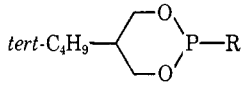
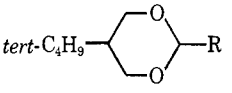
Conformations of Six-Membered Ring Phosphorus Heterocycles. Preferred Axial Orientation of Methyl on Phosphorus in a Six-Membered Ring *tert*-Butyl-Substituted Methylphosphonite

Sir:

The dramatic effect of heteroatom substituents upon the conformational properties of six-membered rings has been amply shown by studies of similarly substituted cyclohexanes, 1,3-dioxanes,[1] and trimethylene sulfites.[2] Recent evidence[3] suggests the orientational preferences of substituents at phosphorus in 1,3,2-dioxaphosphorinanes, *e.g.*, **1b** and **1c**, also may be quite different from those of the related 2-substituted 1,3-dioxanes.



1a, R = CH_3
b, R = C_6H_5
c, R = CH_3O



2a, R = CH_3
b, R = C_6H_5
c, R = CH_3O

We report here the very surprising finding that for 2-methyl-5-*tert*-butyl-1,3,2-dioxaphosphorinane (**1a**) the methyl substituent shows a decided, ~1 kcal/mol, preference for the axial position. This is especially striking when viewed against the 4 kcal/mol equatorial preference[1a,c,d] for the 2-methyl in the 1,3-dioxane system **2a**.

The methylphosphonite **1a** was synthesized from methylphosphonous dichloride, CH_3PCl_2, and 2-*tert*-butyl-1,3-propanediol as a mixture of cis and trans stereoisomers. A third species is also formed if the mixture of methylphosphonites is not cooled to Dry Ice temperatures immediately after vacuum distillation. This form was at first thought on the basis of ^1H and ^{13}C nmr data to be a second conformer of one of the stereoisomers. However, careful temperature and concentration dependence studies as well as ^{31}P spectroscopy point to a polymeric structure for this material,[4] which is apparently formed reversibly in equilibrium with the monomeric species. Examination of the phosphonite mixture by ^1H, ^{31}P, and ^{13}C spectroscopy allowed the relative amounts of cis and trans forms to be determined quantitatively.

A freshly prepared sample of **1a** was distilled (bp 30° (0.05 mm)) directly into degassed C_6D_6 at Dry Ice temperature (75% v:v solution). A pmr spectrum was taken at 100 MHz (40°). The ratios of the *tert*-butyl proton areas are recorded in Table I. As quickly as possible, a ^{31}P spectrum was then taken which showed only two absorptions (Table I). At the ambient probe temperatures, the ratio of ^{31}P peaks was seen to decrease slowly until a constant, apparently equilibrium value was established (6 hr). A ^{13}C spectrum was then obtained, and the intensity data for the methyl carbons of the *tert*-butyl group are recorded in Table I. Where applicable, consistent overall spectrum integrals were also obtained. No evidence for more than 3% of any other species could be found by any of the three methods. That equilibrium has been reached in the above system was further shown by the change in ratio (pmr) from 19/81 at 40° to 28/72 at 140° in *o*-dichlorobenzene solvent. The original ratio was reestablished on return to 40°.

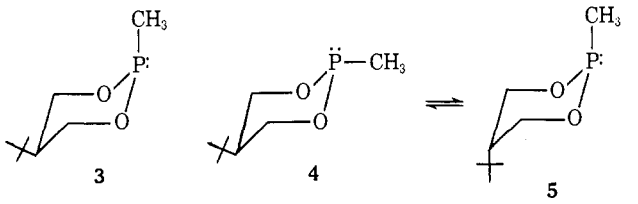
Table I. Determination of Cis–Trans Stereoisomer Ratio for **1a** by ^1H, ^{31}P, and ^{13}C Nmr[a]

	^1H		^{31}P		^{13}C	
Chemical shift	0.73[b]	0.58	−161.6[c]	−185.2	100.5[d]	101.2
% total area						
Initial	35	65				
2 hr			20	80		
6 hr	16	84	14	86	16	84

[a] 75% (v:v) solution in C_6D_6, 40°. [b] In parts per million downfield from internal TMS. Chemical shifts measured on C_6H_6 solution. [c] In parts per million relative to external 85% H_3PO_4. [d] In parts per million relative to benzene as internal standard. Measured for methyl carbons of the 5-*tert*-butyl group.

The cis form of **1a** was established as the predominant stereoisomer by stereospecific oxidation with N_2O_4 at 0° which in all probability involves retention of configuration at phosphorus.[5] Oxidation of the above equilibrated sample gave an 80/20 ratio of the two corresponding methylphosphonates in >90% yield based on starting methylphosphonite. The major phosphonate is identified as the one having the *tert*-butyl and methyl cis by comparison with an authentic sample whose structure has been determined by X-ray crystallography.[6] Oxidation by N_2O_4 is instantaneous at 0°, obviating the possibility that reaction control by the Hammett–Curtin principle had accidently given coincidental apparent stereospecificity. Further, oxidation of a sample heated to 140° in *o*-dichlorobenzene and quenched at 0° gave a ratio of methylphosphonates of 72/28, yield >90%.

