

Tetracyclo[8.2.2.2^{2,5}.2^{6,9}]octadeca-1,5,9-triene

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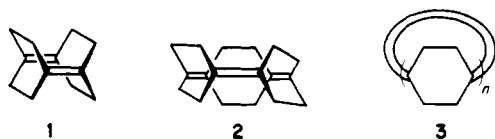
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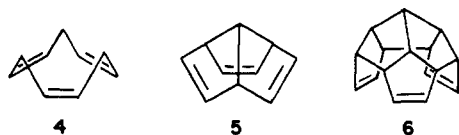
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Imagine a class of compounds made up of n six-membered rings joined together by double bonds to form a large overall ring as in 3. The parent member of the class, tricyclo[4.2.2.2^{2,5}]dode-



ca-1,5-diene (1), was reported recently by Wiberg,¹ but other members have not been prepared.

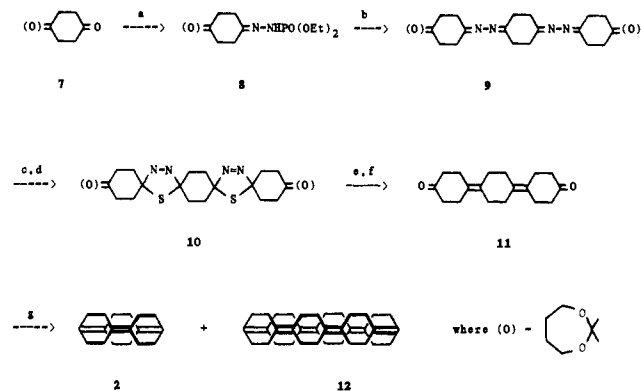
The second member of the class, tetracyclo[8.2.2.2^{2,5}.2^{6,9}]octadeca-1,5,9-triene, (2), might be expected to possess unusual properties because of the proximity of its three double bonds. The p orbitals of these double bonds have a geometry potentially suitable for $pp\sigma$ overlap, raising the question of whether 2 might exhibit neutral homoaromaticity.² Although other molecules that have similar double-bond arrangements, such as 1(Z),4(Z),7-(Z)-cyclononatriene (4), triquinacene (5), and C₁₆-hexaquinacene



(6), have been found³ not to show homoaromaticity, molecular models indicate that the three double bonds in 2 may be better aligned for overlap than the bonds in 4, 5, or 6. Thus, in 4 and 5, the double bonds are canted out of plane,^{4,5} whereas they lie in a common plane in 2. In 6, the double bond distance³ is 2.85 Å, whereas the distance is 2.60 Å in 2.

After many false starts, caused primarily by migration of the exocyclic double bonds in numerous possible precursors of 2 to more stable endocyclic positions, triene 2 was synthesized according to the route shown in Scheme I.

Horner-Emmons condensation of diethylphosphonohydrazone⁶ with the tetramethylene acetal of 1,4-cyclohexanedione gave phosphonohydrazone 8, which was coupled with 0.5 equiv of 1,4-cyclohexanedione to yield azine 9. Addition of H₂S and oxidation with Pb(OAc)₄ then gave 10, which was treated with aqueous acid to remove the acetal groups and heated, first in

Scheme I. Synthesis of Tetracyclo[8.2.2.2^{2,5}.2^{6,9}]octadeca-1,5,9-triene

(a) H₂NNHPO(OEt)₂, 91%; (b) 1,4-cyclohexanedione, 81%; (c) H₂S, CH₃CN, 77%; (d) Pb(OAc)₄, 63%; (e) H₃O⁺, THF, 97%; (f) toluene reflux, then P(OEt)₃, 76%; (g) TiCl₃/Zn/Cu, THF, 40 h addition, 16 h reflux; 24%.

