and **12** in the cycloalkyne case may reflect a smaller negative entropy of activation for transannular insertion relative to the same reaction of **10**. Alternatively, since the conformations of cycloalkyne and diazoketone are obviously different, we may be observing the reactions of two conformationally different ketocarbenes with an entropy factor favoring transannular insertion in the former case. (This would assume of course that subsequent reaction is faster than conformational changes.) Studies are currently in progress to further elucidate the mechanistic implications of these observations.

[20] National Defense Education Act Trainee, 1969–1970.

[21] National Science Foundation Trainee, 1969–1970.

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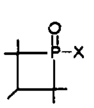
Inhibition of Rate of Displacement at Phosphorus Due to Angle Strain in a Four-Membered Ring. A Tool to Distinguish Mechanism[1]

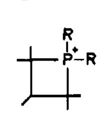
Sir:

The angle strain present at phosphorus in small rings is known to produce large accelerations in rates of displacement at phosphorus.[2] These results are important evidence for displacement through a pentacoordinate intermediate in which pseudorotation is possible. We now report two cases in which the same structural effect results in a very large inhibition in rate of displacement at phosphorus. The contrasting effects enable discrimination between associative displacement through a pentacoordinate intermediate and an SN2-like direct displacement mechanism.

There has recently been great interest in the four-membered ring (**1**) which is readily available.[3] This ring system has a twofold effect. (1) The four α-methyl groups provide considerable steric hindrance. (2) The C–P–C angle is approximately 83°. This provides a considerable driving force for formation of pentacoordinate intermediates in which strain can be released.[2] These effects appear in the esters **1** (X = OCH_3, OC_2H_5) which undergo alkaline hydrolysis with displacement at phosphorus[4] at a rate which is comparable to much less hindered phosphinates[4,5] and 10^5 faster than the similarly substituted (but probably more hindered) di-*t*-butylphosphinate.[6] Retention of configuration in displacement by hydroxide on phosphonium ions (**2**) has been observed.[7,8]



1



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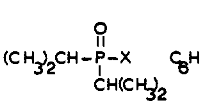
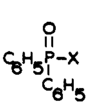


$$(CH_3)_2CH-\overset{\overset{\displaystyle O}{\|}}{\underset{\underset{\displaystyle CH(CH_3)_2}{|}}{P}}-X$$

3



$$C_6H_5-\overset{\overset{\displaystyle O}{\|}}{\underset{\underset{\displaystyle C_6H_5}{|}}{P}}-X$$

4

We have observed inhibition of rates of displacement at phosphorus in the acid-catalyzed hydrolysis of phosphinamides and in the solvolysis of acid chlorides. The acid-catalyzed hydrolysis of **1**, **3**, and **4** [X = $N(CH_3)_2$] were studied in 20% dioxane–H_2O.[9] The progress of the reaction was monitored by the decrease in intensity of the $N(CH_3)_2$ doublet in the nmr spectra. The relative second-order rate constants ($v = k[H^+]\cdot[\text{amide}]$) at 30° for those phosphinamides were $k(\mathbf{1}):k(\mathbf{3}):k(\mathbf{4}) = 1.5 \times 10^{-3}:1:3.8 \times 10^2$. Yet the ethyl ester of **1** undergoes alkaline hydrolysis at about the same rate as esters of **4**[4,5] and considerably faster than the ethyl ester of **3**.[6]

We have also studied the solvolysis of acid chlorides. Rates were measured in CF_3CO_2H and in 41% aqueous acetone. In these two solvents *t*-butyl chloride solvolyzes at nearly identical rates, so they are solvents of approximately equal ionizing power but vastly different in nucleophilicity.[10] The relative rates for the acid chlorides of **1** and **3** are: $k(41\%\ \text{acetone–water})/k(CH_3CO_2H) = 2000$ for **3** (X = Cl) but only 10 for **1** (X = Cl). The transition state for solvolysis of **1** therefore has considerable dissociative character. However, in both chlorides the transition state for hydrolysis appears to involve some nucleophilic participation by water. The four-membered ring chloride (**1**, X = Cl) hydrolyzes 6.5×10^4 times more slowly than **3** (X = Cl) in 41% aqueous acetone—a large rate effect in the same direction as observed in the acid-catalyzed hydrolysis of amides.

The amide hydrolysis has been shown to proceed by an A2 mechanism involving nucleophilic attack by water on the N-protonated amide.[9] Therefore, in both the chloride and amide reactions there is nucleophilic attack by water on phosphorus species with very labile bonds: P–Cl and $P–N^+R_3$, respectively. The rate inhibition due to the four-membered ring indicates increased strain in the transition state; this requires that the preferred geometry has entering and leaving groups colinear with the phosphorus atom. A reasonable conclusion is that in these reactions direct displacements, similar to SN2 reactions, are involved.

