(50 mg) was introduced with stirring. Small pieces of sodium were added to maintain a blue color during the reaction. The reaction mixture was quenched with ammonium sulfate, the ammonia was evaporated, and the residue was extracted with a mixture of chloroform and methanol. Separation of the products could be achieved by column chromatography or preparative TLC with mixtures of chloroform and methanol as the eluant. All reaction products which were formed and isolated were known compounds except 2-methoxy-9-methylpurine (3, X = OCH_3), mp 140.5–142.5 °C. Its structure was proven by ^1H NMR (Me_2SO-d_6) [δ 3.72 (s, NCH_3), 3.93 (s, OCH_3), 8.26 (s), 8.79 (s)], by comparison of the UV spectrum with that of 2-ethoxy-9-methylpurine[28] (pH 1, λ_{max} = 282 nm; pH 7, λ_{max} = 280 nm), and by mass spectroscopy (exact mass calcd for $C_7H_8N_4O$ m/e 164.0698, found m/e 164.0703).

Acknowledgment. We are indebted to Drs. C. A. Landheer and Mr. W. P. Combé for the mass spectroscopic data, to Mr. A. van Veldhuizen for measuring some NMR spectra, and to Mr. H. Jongejan for carrying out the microanalyses.

Registry No. 6-NH_2-9-CH_3Pur, 700-00-5; 6-NH_2-9-(2-THP)Pur, 7306-67-4; 2′,-3′-*O*-isopropylideneadenosine, 362-75-4; 6-$NHCH_3$-9-CH_3Pur, 2009-52-1; 6-$N(CH_3)_2$-9-CH_3Pur, 3013-82-9; 2-Cl-6-NH_2-9-CH_3Pur, 7013-21-0; 2-OCH_3-6-NH_2-9-CH_3Pur, 61494-91-5; 2,6-di-NH_2-9-CH_3Pur, 30720-65-1; 6-SCH_3Pur, 50-66-8; 8-SCH_3Pur, 33426-53-8; 8-SCH_3-9-CH_3Pur, 24851-51-2; 9-CH_3Pur, 20427-22-9; 9-(2-THP)Pur, 16347-32-3; 2′,3′-*O*-isopropylidenenebularine, 67604-85-7; 2-OCH_3-9-CH_3Pur, 79069-17-3; 2-NH_2-9-CH_3Pur, 5752-08-9; 6-SHPur, 50-44-2; 8-SHPur, 583-40-4; 8-SH-9-CH_3-Pur, 74537-62-5; 7-methylpurine, 18346-04-8; 2,6-dichloro-9-methylpurine, 2382-10-7; 2,6-diaminopurine, 1904-98-9; 6-amino-2-methoxypurine, 28128-30-5.

(28) Barlin, G. B. *J. Chem. Soc. B* **1967**, 954.

X-ray Analysis, Molecular Structure, and Nuclear Magnetic Resonance Spectra of the Second Dimer from Thermal Rearrangement of 1,1-Dichloro-2,5-diphenylcyclopropabenzene: (*Z*)-2,2′,3,3′-Tetrachloro-4,4′,7,7′-tetraphenyl-1,1′-bicycloheptatrienylidene

Ward T. Robinson* and Evert J. Ditzel

Department of Chemistry, University of Canterbury, Christchurch 1, New Zealand

Helmut M. Hügel and David P. Kelly*

Department of Organic Chemistry, University of Melbourne, Parkville, Victoria 3052, Australia

Brian Halton*

Department of Chemistry, Victoria University of Wellington, Private Bag, Wellington, New Zealand

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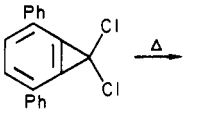
Introduction

We have recently reported the crystallographic analysis of a pale yellow dimer A, $C_{38}H_{24}Cl_4$, produced from thermal decomposition of 1,1-dichloro-2,5-diphenylcyclopropabenzene (1) in either acetone or benzene.[1,2] This dimer was shown to have the novel cycloheptatrienylidene (heptafulvalene) structure **2** in which the two seven-membered rings are bent up facing each other in a "U" shape. The puckering of these rings and the parallel arrangement of the two halves of the molecule result in spectroscopic properties quite unlike those expected from a planar, conjugated cycloheptatrienylidene structure.[3] The most likely pathway for the conversion **1** → **2** has been discussed.[2]