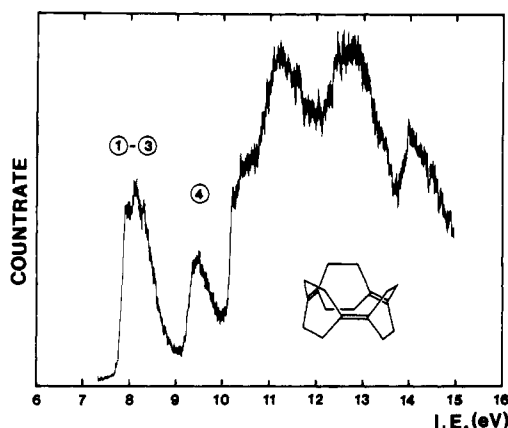


Figure 1. He I photoelectron spectrum of triene 2.

Table I. Vertical Ionization Energies ($I_{v,j}$) and Calculated (MINDO/3) Orbital Energies (ϵ_j) of Triene 2 (D_{3h})^a

band	$I_{v,j}$	assignment	$-\epsilon_j$
①	7.9	6a ₁ ' (π)	8.71 (6a ₁ ')
②	8.1	9e ^t (π)	9.19 (9e ^t)
③	8.3		
④	9.5	3a ₁ '' (σ)	9.34 (3a ₁ '')

^a Values are in eV.

toluene and then with triethyl phosphite, to effect extrusion of nitrogen and sulfur.⁷ Slow addition of diketone 11 over a 40-h period to a refluxing slurry of TiCl₃/Zn/Cu according to our previously published method⁸ then gave triene 2 (24%), along with a substantial amount of hexaene 12 as byproduct.

Triene 2, which could be readily purified by vacuum sublimation, showed the following properties: mp 259–259.5 °C; ¹H NMR (CDCl₃) AA'BB' symmetrical pattern at δ 2.46 (m, 12 H), 2.01 (m, 12 H); ¹³C NMR (CDCl₃) δ 129.86, 28.43. Single-crystal X-ray analysis⁹ confirmed the structural assignment. As expected, triene 2 shows D_{3h} symmetry. The three six-membered rings have perfect boat geometries, but there is a slight outward pucker of the double bonds to increase the distance between p-orbitals. The intramolecular C1–C₄ distance between neighboring double bonds is 2.60 Å, which is some 0.5 Å shorter than the normal 3.1–Å

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aromatic-stacking distance and some 0.25 Å shorter than the corresponding intraorbital distance in C₁₆-hexaquinacene (6). Perpendiculars drawn from the midpoints of the three double bonds intersect on the threefold axis at a distance of 2.07 Å from each bond.

The He I photoelectron (PE) spectrum of triene 2 shown in Figure 1 exhibits a relatively broad band near 8 eV and a smaller one near 9.5 eV in the ratio 3:1. The PE bands were assigned both by empirical correlation with similar molecules and by comparing the sequence of bands with the results of semiempirical MINDO/3 calculations. The results, given in Table I, reveal a split between the $\epsilon(\pi)$ and $a_1'(\pi)$ bands of 0.3 eV, indicating a relatively small interaction between the π fragments. This result can be understood by considering the distance between the termini of the π fragments in 2 (2.60 Å) in comparison with the distances and band splits reported for 4 (2.46 Å;⁴ 0.6 eV¹⁰), 5 (2.53 Å;⁵ 0.4 eV¹¹), and 6 (2.85 Å;³ 0.47 eV³).

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Registry No. 2, 91266-48-7; 7, 80427-20-9; 8, 91266-49-8; 9, 91266-50-1; 10, 91266-51-2; 10 (diketone), 91266-52-3; 11, 91266-53-4; 12, 91266-54-5.

Supplementary Material Available: Tables of fractional coordinates, thermal parameters, bond distances, bond angles and torsion angles, and observed and calculated structure factors for the X-ray analysis (14 pages). Ordering information is given on any current masthead page.

