# Notes

## Substituent Control of the Regiospecificity of Trifluoroacetic Acid Addition to an Allene

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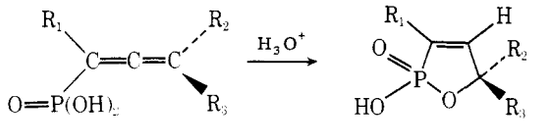
*Received April 4, 1977*

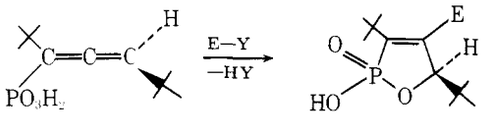
Electrophilic additions to allenes can occur with attachment of the electrophile to either the central or terminal carbons of the allene linkage. Such reagents as sulfenyl halides,[1a] molecular halogens,[1b] and mercury salts[1c] seem to add regiospecifically and stereospecifically to the central atom, while hydrogen halide addition[1d] and acid-catalyzed hydration[1e] generally occur with terminal orientation.[1f]

We recently found[2] that allenic phosphonic acids (**1**) with alkyl substituents for *both* $R_2$ and $R_3$ undergo facile Brønsted acid-catalyzed cyclization to give oxaphospholenes (**2**). This



**1a**, $R_1 = R_3 = t\text{-}C_4H_9$; $R_2 = H$
b, $R_1 = t\text{-}C_4H_9$; $R_2 = R_3 = CH_3$ — **2**

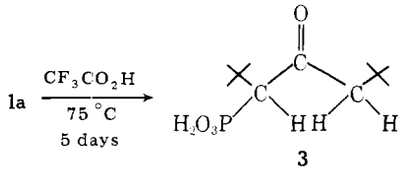
reaction can be visualized as "unusual" central protonation followed with attack by internal nucleophile. In contrast, compounds with $R_2$ and/or $R_3$ = H completely resisted cyclization. For example, **1a** ($R_1 = R_3 =$ *tert*-butyl, $R_2$ = H) was unchanged after 11 days at 90 °C in 2 M HCl (aqueous dioxane).[2] More powerful electrophiles such as bromine or mercuric acetate *did* effect the cyclization of **1a**, giving 4-substituted oxaphospholenes.[3] When these cyclizations were carried out with optically pure (*R*)-(−)-**1a**, the oxaphospholenes were formed with stereospecificity ranging from >41 (EY = $Br_2$) to 86% [EY = $Hg(OAc)_2$].[3]



**1a**

Continuing our search for a Brønsted acid capable of cyclizing **1a**, we examined the effectiveness of trifluoroacetic acid (TFA).[4] Not unexpectedly, **1b**[2] ($R_1$ = *tert*-butyl, $R_2 = R_3 = CH_3$) in TFA (127 mg/mL) underwent nearly quantitative cyclization to **2b**[2] during 16 h at 60 °C. But when **1a** was subjected to similar conditions, the reaction took an unwanted detour.

The reaction of **1a** with TFA at 75.0 °C, which could be conveniently monitored by $^1H$ NMR, resulted in conversion[5] to a new compound. This product is assigned structure **3** on the basis of its $^1H$ NMR spectrum [δ (TFA-$d_1$): 1.11 (s, 9 H), 1.30 (s, 9 H), 2.80 (s, 2 H), 3.60 (d, $J$ = 21 Hz, 1 H), 11.30 (s, 3 H[6])] and other analytical data (see Experimental Section).