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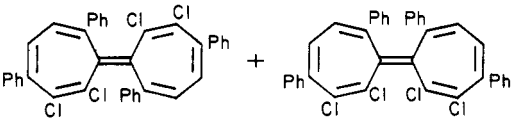

pale yellow dimer A **2** bright yellow dimer B **3**

Table I. Crystal Data

formula	$C_{38}H_{24}Cl_4$	$a = b$ 17.530 (2) Å
mol wt	622.427	c 36.611 (9) Å
space group	$I4_1/acd$	
$\rho_x(16C_{38}H_{24}Cl_4/\text{cell})$	1.36 g cm^{-3}	

The second, "bright yellow dimer B", is produced concurrently with and was separated manually from **2**.[1,2] The spectroscopic properties of the two dimers were almost identical except for subtle differences in their ^1H spectra, and consequently it was not possible to distinguish between a conformational and a configurational isomer of **2** as the structure for dimer B.[2] We now report the X-ray analysis and determination of the molecular structure of the bright yellow dimer B, which is in fact the *Z* isomer **3** but with the two seven-membered rings in an anti orientation to one another. Rationalization of the spectroscopic data obtained at 23.5 kG is now possible.

X-ray Analysis

Experimental Methods. Both dimers were recrystallized from acetone and a specimen (0.48 × 0.95 × 1.58 mm) of the bright yellow dimer B was chosen for study. From the diffraction symmetry and systematic absences, the space group was deduced as $I4_1/acd$. Unit cell parameter (Table I) and intensity data were obtained by using Zr filtered Mo Kα radiation (λ = 0.7107 Å) on a Hilger and Watts four-circle diffractometer. Data reduction yielded 2125 unique reflections, which were not corrected for absorption or polarization.

Application of conventional heavy atom methods, difference Fourier syntheses and full-matrix least-squares calculations were used to complete and refine the model. Final least-squares refinement cycles were performed with 98 variables and the 1193 data with $|F_o^2| > 3\sigma(F_o)^2$. Standard atomic scattering factors[4] were used and shifts in the atomic parameters on the last cycle were $<0.06\sigma$. At convergence a conventional R factor of 0.080 was obtained. A final difference Fourier map showed peaks due to hydrogen atoms, the highest of these being one-third the height of the least carbon atom peak. Tabulations of the final positional and thermal parameters and a listing of the observed and calculated structure factors are available as supplementary material.

(1) Hügel, H. M.; Kelly, D. P.; Browne, A. R.; Halton, B.; Milsom, P. J.; Woolhouse, A. D. *J. Chem. Soc., Perkin Trans. 1* **1977**, 2340–2342.
(2) Fahey, J. A.; Hügel, H. M.; Kelly, D. P.; Halton, B.; Williams, G. J. B. *J. Org. Chem.* **1980**, *45*, 2862–2865.
(3) Meyers, J. A.; Joines, R. C.; Jones, W. M. *J. Am. Chem. Soc.* **1970**, *92*, 4740–4742.
(4) Cromer, D. T. *Acta Crystallogr.* **1965**, *18*, 17–23. Cromer, D. T.; Mann, J. B. *Acta Crystallogr., Sect. A* **1968**, *24*, 321–324.
(5) Johnson, C. K. Report ORNL 3794; Oak Ridge National Laboratory: Oak Ridge, TN.

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Table II. Endocyclic Torsion Angles (in Degrees)

atoms	Z isomer 3[a]	E isomer 2[b]
C(7)–C(1)–C(2)–C(3)	+62.2	+66.6
C(1)–C(2)=C(3)=C(4)	+0.0	+4.7
C(2)=C(3)–C(4)=C(5)	-38.1	-42.4
C(3)–C(4)=C(5)–C(6)	+2.4	+0.9
C(4)=C(5)–C(6)=C(7)	+37.0	+36.9
C(5)–C(6)=C(7)–C(1)	+3.6	+3.9
C(6)=C(7)–C(1)=C(2)	-57.7	-70.2

[a] This work. [b] Taken from the data reported in ref 2.