The problem of intermediates in displacement at phosphorus has often been in a confused state. The transition states for all but a few reactions at phosphorus[11] appear to have considerable associative character. Since phosphorus is known to form many stable pentacoordinate compounds,[12] transition states in associative reactions would be expected to be stabilized to at least a small extent by pentacoordinate character and intermediates generally may be involved.

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[1] (a) Research supported by Grants GP-8142 and GP-13453 from the National Science Foundation and by Grant AM-12743 from the National Institutes of Health. (b) Some of the results on which this communication is based are found in the Ph.D. Theses of Robert D. Cook (1967) and Paul S. Ossip (1968), University of California, Los Angeles, Calif.

[2] F. H. Westheimer, *Accounts Chem. Res.*, **1**, 70 (1968).

[3] (a) J. J. McBride, E. Jungermann, J. F. Killheffer, and R. J. Clutter, *J. Org. Chem.*, **27**, 1833 (1962). (b) The structure has been confirmed by determination of the crystal structure: D. D. Swank and C. N. Caughlan, *Chem. Commun.*, 1051 (1968); M. Haque and C. N. Caughlan, *ibid.*, 1228 (1968).

[4] P. Haake, R. D. Cook, W. Schwarz, and D. R. McCoy, *Tetrahedron Lett.*, 5251 (1968).

[5] P. Haake, C. E. Diebert, and R. S. Marmor, *ibid.*, 5247 (1968).

[6] W. Hawes and S. Trippett, *Chem. Commun.*, 577 (1968). The four-membered ring should cause the α-methyl groups to shield phosphorus considerably less in **1** than in di-*t*-butylphosphinates.

[7] W. Hawes and S. Trippett, *ibid.*, 295 (1968).

[8] K. E. DeBruin, G. Zon K. Naumann, and K. Mislow, *J. Amer. Chem. Soc.*, **91**, 7027 (1969).

[9] P. Haake and T. Koizumi, unpublished results. The solvent isotope effect, entropy of activation, substituent effects, and relative rates to carboxylic amides strongly support an A2 mechanism involving nucleophilic attack by water on the N-protonated amides.

[10] A. H. Fainberg and S. Winstein, *J. Amer. Chem. Soc.*, **78**, 2770 (1956).

[11] P. Haake, P. S. Ossip, and D. A. Tyssee, unpublished results.

[12] E. L. Muetterties and R. A. Schunn, *Quart. Rev. Chem. Soc.*, 20, 245 (1966).

Whether one can detect an intermediate is then a matter of stability, geometry, rates of pseudorotation, and proton transfer, etc.[2] In the chloride and amide hydrolyses, any intermediate must have entering and leaving groups colinear with phosphorus; the labile P–Cl and $P\text{–}N^+R_3$ bonds which are broken appear to preclude an intermediate with a lifetime sufficient to allow any other geometry. This mechanism is therefore a type of direct displacement although the activated complex could have some stabilization through pentacoordinate character.

It therefore appears that comparison of rates of reaction of **1** with rates of reaction of **3** and/or **4** is *a criterion for mechanism of reaction at phosphorus.* Reaction through an intermediate of sufficient lifetime for pseudorotation can result in rate enhancement when the phosphorus atom is part of a strained ring. Direct displacement results in decreased rates with strained rings such as **1**.

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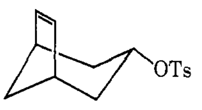
Nature of the Carbonium Ion. III. A π-Route Protoadamantyl Cation

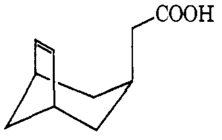
Sir:

We have recently been investigating alternate routes to substituted adamantanes which utilize the favoring energetics of the carbonium ion rearrangements discovered by Schleyer and Donaldson.[1] In contrast to these Lewis acid catalyzed "adamantanizations," our methods involve the less stringent conditions of solvolytic reactions to generate the necessary ions. We now wish to report an example of a solvolytically initiated π-route ring closure[2] which leads preferentially to adamantyl derivatives substituted exclusively in the 2 position. Due to the simplicity of their rearrangements, the carbonium ions generated in this fashion also have the as yet unexploited capability of producing single isomers of polysubstituted adamantyl derivatives, depending only on the substitution pattern of the bicyclic starting material.