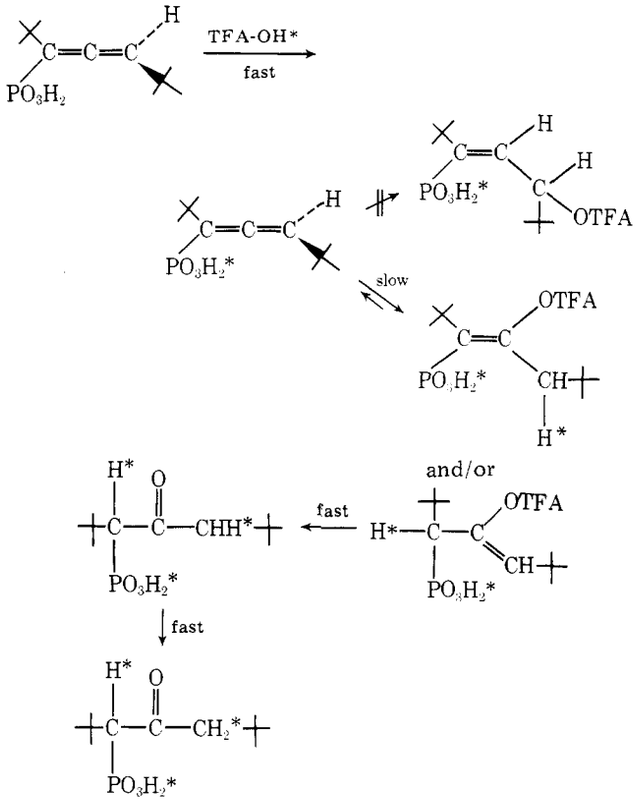


**3**

The formation of **3** followed first-order kinetics, with $k_{75.0°C} = (4.8 \pm 0.1) \times 10^{-4}$ min$^{-1}$ ($t_{1/2}$ = 24 h). Evidence that **3** did *not* arise *via* **2a**[7] came from the observation that the latter was totally unchanged after 4 days in TFA at 75 °C. Further, **3** itself was stable during further heating in TFA.

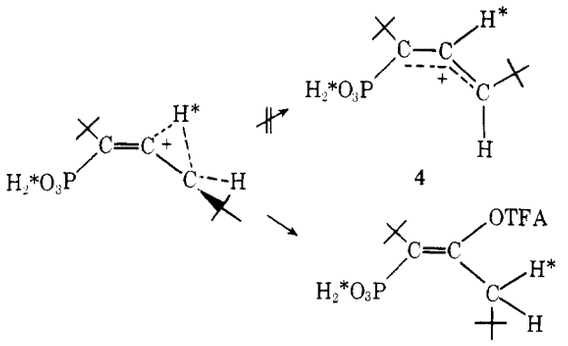
Treatment of **1a** with deuterio-TFA at 75.0 °C resulted in the formation of **3**-$d_5$, with no trace of the methylene or methine protons detectable at any time during the reaction. The rate of this reaction was notably slower than in TFA–OH, the solvent deuterium isotope ($k_H/k_D$) being 7.4 ± 0.7.[8] A control experiment with **3** in TFA-$d_1$ at 75.0 °C showed rapid exchange of the methylene protons ($t_{1/2}$ < 5.5 h),[8] and slow exchange of the methine proton ($t_{1/2} \sim$ 70 h).[8] The allenic proton doublet of **1a** (δ5.62, $J$ = 14 Hz) appeared to exchange about as rapidly as the methine proton in **3**.[9] Not unexpectedly, optically pure **1a**,[3] $[\alpha]^{25}_D$ −73.7° (*c* 0.0435 g/mL, TFA), gave **3** of much reduced rotation ($[\alpha]^{25}_D$ −1.2°, *c* 0.0386, TFA). Unfortunately, because of the developing color of the reaction mixture,[5] it was not possible to measure the rate of loss of optical activity, which should exceed the rate of **1a** → **3**.[10]

The most straightforward mechanism consistent with the above data is shown below. The rate-determining step of this



mechanism involves terminal electrophilic addition of TFA, exactly opposite to the course of protonation with **1b** (vide supra). We conclude that it will not be possible to cyclize allenic phosphonic acids with Brønsted acids unless the terminal carbon readily accommodates a positive charge (e.g., $R_2 = R_3$ = alkyl). If just one of the positions is substituted, the molecule will be highly resistant toward protonation, but in the presence of sufficiently strong Brønsted acids it will undergo terminal, rather than central, attack. It is somewhat surprising that twisting of the protonated allene linkage to give relatively stable allylic ion **4** does *not* occur, indicating that the activa-

tion barrier for the twist must exceed the barrier for trifluoroacetate addition to the central carbon atom.