Table III. NMR Spectral Data[a] of 3 Determined in $CDCl_3$

position	^1H[b]	^{13}C[c,d]
1		130.66 (s)
2		138.26 (s)
3		120.77 (s)
4		140.02 (s)
5	6.58 (1 H, J = 6.6 Hz)	129.93 (d)
6	6.23 (1 H, J = 6.6 Hz)	122.81 (d)
7		137.53 (s)
8		140.56 (s)
9,13		126.71 (d)
10,12	7.0–7.16 (5 H, m)	128.32 (d)
11		127.98 (d)
14		141.00 (s)
15,19		127.83 (d)
16,18	7.47 (5 H, m)	128.57 (d)
17		127.98 (d)

[a] In parts per million relative to Me_4Si. [b] Chemical shifts are given as the centroid of the multiplets. [c] ±0.05 ppm. [d] Assignments of all the quaternary carbons are uncertain.

Discussion. As with the *E* isomer **2**, the asymmetric unit of the *Z* isomer **3** comprises only half the molecule. Within this fragment of the two dimers, bond angles and distances are very similar. Even the nature and degree of puckering in the seven-membered ring, as expressed by the torsion angle data in Table II, are comparable. In both cases the molecule is completed by the action of a crystallographically imposed twofold rotation axis. This runs through the C(1)–C(1′) bond with the axis for the B dimer being perpendicular to that for the A. The resulting arrangements of the seven-membered rings in the two dimers avoid any unusual intramolecular contacts by the bulky substituent groups and prevent cross conjugation between the two rings.

NMR Spectra

Experimental Methods. The spectra were recorded on a JEOL FX-100 instrument operating at 99.54 MHz for ^1H and 25.00 MHz for ^{13}C. The ^1H spectra were obtained for an approximately 0.01 M solution in "100%" $CDCl_3$, using instrumental parameters similar to those described previously.[2] The ^{13}C spectrum was recorded for a dilute solution in $CDCl_3$ in a 10-mm tube with a spectral width of 5000 Hz, 8192 data points, and a 45° pulse angle. Ten thousand transients were accumulated with a recycle time of 5 s in order to observe the weak quaternary carbon resonances. Chemical shifts are ±0.05 ppm from Me_4Si, calculated from the central line of $CDCl_3$ at 76.95 ppm.

Discussion. The proton spectrum of the *Z* isomer **3** shows, like the *E* isomer **2**, an AM pattern with very similar chemical shifts and coupling constants (Table III). However, inspection of a model of the structure shows that H(6) (labeled H61 in Figure 1) now lies above the plane and in the shielding region of the phenyl group attached to C(7′), whereas H(5) of the *E* isomer **2** was shielded by the phenyl at C(4′) on the other half of the molecule. The assignments have therefore been reversed for **3**, H(6) [H(6′)] at δ 6.24 and H(5) [H(5′)] at 6.58 (J = 6.6 Hz) and are again less deshielded compared with less substituted heptafulvalenes.[3]

The phenyl proton resonances occur as two multiplets of five protons each, a more symmetrical, less widespread multiplet at δ 7.47 and a complex multiplet at δ 7.0–7.16. Double irradiation of the band at δ 7.47 has no effect on the other multiplet at δ 7.0–7.16, indicating that each

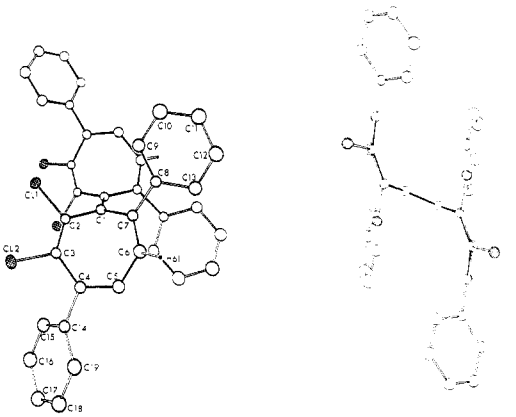

Figure 1. Views normal to, and coincident with, the crystallographic twofold axis. The diagrams were computer produced (see ref 5), but the hydrogen H61 is shown in a calculated position and is not drawn to scale.