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Determination of Enantiomeric Purities of Alcohols and Amines by a ³¹P NMR Technique

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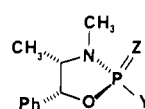
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Techniques that do not rely on optical rotation have been developed for the determination of enantiomer excesses (ee's) of various classes of compounds.¹⁻⁵ Several convenient and reasonably accurate methods utilize NMR to distinguish between diastereomeric adducts or complexes in solution. This has been accomplished through the use of chiral solvents,³ chiral shift reagents,⁴ and the preparation of diastereomeric derivatives.⁵ In order to accurately determine enantiomeric purity by the use of chiral derivatizing reagents in conjunction with NMR several criteria must be met: (1) The reagents must be available in

enantiomerically pure form. (2) The substrate and the reagent must react to produce the required adducts in quantitative yield, and the adducts should not be subjected to purification techniques which could lead to enrichment of one diastereomer. (3) In the process of adduct formation perturbations at chiral centers should not occur or should occur with complete stereospecificity. (4) The difference in chemical shifts between selected groups in the two diastereomeric adducts should be great enough to allow for accurate integration.

Since ³¹P NMR chemical shifts occur over a wide range (ca. 400 ppm) and peaks appear as singlets (in the usual decoupled spectra), it appeared to us that chiral phosphorus compounds might be well suited as chiral derivatizing reagents for NMR analysis of enantiomeric excesses.⁶ Two of the more readily obtainable classes of compounds enantiomerically pure at phosphorus are the 2-halo-1,3,2-oxazaphospholidine 2-sulfides and 2-oxides derived from the condensation of the appropriate phosphorus halides and enantiomerically pure amino alcohols.⁷ The 1,3,2-oxazaphospholidine 2-sulfides and 2-oxides derived from *l*-ephedrine are readily obtained in enantiomerically pure form and have received considerable attention as substrates for physical organic studies.⁸ Substitution of halide in these systems is known to proceed with complete retention of configuration at phosphorus.⁹

Compounds 1 and 2 were prepared by reaction of *l*-ephedrine



1 Z=S, Y=Cl 2 Z=O, Y=Cl

3 Z=S, Y=NHR* 4 Z=O, Y=NHR*

5 Z=S, Y=OR* 6 Z=O, Y=OR*

with thiophosphoryl trichloride and phosphoryl trichloride according to the procedure of Cooper, Harrison, Hall, and Inch.^{9b} The major isomer (shown) prevailed over the minor one (epimeric at phosphorus) by a ratio of 8:1 in the case of Z = S and 11:1 in the case of Z = O. In both cases, recrystallization led to optically pure material in approximately 60% yield.

Compounds 1 and 2 were treated with a series of chiral amines and alcohols to provide, in essentially quantitative yields, the amide (3 and 4) and ester (5 and 6) derivatives, respectively, as diastereomeric mixtures. Although both series of derivatives were suitable for quantitation of ee's of the substrates, the thio derivatives, in general, had superior ³¹P chemical shift differences and, in addition, were more responsive to supplemental quantitation by HPLC. For these reasons this preliminary account will focus on reagent 1.

For the preparation of amides from chiral primary amines, the following procedure was employed: Halide 1 (1 mmol) was dissolved in 5 mL of tetrahydrofuran and triethylamine (1.5 mmol) was added. The amine of interest (1.00 mmol) was added, and the mixture was stirred at room temperature for 24 h and then at 65 °C for 24 h. The reaction mixture was poured into diethyl ether and water. The organic layer was separated, dried over sodium sulfate, and concentrated. The diastereomeric amides were analyzed without further purification. For the preparation of the esters from chiral primary and secondary alcohols the following procedure was used: The chiral alcohol (1 mmol) was dissolved in diethyl ether (10 mL), the solution was cooled to 0 °C and treated with 1 equiv of butyllithium in hexane. Reagent 1 (1 mmol) was added, and the reaction mixture was refluxed for 15-20 h. The workup was accomplished in the same manner as described above for the amides.

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