-E. *Acta Chem. Scand.* **1972**, *26*, 2752.
(8) Wong, H. N. C.; Hou, X. L. *Synthesis* **1985**, 1111.
(9) Wong, H. N. C.; Garratt, P. J.; Sondheimer, F. *J. Am. Chem. Soc.* **1974**, *96*, 5604. Wong, H. N. C.; Sondheimer, F. *Tetrahedron* **1981**, *37* (S1), 99.
(10) Xing, Y. D.; Huang, N. Z. *J. Org. Chem.* **1982**, *47*, 140.
(11) Satisfactory elemental analyses and/or high-resolution mass spectra have been obtained for all new compounds.

0002-7863/87/1509-1868$01.50/0

Scheme III



2 H), 7.05 (m, 8 H), 7.40 (s, 2 H). Conversion of **9** to **10** was accomplished by hydrogenation over 10% Pd-C using EtOAc as solvent. Compound **10** was not isolated and was oxidized directly with $RuO_2 \cdot H_2O$-$NaIO_4$[12] to ester **11** in 44% overall yield from **9**. Hydrogenation of **12**[8] over 10% Pd-C also yielded **11**, which formed colorless crystals[11] from cyclohexane: mp 155-156 °C; ^{1}H NMR ($CDCl_3$) δ 2.90 (s, 4 H), 3.50 (s, 6 H), 6.80-7.15 (m, 8 H), 7.90 (s, 2 H). In view that only intractable and polymeric products could be obtained through direct Friedel-Crafts cyclization of the diester **12** or its corresponding diacids, due perhaps to the reactivity of the olefinic bond toward acid conditions, the ester **11** was used instead as the pivotal intermediate in order to realize the synthesis of compound **1** (Scheme I). Thus, polyphosphoric acid smoothly converted **11** to the polycyclic ketone **13** in 58% yield. Ketone **13** formed light-yellowish needles[11] ($CHCl_3$-EtOH): mp 267-270 °C; ^{1}H NMR ($CDCl_3$) δ 2.58, 3.36 (dd, AB, J = 12 Hz, 4 H), 7.32-7.38 (dd, J = 7.14, 1.28 Hz, 2 H), 7.25-7.31 (t, J = 7.14, 7.14 Hz, 2 H), 7.68-7.72 (dd, J = 7.14, 1.28 Hz, 2 H), 7.75 (s, 2 H); UV (THF) λ_{max} 234 nm (ϵ 58 900), 290 (17 600), 318 (25 800). Introduction of a bromo group to **13** was effected by reaction with NBS and benzoyl peroxide in CCl_4 from which the monobromide **14** was isolated in 80% yield. The monobromide **14** was not purified further and was allowed to undergo dehydrobromination reaction with KO-*t*-Bu in THF to give the desired diketone **1** in 30% yield (Scheme II). Diketone **1** formed red needles[11] ($CHCl_3$): mp 305-310 °C (sealed capillary, rapid heating); ^{1}H NMR ($CDCl_3$) δ 5.83 (s, 2 H), 7.00-7.04 (dd, J = 7.48, 1.29 Hz, 2 H), 7.10-7.17 (t, J = 7.48, 7.48 Hz, 2 H), 7.44-7.48 (dd, J = 7.48, 1.29 Hz, 2 H), 7.49 (s, 2 H); UV (THF) λ_{max} 234 nm (ϵ 62 200), 299 (33 000), 313 (48 600); IR (KBr) 1700, 1595 cm^{-1}.

Treatment of **11** with excess methyllithium led to alcohol **15**. Compound **15** was not purified and was directly cyclized by treatment with concentrated H_2SO_4 to furnish **16** in 50% overall yield from **11**. Hydrocarbon **16** formed light-yellowish crystals[11] (EtOH): mp 187-189 °C; ^{1}H NMR ($CDCl_3$) δ 1.52 (s, 6 H), 1.53 (s, 6 H), 2.85, 3.36 (dd, AB, J = 11.4 Hz, 4 H), 7.11-7.15 (dd, J = 7.24, 1.16 Hz, 2 H), 7.20-7.27 (t, J = 7.24, 7.24 Hz, 2 H), 7.32-7.36 (dd, J = 7.24, 1.16 Hz, 2 H), 7.44 (s, 2 H); UV (THF) λ_{max} 232 nm (ϵ 17 100), 259 (18 400), 268 (23 900), 306 (29 300), 319 (25 000). The introduction of a bromo group to **16** was not trivial. Indeed, due to the rigidity of the molecule, the ethano bridge could not acquire coplanarity with the benzene rings. Hence the ethano bridge is particularly difficult to functionalize.[13] Variable-temperature NMR studies show that the energy barrier for the free rotation of the ethano bridge is approximately 20 kcal/mol at 410 K, at which the two signals of the ethano bridge coalesce.[14] After some experimentation, it was finally found that reaction with 2.2 equiv of NBS and benzoyl peroxide in CCl_4 at reflux temperature converted **16** to the monobromide **17**, albeit in only very low yield. Monobromide **17** was subjected to dehydrobromination reaction with KO-*t*-Bu in THF to provide the desired compound **2** in merely 8% yield from **16** (Scheme III). Compound **2** formed light-yellowish needles[11] (EtOH): mp 215-217 °C; ^{1}H NMR ($CDCl_3$) δ 1.41 (s, 12 H), 5.91 (s, 2 H), 6.80-6.86 (dd, J = 7.45, 1.46 Hz, 2 H), 7.00-7.10 (t, J = 7.45, 7.45 Hz, 2 H), 7.10-7.15 (dd, J = 7.45, 1.46 Hz, 2 H), 7.19 (s, 2 H); UV (THF) λ_{max} 242 nm (ϵ 15 600), 279 (61 700), 307 (7000), 351 (10 600), 370 (9600).