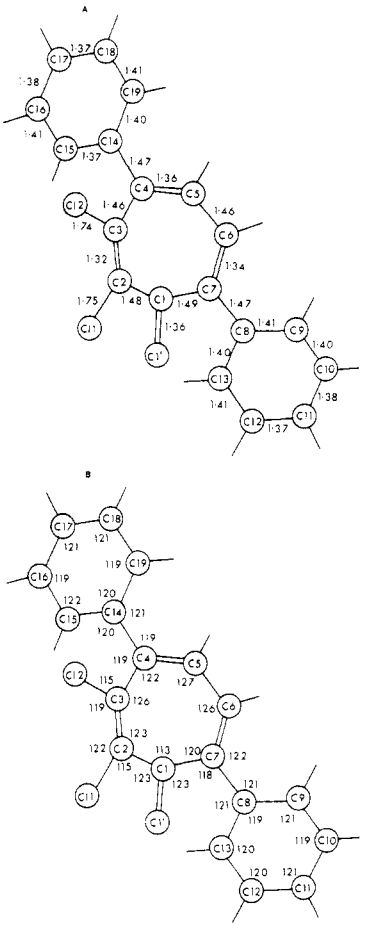

Figure 2. Bond distances (part A) and interbond angles (part B) for the crystallographically unique half of compound **3**. Atom C1′ is symmetry related to atom C1 by a twofold axis. Average standard deviations for the C–Cl bonds were 0.01 Å and for the C–C bond 0.014 Å. Standard deviations for the angles were of the order 1.0°.

multiplet comprises five protons from the one phenyl ring. The less perturbed multiplet at δ 7.47 is assigned to the unencumbered phenyl group at C(4) [C(4′)].

The assignment of the ^{13}C spectrum relies heavily on the assignments of that for the *E* isomer **2**, in which extensive single-frequency, proton-decoupling experiments were possible.[2] Of the protonated carbon resonances, those at δ 122.8 and 129.9 were assigned to C(6) and C(5), respectively, in the same order as in **2**. Of the five most intense lines, that at δ 126.7 is assigned to the ortho carbons C(9), C(13) of the most sterically restricted phenyl group attached to C(7) and that at δ 127.8 to the ortho carbons C(15), C(19) of the unrestricted phenyl group at C(4).

Of the seven, low-intensity quaternary carbons, the three at δ 120.8, 130.7, and 138.2 are very weak and are therefore assigned to C_3, C_1, and C_2, respectively, on the basis of those in **2** and their distance from protons (assuming dipole–dipole relaxation to be dominant for these carbon atoms).

Acknowledgment. Financial assistance from the New Zealand Universities Grants Committee and the Australian Research Grants Committee is gratefully acknowledged.

Registry No. 1, 33253-76-8; (*Z*)-3, 65961-19-5.

Supplementary Material Available: Tables of atomic coordinates and thermal vibration parameters for nonhydrogen atoms and observed and calculated structure factors (9 pages). Ordering information is given on any current masthead page.

Rearrangements of Allylic Acetates Catalyzed by Palladium(II): An Enantiospecific Synthesis of a Key Intermediate for the Preparation of 12-Hydroxyprostaglandins

Paul A. Grieco,* Paul A. Tuthill, and Hing L. Sham

Department of Chemistry, Indiana University, Bloomington, Indiana 47405

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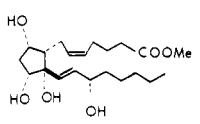
Our continued interest in prostaglandins possessing luteolytic properties has led us to develop an enantiospecific synthesis of 12-hydroxyprostaglandin $F_{2\alpha}$ methyl ester (**1**),



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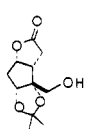
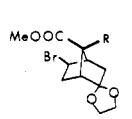


2

which we have previously shown in racemic form exhibits, when compared with natural $PGF_{2\alpha}$, comparable activity in terminating pregnancy in hamsters while displaying only minimal smooth muscle stimulating properties.[1] Since the original report describing the synthesis of (±)-**1** was published, which proceeded via the intermediacy of bicyclic lactone **2**,[1] Nelson and Scahill of the Upjohn Laboratories have detailed a synthesis of **2** in optically active form.[2] We describe here the efficient transformation of the known optically pure bromo ketal ester **3** (R = H)[3] into the enantiomerically pure bicyclo[2.2.1]heptane derivative **4**, which represents a viable intermediate along the pathway to **1**, employing the "conventional" bicyclo[2.2.1]heptane route to prostaglandins.