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## Experimental Section

The instrumentation used in this work has been previously described.[2,3,7]

**Preparation of 3.** A 303-mg sample of phosphonic acid **1a**[7] in 5.8 mL of TFA was heated to 75 °C for 5 days, after which $^1$H NMR indicated no starting material and ~85% pure **3**.[5] The burgandy colored solution was rotary evaporated, dissolved in 5 mL of benzene, then rotary evaporated again. The dark semisolid residue was recrystallized four times from minimum benzene to give 137 mg (42%) of colorless **3**, mp 167–168 °C. Its $^1$H NMR spectrum is given in the text: IR (KBr) 1720 cm$^{-1}$; MS (20 eV) *m/e* (rel absorbance) 250 (13), 179 (12), 152 (97), 137 (100), 122 (47), 99 (52), 57 (48).

Anal. Calcd for $C_{11}H_{23}O_4P$: C, 52.78; H, 9.26. Found: C, 52.76; H, 9.20.

**Kinetics measurements** were done by $^1$H NMR integration of the intensity of the doublet in **1a** compared to the doublet in **3**. In the case of TFA-$d_1$, $^1$H NMR peak heights in the *tert*-butyl region were used.

**Registry No.**—**1a**, 42087-76-3; **3**, 63088-99-3; TFA, 76-05-1.

## References and Notes


(1) (a) T. L. Jacobs and R. C. Kammerer, *J. Am. Chem. Soc.*, **96**, 6213 (1974); (b) M. C. Findlay, W. L. Waters, and M. C. Caserio, *J. Org. Chem.*, **36**, 275 (1971); (c) R. D. Bach, *J. Am. Chem. Soc.*, **91**, 1771 (1969); (d) see, for example, T. L. Jacobs, and R. N. Johnson, *ibid.*, **82**, 6397 (1960); (e) A. V. Fedorova and A. A. Petrov, *J. Gen. Chem. USSR*, **32**, 1740 (1962); (f) allene itself undergoes terminal protonation in the gas phase: D. H. Aue, W. R. Davidson, and M. T. Bowers, *J. Am. Chem. Soc.*, **98**, 6700 (1976).

(2) R. S. Macomber and E. R. Kennedy, *J. Org. Chem.*, **41**, 3191 (1976), and references cited therein.

(3) R. S. Macomber, *J. Am. Chem. Soc.*, **99**, 3072 (1977).

(4) MCB reagent, used without further drying.

(5) Although <15% of other products were indicated by $^1$H NMR (weak singlets at $\delta$ 0.99 and 1.41), the reaction mixture became burgandy colored during the reaction due to a small component of acid-catalyzed polymerization.

(6) The excess OH integration is due to adventitious water in the TFA-$d_1$.

(7) R. C. Elder, L. R. Florian, E. R. Kennedy, and R. S. Macomber, *J. Org. Chem.*, **38**, 4177 (1973).

(8) Precision estimated to be ±10%.

(9) As the doublet at $\delta$ 5.62 decayed, due both to exchange and conversion to **3**, another weak multiplet appeared at $\delta$ 5.74. No such absorptions were observed in the TFA–OH reaction.[10]

(10) TFA containing 9% (w/w) water shows a slightly increased rate of coloring,[5] but the rate of hydration is depressed by 75%. When TFA containing 42% (w/w) trifluoroacetic anhydride is used, **1a** ($\delta$ 5.62, d, $J$ = 14 Hz) is rapidly converted at 25 °C to a closely related compound (presumably the mixed anhydride) with $\delta$ 5.73, d, $J$ = 15.5 Hz.[9] This solution gives no **3** (or its anhydide) after 3 days at 75 °C, nor does it show any coloring.[5]