We propose that the conformation of the cis isomer, the thermodynamically more stable form, is a chair, **3**, with equatorial *tert*-butyl and axial methyl. Although it is conceivable that a boat or twist form with the methyl pseudoaxial could be more stable than form **3**, it is highly unlikely that the former would be more stable than the trans isomer. The same may be



3 **4** **5**

(1) (a) F. W. Nader and E. L. Eliel, *J. Amer. Chem. Soc.*, **92**, 3050 (1970); (b) E. L. Eliel and C. A. Giza, *J. Org. Chem.*, **33**, 3754 (1968); (c) E. L. Eliel and M. C. Knoeber, *J. Amer. Chem. Soc.*, **90**, 3444 (1968); (d) K. Philaja and S. Luoma, *Acta Chem. Scand.*, **22**, 2401 (1968); F. G. Riddell and M. J. T. Robinson, *Tetrahedron*, **23**, 3417 (1967).

(2) H. F. VanWoerden, H. Cerfontain, C. H. Green, and R. J. Reijerberk, *Tetrahedron Lett.*, 6107 (1968); H. F. VanWoerden and E. Havinga, *Recl. Trav. Chim. Pays-Bas*, **86**, 341 (1967); G. Wood and M. H. Miskow, *Tetrahedron Lett.*, 1109 (1969); L. Cazaux and P. Maroni, *ibid.*, 3667 (1969).

(3) W. G. Bentrude and J. H. Hargis, *J. Amer. Chem. Soc.*, **92**, 7136 (1970); W. G. Bentrude and K. C. Yee, *Tetrahedron Lett.*, 3999 (1970).

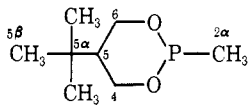
(4) We thank Dr. D. W. White for suggesting to us this interpretation. Similar polymerization effects have been noted by Professor D. B. Denney and coworkers in closely related 2-methyl-1,3,2-dioxaphosphorinanes.

(5) D. Z. Denney, G. Y. Chen, and D. B. Denney, *J. Amer. Chem. Soc.*, 91, 6838 (1969).

(6) M. Haque, C. N. Caughlan, J. H. Hargis, and W. G. Bentrude, *J. Chem. Soc. A*, 1787 (1970).

said for the chair form with *tert*-butyl axial. Additional evidences for conformation **3** are gained from the ^{13}C spectra (Table II) of the isomers of **1a**. For 14 ex-

Table II. ^{13}C Spectral Data[a] for **1a**



Carbon	Chemical shifts (coupling constant, J_{CP}) Cis isomer	Trans isomer
2α	114.2$_1$ (42.8)	108.9$_0$ (32.2)
4,6	67.3$_8$ (4.0)	63.9$_5$ (1.2)
5	81.8$_4$ (4.8)	81.7$_9$ (7.0)
5α	97.7$_2$	97.4$_2$
5β	101.2$_0$	100.5$_4$

[a] 75% (v:v) solution in C_6D_6, 40°. Shifts in parts per million upfield from benzene as internal standard. Coupling constants in hertz.

amples of 5-*tert*-butyl-1,3-dioxanes and *tert*-butyl substituted trivalent and pentavalent six-membered ring phosphorus compounds, for which pmr analysis has established the equatorial position of the *tert*-butyl, a chemical shift of 101 ± 0.22 ppm for the *tert*-butyl methyls (5β) has been noted.[7] Several *cis*-5-*tert*-butyl-1,3-dioxanes with axial *tert*-butyl showed downfield shifts for the *tert*-butyl methyls of about 2 ppm relative to those for the equatorial analogs. These results indicate that the *tert*-butyl is equatorial in *cis*-**1a** as depicted in **3**. A *predominantly* equatorial *tert*-butyl is indicated for *trans*-**1a** (form **4**) which may be in rapid equilibrium with a lesser proportion of a conformation **5** with *tert*-butyl axial, leading to a time-averaged 0.7 ppm downfield shift in *trans*-**1a** compared to *cis*-**1a**. Comparison of chemical shifts and carbon–phosphorus couplings (Table II) shows the methyl group on phosphorus in the two stereoisomers to be in significantly different environments. Axial methyls have previously been shown to be shifted upfield compared to equatorial ones in cyclohexanes.[8] A reasonable conclusion is that the methyl is axial in *cis*-**1a** and largely equatorial in *trans*-**1a**. Using a value[1c,d] of −1.5 kcal/mol for $\Delta G°_{25}$ for the axial → equatorial interconversion of a 5-*tert*-butyl in the 1,3-dioxane series and an assumed axial preference of the methyl of −1.2 kcal/mol, a 2:1 ratio of **4** to **5** is calculated in reasonable agreement to the ratio predicted by the time-averaged ^{13}C *tert*-butyl chemical shift of *trans*-**1a**.