Synthesis of 2-*endo*-(bicyclo[3.2.1]oct-6-en-3-yl)-ethanol (**3a**) was accomplished from the known[3] *exo*-bicyclo[3.2.1]oct-6-en-3-yl *p*-toluenesulfonate (**1**). This was first subjected to malonic ester chain extension giving ultimately the *endo* acid **2**, mp 58.5–60.0°. Lithium aluminum hydride reduction afforded **3a**, bp 71° (0.08 mm), which was obtained in 55% overall yield from **1**. The saturated analog **4a** was synthesized in identical fashion from bicyclo[3.2.1]octan-3-ol.[4] Conversion of **3a** to its *p*-bromobenzenesulfonate



1



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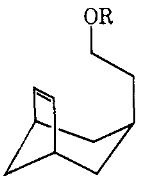

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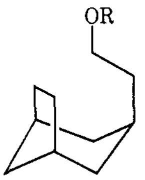
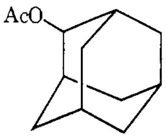


4

a, R = H
b, R = Bs
c, R = Ac

ester **3b** was difficult to accomplish except by cold treatment of the lithium alkoxide of **3a** with *p*-bromobenzenesulfonyl chloride. That this difficulty of synthesis was due to steric hindrance of the alcohol rather than the ease of dissociation of the ester was revealed by the solvolytic rate constants of **3b** in glacial acetic acid with sodium acetate buffer. These were 0.58 × 10^{-5} sec^{-1} at 60°, 3.8 × 10^{-5} sec^{-1} at 80°, and 27 × 10^{-5} sec^{-1} at 100°. From these values $\Delta H^{\ddagger} = 24$ kcal/mol and $\Delta S_{60}^{\ddagger} = -12$ eu. The rate constant for acetolysis of **4b**, mp 68–72° (which afforded only **4c** as a product), was 1.5 × 10^{-5} sec^{-1} at 100°. Three of the products from the acetolysis of **3b** could be identified as uncyclized acetate **3c**, 2-adamantyl acetate[5] (**5**), and *exo*-4-protoadamantyl acetate[6] (**7**) by comparison with authentic samples. A fourth product was assigned as *exo*-2-protoadamantyl[7] acetate (**6a**) on the basis of the following reaction sequence. The chloro ketone, obtained from **3a** by way of the unsaturated chloride and chloro alcohol,[8] gave 2-protoadamantanone[9] (**8**), mp 245.5–246.0°, upon sodium hydride catalyzed cyclization. Reduction of **8** with sodium in ethanol afforded a mixture of two alcohols, the minor component of which corresponded to **6b** from solvolysis. The major reduction product was identical with the sole product from lithium aluminum hydride reduction of **8**. This was assumed to be the epimeric



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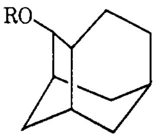

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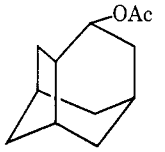

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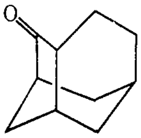

8

a, R = Ac
b, R = H

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[1] For a review, see R. C. Fort, Jr., and P. v. R. Schleyer, *Chem. Rev.*, **64**, 277 (1964).

[2] For summaries of the literature, see (a) J. A. Berson in "Molecular Rearrangements," Part 1, P. de Mayo Ed., Interscience, New York, N. Y., 1963, Chapter 3; (b) P. D. Bartlett, W. S. Trahanovsky, D. A. Bolon, and G. H. Schmid, *J. Amer. Chem. Soc.*, **87**, 1314 (1965); (c) W. S. Johnson, *Accounts Chem. Res.*, **1**, 1 (1968).

[3] N. A. LeBel and R. J. Maxwell, *J. Amer. Chem. Soc.*, **91**, 2307 (1969).

[4] W. Kraus, *Chem. Ber.*, **97**, 2719 (1964).

[5] P. v. R. Schleyer and R. D. Nicholas, *J. Amer. Chem. Soc.*, **83**, 182 (1961).

[6] We are grateful to Professor Schleyer and Dr. D. Lenoir for supplying us with a sample of the corresponding alcohol from which the authentic acetate was prepared.

[7] The tricyclo[4.3.1.$0^{3,8}$]decane carbon skeleton has been given this trivial name by J. E. Baldwin and W. D. Foglesong, *ibid.*, **90**, 4303 (1968).

[8] Alcohol **3a** was treated with triphenylphosphine dichloride and the product subjected to mercuric acetate–tetrahydrofuran–sodium borohydride.

[9] This is the first unequivocal synthesis of 2-protoadamantanone. A comparison of our material with that given this assignment earlier by Whitlock and Siefken[10] was effected by these workers. We are indebted to Professor Whitlock for the report that the samples were identical.

[10] H. W. Whitlock and M. W. Siefken, *ibid.*, **90**, 4929 (1968).