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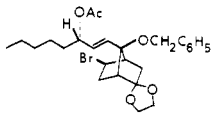
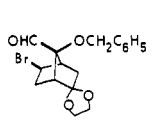


4

The conversion of **3** (R = H) into **4** was reduced to practice as a result of two completely stereocontrolled operations. The first centered around the observation that addition of 1-lithio-1-*cis*-heptene[4] to aldehyde **5**,[5] $[\alpha]^{25}_D$ −109.2° (*c* 2.04, $CHCl_3$), provided allylic alcohol **6** (R = H), $[\alpha]^{25}_D$ −58.5° (*c* 2.74, $CHCl_3$), in 86% isolated yield as the sole product. The exclusive formation of **6** (R = H) was not totally unexpected in view of prior experience with similar systems.[6a,b]



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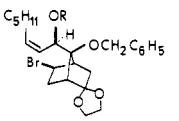
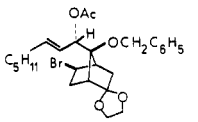


6

Taking advantage of the fact that catalytic amounts of palladium(II) salts will equilibrate allylic acetates with complete chirality transfer,[6a,c] we subjected the acetate **6** (R = Ac) derived from **6** (R = H) to rearrangement [$PdCl_2(CH_3CN)_2$ (0.04 equiv), THF, 24 h], giving rise (77%) to a single rearranged allylic acetate, **4**. Note that under the reaction conditions, the catalyst would be expected to set up an equilibrium between the desired allylic acetate **4** and the undesired *trans*-allylic acetate **7**. Despite this, one finds no trace of the allylic acetate **7**. The absence of **7** is reasonable in view of the conformational rigidity of the bicyclo[2.2.1]heptane ring system and the presence of the C(5) bromine atom; both factors act to drive the equilibrium between **4** and **7** in favor of **4** by minimizing steric congestion.



7

The configuration about the newly created chiral center was unambiguously established by employing a modification of a procedure recently introduced by Just and Oh.[7] The method takes advantage of the fact that (+)- and (−)-2-acetoxyheptanal react with *l*-ephedrine, giving rise to oxazolidines whose R_f values on TLC analysis are characteristic of the absolute configuration about the carbon bearing the acetoxy function. Ozonolysis (10 min) of **4** (10 mg) in dry methylene chloride (0.3 mL) at 0 °C using 0.75 mL of a 0.04 M solution of ozone in methylene

(1) Grieco, P. A.; Yokoyama, Y.; Withers, G. P.; Okuniewicz, F. J.; Wang, C.-L. J. *J. Org. Chem.* **1978**, *43*, 4178.
(2) Nelson, N. A.; Scahill, T. A. *J. Org. Chem.* **1979**, *44*, 2790.
(3) Grieco, P. A.; Owens, W.; Wang, C.-L. J.; Williams, E.; Schillinger, W. J.; Hirotsu, K.; Clardy, J. *J. Med. Chem.* **1980**, *23*, 1072.
(4) Prepared from the corresponding 1-iodo-1-*cis*-heptene (Dieck, H. A.; Heck, R. F. *J. Org. Chem.* **1975**, *40*, 1083.
(5) Aldehyde **5** was prepared via a four-step sequence: α-Hydroxylation of **3** (R = H) using the previously published procedure[1] gave rise to **3** (R = OH), $[\alpha]^{25}_D$ +1.7° (*c* 2.18, $CHCl_3$), which upon benzylation afforded **3** (R = $OCH_2C_6H_5$). Reduction of ester **3** (R = $OCH_2C_6H_5$) and subsequent Collins oxidation provided aldehyde **5** (see Experimental Section).
(6) (a) Grieco, P. A.; Takigawa, T.; Bongers, S. L.; Tanaka, H. *J. Am. Chem. Soc.* **1980**, *102*, 7587. (b) Majetich, G.; Grieco, P. A.; Bongers, S.; Erman, M. G.; Langs, D. A. *J. Org. Chem.* **1981**, *46*, 209. (c) Also see Henry, P. M. *J. Am. Chem. Soc.* **1972**, *94*, 5200. Overman, L. E.; Knoll, F. M. *Tetrahedron Lett.* **1979**, 321.
(7) Just, G.; Oh, H. *Tetrahedron Lett.* **1980**, 3667.

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