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# Micellar Effects on the Monohalogenation of *n*-Pentyl Phenyl Ether


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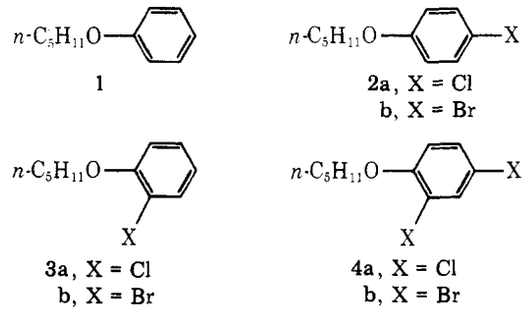
*Received April 26, 1977*

Micellar catalysis of organic reactions has been studied with numerous and diverse systems.[1] However, the synthetic application of micellar catalysis has received limited attention,[2] although stereochemical control has been the subject of several investigations.[3] If a substrate with several potential reaction sites is solubilized by a micelle in a specific manner, it is conceivable that some control of regioselectivity might accompany micellar catalysis of a given reaction.

We have examined the ability of micellar catalysis to influence the regioselectivity of two electrophilic aromatic substitution reactions of *n*-pentyl phenyl ether (**1**).[4] Ether **1**



1 2a, X = Cl; b, X = Br

3a, X = Cl; b, X = Br 4a, X = Cl; b, X = Br

was monochlorinated with chlorine and hypochlorous acid in aqueous micellar sodium lauryl sulfate (NaLS) and was monobrominated with bromine in aqueous micellar NaLS, sodium laurate (NaL), and cetyltrimethylammonium bromide (CTABr), and the ratios of para (**2**) to ortho (**3**) products were determined.[5] For each run, the concentration of **1**, halogenating agent, and micelle was $2.0 \times 10^{-4}$ M. After the reaction period, the ether product mixture was isolated by one of two methods. In the first, the micellar solution was eluted through a column of ion-exchange resin (Dowex 2-X8 for NaLS and Bio-Rex 70 for CTABr runs). The surfactant and organic material both were retained by the column, and the latter was recovered by elution with methanol and ether. In the second method, organic material was extracted into hexane as surfactant was precipitated by the slow addition of calcium chloride (for NaLS and NaL runs) or sodium perchlorate (for CTABr runs) to a vigorously stirred mixture of micellar solution and hexane. Recoveries by the two methods were comparable, but the latter was quicker and therefore preferred.

The isolated product mixtures were analyzed by GLC after the addition of a hydrocarbon internal standard. For each run where recovery based on starting material was <90%, a control demonstrated that para (**2**) and ortho (**3**) products do not fractionate on isolation.

Ether **1** also was monohalogenated with chlorine and bromine in water. For these runs the concentration of **1** was $6.7 \times 10^{-5}$ M (saturated solution) and that of halogenating agent $4.0 \times 10^{-5}$ M, and standard extraction procedures were used for isolation of products, which were analyzed by GLC. The results of all halogenation runs are given in Table I. For any run, no more than a trace, if any, of 2,4-disubstituted product **4** was detected.

Ultraviolet (UV) spectroscopy was used to assess the microenvironments of chlorine, bromine, and **1** in micellar media. A comparison of the UV spectra of chlorine and bromine in micellar NaLS with those in water and heptane led to the conclusion that in micellar NaLS chlorine and bromine do not reside in the micelle hydrocarbon core, but rather in an aqueous environment; the same is assumed for hypochlorous acid. It is further assumed that in micellar NaL and CTABr bromine resides in an aqueous environment. An analogous comparison of the spectra of **1** in micellar NaLS, NaL, and CTABr with those in water, heptane, and 40:60 (v/v) water–dioxane led only to the conclusion that in the micellar media the phenoxy group of **1** does not reside in the bulk aqueous phase. Furthermore, by UV spectroscopy it was demonstrated