Compounds **1** and **2** are extremely stable both in crystalline and solution states. They presumably contain planar conjugated eight-membered rings. Thus, the electronic spectra of **1** and **2** indicate them to the highly conjugated systems by showing a bathochromic shift as well as a hyperchromic effect, which reflect a certain degree of π electron delocalization due to their coplanar geometry. The presence of a coplanar conjugated $4n$-membered ring in **1** and **2** should be reflected in a paratropic contribution to the ring currents. The high field positions of the olefinic proton resonances in the ^{1}H NMR spectra of **1** (δ 5.83) and **2** (δ 5.91) as compared to those of **12** (δ 6.90)[8] and **7** (δ 6.60)[8] convincingly support the presence of such a contribution. It is interesting to note that even the aromatic proton resonances of **1** and **2** experience high field shifts as compared to their nonplanar counterparts **13** and **16**. Furthermore, appearance of only one sharp singlet for the four methyl groups in the ^{1}H NMR spectrum of **2** also leads us to the conclusion that compound **2** should possess a coplanar structure so that all methyl groups are equivalent.

The X-ray diffraction study of **1** and **2** is in progress. The radical anion of **2** serves as a unique planar model for ESR study as compared to other presumably nonplanar radical anions of tribenzo[*a*,*c*,*e*]cyclooctene derivatives.[15] The possible conversion of the olefinic bonds of **1** and **2** to acetylenic bonds is also under investigation.

Acknowledgment. We thank Y. H. Law, K. W. Kwong, and C. W. Fung for measuring 250-MHz NMR spectra as well as accurate masses for some compounds.

(12) Schuda, P. F.; Cichowicz, M. B.; Heimann, M. R. *Tetrahedron Lett.* **1983**, *24*, 3829.

(13) Mitchell, R. H.; Weerawarna, S. A. *Tetrahedron Lett.* **1986**, *27*, 453 and references cited therein.

(14) Hou, X. L.; Wong, H. N. C., unpublished results.

(15) Gerson, F., private communications.

Design of Polymeric Inhibitors for the Control of Crystal Polymorphism. Induced Enantiomeric Resolution of Racemic Histidine by Crystallization at 25 °C

I. Weissbuch, D. Zbaida, L. Addadi,* L. Leiserowitz,* and M. Lahav*

Department of Structural Chemistry
The Weizmann Institute of Science
Rehovot 76100, Israel

Received September 30, 1986

Precipitation of metastable polymorphic crystalline phases is of topical importance in several fields of science. In previous studies we have described the design of low molecular[1] and polymeric additives[2] as enantioselective inhibitors of crystal nucleation and growth of conglomerates (i.e., racemic mixture of enantiomorphous crystals in monomorphic systems). The design took into account the packing arrangement in the crystal and the orientation and conformation of the molecules vis-à-vis the various

(1) Addadi, L.; Berkovitch-Yellin, Z.; Weissbuch, I.; van Mil, J.; Shimon, L. J. W.; Lahav, M.; Leiserowitz, L. *Angew. Chem., Int. Ed. Engl.* **1985**, *24*, 466. Addadi, L.; Berkovitch-Yellin, Z.; Weissbuch, I.; Lahav, M., L. Leiserowitz, L. *Top. Stereochem.* **1986**, *16*, 1.

(2) Zbaida, D.; Weissbuch, I.; Gati, E.; Addadi, L.; Leiserowitz, L.; Lahav, M. Third International Conference on Polymer Reactions in Organic Chemistry; Jerusalem, July 6-11, 1986.

0002-7863/87/1509-1869$01.50/0