The methyl equatorial preference in **2a** is so great that the trans isomer is the thermodynamically more stable form, and the cis chair conformation has the *tert*-butyl group axial and methyl equatorial. At least two important factors may contribute to the exceptional differences in conformational properties of systems **1a** and **2a**. First, syn-axial interactions may be greatly reduced in **1a**, since the phosphorus–oxygen bonds are considerably longer than carbon–oxygen bonds, and because of possible consequent flattening of the ring about phosphorus. Second, the conformational competition in **1a** is between methyl and an electron pair rather than between methyl and a hydrogen. An important result is that the interaction of the lone pair on phosphorus with adjacent lone pairs, nuclei, and bonding electrons may play a decisive role in determining the configuration at phosphorus.[9] The probable significance of vicinal lone-pair–lone-pair interactions in systems showing large single bond rotational barriers has been recently emphasized.[10]

Acknowledgment. This work was supported by a grant to W. G. B. from the National Cancer Institute, Public Health Service Research Grant No. CA-11045, and by a grant from the National Institutes of Health (GM-08521-10) to D. M. G.

(7) D. M. Grant, E. L. Eliel, W. G. Bentrude, J. H. Hargis, A. R. Jones, and R. D. Bertrand, unpublished results.
(8) D. K. Dalling and D. M. Grant, *J. Amer. Chem. Soc.*, **89**, 6612 (1967).
(9) See, *e.g.*, A. Rauk, S. Wolfe, and I. G. Csizmadia, *Can. J. Chem.*, **47**, 113 (1969); L. C. Allen, *Chem. Phys. Lett.*, **2**, 597 (1968).
(10) M. Raban, G. W. J. Kenney, Jr., and F. G. Jones, Jr., *J. Amer. Chem. Soc.*, **91**, 6677 (1969); A. H. Cowley, M. J. S. Dewar, W. R. Jackson, and W. B. Jennings, *ibid.*, **92**, 5206 (1970).

Wesley G. Bentrude,* K. C. Yee
Richard D. Bertrand, David M. Grant
Department of Chemistry, University of Utah
Salt Lake City, Utah 84121
Received August 4, 1970

Synthesis and Solvolysis of 1-Cyclopropylcyclopropyl Tosylate

Sir:

Solvolytic reactions of simple cyclopropyl derivatives usually afford only allyl products.[1] Theoretical[2] and experimental[3] evidence suggests that the mechanism of these reactions involves a concerted ionization and ring opening to an allyl cation. However, in bicyclic systems in which there is an extrasymmetric[4] steric prohibition of the favored disrotatory ring opening, unrearranged products have been obtained. In these cases, mechanisms involving partially opened ions[5–7] and nonconcerted[7] ionization and ring opening have been postulated. Landgrebe and Becker reported the first example of a simple cyclopropyl derivative, 1-cyclopropylcyclopropyl chloride, that afforded solvolysis products of unrearranged structure.[8]

In an effort to determine the extent to which extrasymmetric *conjugative* interactions can alter the mechanism of such reactions, we are investigating the solvolytic behavior of a variety of 1-substituted cyclopropyl tosylates. The results of our initial study of 1-cyclopropyl-, 1-vinyl-, and 1-isopropylcyclopropyl tosylates (**1**, **2**, **3**)[9] bear on this question. In addition,

(1) J. D. Roberts and V. C. Chambers, *J. Amer. Chem. Soc.*, **73**, 5034 (1951).
(2) (a) R. B. Woodward and R. Hoffmann, *ibid.*, **87**, 395 (1965); (b) W. Kutzelnigg, *Tetrahedron Lett.*, 4965 (1967); (c) D. T. Clark and D. R. Armstrong, *Theor. Chim. Acta*, **13**, 365 (1969).
(3) (a) C. H. DePuy, L. G. Schnack, J. W. Hausser, and W. Wiedemann, *J. Amer. Chem. Soc.*, **87**, 4006 (1965); (b) S. J. Cristol, R. M. Sequerra, and C. H. DePuy, *ibid.*, **87**, 4007 (1965); (c) P. von R. Schleyer, G. W. Van Dine, U. Scholkopf, and J. Paust, *ibid.*, **88**, 2868 (1966); (d) P. von R. Schleyer, T. M. Su, M. Saunders, and J. C. Rossenfeld, *ibid.*, **91**, 5174 (1969), and references therein.
(4) J. A. Berson and S. S. Olin, *ibid.*, **92**, 1087 (1970).
(5) U. Schollkopf, K. Fellenberger, M. Patsch, P. von R. Schleyer, T. Su, and G. W. Van Dine, *Tetrahedron Lett.*, 3639 (1967).
(6) D. M. Ledlie and E. A. Nelson, *ibid.*, 1175 (1969).
(7) D. T. Clark and G. Smale, *Chem. Commun.*, 868, 1050 (1969).
(8) J. A. Landgrebe and L. W. Becker, *J. Amer. Chem. Soc.*, **89**, 2505 (1967).
(9) (a) The alcohols used in this study were prepared by the method of Wasserman[10] and were converted to tosylates by the Tipson proce-